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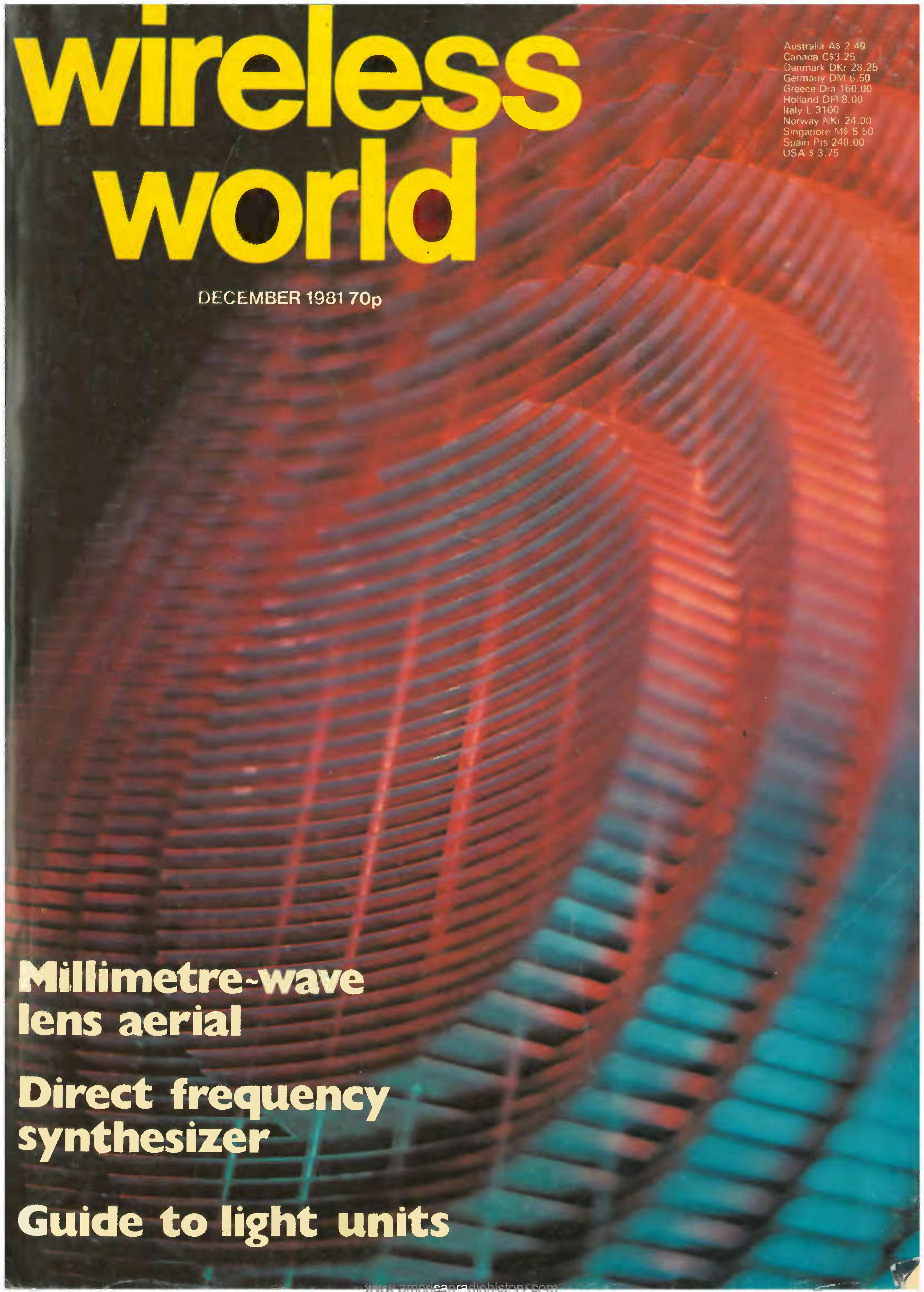

Millimetre-wave lens aerial

Direct frequency synthesizer

Guide to light units

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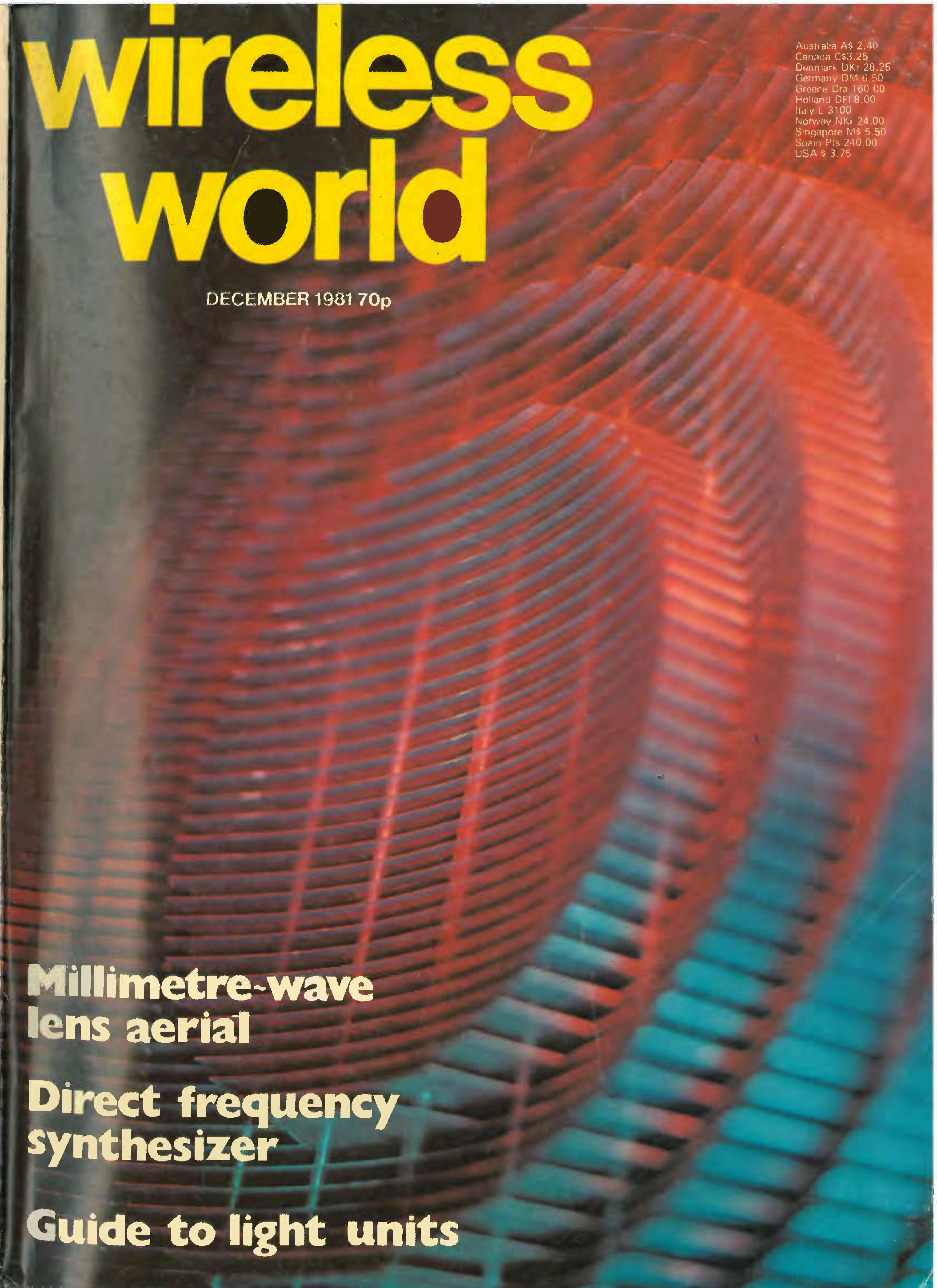

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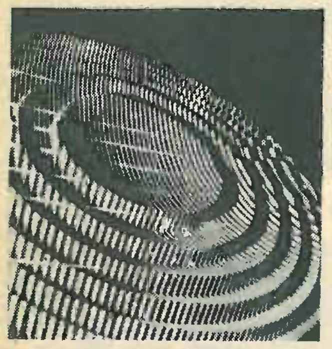
DECEMBER 1981 Vol 87 No 1551



Front cover shows the millimetre-wave lens aerial of new construction described in this issue. Photo by Paul Brierley.

IN OUR NEXT ISSUE

Nanocomp EPROM programmer, a device designed by Bob Coates for his microcomputer published in January and July 1981 issues.

Clandestine radio, used for espionage during the war, helped in the development of portable h.f. equipment. Pat Hawker tells the story.

Cardboard clock, a fun project for the holiday period, also suitable for demonstration purposes in schools.

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Editorial & Advertising offices: Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

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Subscription rates: 1 year £12 UK and £15 outside UK.

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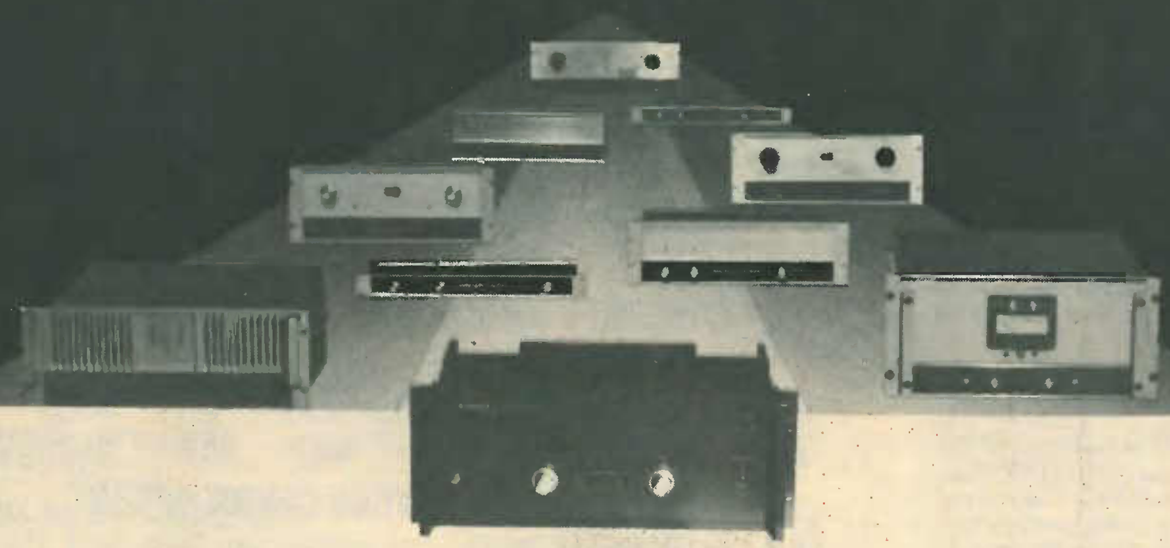

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K612	Dimmer 1000W ...	5.59
K613	Dimmer 1000W (Deparasite)... ...	12.64
K1716	20W Amplifier... ...	10.32
K1771	FM Oscillator	5.45
K1803	Universal Pre-Amplifier ...	3.62
K1823	1A Power Supply ...	6.99
K1861	Power Supply for 60W Stereo... ...	12.94
K2542	Single digit counter	6.90
K2544	Complex Sound Generator	8.28
K2566	CB Power Supply ...	26.22
K2565	Tape/Slide Synchronizer ...	9.66
K2566	Coloured Light Unit	15.53
K2569	Three-tone Bell ...	6.56
K2570	Power Supply, 5-14V DC 1A ...	6.56
K2572	Universal Stereo Pre-amplifier ...	6.56
K2573	Stereo RIAA Corrector Amplifier	6.56
K2575	Microprocessor Doorbell with 26 tunes	15.53
K2579	Universal Start/Stop Timer	6.21

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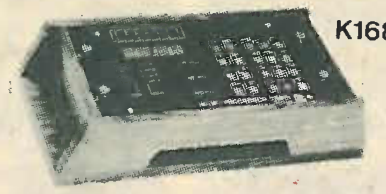
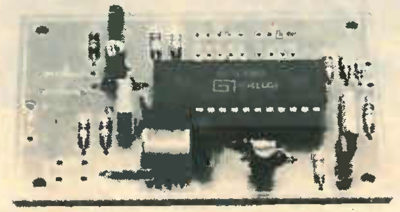
K1804	60W Amplifier... ...	15.15
K1874	Running Light Unit	12.56
K2543	Transistor Ignition ...	9.97
K2549	Infra-red Detection System (Transmitter) ...	10.63
K2550	Infra-red Detection System (Receiver)	12.42
K2553	FM Stereo Decoder	11.49
K2557	Digital Precision Thermometer ...	26.57
K2571	Light Computer ...	36.23
K2574	Four-digit up/down counter with comparator	34.16
K2576	40W Audio Amplifier	12.80
K2577	Universal AC Motor Speed Control ...	7.59


K1682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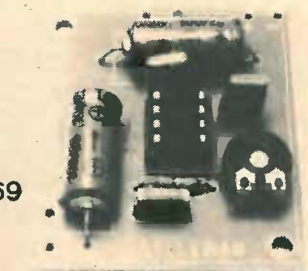
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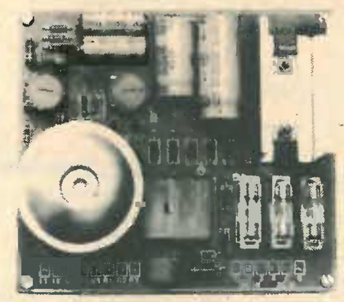
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K2578

Difficulty Grade: 3

		£
K615	High Precision Stopwatch	43.13
K1682	Microprocessor Universal Timer ...	48.37
K2545	50Hz Crystal time Base	11.39
K2547	Four-channel Infra-red Remote Control (Transmitter) ...	17.32
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K2562	Infra-red Receiver for K2558	30.02
K2563	Infra-red Transmitter for K2558	18.11
K2567	20CM Display (Common Anode)	21.05
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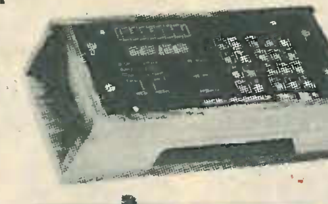

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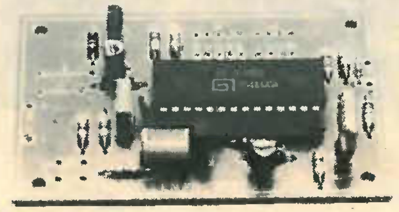

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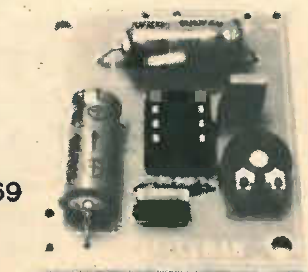

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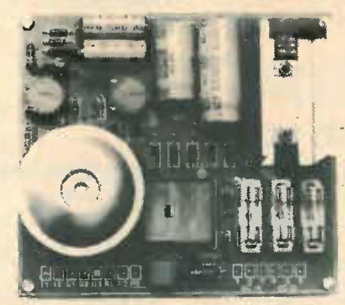

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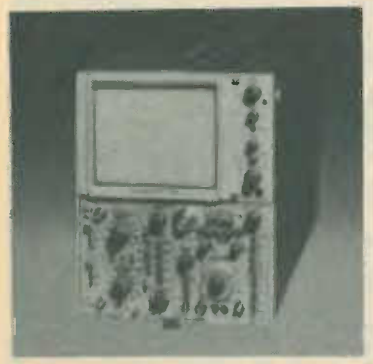

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606B AM Signal Generator 50KHz-65MHz. AM 0-95% £850.00
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TF2361 Sweep Generator with TM9693 Plug in to give 1-300MHz with internal or external markers. TM9695 attenuator 0 5-500m Volts in 1dB steps, TM9701 UHF detector TM9958 RHO-Bridge to measure V.S.W.R. ... £1500.00

Philips.
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Radiometer
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521A PAL Vectorscope. Measures Luminance Amplitude, Chrominance Phase, Chrominance Amplitude, Differential Phase and Gain. As new condition £2650.00
1481C PAL Waveform monitor in as new condition £2275.00

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Marconi.
TF2332 AF Transmission Test Set. 20Hz-20KHz £425.00
TF2343 Quantization Distortion Tester checks A.F. to A.F. distortion of P.C.M. Systems £600.00

Siemens.
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Wandel and Golterman.
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MISCELLANEOUS

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2409 Electronic Voltmeter. True RMS. Average and Peak 2HZ-200KHz £250.00

Ferrograph.
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Fluke
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Marconi.
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TF2163S UHF Attenuator 0-142dB 50Ω impedance DC-1GHz £250.00
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TF2331 AF Distortion Meter 20Hz-20KHz. 0.1%-100% 1mV-30V voltage range £395.00
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TM8339 AC/DC mixer for TF2702 ..... £295.00

Miles Hivolt
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H1000 The low, low priced teletypewriter-compatible video display terminal, offering your choice of transmission speeds up to 9600 baud as well as parity generation and checking. 12 × 80 display upper case ASCII, RS232 interface, choice of baud rates Standard baud rates either (a) 110/300 or (b) 300/1200. (£25 surcharge for other combinations up to 9600 baud).
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4010-1 Graphics Terminal with high-resolution graphics mode, standard alphanumeric mode, printer port, integral stand . . . **£1,750.00**
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(mail order total) ..£23.00)

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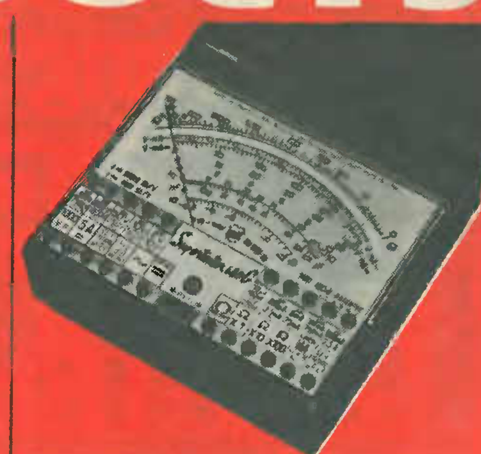

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NEW MODEL

HM 203 PORTABLE OSCILLOSCOPE (ILLUSTRATED)

Dual Trace. DC to 20MHz. 8 × 10cm display. Risetime 17.5nS. Sensitivity 5mV/cm-20V/cm. Timebase 0.5µs-0.2s. X5 magnifier. X-Y operation. Auto or variable trigger. Channel 1, Channel 2, line and external. Coupling AC, or TV low pass filter. Weighs only 6Kg. Size (m.m.) H. 145, W. 285, D. 380.
Europe's standard service scope Unbeatable value at **£220.00**

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NEW MODEL.

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Still at only **£350.00**

HM 512-8 OSCILLOSCOPE

Dual trace. DC - 50MHz. Risetime 7nS. 5mV/cm-20V/cm. Timebase 100nS/cm-2S/cm. X5 magnifier. X-Y operation. Z modulation. Sweep delay and delay line permits viewing of leading edge.
THE BEST PRICED 50MHz SCOPE ON THE MARKET AT **£580.00**

All the above scopes are available with P7 long persistence C.R.T's (except HM 307) prices on application

The above prices do not include carriage or VAT (15%). Please send for Technical Literature.

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3½ Digit hand held LCD. DMM. AC/DC volts, DC/AC current, resistance, diode test. 0.25% basic DC accuracy. Overload protection. Vinyl carrying case C90 £8.00 . . . **£75.00**

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Same spec as 8022B with additional audio tone for continuity. Vinyl case C90 £8.00 . . . **£85.00**

***Fluke 8020B**
3½ digit 0.1% basic DC accuracy. DC/AC volts, DC/AC current, resistance, diode test and conductance. Continuity beeper. Vinyl case C90 £8.00 . . . **£117.00**

***Fluke 8024B**
3½ digit. 0.1% basic DC accuracy. DC/AC volts, DC/AC current, resistance. Diode test, conductance, logic + continuity detect + temperature. Peak hold on voltage and current functions, continuity beeper. Vinyl case C90 £8.00 . . . **£155.00**

FLUKE 8050A
4½ Digit LCD DMM with true RMS on AC volts and current DC volts 200mV-1KV, 10µV resolution AC volts. 200mV-750V, 10µV resolution. DC/AC current 200µA-2A, 0.01µA resolution resistance 200Ω-20MΩ, 0.01Ω resolution. Also reads dB direct referenced to 16 stored impedances. Conductance ranges 2mS and 200nS. **£245** mains model **£285** mains battery.

FLUKE 8012A
3½ Digit LCD DMM with true RMS on AC volts and current. DC volts 200mV-1KV, 100µV resolution. AC volts 200mV-750V. 100µV resolution. DC/AC current 200µA-2A, 0.1µA resolution. Resistance 200Ω-20MΩ, 0.1Ω resolution Low resistance 2Ω and 20Ω, 1mΩ resolution Conductance ranges 2mS-20µS-200nS **£218.00** mains model **£244.00** mains battery.

FLUKE 8010A
3½ Digit LCD DMM Same spec as 8012A plus a 10Amp AC/DC current range, but not low resistance range. **£167.00** mains model **£193.00** mains battery.

Also available a range of accessories including current shunts. EHT probe, rf probe, Temperature probe and touch and hold probe. Full details on request.

The above prices do not include carriage or VAT (15%). Please send for Technical Literature.

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I.C.E.

680G MULTIMETER (ILLUSTRATED) 48 RANGES

DC volts: 100mV-2-10-50-200-500-1000V AC volts: 2-10-50-250-1000-2500V DC current: 50-500µA-5-50-500mA-5A AC current: 250µA-2.5-25-250mA-2.5A Resistance Ω × 1-Ω × 10-Ω × 100-Ω × 1000 and LowΩ, full range 1Ω-10MΩ Up to 100MΩ can be measured using ext. AC supply. dB scale -10 to +22dB. OdB = 1mW into 600Ω Sensitivity DC 20KΩ/V. AC 4 KΩ/V. Accuracy 2.0% AC and DC. Battery Eveready No. 8 Overload capability 1000:1 on resistance ranges. Protected by internal 3ΩFuse. Size with case 10.8 × 11 × 3.7cm. Meter size 10cm. Supplied with leads and carrying case.

£24.50

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DC volts: 100mV-2-10-50-200-500-1000V AC volts: 2-10-50-250-1000-2500V DC current: 50-500µA-5-50-500mA-5A AC current: 250µA-2;5-25-250mA-2.5A X2 switch on all voltage and current ranges except 2500V AC setting. Resistance: Ω × 1-Ω × 10-Ω × 100-Ω × 1000 and LowΩ, full range 1Ω-10MΩ, up to 100MΩ can be measured using ext. AC supply. dB scale —10 to +22dB. 0dB = 1mW into 600Ω Sensitivity DC 20KΩ/V, AC 4KΩ/V. Accuracy DC 1%, AC 2%. Battery Eveready No. 3. Overload capability 1000:1 on resistance ranges. Protected by internal 3Ω fuse. Size with case 13.7 × 10.4 × 5.4cm. Meter size 12cm. Supplied with leads and carrying case.

£32.00

MICROTEST 80 POCKET SIZED MULTIMETER 40 RANGES

DC volts: 100mV-2-10-50-200-1000V AC volts: 1.5-10-50-250-1000V DC current: 50-500µA-5-50-500mA-5A AC current: 250µA-2.5-25-250mA-2.5A Resistance: Ω × 1-Ω × 10-Ω × 100 and Low Ω, full range 1Ω-5MΩ dB scale —10 to +22dB, odB = 1mW into 600Ω Sensitivity: DC 20KΩ/V, AC 4KΩ/V Accuracy 2% AC and DC. Battery Mallory RM 625N. Overload capability 1000:1-on resistance ranges. Protected by internal 3Ω fuse. Size with case 9.3 × 9.6 × 2.3cm. Meter size 8.5cm. Supplied with leads and carrying case.

£16.60

Please add £1.50 carriage per meter plus 15% VAT on total meter and carriage price. Send for Literature.

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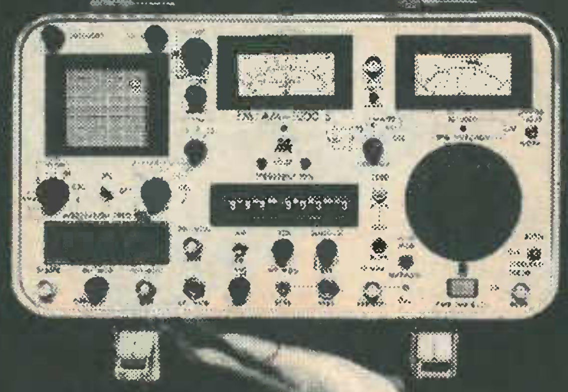
Testing... Testing... Testing...



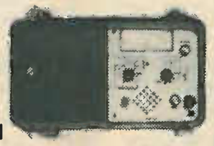
anywhere!

FM/AM 1000s with Spectrum Analyser—we call it the SUPER—S

A portable communications service monitor from IFR, light enough to carry anywhere and good enough for most two-way radio system tests.
The FM/AM 1000s can do the work of a spectrum analyser, oscilloscope, tone generator, deviation meter, modulation meter, signal generator, wattmeter, voltmeter, frequency error meter—and up to five service engineers who could be doing something else!

A PRACTICAL TOP UP!
MM-100 MULTI-METER

Simply replaces the protective lid of the FM/AM 1000s. It includes a modified probe. PB-114, and a built in speaker unit with independent volume control for audible response to signal measurement. This practical 'top up' will perform the following functions.



Sinad: Measurements for 1 kHz tone (± 20 Hz)
Distortion: To 30%
DC Volts: Up to 300 volts and up to 800 volts when the X10 probe is used
AC Volts: 600 VRMS maximum for frequencies between 25 Hz and 25 kHz
Ohms: Using the modified probe, part number PB-114, Ohms can be measured on scales X1 to X10 K
% AM Measured on the RF signal applied to the FM/AM-1000 unit

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A choice of R.F. power attenuators and protective carrying cases.

For further information contact Mike Taylor

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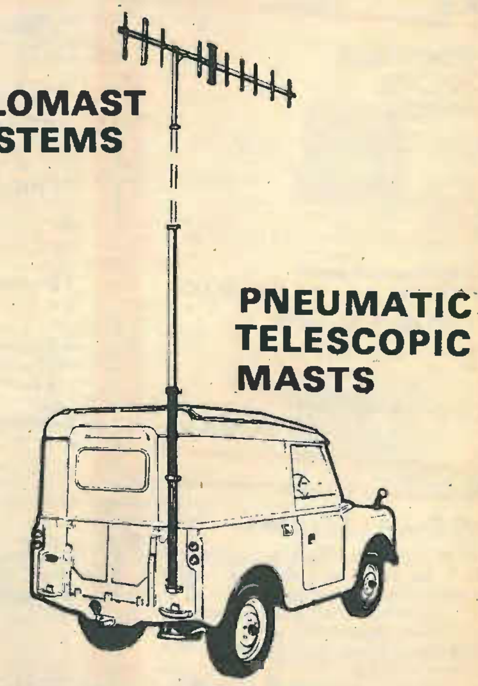
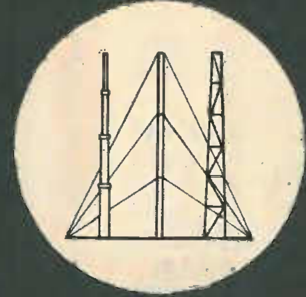


PNEUMATIC TELESCOPIC MASTS



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2113 Audio Frequency Spectrometer	1400
2203 Sound Level Meter	450
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4230 Sound Level Calibrator	95
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DAS56 DC V and I Calib 1μV-10V 30mA	600
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4342 QLC Meter 22 KHz-70 MHz	1400
MARCONI	
TF868A Universal LCR Bridge	250
WAYNE KERR	
B521 LCR Bridge	115

COMMS & CABLE TEST EQUIPMENT

CHASE	
35A Field Strength Meter 20-850 MHz	600
HEWLETT PACKARD	
3556A psophometer 20 Hz-20 KHz	250
TEKTRONIX	
1502 TDR Cable Tester CRT + Recorder	2950

COMPUTER EQUIPMENT

CENTRONICS	
702 matrix printer	500
TEKTRONIX	
4610-1 Hard copy printer for 4010 series computer display terminals	1800

COUNTERS & TIMERS

FLUKE	
1910A-1 125 MHz 7 digit Cntr. AC/Batt	300
1912 520 MHz 7 Digit Counter	375
1912A01 As 1912A but inc. re-charging batteries	430
1920A 520 MHz 9 Digit Counter inc. Brst. mode	575
1920A14 1250 MHz otherwise as 1920A	750
HEWLETT PACKARD	
5300A 6 Digit Display Unit — P/in reqd.	160
5305B 1300 MHz Counter for 5300	325
RACAL	
9024 600 MHz 7½ digit Counter	220
9025 1 GHz 8 digit Counter	450
9905 200 MHz 8 digit Counter Timer	360
SYSTRON DONNER	
6053 3 GHz 9 digit Counter BCD O/P	790
5103B Strip Printer for 6053/6054	375

DIGITAL TESTING EQUIPMENT

HEWLETT PACKARD	
5011T Logic troubleshooting kit	125
1600S Logic Analyser 32ch 20 MHz	2750
TEKTRONIX	
7D01F Logic Analyser 16ch 50 MHz P/in	2650
832 Datacomm Test V24/RS232/I loop	1150

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FLUKE 8921A
Digital and analogue true RMS AC voltmeter and power meter. Frequency range 10 Hz-20 MHz.
Readout – 3½ digit LED display and analogue meter for peak and null adjustments.
Ranges – 2mV FSD to 700V FSD plus dBm ranges reading power delivered to 12 standard input impedances from 50Ω to 1200Ω. Also relative dB mode for flatness/difference measurements.
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DC Analogue Meter with centre zero scale.
12 Current Ranges from 100nA to 30mA FSD.
12 Voltage Ranges from 100μV to 30V FSD.
Can be used in conventional mode or as a sensitive null meter.
These instruments are new.
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T1007 Volt/Freq/Spike Monitor Rec O/P	110
DATALAB	
DL019 Mains Interface for DL905	300
DRANETZ	
606 3ch Volts Av/Spike/Time/Printer	2950
GAY	
LDM AC/DC/Spike/Time inc Printer	1250

MISCELLANEOUS

AVO	
RM215 AC/DC Breakdown/Leakage Tester	475
COMARK	
1601BLS Thermom 10ch 87 + 1000°C type K *N.B. Thermocouples not included*	50
DATALAB	
DL901 Digital Transient Recorder	500
HEWLETT PACKARD	
X382A Rotary Vane Attenuator WG16	175
MULTIMETRICS	
AF120 Dual H/Pass L/Pass active filter 20 Hz – 2 MHz	600
RESEARCH INSTRUMENTS	
Micro manipulator — 4 Probes moveable in all planes. Adjustable test table — Watson Burnet optics. Complete system mounted in perspex enclosure	475
TEKTRONIX	
521PAL Vectorscope	2200
528 TV Waveform Monitor	750
575 Semiconductor Curve Tracer	425
1485C TV Waveform Monitor PAL/NTSC	2300

NETWORK ANALYSERS/ PHASEMETERS

DRANETZ	
305B/3001 Phasemeter 2Hz-700KHz	990
HEWLETT PACKARD	
8405A Vector Voltmeter 1-1000 MHz	2350
8414A Polar Display for 8410 N.W.A.	750

OSCILLOSCOPES & ACCESSORIES

GOULD ADVANCE	
OS3300B 50 MHz 1mV 2 Trace 2T base	675
HEWLETT PACKARD	
1804A 50 MHz 20mV 4 Trace Plug-in	625
1825A Dual Timebase Plug-in	500
1805A 100 MHz 5mV 2 Trace Plug-in	625
PHILIPS	
PM3211 15 MHz 2mV 2 Trace TV trig	390
PM3212 25 MHz 2mV 2 Trace TV trig	550
PM3244 50 MHz 5mV 4 Trace 2T base	1450
PM3260 120 MHz 5mV 2 Trace 2T base	1475
PM3262 100 MHz 5mV 2 Trace 2T base Tr View	1150
TEKTRONIX	
465 100 MHz 5mV 2 Trace 2T base	1250
465B 100 MHz 5mV 2 Trace 2TB, inc Probes	1550
475 200 MHz 2mV 2 Trace 2T base	1750
485 350 MHz 5mV 2 Trace 2T base	2300
661/4S3/5T1A 1 GHz Sampling scope	775
7A12 105 MHz 5mV 2 Trace Plug-in	300
7A18 75 MHz 5mV 2 Trace Plug-in	420
7A19 500 MHz 10mV 1 Trace Plug-in	990
7A22 1 MHz 10μV Differential Plug-in	595
7A24 350 MHz 5mV 2 Trace Plug-in	990
7A26 200 MHz 5mV 2 Trace Plug-in	655
7B53A 2 Timebase Plug-in 100 MHz Trig	530
7B80 Single Timebase 400 MHz Trig	575
7B85 Timebase with delay 400 MHz Trig	670
7603 100 MHz CRT r/out 3 slot M/Frame	1350
7704A 200 MHz CRT r/out 4 slot M/Frame	1450
P6013A X1000 12KV Probe	95
TELEQUIPMENT	
D63/V1/V1 15 MHz 2 Trace 1mV	499
D83/V4/S2A 50 MHz 1mV 2 Trace 2T Big CRT	750
D1015 15 MHz 5mV 2 Trace TV trig	295
VUDATA	
PS935/975 35 MHz 5mV 2 Trace – unit has built-in 3½ digit DMM + 3½ dig. cnter	675
Note: we hold a range of cameras	P.O.A.

OSCILLOSCOPES (STORAGE)

HEWLETT PACKARD	
1703A 35 MHz 10mV 2 Tr 2TB 1000 Div/ms	1400
TEKTRONIX	
466 100 MHz 5mV 2 Tr 2TB 1350cm/μs	2950
603 Bistable Storage Monitor XYZ amps	750
T912 10 MHz 2mV 2 Tr 1TB 250cm/ms	850
7834 400 MHz 4 Slot M/Frame 2500cm/μs	4990

POWER MEASUREMENT

	Prices from £
HEWLETT PACKARD	
8481A Type N Coax sensor for 435A	200
MARCONI	
TF2512 DC-500 MHz Powermeter	189
TF893A 10 Hz-20 KHz Powermeter	135

POWER SUPPLIES etc

ADVANCE	
1V5S Inverter 24V DC to 240V AC 500W	300
FARNELL	
FFSL 5 V – 20 A PSU module	100
L30B 0-30V variable 1A Metered	80
FLUKE	
415B 0-3.1 KV variable 30mA Metered	550
HEWLETT PACKARD	
6966A 0-36 V variable 10 A metered	450
PHILIPS	
PE1646 0-75V variable 6A Metered V + I	495

PULSE GENERATORS

ADVANCE	
PG57 10 Hz-50 MHz 10V 50Ω Vari RT 6ns	190
EH RESEARCH	
132 10 Hz-3.5 MHz 50V 50Ω RT 10ns 2 pulse	120
MARCONI	
TF2025 0.2 Hz-25 MHz 10V 50Ω RT 7ns 2 pulse	350

RECORDERS & ACCESSORIES

BRUNO WOELKE	
ME102B Wow and Flutter meter	75
BRYANS SOUTHERN	
BS316 Chart 10" 6 Pen 16 speed	2500
HEWLETT PACKARD	
7015A XY 1 pen A4 size	700
7046A XY 2 pen A3 size	995
PHILIPS	
PM8041 XY 1 pen A4 size	750
PM8251 Chart 10" 1 pen 12 speed	375
SE LABS	
994 6 ch galvo preamp + DC bridge supply	450
6008 UV chart 8" 25 ch 16 speed	950
6150/51 UV recorder 12 ch-inc 6 ch amps	1000
SMITHS	
RE541 Chart 8" 1 pen 8 speed	250
RE501/4701 Cht 4" + XY 1ch 10 spd AC Batt	200
SOLARTRON	
3240 Modular Data Logger system	P.O.A.
Note: UV recorders are priced less galvos	

SIGNAL ANALYSIS EQUIPMENT

MARCONI	
TF2300A Mod Meter 1 MHz-1 GHz AM/FM	450
TF2330 Wave Analyser 20 Hz-50 KHz	900
Note: see also "Spectrum Analysers"	

SIGNAL/FUNCTION/ + SWEEP GENERATORS

ADVANCE	
SG63D Generator 4-230 MHz AM/FM	200
GENERAL RADIO	
1362 Generator 220-920 MHz	375
HEWLETT PACKARD	
8640B Generator 500 KHz-512 MHz AM/FM Phase Lock	3800
618B Generator 3.8-7.5 GHz	975
612 Generator 450-1230 MHz	750
614 Generator 0.8-2.1 GHz	825
MARCONI	
TF144H/4S Generator 10 KHz-72 MHz AM	550
TF801D Generator 10 MHz-470 MHz AM	180
TF955/2 Generator 0.2-220 MHz AM/FM	670
TF1066B/1 Generator 10-470 MHz AM/FM	690
TF2012 Generator 400-520 MHz FM	550
TF2015 Generator 10-520 MHz AM/FM	1150
PHILIPS	
PM5127 Function 0.1 Hz-1 MHz Sin Sq Tri Rmp	450
PM5129 Function 1 mHz-1 MHz Sin/Sq/Tri/Ramp/Pulse + Sweep + Burst	645
TEXSCAN	
9900 Sweeper 10-300 MHz 6/in CRT disp	525
VS60 Sweeper 5-1000 MHz	890

SPECTRUM ANALYSERS

	Prices from £
HEWLETT PACKARD	
141T/8552B/8555A Complete .01-18 GHz	8500
3580A 5 Hz-50 KHz with digi store disp	2450
8445A Pre-selector 0.01-18 GHz	2000
8558B 0.1-1500 MHz Plug-in for 180 series	3750
MARCONI	
TF2370 30 Hz-110 MHz Digi-store display built-in counter and tracking gen	7700

VOLT/MULTI-METER (ANALOGUE)

AVO	
8 Mk4 AC/DC/–VI + Ω	70
BOONTON	
92C AC/RF 10 KHz-1.2 GHZ ½mV-3V	350
HEWLETT PACKARD	
400E 10 Hz-10 MHz 1mV-300V DC O/P	285
400H 10 Hz-4 MHz 1mV-300V	75
411A 0.5-500 MHz 10mV-10V DC O/P	175
427 AC/DC/V/Ω	195
3400 TRMS 10 Hz-10 MHz 1mV-300V DC-O/P	390
MARCONI	
TF2603 50 KHz-1.5 GHz 300μV-3V	300
TF2604 20 Hz-1.5 GHz 300mV-300V	425
PHILIPS	
PM2454B 10 Hz-12 MHz 1mV-300V DC O/P	250
RACAL	
9301 RMS 10 KHz-1.5 GHz 100μV-300V	550
VIBRON/E.I.L.	
33B-2 1mV-1V Electrometer	200

VOLT/MULTI-METER (DIGITAL)

BOONTON	
92AD 1999FSD 10 KHz-1.2 GHz 10μV res	525
FLUKE	
8010A 2000 FSD TRMS AC/DC/VIΩ	140
8010A01 As 8010A + re-charging batteries	159
8020A 2000 FSD Handheld AC/DC/VIΩ + cond.	99
8022A 2000 FSD Handheld AC/DC/VIΩ	75
8030A-1 2000 FSD AC/DC/VIΩ Batt + AC	165
8050A 20000 FSD AC/DC/VIΩ dB TRMS	215
8800A 200000 FSD AC/DC/VΩ	550
GOULD	
DMM7 1999 FSD AC/DC/V/I/Ω	100
HEWLETT PACKARD	
3490A 100000FSD AC/DC/V/Ω	625
SOLARTRON	
A200 19999FSD DC only 1μV-1 KV	75
A203 19999FSD AC/DC/V/Ω	175
A205 19999FSD TRMS AC/DC/V/Ω	195

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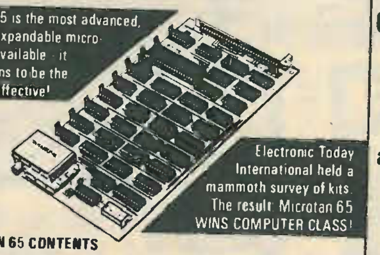
MICROTAN 65



Microtan 65 is the most advanced, powerful, expandable micro-computer available - it also happens to be the most cost effective!

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MICROTAN 65 CONTENTS
High quality, plated thru hole printed circuit board, solder resist and silk screened component identification. 6502 microprocessor. 1K monitor TANBUG. Now with 'V' Bug. 1K RAM for user programme, stack and display memory. VDU alphanumeric display of 16 rows by 32 characters. MICROTAN 65 system file binder. 136 page, bound, users hardware/software manual with constructional details and sample programmes. Logic and discrete components to fully expand MICROTAN 65.

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TANBUG V2.3 Kit £21.85 incl.

MICROTAN 65 OPTIONS

LOWER CASE PACK
Two integrated circuits which connect into locations on MICROTAN allowing 128 displayable characters.
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MINI MOTHER BOARD
Used to connect Microtan to Tanex.
Built **£10.00** + VAT

GRAPHICS PACK
Five integrated circuits which connect into locations on MICROTAN allowing the display of chunky graphics (64 x 64 pixels). What are chunky graphics? Well, imagine a piece of graph paper with 64 squares vertically and 64 squares horizontally, a total of 4096. Each square can be made black on white.
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20 WAY KEYPAD
Inexpensive means of getting up and running. Uses 'Schoeller' key-switches, and connects to MICROTAN through a 16 pin D.I.L. plug on ribbon cable. Black anodised escutcheon, with TANGERINE legends, finishes off what must be the best value for money keypad available. Available assembled and tested.
£10.00 + V.A.T. £1.50, total £11.50.

*Space Invaders game (for use with keypad only)
£15.22 + V.A.T. £2.28 total £17.50.

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MINI-SYSTEM RACK
We have produced a mini-system rack which accepts MICROTAN 65, TANEX and our mini-mother board. It has an integral power supply, just plug it into the mains and away you go! Finished in TANGERINE/BLACK, it gives your system the professional finish. Front panel access for I/O cables. AVAILABLE AS AN ASSEMBLED UNIT.
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For the man that has everything! 19 inch wide system rack which accepts: MICROTAN 65, TANEX, TANRAM, SEVEN FURTHER EXPANSION BOARDS, TANDOS and THE SYSTEM POWER SUPPLY. Available in many formats, e.g. Individual front panels, full width hinged front panel, back panel with or without connectors.
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SYSTEM RACK MICRON **£550 incl.**

6502 based microcomputer VDU alpha numeric display. Powerful monitor TANBUG. 8K RAM. 32 parallel I/O lines. 2 TTL serial I/O lines. Four 16 Bit counter timers. Cassette interface. Data bus buffering. Memory mapping contol. 71 key ASCII Keyboard, including numeric keypad. Includes power supply. Also includes the first "10K MICROSOFT BASIC" available in the U.K. All the usual BASIC commands.

FULL MANUALS: MICROTAN, TANEX, BASIC, X BUG
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TANRAM
AVAILABLE NOW TANRAM - 40K Bytes on one board! Single board of bulk memory offering: 7K Static RAM (2114), and 32K Dynamic RAM (4116). Onboard refresh is totally transparent to CPU operation and is unaffected by normal DMA's. TANRAM fully expands the available address space of the 6502 microprocessor. MICROTAN, TANEX and TANRAM together provide 16K RAM, 48K RAM, and 1K I/O - that's a lot of memory and a lot of I/O! Built and tested. TANRAM ASSEMBLED.

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EXPANDED TANEX ASSEMBLED
£99.70 + V.A.T. £14.96, total £114.66.
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SERIAL I/O BOARD MIN. (2 PORTS)	£66.70	32K RAMCARD 32K VERSION	£115.00	2 PORT SERIAL I/O KIT	T.B.A.
		32K ROMBOARD (EXCL. ROM)	£54.65	HIGH RESOLUTION GRAPHICS	£90.85
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Practical Wireless

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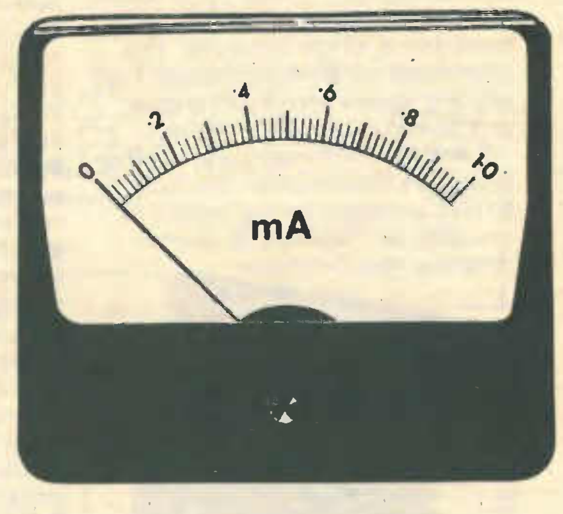

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Sinclair ZX81 Personal Computer- the heart of a system that grows with you.

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

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

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

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

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

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

New BASIC manual

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

Kit: £49.95

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

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

New, improved specification

- Z80A micro-processor – new faster version of the famous Z80 chip, widely recognised as the best ever made.
- Unique 'one-touch' key word entry: the ZX81 eliminates a great deal of tiresome typing. Key words (RUN, LIST, PRINT, etc.) have their own single-key entry.
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- Multi-dimensional string and numerical arrays.
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- Cassette LOAD and SAVE with named programs.
- 1K-byte RAM expandable to 16K bytes with Sinclair RAM pack.
- Able to drive the new Sinclair printer.
- Advanced 4-chip design: micro-processor, ROM, RAM, plus master chip – unique, custom-built chip replacing 18 ZX80 chips.

Built: £69.95

Kit or built – it's up to you!
You'll be surprised how easy the ZX81 kit is to build: just four chips to assemble (plus, of course the other discrete components) – a few hours' work with a fine-tipped soldering iron. And you may already have a suitable mains adaptor – 600 mA at 9 V DC nominal unregulated (supplied with built version).

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

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

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

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

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

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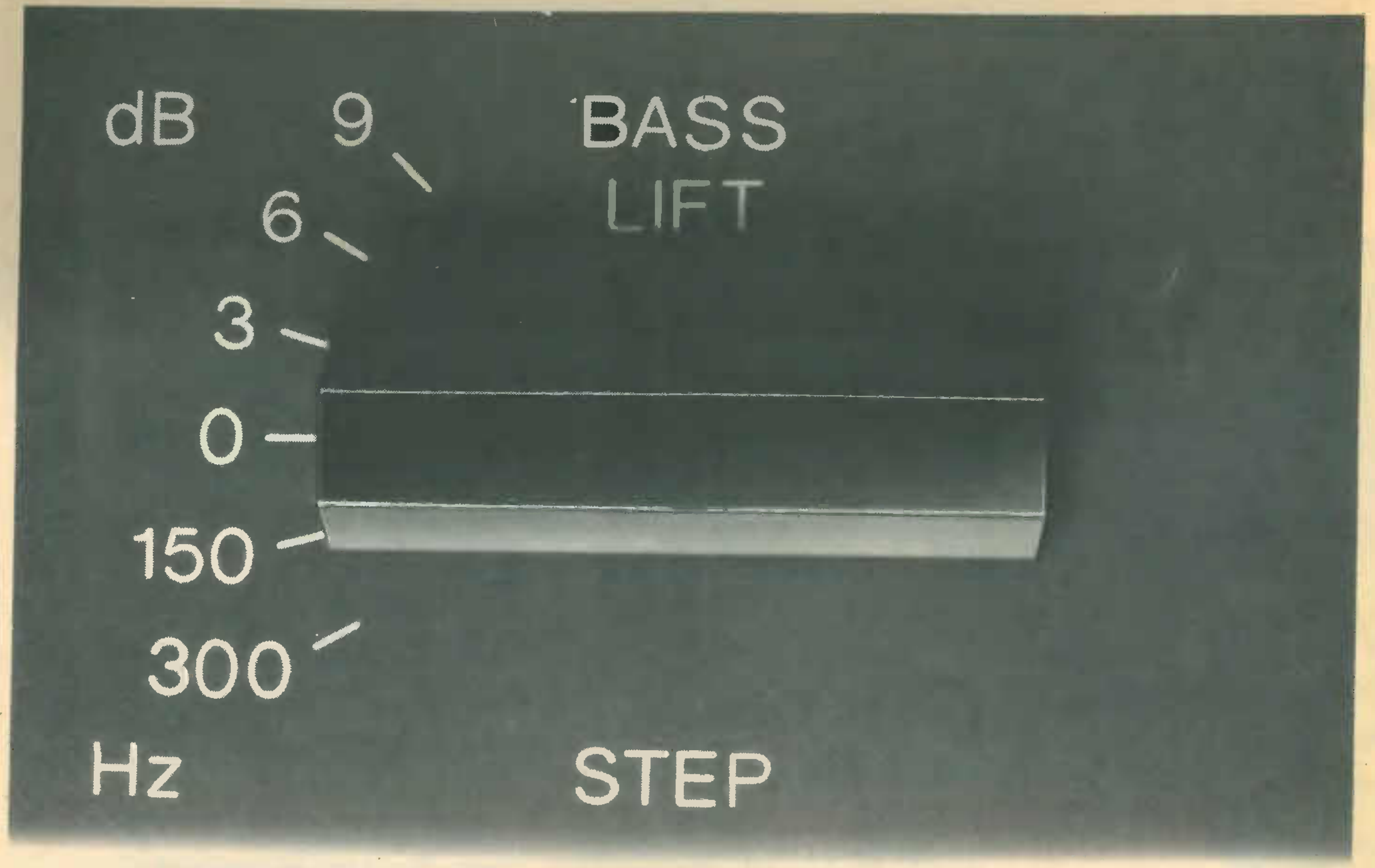

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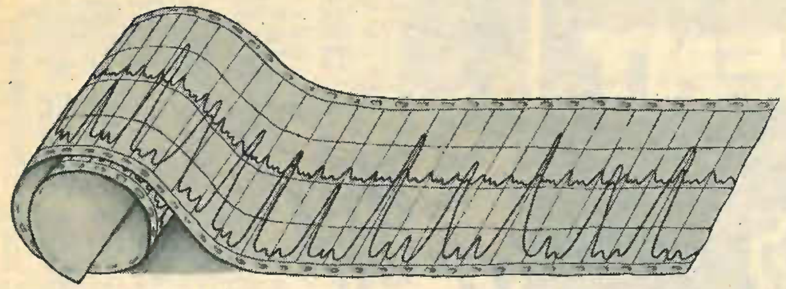

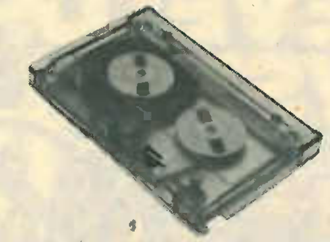

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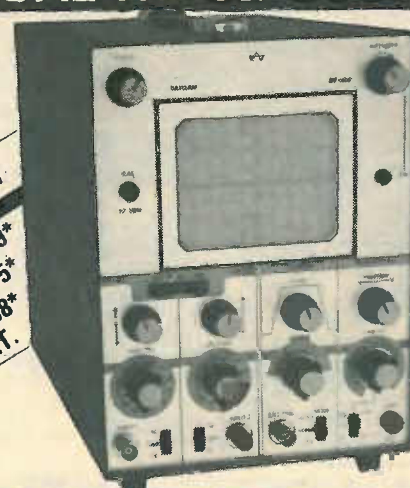

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SOFTWARE DESCRIPTION (KEYBOARD FUNCTIONS)

● HEXADECIMAL ENTRY — DATA is written to SCREEN ADDRESS indicated by CURSOR HIGHLIGHT and the cursor is automatically incremented. ● CURSOR FUNCTIONS — UP. DOWN. LEFT. RIGHT. PAGE — The CURSOR KEYS control movement of the cursor highlight DATA is displayed as a pair of HEX DIGITS which show CODE CONTENTS of each ADDRESS LOCATION. ADDRESSES are MAPPED in X-Y fashion on the screen of a TV receiver or MONITOR. Any of 16 PAGES may be viewed each containing 512 BYTES plus STATUS information. PAGE changes automatically as the cursor crosses the page BOUNDARY. ● ALTERNATE CURSOR — The FIX key stores the current cursor position for later reference. providing a LABEL in ADDRESSING SPACE. Thereafter SOFTY calculates and displays the HEXADECIMAL DIFFERENCE between cursors (showing correct value of RELATIVE JUMP. For example). ● SWAP function exchanges the stored cursor with the current cursor (which complements the HEX difference as displayed on-screen). ● MATCHBYTE function will highlight and count all locations containing any REQUESTED BYTE. This instruction may be repeated to find specific sections of code ● CLEAR operates in either FORWARD or BACKWARD modes to clear RAM BUFFER as requested. Cleared memory is all-high, rather than all-low. An unprogrammed EPROM contains all FF bytes. ● INSERT looks forward in memory to find THREE UNUSED BYTES in succession (FF FF FF) and shifts intervening code rightwards to permit extra instruction to be inserted ● DELETE removes the instruction at the cursor location and shifts code leftwards from first three unused bytes ● SERIAL and PARALLEL INPUT and OUTPUT ROUTINES are available to fill the RAM BUFFER from an external device such as a COMPUTER running an ASSEMBLER PROGRAM or a PUNCHED-TAPE READER. BUFFER CONTENTS may also be transmitted to a TAPE-PUNCH or PRINTER. These routines convert between HEX and ASCII. it is easy to interface SOFTY with RS232 and CENTRONICS compatible devices (and with other BUS STRUCTURES by writing specific software and assigning a keyfunction). ● TRANSWIFT is a FAST SERIAL DATA TRANSFER system which can be used with ANY MICRO via a single bit of I/O. It is used for EASY SERIAL INTERFACES and for direct connection with a TAPE RECORDER to store OBJECT CODE on tape. (EPROM or BUFFER contents) ● EX-RAM function permits extension of RAM BUFFER to 4K BYTES by using a BYTE-WIDE RAM in the ZIF SOCKET. There is provision for connection of SOFTY'S WRITE STROBE to the socket and BUFFER CONTENTS may be transferred using this function. ● INTERNAL MICRD functions — SOFTY'S own INS8060 will run PROGRAMS in SCRATCHPAD. RAM BUFFER or EPROM. ● COPYFIRM copies back FIRMWARE into the RAM BUFFER. Thus it is possible to modify SOFTY and reprogram it for CUSTOM APPLICATIONS. write APPLICATION-ORIENTED KEYFUNCTIONS etc. ● RUN function will transfer control to the device in the ZIF SOCKET. Programs particular applications may be committed to EPROM for use when required (2K bytes permits quite pov... applications — a disassembler perhaps?) ● GOSUB will perform the program in SCRATCHPAD — in effect provides USER-PROGRAMMABLE KEYFUNCTIONS ● EXECUTE will action the program in RAM BUFFER "before your very eyes". as it were. permitting insertion of BREAKPOINTS which cause the processor to stop without LOSS DF STATUS and print contents of INTERNAL REGISTERS. SUBROUTINE POINTER etc. in the STATUS LINE. ● BLOCK FUNCTIONS are available to handle code in blocks. ● DEFINE permits definition of the block using the CURSOR KEYS (The CURSOR HIGHLIGHT expands to enclose the BLOCK). ● MOVE allows the block to be SHIFTED around in memory by use of the CURSOR KEYS. Intervening code is not erased: it moves to the other side of the block. This is a relocation function. ● STORE will take the block into SCRATCHPAD memory. where it can be called as a SUBROUTINE to provide an extra key-function. re-inserted into code later as a MACRO — or just provide a means to put the block back elsewhere without relocating other code. ● REPLACE writes the stored block into memory from the current cursor address and transfers the cursor to the end of it. ● EPROM-HANDLING FUNCTIONS — SOFTY'S CHIEF PURPOSE is the HANDLING of OBJECT CODE and PROGRAMMING of EPROMS. ● PRETEST checks that the program will go into the EPROM. This is not merely a test for erasure (it CAN be if memory is cleared first) each location is examined in turn and compared with the code it will receive. Those locations which cannot be programmed (BITS which must be HIGH are already LOW) are HIGHLIGHTED and COUNTED. One useful application of this function is the employment of defective EPROMS which have a bit or two "stuck low". This happens. Perhaps even more useful is the possibility of modifying an EPROM because the changes are in the "right direction" — one can be lucky! ● COMPARE checks each location in EPROM with the corresponding byte in RAM BUFFER and counts and highlights differences. This function is also called automatically after a programming operation. It is useful for testing suspect ROMS and EPROMS. SOFTY MAKES A USEFUL PRODUCTION ROM CHECKER. ● COPY transfers the EPROM contents into RAM BUFFER. ● BURN transfers the RAM BUFFER contents into EPROM by applying a 50 millisecond PROGRAM PULSE to each location in turn whilst holding PROGRAM ENABLE at +25 volts. LOCATIONS WHICH DO NDT REQUIRE PRDGRAMMING ARE SKIPPED so a short program under development will burn much more quickly than a full EPROM

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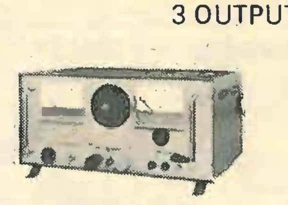

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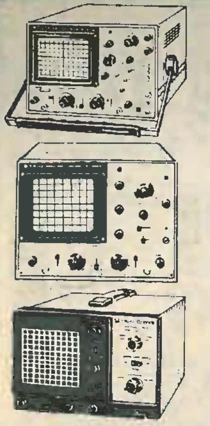

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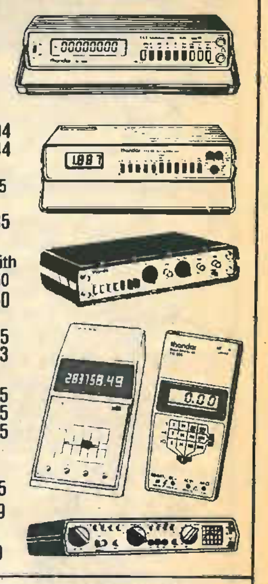

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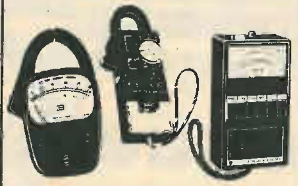
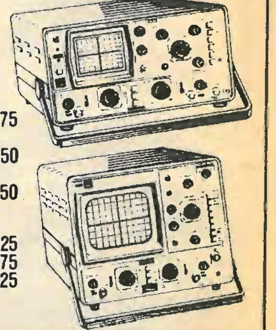


Multi-range clamps all with resistance range, carry case & leads. Also digital and DC clamp in stock (UK c/p 75p)
ST300 300A 600V 9 ranges £25.95
ST310 300A 600V 9 ranges £29.95
K2602 150A, 600V, AC 7 ranges £35.95
*K2606 300A, 600V, AC 8 ranges £44.00
K2803 300A, 600V, AC 9 ranges £53.95
K2903 900A, 750V, AC 9 ranges £77.50
K2103 1000A, 750V, AC 9 ranges £95.00
*Optional temperature probe £13.80

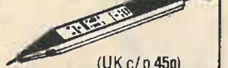
ELECTRONIC INSULATION TESTERS
Battery operated complete with carry case (UK c/p £1.00)
YF500L 500V/100Meg. Plus 0-100 ohm £55.00
K3103 600V/100Meg. Plus 0-2.6K ohm £95.00
K3106 500V & 1000V, 1000 & 2000Meg. £104.00
K4101 Earth resistance tester £136.50
M500 Hand cranked insulation tester 500V/100Meg. £67.50

CROTECH OSCILLOSCOPES



Range of Portable Scopes mains and battery operated. Plus special features (UK c/p £3.00)
3030 Single trace 15 MHZ, 5 mV, 0.5 micro secs. Plus built in component tester, 95mm tube £166.75
3131 Dual trace 15 MHZ, trig to 35 MHZ, 5mV, 0.5 micro sec. 130mm tube, plus component tester. £264.50
3034 Battery-mains dual trace 15 MHZ, trig to 20 MHZ, built in Nicads, 5mV, 0.5 micro secs. (Eliminator charger optional £28.75) £356.50
Also Available 3033, single trace 3034 £293.25
3035, 130mm 3030 £189.75
3337, dual 30 MHZ, 130mm £408.25
(Optional Probes all models – see Trio above)

LOGIC PROBE



(UK c/p 45p)
Leader LDP076 50 MHZ. 10MEG ohm, 10n Sec. with carry case £56.90

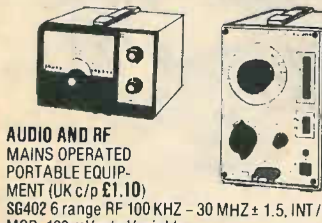
DIRECT READ HV PROBE

(UK c/p 65p)
0/40KV: 20K Volt £18.40

OSCILLOSCOPE PROBE KITS

(UK c/p 50p per 1 to 3)
Available BNC plug or Banana
X1 £7.95, X10 £9.45
X1-X10 £10.50
Also X100 (BNC only) £16.95

TRIO GENERATORS

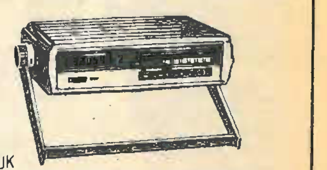


AUDIO AND RF
MAINS OPERATED PORTABLE EQUIPMENT (UK c/p £1.10)
SG402 6 range RF 100 KHZ – 30 MHZ ± 1.5, INT/EXT MOD. 100 mV o/p Variable £68.00
AG202A Matching 4 range Audio. 20 HZ – 200 KHZ Sine Square. Distortion 0.5-1% Variable o/p to 10V £78.20
AG203 5 band 10 HZ – 1 MHZ. Sine/Square: 0.5dB deviation. Distortion Max. 0.1% Switched Alternator & variable. £126.50
ALSO IN STOCK Newtronics 200P & 200SPC 0.002 HZ 5.5 MHZ Generators (200 SPC with 100 MHZ counter)

PROFESSIONAL MULTIMETERS

(UK c/p £1.50) All featuring AC/DC Volts/Current & Ohms ranges.
M1500 43 range 20K/Volt: AC/DC 10A £53.50
M1200 30 range 100K/Volt: AC/DC 15A 200 Meg ohm. With leather case Was £84. Now £49.00
K1400 26 range large scale 20K/Volt: 10A AC/DC. 20 Meg ohm: 5kV AC/DC £79.95
K200 39 range 10 Meg ohm input. 25 HZ-1 MHZ £95.00
OPTIONS Cases: M 1500 & 1200 £16.50: K1400 £19.00
Temperature Probe for K1400 £13.80

THURLBY DIGITAL MULTIMETER



4¾ Digit. 0.05% 7 Function LCD
Made to exacting standards in UK
30 ranges: 1200V DC, 750V AC, 10A AC/DC, 32 Meg ohm. Also includes frequency measurement to 4 MHZ and 4 KHZ output.
Price is with batteries, test leads and mains adaptor.
(optional carry case £20.45)
£171.00
UK c/p £1.00

CALLERS WILL ALWAYS FIND A RANGE OF LOW COST TEST EQUIPMENT. ACCESSORIES, TOOLS, IRONS AND BOARDS IN STOCK. ALSO SPECIAL OFFERS FOR CERTAIN EQUIPMENT WHICH WILL VARY FROM TIME TO TIME

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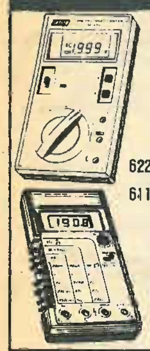
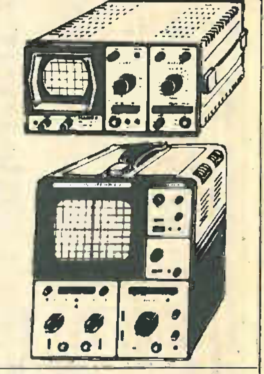
LCD DIGITAL MULTIMETERS SPECIAL PURCHASE – LIMITED PERIOD ONLY



6220 Reliable 22 range hand held 3½ digit LCD with volt/ohms auto range, unit and range signs, 10 amp AC/DC, battery warning, lower power ohms range: Model 6110 Also has range hold, continuity buzzer and improved accuracy. All models high quality rotary operation. Resolution 0.1 milli volt: 10-Micro amp: 0.1 ohm.
6220 1000v DC: 0.2/10A AC/DC: 600v AC: 2meg ohm. Was £55.95 NOW £42.95
6110 As above plus 20mA AC/DC and improved accuracy. Was £85.95 NOW £59.95

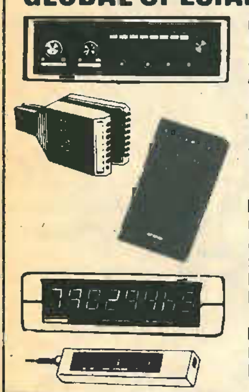
THIS SPECIAL OFFER IS QUALITY WITH VALUE
Also in stock.
DD601 27 range, push button, 2A, AC/DC £39.95
188m 16 range with Hfe checker, 10 amp, DC, push button £43.50
189m 30 range with Hfe checker, 10 amp, AC/DC, rotary £69.95

HAMEG OSCILLOSCOPES



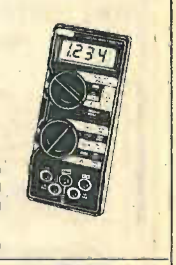
Range of top quality scopes for Amateur and Professional (UK c/p '307' £3.00, other £4.00)
307 Single trace 10 MHZ: 5mV: 0.5 micro sec. Plus built in component tester, 6 x 7cm display. £158.70
(Optional carry case £18.40)
203 Dual 20 MHZ: Trig to 30 MHZ: 5mV: 0.5 micro secs: 8 x 10cm display (replace model 312) £253.00
412-5 Dual 20 MHZ delayed sweep: trig to 40 MHZ: 5mV: 0.1 micro sec. 8 x 10cm display. £402.50
705 Dual 70 MHZ Delayed sweep. Single sweep. Delay line. Trig to 100 MHZ. 5mV 0.1 micro sec 8 x 10cm display £667.00
Options 203/412/512 Viewing hood £6.90
Component tester 203, 412, 512 £46.00
Carry case (state model) £21.85
Optional Probes (All models) XI £8.50, X10 £9.45. XI-10 £10.50. X100 £16.95.

GLOBAL SPECIALISTS EQUIPMENT



Generators (UK c/p £1.00)
2001 1 HZ-100 KHZ sweepable function generator. TTL/Sine/Square/Triangle. All facilities: Mains £89.00
4001 Ultra Variable Pulse Generator: 0.5 HZ-5 MHZ Every facility: Mains. £109.00
Frequency Counters (UK c/p 80p)
MAX100 100 MHZ Counter. Battery operated. 8 Digit 30mV typical. Bench portable LED £89.00
MAX50 6 Digit 50 MHZ Hand held LED £56.00
MAX550 2 range 6 Digit 550 MHZ hand held LED £97.75
PS500 500 MHZ prescaler for MAX50/100 £34.50
Circuit Powered Logic Probes Pulser and Monitors (UK c/p 65p)
LP1 DTL/TTL/CMOS: 10 MHZ. 100K ohm: Pulse: Memory £35.50
LP2 DTL/TTL/CMOS: 1.5 MHZ. 300K ohm: Pulse £19.95
LP3 DTL/TTL/CMOS: 50 MHZ. 500K ohm: Pulse: Memory £55.95
LM1 All, 8, 10, 12, 14 & 16 Pin IC'S. Indicates Pins on/off DTL/TTL/CMOS/HTL. Logic Monitor £33.00
DP1 Digital Pulse. Single shot or 100pps. £58.50

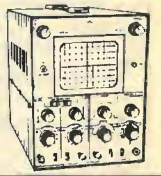
KEITHLEY PROFESSIONAL DIGITAL MULTIMETER



Model 130, 25 range. Easy to hold and use LCD DMM. Size 7 x 3.1 x 1.5
Ranges
DC Volts 200mV-1000V 0.5% 100 micro volt
AC Volts 200mV-750V 1% 100 micro volt
DC current 2mA-10AMP 1-2% 1 micro amp
AC current 2mA-10AMP 2% 1 micro amp
Resistance 200 ohm-20 Meg 0.5% 0.1 ohm £102.35

PROFESSIONAL TRANSISTOR CHECKERS UK C/P £1.50
All feature auto test and matching.
LTC 906A plus DC Parameters £111.55
LVT plus F.E.T. Multimeter £147.20
LTC 907 plus multi band signal injector £173.60
Also LTC 905 semi conductor curve trace (use with scope) £95.45

SAFGAN PORTABLE OSCILLOSCOPES



Range of low cost Dual Trace Scopes mains operated. Made in UK to exacting standards. Available as 10 MHZ; 15 MHZ or 20 MHZ. All feature 5mV sensitivity; 0.5 micro sec: 6.4 x 8cm display. (UK c/p £2.50)
DT410 Dual 10 MHZ £194.35
DT415 Dual 15 MHZ £201.25
DT420 Dual 20 MHZ £216.20
Optional probes available (see Hameg above)

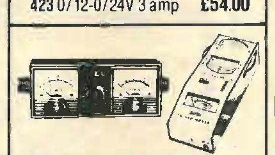
SABTRONICS EQUIPMENT

New reliable range of DMM's and frequency computers with those extra facilities and competitive prices. All battery operated (supplied). Except 5020A mains. Optional mains eliminators available.
8 DIGIT COUNTERS 0.1 HZ to 10 HZ Res. 10mV sensitivity to 100 MHZ (UK c/p £1.00)
8110A 20 HZ-100 MHZ in 2 ranges £95.45
8610A 20 HZ-600 MHZ in 3 ranges £113.85
9 DIGIT COUNTERS 30mV sensitivity to 1GHZ. Resolution 0.1 HZ-10 HZ
8610B 10 HZ-600 MHZ in 3 ranges. £125.35
8000B 10 HZ-1GHZ in 3 ranges £184.00
FUNCTION GENERATOR (UK c/p £1.00) with mains adaptor
5020A 1 HZ-200 KHZ Sine/Square/Triangle/TTC Freq. sweep. Low distortion £98.90
DIGITAL MULTIMETERS Two LCD hand held – one with temperature range. Also LCD and LED Bench models
2035A 3½ digit LCD hand. 2A AC/DC 20Meg ohm ETC £95.45
2037A As 2035A with −50°C to + 150°C Temp. range 0.1° resolution £109.25
2010A 3½ Digit LED. Auto decimal & minus. 10A AC/DC: 20Meg ohm etc. £95.45
2015A LCD version of above £109.25
(c/p 2035/37A 65p: All others £1.00)
Options Touch & hold Probe for DMM's £14.95
Battery eliminators (state model) £5.69

VARIABLE REGULATED POWER SUPPLIES

Mains operated regulated single meter (UK c/p £1.50)
241 0/12-0/24V 1 amp £35.00
154 5-15 volt 3 amp £44.00
423 0/12-0/24V 3 amp £54.00

AMATEUR/CB



KDM6 1.5 to 250 MHZ Dip meter 6 ranges £38.50
SWR9 3-150 MHZ SWR + F/S £9.50
SWR50 Twin meter SWR + Power 1KW max. £13.95
310 Single meter SWR + Power 10W £8.95
110 SWR/Power/FS-10/100W £11.95
171 As '110' Twin meter £14.50
175 SWR/FS/AE Match (40 MHZ) £13.80
176 As '175' + 0/5/50 Watt power £16.95
178 As '175' + 0/10/100W + MOD Scale £19.50
HM20 SWR meter Plus 20K/Volt 19 range Multimeter £28.95
(Note: SWR-Power ETC to 144/150 MHZ)
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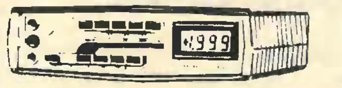
POWER SUPPLIES

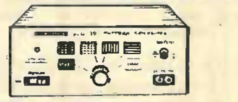
13.8 volt. Output regulated mains operated (c/p £1.00)
3 to 5 amp £13.95
5 to 8 amp £17.95

LASCAR BENCH MULTIMETER



3½ Digit LCD Made in UK: 25 ranges with basic 0.1% accuracy: 2A AC/DC with 0.1. Microamp resolution: 1KV AC/DC 20Meg ohm ETC.
LM100 £89.00 (UK c/p £1.00)
Also model LM2001 hand held model 2Meg ohm. 2A AC/DC ETC. £57.70 (UK c/p 65p)

TV COLOUR BAR PATTERN GENERATORS



PAL UHF and VHF Models All 220/240V AC
LGC393 VHF 6 pattern £143.75
LCG392u UHF 15 pattern £228.85
LCG392v VHF 15 pattern £231.15
LCG399 VHF/UHF 13 pattern £572.70
MC101 UHF pocket colour £162.50

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LSG 231 FM Stereo Generator 100 ± MHZ, all facilities £211.60

AUDIO
LAG26 4 range 20 HZ-20 KHZ. Sine/Square: 5V o/p: Distortion 0.5-1% £73.60
LAG120A 5 range 10 HZ-1 MHZ. Sine/Square: 3V o/p: 0.05-0.8% Max Distortion Switched attenuator. £146.00
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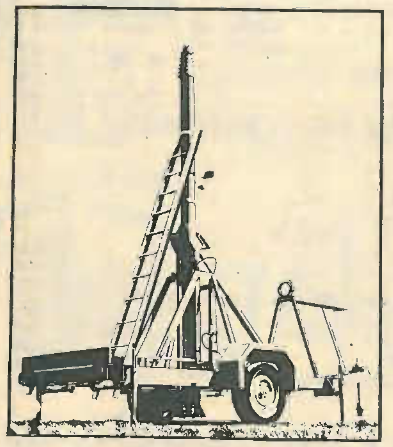

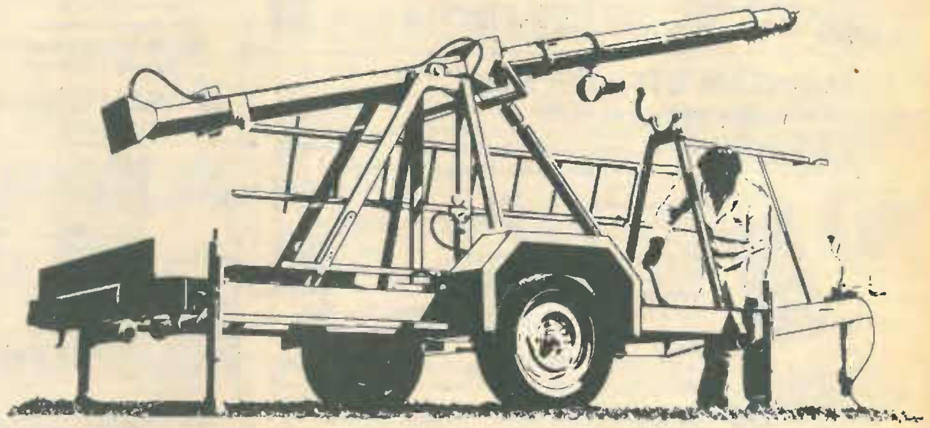

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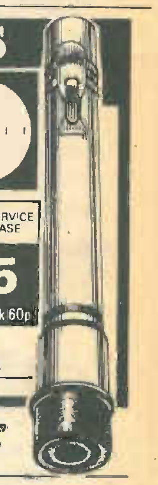

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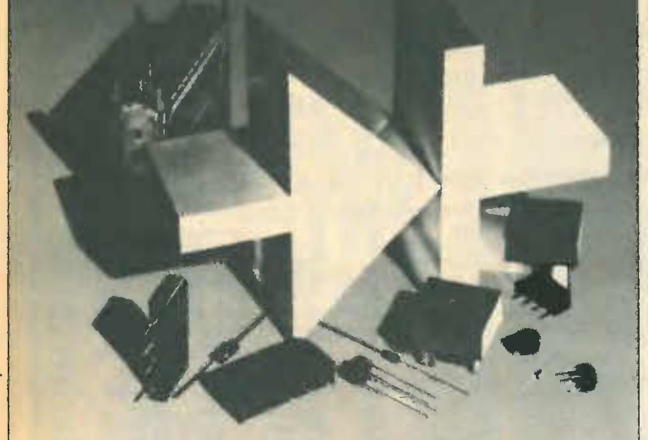
Diodes·High Speed Diodes·Zener Diodes
Rectifer Bridges·UHF·VHF Tuners



Rectifer Diodes
1A Series 1N 4000
3A Series 1N 5400 and BY 251
High Speed Diodes
1A Series BA 150 and 1P 640
2A Series BY 290
3A Series BY 390
Switching Diodes
0.1A Series BA 243 – BA 243A
Zener Diodes
500mW Series ZPD (2V7 – 51V)
500mW Series BZX55C (5V1 – 62V)
1.3W Series BZX 85C (5V1 – 62V)
1.5W Series BZY97C (7V5 – 200V)

Rectifer Bridges
0.8A Series C800, C800A
1A Series C1000, C1000A
1.5A Series C1500R
1.5A Series C1500/1000
2A Series C2000/1500
3.7A Series C3700/2200
5A Series C5000/3300
10A Series FB1000, FB1000L
25A Series FB2500
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*French System
*RTMA System
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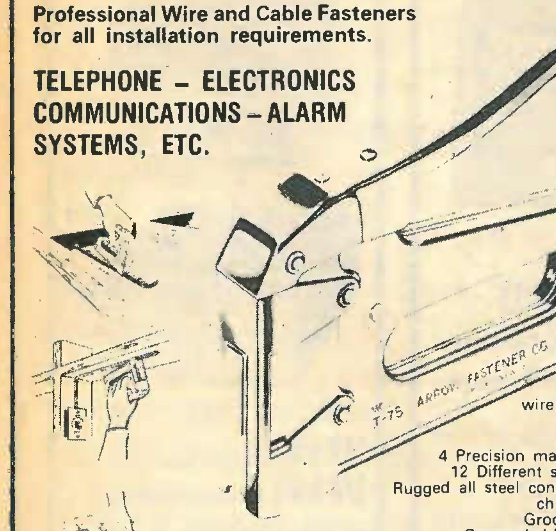

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2114L-300ns	1+1.28
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2716 450ns	1+2.49
	25+2.37
2716 350ns	6.95
2532 450ns	1+5.50
	25+5.31
2732 450ns	1+4.80
	25+4.08
4116 150ns	1+1.15
	25+1.06
4116 200ns	1+0.80
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6116 200ns	10.95
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81LS97	0.90
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ZN426E-8	3.00
ZN427E-8	6.28
ZN428E-8	4.78
ZN429E-8	2.10
ZN432CJ-10	28.09
ZN433CJ-10	22.59
ZN440	56.63
MISCELLANEOUS	
AY-3-1015	3.90
AY-5-1013	3.45
AY-5-2376	6.95
MC1488	0.64
MC1489	0.64
MC14411	6.94
MC14412	7.99
RO-3-2513L	7.70
RO-3-2513U	7.70
ZN450E	7.61
7805	0.50
7812	0.50
7905	0.55
7912	0.55
ZILOG Z80 FAMILY	
Z80 CPU	4.00
Z80A CPU	4.82
Z80 CTC	4.00
Z80A CTC	4.00
Z80 DART	7.18
Z80A DART	7.18
Z80 DMA	11.52
Z80A DMA	9.99
Z80 PIO	3.78
Z80A PIO	3.78
Z80 SIO-0	13.95
Z80A SIO-0	13.95
Z80 SIO-1	13.95
Z80A SIO-1	13.95
Z80 SIO-2	13.95
Z80A SIO-2	13.95
EFCIS 6800 FAMILY	
EF6800	3.70
EF6802	5.11
EF6803	11.80
EF6809	11.95
EF6810	1.35
EF6821	1.74
EF6840	4.20
EF6845	9.50
EF6850	1.70

Device	Price
EF6862	6.91
EF6871-A1T	18.70
EF6880	1.07
EF6887	0.80
EF68488	9.11
EF6875	4.18
6502 FAMILY	
SYP6502	4.95
SYP6520	3.15
SYP6522	4.95
SYP6532	7.95
8060 FAMILY	
8085A	5.50
8212	1.70
8216	1.70
8224	2.45
8228	3.95
8251	3.95
8253	7.95
8255	3.95
CMOS 4000 'B' SERIES	
4000	0.12
4001	0.13
4002	0.13
4006	0.60
4007	0.17
4008	0.55
4009	0.28
4010	0.28
4011	0.14
4012	0.17
4013	0.33
4014	0.58
4015	0.58
4016	0.28
4017	0.45
4018	0.58
4019	0.29
4020	0.58
4021	0.60
4022	0.62
4023	0.17
4024	0.38
4025	0.16
4026	0.99
4027	0.30
4028	0.55
4031	1.65
4033	1.60
4034	1.55
4035	0.72
4040	0.57
4041	0.69
4042	0.54
4043	0.59
4044	0.64
4045	1.65
4046	0.68
4047	0.68
4048	0.54
4049	0.30
4050	0.30
4051	0.59
4052	0.68
4053	0.59
4054	1.20
4055	1.20
4060	0.89
4063	0.95
4066	0.34
4068	0.17
4069	0.17
4070	0.19
4071	0.19
4072	0.19
4073	0.19
4075	0.17
4076	0.60
4077	0.22
4078	0.24
4081	0.14
4082	0.19
4085	0.63
4086	0.69
4093	0.39
4502	0.69
4507	0.39
4508	1.90
4510	0.60
4511	0.49
4512	0.60
4514	1.49
4515	1.49
4516	0.75
4518	0.40
4519	0.28
4520	0.69
4521	1.49
4522	1.20
4526	0.70
4527	0.89
4528	0.70
4532	0.89
4541	1.39
4543	0.99
4553	2.90
4555	0.49
4556	0.54
4585	0.98

Device	Price
LOW POWER SCHOTTKY TTL ICs – 74LS SERIES	
74LS00	0.11
74LS01	0.11
74LS02	0.12
74LS03	0.12
74LS04	0.13
74LS05	0.13
74LS08	0.13
74LS09	0.13
74LS10	0.13
74LS11	0.14
74LS12	0.15
74LS13	0.22
74LS14	0.44
74LS15	0.13
74LS20	0.12
74LS21	0.14
74LS22	0.14
74LS26	0.18
74LS27	0.14
74LS28	0.19
74LS30	0.12
74LS32	0.14
74LS33	0.16
74LS37	0.16
74LS38	0.16
74LS40	0.13
74LS42	0.34
74LS47	0.39
74LS48	0.60
74LS49	0.59
74LS51	0.14
74LS54	0.15
74LS55	0.15
74LS73	0.20
74LS74	0.17
74LS75	0.28
74LS76	0.20
74LS78	0.24
74LS83	0.50
74LS85	0.70
74LS86	0.17
74LS90	0.30
74LS91	0.80
74LS92	0.35
74LS93	0.34
74LS95	0.44
74LS109	0.25
74LS112	0.25
74LS113	0.25
74LS114	0.25
74LS122	0.39
74LS123	0.55
74LS124	1.00
74LS125	0.28
74LS126	0.28
74LS132	0.45
74LS136	0.28
74LS138	0.34
74LS139	0.37
74LS145	0.75
74LS148	0.90
74LS151	0.34
74LS153	0.35
74LS155	0.39
74LS156	0.38
74LS157	0.34
74LS158	0.36
74LS160	0.39
74LS161	0.39
74LS162	0.39
74LS163	0.39
74LS164	0.47
74LS165	0.99
74LS166	0.84
74LS173	0.70
74LS174	0.54
74LS175	0.54
74LS181	1.30
74LS190	0.55
74LS191	0.55
74LS192	0.69
74LS193	0.59
74LS194	0.39
74LS195	0.39
74LS196	0.58
74LS197	0.65
74LS221	0.60
74LS240	0.89
74LS241	0.89
74LS242	0.79
74LS243	0.79
74LS244	0.79
74LS245	0.89
74LS247	1.34
74LS248	1.00
74LS249	0.66
74LS251	0.39
74LS253	0.39
74LS257	0.44
74LS258	0.38
74LS259	0.38
74LS261	1.90
74LS266	0.23
74LS273	0.90
74LS279	0.34
74LS283	0.44
74LS290	0.56
74LS293	0.45
74LS365	0.34
74LS366	0.34
74LS367	0.34
74LS368	0.34
74LS373	0.74
74LS374	0.74
74LS375	0.47
74LS377	0.89
74LS378	0.69
74LS379	0.84
74LS386	0.28
74LS390	0.59
74LS393	0.59
LOW PROFILE DIL SOCKETS	
Number of Pins:	
8	0.07
14	0.09
16	0.09
18	0.15
20	0.17
22	0.21
24	0.23
28	0.25
40	0.29
CRYSTALS	
1 Mhz	3.00
1.8432 Mhz	2.50
4 Mhz	1.65

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10%

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Buy Ambit's new concise component catalogue and get £1 vouchers. Use them for a £1 discount per £10 spent. But even without this, you will still find WR&E offers the low prices, fast service and technical support facility second to none.

Here are some examples from the current issue:

Z80 SERIES

Z80A	4.99
Z80ADRT	7.50
Z80APIO	4.10
Z80ASIO/1	14.00
Z80ASIO/2	14.00
Z80ASIO/9	14.00
Z80CTC	4.00
Z80ACTC	4.50
Z8001	65.00

PROM

2708	2.00
2716	3.55
2532	8.50
2732	8.50

RAM

2102	1.70
2112	3.40
2114/2	1.49
4027	5.78
4116/2	1.59
4116/3	1.49
4864P	12.50
6116P-3	12.50
6116P-4	11.25
8264	12.50

I.C. SOCKETS

A range of high quality, low cost, low profile DIL sockets ideally suited for both the OEM and hobbyist. All types feature double sided phospher bronze contacts, tin-plated for low contact resistance.

8 x 0.3"	12p	22 x 0.3"	20p
14 x 0.3"	13p	22 x 0.4"	20p
16 x 0.3"	13p	24 x 0.6"	22p
18 x 0.3"	18p	28 x 0.6"	25p
20 x 0.3"	19p	40 x 0.6"	35p
20 x 0.4"	19p	42 x 0.6"	38p

VOLTAGE REGULATORS

78XX1A TO-220 pos	0.58
79XX1A TO-220 neg	0.60
78G 1A TO-220 adj pos	1.10
78G 1A TO-3 adj pos	3.95
78H5A TO-3 5v pos	4.25
78H5A TO-3 12v pos	5.45
78HG5A TO-3 adj pos	7.45
79HG5A TO-3 adj neg	7.45
LM317.5A adj pos	1.30
LM337.5A adj neg	1.75
78S401.5A adj pos sw reg	1.20

DISCRETES

BC237	8p	BC556	12p		
BC238	8p	BC550	12p	2SK168	35p
ZTX238	9p	BC560	12p	J310	69p
BC239	8p	BC639	22p	J176	65p
BC307	8p	BC640	23p	40823	65p
BC308	8p	2SC1775A	22p	3SK45	49p
BC309	8p	2SA872A	18p	3SK51	54p
BC413	10p	2SD666A	30p	3SK60	58p
BC414	11p	2SB646A	30p	3SK88	99p
BC415	10p	2SD668A	30p	MEM680	75p
BC416	11p	2SB648A	40p	BF960	99p
BC546	12p	BF256	38p	BF961	70p
		2SK55	28p	BF963	99p

XTALS

1MHz	3.00
3.2768MHz	2.00
4MHz	1.70
4.194MHz	1.70
4.43MHz	1.25
5MHz	2.00
6.5536MHz	2.00
7MHz	2.00
8MHz	2.00
9MHz	2.00
10MHz	2.00
11MHz	2.00

Prices shown exclude VAT. Postage 50p per order (UK). ACCESS/BARCLAYCARD may be used with written or telephone orders - official MA details on application, and a special prize for those who read our ads carefully - a free 4 or 8MHz crystal filter with every CPU IC you buy - just clip out the paragraph and attach it to your order. E&OE.

AMBIT international TELEPHONE (STD 0277) 230909 TELEX 995194 AMBIT G POSTCODE CM14 4SG
200 North Service Road, Brentwood, Essex

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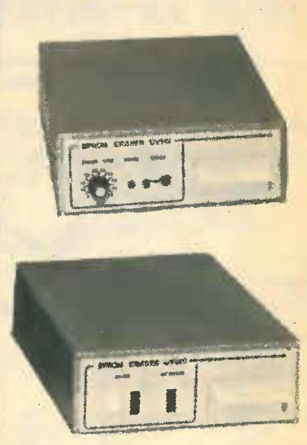
EP4000 EPROM EMULATOR PROGRAMMER

- Copy/Program/Emulate 2704/2708/2716(3)/2508/2758/2516/2716/2532/2732 Eproms
- 4K x 8 Static Ram
- Video O/P and 8 digit LED display
- Emulates simply at the push of a key
- Powerful editing facilities
- Comprehensive In/Out (RS232, TTL, 20MA Loop, Parallel, DMA) as standard
- 2764 adaptor now available
- EP4000 ex-stock at **£545** + VAT + £12 delivery

P4000
EPROM PRODUCTION PROGRAMMER

- Program up to 8 Eproms simultaneously
- Covers same Eproms as EP4000
- Powered down sockets
- Independent blank check/verify/program modes
- Simple to use with mode pass/fail LEDs for each copy socket
- Ex-stock at **£545** + VAT + £12 delivery



UV141 BENCH TOP
UV140 EPROM ERASERS

- Two units with 14 Eprom capacity
- Safety interlocked
- Electronic timer (UV141)
- Convenient slide tray loading
- UV141 ex-stock at **£78** + VAT
- UV140 ex-stock at **£61.50** + VAT

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UNIT 6, TOTNES INDUSTRIAL ESTATE
TOTNES, DEVON TQ9 5XL. TEL: (0803) 863360. TELEX: 42596

GP

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PHILIPS SCOOPS THE HONOURS WITH A NEW CONCEPT IN DIGITAL INSTRUMENTS

AWARD YOURSELF THE DMC FOR SERVICES TO MEASUREMENT

Philips amazing new Digital Measurement Centre is so much more than an ordinary 4½-digit autoranging instrument. Just look at all these quantities which the calculating power of its microcomputer allows the DMC to measure:

✱ Volts, current and resistance
✱ Frequency
✱ Time
✱ dB (and relative dB)
✱ Peak voltage
✱ Relative reference
✱ Temperature
✱ Diode forward volt drop

In addition, it's got 5% longer ranges than usual, compensated current measurements and self-test and calibration. A battery version will be available soon.

For a free eight-page colour leaflet about the DMC, circle Reader inquiry number 220

VERSATILE TV GENERATOR

Philips PM 5519 Colour Pattern Generator can be used with CTV, TV, VCR or VLP, operating with practically all international TV broadcasting systems and standards.

✱ Over 20 combinations of test patterns (colour and black/white)
✱ Adjustable (0–1.5V) video output available for CCTV systems
✱ All signals to TV standard CCIR, System G-I-M and N, Colour PAL (RTMA-NTSC version available)
✱ Full RF coverage: TV IF, Bands I, III, IV and V
✱ Electronic tuning with six preset channels

Reader inquiry number 221

Circle the inquiry card numbers listed below, to receive information about relevant product groups.

	Inquiry No.
PM 2521 Digital Measurement Centre	**220**
PM 5519 Colour pattern generator	**221**
PM 6667 High resolution counter	**222**

Alternatively, 'phone Cambridge **(0223) 358866** and speak to our Commercial Office on extensions **145** or **148.**

INPUT
FROM PHILIPS TEST & MEASURING INSTRUMENTS

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Philips Electronic Instruments Dept,
York Street, Cambridge CB1 2PX
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EXCLUSIVE MULTIMETER OFFERS

Top quality meters all supplied with test leads, batteries, handbook and carry case.

WHILE STOCKS LAST!

LCD DIGITAL MULTIMETER

MODEL 6110

3½ Digit LCD featuring 23 ranges with volts/ohms autorange, unit and sign indicators, 10 amp AC/DC, battery warning, low power ohms ranges. Range hold and continuity buzzer. Fuse protected. Resolution 0.1mV DC, 1mV AC, 10 microamp, 0.1 ohms. Supplied with battery and leads. Fitted top quality rotary switch.

RANGES

AC/DC Current - 20mA/200mA/10 amp.
DC Voltage (auto) - 200mV/2V/20V/200V/1000V.
AC Voltage - 2V/20V/200V/600V.
Resistance (auto) - 200/2K/20K/200K/2000K ohm.

MODEL 6110 as advertised by us at ~~£85.95~~ including VAT

NOW £59.95 inc.VAT

UK Carriage/packing paid

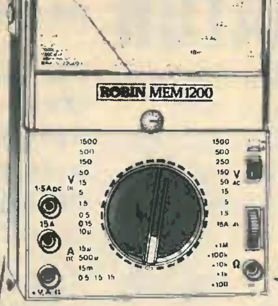
ALSO AVAILABLE MODEL 6220
As 6110 but without range hold and continuity buzzer. Only two AC/DC 200mA/10 amp ranges i.e. 22 ranges. Was £55.95. Now **£42.95** post paid.

PROFESSIONAL MULTIMETER 100,000 ohms/volt

SAVE £35

- Exclusive offer for limited period of this versatile, professional, top quality multimeter.
- 30 Ranges ● 15 AMP AC/DC
- Size 7"x 5"x 2½"

This special offer includes leather carry case (normally £16.50 extra)



Model M1200

As advertised by us at £67.50 + case
Total £84.00 including VAT

As advertised by us at £67.50 + case i.e. £84.00

MODEL M1200 SPECIFICATIONS
DC Voltage: 0.15-0.5-1.5-5-15-50-150-500-1,500V (100k ohms per volt)
AC Voltage: 1.5-5-15-50-150-250-500-1,500V (31.6k ohms per volt)
DC Current: 10-15-5000uA-15-500mA-1.5-15A **AC Current:** 0-15A
Resistance: 20k ohms-200k ohms-2-20-200M ohms (100 ohms-1-10-100k ohms-1M ohms midscale)
Accuracy: DC Volts: ±2% of full scale Amps/AC Volts: ±3% of full scale
Dimensions: LWD 180 x 125 x 65mm
Approximate Weight: 650g

NOW £49 inc. VAT (UK c/p £1.50)
Supplied with test leads, batteries, handbook and leather case.

Plus many other features including mirror scale, polarity reverse switch, electronic overload protection and taut band suspension.

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Test Equipment catalogue send large 20p SAE

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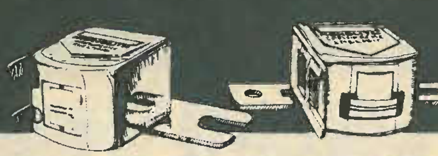
SOUND INVESTMENT



Replacement tape heads from Monolith could mean a big improvement in sound quality from your tape recorder. A full catalogue is available, price 50p, which features a wide range of heads for cassette and reel to reel machines, as well as replacement motors, tape transports, etc.

Universal cassette heads to EIAJ standard, hole centres 17mm apart, 12mm from head face:

B12-02	Mono record/playback	£ 4.62
B24-01	Stereo playback	£ 4.62
B24-02	Stereo r/p	£ 7.66
B24-07	Stereo r/p for Dolby systems	£ 9.05
C42RPH20	Stereo r/p sendust head, suitable for chrome & metal tapes	£10.67
C42RPH04	Stereo r/p glass ferrite, the ultimate long life, high performance head	£13.34
C42RPS18	Stereo twin gap r/p long life head for record monitoring	£28.99
C21ES18	Mono/Stereo erase head	£ 2.13
C44RPH03	Four channel/track r/p	£15.15
C22ES04	Twin half track erase	£ 5.43

Ex stock deliveries, all prices include VAT. Post and packing 40p.

MONOLITH electronic products

The Monolith Electronics Co. Ltd., 5/7 Church Street, Crewkerne, Somerset TA18 7HR. Tel: 0460 74321. Telex: 46306 MONLTH G.

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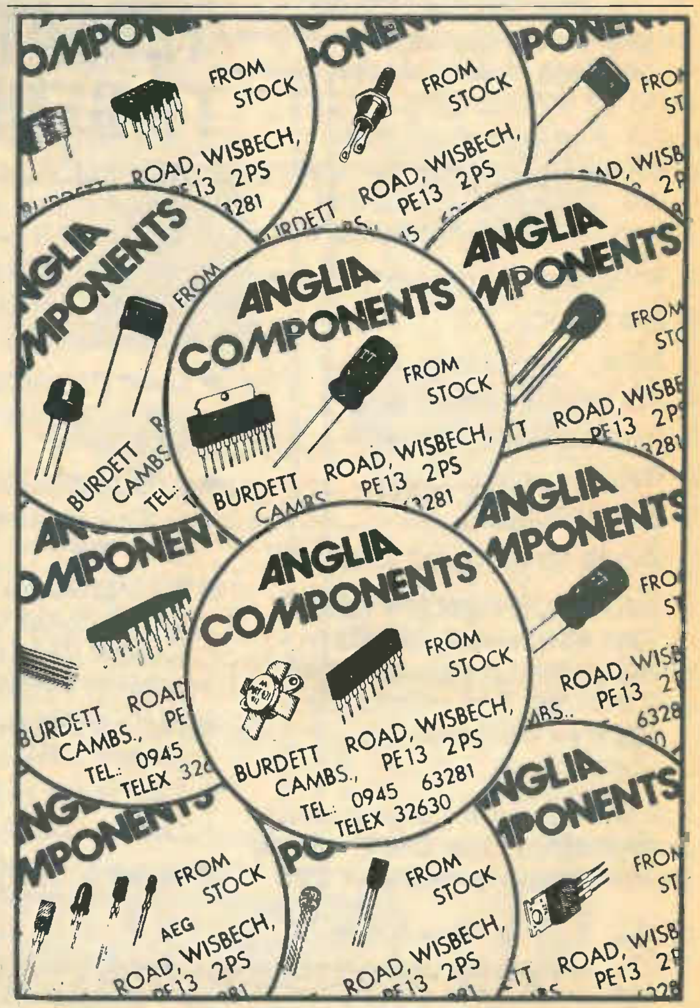

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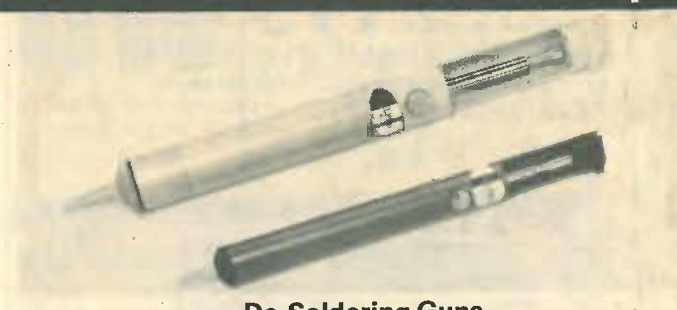
Hand Tools & Production Aids for the Electronics Industry

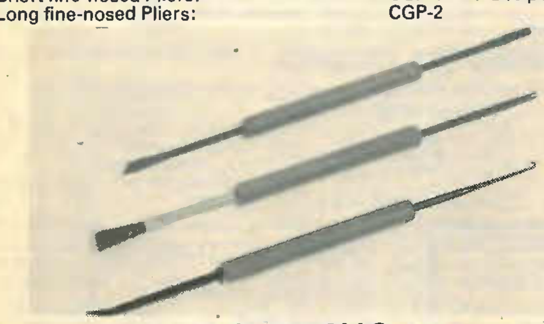
Cushion-Grip Hand Tools

Angled Side Cutter: (fitted with safety spring to hold cut wire ends) CGC-1
Short fine-nosed Pliers: CGP-1
Long fine-nosed Pliers: CGP-2
£3.75 each or £10 per set



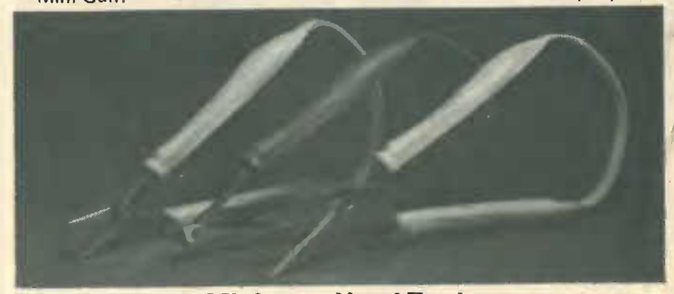
De-Soldering Guns

Standard Gun: TSG-1
Mini-Gun: TMG-1
£5.95 each or £10 per pair



Solder-Aid Set

Knife – Scraper – Stainless Steel brush – Fork – Reamer – Hook
£3.74 per set



Miniature Hand Tools

Fine Tweezer/Plier: PEG-203
Miniature Side Cutter: PEG-302
Serrated Scissor/Shear: (for cutting fine wires, foil and card) PEG-4
£3.75 each or £10 per set

FREE With all orders over £10. Reel of de-solder wick and tweezer (value £1.20) All prices include P. & P. and V.A.T.

TELE-PRODUCTION TOOLS LIMITED Dept. WW-1
Stiron House, Electric Avenue, Westcliff-on-Sea, Essex, SS0 9NW Telephone: Southend (0702) 352719

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JOIN THE PROFESSIONALS...

If you are looking for amplification, take advantage of the same superb quality Crimson modules that the BBC, IBA, KEF and numerous recording studios have been using for years! Our expertise in this field of electronic design is internationally renowned, our reputation is based on quality, reliability and value for money and when it comes to technology, our modules feature possibly some of the world's most advanced audio circuitry yet devised. The Crimson range of audio amplifier modules is available to industry and public alike and is backed by full technical data, free technical advisory service, fast delivery and a full range of complimentary components available such as toroidal power supplies and heatsinks, etc.

SPECIFICATIONS

Type	O/P 8 ohms*	O/P 4 ohms	PSU	H/sinks	Slew limit	S/N	Sensitivity	THD (typ)	FR(–3dB)	Size
CE 608	38	—	CPS 80	HS50	30VuS	110dB	775mV	0.0035%	1.5Hz—50KHz	80—120—25
CE1004	44	70	CPS150	HS50/100	30VuS	110dB	775mV	0.0035%	1.5Hz—50KHz	80—120—25
CE1008	65	—	CPS150	HS50/100	30VuS	110dB	775mV	0.0035%	1.5Hz—50KHz	80—120—25
CE1704	85	121	CPS250	HS100/150/FM1	30VuS	110dB	775mV	0.0035%	1.5Hz—50KHz	80—120—25
CE1708	125	—	CPS250	HS100/150/FM1	30VuS	110dB	775mV	0.0035%	1.5Hz—50KHz	80—120—25
CE3004	170	250	CPS250	HS150/FM2	30VuS	110dB	775mV	0.008 %	1.5Hz—50KHz	161—102—35
CPR1X	output	775mV	REG1	—	3VuS	70dB	2.8mV	0.008 %	10Hz —50KHz	138— 80—35
MC1X	output	2mV	REG1	—	3VuS	65dB	70/150uV	0.008 %	10Hz —50KHz	80—120—35
XO2/3	output	775-2500mV	REG1	—	9VuS	90dB	775mV	0.01 %	Preset	150— 50—20

*Power output is quoted in WRMS and is given for two modules off the same power supply. Higher powers can be obtained if using our dual power supplies or one module per PSU or if using a stabilised power supply.

Crimson modular audio amplifiers feature ★ low values of transient and steadystate distortions ★ envelope distortion (below 500 Hz) less than 0.05% ★ on board electronic protection ★ PCB pin and edge connector termination ★ full range of complimentary components available ie. PSUs, heatsinks, etc.

NEW: We now have a completely new Hi-Fi Kit package to offer:
CK 1010 contains pre-amp circuitry, all metalwork, connectors, wire, etc., to make a complete pre-amplifier.
CK 1040 contains power amp modules, all metalwork, dual power supply, connectors, heatsinks, wire, etc., to make a complete 40 w/channel power amplifier.
CS 1100 as CK 1040 but at 100 w/channel

Unlike other module manufacturers CRIMSON have a major share of the esoteric, specialist Hi-Fi market. **Unlike** many manufacturers we acknowledge the massive audible differences that small component/circuit changes can produce. However our amplifiers **are** technically outstanding and have been subjectively 'tuned' to a stunning level of crisp and detailed reproduction.

PRICES

Power amp modules		Power supply modules		Heatsinks	
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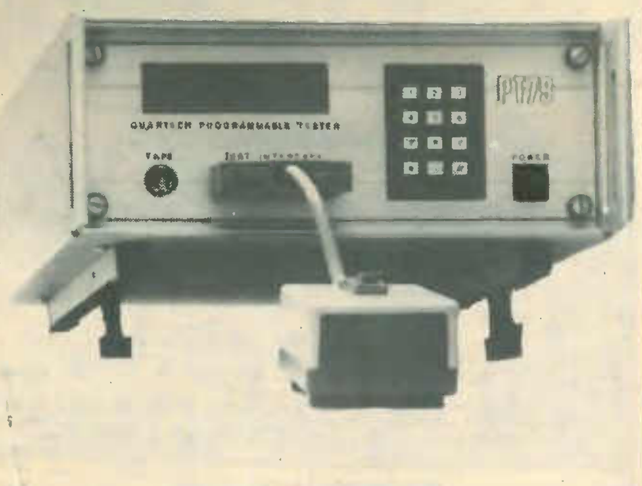

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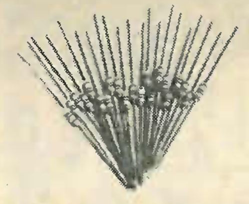

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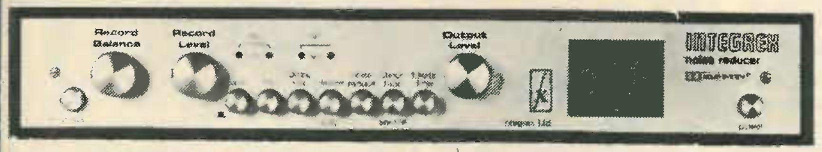

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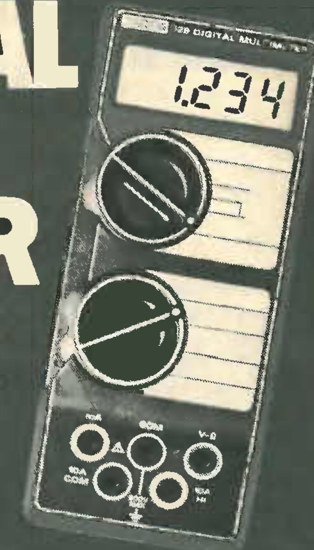

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A charter for isolation

One small indication of the nature of the UK's new Engineering Council is the fact that the job of chairman is to be part-time and unpaid. The high abilities of Sir Kenneth Corfield, who will be the first to occupy the seat, are beside the point. Apparently the duties are not considered important enough to require full-time attention nor valuable enough to be rewarded. Of much greater significance, though, is the fact that this creation of the Department of Industry is being incorporated by Royal Charter, rather than by statute as recommended by the Finniston Committee. As such it has the approval of the monarch, and hence of the government, with all the social cachet this implies; it is guaranteed continuance and the monopoly power to do its own thing; and there are the financial advantages of being a charity. But it has no real power to make changes: unlike a statutory body it has neither the authority of Parliament behind it nor the responsibility of having to be accountable to Parliament for its actions.

The individual British engineer may be forgiven for wondering what this cosy group of big-wigs can actually do for him – or, indeed, for the country as a whole, in the sense that Finniston had in mind (see his famous report). At the time of writing the emergent Council does not even possess the powers of that other chartered and ineffectual council, the CEI, which at least has its own national register of engineers and the right to dub us "chartered engineer".

But it is only fair to wait and see. We can only judge by the results. What is, however, immediately obvious from the government's decision not to allow a statutory Engineering Authority is that British engineers as a body are to be firmly isolated from public affairs.

Engineering is changing the world, and it is in politics whether one likes it or not. (If you doubt this, think of weapons systems for a start.) Yet in the UK engineers are not considered good enough to be involved in the decision making which determines the uses of their work in the wider world. Or is it, perhaps, that they are considered too dangerous – because they are often the first to know what is really going on? The Oxbridge arts men who are still the most influential members of Britain's bureaucracy do not like to admit that they are really running a technocracy. To open the doors to engineers would make this too explicit. They prefer to keep engineers in a bin and take them out to perform like puppets when required – then put them back and close the lid firmly, before they start asking awkward questions about the purpose of the act. It would not do to let engineers become too aware of their real power.

Fortunately for the bureaucrats, and their political bosses, engineers as a body tend to be conservative in outlook. When roused, they will proudly unfurl a banner with the strange device *Nihil aliud nisi officium* (I'm only doing my job). This attitude, according to one contributor to this issue, Dr Peter Hartley, is a result of a system of engineering education which is inappropriate for the contemporary world – a system rooted in the 18th-19th century ethos of humanism and the "conquest of nature". It leaves us, says Hartley, with a "conception of the engineer as no more than a high-grade technician, a functionary not fully professional – that is, with no responsibility for his actions beyond their technical adequacy." Of course, most engineers like to think of themselves as being responsible in a fully professional way; but where do they get this idea? More often than not it is a delusion, arising because their education is different from that of technicians and probably longer, because their work is often more difficult as a result of having to consider options and decide among them, and because these decisions are likely to have wider effects. But if with all this the engineer still really does no more than react to requirements that he must accept as given, he is not being fully professional, says Dr Hartley, since he is not taking into account the ultimate meaning and consequences of his professional actions.

A new body like the Engineering Council would be in a good position to initiate a system for educating engineers to become fully professional in the above sense. But while this organization remains virtually a cocoon, isolated from interaction with public policies except through the market for engineering products, there is not much chance of this happening.

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Millimetre-wave lens aerials

New method for constructing metal plate refractors is simpler

by K. L. Smith Ph.D.
University of Kent at Canterbury

Metal plate refractor aerials were once popular for use at lower frequencies, but fell into disuse mainly because of manufacturing difficulties. They have considerable advantages for some purposes and a new way of constructing them is described here. This economic method yields a large number of identical units.

While looking at aerials for experimental propagation studies and communications tests near 24GHz, we had to face the usual daunting task of figuring dishes for sufficient accuracy of surface. Alternatively, trying to raise enough money for someone else to do it would be nearer the truth. Winston Kock's early paper[1] on metal plate lenses, where the effective dielectric constant for the waves is less than one, seemed tantalising enough to offer an excellent system if simple design and construction techniques could be developed to give efficient operation at millimetre wavelengths.

We carried out the design described here and obtained the good results reported. During the design for one aerial, twelve were actually made as a by-product of the method. The cost of these twelve at the design price of one was simply the extra cost of the materials. One of the lenses is shown in Fig. 1 and on the front cover.

Fig. 1. One of the lens aerials constructed by the new method.

Advantages over a reflector

Because both the incident and the reflected waves are distorted or scattered by any irregularity on the surface of a mirror, the figure or accuracy of the surface of a reflector has to be held quite rigorously in terms of fractions of a wavelength. But a wave passing the surface of a lens is only affected once, so that the figure of that surface can be relaxed to half the accuracy for the same performance. A reflector operated off the axis of symmetry introduces a rapid deterioration of gain, beamwidth and performance generally. The lens aerial described is relatively insensitive to this off-axis operation – so much so that two (or more) feeds can be used for simultaneous communication with more than one station, yet with only a small reduction in aerial gain over a considerable solid angle around the axis. The lens performance is also insensitive to small amounts of twisting of this shape. (A reflector is very sensitive to this twisting.) These properties correspond to performance with respect to 'coma' and 'astigmatism' in optics.

Another advantage of the lens is that the energy is transmitted forward through the lens and only a fraction of the already small percentage reflected back is able to re-enter the feed horn. At first sight, the required thickness of the lens would appear to be comparable to the depth of a reflector, but an aerial of this type can be 'stepped' and this reduces the thickness and therefore the amount of material used. One small disadvantage of stepping is the slight shadowing that occurs, as it reduces the effective aperture a little. But to make up for this, one should consider the absence of feed horn or secondary mirror blocking that occurs in reflectors.

Slightly more sophisticated advantages accrue from the strongly polarising effect of the grid of plates making up the entire aperture. This yields an aerial with a remarkably low cross polar response. Frequency re-use systems might find this of considerable value. One disadvantage of a lens aerial over others is that it is bandwidth limited (equivalent to chromatic aberration in optics), although some people may consider this an advantage. Stepping the lens profile has the interesting effect of broadening the bandwidth.

Theoretical operation

From the simple derivations in the appendix the predicted curve on the surface is an ellipse on one side, for a plane surface on the other. Readers might think it strange that a *concave* lens is required to give the plane wave from a point source. The explanation is that the phase velocities of the wave are greater than the velocity of light inside the plates, which yields a refractive index less than one – hence the concave shape for a converging system. At every point where the phase of the wave increases by 360° as one moves out over the lens from its centre, that much of the metal plate may be removed without affecting the final plane wave phase front. This is the explanation of the stepping.

The spaces between the plates form a waveguide and for this reason the spacing cannot be less than half a wavelength, or the 'waveguide' would be below cut-off and no propagation would result. The actual thickness in terms of the wavelength sets the value of the refractive index. Of course, wavelength changes with frequency – so therefore does the refractive index, as can be seen from equation A_3. This is what makes the lens frequency-sensitive.

Because the refractive index is determined by the separation of the plates, then careful spacing for constancy over the surface is required. This was achieved by small accurate spacers threaded on high tensile wires, as shown in Fig. 2.

Construction

To make the project a little more challenging, the design frequency was increased to 30GHz (wavelength = 1cm). The very complex problem of developing stepped curves gradually changing plate by plate, which when assembled make up the lens, was obviously one of the 'acute manufacturing problems' reported in the earlier literature. It was while working out how to make this surface of revolution in one operation that the original idea in this work occurred. The material chosen was thin aluminium sheet – which, of course, had an intrinsic thickness according to its gauge. By choosing the appropriate gauge and stacking twelve of these strips, one obtains the precise design spacing, a, by taking strip one, thirteen, twenty-five and so on. Eleven other lenses are obtained by taking the corresponding strips in the series.

The important advantage of this procedure is that once the strips are assembled and the template made, then by turning the whole stack on a large lathe (and engineers have mentioned that vertical axis lathes are available to turn everything up to four metres diameter!) all the strips are cut to the precise figure at each point. In practice this process was fairly simple, once the strips were bolted together and bedded in wax against the faceplate. Fig. 3 shows this work in progress.

No mention has been found in the literature indicating that this method has been employed before. Most of the difficulties of making these lens aerials are overcome by employing it.

Design example

The wavelength at 30GHz is just 1cm. When the refractive index has been decided on, the spacing of the plates is calculated from equation A_3. If the refractive index is too small, reflection losses at the surface increase. On the other hand if it is too large, the lens thickness tends to become unmanageable. Gaining experience with such considerations enables a com-

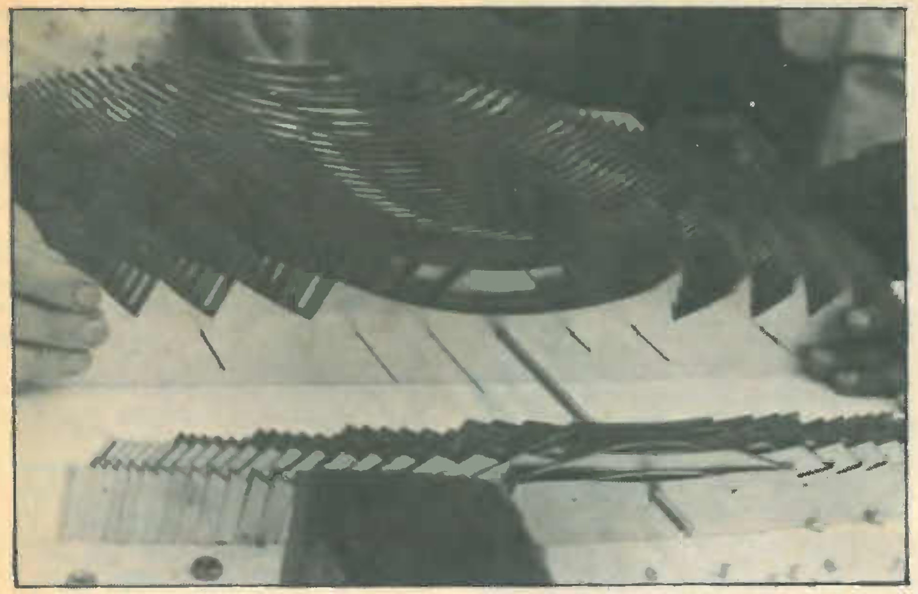


Fig. 2. Assembling the aluminium strips on high tensile wires, with spacers threaded on the wires to form the waveguide between strips.

Fig. 3. Aluminium strips bolted together and bedded in wax are turned on a large lathe to produce the required figure. A vertical-axis lathe could be used for larger diameters.

promise choice to be made. We chose n = 0.583 and using equation A_3

$$a=\frac{\lambda}{2\sqrt{1-n^2}}=0.62\text{cm}$$

Now the size of the lens aperture requires a decision. This depends on the gain G you are looking for, which, as shown in the appendix, is closely linked with the beam-width obtained.

An important relation between the maximum gain of an aperture aerial over that of an isotropic radiator, and the area A of its aperture, is given by

$$G=\frac{4\pi A\eta}{\lambda^2}$$

or in dBs,

$$G_{dB}=10\log\frac{4\pi A\eta}{\lambda^2}$$

Here η is called the *efficiency* and is a fraction of how close the effective electrical area approaches the geometrical area.

The other variable yet to be decided on is the focal length, f. We decided to work to a chosen gain, to see how closely we could achieve it. The choice was 45dB over an isotrope. This gave

$$A=\frac{\pi d^2}{4},$$

where d is the required diameter. Placing this into the gain equation;

$$G=\frac{\pi^2 d^2}{\lambda^2}$$

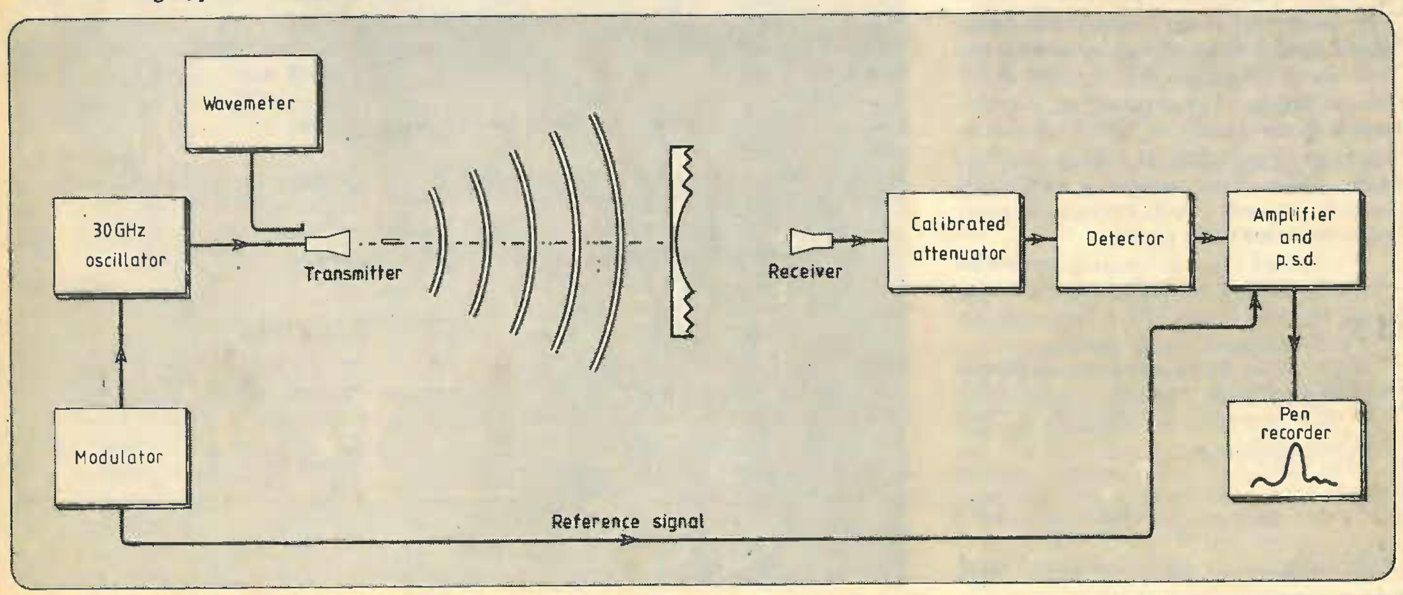
$$\text{or } d=\frac{\lambda}{\pi}\sqrt{G}=56\text{cm}$$

As work progressed, the final diameter as swung on our lathe was 54cm, yielding a theoretical gain expectation of 44.59dB. Using d, we have immediately the 3dB beam width from equation A_9,

$$\theta°\ \frac{57.3\lambda}{d}=1.06°$$

Also knowing d, the number of plates in each lens is easily found from $d/(a + g)$ = 82 (g = plate material gauge) which was 24 s.w.g. (≃ 0.57 mm). Finally, having established d, the focal length can be chosen. Often this is set by the beam pattern of the primary feed horn, or by the ease of making the horn to meet the dish or lens illumination requirements. The power density pattern from a feed radiator drops off gradually from its maximum along the axis, so it is not possible to illuminate aperture aerials uniformly up to their edges, then have the feed power drop off instantly to zero. The compromise chosen is often based on the '10dB down' rule, that is, when the 10dB down circle in the (hopefully!) uniform primary feed pattern falls on the perimeter of the dish or lens, 'optimum' illumination is said to be achieved. The wasted 'spillover' is ignored, but contributes to the inefficiency. This was the criterion chosen here and a diagonal horn was designed to feed the lens from a focal

Fig. 4. Set-up for measuring the performance of the lens aerial. Calibrated attenuator is set to equalize r.f. power at detector, then attenuator readings give gain of aerial over standard horn.



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point 64cm behind it.[2]

With the focal length settled, and a known refractive index, the various ellipses were carefully plotted to scale, according to the equations given on Fig. A_2. A metal template was worked to these curves, and this enabled the final figure to be achieved while turning the curves on the lathe. The focal length and diameter chosen resulted in six steps across the lens radius.

Performance measurements

A horizontal test range has to be long enough to enable the sending and receiving aerials to be in the far field zone. The minimum distance for this condition is

$$\text{Range} \geqslant \frac{2d^2}{\lambda} = 58 \text{ metres for this aerial}$$

We measured the gain and beam pattern over a 60-metre range. There are standard gain horns available commercially and the measurements on any test aerial can be relative to one of these. The system used to do this is shown in Fig. 4. By using a calibrated attenuator the received r.f. power reaching the detector can be equalised in both cases. The difference in attenuator readings indicates directly how much higher the gain of the test aerial is over the standard horn. The synchronous, or phase sensitive detection [3] system yields a more precise performance in this kind of measurement and greatly increases the signal-to-noise sensitivity.[4] The result obtained was a gain of 39.3dB for one sample lens and 38.2dB for another. This shows a good agreement in performance.

For the best sample, the efficiency is η = 30%. This means that the 54cm physical diameter of the lens is equivalent to a perfect one 32cm in diameter, although a rigorous discussion of this point brings in consideration of what is called the aerial directivity, D, as well as the gain, G. This performance is quite good, when it is remembered that the theoretical uniform power distribution across the aperture is never obtained in practice and that some power is wasted through "spillover", scattering and reflection.

Beamwidth and sideholes

The same test range enables the beam power pattern to be plotted by turning the lens about a vertical axis through small known angles. The drop-off in received power as the system is turned off-axis is made up by reducing the calibrated attenuator value, thus gaining a direct dB reading for each point. Plotting on polar paper gives the beam pattern.

We cheated a bit on this measurement in that a direct X-Y plotter arrangement was used, but this luxury is not necessary for less well-equipped experimenters.

Fig. 5 shows the pattern obtained for the 39.3dB gain aerial. The 3dB beamwidth is 1.4° and directly from equation A_9 the effective diameter is

$$d_{\text{eff}} = \frac{57.3 \times 1}{1.4} = 41\text{cm}$$

This is larger than the predicted size from

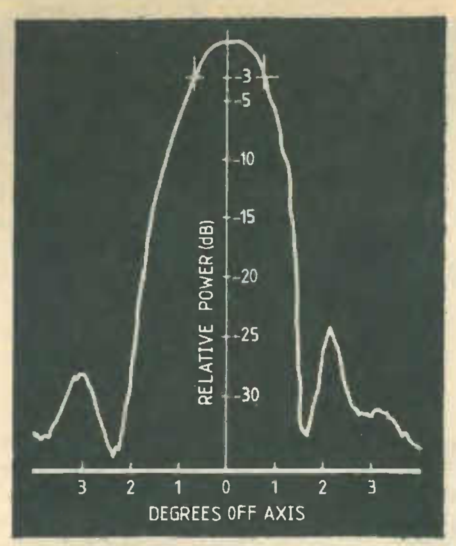


Fig. 5. Polar diagram of lens aerial. Slight asymmetry suggests astigmatism in lens.

the efficiency calculated from the gain measurement. This is explained by the lack of consideration of "spillover", scattering and reflection in the calculation. Thus the aerial is more directive than the gain calculation suggests and further illustrates the difference between the ideas of gain and directivity of an aerial.

From Fig. 5 the slight asymmetry on the polar diagram shows that in all likelihood there is a small amount of astigmatism in this lens. The unequal sidelobes strengthen this assertion. The worst case sidelobe is approximately 25dB down on the main beam peak.

Concluding remarks

Building aerials is interesting work and the pleasure of obtaining such a good result was satisfying. Many other possibilities for lens aerials have arisen from this work and the author would be pleased to see someone obtain good 'on-air' results at 24GHz. Amateurs could certainly design a system from the data and example given.

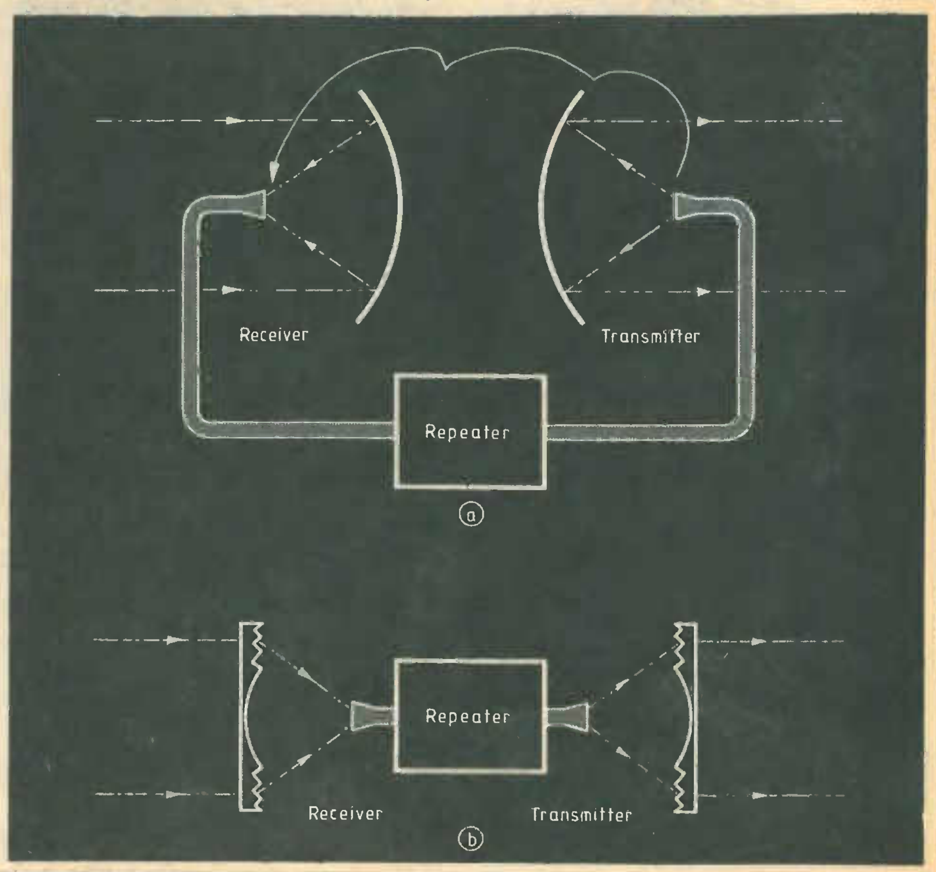
But a number of other applications come to mind and there could be considerable development work for interesting student projects or professional applications.

We attempted to measure the off-axis cross polarisation peaks, but no response at all was seen! A much greater sensitivity might yield some cross polar performance figures, but these appear to be many tens of dB down on the co-polar levels. Future work is planned to find these cross polar levels.

One advantage of lenses for repeater links is the reduction of cross-talk between transmitting and receiving aerials. This often plagues reflector systems in that the transmitting horn points towards the receiving horn and spillover is likely to cross couple. This is absent in double lens repeater stations, as shown in Fig. 6. Switched beam repeater stations can be designed easily, by erecting two or more lenses in the surface of the 'bin' on the tower and simply switching round the feed horn to the appropriate focal point.

An outstanding possibility exists for an experimenter to develop a 'venetian blind' erecting system for the plates of this lens system. Although this would be awkward and unstable on Earth with gravity and wind effects, a number of satellite people with whom we had a discussion got quite excited about the possibility. Once in orbit, the stacked plates would be pulled up

Fig. 6. Use of lens aerials in repeater station (b) reduces cross-talk between transmitting and receiving aerials indicated by arrow around dishes in (a).



on fine cords and would remain fixed and rigid at highly accurate spacings.

The project has been interesting and I would like to thank Mr U. E. Ekaette, who carried out experiments on this project, and the staff of the Electronics Laboratories, UKC, who undertook constructional work.

Appendix

The phase velocity of the e.m. wave between metal plates is given by waveguide theory as [5]:

$$v = \frac{c}{\sqrt{1-\left(\frac{\lambda}{2a}\right)^2}} \qquad A_1$$

where c is the velocity of light, a is the plate spacing and λ is the free space wavelength. If a is set at $\lambda/2$, v goes to infinity; in other words no propagation is possible. The waveguide is said to be 'cut-off' for a larger than $\lambda/2$, v is greater than c.

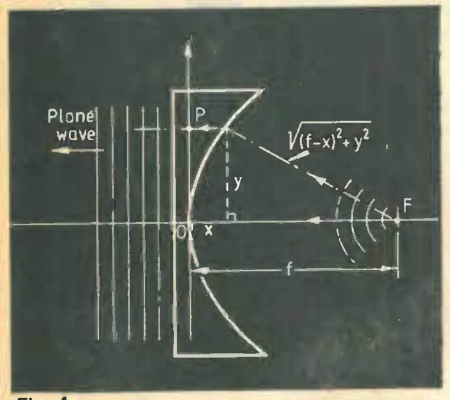


Fig. A_1

From definitions in optics, the refractive index n is the ratio of wave velocities in the two media,

$$n = \frac{c}{v} \qquad A_2$$

and for this work, n is less than 1. From A_1

$$n = \sqrt{1-\left(\frac{\lambda}{2a}\right)^2} \qquad A_3$$

Again from optics, optical paths (that is, paths along which the phases are the same) are defined as

$$\frac{\text{geometrical path}}{\text{wave velocity}} = \text{optical path} \qquad A_4$$

Consider Figure A_1. If the curve is such that all optical paths from P to the axis OY are equal, then the point source radiating spherical waves at F will end up sending out a plane wave to the left from OY onwards. Clearly for all parts of the incident spherical wave to end up producing a plane wavefront in phase along OY, the velocity between the plates must be greater than c.

Therefore, equating the optical paths OF and P will give an equation for the required curve.

$$\frac{\sqrt{(f-x)^2+y^2}}{c} + \frac{x}{v} = \frac{f}{c} \qquad A_5$$

Tidying up and writing in n for c/v,

$$(1-n^2)x^2 - 2(1-n)fx + y^2 = 0 \qquad A_6$$

Co-ordinate geometry buffs will immediately recognise this as the equation of an ellipse. If we cut this curve as a concave ellipsoid surface on the stack of metal plates, it should act as a precision aperture aerial of focal length f.

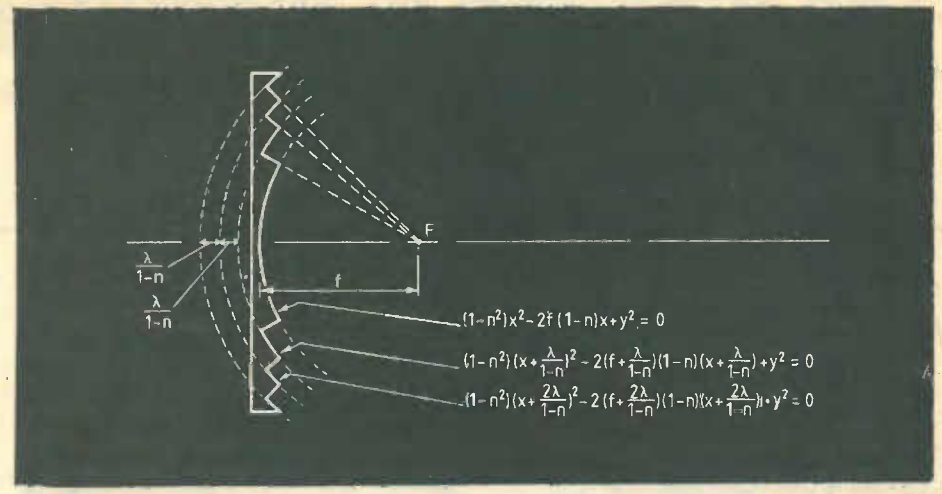


Fig. A_2

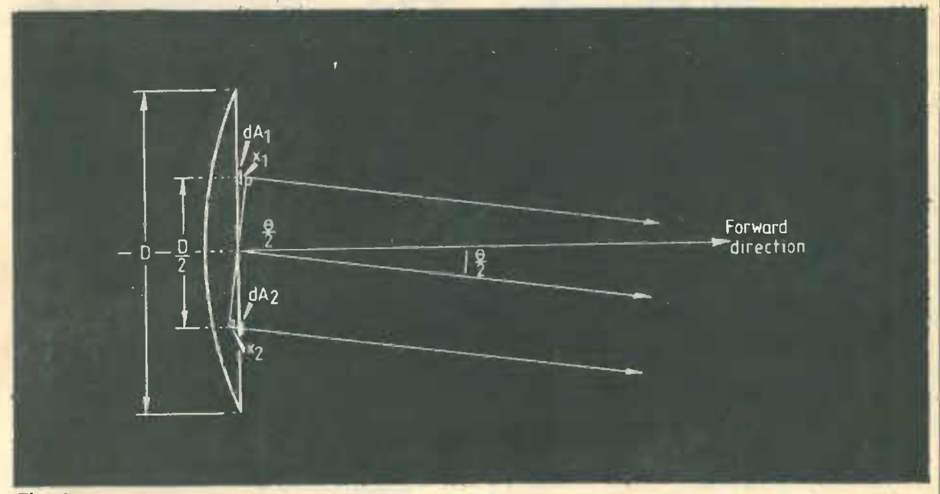


Fig. A_3.

Stepping

In a distance $\lambda/(1-n)$, the phase of the wave changes by 2π radians inside the plates. So a whole family of ellipses with $\lambda/(1-n)$ as a running parameter enables metal to be removed as shown in Figure A_2.

These curves can be plotted accurately in order to construct a template, which can be used during manufacture to yield a surface figure whose r.m.s. errors are much less than a wavelength ($\sim \lambda/16$ at 30GHz with care).

Approximate beamwidth of aperture aerial

In microwave communication (and at many other frequencies for that matter) the ability to 'beam' the energy towards the intended receiver is a great help in keeping the required transmitter power down; making the system more interference free; making the communication relatively private; and in some cases avoiding problems with 'multipath' effects – which is a version of freedom from interference. All this is especially true in satellite communication systems. The contour diagram of the aerial beam intersecting the Earth in that application is termed the 'footprint'.

Consider the aperture aerial in Figure A_3. If the aperture is illuminated uniformly right across the dimension d, then any small element of the wavefront dA, will radiate in phase along the forward direction. It will also radiate nearly equally in other directions (some readers will recognise that this is what Huygens said in his comments on 'secondary wavelets'). However, the *phase* of the waves in these directions will differ.

In Figure A_3, consider waves along direction $\theta/2$ to the forward direction. If the waves from dA_1 and dA_2 vibrate 90° out of phase along direction $\theta/2$ then that will be true also for all dAs separated by $d/2$. But this amount of phase difference means that the power density in the wave is now half that going along the forward direction. This is called the '3dB down' direction. To get 90° phase difference in the contributions from the dA_1s and dA_2s, x_1+x_2 must equal quarter of a wavelength.

∴ from the right angled triangle:

$$\sin\frac{\theta}{2} = \frac{\lambda}{8} \div \frac{d}{4} = \frac{\lambda}{2d} \qquad A_7$$

Now for any reasonably high gain aerial, the '3dB down' beamwidth θ will be small. This means that $\sin \theta/2 \simeq \theta/2$ for the angle in radians.

$$\text{radians} = \frac{\lambda}{d} \qquad A_8$$

$$\text{or } \theta° = \frac{57.3\lambda}{d} \qquad A_9$$

This is approximate, but quite good in practice. Real beamwidths would always be greater than this optimistic estimate.

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The function of functions

An approach to Walsh functions from telecommunications history

by Thomas Roddam

Named after their originator, an American mathematician, Walsh functions are now beginning to find applications in electronics. This article first discusses the use of mathematical functions in general in telecommunications then goes on to illustrate the nature of Walsh functions through a practical technique for avoiding crosstalk between overhead telephone wires. Generation of Walsh functions and some of their applications will be dealt with in the concluding part of the article to be published later.

At somewhat irregular intervals readers of *Wireless World* find themselves confronted by an article on some mathematical function. It may be, indeed it often is, our old friend the exponential, or it may be, say, Muratori's function. Why does this happen, why do we write these things, why do you read them?

It is not just the money, barely enough to pay the ink bill, which makes the author produce this stuff. There is a real satisfaction in attempting to make poor old $\exp(x)$ fresh and interesting: there is a real challenge in explaining Muratori's function clearly without boring the reader stiff.

The reader is more of a problem. Many years ago the editor, not this one or his predecessor, told me how he had actually seen a reader, reading the latest issue. In the Underground. However, little is known about the great mass who live a no doubt quiet and industrious life, and never write letters or complete questionnaires. The problem is quite simply this. Either they know all about the Binomial Theorem, let us say, or they don't. If they don't, either they need to, or they don't. The last group have lived happily in ignorance, while the ignorant who need to know must surely need to know more than can be packed into a few pages.

The answer, I have decided, lies in the sort of people we are. In most organisations there are two sets of people. There are the hard-headed men committed to getting stuff out of the factory gate and the long-haired boys messing about with slide-rules. If you prefer it there are the fossils who spend a week getting it wrong with a soldering iron rather than a morning on the computer finding an optimum solution. Muratori's function is a weapon used by the theorist to defend himself against the pragmatist, especially if the pragmatist is his boss. Know your enemy.

With this in mind I began to peer back into the early days of our trade. It turns out that we have been in business longer than I thought. The electric telegraph is, of course, the starting point, but it is surprising to find that the proposal for an electric telegraph actually preceded the work of Volta and Galvani. The first proposal, in the *Scots Magazine*, was in 1753, and the scheme was to use 26 wires, each with a hanging pith ball which would strike a bell, using a Leyden jar as source. Once the cell had been invented, and Oersted had found that a current would influence a magnet, the way was open.

By about 1850 things were really moving and the contrasts, the tunnel vision, all the factors of our modern technology were showing themselves in all their glory. The submarine cable, and especially the Atlantic cable, bring out all that is finest in pragmatism, theory, and the use of theory for analysis but not for synthesis. Fig. 1

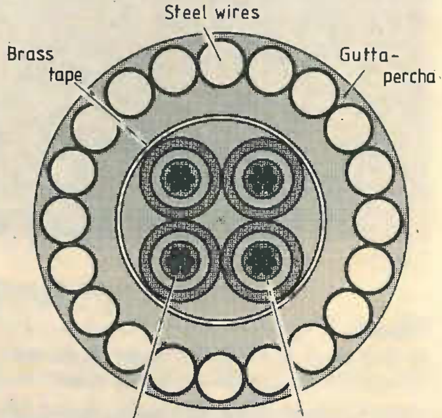

Fig 1. Cross-section of a submarine telegraph cable, as constructed at about the turn of the century.

comes from Notes on Telegraphy, A. G. Pratt and G. Magg, which my mother seems to have bought in 1903. The use of the stranded conductor was the idea of Professor William Thomson, later Lord Kelvin, in 1854. Clearly he was a sound practical man. In 1855, however, he was considering the partial differential equation

$$LC\frac{\partial^2 n}{\partial t^2}+(CR+LG)\frac{\partial n}{\partial t}+RGn=\frac{\partial^2 n}{\partial x^2}$$

The trouble is that he decided to neglect the inductance, L, and the leakage, G. The full equation, called the telegrapher's equation, was published by Kirchhoff in 1857, and forgotten, by Heaviside in 1876, but Heaviside never had any luck, and by Poincaré in 1893. Thomson comes up with a solution for the line current at time t, I_t, in terms of the maximum current the battery can produce, I_o, of:

$$I_t=I_o(1-2(\epsilon^{-\pi 2t/kcl2}-\epsilon^{-4\pi 2t/kcl2}+\epsilon^{g\pi 2t/kcl2}\ldots))$$

where $\epsilon=(3/4)^{t/a}$ and $a=kcl^2\log_e(4/3)/\pi^2$

There's glory for you. At the end of the day it boils down to saying that for a particular type of line the speed of working is inversely proportional to the square of the length.

At this point there are three ways to go. The first, Thomson again, is the purely instrumental one. When the battery is applied at one end of the great distributed RC circuit the current starts to grow, very slowly, at the far end. Invent a very sensitive detector and it will only be necessary to hold the key down for a relatively short time to get a signal, and the reduced charge in the system will soon die away ready for the next mark.

The next step is to use what politicians call a U-turn: at the end of a positive mark the battery is reversed, to send a curbing current down the line. The duration of the curbing current was changed according to the speed of working but was typically about four-fifths of the mark pulse. After the curb came an inter-pulse interval, with the line earthed.

This is nothing but something we tend to regard as quite a modern idea. The signal characteristics have been tailored, coded, to suit the characteristics of the medium. Indeed, the telegraphers did quite a lot of this. Morse produced a code in which the commonest letters used the shortest groups, and on the long cables, with the sensitive receivers, input and output capacitors were used to eliminate the effects of earth currents. Then they went to multiplexing by using three-value logic, and to some quite sophisticated time division multiplex systems for short lines, with synchronisation between the two ends.

All this ingenuity, all this tedious calculation of the rise and fall of current in long lines, but no-one really looking at the telegrapher's equation. At least, memory suggests that Heaviside did, but his sad cry 'even Cambridge mathematicians deserve justice' summarizes his influence. In Europe the invention of the loading coil is attributed to Pupin, but really it is sitting there, just waiting for someone to ask "what value of L do we need?"

If there is a moral, and I think there is one, it is that it is a waste of time to use mathematics to find out why it works. Use the mathematics to find out if it will work, or how to make it work better.

Under certain conditions the telegrapher's equation brings up the Bessel functions in its solutions. The Bessel functions weave in and out of the history of telecommunications. They became very trendy

just after someone had the idea of sticking a paper cone to the centre of an ear-piece, instead of fastening the ear-piece to the end of a large horn. Looking back we can ask why there was such interest in calculating how the cone would break up into spatial harmonics when the real problem was to prevent this happening at all. More recently the Bessel functions have appeared in filter design, although I found them in a pulse response problem quite a long time ago.

Then, of course, there was frequency modulation. The idea, that by keeping the carrier going at full power all the time the noise at the receiver could be kept down, seems a fair one to use for examining a system. And it seemed to work. The theoreticians began to study the characteristics of

$e=E_o\sin(\omega t+m_f\sin pt)$, where

$\omega=2\pi f_c$, with f_c the centre frequency

$p=2\pi f_s$, with f_s the signal frequency

and m_f, the modulation index, is the ratio $\delta f_c/f_s$.

When this expression is expanded it becomes

$$\begin{aligned}e=&E_o[\mathcal{J}_o(m_f)\sin\omega t\\&+\mathcal{J}_1(m_f)\,[\sin(\omega+p)t-\sin(\omega-p)t]\\&+\mathcal{J}_2(m_f)[\ \ldots(\omega+2p)\ldots(\omega-2p)\\&+\mathcal{J}_3(m_f)\ldots\end{aligned}$$

At this point the interpreters did the wrong thing. If the spectrum is to be kept into the same bandwidth as we need for amplitude modulation we must have $\mathcal{J}_2(m_f)$ and the higher Bessel functions small, so that the $(\omega+2p)$, $(\omega+3p)$ etc. terms can be neglected. This leads to a modulation index of about one half, for which the $\mathcal{J}_2$ term becomes about 3%. If you go on to calculate the noise advantage you find that the whole thing is just a lot of nonsense. Mathematically it is clear that there is no point in taking it seriously. Every schoolboy knows now that the two keys to f.m. operation are hard limiting and a high modulation index.

Here we have the theoreticians saying something would not work, and the practical man showing that it did. A rather bizarre phase was the 'sidebands don't exist' period. The expansion of

$$A(1+m\sin 2\pi f_s t)\sin 2\pi f_c t$$

to give a carrier, $A\sin 2\pi f_c t$, and two sidebands at $(f_c\pm f_s)$, is not the most difficult mathematics we expect to meet. It was, however, too much for a school of thought, still alive around 1930, which held that the signal was there, in the carrier, and could be received with a very narrow band receiver. Circuits were published, sets were made. We shall never know just why they seemed to work, but there are two obvious possibilities. The narrow bandwidth was produced by a string of tuned circuits, which would not be all that narrow even if they were tuned to the same frequency. The detectors used

Sir George Jefferson, chairman of British Telecom, waves cheerily from an elevated position at BT's training school, where engineers practise climbing on these short poles.

then behaved much better at low modulation, so that the carrier enhancement would have improved the detector. The audio amplifier, with CR interstage coupling, could easily have boosted up the lost treble. Alternatively, or additionally, we must not forget one of the great design problems of the time, the feedback from anode to grid through the valve capacitance. Strong coupling, both capacitive and inductive, between the tuned circuits must have been present. Immediately we have a bandpass structure, not a single narrow slit. The true believers would not be deterred.

I referred to this as a bizarre event, because it took place when multi-channel carrier systems were already in use on telephone lines. The distance-limit of speaking by telephone depends on the product of the resistance of the circuit, (in ohms) R, and the capacitance of the circuit (in microfarads) K – or KR. The following figures show approximately the KR which limits easy and practical speech, and indicate the telephonic value of the conductors:

copper wire (open)	KR 10,000
cables or underground lines	8,000
iron wire (open)	5,000

The low value of iron is due to the presence of *electromagnetic inertia*, which is absent in copper.

So the next step was to put in more electromagnetic inertia, in the form of the loading coil.

The great influence which the loading coil was to have on the communications industry arose from the simple fact that the numbers needed were enormous. In the Bell System light loading was a coil every 6,000ft, and heavy loading a coil every 3,000ft. At 3,000Hz loading brought the attenuation per loop mile down from about 2dB to about 0.5dB. Longer circuits, better circuits, more traffic, and so more circuits and more loading coils. The size and the spacing demanded close study. This study, of a long ladder of series inductors and shunt capacitors, brought the functions cosh θ and sinh θ into the communication engineer's life. The development of the low-pass filter, followed by the other classic filters, from the long line analysis explains the awkwardness of early filter theory. In the long line the problems of end effects were relatively trivial, but the ends could wag the filter if only a couple of sections sufficed. Clever systems of high class bodging, like m-derivation, mm' derivation, α-matching, and tedious calculations of mis-match and interaction loss made filter disign an art. Then we found Tchebycheff. If my memory is correct, his interest, in St Petersbourg (he wrote in French) in 1875, was steam engines. All those shiny bits that move to and fro, while the wheels go round, should move in a straight line. Like the pass-band response

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of a filter. The Tchebycheff functions were a step in linkage design.

Not very much relevant to our theme can be found in the history of modern filter design. Once it was seen that the problem was, quite simply, to design a finite network of defined properties, it became a matter of using well-known techniques. The vital step was the realisation that the idea was to find the best value to use in the structures which had grown up from the long line.

Softly the functions come and go, or, if your taste is more demotic, I go, I come back. The Laguerre polynomials have cropped up again, though I haven't seen them around since I dealt with a chain of regulating repeaters, back in about 1950.

The story began with telegraphy, with signals which were either marks or spaces, and moved on to telephony, with the signals a mixture of sine waves. In the 1930s, however, Alec Reevés was building one pulse modulation system after another. Before any of them came into service the digital computer was on the way. The Boolean algebra, which we had come to associate with the use of mathematics in cleaning up classical logic, began to be a really bread and butter affair.

Although Boole's logic, and the techniques based on it, like the Karnaugh map, were central to the signal processing operation, the signal frequently needed to be transmitted from place to place. The available telephone channels, and the general thinking of the radio circuit designers, were based on bandwidth, on the available chunk of frequency spectrum. Information theory, which started well before it really mattered, defined what could be done. Fourier analysis could be used to discover just what the circuits did to the pulses. There is a faint memory of Heaviside here. The pulse gives an infinite series, and then the bandwidth limitations just chops off most of the terms. In pulse modulation systems, indeed, the sine wave really needs an infinite number of pulses, and the pulses need an infinite Fourier series.

The pulse-makers clearly need a new kind of series, to do for them what the Fourier series had done for sinusoidal waveforms. It is to the favourite in this field that we now turn our attention. The biggest advance since sliced bread, we are told, is the Walsh functions, although I regard sliced bread as a cruel and unnatural punishment. But Walshites have written:

"We may well come to the point of view that if Walsh functions had been with us from the start and someone had then come up with the idea of sinusoids we would all want to know what use they were."*

A fund is being started to buy ocarinas for supporters of this view.

We have already seen how important it is to keep one's feet firmly planted on the

★ R. Barrett, J. A. Gordon, D. Brammer. Theory and applications of Walsh functions. Hatfield Polytechnic Symposium 1971.

† I am indebted to Mr A. Emmerson of British Telecom for locating Fig. 2 in the book referred to.

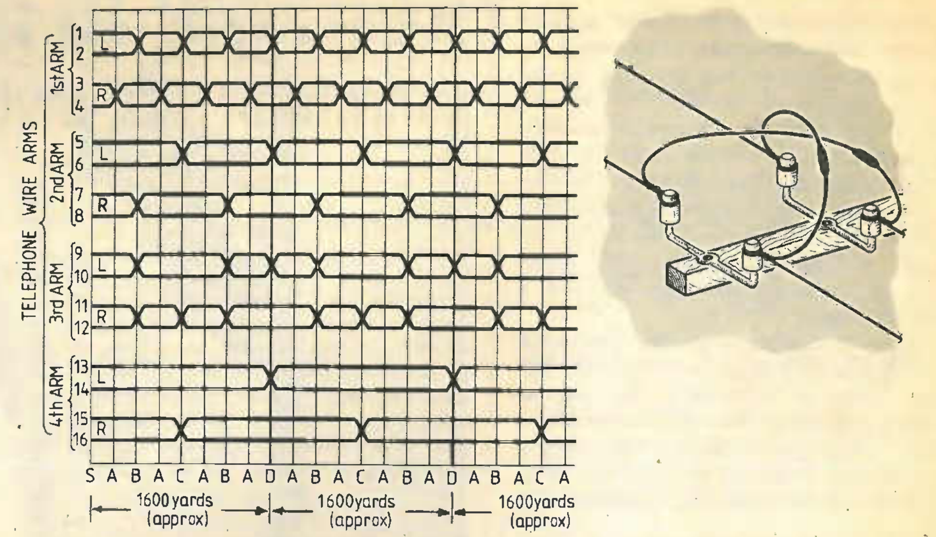

Fig. 2. Transposition of telephone wires for avoiding crosstalk caused by mutual inductance. On the left is the pattern employed and on the right the method of wiring at a transposition point. (Adapted from Railway Signalling and Communications, Tattersall et al, 1946.)

ground when considering the use of mathematics. It is therefore appropriate to look at Fig. 2. When telegraph poles began to be used for telephone circuits it was soon found that if the two wires of one pair simply ran parallel to the two wires of another, the mutual inductance produced cross-talk from one to another. A simple answer is to split the run in half, and cross one pair at the mid point. We can write this symbolically as:

$$\begin{matrix} 1 & 1 \\ 1 & -1 \end{matrix}$$

When there are more than two pairs we can start by taking two pairs as a quad, and use the same symbolic solution, which we can bracket up to be a matrix:

$$\begin{pmatrix} Q & Q \\ Q & -Q \end{pmatrix}$$

This is short for:

$$\begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{pmatrix}$$

Four pairs can be transposed according to this pattern, with the total run split into four sections. If we call this (G), we can transpose eight pairs according to the scheme

$$\begin{pmatrix} G & G \\ G & -G \end{pmatrix}$$

We can go on expanding in this way, and what we are doing is working with Hadamard matrices. Using the definition

$$H_2 = \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

we have

$$H_N = H_{N/2} \otimes H_2$$

where $\otimes$ is the Kronecker product, so that

$$H_8 = H_4 \otimes H_2$$

$$= \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{pmatrix}$$

The working of Fourier analysis depends on the fact that the sine and cosine wave system is orthogonal, so that

$$\int_0^{2\pi} \cos m\theta \cos n\theta \, d\theta = \theta \text{ if } m \neq n$$

The rows, and the columns, of the Hadamard matrix have this orthogonality characteristic, which is why row 1 transposition does not couple to any other row. And the rows are, quite simply, the Walsh functions. There is another way of producing them, which gives a different order. The Rademacher functions are defined as

$$r_n(\theta) = \text{sign of } (\sin(2^{n-1}\pi\theta)),\ 0 \leqslant \theta \leqslant 1$$

and some of the Walsh functions are

$$\begin{aligned} \text{wal}\,(1,\theta) &= r_0(\theta) \\ \text{wal}\,(3,\theta) &= r_1(\theta) \\ \text{wal}\,(7,\theta) &= r_2(\theta) \\ \text{wal}\,(2^k-1,\theta) &= r_{k-1}(\theta) \end{aligned}$$

The way in which the rest of the family is derived depends on an equation which looks very simple:

$$\text{wal}\,(i,\theta)\,.\,\text{wal}\,(j,\theta) = \text{wal}\,(i \oplus j, \theta)$$

The symbol $\oplus$ stands for modulo-2 addition, which is binary addition without a carry sign. If we take

$$\begin{aligned} 1 &\rightarrow 0001 \\ \oplus 3 &\rightarrow 0011 \\ 2 &\leftarrow 0010 \end{aligned}$$

so that wal (1,θ). wal (3, θ) = wal (2, θ)

A set of wal functions is shown as Fig. 3. A point to notice is that θ is a time base,

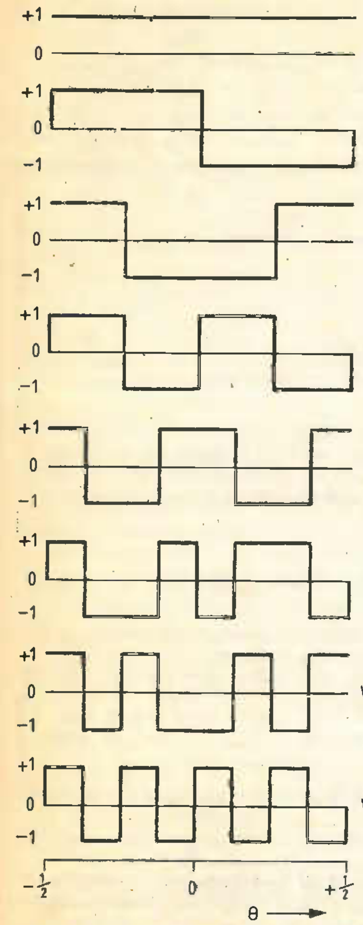

Fig. 3. A set of Walsh functions, wal(n,θ). Note that θ is a time base and that, as the functions have the values ±1, they are rectangular in form.

which goes from −½ to +½ in the time interval *T*. Another important feature is that the functions can be sorted out into two groups. If you imagine a sine wave and a cosine wave which have been clipped right down, a technique used, with 20dB of clipping, for some transmission systems on noisy circuits, you will see that wal (1, θ) looks very much like a clipped sine wave, and wal (2,θ) like a cosine wave. The odd Walsh functions, which are antisymmetric, are written as sal (i, θ), while the symmetric properties of the even functions give them the form cal (i, θ).

The sine wave we assumed to be clipped right down to give sal (1,θ) possessed the property of having a frequency. sal (1, θ), a single cycle in the sine wave, has two crossings of the zero axis in each unit of time. (As shown the end zeros are shared with the next cycle.) The *sequency* of a Walsh function is similarly defined as:
Sequency in crossings per second = ½ (average number of zero crossings per unit time)

What have we now got? A set of orthogonal functions, and the concept of sequency. It is the switching man's equivalent of the sinusoids and the concept of frequency.

To be concluded in the next article, which will show how Walsh functions can be produced by hardware and discuss their use.

Police communications use computerised switching

When Leicestershire police planned to move their headquarters from the centre of the city of Leicester to a new site 5 miles out at Enderby, they decided to modernize their communications system at the same time. The up-to-date communications centre is now working, though the rest of the headquarters had to be left behind because of government spending cuts.

The essence of the new system, designed and built by Burndept Electronics, is that it is based on a computer. This provides, first, real-time switching between audio channels in a networking system which deals with radio and telephone messages and interconnects the police officers concerned in any required pattern – for example, a policeman on his beat, a patrol car and a monitoring operator at the headquarters. Secondly the computer receives, stores, displays and prints out digital information from a data transmission system which gives the locations and availability of 236 police vehicles in Leicestershire. Thirdly, it provides a means of transferring textual information over private police lines and a store of data accessible to main police stations. (Actually three computers are installed: one operating, one standby and one spare.)

For the networking system there are six consoles in the main control room (see picture). Each console has a v.d.u. and keyboard connected to the main computer and also two switching control positions based on local microcomputers. At each of these switching positions an operator can use a keyboard and an l.e.d. display unit to control up to 10 audio channels. With each channel the operator can order patterns of switching for a variety of functions. For example a "talk-through" function allows intercommunication between mobile radio sets, such as between a patrol car and policeman on foot with a hand-portable set. Link-ups can be made between radio and radio (v.h.f. or u.h.f.), between telephone and telephone, and between radio and telephone. Six functions are available for each channel, and whichever is operating is shown by a l.e.d. lighting alongside an appropriate label. The control positions also allow the operators at the consoles to communicate with each other and to be connected to a PABX system. And, of course, they allow the Leicestershire police to communicate with police forces in other areas. As a safeguard to ensure that all calls are answered, any unanswered call is indicated at all the control positions until it is dealt with.

For dealing with unusual incidents there is also available a special remote control console which can be operated, for example, from inside a van. This is connected to the rest of the system by modems.

The actual electronic switching of channels under computer control is done by a solid-state space matrix, using a 4-wire switch for each channel.

The vehicle monitoring system mentioned above was developed by Burndept Cyfas. It uses a data encoding and transmitting unit connected to the mobile radio in each car and, at the communications centre, a decoding unit connected to the main computer. In the vehicle a small control box fitted under the dashboard carries a rectangular grid pattern corresponding to the grid on a map of the area. Against the rows and columns of this grid are press-buttons. At regular intervals a policeman in the vehicle presses a row-button and a column-button, which together indicate the vehicle's position on the grid at the intersection of the row and column. He presses further buttons to signify whether the vehicle is available for duty or not. As a result binary digital codes are generated at a data rate of 100 bit/s and these modulate the vehicle's radio transmitter on one of its voice channels by two-tone frequency shift keying. The codes are available to the police officers as pairs of decimal digits (for example 5/8 means the car is at the police station and the crew is coming off duty) and these automatically indicate the type of vehicle (e.g. 5 for Panda cars, 6 for Range Rovers).

At the communications centre, the data is demodulated from the radio voice channel, decoded and fed into the computer system, where a complete list of vehicle locations and states of availability can be displayed on the v.d.us and printed out.

Leicestershire police say that the new system has not only improved their communications but also made administration easier and more efficient. At the same time as adopting this new technology they do recognize the increasing need of communities for the friendly, neighbourhood policeman on foot, the old-fashioned "bobby on the beat".

Main control room in the Leicestershire police communications centre.

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Direct digital frequency synthesizer

Ion spectrometer application needs all-digital technique

by J. H. J. Dawson, Ph.D.

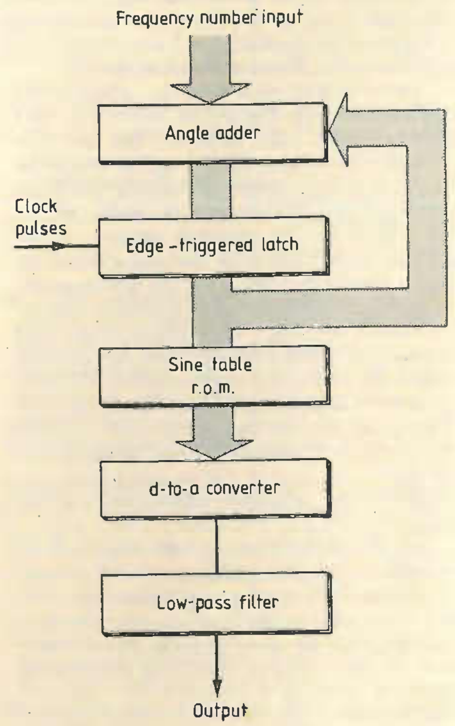
A 1MHz per millisecond scanning rate and absolute phase reproducibility are the essential features of this recent synthesis technique. The unit described performs entirely numerical manipulations and is ideally suited to being computer driven, using a d-to-a converter only as the final operation.

A direct digital frequency synthesizer is the hardware equivalent of a function generator constructed from a computer and a digital-to-analogue convertor. The combination could be programmed to calculate incrementing angular values of a sine wave function and to output them via the converter at a fixed rate. Frequency would be determined by the size of the angular step and the output rate, which might require some software/hardware synchronization to hold it constant. The maximum frequency which could be generated would depend upon how quickly new sine values could be calculated or fetched from a pre-calculated data table. To push the output frequency up into the rf band computation time must be drastically reduced: a dedicated hardware processor must be built.

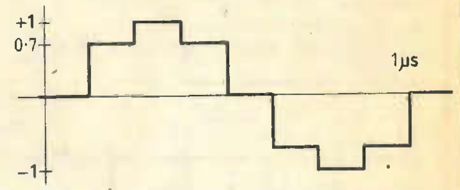
Figure 1 shows the basic arrangement of such a synthesizer. The d-to-a converter is fed with numbers generated by stepping through a sine table read-only memory in (fixed) angular steps at a fixed clocking rate. The step size is chosen according to the output frequency required. For example in this synthesizer a 1MHz output is generated by advancing through the sine table by 45° once every 125ns. The process need not start from 0°, but if it does, the r.o.m. output will follow the cycle 0°, $+1/\sqrt{2}$, $+1$, $+1/\sqrt{2}$, 0, $-1/\sqrt{2}$, -1, $-1/\sqrt{2}$, 0. Converter output would then be as shown in Fig. 2. A good low-pass filter converts this waveform into a sinewave, but for a full treatment of the distortions arising from step approximations and numerical rounding errors consult *IEEE Transactions on Audio* vol. AU-19, 1971, pp. 497-505.

Figure 1 glosses over one practical snag from which much of the complexity of a practical synthesizer arises. As with paperback sine tables, commercially available r.o.ms include only sine values for the first quadrant. It is left to the user to generate the values for the other three quadrants by reflection and inversion operations. Another complexity arises because the r.o.m. used does not actually contain the angle 90°.

That is because the first quadrant has been divided up into 90°/1024 steps starting from 0°. The zero-crossing errors which would result from ignoring this fact have been eliminated in this design, but a negligible error has been accepted in approximating the value of the sine of 90° to that of its adjacent angle in the r.o.m.

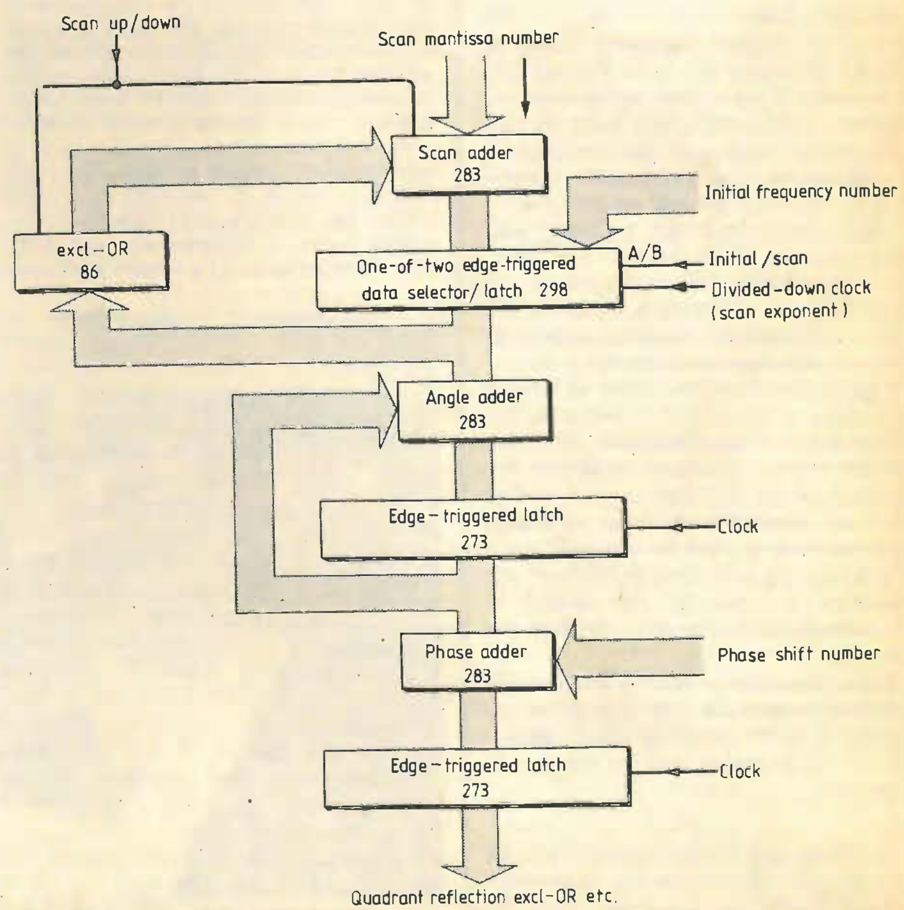


◀ *Fig. 1. Digital-to-analogue converter is fed with numbers generated by stepping through a sine table read-only memory in angular steps at a fixed rate.*



▲ *Fig. 2. Step size is chosen according to the output frequency required. For example, a 1MHz output is generated by advancing through the sine table by 45° once every 125ns.*

Fig. 3. Control over the output phase can be obtained by placing another adder immediately after the angle adder. Another adder and data selector/latch before the angle adder allows frequency scanning. Toggled to its other set of inputs the latch increments by the scan mantissa at a rate fixed by scan exponent. ▼



The next practical complication occurs because the logic which generates the sine values for the third and fourth quadrants does so simply by supplying a sign bit to go with the magnitude generated as for the first two quadrants. Alas, sign/magnitude input coding is not found in commonly available d-to-a converters and so code conversion to straight binary has to be adopted; this is not difficult, but requires another six i.cs. Finally, since this synthesizer is designed to clock as fast as possible, commensurate with a reasonable safety margin, extra edge-triggered latches are needed to achieve synchronous operation at 8MHz.

Circuit description

The input frequency number in true 16-bit binary code is fed, as in Fig. 1, to the 16-bit full adder IC_{1-4}. There is no carry input, but the carry output passes to an exclusive-OR gate IC_{10} which functions as a partial adder and thence with the other adder outputs to the D inputs of 17 edge-triggered latches, IC_{5-7}. The clear line for these three latch chips is shown as held high, but if you want to add a clear facility to the synthesizer then this is the place to do it. The latch outputs go back to the other set of adder input ports so that the present state of the latch outputs will always be incremented by the input frequency number at the next positive-going clock edge. If the input number is simply a 1 in the most significant bit (m.s.b.) then the angle adder will come back to its initial state after four clock pulses. In other words, the m.s.b. input corresponds to an output frequency of one quarter of the clocking frequency, which in this case means 2MHz. The l.s.b. input must therefore correspond to 2^{-14}MHz (about 61Hz) and so the output frequency is defined as $N\times2^{-14}$MHz, where N is the input number.

Reflection (looking backwards through the r.o.m.) in the second and fourth quadrants is performed by the exclusive-OR gates IC_{8-10} which invert when the m.s.b. output from IC_6 is high. Except at 90° and 270° (conditions detected by the gates in IC_{11-12}) the reflected angle is incremented by 90°/1024 so that the reflection does actually occur about 90° even though it isn't present in the r.o.m. At 90° and 270° this addition is not performed, with the result that the memory is addressed at the maximum angle which it does actually contain, viz 90°×1023/1024. With the Schottky and low-power Schottky chips specified, the latch propogation delays, gate delays, typical add times and latch set-up times in this section of the circuit amount to about 36ns less than the 125ns interval between clock pulses.

The read-only memory IC_{18} is rather slow (maximum address access time 100ns) and so it is sandwiched between two layers of latches $IC_{16,17,19}$. The sign bit, derived from the carry output of IC_4, is also passed through the latches to equalize delays and this must now be combined with the sine magnitude information derived from the r.o.m. to form a straight binary-coded output. This is done by the standard method of complementing the magnitude in IC_{20-22} and adding 1 in IC_{23-25} when the sign bit is high. The inverted form of the sign bit must be added to the carry output of the complementing operation if disaster is not to occur at 180°. The resultant binary number is latched again before the d-to-a converter so that when a fast converter is used de-glitching should be unnecessary. The output code swings symmetrically from 0000000001 to 1111111111 about the zero level 1000000000.

To squeeze the last bit of frequency range out of the synthesizer a sharp multisection elliptic low-pass filter is used in the circuit shown, after the d-to-a converter. It is designed to be 1dB down at 3.3MHz and with a minimum stop-band

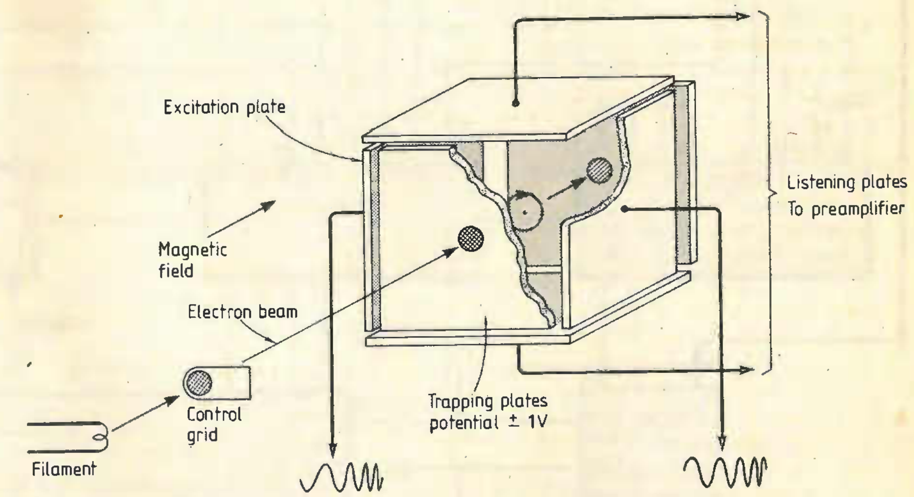
Ionic chemistry without solvents

The circuit described in this article, together with scanning, timing and control logic, made up the programmable frequency synthesizer required for a Fourier transform ion cyclotron resonance (FTICR) mass spectrometer. The heart of this instrument is a 1-inch cubed "trapped ion cell", see diagram, housed in a continuously pumped vacuum chamber and situated between the pole pieces of a large electromagnet. Chemicals are leaked into the vacuum so as to give a sample pressure of about 10^{-10} atmosphere inside the cell. Gas molecules are ionized by passing a 20eV electron beam current of 50nA through the cell for 5ms, and trapped inside by the combined effects of the magnetic field and a potential well created by a small potential (1V) on the plates parallel to the magnet pole caps. The remaining four cell plates are d.c. grounded, one opposing pair being connected to the differential outputs of the synthesizer, and the other pair through a preamplifier to a small computer, being digitized at rates up to eight megasamples per second.

Just prior to "detection" the cyclotron motions of the ions present in the cell are excited by a swept frequency burst from the synthesizer, say 30Vpk-pk at 2ms/decade. Ions of the same mass have the same cyclotron frequency

$$F(\mathrm{kHz}) = \frac{1537B(\mathrm{kg})}{m(\mathrm{a.m.u.})}$$

so that at 15kG a mass range of 10 to 100 atomic mass units requires a frequency range from 2.3MHz to 230kHz. Each group of coherently-excited similar-mass ions makes its contribution in the form of a decaying sine wave to the total transient signal which the preamplifier picks up. To improve the signal-to-noise ratio of the instrument it is then usual to quench the ions in the cell by reversing the polarity of the side plates, repeat the whole sequence of events, and to accumulate successive transients within the computer's main memory. It is so that this may proceed smoothly that the rapid sweep from the synthesizer must be absolutely reproducible with respect to phase, as must all timing operations concerned with the detection process. As in a spectrum analyser, a Fourier transform program will then separate the individual frequency components from the transient and allow ion concentration versus mass to be plotted.



The technique is insensitive by comparison with conventional mass spectrometers having electron multiplier detectors, but mechanically it is very simple and yet can provide exceptionally high mass resolution. The real use of the technique comes from delaying the detection process until a second or so after the electron beam pulse. During that time ion-molecule collisions occur and if some of them produce new chemical species the mass spectra will change accordingly – ionic chemistry without solvents. The chemistry of complex mixtures can always be unravelled by studying the effect of running the synthesizer at a fixed frequency shortly after the electron beam pulse so as to over-excite and hence expell one by one each possible reactant ion.

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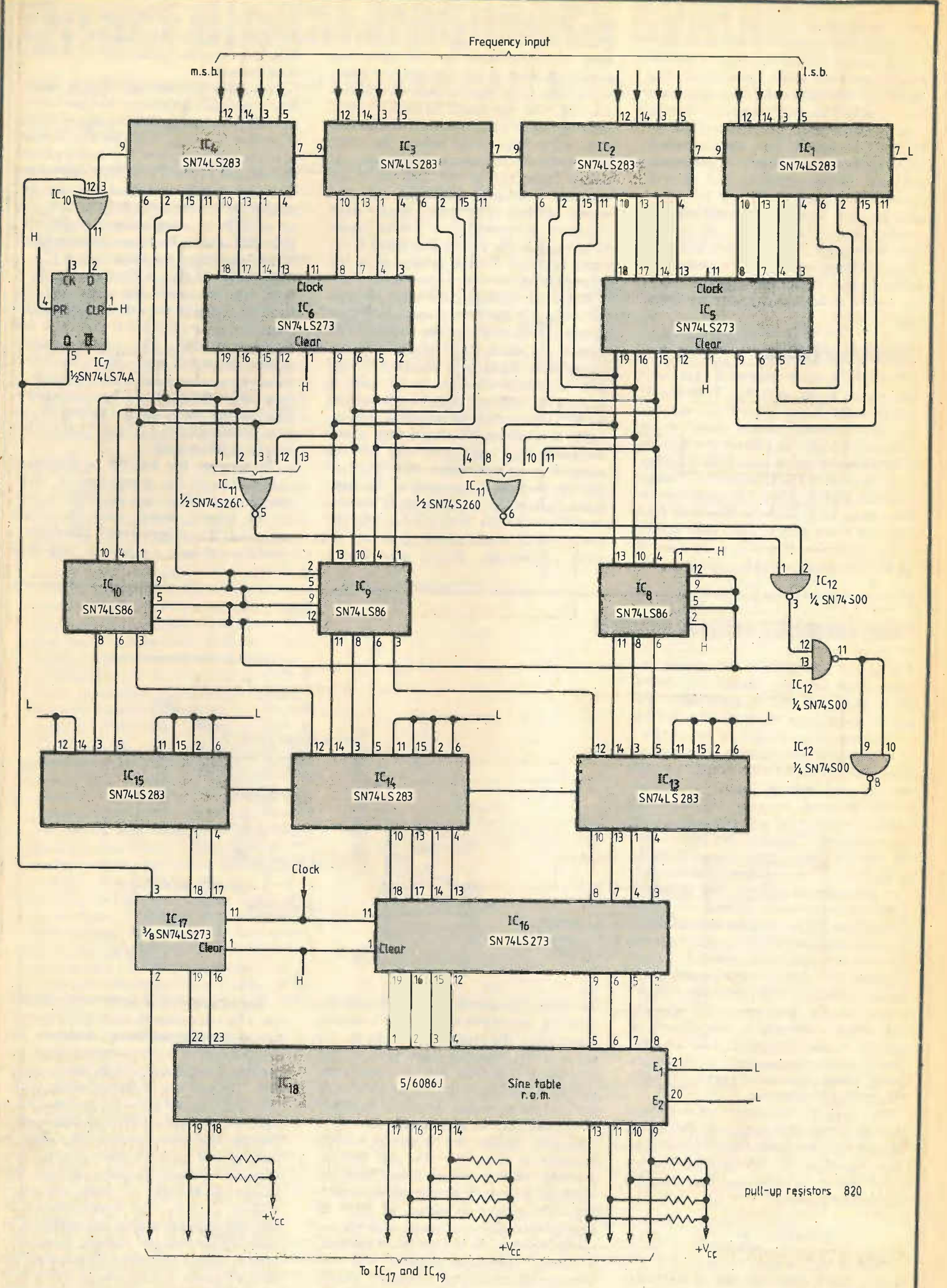

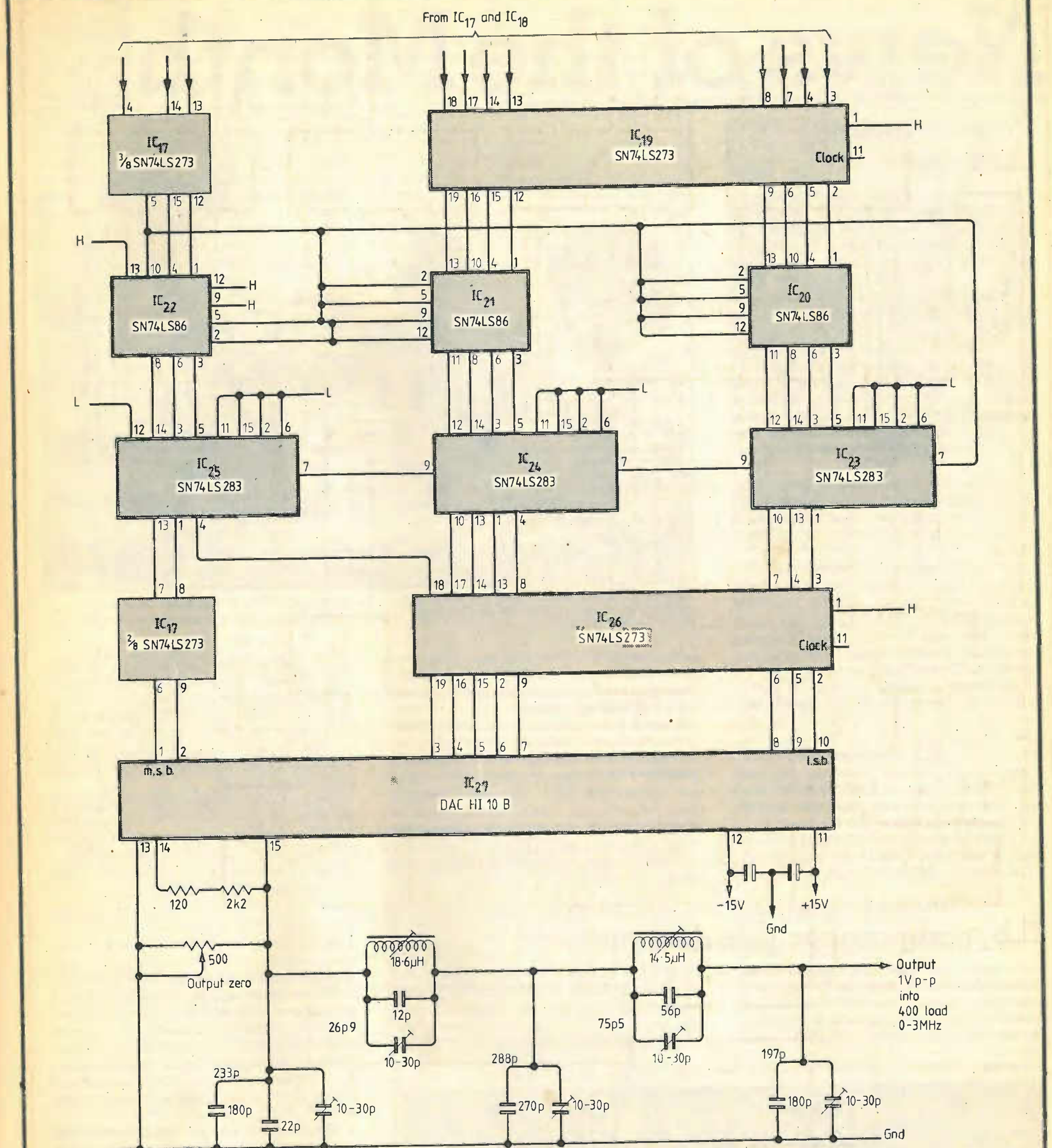

attenuation of 50dB starting at 4.65MHz. The filter was designed from data contained in Simplified Modern Filter Design, by Philip Geefe (Iliffe Books, London, Table A4-4, page 146). In setting up the filter the nodes should be tuned to 7.7814 and 4.8147MHz. The converter and filter have been matched to deliver 1V pk-pk into a 400-ohm load.

Possible modifications

Finer frequency control can be provided by widening the angle adder; for example, a 24bit-wide adder when used with a clocking rate of 8.388608MHz will make the l.s.b. of the input number correspond to a ¼Hz step in the output. If only audio frequencies were required the clock frequency could be lowered and the latches around the r.o.m. discarded. Unbelievably versatile dynamic control over the output phase can be achieved by placing another adder immediately after the angle adder as indicated in Fig. 3.

The method for introducing frequency scanning has also been incorporated into Fig. 3. Another adder and bi-functional latch are introduced before the angle adder. In one state the data selector/latch simply passes the initial frequency to the angle adder, but when toggled to its other set of inputs the latch will keep incrementing the number fed to the angle adder by the scan mantissa at a rate determined by the scan exponent. The exclusive-OR gates in the scan adder loop will enable the instrument to scan down as well as up. Unless astronomic scan rates are required the scan exponent will need to be a divided-down version of the clock rate and it may be desirable to have a rather wide-scan adder, with the scan mantissa being fed to bits which are less significant than the l.s.b. of the initial frequency number.

News of the Month

Prize-winning computer

Messrs Thomas, Morel and Melville with a production model of the 3DO9 computer which they designed while still at school, and which won them a prize in the Young Engineer for Britain Awards.

Sixth-formers Alistair Melville, William Morel and Chris Thomas won the first prize in the group entries for 18 to 19 year old age group in the Young Engineer for Britain 1981 Awards. Their entry was a microcomputer system and their prize was a North Sea trip and £200. Their real prize, however, was one that they had organized for themselves. At a computer exhibition they established contact with a firm specializing in microcomputer interfaces, 3D Digital Design and Development, and managed to negotiate a deal for 3D to manufacture the computer and for them to take a royalty and to continue to develop the system. They seem to have traded part of their deal for regular salaries as, after completing their A-levels, they are all employed at 3D.

The three seem to constitute an ideal combination with one of them, Chris Thomas as the hardware expert; William Morel specializing in software and Alistair Melville as the businessman.

The microcomputer has received the name 3D09 and because of its modular, rackmounted p.c.b. structure, it is very versatile. It is based around a MC68B09 and this gives it high speed, with a 500ns cycle time. The MC68B09 has an architecture which encourages structured programming. The computer has an e.p.r.o.m.-resident operating system enabling the user to have several programmes running concurrently. Low-level and high-level programming languages are incorporated in the Flex disk operating system. Available languages include Basic, Labasic (with optional structured programming), Pascal, Fortran, Forth, Algol68, Lisp and Pilot as well as assembler, disassembler, and simulation operations.

Technically the computer includes a processor card with 2Kbyte e.p.r.o.m., 2Kbyte static r.a.m, two full RS232 interfaces, a 3-channel counter/timer, a 1Mbyte addressing range with an optional cassette interface. Random access memory is expanded by the addition of memory cards with 64K on each card.

There is a controller for up to four floppy disc drives which are available in a number of combinations of sizes and density. The video controller provides 40 or 80 characters width with 24 lines, and graphics with 640 × 240 pixels. There is a choice of keyboards. Further developments include high resolution and colour graphics; a Uniflex operating system which will allow the computer to operate exactly like a PDP11; and multi-user capabilities.

The computer has been designed for maximum flexibility with a wide range of options and its designers are expecting the majority of users to be in industrial or scientific fields. It can be linked up to monitor and control processes and may also be used for business applications, such as administration and records, accounting, data and word processing.

Concentrating on their computer design, the designers did not get very good results in their A-levels. However, the success of the design and the winning of the award has assured them of university places and they will return to Academia in September 1982.

C.b. campaigner into designer

James Bryant, well known as a campaigner for citizens' band radio through the Citizens' Band Association, has now returned to his normal work as an electronics engineer and designed a c.b. set for the new British market. Under the trade name Tenvox, the 40-channel f.m. transceiver is being manufactured by Voxson Audio Ltd, of Abingdon, with whom Mr Bryant now works full time. The set conforms to the recent Home Office specification MPT 1320 (June issue, p.65) and, as well as being designed and produced in the UK, it uses British made semiconductors, from Plessey, for the r.f. and frequency synthesizer circuitry. In fact the synthesizer circuitry is similar to that published by Peter Chadwick of Plessey Semiconductors in our September issue, p.59-61. Mr Chadwick collaborated with Mr Bryant in the design of the set.

The receiver has p-i-n diode antenna switching and a mixer with high dynamic range (avoiding the need for an r.f. gain control). The first i.f. is about 10.7MHz while the second high dynamic range mixer produces an i.f. at 450kHz. The f.m. detector is a phase-locked loop type, and there is a 5W audio output stage compatible with the 4-ohm loudspeakers already fitted in cars. The transmitter includes automatic speech processing to avoid the need for a power microphone and there is a three-stage power amplifier. On the control panel are two touch buttons for electronic channel selection ('up' and 'down'), slider controls for volume and squelch, selectors for high or low power transmission and l.e.d. indicators for signal strength, transmit/receive modes and channel selection. The set will be on sale in early 1982 through appointed dealers.

The British designed and made Tenvox c.b. transceiver.

Do-it-yourself integrated circuits

Integrated circuits make commercial sense even for the smaller manufacturer of electronics goods, according to Marconi Electronics Devices (MEDL), who recently launched their System 85 – gate array design system. Gate array is another name for uncommitted logic array; a matrix of pre-processed cells which require only a single layer of metal interconnections to form an integrated circuit for a specific purpose. This allows a large number of wafers to be manufactured in advance which can then be completed in small numbers and in a short time to a customer's specification. Marconi have called the system 'gate array – plus' and the plus refers to the ability of any competent electronic engineer, who can, for instance, lay out a printed circuit board, to lay out the metal tracks for the integrated circuit.

To do this the engineer requires a 'design pack' which consists of an instruction manual, with a step-by-step procedure for manually interconnecting the gate arrays; a printed copy of the library of cells is available and the cells are also printed on to 'decals', self-adhesive block schematic representations of the gates which may be stuck down onto a layout sheet, preprinted with the basic logic array. The design is then sent in to Marconi who will code it into their computer which can simulate the design and run a series of checks to ensure that the circuit conforms to a number of design rules. The design for the interconnect mask will then be produced automatically. This process can be used for comparatively small production runs of a device. If subsequently larger numbers are required the same computer information can be used to produce an Iso-Cellmos device (see *Wireless World*, News of the Month, April 1981). The same computer can also produce a series of test patterns to test the device automatically. If the designer knows how to use a computer, he can hire time at the Marconi Design Centre, input the data himself and verify his design. MEDL will also offer the CAD facility as a software package to be run on the designer's own computer.

System 85 is available in a family of four devices. The MA8505 has up to 560 gates, the MA8510 has 960 gates, the MA8515 has up to 1440 gates and the MA8520 has 2014 gates fitting into a 24-pin package.

All the manufacturing of the devices takes place in a brand new processing plant recently opened in Lincoln. The plant represents an initial investment approaching £15 million and is part of MEDL's ten-year expansion plan. Occupying some 100,000 sq. feet, the plant has twice that amount assigned for future expansion. Five hundred people are employed there and the company is recruiting staff at all levels from senior engineers to factory operators.

The Iso-cmos process used in the manufacture of the devices is also used by Plessey Semiconductors and the two companies have agreed to second-source each other's products.

● The Department of Industry has announced the UK5000 gate array project which is a venture to produce a suite of design software for use with c.m.o.s. gate arrays. The gate arrays will have up to 5,000 usable gates using oxide isolated c.m.o.s. technology and a double layer of metal interconnections. The software will simulate the logical behaviour of a design, automatically convert a proven design into pattern generator tapes from which the masks for committing the arrays can be made, and automatically produce a test pattern which can be used to test the resulting chips.

The organisations involved in the project are British Telecommunications, the Science and Engineering Research Council, the Ministry of Defence, ICL, GEC, STC, and TMC Ltd. They will be meeting their own project costs but the industrial members may qualify for support under the DoI's Microelectronics Industry Support Scheme.

An outline specification has been drawn up at the Rutherford Appleton Laboratory and project teams have been appointed by all the participants. The SERC hopes to encourage the involvement in the project by the academic community. The DoI is providing an independent chairman for the management committee and British Telecom has provided the project manager.

Channel 4 transmitters are ready

The first pair of television transmitters for the Independent Broadcasting Authority's Channel 4 service have been connected to their channel combiners and handed over ready for use when the IBA brings Channel 4 into service during 1982.

The two transmitters, Marconi 15kW Type B7445 u.h.f. equipments, have been installed and commissioned at Winterhill, Lancashire, by Marconi Communication Systems Limited. Marconi is equipping a further eleven IBA sites throughout the United Kingdom with similar transmitter suites, as well as installing a one-B7445/one-B7442 (4kW) u.h.f. combination at a further thirteen sites, all for the Fourth Channel network. All these, as well as some twenty five further sites throughout the United Kingdom are being equipped with Marconi-designed channel combining units which will enable all four television channels to be transmitted from the same mast.

Mike Aldrich, managing director of Rediffusion Computers, with a Telepuputer system, one of a range of videotex terminals that his firm believes willl be at the centre of the 'home information system' towards the end of the 1980s. The terminals combine broadcast tv, videotex, video tape recorder, video disc and telecommunications with personal computers.

Ruth Everard, 19 months old, suffers from spinal muscular atrophy. She is seen here driving the wheelchair designed for her by her father, Dan Everard, who is perched behind. The design departs from standard practice by using shunt-wound motors controlled by c.m.o.s. to give free movement in three dimensions. The seat design is modular and can be made to fit any child; it can even be replaced with a standing platform. Its controls require very little strength to operate although the chair is capable of carrying an adult passenger, as shown. Ruth is learning to drive it about as quickly as most children learn to walk. The chair has been built in the labs of Cambridge Consultants Ltd. Dan once worked for CCL and the company have contributed laboratory space and engineering effort. In 1974 CCL developed a sensitive electronic wheelchair controller after working on a prototype wheelchair designed by his father for Terry Wiles, a thalidomide victim. That experience has now found another use in helping Dan with Ruth's chair.

High-speed Ceefax

Waiting time for BBC Ceefax pages to appear on the screen has been halved – and now averages seven seconds. The improvement has been brought about by using two extra data lines. The maximum time for a page to appear after it has been selected will be up to 14 seconds, depending upon whether or not the chosen page has just been transmitted.

Timed to coincide with National Teletext Month, October, the improved system overcomes the problem of lengthy waiting between pages, previously considered to be a drawback.

Colin McIntyre, editor of Ceefax, said, "We decided to use the extra lines to cut the waiting time for the next page to appear to make the service even more attractive to the viewer. There is a great deal of enthusiasm in the trade for Teletext and the future looks assured".

Since the start of the service in 1974 the BBC has used two blank television lines, 17 and 18, to carry data for each of the BBC 1 and BBC 2 magazines. Now, four lines are being used for each magazine – 15, 16, 17 and 18. The digital pulses for the Ceefax and Oracle systems are carried on the normal television signals as the receiver scanning spot returns to the top of the screen between pictures.

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World of Amateur Radio

Three bands to open

The first new amateur h.f. bands to open since 21MHz in 1952 will become available to UK amateurs (on a secondary basis) from January 1, 1982. These are 10,100 to 10,150 kHz; 18,068 to 18,168 kHz; and 24,890 to 24,990 kHz, the new allocations agreed at the World Administrative Radio Conference in 1979. The 18 and 24 MHz bands remain allocated to the fixed and land mobile services until existing assignments have been transferred to new frequencies, after which the bands become "exclusive" amateur allocations. They are being made available in the UK to the "amateur" and "amateur satellite" services on a non-interference basis.

Under voluntary band-planning proposals it is being recommended that operation in the narrow (50kHz wide) 10MHz band should be restricted to c.w./r.t.t.y. operation. Since the Home Office is one of the first administrations to permit amateur use of 18 and 24 MHz the initial activity may be rather restricted and most amateurs will need to modify their equipment for operation on these bands.

Considerable interest is being shown by amateurs in wideband aerials that could be used effectively on the 14, 18, 21, 24 and 28 MHz bands, including centre-fed dipoles fed from open-wire (or 300-ohm) balanced line and brought to resonance by means of aerial tuning units, also the classic W8JK bi-directional array and various forms of log-periodic arrays.

Here and there

Long sea-path ducting has brought about another 144MHz contact between the British Isles and the Canary Islands off the coast of Africa. On September 4, a late-evening (2240 GMT) opening enabled Richard Baker, GD8EXI in the Isle of Man to make two-way contact over a distance of about 3025km with EA8XS. Attempts were also made to use the duct on 432MHz and while no two-way contact resulted, EA8XS reported hearing signals from GD8EXI on that band. The year has thus seen 144MHz from the UK with both Africa and Asia (G3VYF and 4X4IX, a 3540km contact in June).

A distance of just over 1000km has been achieved by European stations on 2.3GHz with a two-way contact between DL7QY, Germany and SM6HYG, Sweden. Weak signal reception on the microwave bands is clearly benefiting from the availability of low-noise GaAs f.e.t. devices ("gasfets").

AMSAT-UK, the radio amateur satellite organisation of the United Kingdom, has published an A5-sized technical handbook covering the University of Surrey amateur radio scientific satellite. The 22-page booklet provides technical data and operating aids for the slow-scan television system, the h.f. propagation beacons and the other experiments. Non-members of AMSAT-UK can obtain copies from R. Broadbent, G3AAJ, 94 Herongate Road, Wanstead Park, London E12 5EQ (£1.16 includes postage).

Although it is now almost two years past the peak of solar cycle 21, the 1981 autumn season has again seen very high maximum usable frequencies, including north/south openings on 50MHz. Several South African stations were heard on 50MHz on September 20 and ZS3E on September 27. Conditions have been good on 28MHz.

Death of "Steve"

Roy Stevens, MBE, G2BVN who over the past two decades has played a leading and influential role in many of the national and international amateur radio activities died on September 27. A former president (1966) of the RSGB, for many years chairman of its technical and publications committee, telecommunications liaison officer and secretary and editor for the IARU Region 1 Division, he was a member of the UK delegation to the Geneva WARC in 1979. He received the MBE in the Queen's Birthday Honours List 1980 in recognition of his work for amateur radio.

Roy Stevens was licensed in 1937 and became one of 37 amateurs in the first draft of the RAF Civilian Wireless Reservists to reach France on September 5, 1939 only two days after the outbreak of World War II – a draft that became known as "The Early Birds".

The deaths have also occurred of Edgar Wagner, G3BID, one of the pioneers of mobile h.f. operation in the UK and A. J. H. Watson, G2YD, a former honorary treasurer of the RSGB.

Interference to home equipment

A new "Information Sheet" has been produced by the RSGB's interference committee concerning the problem of interference to domestic entertainment equipment caused by local transmissions. This surveys the problems that can arise, explains how the viewer or listener can benefit from the radio interference service operated by the Post Office on behalf of the Home Office, outlines the basic differences between interference to radio receivers and television receivers compared with other forms of domestic equipment in which unwanted detection of local transmissions is "wholly due to deficiencies in the equipment suffering the breakthrough," and provides some facts about the regulation of amateur radio. The information sheet, entitled "Domestic entertainment equipment and the radio amateur" is available from RSGB, 35 Doughty Street, London WC1N 2AE on receipt of a s.a.e.

Transatlantic anniversaries

December 1981 marks two notable anniversaries in the history of transatlantic communication: Marconi's classic, but still controversial reception at St John's, Newfoundland on December 11, 1901 of the "S" signals from Poldhu, Cornwall, a feat that many considered impossible; and the reception by Paul Godley, 2ZE, a noted American receiver designer, at Ardrossan, Scotland, of the first message to be transmitted by amateur radio across the Atlantic. This came from the special station, 1BCG, set up by the Radio Club of America for the transatlantic tests organized in the UK by *Wireless World*. One of the signatories to that message was Howard Armstrong, whose long string of inventions included the development of frequency modulation and the superhet.

In brief

The 1982 president of the RSGB will be Jack Anthony, G3KQF, of Derby, currently chairman of the Society's education committee and also of its membership and representation committee . . . . GB2VER, a special event station operating on h.f. bands and 144MHz during November, marks the 21st anniversary of the founding of the Verulam Amateur Radio Club of St. Albans . . . . Membership of the British Amateur Radio Teleprinter Group is now approaching 900 and continues to bridge the gap between mechanical and electronic teleprinting . . . . The high cost of diesel fuel on remote Pitcairn Island has limited local power supplies to about two hours a day but Tom Christian, VR6TC, is able to operate using a bank of three solar panels containing 36 photovoltaic cells to keep batteries charged . . . . For ardent "country chasers" China remains the most elusive country to work as it is now many years since regular amateur activity was permitted there, although hopes are being expressed that this may change soon . . . Efforts to increase amateur activity in Third World countries continue with the American ARRL "Goodwill Project" and the German DARC worldwide amateur training activities in Sri-Lanka, Sudan, India, Iran, Egypt, Libya and Kenya.

PAT HAWKER, G3VA

Current mirrors, amplifiers and dumpers

Improving the performance and application of the basic circuit

by **B. Wilson**, B.Sc., Ph.D., Department of Instrumentation and Analytical Science, UMIST.

The accuracy of a two-transistor current mirror circuit can be greatly improved by the addition of a further two transistors. The resulting four transistor mirror can be used to design simple low-distortion operational-amplifier circuits that produce an output current proportional to either input voltage (v.c.c.s.) or input current (c.c.c.s.). In addition, they make possible the design of "current-dumping" amplifiers where the output current is controlled by a pair of unbiased transistors, operating entirely in Class B with the crossover distortion eliminated by a feedforward amplifier using current mirrors.

The simple two-transistor current mirror in Figure 1 attempts to produce at its output B an identical copy of the input current at A, whilst minimizing unwanted current-voltage interactions. Its operation can be easily understood by considering the input transistor as a collector-base connected diode, driving an output transistor with a matched V_{BE} to produce an identical collector output current. The basic mathematics of its operation were described recently and will not be repeated here [1]. Figure 2 shows the symbol often used to signify a current mirror, indicating by an arrow both the polarity of the current and the input side of the mirror. It should be remembered that, due to the circuit topology, the input terminal will always remain at a fixed voltage, in contrast to the output terminal which will take up a voltage determined by the load conditions.

The current transfer ratio I_o/I_{in}, usually termed λ, is normally the most important parameter when using current mirrors. It is obviously desirable that λ should be constant, irrespective of changes in current and output voltage. (Whilst most current mirrors are intended for operation with a unity value of λ they can be designed for other integral values by duplicating transistors accordingly.)

Unfortunately, the performance of the two-transistor mirror is often inadequate, largely due to the high dependence of λ on the values of the transistor parameters in such a simple, uncompensated circuit. It can be shown [2], by considering basic transistor operation, that the departure from unity current transfer ratio for a two-transistor mirror can be represented by:

$$\lambda_2=1\pm(2/\beta)\pm(V_{OS}/V_T)-V_{\Delta Q}/(V_I)_Q$$

where β is the common-emitter current gain, V_{OS} is the difference in base-emitter voltage required to produce identical collector currents, V_T is the thermal voltage $\simeq$ 25mV, $V_{\Delta Q}$ is the difference in collector-base voltages of the two transistors and $(V_I)_Q$ is the Early intercept voltage at the operating point Q*.

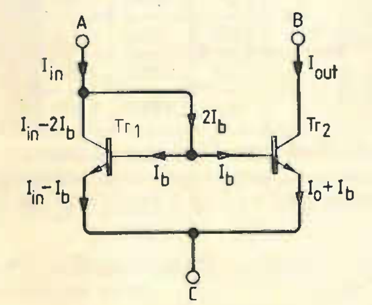


Fig. 1. Basic, two-transistor, n-p-n current mirror

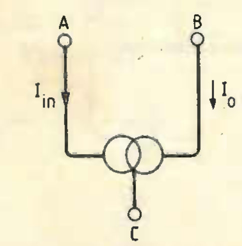
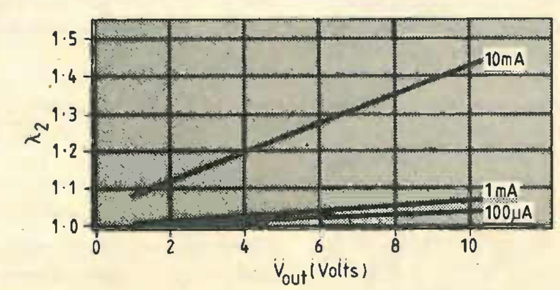


Fig. 2. Shorthand symbol for circuit of Fig. 1.

Fig. 3. Accuracy of current transfer between input and output depends on output voltage and output current. Ratio I_o/I_{in} is plotted here for currents up to 10mA at up to 10V.



The β term arises due to the effects of base current in an asymmetrical circuit with the V_{OS} term being due to the mismatch in the transistors' base-emitter voltages. The contribution of the Early intercept voltage is best described as being due to the slope in the transistor I_C vs. V_{CB} characteristics. Of course all these terms are dependent on current or temperature, making a general analytical evaluation quite difficult! Figure 3 illustrates the results obtained when using an RCA CA3096AE transistor array, connected as a two-transistor mirror and operating at currents of 100μA, 1mA and 10mA. Typical values for the n-p-n transistors in the RCA array are: β=200, V_{OS}=0.3mV and $(V_I)_Q$ = 100V, producing error components of around 1%, 1% and 1-5% respectively for the three contributions.

Clearly, the accuracy of the current mirror action for a two-transistor mirror is not very good, degenerating progressively

* The Early intercept voltage is the intercept of the tangent to the I_C vs. V_{CB} curve projected backwards to the $-V_{CB}$ axis. It is therefore dependent on the operating point of the transistor.

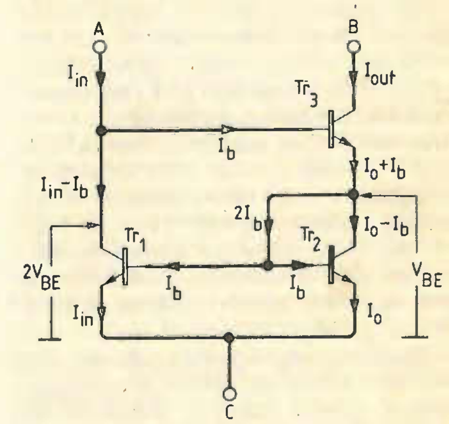


Fig. 4. Addition of Tr_3 helps to isolate Tr_2 from output voltage changes.

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above a milliamp. For p-n-p transistors the situation is even worse, because β is very sensitive to collector current for p-n-p planar transistors, falling to extremely low values (≃ 10) at currents above several milliamps. The uncertainty due to V_{OS}, however, is slightly reduced, since in general p-n-p transistors have tighter V_{BE} matching.

The performance of a two-transistor mirror can be greatly improved by the addition of a third transistor, as in Figure 4, resulting in the standard Wilson current mirror. The third transistor Tr_3 fulfils two roles; the first of which is to buffer Tr_2 from changes in collector voltage and remove to a large extent the voltage sensitive component in the current transfer ratio λ. Changes of collector voltage have much less effect on Tr_3 because it is effectively current driven from its emitter. The second improvement arises from the redistribution of base currents within the circuit, bringing the current-transfer ratio much nearer to unity. Figure 4 shows that, to a second-order approximation, the input and output currents are now equal. In a similar fashion to Equation 1, the current-transfer ratio for a three-transistor mirror can be represented by:

$$\lambda_3 = 1 \pm 2(\Delta\beta/\bar{\beta}^2) \pm (V_{OS}/V_T) - V_{BE}/(V_I)_{0.7}$$

where $\bar{\beta}$ is the mean of the transistor current gains, Δβ represents the spread of β values for the three transistors and $(V_I)_{0.7}$ is the Early intercept voltage evaluated at a V_{CB} operating point of approximately 0.7V, as this is the difference between the collector voltages of Tr_1 and Tr_2 in a three-transistor mirror circuit. The improvement in the current-transfer ratio in this equation is largely due to a reduced dependence on β and the small voltage difference (≃ V_{BE}) between Tr_1 and Tr_2. A spread of ±20% in current gains for the three transistors in the mirror would produce error components of ±0.2%, ±1% and −1% or, overall, approximately +0 to −2% tolerance. Texas Instruments have recently introduced monolithic three-transistor Wilson current mirrors exhibiting a current transfer ratio accurate to within 1% of unity up to a milliamp, with a voltage capability of 35V (TL 011). Also, by paralleling transistors within the mirrors they have produced circuits displaying halving, doubling and quadrupling functions (TL 021, TI 012 and TL 014).

Further improvements in mirror performance can be obtained by the introduction of a fourth transistor to equalize the collector voltages of Tr_1 and Tr_2, as shown in Fig. 5. Note that the same symbol can be used to represent current mirrors, irrespective of the number of transistors used. The only errors remaining now are due to finite β and base-emitter voltage differences, giving:

$$\lambda_4 = 1 \pm 2(\Delta\beta/\bar{\beta}^2) \pm (V_{OS}/V_T)$$

producing, typically, for the CA3096AE array:

$$\lambda_4 = 1 \pm 0.1\% \pm 1.0\% \simeq 1 \pm 1\%$$

A comparison between the three- and four-transistor mirrors is given in Fig. 6.

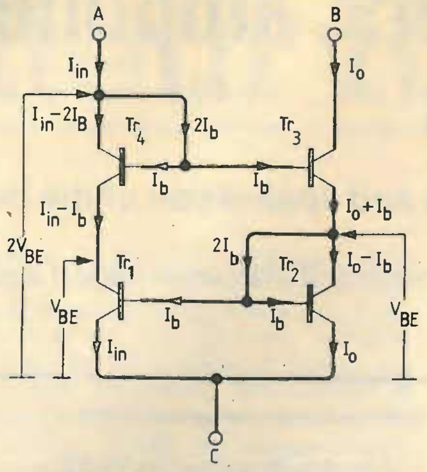


Fig. 5. Fourth transistor equalizes input and output collector voltages, further reducing unbalancing influences.

RCA CA3096AE transistor array

I_{in}	V_o	Transfer ratio λ_3	Transfer ratio λ_4
100µA	2V	0·995	1·001
	10V	0·996	1·001
1 mA	2V	0·990	0·999
	10V	0·991	1·000
10 mA	2V	0·886	0·991
	10V	0·890	0·994

Fig. 6. Table shows improvement in tolerance to current and voltage variations between circuit of Fig. 4 and that of Fig. 5.

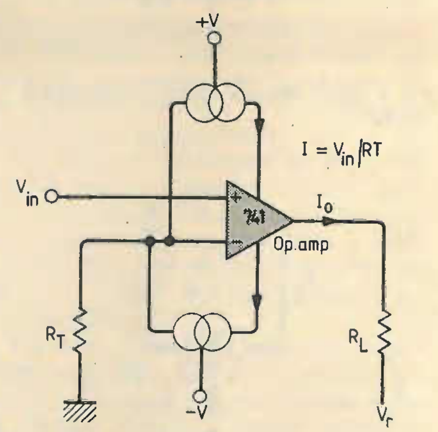


Fig. 7. Voltage-controlled current source. I_o is proportional to V_{in}.

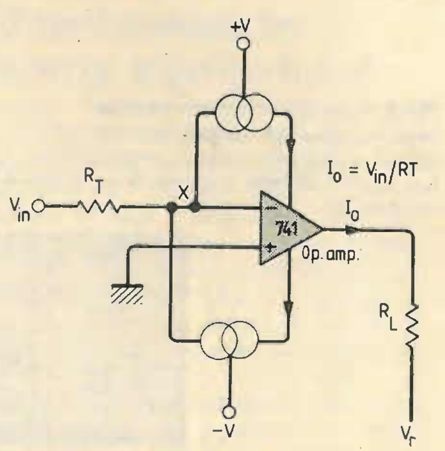


Fig. 8. Shunt feedback instead of the series type in Fig. 7 produces inverting v.c.c.s.

The two sets of results were taken from the circuit of Fig. 5, with the currents measured directly by 4½-digit digital meters. Transistor Tr_4 was then shorted out to obtain the results for a three-transistor mirror. In both cases it can be seen that the current-transfer ratios are held very constant against output voltage changes. The removal of the Early intercept error component (approximately −1%) from the four-transistor circuit is evident. In addition, the current transfer ratio is maintained to higher current levels because of the increased β buffering action with the four-transistor mirror. At 10mA it is still within 1% of unity, whereas the three-transistor version has fallen to approximately 90%. These factors make the four-transistor modified Wilson mirror the best choice for circuit designs, both discrete and monolithic. For precision circuits MAT 01 AH matched transistor pairs (Precision Monolithics) can be used for Tr_1 Tr_2 and Tr_3 Tr_4 to give a current-transfer ratio of unity to within 0.4%, due mainly to their very close V_{BE} matching.

Current mirror applications

In many applications it is desirable to control the output current rather than the output voltage of a circuit, especially when driving reactive loads or current-activated transducers. For example, a controlled current is required to produce a defined magnetic field from an inductive coil. It is not always feasible to voltage drive the load through a high-values series resistor, particularly if a significant back e.m.f. is generated. (An appropriate example could be that of a recording head for magnetic tape and cassettes.)

Unfortunately, all the standard textbook circuits for producing controlled bipolar output currents from ordinary operational amplifiers using grounded sources and loads suffer from serious practical problems, usually due to the extremely tight matching required for the resistors controlling the balance of negative and positive feedback [3]. Circuits requiring non-critical resistor matching that produce superior results can be designed using four-transistor current mirrors. Both transconductance and current amplifier configurations are possible, normally termed voltage-controlled current sources (v.c.c.s.) and current controlled current sources (c.c.c.s.) respectively.

Figure 7 shows the circuit of a bipolar transconductance amplifier (v.c.c.s.) using both n-p-n and p-n-p current mirrors where the output will be proportional to the input voltage. The RCA CA 3096 AE transistor array contains three n-p-n and two p-n-p transistors, which means that two arrays are required to construct a positive and negative four-transistor current mirror pair. The current mirrors are used to sense the operational amplifier's supply currents which, apart from the nearly constant bias currents, are proportional to the output current [4]. A copy of the output current, whether positive or negative, is thus fed back to the inverting input terminal to be compared with the input voltage.

This forces the op.-amp. to generate an output current equivalent to the input voltage V_{in} divided by the transconductance gain setting resistor R_T. Output currents up to 20 mA pk-pk can be obtained with very low distortion independent of the output voltage. Below 1mA the harmonic distortion, mainly second harmonic, is almost constant at 0.03%, rising to 1% at 20mA. It is not necessary with this type of circuit to return the load resistor to ground: it can be terminated on any voltage as long as the resulting load voltage excursions are within the capability of the op.-amp. and the voltage supplies. The recommended op.-amp. frequency compensation should be followed, remembering that for a transconductance amplifier the equivalent voltage gain is given by R_L divided by R_T. Care must be taken when using high values of R_T (equivalent to a low transconductance gain) to ensure that adequate compensation is provided for the op.-amp., since the resulting voltage gain can turn out to be surprisingly low. The circuit can be treated as an ordinary operational amplifier circuit with a slightly restricted bandwidth caused by the shortfall in gain-bandwidth product of the p-n-p transistors in the RCA array. Any op.-amp. similar to a 741 or 301A can be used.

An inverting circuit can be obtained by changing the series-feed back connexion to the shunt-feedback arrangement of Fig. 8. Now the feedback current is balanced against the input current in R_T produced by the input voltage V_{in}: the inverting transconductance gain is still given by $1/R_T$. The distortion figures are marginally superior to the series-feedback case, since there is no voltage excursion

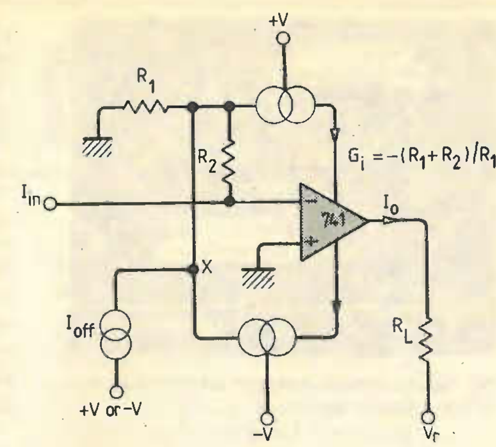


Fig. 9. Attenuating current feedback introduces gain into current-controlled current source, which is similar to v.c.c.s. but without input resistor R_T.

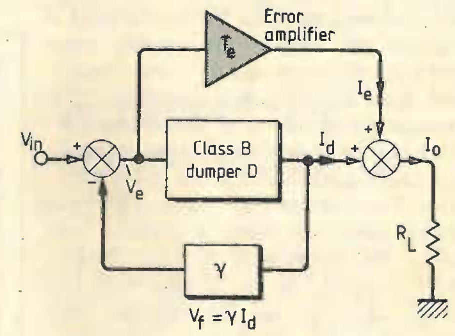
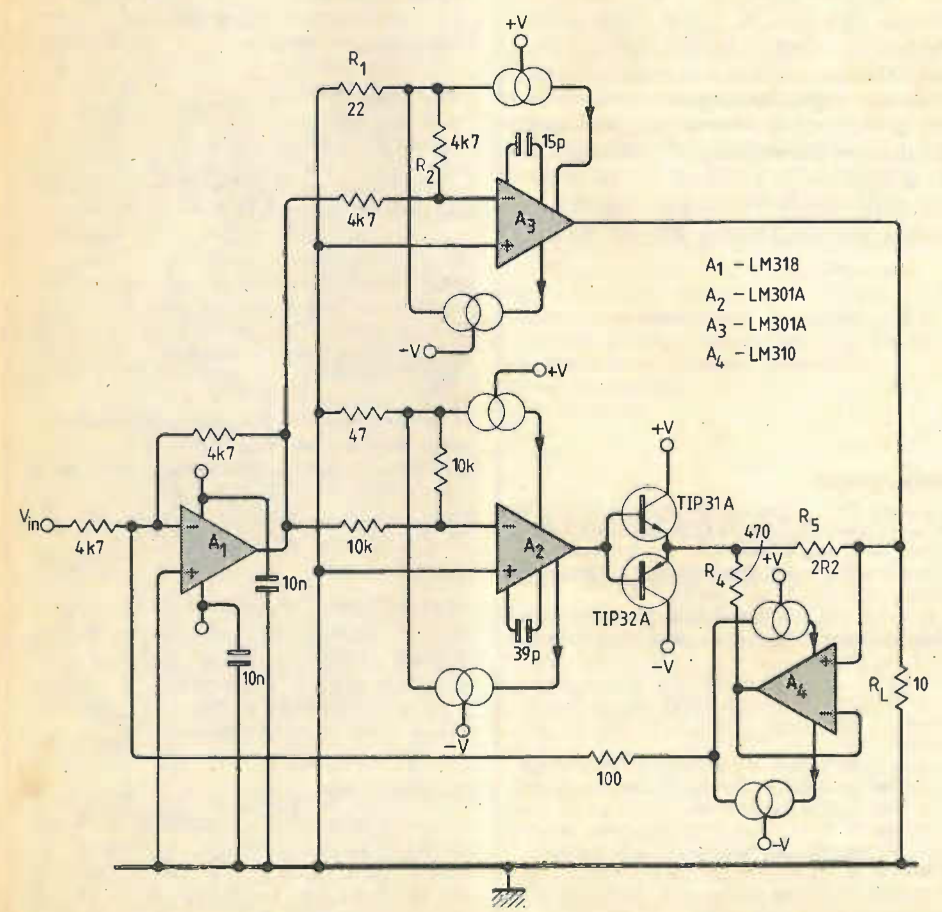


Fig. 10. Transconductance amplifier with feedback and error feedforward.

Fig. 11. Practical 1A Class B current-dumping v.c.c.s.



whatsoever at the virtual earth connexion [5].

This topology also presents an opportunity for the design of a current amplifier (c.c.c.s.) simply by removing the input resistor, leaving an amplifier with 100% negative shunt feedback derived from the output current. Gain can be introduced into the circuit by attenuating the feedback current before it is summed at the op.-amp. input. The circuit of the bipolar current amplifier in Fig. 9 uses two resistors to produce the required current attenuation in a manner analogous to a potential divider. The current gain is then defined simply by:

$$G_i = -(R_1 + R_2/R_1)$$

Measurement of the input impedance of the circuit of Fig. 9 with a gain of 20 indicates 1Ω at 100Hz, rising to 25Ω at 10kHz. The output impedance varies in the opposite manner, being 150kΩ at 100Hz dropping to 25kΩ at 10 kHz. The output impedance figures could be improved if manufacturers provided a range op.-amps. with alternative output stages in place of the voltage output stages presently used.

In contrast to voltage-controlled circuits, current amplifiers are required to operate from high source impedances and into low load impedances. It is still desirable to null the op-amp. input offset voltage for critical work to maintain a low output offset current for lower values of source impedance. The Fig. 9 circuit produces an output offset current of around 10µA with the input open circuit and the op-amp. input nulled to better than a millivolt. This offset current, caused largely by the affects of op.-amp. bias currents being reflected through the current mirrors, can be drastically reduced by connecting an equivalent bleed current to the output of the current mirrors, point X in Figs 8 and 9. A single resistor to whichever supply rail is indicated will perform the task adequately. The most convenient method of determining the output offset current is by using a digital voltmeter to monitor the output voltage across a temporary high-valued load resistor. An output offset of less than 50nA can be easily obtained after adjustment. In this respect, current output amplifiers can be more accurate than voltage amplifiers since, under most conditions, their output offset signal represents a smaller fraction of their maximum output.

Current amplifier using error feedforward

The three previous designs, whilst being extremely useful at low currents, cannot readily be extended to high currents because of the restricted current handling capacity of the transistor arrays forming the mirrors. Class AB current boosters could be used but their well known thermal limitations make it desirable to operate a high-current output stage completely in Class B where there are no critical bias adjustments. Unfortunately, the crossover distortion produced by Class B output stages has traditionally made them unsuitable for applications requiring precision low-distortion waveform reproduction.

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However, the technique of error feedforward around a Class B output stage, often referred to as "current dumping", previously employed for a voltage power amplifier[6], can be applied to current output amplifiers with very good results[7].

An outline of the proposed method is shown if Fig. 10. A feed-back voltage is derived directly from the Class B dumper output current and compared to the input voltage of the system. The resulting error voltage drives both the dumper pre-amp and the error feedforward amplifier. By choosing a suitable gain for the error amplifier any non-linearities in the gain of the dumper and its pre-amp can be compensated by the amplified error signal added at the output connexion. The relevant equations for the sub-units are:

$$I_o = I_d + I_e$$
$$V_f = \gamma . I_d$$
$$V_e = V_{in} - V_f$$
$$I_e = T_e . V_e$$
$$I_d = V_e . D$$

From these equations it can be shown that:

$$I_o = V_{in} . T_e (1 + D/T_e)/(1 + \gamma . D)$$

This equation can be made insensitive to D and its variations (non-linearities) by setting:

$$\gamma . T_e = 1$$

The balance equation indicates that if the transconductance of the feedback network γ^{-1} is made equal to the transconductance gain T_e of the forward error loop, then the gain of the system becomes insensitive to non-linearities within the Class B output stage and its pre-amp. The ratio of current contributions from the Class B dumper and the error amplifier is determined by the ratio of their transconductance gains. By a suitable choice of open-loop gain and feedback factors it can be arranged that the error amplifier normally supplies only a small proportion of the output current, except during the crossover period of the dumper transistors when there is no feedback signal, and the error amplifier supplies all the output current. The transconductance of the system at balance is given by the transconductance of the error feedforward amplifier alone. The overall result of this is ideally zero distortion at the balance condition. However, in practice, the error amplifier and the floating current monitor A_4 contribute their own distortion, but this is quite small, since they only operate at low currents.

One possible circuit for the combined feedforward/feedback approach is shown in Fig. 11. The error feedforward amplifier A_3 and the dumper pre-amplifier A_2, intended for 25mA pk-pk maximum output, use four-transistor mirrors as previously described. The non-linear dumper consists simply of a pair of unbiased power transistors. A fractional copy of the dumper output current is obtained by A_4 and returned to the input summing amplifier A_1. The feedback factor R_4/R_5 is set equal to the forward error gain $(R_2 + R_1)/R_1$ to satisfy the balance condition.

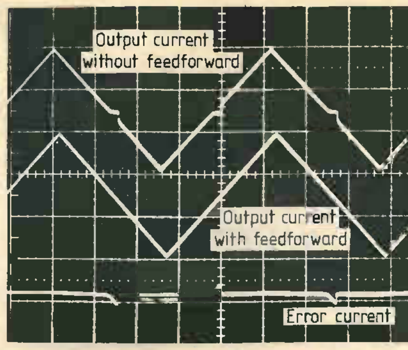

Fig. 12. Triangular wave at 2kHz with and without feedforward.

The upper trace of Fig. 12 shows a 2kHz triangular voltage waveform across the 10Ω load resistor when the feedforward is disconnected, whilst the middle trace shows the effects of adding in the feedforward error at the output connexion. The error-cancelling affects of the balance condition can be clearly seen, there being no discernible disturbance in the linear waveform. The bottom trace shows the error current measured across a separate 10Ω resistor for comparison. Output currents up to 1Apk-pk. can be obtained with this circuit, although the photographs were taken at a low current (15mApk-pk.) where the effects of crossover distortion are more noticeable.

Distortion measurements indicate that the second harmonic is 70dB below the output at 100mA pk-pk., rising by approximately 10dB at 10mApk-pk. and 1Apk-pk. The third harmonic is also lowest at around 100mApk-pk, being 85dB below the output, rising to 75dB at 10mApk-pk. and 80dB at 1Apk-pk. Second-harmonic distortion is generated by the current mirrors in the error feedforward amplifier and the dumper current monitor, whereas the third harmonic is produced by the crossover behaviour of the dumper. Higher harmonics are also present, but are significantly below the level of the second and third under similar conditions. Disconnecting the error feedforward loop increases both the second and third harmonic distortion by around 30dB in the critical low-level output region. The relative improvement in distortion performance due to the feedforward connexion is maintained at higher frequencies where the effects of uncompensated crossover distortion become more significant. A further reduction in distortion would require a specially optimized feedforward amplifier and current monitor using discrete components.

Current mirror circuits offer a versatile design tool that can be employed in most applications where a controlled current is required. In conjunction with op.-amp supply current sensing they facilitate the design of a wide range of low-distortion transconductance and current amplifiers.

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Literature Received

Six-page colour brochure from Crow of Reading gives an outline of the company's activities in the field of broadcast television engineering, which extends from the supply and installation of a single monitor to the design, construction and commissioning of large studios and switching centres. Brochure can be had from Crow at PO Box36, Reading, Berks, RG1 2NB **WW401**

Important characteristics and application information on a range of p.r.o.ms and similar devices from a number of manufacurers is presented in convenient form on a wallchart, available from Microsystem Services, Duke Street, High Wycombe Bucks. **WW403**

Small tools for use in the production of electronic equipment – wire strippers and cutters, board assembly tools and p.c.b. cleaning brushes – are featured in a leaflet published by Eraser International Ltd, Unit M, Portway Industrial Estate, Andover SP10 3LU. **WW404**

An extremely wide range of microwave aerials, cables and waveguides is fully covered in a weighty catalogue (around 200 pages) which can be had from Andrew Antennas, Lochgelly, Fife, KY5 9HG. **WW405**

A range of silicon controlled rectifiers and triacs made by TAG Semiconductors is listed in a selection guide, with main characteristics and a cross reference to other makes. The guide is obtainable from TAG Semiconductors Ltd, 73/79 Rochester Row, London SW1P 2NX. **WW406**

Publication HCG 1 from Highland describes the types of multiway connector currently available. Heavy and light-duty types are made, with from 2 to 128 poles and in ratings from 8A 250V to 35A 440V. Highland Electronics Ltd, Highland House, 8 Old Steine, Brighton, BN1 1EJ. **WW407**

Large colour catalogue from Ross illustrates a very wide range of audio equipment and accessories, including headphones, test gear, intercom, audio and video leads and adapters and microphones. Ross Electronics, 49/53 Pancras Road, London NW1 2QB. **WW408**

Letters to the Editor

EMP protection

Your news report in the September issue highlights the EMP (electromagnetic pulse) threat to solid state communications equipment. However, both Mr Tucker's article of July 2nd in *The Guardian* and your report tend to give a misleading impression of the steps which are being taken to counteract the threat.

Mr Tucker stated that the pulse is "far too rapid for any currently available protection systems". My company has available a gas-filled protection device which will operate in less than one nanosecond. It has been shown that this device will protect solid state receivers and telephone equipment in a simulated EMP environment. We find that suppliers of communications equipment are well aware of the threat and have taken steps to counteract it.

A text book on the subject "EMP Radiation and Protective Techniques" was published by John Wiley and Sons in 1976.

Kenneth Cook
The M-O Valve Co. Ltd
Hammersmith
London W6

Television subtitling

I was very pleased to see your report on "TV subtitles for the deaf" in September's *Wireless World*, in which you review my "Guidelines for the subtitling of television programmes". I would, however, like to clarify one or two points.

First, it is important to stress the distinction between subtitling *live* programmes (such as the Royal Wedding) and subtitling the general run of recorded programmes. The published "Guidelines" from Southampton University do not go into live subtitling in any depth, since this particular area is still under investigation. The "Guidelines" are geared primarily towards teletext subtitling of recorded television programmes, and they have been in use at ITV Oracle for several months.

The coverage of the Royal Wedding, on the other hand, reflected the state of the art of *live* television subtitling. The subtitles transmitted on BBC2 were generated by means of the Palantype semi-phonetic machine shorthand system, capable of producing a word for word transcription of speech in real time, but with some words spelt unconventionally. ITV Oracle's coverage represented a radically different approach to live subtitling. In this case, subtitles were transmitted in the form of a summary of the programme commentary, typed on a standard keyboard in standard English spelling. The pros and cons of these two alternative methods are currently under review.

I would also like to expand on your editorial comment on lipreading. This is an important point and it has received considerable attention during the research project at Southampton University. It has become clear that lipreading of a two-dimensional television picture is extremely difficult, especially when speakers are frequently in half-profile, facing away from the camera, too distant, or out of shot altogether. In spite of this we do give consideration to the exceptional viewer who attempts, where possible, to match subtitles and lip movements (see page 12 of the "Guidelines"). This is done by carrying out script-editing in close conjunction with the original script and the videotape, especially when the speaker is presented in full-face head and shoulders close-up or middle distance shot. Nevertheless we place a far higher premium on providing subtitles in familiar language with adequate reading time, without which the viewer will have no opportunity to attempt to lipread the speaker in any case.

Robert G. Baker
Department of Electronics
Southampton University

Decline of the philosophical spirit

How refreshing to see your July editorial on the dearth of true philosophical thinking in science. It is because science and technology have come to be motivated by pragmatic materialism that we have become too cynical as a species to aspire to civilisation. The spirit of enquiry has been replaced by militarism and social justification. Money no longer serves as a token of currency alone, it has become the primary structure upon which our society is organised. Economics is no longer a means to an end. It is a barrier to significant human progress and could be for decades, if not centuries, to come.

This kind of outlook has narrowed the thrust of pure research into unimaginative and abstract analysis. The quest to reduce the known universe into an elegant set of mathematical relationships, while commendable in its own right, is impotent if no philosophical conclusions are drawn from the end results. Pure research should not be confused by the layman with an attempt to 'explain' anything. In obtaining a degree in physics I came to realise that this most fundamental of disciplines seeks only to describe and not to explain. We are no closer to understanding what a magnetic field is today than we were a hundred years ago. We are simply in a better position to describe and exploit its properties.

Terry Edwards
Ongar
Essex

Television for no-signal areas

A great deal of 'doubtful' technical and commercial advice is now being offered through *Wireless World*. The former appears to be an introduction to the latter which, in my opinion, is completely out of place in this excellent technical journal. Perhaps the following points should be read in conjunction with the letter from M. J. Rutty (September letters) to further assist the lay persons normally expected to consider these schemes.

1. Theoretically a doubling of aerial size is necessary to achieve a maximum 3dB gain. Thus, to increase the gain of a 10-element u.h.f. Yagi aerial by a maximum of 9dB would demand eight such aerials (eighty elements) efficiently harnessed – practically 9dB would not be achieved. However, aerials with 'claimed' gains of plus 9dB relative to the 10 elements listed in J. M. Osborne's article (May 1981) are manufactured by certain companies. Unfortunately, the basic choice of aerial is normally determined by all the parameters in practice and not merely the gain.
Additionally, if minimising the possibility of interfering with other viewers depends on the choice of different commercial aerials, serious consideration should be given to this problem before proceeding.
2. The use of a.c. line powering does not eliminate voltage drops but does overcome the electrolytic problems associated with d.c. line powering. Wolsey line powered equipment employs 55V a.c. (nominal) which, for a given power consumption, minimises the cable voltage drops calculated for each system. Powering of some systems demands long cable runs which should be considered carefully, especially if coaxial cable carrying r.f. signals in addition to line power feeding is employed.
3. Ferrite splitter/combiner units can be used, in place of cable matching sections, for multiple transmitter aerial systems but impedance problems associated with certain cheap imported units can result in unsatisfactory end results.
4. For active deflector systems the Home Office has stipulated a maximum e.r.p. of 1 watt, which in practice means a 53mW transmitter power fed to an aerial of 12dB gain. To make full use of the dynamic range of such an amplifier demands accurate signal level setting after all derating and other allowances have been made.
With the variations of portable television receiver sensitivities, viewing error and the unpredictable additive error of the common (B/L type) v.h.f. attenuators used in practice 'eyeballing' tests are really not on.
5. The amount of pre-amplification employed to drive any system output amplifier depends on its gain and output capability, for a specified level of measured distortion. This pre-amplification will derate the specified output and, depending on the equipment employed, can be the limiting factor. Use of an attenuator between the aerial output and pre-amplifier input stage will usually degrade the signal-to-noise ratio of the system. If attenuation is necessary its position must be carefully chosen.
6. Solar or wind generator powering can be successful under certain well defined conditions. However, the use of such schemes is fraught with difficulties if the 'arithmetic' is not carefully carried out and, if wrong, can result in frequent trips to the site with freshly charged batteries!
7. A maximum usable line of sight range at u.h.f. frequencies cannot be stated without reference to maximum e.r.p., propagation loss, receiving site aerial gain and noise performance specifications etc. In practice this can vary from ¼ mile to 3 miles.
8. Finally, may I say that the most important consideration of self-help schemes is technical backing and not cut-price equipment of doubtful specification and performance. In television distribution systems we have experienced the result of a low level of engineering expertise. It would be sad to see

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self-help schemes perpetuating this state of affairs. Communities considering these schemes would be well advised to seek the professional and free advice of the BBC/IBA engineering information departments.
V. Lewis
Wolsey Electronics
Porth, Rhonnda
Mid Glamorgan

Phase locked detector

I thought that detectors such as the one described in the September issue under the title Phase Locked Detector could no more be of interest to professional engineers.

Even here, in Syria, double-sideband *suppressed carrier* (d.s.b.s.c.) detection is performed by a simple low cost circuit which has a large capture (and lock) bandwidth and no transient delays (i.e. no missed syllables at the start of transmission).

Also we are experimenting with an improved design to detect, with equal ease, two d.s.b.s.c. signals in quadrature. Therefore d.s.b.s.c. transmissions will have the same power and channel density as s.s.b., with the advantage of using simpler systems.
A. R. Moubayed
Autolight
Aleppo
Syria

Evidence for neutrons

Before Mr Burrows (October Letters) uses the success of nuclear reactors to "prove" the existence of the neutron, he should remember that every piece of iron that rusts "proves" in the same way the existence of phlogiston.
C. W. Hobbs
Bern
Switzerland

Unified circuit theory

In his interesting article in the March issue, E. H. Pollard makes the statement that Millman's theorem deserves to be better known than it is.[1] Indeed this is true because the theorem is often a real time-saver, and as a network tool it does everything Pollard says, and more. An extension of the paper into dependent sources would have been most welcome. In today's transistor and i.c. world, dependent sources show up everywhere, and it is necessary that we know whether a certain theorem holds for dependent sources or breaks down. As an example, the theorem in Corollary 3, the Superposition Theorem, does not hold if dependent sources are manipulated, and must be replaced by a much more recent theorem, the Function-Source Superposition Theorem.[2] Using this theorem, we open and close dependent sources, however objectionable this may be to the analytic mind. The theorem in Corollary 5, the Reciprocity Theorem, does not hold for dependent sources. The textbook version in Pollard's paper is only half of the complete reciprocity theorem, the other half pertaining to current-source drive. And Thévenin's and Mayer's (Norton's) Theorems only hold if we avoid manipulating dependent sources.[2]

While Millman's theorem is highly useful, it only represents one side of the story, since the theorem also can be written in a sort of dual form, doubling its field of applications. Called the Parallel-form Generator Multiple-source theorem, the additional theorem was published by this author in 1977.[2] Practically every statement in Pollard's article can be repeated in appropriate form and be applied to the second theorem, pertaining to networks such as the one shown in Fig. 1.

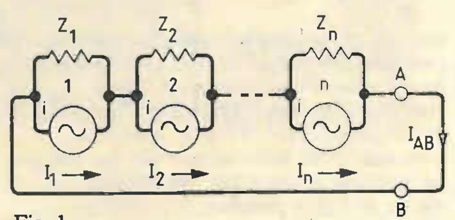

Fig. 1.

Pollard's equation (1) now takes the form

$$I_{AB}=\sum_{k=1}^{n}Z_kI_k\Big/\sum_{k=1}^{n}Z_k$$

One of the most important characteristics of the two theorems is that they hold for dependent sources, thus providing highly useful tools in today's network analysis and synthesis. The dependent sources we have in mind are of the simple form kV or kI, and either theorem handles any mixture of dependent and independent sources, with their associated immittances forming generators, such as "1", "2" and "*n*" in Fig. 1.

The Parallel-form Generator Multiple-Source Theorem is not in need of a separate proof, although a proof can be provided, similar to that presented by Pollard. We may in this connection note the existence of the fundamental and very important Source-transformation Theorem, the one we use when turning a Thévenin generator into a Mayer (Norton) generator, or vice versa. By means of this theorem we can turn any generator in Fig. 1 in to Series-generator form and then independently sum up all voltages and all impedances. The proof the degenerates into Ohm's law. A similar simple proof exists for Millman's theorem.

When we begin to derive one theorem from another, the philosophy of doing this forces us to think of the old slogan: "which comes first, the chicken or the egg". Surely, in the vein of Pollard's paper one can proceed and even derive Tellegen's theorem from Millman's theorem, however absurd the thought may appear.[3] Tellegen's theorem is one of the cornerstones in modern network theory, and from it we drive analytically another corner-stone theorem, the Source-transformation Theorem mentioned above. In the simplest case, and starting from Tellegen,

$$P_{source}+P_R+P_{load}=0$$
$$-EI+RI^2+R_LI^2=0$$
$$E-RI-V=0 \qquad (2)$$

where $V=R_LI$. This is the same equation as

$$ER-I-V/R=0 \qquad (3)$$

Thus we have derived analytically, without opening or closing any sources, the Series-form Generator, eq. (2), known as the Thévenin Generator, and the Parallel-form Generator, eq. (3), known as the Mayer (or Norton) Generator. We do not need either Thévenin's or Mayer's theorem, although they are invaluable time-savers. (And by the way, by invoking the energy principle (Tellegen's theorem) we eliminate the tedious textbook proofs of Thévenin's theorem.) Now, where does Millman's theorem come in? It is simply an additional theorem in the specific area of multi-source linear networks, just like Blakesley's theorem. Millman's theorem is not a contestant to single-source theorems, and should not be used to derive them. But when we encounter many sources, and as a minimum two sources, Millman's theorem, as well as the Parallel-Form Generator Multiple-Source theorem, provide highly useful network tools.
Harry E. Stockman
Sercolab, Arlington, Mass. USA

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Wire recorder

Would it be possible to enquire through your readership for any information concerning the Wirek wire recording machine? This machine was manufactured under licence by Boosey and Hawkes but unfortunately a fire destroyed most of the records concerning the instrument.

As very little appears to have been written about the machine I would be most grateful to have any information that may be available, particularly in regard to numbers manufactured, technical data and details of its use. Of course I should also be pleased to obtain a sample of the machine if this is possible.

All information will be passed to the Science Museum at Kensington, London. As I was once concerned in the manufacture of the machine in 1948 it seems a pity that a small piece of recording history should be allowed to pass into oblivion.
R. A. Ridley G3UTX
23 Greenacre
Worlesbury
Weston-S-Mare
Avon

The dream of objectivity

I was very interested to read your March editorial, but I think that your conclusion could be somewhat false.

Whilst we may all readily agree to your statement that "The observer would not exist if it were not for the phenomena of the world", it is by no means so obvious that "the phenomena of the world would not exist if it were not for the observer". In fact, and to the contrary, I am sure that a lot of them would. The human observer (as simply, a data receiving, processing and transmitting system) is a fairly latecomer on the scene, and is the result of a fairly short period of evolution, on a cosmic time scale. One can suppose the existence of coloured rainbows and roaring sounds from the breakers on the seashore long before there existed any form of living creatures (i.e. how far is it really true to say that the sound of the breakers on the seashore is dependent on their being heard, or the colours of a rainbow on its being seen? – by whom, or what, for example?)

Professor Gilbert Ryle continually stressed in his very important book that we do not, in fact, "mentally observe our own experiences" (as you suggest in your editorial) and that sensations (such as sounds and colours) are not really subjective at all. He says, for example, "The procedure of describing sensations by referring in a certain way to common objects like haystacks, things that hum, and pepper is of great theoretical importance." and again, "We do not employ a 'neat' sensation vocabulary. We describe particular sensations by referring to how common objects regularly look, sound and feel to any normal person." (pp. 202-203, "The Concept of Mind"). I would conclude therefore, that so long as there are plenty of fairly normal persons about we can still have a considerable amount of objectivity in our dealings with each other. Hence objectivity certainly need not be only a dream, though it may be a matter of understanding, and therefore criticising and discussing each other's use of language.
Peter G. M. Dawe
Oxford

From discussions with Mr Dawe it emerges that his understanding of the word "phenomenon" is different from ours. In our March editorial it was used as defined in the O.E.D. – something that appears or is perceived. – Ed.

'Unpublished' D/F beacons

Having coaxed my ageing faculties to restore a rather sophisticated marine radio receiver (Derritron D/F 70 with ferrite "loop") to normal, acceptable performance, I tried it out on the beacon band. Dungeness (310.3 kHz) yields the strongest signal here and is one of a chain of beacons operating on the same frequency in succession. It came in loud and clear, followed by the others at acceptable, weaker levels. However, during the whole of the chain cycle a weaker DU signal persisted and the loop indicated it was co-sited with Dungeness proper.

I telephoned North Foreland Radio, Dungeness Coast Guard, RN Radio Centre, Chatham, BBC, Trinity House Gravesend and finally Trinity House "Lights", London. The last named, after some delay, were able to phone me back with an explanation.

It appears that an experimental transmitter is now operating at Dungeness on 311.5 kHz, using same call sign DU. It is "unpublished" – whatever that means – and "will not go on for long". I pointed out to my informant that the two frequencies were only separated by less than 0.4% and that most D/F receivers would not discriminate to that extent. In any case, it is conceivable that the requisite filters would not be switched in if the operator was not alerted to the danger. He said he "took my point".

The situation seems potentially dangerous – a yachtsman at certain points in the Channel, taking a bearing on, say, Cap Gris Nez, 310.3kHz, could have it "bent" by the "unpublished" Dungeness on 311.5 kHz radiating at the same time.

On what authority can one start up these "unpublished" transmissions. Is it permissible to have two transmitters on differing frequencies sharing the same call sign? Is there not a central authority monitoring all UK transmissions to which one could refer when trying to identify their origins?
Frank Henry,
Chatham,
Kent.

Wien bridge improvement

Mr Linsley Hood's article on an improved Wien bridge oscillator (May issue) soon had me digging out my 1974 design notes on similar work.

One of the disadvantages of the basic Wien network is the low Q and hence low

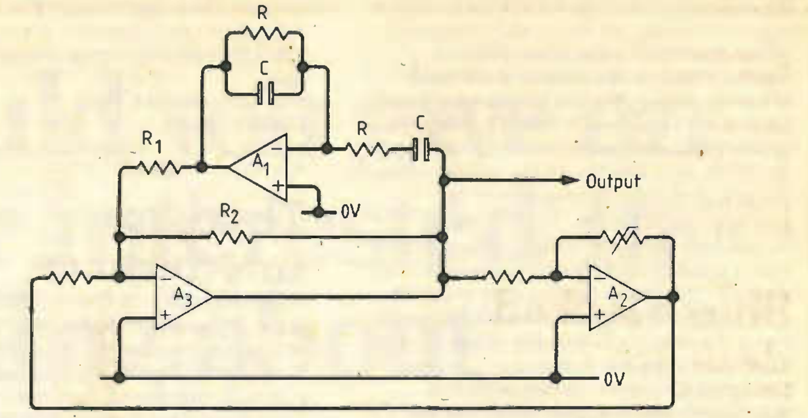
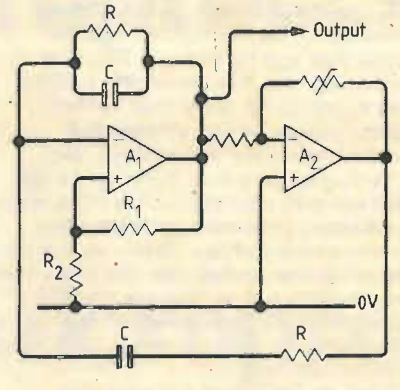


Fig. B.



$$Q=\frac{1}{2-\frac{R_2}{R_1}} \qquad R_2<2R,\ \text{for stable operation}$$

Fig. A.

discrimination against harmonics. It therefore seemed sensible to use the Q multiplying configuration of Fig. A where distortion introduced by the stabilising amplifier is rejected by the relatively narrow band-pass characteristic of the tuned amplifier. Fig. A reduces to Fig. 4 of the article if $R_2/R_1=0$ ($Q=½$) with the important difference that the output is taken from A_1. With a Q of 4, over 20dB reduction of thermistor induced l.f. distortion was obtained, this being the prime design objective. For satisfactory operation the frequency determining components must obviously be well matched.

Of course, the main design feature of Mr Linsley Hood's article is the elimination of the common mode signal at A_1. My circuit did not achieve this though a discrete component amplifier was used to minimise common mode effects.

Fig. B offers the possibility of Q multiplication with no common mode problems and might lead to an optimum distortion performance across the band.

Finally, I assume the gremlins have crept into Fig. 5 of the article. A_2 should in fact be inverting.
Bill Young
Cobham
Surrey

The author replies:
I have read Mr Young's contributions with interest, and note his suggestion that the harmonic distortion introduced by the stabilising circuit may be reduced if the output is taken from the tuned amplifier rather than from the output of the stabilising amplifier.

May I apologise, in this context, for the two errors in the article. As Mr Young indicates, A_2 should be shown as an inverting amplifier, in both cases, and the illustrations shown as Fig. 4 and Fig. 5 should be interchanged.
J. L. Linsley Hood

The death of electric current

In his September 1981 letter, R. T. Lamb seems to think that if he establishes that we are merely discussing a *model* rather than a theory or a fact, he has also established that a bad model is no worse than a better model. When he writes, "... any model that shows that electric current is not needed in that model," I would reply that the successful removal of primitives such as ρ and *J* from a model is a major advance. It is important that unnecessary accretions be cleared away from a model (cf. Occam's Razor). This is particularly true if these accretions create insurmountable difficulties – see my first two paragraphs, August 1981 issue, page 40. Why hold on grimly to redundant primitives, ρ and *J*, if they create the insoluble problem there discussed? If Lamb thinks (unlike me) that a mere model is in dispute, why the tenacity?

In the first paragraph of his letter in the March issue, Lamb accepts the reciprocating model for a charged capacitor as true. This model, when used in the discharge of a capacitor through a resistor, does not result in an exponential, as Lamb suggested on page 46 of the September issue. Using time domain reflectometry, my colleague Malcolm Davidson has experimentally established that when a resistor is switched across a charged capacitor the result is a series of steps (similar to the appendix to our article "Displacement Current" in the December 1978 issue) and not an exponential.
Ivor Catt
St Albans
Herts

Mr Ivor Catt's assertion (August Letters) that conventional electromagnetic theory cannot cope with transients for which it was specifically developed is, to say the least, a trifle rich.

Tilting at the giants of our great heritage of scientific understanding is a useful pastime, even if it only serves to stimulate the thinking of others. I think that Mr Catt has some fundamental misunderstandings of conventional theory which is giving rise to some difficulty in having his own accepted.

A conductor cannot have an electric field in it; the wires of a transmission line cannot have an electric field along their length but Mr Catt's August letter shows a deficiency of charge to the right of his wavefront, a situation which would result in a field along the axis of the wire, the

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axis of propagation of the wave. But the wave is transverse (TEM) and has no such component.

Electromagnetic wave theory does not consider a wave to be a column of electrons advancing down a wire like peas down a tube. A conductor is a region with a large number of free carriers in charge equilibrium with fixed carriers; a metal wire has a large number of free electrons in charge equilibrium with the positively charged nuclei. These electrons interact with electric potentials external to the wire in a manner described by the equations of Maxwell. This can be verified experimentally.

Mr Catt's crude model is thus fundamentally wrong. The model of a wire full of free carriers is also quite crude but at least it is fundamentally correct. In this model it is reasonable to describe the wavefront as the dividing line between that region where carriers have started to move and that where they are not yet disturbed by the approaching wave. It is, of course, fairly common knowledge that the approaching wave is external to the conductor (it cannot be inside, see above) and it influences the surface charges first (skin effect).

Mr Catt's contributions on e.m. theory are shot through with misunderstandings of the same sort. In March 1979 he quotes conventional theory (using displacement current) as requiring two components for charging a transmission line, $i+dD/dt$ (p. 68) where i is the line charging current and dD/dt is the Maxwellian displacement current. But the line charging current is the displacement current according to Maxwell's laws; it is nonsense double them up.

In July 1979 ("The Heaviside Signal") he defines:

$$\sqrt{\frac{\mu}{\epsilon}}=\frac{E}{H}$$

and then goes on to derive:

$$\frac{E}{H}=\sqrt{\frac{\mu}{\epsilon}},\quad \frac{E\mu}{B}=\sqrt{\frac{\mu}{\epsilon}}\ \text{and}\ E=BC$$

all nonsense. Why? Because E, H and B are all vectors and μ and ϵ are scalars. Surely he knows that they cannot be equated?

Maxwell's laws are concerned with electric and magnetic fields. In Mr Catt's, charge appears to give rise to neither. Will he be announcing the death of electric charge next?

Dermod J. O'Reilly
Antwerp
Belgium

The big c.b. con

The proponents of citizen's band radio, including the suppliers of a.m. equipment, are really leading our fellow countrymen into the largest confidence trick imaginable by playing on the fact that little is known technically about types of modulation, propagation, sun-spot cycles etc. and on the desire to do as others are doing – including their mistakes.

Having monitored the 27MHz band in my area, I have yet to hear any UK operator talking to anyone outside his local (groundwave) territory, although no doubt a small number do. Language is still a major barrier and Great Britain does not have many neighbours who have English as their native language, whereas the USA is large enough on its own to receive its own generated transmissions on sky-wave.

I think that, apart from the above deception, the final con. will be evident when sales of a.m. equipment level off due to saturation in this country and, as may well be explained, "a new range of equipment giving less interference and with more efficient transmitter stages" will tempt UK operators into spending yet more money on "improved" equipment – yes f.m.

Come on all you c.b. associations, importers and marketing organisations, play the game and only offer f.m. equipment – for once the Home Office have been far seeing enough to get it right.

J. G. Wheeler, G 8 EMU
Tetbury, Glos.

Thyristor interference

Many thanks to John Flewitt for his very interesting article in the September issue on the BBC sound broadcasting and recording at St Paul's for the Royal Wedding. I was very surprised, however, to learn that trouble was experienced from thyristor interference in the microphone cables.

In 1964, when I was in the BBC Designs Department, thyristor dimmers were just rearing their ugly waveforms at Television Centre, and I was asked to see what could be done to prevent the interference that had already become a serious problem with standard twisted-pair microphone cables.

To shorten a long story, I developed a tight-twist star-quad microphone cable which reduced interference, in the worst conditions when crossing a cable feeding a 10kW spot, to below the microphone amplifier hiss. Since then what first became known as "blue quad" has been manufactured by the mile and has become mandatory in all television studios, both in the BBC and later in ITV.

True, the blue quad has become grey, following the use of chroma key or colour separation; and it has also become thinner and lighter than its ancestor. But you can still see it on any television picture where a microphone is in shot.

Of course these problems do not normally beset the sound broadcasting engineer. But I would have supposed that someone, somehow, would have passed the word. Virtually *all* thyristor interference is coupled to microphone cables inductively, and for a properly balanced pair (or quad) ordinary braid or spiral screening is adequate.

Philip D. R. Marks
Bourne End
Bucks

Ethics in action

Your correspondent Jock Hall (June letters) should be asked "Where are these employers producing electronic equipment of real use to society, and how many can they employ?"

After the war I returned to radio servicing. It was an interesting challenge to get sets from the early thiries and with what valves and components were available to reproduce a good standard of performance. Then came the new sets and disappointment; the only apparent lesson learnt from war-time developments was how to cut material to the bone. One turned a set upside down on the bench at the risk of i.f. cans breaking away from their moorings.

Then came television, and after a while real concern. People with tears in their eyes pleading, "Please repair it here, don't take it away, we don't know what we would do without it". Family quarrels to get children to bed or to do their homework. Visiting friends or relations and not being able to talk because the telly was on.

By the early fifties the novelty had not worn off; the position was worse as so many more people had television. I felt I was helping to create morons, to drive people mad, so, at a considerably reduced salary I took work in a Ministry of Defence inspectorate.

The work was interesting, there could be pride in a product well made and built to last, though, ironically, meant to blow itself up on first use. To begin with there was reasonable hope that these devices would never be used. If that hope has now gone then the distraction of the phantasy world of television, drawing attention away from events in the real world must take a large share of the blame.

The advent of ITV led to fierce competition with the BBC for if one side captures the mass audience the other goes out of business. The direction this fight took was that of more violence, more sex, more trite, easily assimilated material of appeal to the less discerning. Less discernment seems to breed even less discernment, for how often does one observe an audience around a colour television apparently unaware that there is something odd about characters with green or purple hair.

I remember a time when BBC news gave minimal reporting of murder trials. What a change! Half a news bulletin followed by a half hour substituted programme on a mass murderer. I remember when dance music had lyrics of more than four words and was melodious, and its merit was not judged on kilowatts out, or electronic gimmickry. I remember when children played energetic games and did not rob people to get money to play Star Wars.

Electronics has long been a gimmicks industry and has built things not meant to last very long. The most common faults in televisions now are cracked tracks on flimsy circuit boards and overrun resistors that change value or go o/c. This is poor design. The real developments are held up until sale of older systems reach saturation. Baird demonstrated 3D colour television in the forties – remember? I suspect this last condemnation may apply to even such things as medical electronic devices.

One can hardly expect such a journal as *Wireless World* to take up the matter of a general decline in levels of discernment, but where it affects the ethics of engineers, please, give it full publicity. [See November editorial – Ed.]

E. V. Hurran
Margate
Kent

Radio amateurs' licence

Your correspondent M. Jackson (October Letters) has made a useful suggestion regarding the use of c.w. by class 'B' radio amateurs on v.h.f. but I do not think that any responsible amateur can agree with the following of his proposals:

(a) The use of non type-approved equipment on c.b. Most amateur h.f. equipment has a power output far greater than 4 watts and so would not meet the Home Office requirements. Also, amateur h.f. equipment is not suitable for channelized operation.

(b) Amateurs to use c.b. at no extra licence fee. This is a dangerous suggestion because it may well result in counter proposals from c.b'ers to use the amateur bands at no extra fee.

(c) 10-metre band to be used by class 'B' radio amateurs. Class 'B' licencees can already gain access to the 10-metre band by taking the Morse test like everyone else! It is a fallacy to think that 10 metres will be taken over by the c.b'ers.

Far from being a threat to amateur radio in this country, c.b. should result in the swelling of amateur ranks in the coming years. Already in this area c.b'ers are preparing for the December Radio Amateurs Examination.

I. Buffham, G3TMA
Spalding
Lincs

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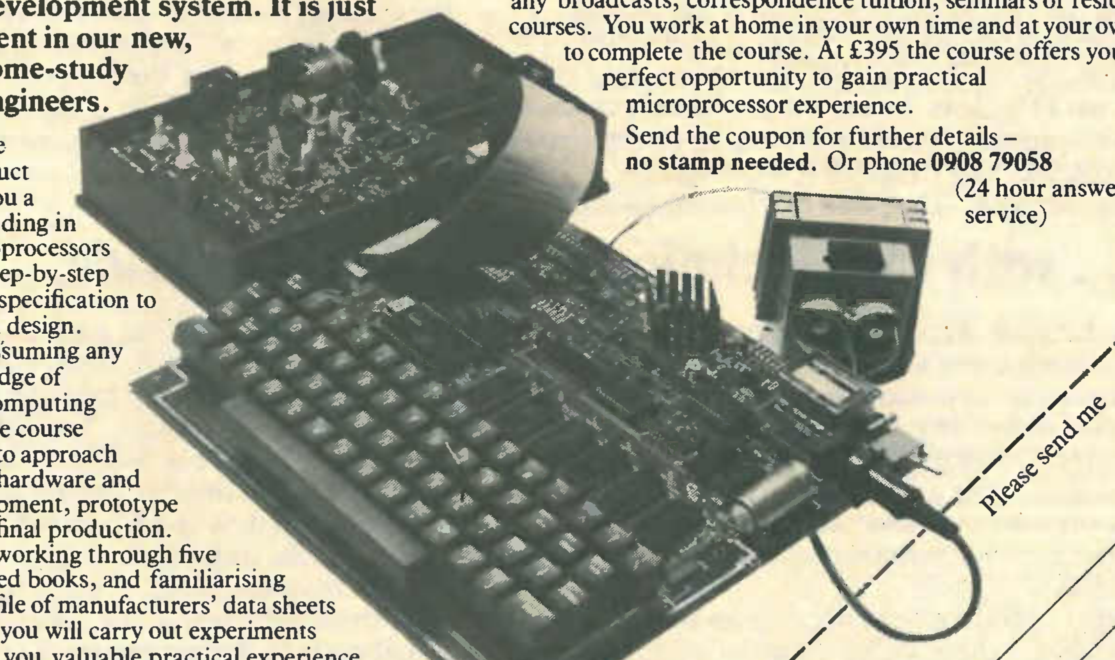

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New BBC/OU production centre opens

by Donald Aldous

In late September production started at Europe's biggest purpose-built educational broadcasting complex, on the campus of the Open University at Milton Keynes, Buckinghamshire. Robert Rowland, head of the new centre, describes the OU as 'the largest university in the kingdom'.

The start of production at the centre is the culmination of some ten years' efforts to create and manage the physical development of the university's 70 acre campus and 13 regional properties, since the OU was established in 1969. The original production facility was at Alexandra Palace, London, and the new site will offer a more convenient working relationship for OU and BBC colleagues on the course teams that compile and produce all OU study material.

This project has cost over £8 million, funded by the Department of Education and Science, and is not extracted in any way from the BBC television licence fee, as has been bruited around by some critics. In fact, the OU's yearly fee to the BBC for production and transmission of programmes is currently around £8.3 million. Total floor area of the building is 11,100m^2 gross, 8.500m^2 net. (The difference is made up of corridors, plant rooms, toilets, etc.). The building is supported by 504 reinforced concrete piles, each individually driven into the ground over a period of about 3 months in the autumn of 1977. The reactions of the OU staff working on the campus at that time can be imagined!

The technical areas are interconnected by 40,000 metres of cable. The power distribution cables add up to a similar total, which in combination would cover the distance between London and Milton Keynes. Electric power reaches the building's own substation at 11kV, 3-phase, where it is transformed down to 415V for distribution throughout the buildings.

The centre at Walton Hall, as it is known, consists of an office block and a technical block, joined together at a main reception area. The technical block contains two tv studios: Studio 1 has a floor space of 336 square metres and Studio 2 has 102 square metres. Studio 1 is a small production studio with four Link 110 colour cameras, and the production suite is at ground floor level to permit easy access. This arrangement is in contrast to the usual high level gallery with observation windows.

The production control suite has separate control, vision and lighting control, and sound control rooms. The desks and monitor stacks are positioned so as to allow direct line-of-sight between the director and staff seated at the desk in the production control room and the personnel in the other two rooms.

The vision control room has a Grass Valley 16-channel, 4-bank vision mixer with multiple re-entry, chroma-key and comprehensive wipe pattern generators. The chroma-key incorporates the BBC fringe suppression system. Lighting is controlled by means of a Thornlite 500 microprocessor based system with 200 dimmer channels and 200 memory files.

Production control room for the larger of the two studios, Studio 1. Through the window in the background can be seen the sound control room.

The sound control room has a 20-channel/4-group control desk built to a standard BBC specification, two Studer A80 ¼-in tape recorders and two BBC designed disc reproducers. There is also provision for adding a multi-track tape recorder and other equipment for post-production editing.

Studio 2 has been equipped for operation on a 'drive-in' basis with a colour mobile control room. The installation has been confined to production lighting and cabling to a connection point in the nearby outside broadcast base, where the vehicle will be parked when used in this mode.

Sound suite

There are two studios in the sound suite, one of 104 square metres and the other a small talks studio of 20 square metres. The larger studio is equipped for drama and music with a Calrec Mk. 2 19-channel general purpose stereo desk, the Studer tape equipment, and BBC disc reproducers. The adjacent talks studio, which also serves as a quality check room, houses two tape machines and one disc player. Control is from a Glensound desk fitted for seven stereo and four mono channels.

This suite also contains three editing/transfer rooms, each with three tape machines and a linking console; a 'try-over disc room' for listening to the content rather than the technical quality of the material; a tape store; an office and a maintenance room.

Central technical area

This area is divided into a number of rooms for video tape recorders, a video rostrum camera or episcope room, telecine, a tv quality check room, maintenance and tv apparatus rooms. Four of the six videotape cubicles will be equipped with broadcast quality machines (Ampex) and one cubicle with a rack of cassette recorders for producing copies of programmes for distribution to OU study centres and libraries.

The video rostrum camera is an invaluable help to OU's insatiable thirst for graphic material. After five years' use at AP, the video rostrum – with its computer controlled camera recording direct on to video tape – remains unique to the production centre. This rostrum enables animation and caption sequences to be checked during recording.

It is noteworthy that equipment to the value of about £1.5m has been transferred from Alexandra Palace. This was originally bought and installed in 1974/5, when it was decided that OU tv programmes should be made in colour. Without this equipment, the total cost of the new centre would have been around £10m.

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Circuit Ideas

Micropower voltage regulator

In battery powered systems which require a constant voltage supply, a regulator is needed to stabilize the voltage as the battery decays. Unfortunately, most i.c. voltage regulators require several milliamps of quiescent current, which makes them impractical for micropower applications. Zener diodes may also be impractical because of short term peak current requirements.

Instead of the traditional bipolar approach, this regulator uses a j.f.e.t. as the series pass element which does not require pre-regulation because the drive comes from the regulated output. Also, the gate-source is isolated from the line by the drain, which provides high line regulation. This is not the case with p.n.p. pass elements where the emitter is the input. Finally, and most important for low power regulation, the f.e.t. requires no current drive.

The emitter-base breakdown voltage of Tr_3 is used as a reference ($\approx$7.2V) in conjunction with Tr_2 to form a shunt regulator. Shunt current drives a current mirror, $Tr_4 - Tr_5$, which produces the gate drive voltage for the f.e.t. The value of the shunt current is determined by R_3 and V_{GS} of the f.e.t. ($I_{R3} \approx I_{shunt}$). High load currents will reduce the shunt current because V_{GS} is lower. Temperature stability is achieved by cancelling the V_{BE} drift of Tr_2 and Tr_3 with the BV_{EB} drift of Tr_3, which results in a negative drift at the base of Tr_2 and the output of 1mV/deg. C.

The f.e.t. I_{DSS} should be much greater than the load current at all temperatures (I_{DSS} has a temperature coefficient of ≈ -0.7%/deg.C) and the breakdown voltage should be greater than the maximum input voltage. Linear operation requires the drain-to-gate voltage V_{DG} to be greater than the pinch-off voltage V_P. By operating the f.e.t. at currents much less than I_{DSS}, the gate-to-source voltage will be close to V_P which allows small drain-to-source voltages. Therefore, for linear operation

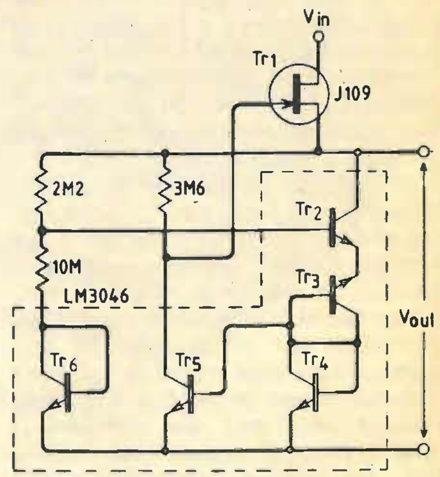
$$|V_{DG}| > |V_P|$$

$$V_{DG} = V_{DS} - V_{GS}$$

For higher loads several f.e.ts can be paralleled without matching.

With a 10V output the line regulation is typically ±0.05%. Load regulation is 0.2% from 10µA to 10mA ($Z_o \approx 10\Omega$) and temperature stability is -1mV/deg.C. The output voltage is given by $V_{BE}(2+R_1/R_2) + BV_{EB}(1+R_1/R_2)$ and can be trimmed by adding a potentiometer at the R_1, R_2, Tr_2 base junction to eliminate BV_{EB} variations or to make the output variable over a limited range. Temperature stability can be improved by replacing Tr_3 with an 8.2V Zener diode, whose temperature drift of about +4mV/deg.C will nearly match the combined V_{BE} drift of Tr_2 and Tr_4. Quiescent current with the values shown is about 4µA.

J. Maxwell
Santa Clara
U.S.A.



Improving converter efficiency

The efficiency of a simple converter can be improved by using a rectified output derived from the input winding. This simple addition reduces the input current for a given output current and increases the output voltage. Also, the output short-circuit current approaches the input current. This form of converter is well suited for variable voltage inputs such as solar-cell panels, especially as no reverse-current input diode is required when the cells are in darkness.

The mains transformer can be used in its original form, but a higher output current can be obtained if the low voltage winding is rewound with 80 turns of 20 s.w.g. enamelled copper wire. The number of turns on the higher voltage winding can be reduced to lower the output voltage and increase the output current. Performance details are shown in the table.

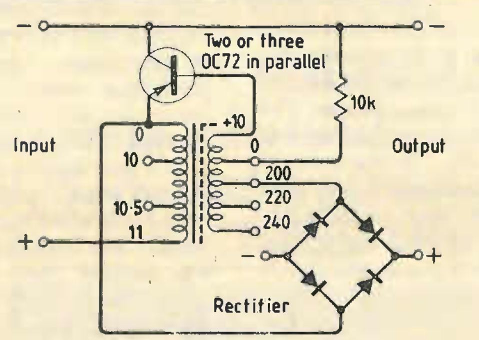
Simple voltage control can be achieved by connecting a suitable high value resistor between the rectifier negative and negative rail.

R. C. T. Stead
Hampton
Middx.

Input nominal voltage	Output normal circuit	open circuit	short circuit
1.5	3mA	13V	–
1.5	800mA	–	50mA
3.0	6mA	24V	–
3.0	1500mA	–	80mA
With rectifier			
1.5	3mA	14V	–
1.5	500mA	–	490mA
3.0	6mA	27.5V	–
3.0	1000mA	–	990mA

Charging efficiency

Input voltage at terminals	nominal voltage	Output charging current	efficiency
1.0	1.5 200mA	10mA	72%
2.0	3.0 600mA	60mA	90%



Contributions for circuit ideas should be typed and include a day time phone number if possible. We now pay a minimum of £20 for all ideas which are accepted for first publication in Wireless World.

Fusible-link p.r.o.m. programmer

Fusible-link p.r.o.ms such as the SN74S288 and SN74S188 can be programmed directly and, by adding up to three more address lines from the counter and using a larger socket, the following devices can also be programmed.

74S287, 74S387	8 inputs 4 outputs
74S470, 74S471	8 inputs 8 outputs
74S472, 74S473	9 inputs 8 outputs

Als5o, data can be easily verified before or after programming. These small low-cost p.r.o.ms can be used to replace logic elements by programming the desired truth table into the device. Although they are not low-power memories, they can reduce system power by replacing several packages.

Without +12V, the circuit reads a p.r.o.m. powered through D_1, and eight l.e.ds monitor the data outputs via inverters. The device is addressed by a 4040 binary counter which is incremented by a push button. The address is monitored by a further five l.e.ds and inverters and, in a 5-bit address range, a reset button is not necessary. For larger p.r.o.ms, a reset button can be added across C_4. Switch S_3 should be set to 0 or 9 during the reading.

To program a device, the address must be set and the bit to be programmed high (the 74S288 is supplied with all locations low) is selected by S_3. This saturates one of the eight transistors and clamps the data outputs low. S_2 is then pressed to trigger a flip-flop which then feeds clock pulses to the 4017 counter. The counter outputs sequentially set and reset two flip-flops to give outputs Q_1, Q_2 as shown in the timing diagram. Chip select on the p.r.o.m. is taken high, a +10.5V program pulse is applied to V_{cc} for 4 clock cycles, and for the second and third clock cycles $\overline{CS}$ is taken low to program the bit.

Flip-flop 3 is reset on the ninth clock cycle and stops the program cycle. Capacitor C_4 and R_1 set the counters and flip-flops to the correct initial states, and the 3k9 resistors apply the correct loads to the unprogrammed outputs during the programming cycle. Diode D_1 disconnects the +5V supply to the p.r.o.m. during programming.

The +12V supply should be rated at 1A, and the only important constructional note is to ensure that a low resistance path exists between the emitters of the eight transistors, 0V on the p.r.o.m., and the +12V ground, so that the programmed bit is held low and a 750mA current pulse flows through it.

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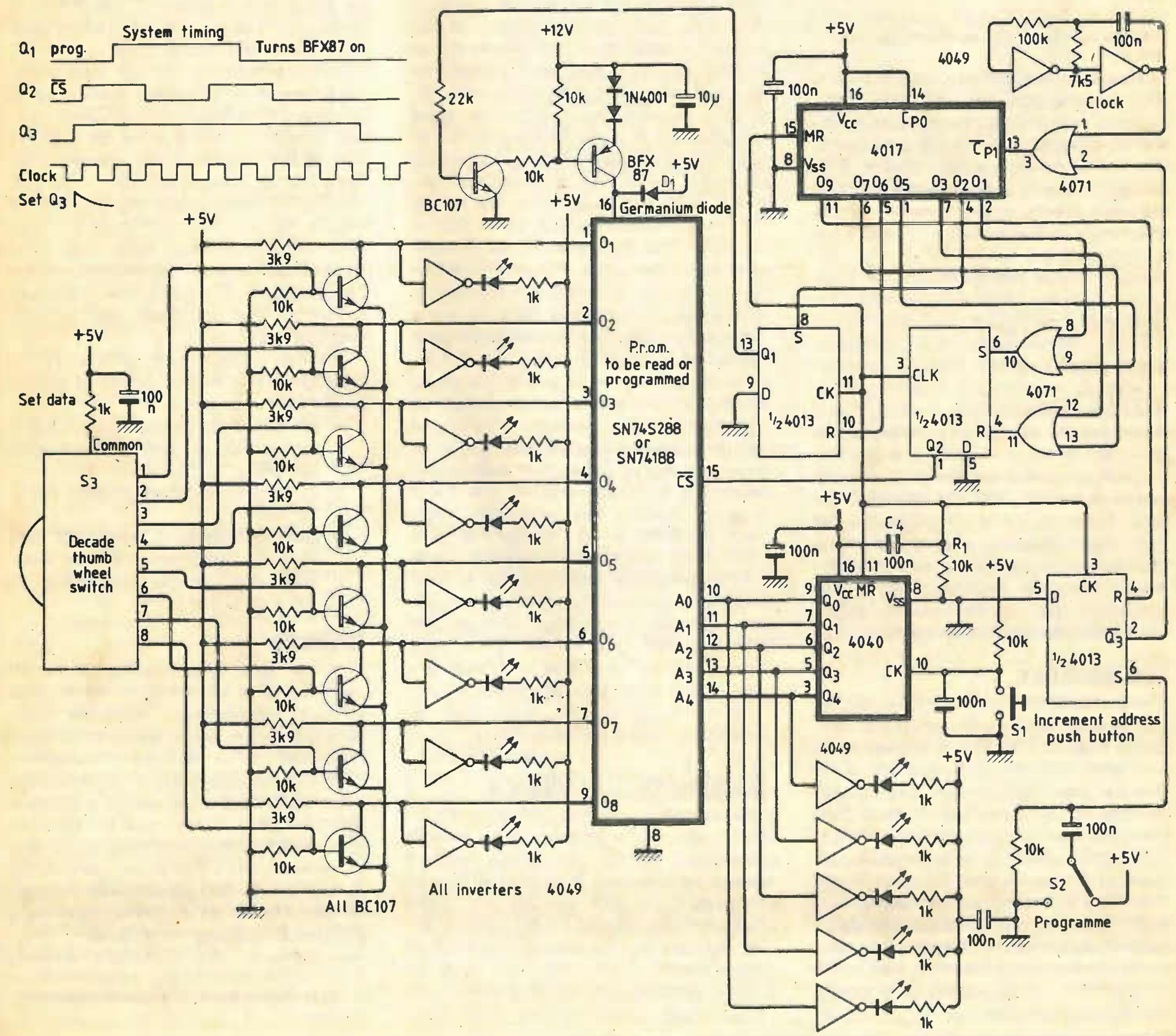

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More light on obscure units

Are you in a muddle over light units?

by J. C. A. Chaimowicz Dipl. Ing. E.S.E., M.I.E.E., M.I.E.R.E., M.O.S.A.

This covers the basic concepts underlying light measurements, deliberately cutting out the dull listing of units and tabulation of conversion factors, relating to four physical quantities: flux, intensity, luminance/radiance and illuminance/irradiance. The treatment emphasizes this physical character of light units, to make them tangible to engineers.

If you are not in a muddle over light units, switch over to another article now. If you are let me take you out of the jungle, to basic concepts with a physical meaning. But first, a glance at the jungle.

One of the units of photometry is called the nit. Page 578 of the Concise Advanced Learner's Oxford Dictionary defines the nit so:

nit[1]/nit/*n* egg of a louse or other parasitic insect (e.g. as found in the hair of persons who seldom wash).
nit[2]/nit/n=nitwit.

Neither nice nor helpful. Another, more often encountered unit for light measurement is the candle. Romantic perhaps, but not very practical. We also have noxes, stibs and apostilbs, sea-mile candles, foot-lamberts, carcels, lumens, luxes, heffners and other talbots, without mentioning the radiometric unit of watts per steradian per metre square per nanometre used by c.r.t specialists. How then do we get out of this jungle? Simple. By going straight to the basic concepts of light measurements.

These concepts are but four, relating to four physical qualities: flux, illuminance-/irradiance, intensity and luminance/radiance. Equipped with these you will be able to put into the right place every single one of the two dozen or so existing units. Articles dealing with stage illumination, with camera sensitivity, with the light performance of l.e.ds, c.r.ts, incandescent and other light sources, with photodiodes, phototransistors and other light receivers will become clear, catalogues will become intelligible, and comparisons of components from different sources possible.

Luminous flux

The first and truly fundamental concept is that of *luminous flux;* the remaining three derive from it. The idea of flux is closely associated with that of flow: think of the flow and you "feel" the flux. For example the flow of people in Oxford Street. How many per hour? Think of the water flow of a mountain stream. How many gallons per minute? Think of your Company's cash flow. Try to remember now the shaft of light you once saw pouring through a stained glass window. Finally, imagine a torch shining on a pitch-dark night – this is light flow – and you will have grasped the notion of light flux.

Light is a form of energy. The luminous flux is the time-rate of the flow of this energy through a certain area or out of a certain solid angle. For instance, in the case of the shaft of light, this will be the "energy" time-rate of the light beam traversing a particular fragment of the stained glass window or the whole of it; in the case of the torch, the total flux is the "power" radiated into the light cone of the torch, out of its apex.

Photometric units are designed to convey a sense of strength of human responses to light and NOT to give an objective measure of the power carried by a beam of light. Whence " " in the previous paragraph. Being physiologically dependent, photometric units of flux are colour-related. Radiometric units are not. They alone represent genuine power – without inverted commas! They alone have licence to use the watt as a unit of flux. The practical consequences of the unequal sensitivity of the human eye to various colours is that even though two fragments of stained glass, one green, the other red, may be transmitting equal amounts of true power (such as would be measured in absolute terms and hence expressed in watts) their photometrically assessed fluxes will be different, the human eye being more sensitive to green than to red light. The photometric unit of luminous flux is the lumen. For pure colorimetric green light 1 lumen corresponds to 1.47 milliwatts. For red light some ten times more is required to produce the same physiological sensation and so, here, 1 lumen corresponds to 15 milliwatts. Green and red colours as used above correspond to monochromatic radiation of 550 and 650nm wavelength respectively. An internationally agreed lumen/watt relationship called the visibility curve for the whole range of colours was established many years ago based on an "average eye", the result of numerous measurements made on a large sample of humans, Fig. 1. This curve gives an immediate answer to a common question of the type: "My gallium arsenide diode emits 0.7mW. How many lumens is that?" As GaAs l.e.ds emit at 900nm, the answer is zero. This is how it should be, as the infra-red radiation produces no visual effects.

Illuminance – Irradiance

The magazine you are reading is illuminated. So is the theatre stage (though sometimes dimly), the shop window display and the road. What they all have in common is the fact that they all receive light shed onto them. To the contrary of, for example, a television screen which is self-luminous. This distinction must be clearly perceived and firmly rooted in the mind for the remaining three of the basic four to be understood.

Illuminance is the area-density of light falling from an external source onto a surface. Hence it is represented by lumens per square metre. The unit used in photometry is lux, with one lux representing an illuminance of one lumen per square metre: 1 lux=1 lumen/1m^2.

When light from more than one source falls onto an area, the individual fluxes are added.*

The radiometric conceptual (not numerical!) equivalent of the lux is the watt per square metre (W/m^2). Here, the area density of incident flux is called *irradiance.* You will have noticed the identity of the basic concept linking illuminance and irradiance. It is obvious from Fig. 2, right, that the more the surface is tilted with regard to the incident rays, the larger the area lit by the same flux and the smaller the illuminance/irradiance. This is what is expressed by saying the sun is hotter midday than morning and evening.

Before going onto the next item of the basic four it is of utmost importance to emphasize that neither illuminance (lux) nor irradiance (W/m^2) gives the slightest idea on how bright an area appears to us. Consider the example of Fig. 2. The illuminance of a black matt table top will be exactly the same whether or not it is covered with a snow-white table cloth. This fits the definition of illuminance which, like irradiance, is concerned with the area density of the on-coming and not the outgoing radiation.

Just how strong a lux is and what practical magnitude a watt/m^2 is can be judged from these few examples

- moonlit landscape receives 0.01lux
- comfortably lit desk is illuminated by 300lux
- St Tropez sunbather receives 1.5 × 10^5 lux
- 2mW helium-neon laser (red) produces an illuminance of a few thousand lux, or an irradiance of 200W/m^2.

Intensity

Few real light sources radiate with the same vigour in all directions. Some, such as the earlier-mentioned torch, are directional by design. Some, meant to be omni-directional, fail in this respect through unavoidable manufacturing or exploitational constraints. Such is the case of a spherical light bulb, Fig. 3, in which the unavoidable contact-bearing base impedes the light preparation into a part of the surrounding space. Clearly, to characterize the strength of the radiation in a certain direction, a directional quantity is required – *luminous intensity.* The luminous intensity represents the flux flowing out of a source in a given direction per unit angle.

* Laser light requires a specialized treatment.

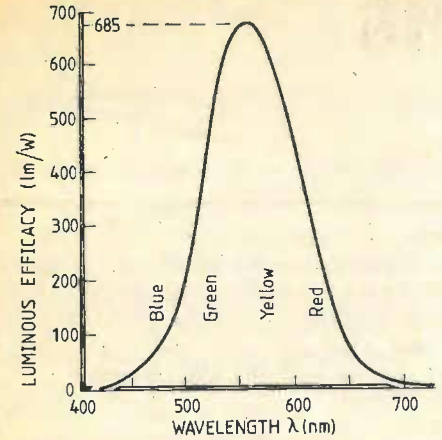


Fig. 1. "My gallium arsenide diode emits 0.7mW. How many lumens is that?" As GaAs l.e.ds emit at 900nm the answer, from the internationally agreed curve, is zero. Which is how it should be as the infra-red radiation produces no visible effect.

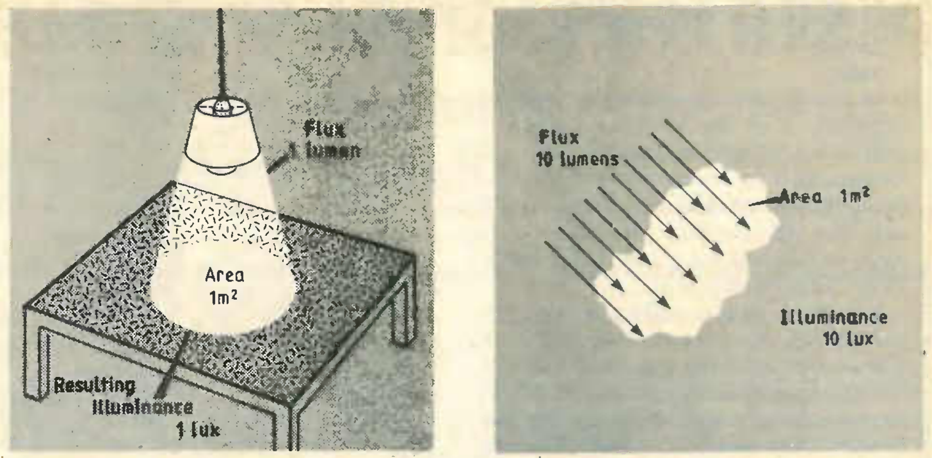


Fig. 2. The area-density of light falling onto a surface is represented by Illuminance, i.e. lumens per square metre, for both divergent light and parallel light.

Fig. 3. As few real light sources radiate equally in all directions a directional quantity is needed to characterize strength of radiation in a particular direction. Candelas are lumens per unit solid angle.

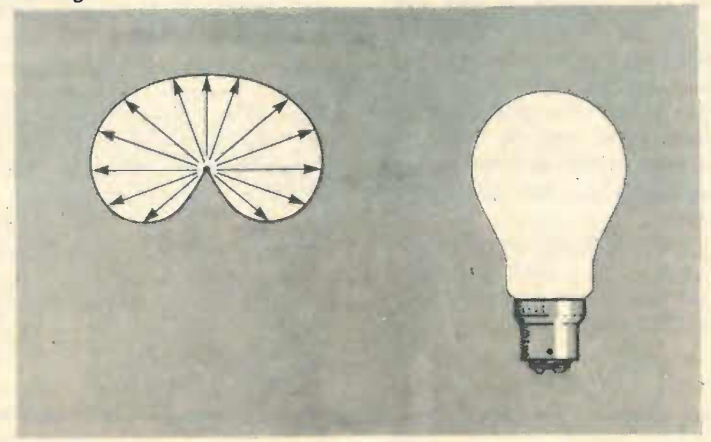
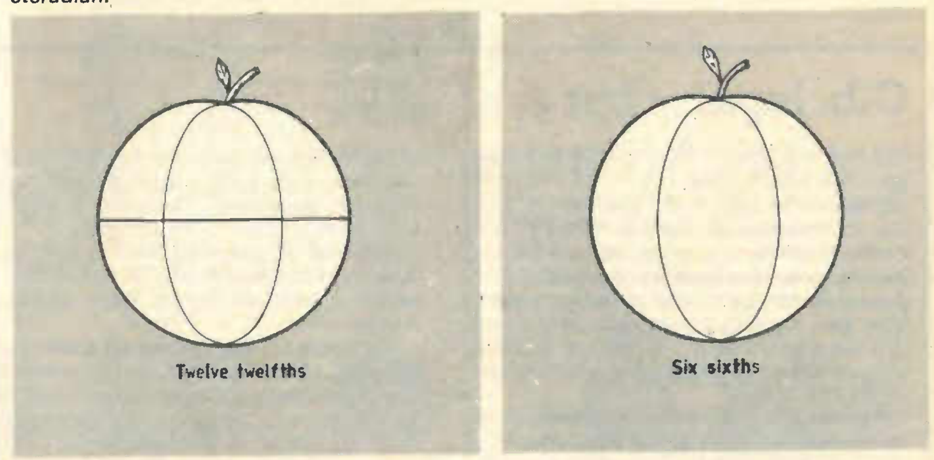


Fig. 4. Cutting an apple into twelfths as shown gives a solid angle that approximates to one steradian.



Because light source beam radiation three-dimensionally a flat angle unit such as the degree will not do here. A space angle unit must be used instead: the steradian. As the unit of flux is a lumen, the luminous intensity will be measured in lumen/steradian. For brevity a single word has been internationally agreed, the candela, to stand for one lumen/steradian.

The choice of a steradian for a unit of spatial angle is unfortunate: a steradian is a very large chunk of space and as such it does not impart well the sense of directionality. Steradians are seldom used in other fields and it will certainly help to describe an easy way of visualizing their size. To form a steradian, take an organe or an apple and cut it into six as if sharing it equitably between six people. Then make a fourth, horizontal cut through the middle, Figs 4 & 5. You have 12 equal portions. Each one of them contains at its apex a space angle of one steradian (within a 4% error). A corner of a room contains approximately 1.5 steradians.

Within the context of light intensity measurments it might be even more helpful to visualize the spatial angle not as the hollow of a three-sided structure, but as the interior of the tip of a cone. A hypothetical cornet with a rounded off "filler" surface having an area just equal to r^2 would make exactly one steradian at its tip.

In radiometry, the third basic concept corresponds to the power radiated into a unit solid angle. This is named radiant *intensity* and is measured in watt/steradian. The intensity concept is valid only for sources small with regard to the surrounding space, aptly called point sources. As long as the linear dimension of the radiating element is some ten times smaller than the distances of interest around them, one can call them point sources and use the intensity concept. This is mostly the case with bulbs, candles, l.e.ds or c.r.t. spots but not with large panels.

Finally, the value of both luminous intensity and radiant intensity in a given direction is independant of the distance from the source at which it is measured, as seen from the sketch of Fig. 6.

Luminance

The last of the basic four concepts of photometry is that of *luminance.* Imagine you are viewing a tiny, compact filament shining through its bulb of clear glass. The bulb, in fact the filament, it is bright that it hurts your eyes. Then imagine that the glass is opalescent. The device emits now very nearly the same amount of light as before but the eye perceives it unhurt. The total flux is constant to a first approximation, but the opal glass envelope spreads the radiation over a much larger surface which re-diffuses it. Luminance expresses the brightness of the source in a given direction.

The surface area of the source has a large part to play, now. Imagine that the milky spherical bulb containing the filament broke and got replaced by another, twice its diameter, Fig. 7. The new bulb will appear four times less bright, despite the constancy of its wattage and its total flux. To convey these effects of source brightness, the luminance expresses luminous intensity per unit surface area of the source. This is of course the same as the luminous flux per steradian per unit area.

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We thus have a unit of luminance:
Candela/metre^2 or lumen/steradian $\times$ metre^2.

It is a unit that characterizes out-going radiation, to be used with objects which emit or re-emit light; a filament, a bulb, an illuminated lamp shade, a working screen or an illuminated table top. An idea of its size: the UK standard for screen luminance in film viewing rooms is 37.5 candelas/m^2 at full illumination.

Luminance is a directional quantity, as is intensity, one of its two constituents. The surface area, the second constituent, must be taken as the projection of the physical radiation area on the plan perpendicular to the direction in case. With certain emitting or re-emitting devices the intensity *versus* viewing angle variation is such that luminance remains constant. This is so because as the observer looks more obliquely at such a source, the projected unit area reduces in the same proportion as the intensity does. Such sources, called lambertian, are exemplified by the moon, flashed opal glass, chalk, good Bristol board. But this directional independence must not be taken for granted, as most devices and materials are not lambertian. Their luminance varies with direction.

Finally, the radiometric sister of luminance is *radiance* and I think that nobody will show puzzlement any longer at the fact that it is usually measured in

$$W/sr \times m^2$$

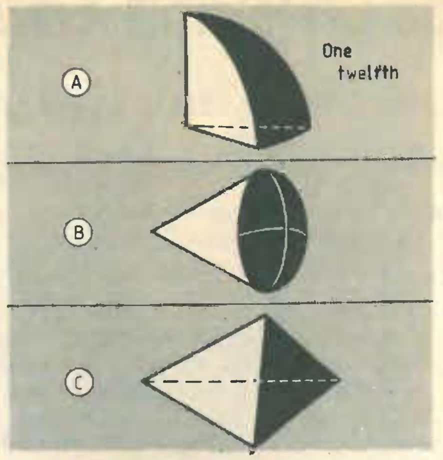

Fig. 5. Spatial angles may be alternatively visualized as that conical fraction of a sphere whose surface area is equal to the square of its radius.

and sometimes (I am sure you will know where and why) in

$$W/sr \times m^2 \times nm$$

And yet "watts per steradian per metre square per nanometre" must have sounded puzzling when first met in the opening paragraph of this article.

Final word of guidance. When you come across an unknown exotic unit try to establish, first of all, to which of the basic four denominations it belongs and whether it is photo or radiometric. The subsequent working out of numerical conversion factors should come easily.

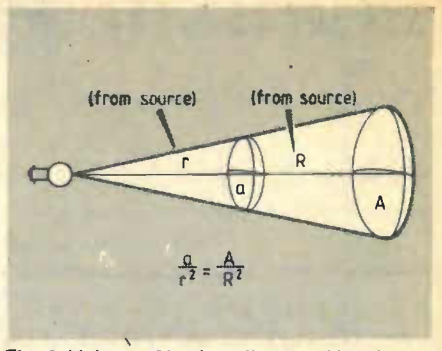

Fig. 6. Values of both radiant and luminous intensity are independant of source distance.

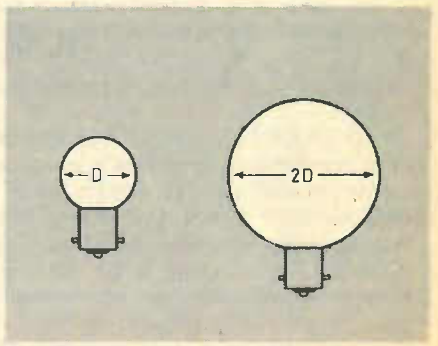

Fig. 7. Luminance expresses brightness of source. Large bulb appears four times less bright than smaller bulb for the same power and flux. Luminance is luminous intensity per unit surface area (which is the same as flux per steradian per unit area).

C.b. legal – but...

The fact that citizens' band radio is now legal gives little relief to those who are suffering from interference because of the illegal use of a.m. sets on unauthorized channels. The Selective Paging Committee, a group representing the manufacturers of radio paging equipment, have pointed out the interference to paging systems. They have conducted tests which have shown that the use of illegal c.b. sets can interfere severely with the paging systems which operate on the 27MHz band.

The chief problem is that the effect of the interference is very insidious. When affected, a bleeper just refuses to bleep and, if detected, the fault is put down to the receiver and not to the interference. When one considers that paging systems are used in hospitals, on industrial premises for maintenance and security personnel, then it becomes apparent that if an urgent call is not received, then there could be very serious consequences. A report by Tom Davies in *The Observer* says that a patient has died because a doctor could not be paged.

What the Selective Paging Committee proposes is that radio paging should be shifted to a different frequency band with a width of 500kHz, between 30 and 41MHz. This band was allocated at WARC to fixed and mobile services. 31.735 to 31.775MHz is already allocated in the UK to on-site radio paging. The majority of the band, however, is allocated for military use.

British Telecom have said that they are getting more than 1,000 complaints each week about c.b. interference. These refer to interference on tv and radio, breakthrough on hi-fi, interference on emergency services and other mobile services, such as taxis. Model aircraft, if control is lost, can become lethal, unguided missiles.

We contacted the Civil Aviation Authority to get their view. So far there have been no recorded incidents of c.b. interference, but they are worried by the possibility of harmonic radiation. Apparently the 4th harmonic of 27MHz which could affect the i.l.s. localiser/v.o.r. band (landing and navigation systems) and the 5th harmonic, which could affect the v.h.f. r/t (air traffic control) band. Spurious radiation can, of course, fall anywhere. The CAA pointed out that in North America there is a recorded case of interference with the i.l.s.; interference with r/t is widespread. A large number of the cases, when investigated, proved to be due to the use of booster transmitter amplifiers; "burners". Such amplifiers are illegal here but are available, and are in use.

Legal c.b. as specified by the Home Office does not present any problems, but the estimated one million illegal broadcasters are unlikely to abandon their current equipment in order to change it for the approved types. The Selective Paging Committee believes that it is only a matter of time before the illegal sets will be accepted as an internationally recognised standard and that the current specifications are an interim measure, not the final decision.

News in Brief

Powertran specialize in selling kits from magazine designs, including some from *Wireless World*. Unfortunately, they have had difficulty in maintaining a construction and servicing facility. They were relieved when they heard of Circolec, an electronic company in Tooting, South London, who were willing to undertake the work, and have now appointed them official Powertran service and manufacturing agents. Circolec can service the complete range of Powertran kits from the simple amplifiers to the most complex synthesizers. This is of special interest to those who have built a kit but cannot get it to work, and to those whose finished kits may have failed some time after assembly. They can also assemble Powertran kits and ensure that they are working properly before dispatch. Many people wish to purchase these kits but are not totally confident of their ability to assemble and set up such kits as the Transcendent Polysynth. Kits purchased from Powertran may be forwarded to Circolec, or the complete order may be sent to Circolec, 1 Franciscan Road, London SW17 8EA.

Multichannel digital tape recorder

Design of the digital additions to the audio cassette recorder

by A. J. Ewins, B.Tech. Research Laboratories, London Transport

Overall design aims of the digital recorder were set out in the first two parts of this article, which continues with a description of the additions to the audio cassette deck for multichannel digital recording.

All the logic used in the design of the digital circuitry is c.m.o.s. and is supplied with a nominal +15V: the analogue circuits use the same +15V supply and one of −15V.

Many of the logic circuit diagrams are complicated and, to keep them as simple as possible, not all the pin connexions to a particular logic device are shown: only those necessary to define the function of the device are indicated – for example, the supply connexions are not normally shown. Again, a divide-by-10 counter (i.c. type 4017) may only be shown with its clock input, carry output and reset connexion, it being left to the reader to appreciate that other inputs may need to be connected to +V or ground, or left unconnected as appropriate. Another example is the use of a D-type flip-flop (i.c. type 4013) as a divide-by-2 counter; it is assumed that the reader knows that the $\overline{Q}$ output must be go to the D input for the device to function correctly. However, whenever it is thought that a particular device may be unfamiliar to readers, a more detailed description of the pin connexions is shown.

Temporary storage buffers, control circuitry

Figure 2 in part 1 of the article showed the two 72-bit temporary data storage buffers, the 8-bit sync. word buffer, a 2-bit shift register, the Miller encoder and associated control circuitry. Figure 12 shows the detailed circuit diagram of the first three and their interconnexion via logic switches. The two 72-bit storage buffers are made up from two shift-register i.cs, types 4014 and 4031, the 4014 type being an 8-bit serial or parallel-in/serial-out device. Since it is used only in its serial-in/serial-out mode, all eight parallel inputs go to ground, as does its parallel/serial mode input, PS. Serial data advances through the shift-register on the positive edge of the clock pulse. The 4031 device is a 64-bit, serial-in/serial-out shift register with the facility to recirculate its internal data, depending on the state of a 'mode' input. To function correctly as a serial-in/serial-out device the 'recirculate' input goes to +V and the 'mode' input to ground. As for the 4014 device, the serial data advances through the shift register on the positive edge of the clock pulse.

The sync. word buffer is an 8-bit shift register (another 4014) operated in the parallel-in/serial-out mode, into which the 8-bit sync. word, permanently present at the parallel inputs, is entered on the positive edge of the clock pulse when the PS input is high. It is shifted serially out on the positive edge of the clock pulse when PS is low. To produce a sync. word sequence of 1, 0, 1, 0, 1, 0, 0, 1, the parallel inputs go to +V or ground as shown.

Filling and emptying of the two 72-bit buffers and operation of the sync. word buffer is under the control of the circuitry detailed in Fig. 13(a), interconnexions between the two circuits being made as indicated. The logic sequence of the control pulses is clearly shown in Fig. 13(b), with a time-expanded picture of the B and sync. word PS '& 2', control pulses shown in

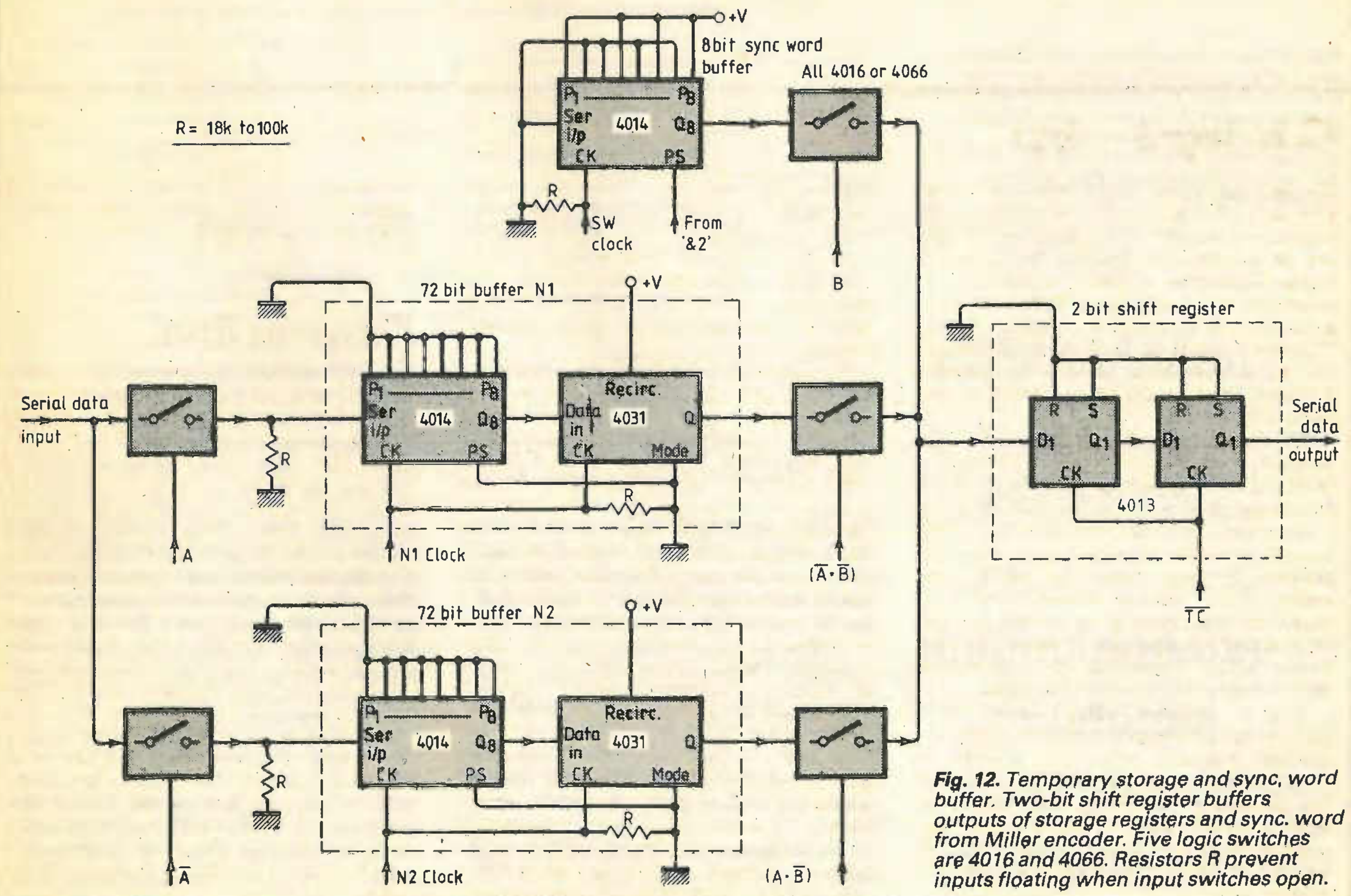

Fig. 12. Temporary storage and sync. word buffer. Two-bit shift register buffers outputs of storage registers and sync. word from Miller encoder. Five logic switches are 4016 and 4066. Resistors R prevent inputs floating when input switches open.

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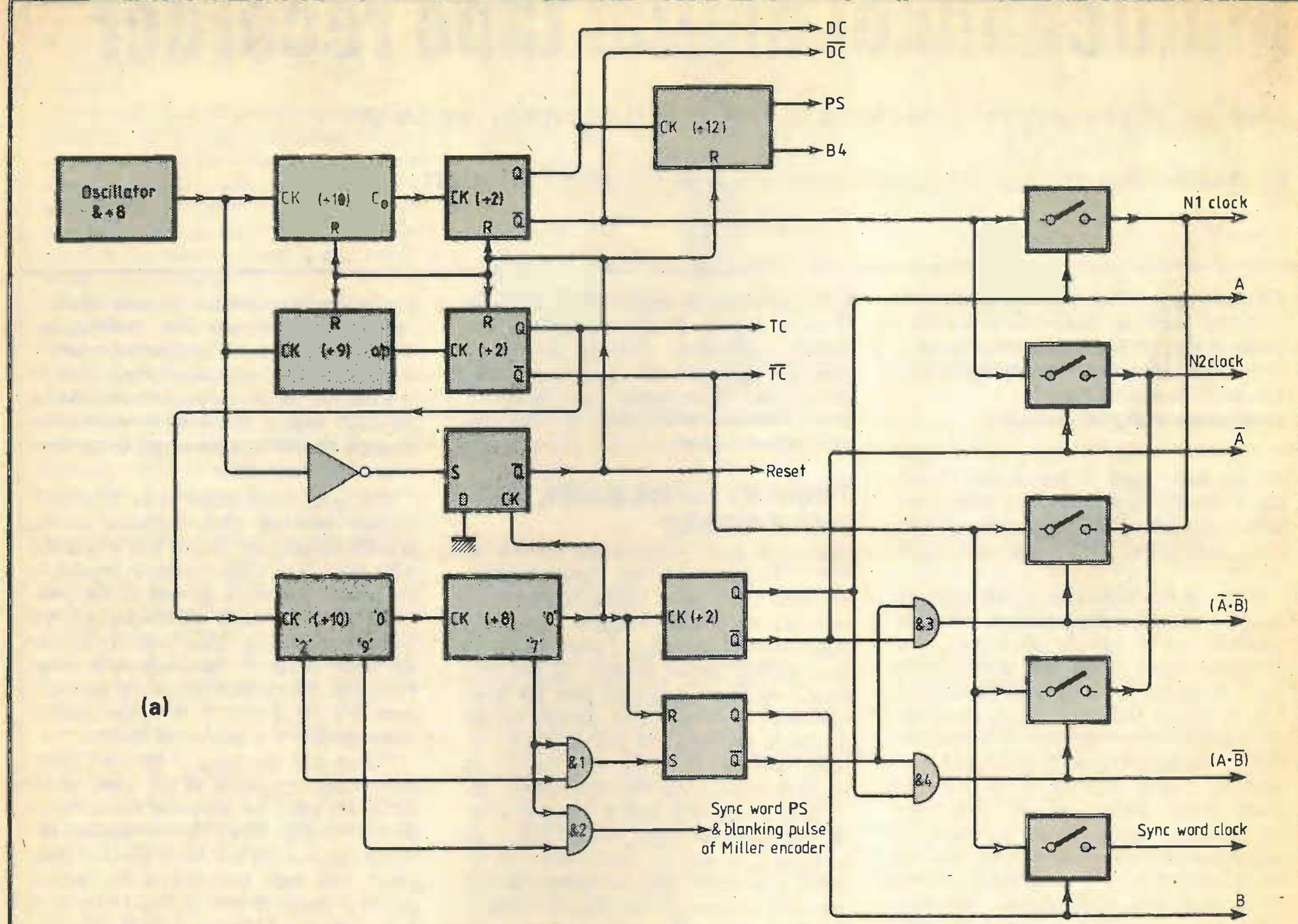
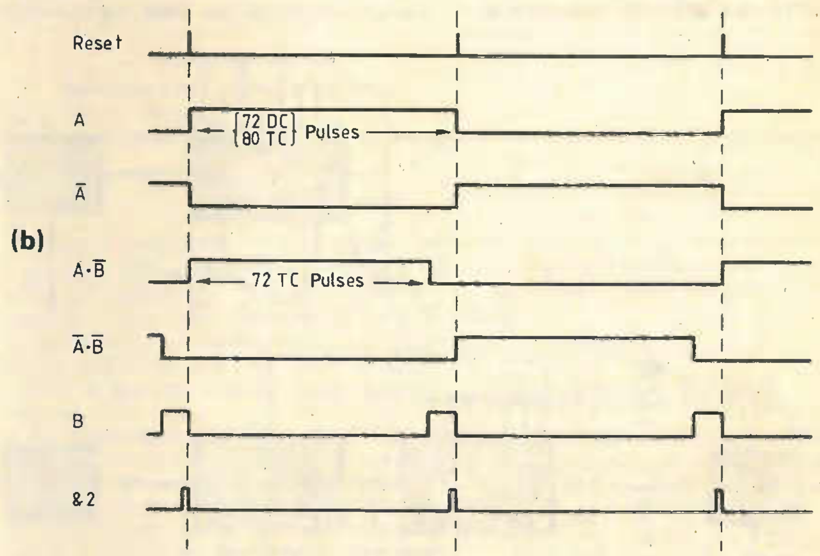


Fig. 13. Control circuitry shown in Fig. 2 of part 1 of article, which controls operation of circuits in Fig. 12. Waveforms at (b) show sequence of control pulse outputs, while at (c) is a time-expanded representation of pulses B and '&2', with the flow of data through the 2-bit shift register in Fig. 12.



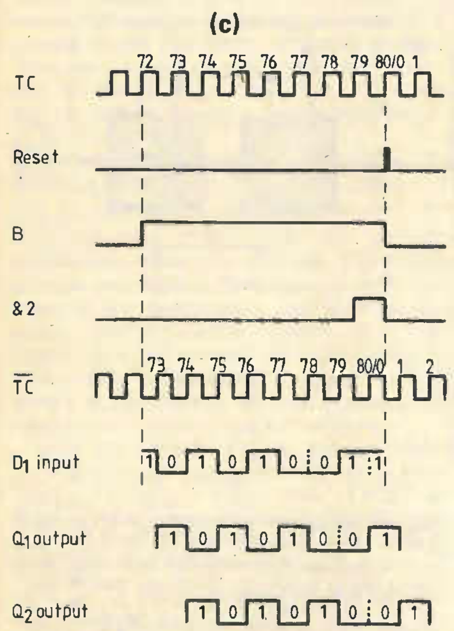


Fig. 13(c). Starting from the moment that the A control pulse goes high, the sequence of operation is as follows. Under the control of the data-clock, $\overline{DC}$, the temporary data store, N1 is filled with serial data – 72-bits in total. Simultaneously, the tape-clock $\overline{TC}$ empties the temporary data store, N2. After 72 $\overline{TC}$ pulses, the control pulse, $A.\overline{B}$, goes low and control pulse, B, high. Eight further $\overline{TC}$ pulses empty the sync. word buffer into the data stream before the control pulse A, finally goes low.

Due to the presence of a high &2 control pulse during the eight sync. word $\overline{TC}$ pulse, the sync. word present at the parallel inputs of the sync. word buffer is re-entered simultaneously with the last bit of the previous sync. word being clocked out. Control pulses $\overline{A}$ and $\overline{A}.\overline{B}$ now go high and B goes low. In a similar manner to that described above, temporary data store N2 is now filled with serial data under the control of $\overline{DC}$ and temporary data store, N1, is emptied under the control of $\overline{TC}$. Again, the sync. word buffer is serially emptied into the data stream during the last 8 pulses of $\overline{TC}$ before $\overline{A}$ goes low. Thus, as described above, the 8-bit sync. word is inserted into the serial data stream

every six data words of 12-bit length without interrupting the serial data flow.

Apart from a time-expanded picture of control pulses B a '&2', Fig. 13(c) shows the passage of the 8-bit sync. word, as part of the serial data stream, through the 2-bit output shift register. Producing a 2-bit delay in the data stream results in the &2 control pulse occurring at the centre of the delayed 1, 0, 0, 1 sequence of the sync. word. The &2 control pulse is thus also used as the 'blanking pulse' of the Miller encoder. (The purpose of the 'blanking pulse' was described in Part 1.)

Three circuit blocks of Fig 13(a) are shown in greater details in Figs. 14(a), 15 and 16. The divide-by-9 circuit, Fig. 15, and the clock oscillator and divide-by-8 circuit, Fig. 16, need no further explana-

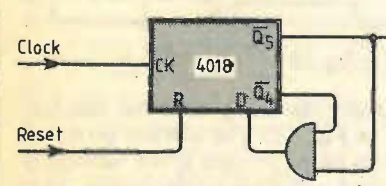
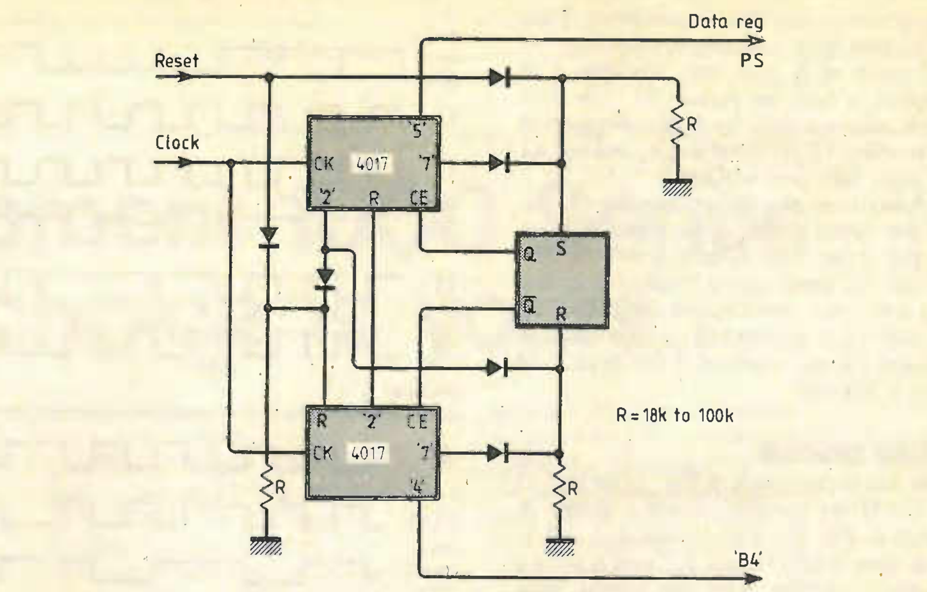


Fig. 15. Divide-by-9 circuit of Fig. 13.

tion and are drawn separately purely for detail. The divide-by-12 circuit, Fig. 14(a), is a little more complicated and needs some explanation. Firstly, it was not only required that the divide-by-12 circuit should produce an output pulse every twelve clock pulses, but that its duration should be for exactly one DC cycle and occur at the eleventh DC pulse. The pulse so produced is referred to as PS and controls the parallel/serial mode of the 12-bit shift register used in the analogue-digital conversion of the input stages (see Fig. 4 of Part 1). Secondly, it was required to produce another similar pulse, referred to as B4, to control the sample/hold circuit of the input stages and to initiate the a.-d conversion. Divide-by-10 counters, i.e. type 4017, produce ten sequential output pulses every ten clock pulses that each last for exactly one clock cycle. By combining two of these counters under the control of a flip-flop, each is made to divide by 6, producing an overall divide-by-12 counter with twelve sequential outputs that last for exactly one clock pulse. The addition of three 2-input, diode OR gates was found essential to determine the correct sequencing of the two-counters with relation to each other and the reset pulse.

The exact logic sequence of the two counters is shown in detail in Fig. 14(b). Upon examining the circuit of Fig. 14(a), it may seem a little odd that output 7 of both counters is used to clock the flip-flop and not, what might more reasonably be expected, output 6. This is done because a negative transition of the clock – enable input, CE, clocks a counter in the same way as a positive transition of the clock input. (A fact that has caught many a de-



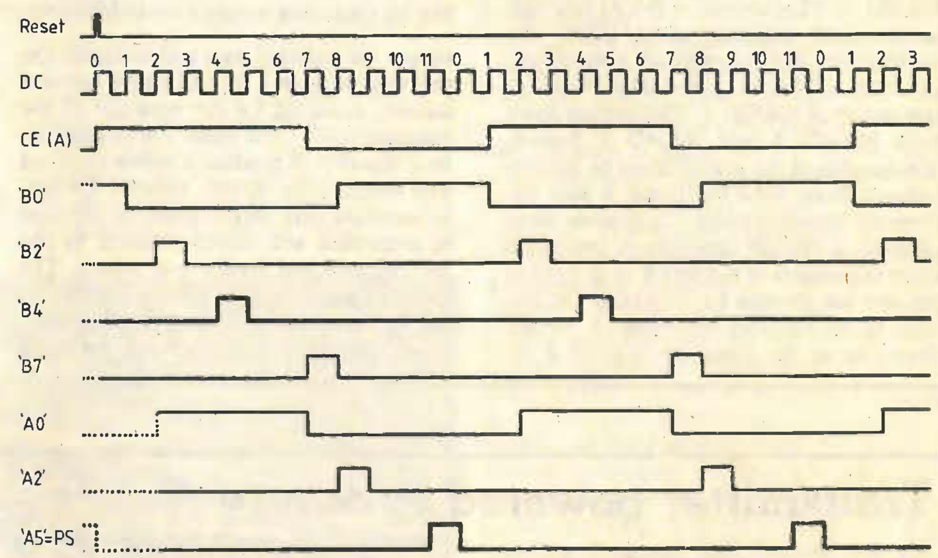


Fig. 14. Divide-by-2 block of Fig. 13 shown in greater detail. Sequence of operation and production of pulses PS and B4 are shown at (b).

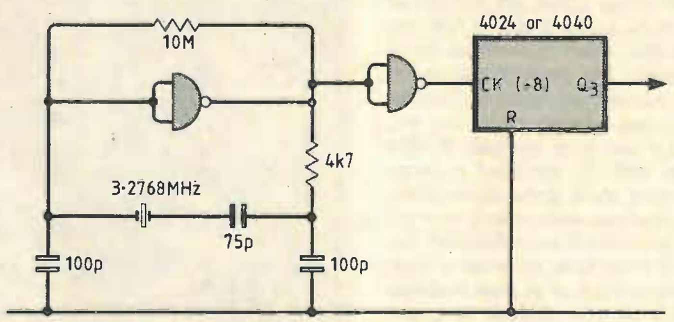


Fig. 16. Clock oscillator and divide-by-8 circuit block of Fig. 13.

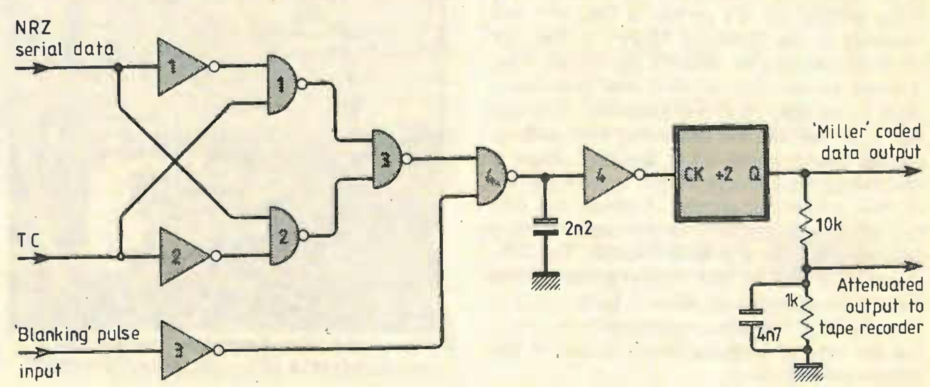


Fig. 17. Miller encoder circuit. Capacitor ▶ and following inverter 4 increases transition times and help to eliminate spurious pulses caused by propagation delays (glitches).

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signer out at one time or another!) Thus as B7 goes high, resetting the flip-flop, the CE input of A goes low, clocking it to produce a high on output A1. The first clock pulse received by A thus advances it to produce a high on output A2 and not A1 as might have been expected.

Apart from the Miller encoder circuit, all the circuit blocks of the block diagram of Fig. 2 (see Part 1) have now been described. All these circuit blocks, excluding the 8-bit sync. word buffer and the Miller encoder, are constructed on one standard 43-way circuit board of 0.1in pitch, 114 mm × 203 mm.

Miller encoder

The last circuit block of Fig. 2 (see Part 1) is the Miller encoder, which is shown in detail in Fig. 17. Two inverters, 1 and 2, and three NAND gates, 1, 2 and 3, form a bi-phase encoder with the output from NAND 3. This output is NANDed with an inverted blanking pulse (from the control circuitry) to produce a modified, inverted, bi-phase-encoded data stream at the output of NAND 4. The outputs from both NAND 3 and NAND 4 contain glitches due to the combination of the two outputs from NANDs 1 and 2 and the inverted blanking pulse. To remove these glitches, a 2200pF capacitor is connected from the output of NAND 4 to ground to remove the glitches by increasing the rise time of the encoded waveform. A further inversion of the signal by inverter 4 reshapes the encoded data and increases the rise time to give a true bi-phase-encoded output, modified by the presence of the blanking pulse. This signal clocks a divide-by-2 flip-flop to produce a Miller-encoded data stream at its output. Finally, the Miller encoded data output from the flip-flop is attenuated and slightly shaped by the two resistors and capacitor as shown. The logic sequence of the pulses produced by the various stages of the Miller encoder, whilst encoding an example of the serial data stream (including the sync. word) is shown in Fig. 18. The glitches produced by the encoding process at the outputs of NAND's 3 and 4 are shown in Fig. 18 to indicate where they occur in the encoding sequence. The influence of the blanking pulse, in suppressing the transition that would normally take place at the centre of the 1, 0, 0, 1 sequence of the sync. word, is also shown.

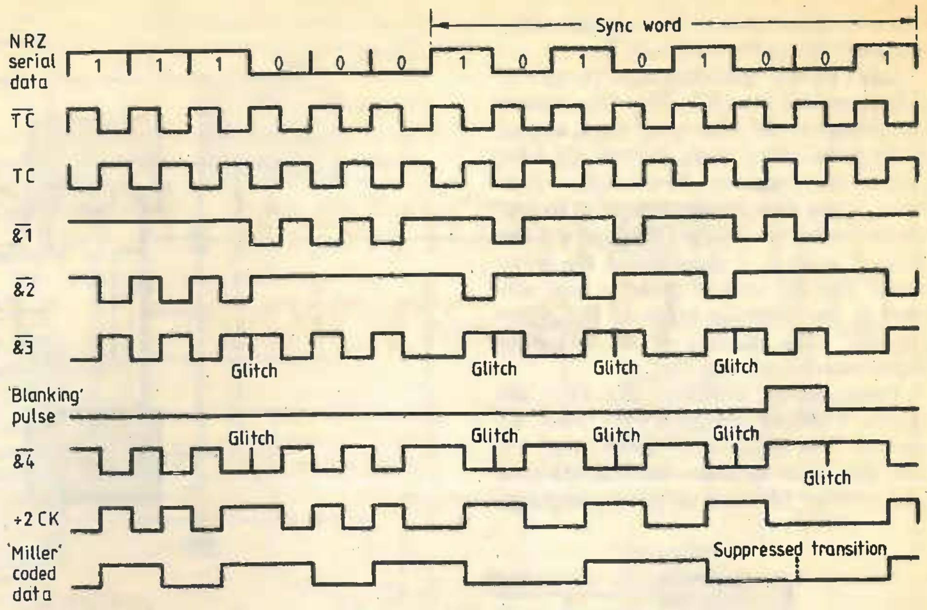


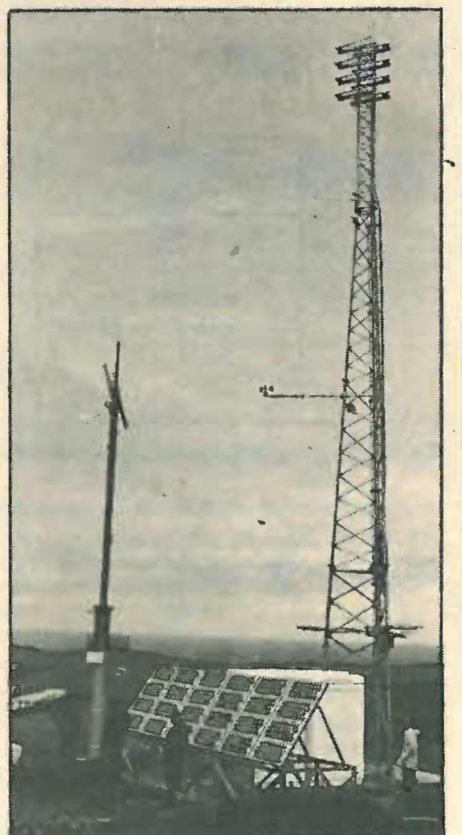
Fig. 18. Sequence of operation of Miller encoder shown in Fig. 17.

To be continued

Transmitter powered by nature

We have received rival reports of naturally powered tv transmitters, both claiming to be the first. The first that we had notice of is the IBA equipment at Bossiney in Cornwall. It will provide programmes to just under 300 people and marks a development in the design of low-cost relay stations capable of serving communities of less than 500 people. The experimental use of combined wind and solar generators is designed to last for several years during which data will be taken daily for computer analysis. Results will be compared with the predicted performance obtained from a study of the Meteorological Office's daily sun and wind records over the past ten years. All power for the Bossiney station will normally come from the wind or solar generators, or from a bank of 36 large lead-acid batteries that will be kept charged by power from the generators.

The other report was of the BBC transmitter in Dychliemore, Argyllshire which will help to bring pictures to 620 people in Dalmally and Lochawe in the Strath of Orchy. It does not broadcast direct but receives the signals from Torosay on the Isle of Mull and retransmits them to the relay station at Dalmally. This also has both wind and sun generators with back-up storage batteries and, as at Bossiney, there is monitoring apparatus to record the performance of each generating system. Analysis will help towards the design of cheaper, more efficient wind and/or solar powered stations. The BBC points out that as the consumption of the transmitter is very low, there is little saving in energy; but it has saved considerably by avoiding the cost of bringing mains power to this remote Scottish site.



The wind and sun powered transmitter installed by the IBA in Bossiney, Cornwall.

News in Brief

Colour codes for miniature fuses. There has been much confusion in the past about marking fuses; a variety of colour dots or single colour bands have been used with no recognised coding, each manufacturer deciding arbitrarily how to do it. The British Electrotechnical Approvals Board had recommended a three band system which met with some success. The International Electrotechnical Commission's members have now come to an agreement that a four band system should be used, with the recognised colours as used for resistors and capacitors, where the first two bands represent the first two digits of the current rating of the fuse, the third band indicates a decimal multiplier and the fourth, wider than the others, would be the time-current characteristic, such as fast blow or time delay fuses. Details are available in IEC Publication 127A.

Testing of components, especially environmental testing, can now be undertaken by Ashcroft Electronics Ltd, whose test house has been allocated an Approval Certificate as a BS 9000/CECC independent test house. A wide range of electronics components and sub-assemblies may be tested under controlled conditions. The test equipment includes that for the simulation and testing for shock, vibration, bump, extremes of temperature, solderability and so on. Ashcroft Electronics are at Somerford Road, Cirencester, Glos. GL7 1TW.

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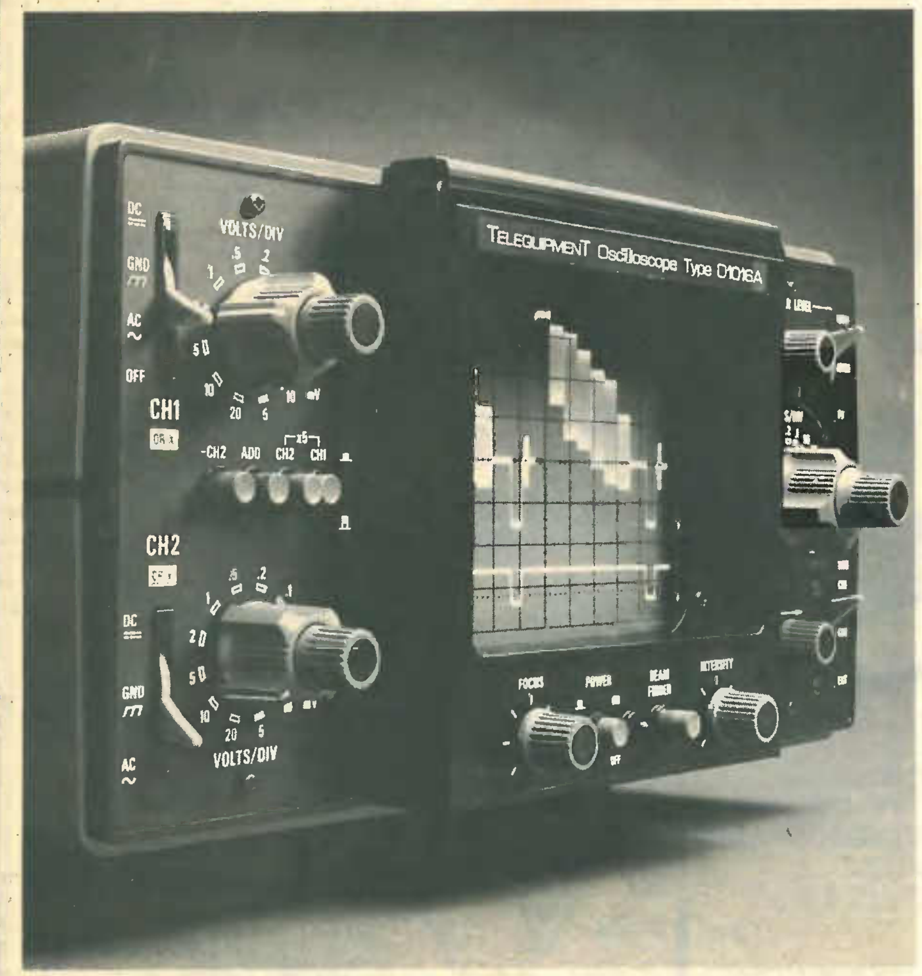

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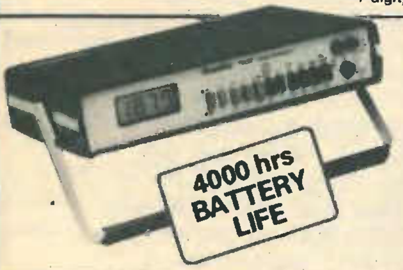

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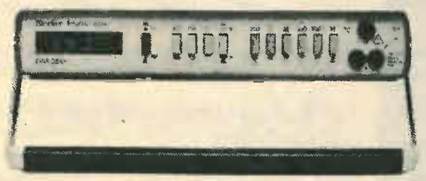

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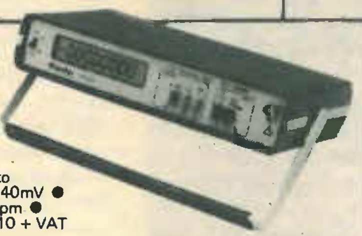

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Displacement current

A field theory approach

by Lawrence A. Jones, M.Sc. (Eng.)

A study of a capacitor as a transmission line by Catt, Davidson and Walton in the December 1978 issue contains, in the author's opinion, inaccuracies, mainly due to the subject being treated as a circuit theory. This article presents an analysis from a field theory viewpoint and shows the importance of the concept of displacement current.

Displacement current is perhaps one of the most difficult field theory concepts and it has been suggested[1] that Maxwell developed it by direct analogy with his equation

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$

It must be borne in mind, however, that this analogy fails when the forces on moving charges are considered. Displacement current is a necessary consequence of Coulomb's law when charges change with time, and the electric field becomes non-conservative.

The fundamental point of Coulomb's law is that this force is transmitted through any medium, i.e., space is just as real a medium as a metal. Consider Coulomb's law:

$$F = \frac{q_1 q_2}{4\pi\epsilon_o r^2}\, a_r$$

In Fig. 1 we have two conducting spheres. Sphere A has a fixed charge while sphere B is connected to ground. As long as both spheres are stationary there will be a constant force exerted by A on B and vice-versa. Let us now start moving sphere A towards sphere B. For simplicity we will consider changes of force in the y-direction

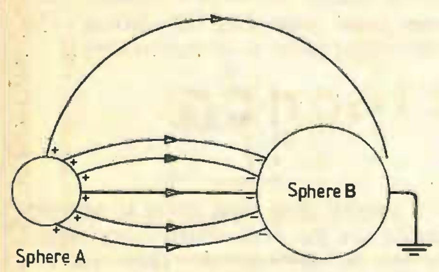

Fig. 1. Two conducting spheres. As long as both spheres are stationary there will be a constant force exerted by A on B and vice-versa.

only, using the following formulae:

$$\frac{\partial E_y}{\partial t} = \frac{1}{4\pi\epsilon_o}\frac{\partial}{\partial t}\left(\frac{q_2}{y^2}\right)$$

$$= \frac{1}{4\pi\epsilon_o}\left(\frac{\partial q_2}{\partial t}y^{-2} - q_2\, 2y^{-3}\frac{\partial y}{\partial t}\right)$$

therefore:

$$\frac{\partial D_y}{\partial t} = \frac{1}{4\pi}\left(\frac{\partial q_2}{\partial t}y^{-2} - q_2\, 2y^{-3}\frac{\partial y}{\partial t}\right)$$

Thus, if the electrostatic energy in the electric field changes, the energy change has to manifest itself in some way. It does so by producing an external flow of current in the conductor connected to sphere B.

It is important to realize that this displacement current does not have the significance of a current in the sense of being the motion of charges. After all, free charge cannot exist in free space, and hence, there cannot be a force proportional to

$$\epsilon_o \frac{\partial \boldsymbol{E}}{\partial t} \times \boldsymbol{B}$$

on the displacement current in empty space. In order to examine the effects of time-changing electric fields three examples will be considered.

For the first example it is required that the charge on a conducting sphere be measured by discharging it on to a large conducting plate connected to an oscilloscope. The resulting voltage pulse is measured and, since the input capacitance of the oscilloscope is known, the charge on the sphere can be calculated. When the resulting pulse is measured and the charge calculated, a serious discrepancy is found to exist between the actual charge on the sphere, which may be found by direct measurement in a Faraday cage, and the charge measured on the oscilloscope; the explanation is interesting.

The energy stored in the electric field is given by

$$W = \frac{1}{2}\iiint_{vol} \boldsymbol{D}.\boldsymbol{E}\, dv$$

As the sphere approaches the plate, the volume of the field is decreasing, so the energy stored in the field has been reduced; but where has the energy gone? As the sphere approaches the plate more negative charge is induced on to the plate and thus more positive charge will flow to ground. At the instant of discharge a pulse is registered on the oscilloscope. This pulse is simply the charge that has not been neutralized by the induced charge on the large conducting plate, i.e., if there was originally +10nC on the sphere and only −8nC induced on the plate then +2nC would flow into the oscilloscope, hence the discrepancy.

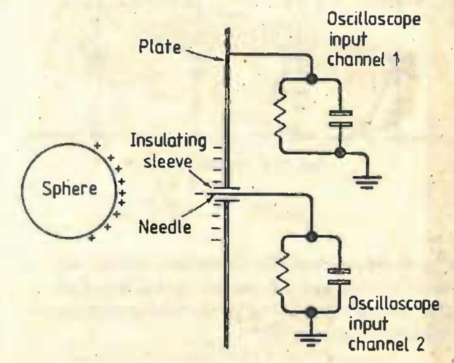

Fig. 2. The set-up used for explaining the discrepancy between calculated and measured electrostatic charges.

The method illustrated in Fig. 2 was used to confirm this theory. In this set-up an extra electrode connected to the oscilloscope's second channel is inserted through a hole in the conducting plate. A protective sleeve insulates this electrode from the plate. Once again the sphere is brought towards the plate but is now allowed to discharge onto the needle. In this case, only −1nC has been induced on the needle so consequently, +9nC will flow into the oscilloscope. The positive pulse measured on the oscilloscope will be almost equal to the charge on the sphere. Similarly, when the discharge occurs, the −8nC induced on the plate will be released since the electric field has collapsed. A pulse of −8nC will be measured on the second channel of the oscilloscope.

The consideration of a capacitor as a transmission line has been discussed[2] in the proposal that displacement current is erroneous. Consider the capacitor in Fig. 3(a): at time $t = 0$ the switch is closed and the capacitor starts to charge. A capacitor cannot charge up instantaneously: it will start to charge with the formation of field line ab, then cd, ef, etc. Hence, the initial

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current flow, i_1, will be

$$i_1 = \epsilon_o \iint \frac{\partial E_1}{\partial t} ds$$

This current flows until field line ab is formed. At a time t seconds later, a current i_2 will flow shown by

$$i_2 = \epsilon_o \iint \frac{\partial E_2}{\partial t} ds$$

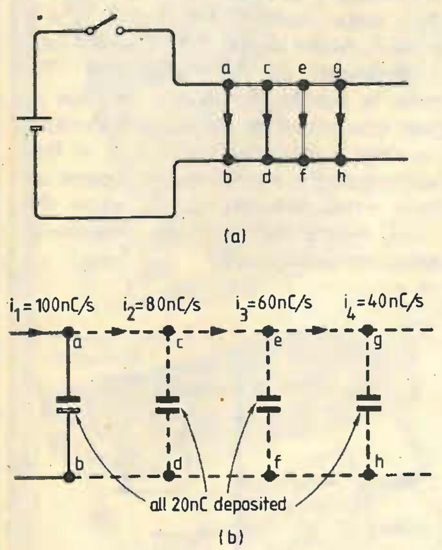
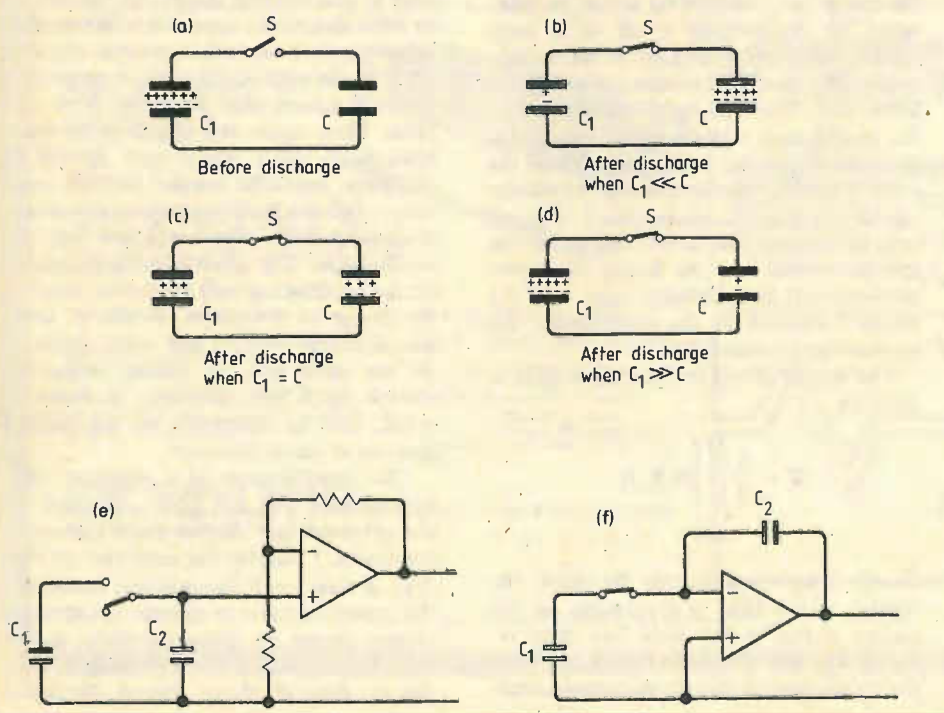


Fig. 3. As a capacitor does not charge up instantaneously, it can be considered to charge up beginning with the formation of field ab, then cd, etc.

Fig. 4. After switch S of 4(a) is closed, 4(b), 4(c) and 4(d) show the charge distribution for charged/uncharged capacitor pairs of various values. Simplified circuits for measuring capacitor discharge are shown in 4(e) and 4(f).



establishing field line cd and so on. Figure 3(b) shows this diagrammatically.

From the above explanation it may be deduced that the transmission line capacitor is in effect an infinite number of small capacitors. I would suggest that this is the reason why it has never been possible to measure inductance in a capacitor, because each capacitor will acquire an infinitely small charge. Obviously this very small amount of moving charge will have an associated magnetic field, but this field will be so weak that it will be undetectable, hence the absence of inductance in a capacitor. It is important to realize that this situation can only arise in a capacitor, because all the applied electrical energy is used in establishing an electric field.

In a standard transmission line with a resistive load the situation is somewhat different. The conductors are spaced well apart from each other so the electric field will be negligible and all the electrical energy will be transferred into the load. In this case electrical energy is transported from one point to another, whereas in the case of the capacitor the energy is distributed over a large area. Inductance now becomes important as a constant time-changing current will produce a changing magnetic field, i.e.

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$

or in circuit terms,

$$v = \frac{L di}{dt} + ir$$

Finally, in considering the effects of displacement current, it is worth discussing the problem of a charged capacitor being connected to an uncharged capacitor (see Fig. 4) and the mystery of where the 'missing' charge goes[3]. The usual explanation is that the closure of the switch initiates the transfer of energy, producing an

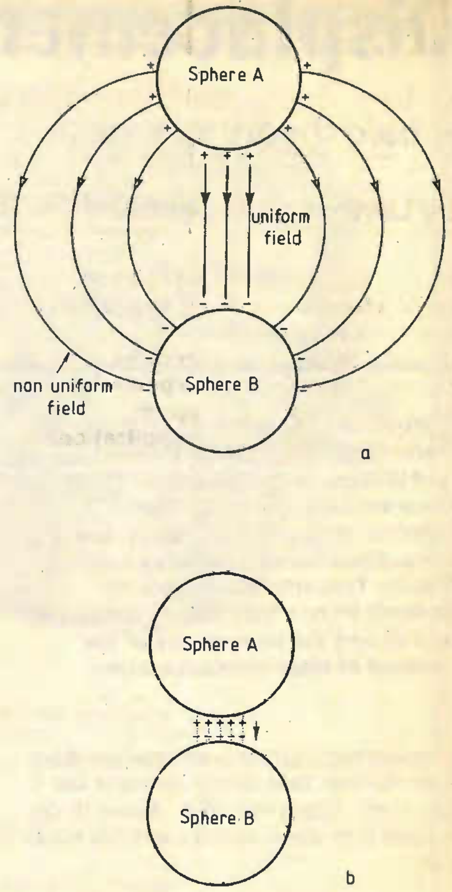


Fig. 5. As spheres A and B of 5(a) move together, ∂E/∂t will change with time on the outer fringes until the total field is uniform as shown in 5(b), resulting in an increase in capacitance between spheres A and B.

oscillation of charge between the two capacitors which finally decays to a steady state.

Consider these two equations for the charge and energy in a capacitor;

$$Q = CV \text{ and } E = \frac{1}{2}\frac{q^2}{C}$$

It is accepted that the charge remains the same before and after the discharge, as can be proved by experiment, but

$$E_1 = \frac{1}{2}\frac{q^2}{C}$$

and

$$E_2 = \frac{1}{2}\cdot\frac{1}{2}\frac{q^2}{C}$$

which would imply an energy loss.

A more thorough study of the equation for the energy stored in a capacitor provides some interesting information. The total energy stored in an electric field is

$$\frac{1}{2}\iiint_{vol} \boldsymbol{D}.\boldsymbol{E}\, dv$$

A parallel plate capacitor is an approximation of a true field, which is represented by two infinite spheres. There are two ways of increasing the capacitance value. One is to move the two spheres closer

continued on page 81

Interfacing microprocessors

Further programming examples

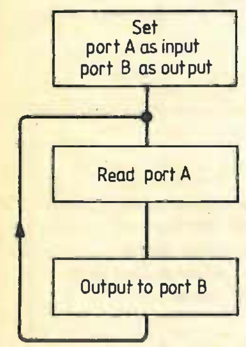
by J. D. Ferguson, B.Sc., M.Sc., M.Inst.P., **J. Stewart, and P. Williams,** B.Sc., Ph.D., M.Inst.P.
Microelectronics Educational Development Centre, Paisley College of Technology

The previous article included brief routines for driving a-to-d, d-to-a and i/o devices in the most straightforward way. Part three describes a range of more powerful programs which cover typical laboratory and industrial applications.

The interface board has been designed for memory-mapped systems, typically 6502 based, but operation with 6800/09 and i/o mapped microprocessors will be discussed later. Machine-code programmes for all 6502 systems will be similar, with variations depending on the memory maps, but assembly-language versions can have greater differences depending on the manufacturers' choice of symbols. A similar problem arises with Basic where access to memory locations is achieved with Peek and Poke or equivalent functions. In this respect the original Acorn Atom Basic uses an idiosyncratic approach which is effective but requires some explanation for those familiar with the Microsoft dialect. For this reason, some of the programs that follow are presented in more than one form.

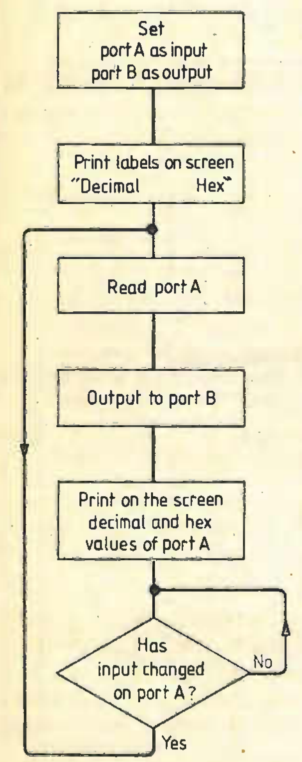
Table 1

1. Simple program to continuously monitor port A and copy to port B



Assembler	Acorn Basic	Aim etc. Basic	Comment
LDA # 00 STA 4003 LDA # FF STA 4002	10 ? # 4003 = 0 20 ? # 4002 = # FF	10 POKE 16387, 0 20 POKE 16386, 255	v.i.a. lies at 4000 - 400F (i.e. 16384 - 16399)
"Again" LDA 4001	30 P = ? # 4001	30 P = PEEK (16385)	
STA 4000	40 ? # 4000 = P	40 POKE 16384, P	
JMP "Again"	50 GOTO 30	50 GOTO 30	

2. Demonstration program, using Acorn Basic, to read the switches on port A, display their decimal and hexadecimal values on the screen, and output their binary value to the L.e.ds on port B.




```
10 ?#4003 = 0
20 ?#4002 = #FF
30 PRINT"Decimal ^^^^^^^ Hex"'
40 P= ?#4001
50 ?#4000 = P
60 PRINT P, &P,"CTRL G"'
70 IF(?#4001) = P GOTO 70
80 GOTO 40
```

Single quote means take a new line

Control G gives a bleep sound

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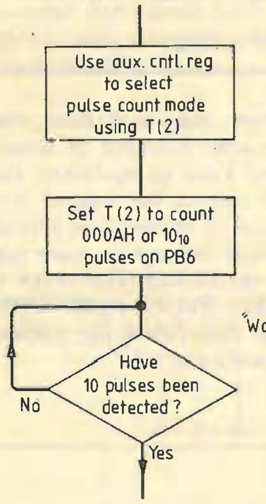
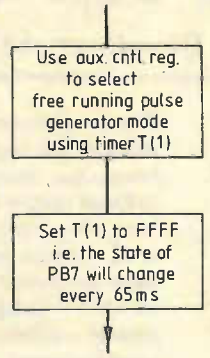
Table 2. Table 3 below

1. Using timer (2) to count 10 pulses on pin 7 of port B (note v.i.a. lies at 4000 – 400F)



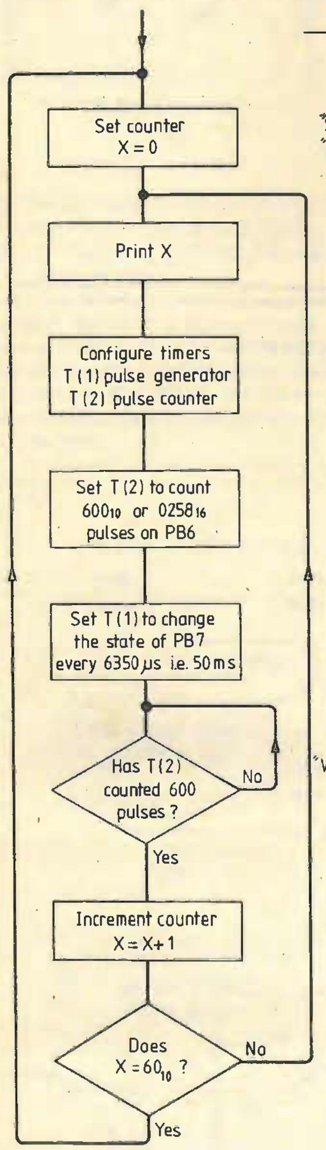
Assembler	Note
LDA # 20	
STA 400B	
LDA # 0A	
STA 4008	
LDA # 00	
STA 4009	Counting starts here
'Wait' LDA 400D	
and # 20	Check if bit 5 of I.F.R. has been set
BEQ 'Wait'	

2. Using timer (1) to produce a square wave, period ~130 ms on pin 6 of port B



Assembler	Note
LDA # C0	
STA 400B	
LDA# FF	This data also goes into 4006 and 4007
STA 4004	
STA 4005	

In this example pB6 and pB7 are linked and timers (1) and (2) are used together to produce time intervals of ~1 minute. A simple counter is used to display the time elapsed in minutes on the microcomputer screen.



Assembler	Acorn Basic	Apple Basic	Comments
'Start' LDX # 00 'Next' JSR EA13 See note (1)	10 FOR X = 0 to 59	10 FOR X = 0 to 59	(1) Assembled subroutines shown are for Aim 65. EA13 clears screen. EA46 displays byte as a 2 digit hex. number.
TXA JSR EA46	20 PRINT X,"CTRL G"	20 PRINT X,"CTRL G"	(2) Apple Basic program assumes the v.i.a. is at C800H — C80FH
LDA # E0 STA 400B	30 ?# 400B = # E0	30 POKE 51211,224	
LDA # 58 STA 4008	40 ?# 4008 = # 58	40 POKE 51208,88	
LDA # 02 STA 4009	50 ?# 4009 = # 02	50 POKE 51209,2	
LDA # 50 STA 4004	60 ?# 4004 = # 50	60 POKE 51204,80	
LDA # C3 STA 4005	70 ?# 4005 = # C3	70 POKE 51205,195	
	See note 3	80 Y = PEEK (51213)	
'Wait' LDA 400D and # 20 BEQ 'Wait'	80 IF (?# 400D) & # 20 = 0 GOTO 80	90 IF Y > 128 THEN Y = Y − 128 100 IF Y > = 64 THEN Y = Y − 64 110 IF Y < 32 THEN 80	(3) Logical and "&" in Acorn Basic makes it easy to test Bit 5 of the interrupt flag register.
INX	90 NEXT X	120 NEXT X	
CPX # 3C BNE 'Next' JMP 'Start'	100 GOTO 10	130 GOTO 10	

6522 v.i.a.

The first routines concern the port and timer function of the v.i.a. Port B is monitored by the eight l.e.ds, and port A is controlled by the switches. This is not obligatory but is a convenient arrangement for demonstration.

Starting with the ports, the routines in Table 1 show two programs which begin by using the data-direction registers to define port A as an input and port B as an output. The first program runs in a continuous loop which repeatedly reads port A (switches) and copies it to port B (l.e.ds). In the second example the program goes a stage further so the computer evaluates and displays the decimal and hexadecimal values of port A before outputting its binary value to port B. These programs, though limited, include the essential elements for general monitoring and control functions, i.e. to establish the operating condition, take data from an input, process the data and send the results to an output.

The next feature of the v.i.a. to consider is the pair of timers, T1 and T2. These can be used in a variety of modes and are able to monitor or drive specific port pins and override other functions. Table 2 shows how timer T2 can count a defined number of pulses on pin 7 of port B, and how T1 can operate as a pulse generator to produce a square wave on pin 6 of port B. Used independently, each timer offers time delays up to around 65ms. However, Table 3 shows how they can be used together to produce longer time intervals. Timer T1 produces pulses on pB7 and T2 counts pulses on pB6 via a short wire link. Time intervals of one minute can be achieved by making T1 measure 50ms intervals and T2 count 600 pulses. Note that the timers can operate in an interrupt mode, releasing the microprocessor for other tasks while waiting for a time-out signal.

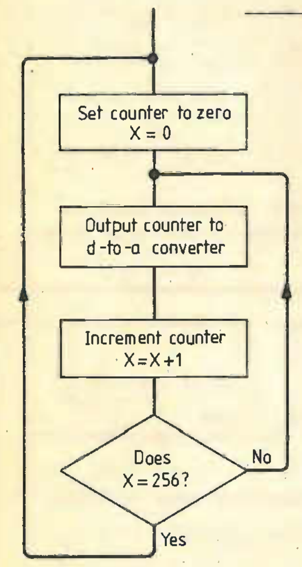
Other 6522 functions include a shift register and control lines, but this article can only introduce the main features. The three references include further program examples.

D-to-a converter

This device is simple to drive because, for any binary data provided, a corresponding analogue output is obtained, in this case with a full-scale range of 2.5V. Table 4

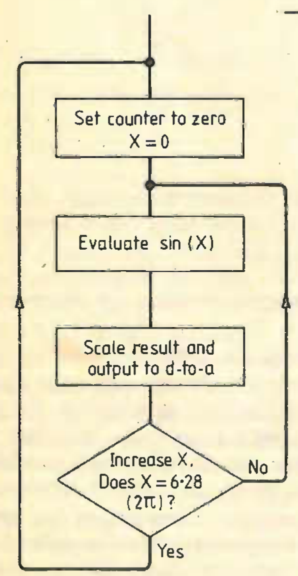
Table 4

1. Generating a sawtooth waveform



Assembler	Acorn Basic	Aim / Apple Basic	Comment
LDX # 00	10 FOR X = 0 to 255	10 FOR X = 0 to 255	(1) d-to-a converter lies at 4020H (i.e. 16416_{10})
'Again' STX 4020	20 ? # 4020 = X	20 POKE 16416, X	(2) In assembler X automatically returns to zero.
INX	30 NEXT X	30 NEXT X	
JMP 'Again	40 GOTO 10	40 GOTO 10	

2. Generating a sinewave



Aim etc. Basic	Note
10 FOR X = 0 to 6·28 STEP 0·1	
20 Y = sin (X) * 128	To give maximum amplitude
30 POKE 16416, (128 + INT (Y))	Ensures positive integer values
40 NEXT X	
50 GOTO 10	

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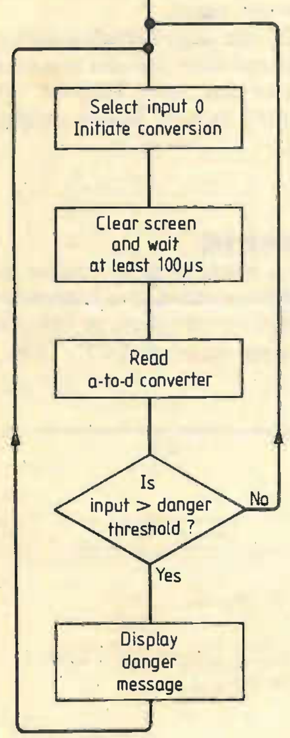
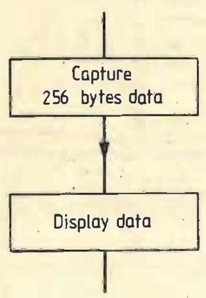
1. Program monitors an analogue input and displays a message if the input voltage rises above a danger threshold.



Assembler	Acorn Basic	Aim etc. Basic	Comment
'Start' STA 4010	10 ?#4010 = 0	10 POKE 16400, 0	(1) In Aim 65 JSR EA13 clears screen JSR E97A sends ASCII character to display
JSR EA13	20 PRINT $ 12	20 PRINT "^"	
LDA 4010	30 X = ?#4010	30 X = PEEK (16400)	(2) Danger level is shown as 80H, 128_{10}
CMP#80 BCC 'START'	40 IF X < 128 GOTO 10	40 IF X < 128 GOTO 10	
LDX # 00 'Next' LDA 'MESS', X JSR E97A INX CPX # 06 BNE 'NEXT' JMP 'START'	50 PRINT "Danger" 60 GOTO 10	50 PRINT "Danger" 60 GOTO 10	(3) MESS contains the ASCII character for the message "Danger"
'MESS' 44, 41, 4E, 47, 45, 52			

2. Two data logging programs in Basic and in Basic with fast machine code subroutine.



Basic only program

```
10 DIM S(255)
20 FOR X = 0 to 255
30 POKE 16400,0
40 S(X) = PEEK (16400)
50 NEXT X

60 FOR X = 0 to 255 STEP 4
70 PRINT S(X); S(X+1); S(X+2); S(X+3)
80 NEXT X
90 END
```

Basic and machine code subroutine

```
10 POKE 04,0    } ; Vectors to start of machine code program at 0C00H
20 POKE 05, 12  }
30 A = USR (1)    ; Causes jump to machine code program

40 FOR X = 0 to 255 STEP 4
50 Y = 3328 + X
60 PRINT PEEK (Y); PEEK (Y+1); PEEK (Y+2); PEEK (Y+3)
70 NEXT X
80 END
```

Machine code subroutine

```
0C00   LDX # 00     ; Set counter to zero
'NEXT' STA 4010     ; Initiate conversion
       JSR 'DELAY'  ; Wait 100 µs
       LDA 4010     ; Read byte
       STA 0D00,X   ; Store from 0D00H,3328₁₀ upwards
       INX
       BNE 'NEXT'
       JMP C0D1     ; Back to Basic
```

Table 5

illustrates the generation of synthesized waveforms using Basic and assembly language where the highest frequency is produced by the low-level language.

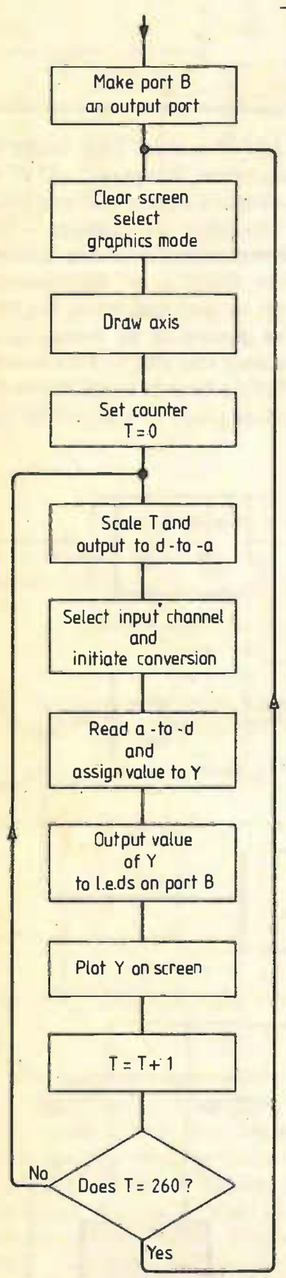
A-to-d converter

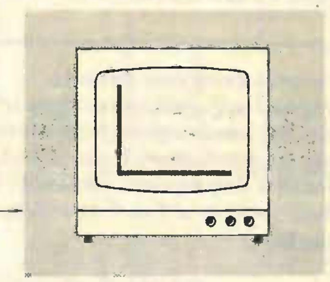
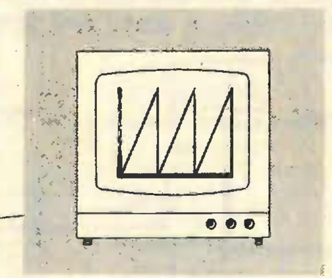
The power of this section of the interface depends on the signal conditioning that precedes it. For example, it can be used directly as a 16-channel data-logger provided the input signals are in the range 0 to 2.5V. However, many transducers provide smaller signals which may not have a common point to ground. For laboratory applications the signal conditioning can be simple, e.g. temperature and light intensity measurements can be made using semiconductor devices which deliver currents proportional to the measured parameter. Such an output only requires a shunt resistor to convert the signal into a voltage.

A-to-d channel selection is achieved with the four least-significant address bits, and the programs in Table 5 show routines that assume a conversion has been completed before the next one is called for. The first program illustrates an alarm system where an analogue input is continuously monitored and a message is displayed if the input voltage rises above a danger threshold. Two versions of a data-logging program are also shown which have been designed specifically for the AIM 65. The first program is written completely in Basic while the second uses a machine-code subroutine for fast data collection and Basic as a convenient method of displaying the results. Table 6 shows a demonstration program which exercises all of the i.cs. The d-to-a converter is driven from a progressively increasing binary value and its analogue output is applied to one input of the a-to-d converter. The signal is then reconverted to binary and the result is used to switch on the l.e.ds connected to port B.

These sample programs illustrate several ways in which the interface board and a typical microprocessor can interact. Part four will discuss ways of extending the boards' functions, and modifications for operation with other microprocessor families.

This demonstration program exercises all 3 i.cs. A simple counter generates a sawtooth waveform at the output of the d-to-a converter. A wire link between the d-to-a and a-to-d converter feeds the waveform back into channel 0 of the a-to-d converter. The program then plots the waveform on the screen and displays its binary value on the l.e.ds. Note v.i.a. 4000 - 400F; a-to-d 4010 - 401F; d-to-a 4020.



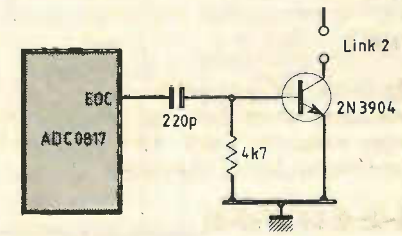
Acorn Basic	Comment
10 ?# 4002 = # FF	
20 CLEAR 0	
30 MOVE 0, 64 40 DRAW 0, 0 50 DRAW 64, 0 60 MOVE 0, 0	
70 FOR T = 0 to 259	
80 ?# 4020 = 3 * T	No delay routine required in Basic between Initiate conversion and Data ready
90 ?# 4010 = 0	
100 Y = ?# 4010	
110 ?# 4000 = Y	
120 DRAW (T/4), (Y * 4)	
130 NEXT T	
140 GOTO 20	

References

1. R. Zaks, *6502 Applications Book*, pub. Sybex.
2. M. L. De Jong, *Programming and Interfacing the 6502, with Experiments*, pub. Sams.
3. Ferguson, Johnson, Procter, "A Learning Package based on 6500 series Microprocessors", pub. Microprocessor Training Systems, Kilsyth.

Table 6

Modification to the ADC0817 end-of-conversion circuit.



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High-resolution weather satellite pictures

Data decoding and processing

by M. L. Christieson

This article describes data-decoding and processing sections of a system for receiving high-resolution picture transmissions from NOAA-6. Before this description, however, the receiver section of the first article is concluded.

The balanced mixer feeds two v.h.f. amplification stages, constructed using dual-gate m.o.s.f.e.t.s in a standard common-source configuration. Many examples of this type of amplifer (for use on 144MHz) can be found in amateur-radio publications[11,12].

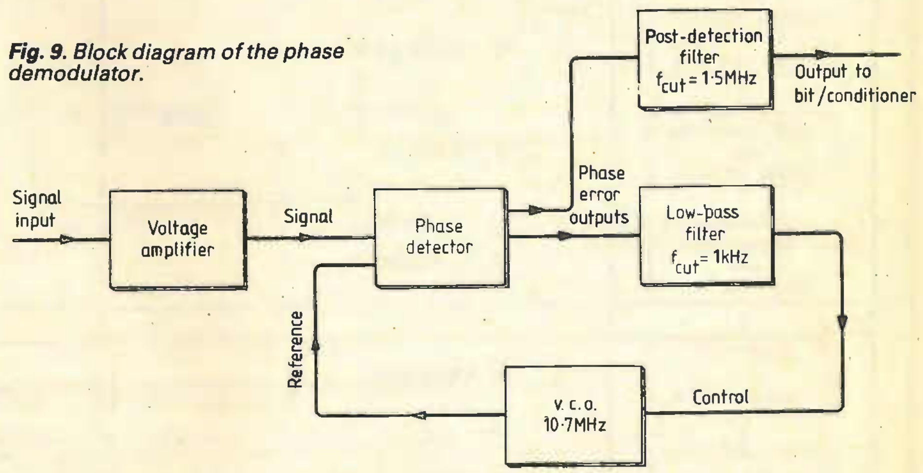
A further dual-gate m.o.s.f.e.t., with the local oscillator fed into its second gate, provides final frequency conversion to 10.7MHz. Local-oscillator drive is provided by a crystal oscillator and tripler circuit. The signal bandwidth is about 5MHz so high-Q circuits should not be used; hence, a heavily-damped tuned circuit follows the mixer, and a wideband i.f. amplifier with SL600 range (Plessey) r.f. i.cs is used as shown in Fig.8. Care must be taken to keep leads short and extensive decoupling is required to prevent spurious oscillation. Also, stray pick-up may occur if the amplifier is placed near other r.f. sources.

Provision is made for a signal-level meter to monitor the amplifier output. Although the meter is difficult to calibrate absolutely, it is quite linear because of the lack of a.g.c. and is therefore useful for making signal-to-noise power-ratio measurements.

Phase demodulation

Referring to the transmission characteristics given in the first part of this article, it can be seen that phase demodulation with an index of ±67.3° is used. This means that instantaneous phase changes of +67.3° and −67.3° represent a binary one and binary zero. To demodulate the changes, a fixed reference is required. Assuming that over several cycles there is an approximately equal number of ones and zeros, the reference may be generated by averaging the carrier frequency and phase. This assumption is applicable here because of the type of digital coding used, as will become clear later.

Fig. 9. Block diagram of the phase demodulator.



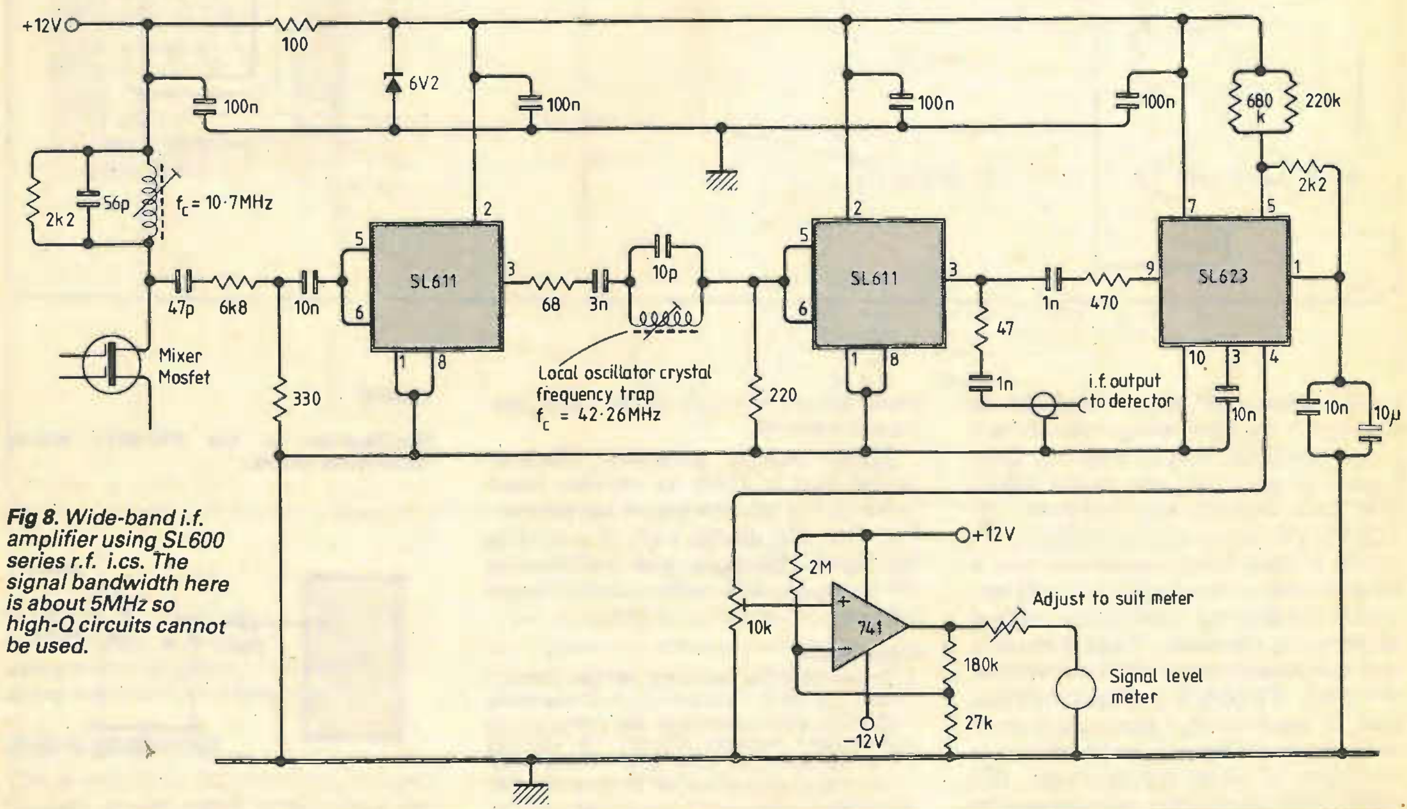


Fig 8. Wide-band i.f. amplifier using SL600 series r.f. i.cs. The signal bandwidth here is about 5MHz so high-Q circuits cannot be used.

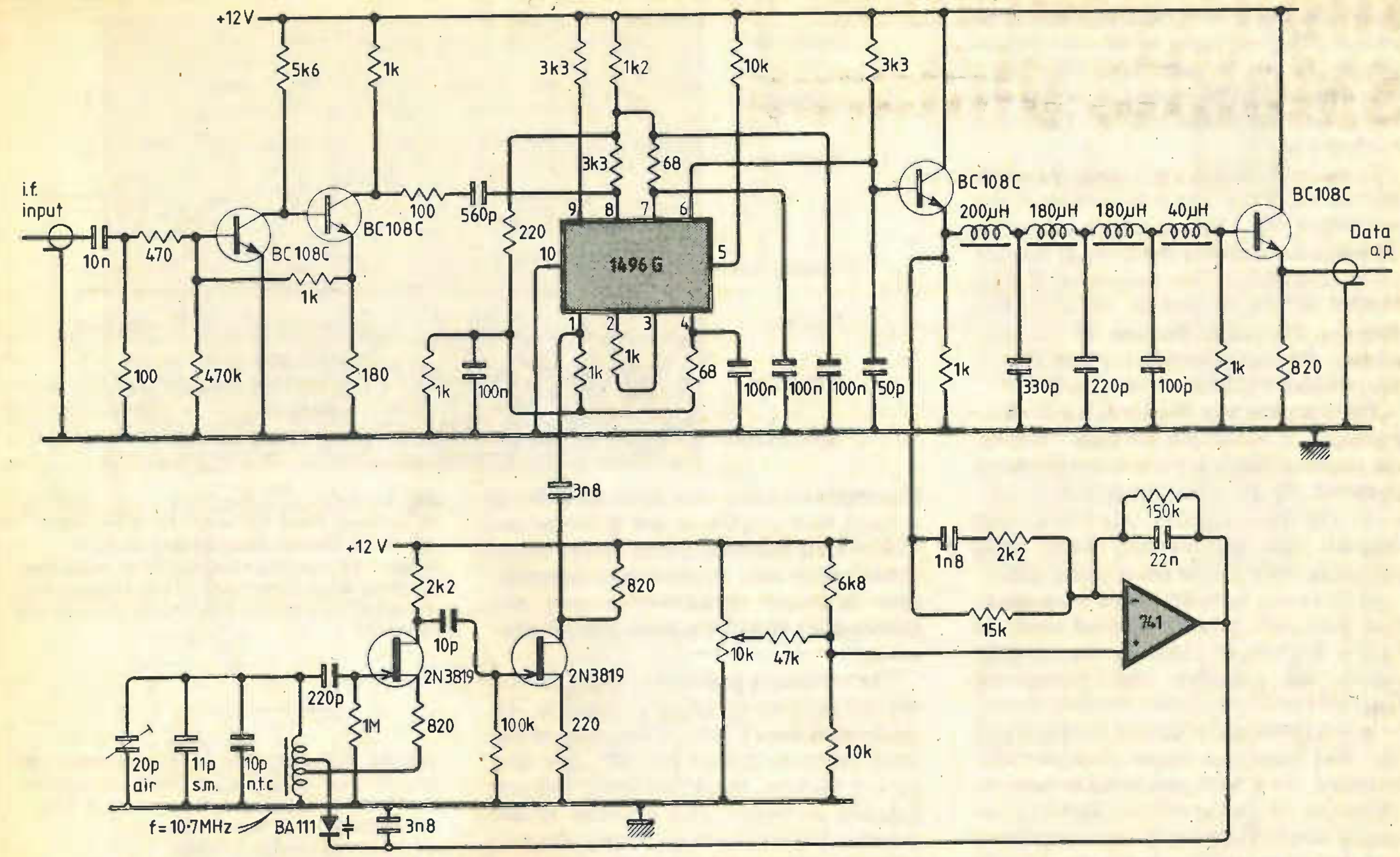
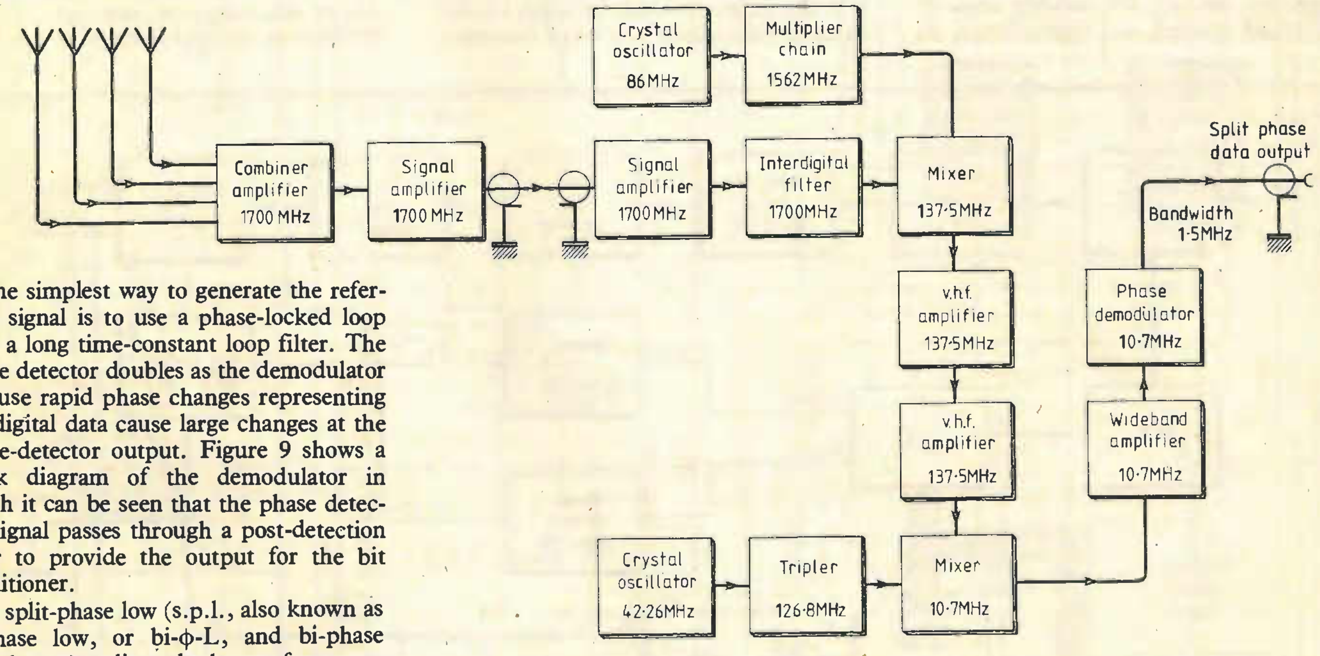


Fig 10. Circuit diagram of the phase demodulator. Oscillator phase noise at the detector output degrades signal-to-noise ratio so an LC/variable-capacitance diode v.c.o. is used.

Fig 11. Complete block diagram of the receiver.



The simplest way to generate the reference signal is to use a phase-locked loop with a long time-constant loop filter. The phase detector doubles as the demodulator because rapid phase changes representing the digital data cause large changes at the phase-detector output. Figure 9 shows a block diagram of the demodulator in which it can be seen that the phase detector signal passes through a post-detection filter to provide the output for the bit conditioner.

In split-phase low (s.p.l., also known as bi-phase low, or bi-φ-L, and bi-phase Manchester) coding, the lowest frequency component is equal to the bit-rate and the highest is twice the bit-rate. The post-detection filter is therefore designed to fall off quite rapidly above twice the bit-rate, i.e., 1.33MHz.

Figure 10 shows the phase demodulator circuit diagram. With the values shown, the v.c.o. capture range is about 100kHz at low signal levels. Because of the effects of Doppler shift on the tracking range (about 75kHz), loop-bandwidth constraints and signal-to-noise ratio degradation caused by phase-noise at the detector output, the v.c.o. circuit is critical and care should be taken in its construction. Note the temperature compensation in the oscillator tuned circuit.

This completes the receiver section of the system and to sum up, Fig. 11 shows an overall block diagram.

Decoding split-phase data

In order to decode the data stream from the detector into images, two processes are required;

−Converting the split-phase data into non return-to-zero (n.r.z.) data and clock.

−Converting the serial n.r.z. stream into parallel words, each 10 bits long.

These processes are completely separate and the first problem to deal with is the split-phase data. This type of coding is probably most easily understood by analysing the coding process. In split-phase data a binary one is defined as having a negative-going transition in the middle of the bit while a zero has a positive-going transition in the middle of the bit.

Figures 12(a) and (b) show a random serial-bit stream and its equivalent in s.p.l. is show in 12(c). An interesting case occurs when a continuous series of ones or zeros is transmitted; the s.p.l. code for these is a single frequency of twice the bit rate. This type of coding is particularly useful be-

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cause the clock rate can be determined even if either all zeros or all ones are received. As can be seen from Fig. 12(c), each data bit can be viewed as having two s.p.l. 'bits' associated with it. These are marked α and β.

In order to decode s.p.l. data, the clock must be extracted: this is done using all the transitions, Fig.12(e), to trigger an oscillator operating at twice the original bit-rate clock, Fig.12(f). This frequency is then divided by two to provide the clock frequency, Fig.12(g). Because of the frequency division, there is a phase uncertainty which will be dealt with later.

The simplest way to decode s.p.l. data, Fig.12(c), is to sample the logic value in the middle of the α period, timed from the extracted clock. This regenerates n.r.z., although fractionally later than the original, and the method works well, providing there is little noise on the signal.

In this case, however, there is considerable noise and a better method must be found. Because of filtering, the received signal will resemble that shown in Fig.12(d) and will contain random amplitude and phase perturbations from noise in the data-frequency band. Suppose the extracted clock were processed to provide pulses that divide the received signal into α and β periods. If the signal were integrated over period α and the result stored and then compared with the value integrated over period β, the result would be the original data displaced by one n.r.z. bit. Using this method, the decision level is continually updated, so avoiding much of the amplitude noise, and signal integration reduces both amplitude and phase noise. This system resembles a fully synchronous demodulator with its associated improvement in output signal-to-noise ratio, the mathematics of which may be studied elsewhere[13].

The remaining problem involves the recovered clock-signal phase uncertainty. As can be seen from Fig.12, if the phase of the clock becomes shifted by 180° after frequency division, the demodulator will not function correctly. This situation is detected as follows; a second output of n.r.z. is generated by checking whether integration over period α exceeds a preset limit, usually half the maximum possible period for a full 'one'. If the clock phase is incorrect, this output is simply inverted, but the integrated output not only becomes

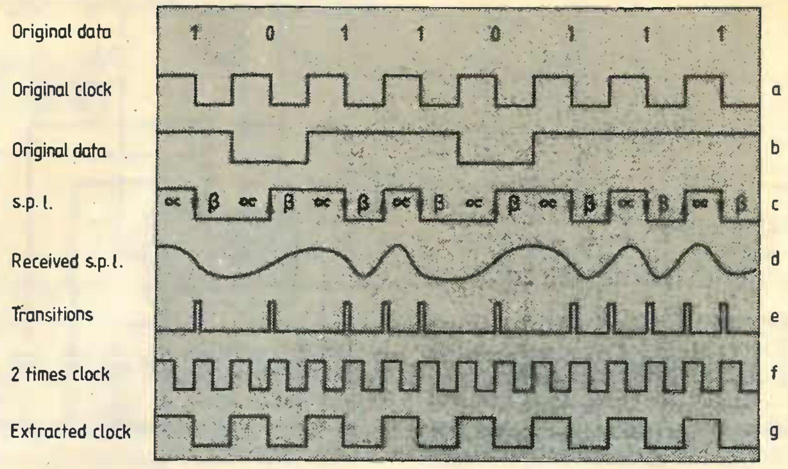


Fig. 12. A random example of s.p.l. data in its original form, (c), and as it is received (d). In (e), the data transitions used to trigger an oscillator operating at twice the original clock frequency (f) are shown. The signal of (f) is divided by two to provide the clock (g).

Fig. 14. Circuit diagram of the decoder ▶ circuit in which raw s.p.l. data is amplified and fed into a comparator and v.c.o. The unmarked p-n-p transistors are complementary to BC108C.

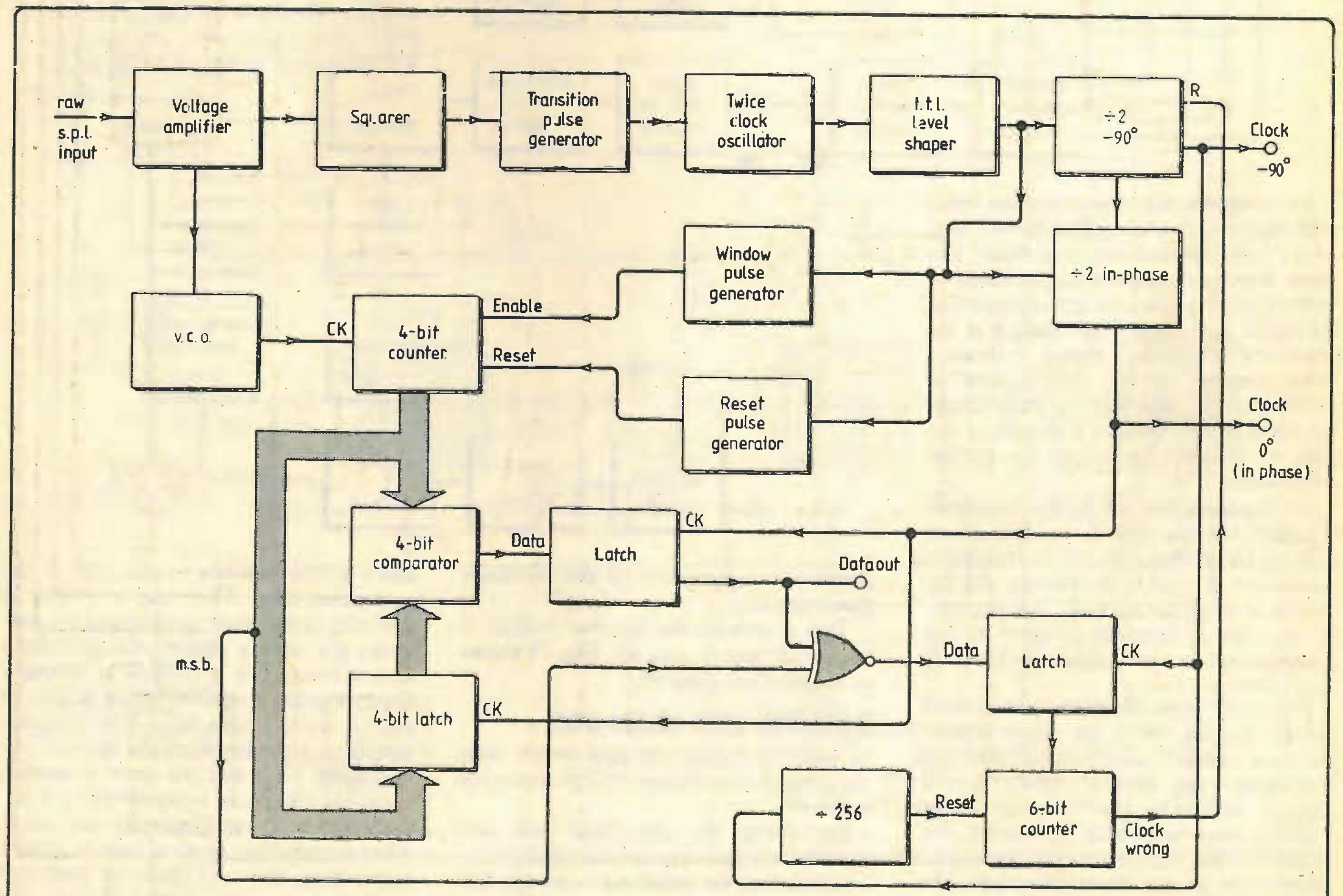
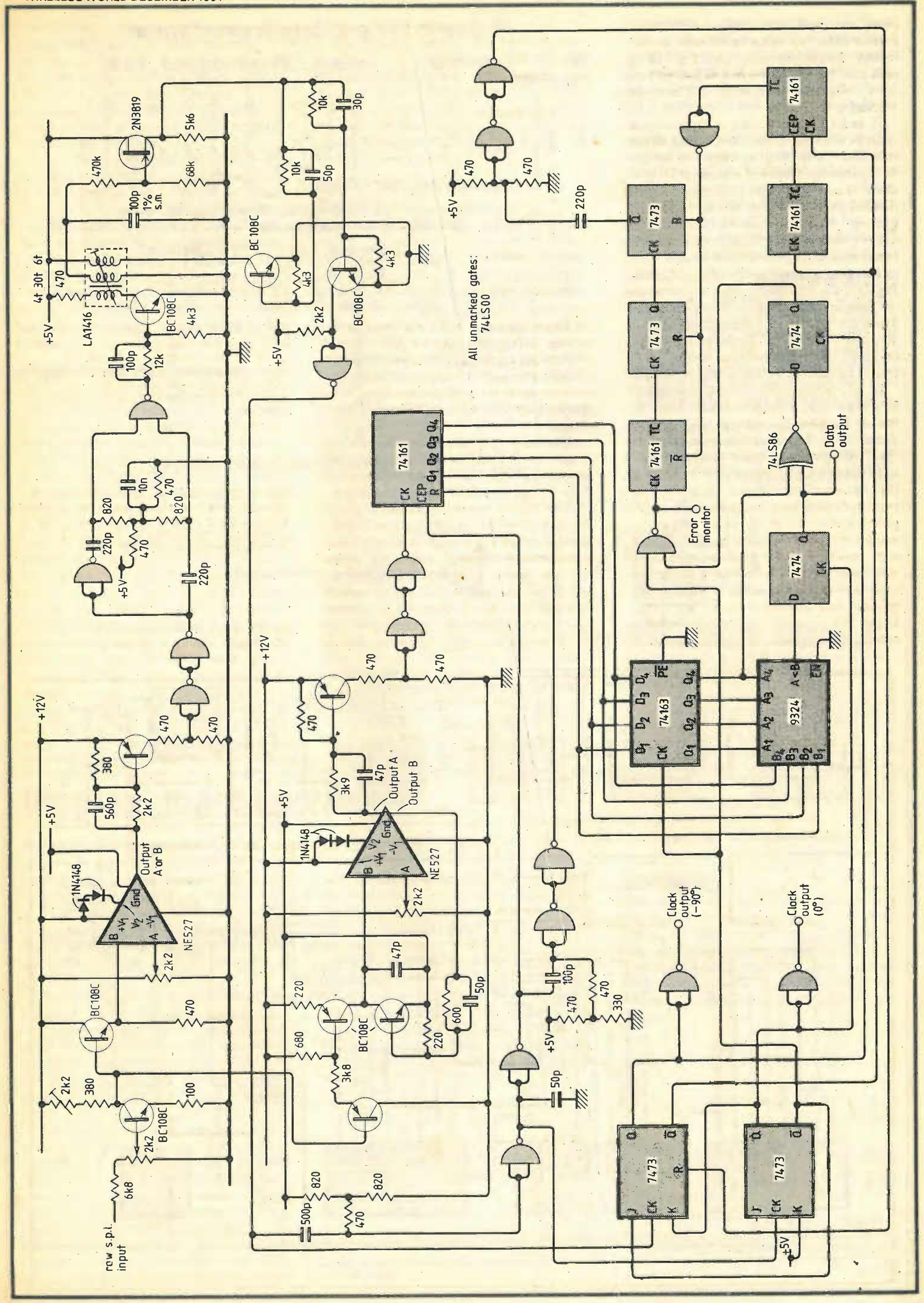


Fig. 13. Block diagram of the bit-conditioner and s.p.l. decoder.



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inverted but contains errors. A continuous comparison is made between these two outputs and the number of non-coincident bits totalled over a few-hundred cycles. If this exceeds a certain limit, the phase of the clock is in error, and thus changed by 180°.

In practice the integration may be either analogue or digital. In a digital integrator, a variable frequency and counter replaces a variable voltage and capacitor. This method can work well where short integration and comparison times are required. Figure 13 is a block diagram for a decoder using the principles described.

Practical decoder

Figure 14 shows the decoder circuit used in which raw s.p.l. data is amplified and fed into a comparator and a voltage-controlled oscillator. The output of the comparator is used to generate transition pulses for clock regeneration. A pulsed LC oscillator forms the twice clock-rate oscillator. The v.c.o., a type of relaxation oscillator, is essentially a variable constant-current source charging a small capacitor. When the voltage reaches a preset value, a comparator causes the capacitor to be discharged. The output of this oscillator takes the form of narrow pulses ranging from 100kHz to 25MHz.

A four-bit counter, reset and enabled by the clock oscillator, counts the pulses from successive cycles. The outputs are compared by a four-bit digital comparator. This forms the output-data stream. Automatic clock phasing is achieved as described, an error signal resetting the two dividers that produce the data rate clock. Two clock phases are provided for use in the sync. sequence detector described later. A.c. coupling is used to simplify the design.

Serial-to-parallel conversion

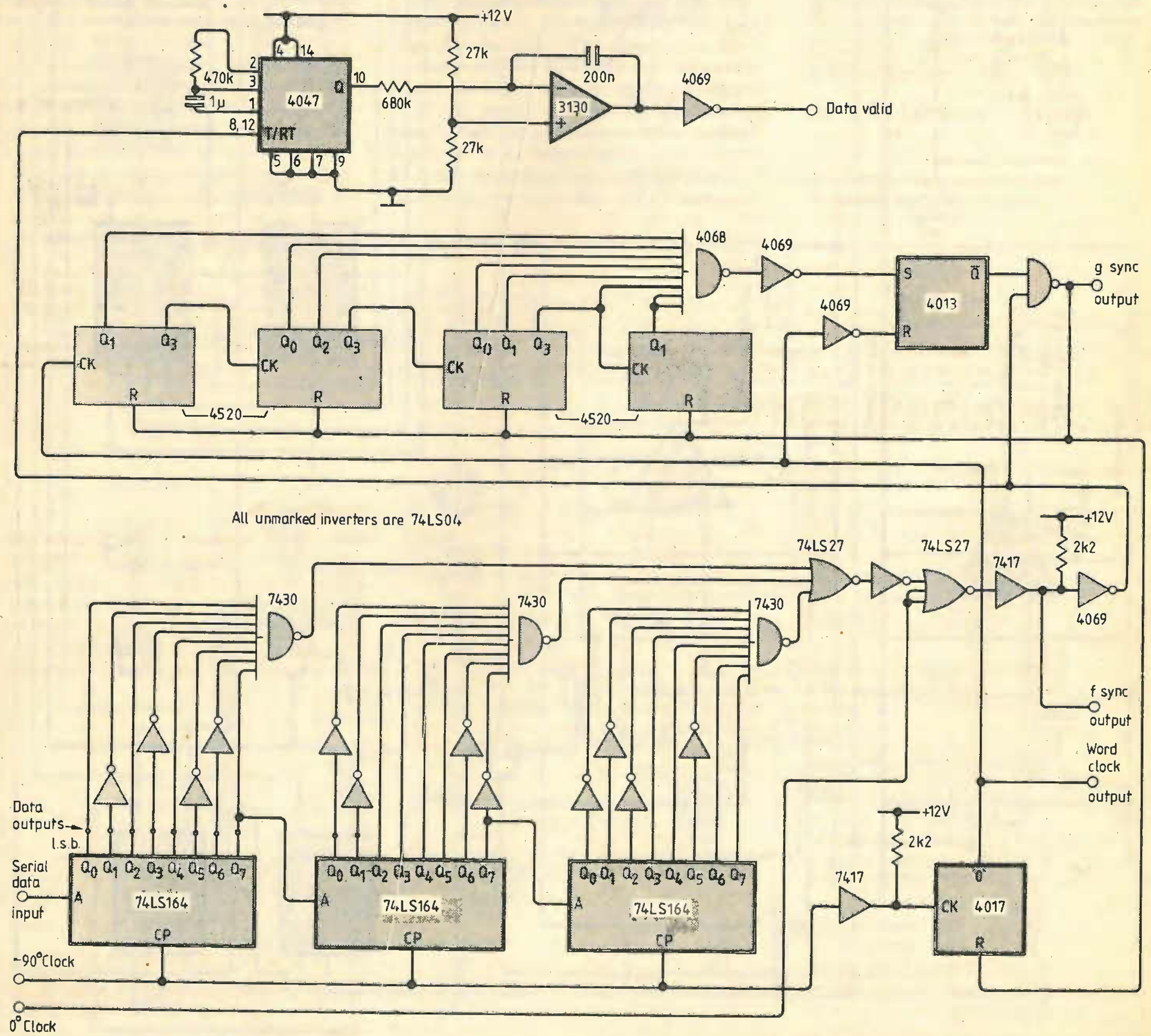
The output from the s.p.l. decoder is a serial stream of n.r.z. data with a two-phase clock. The next step is to convert the data to ten-bit words with a 'word clock' to signify the presence of a new word. A further useful signal generated at this point is a data-valid level, indicating that the available data is true h.r.p.t. It is easy to divide the serial-bit stream into ten-bit words using a counter, but the problem is to divide the stream at the correct point so that the bits are correctly located in the word. The h.r.p.t. (high-resolution picture transmission) format contains a synchronizing sequence, consisting of six words, which divides the data up into blocks of 11090 words long. These blocks are called frames and Table 1 shows the structure of one data frame. Six are transmitted every second, each containing the information from one line scan of the radiometer and telemetry. The telemetry is updated at a different rate, but this may be ignored.

Information from the five spectral bands is multiplexed sequentially so further processing is required later to isolate one spectral-band image. The spacecraft at present in orbit carry a four channel radiometer so the data in channel 5 is a repeat of channel 4. Future spacecraft will carry all five channels.

Table 1: H.r.p.t. data-frame format

Word number	Function	m.s.b. Word content l.s.b.	
1	frame-sync. words	1 0 1 0 0 0 0 1 0 0	
2		0 1 0 1 1 0 1 1 1 1	
3		1 1 0 1 0 1 1 1 0 0	
4		0 1 1 0 0 1 1 1 0 1	
5		1 0 0 0 0 0 1 1 1 1	
6		0 0 1 0 0 1 0 1 0 1	
7 to 750	telemetry, spacecraft identification, time code, calibration, t.o.v.s., sync. timing and spare words		
		channel	sample
751	a.v.h.r.r. earth data, 10-bit radiance values (1023 levels), m.s.b. sent first	1	1
752		2	1
753		3	1
754		4	1
755		5	1
756		1	2
757		2	2
758		3	2
759		4	2
etc.to 10990		5	2048
10991 to 11090	auxiliary sync.	(further pseudo-random sequence)	

Fig. 15. Serial-to-parallel converter circuit. Outputs are 10 parallel data lines, word clock, data valid and frame-sync. pulses. The c.m.o.s. i.cs may be replaced by t.t.l. parts if more convenient.



Sync. detection and word framing

In order to locate the sync. sequence within the serial-bit stream, it is passed through a shift register, clocked at the data rate. After each new bit is entered, the outputs are checked for the sequence. Ideally the register should be sixty bits long and each bit should be correct before the sync. flag is raised. However, this requirement can be reduced to say 24-bits but with an increased chance of picking up a false sync. signal. Because there are also errors in the data, the chance of picking up 24 out of 24 correct is better than 60 out of 60. Although other solutions are possible, 24-bit shift registers are easily constructed and the detection circuit is simplified.

Suppose the detector is set to find the last 24-bits of the sequence. When the flag is raised it means that the contents of word six are located in the ten bits of the register nearest the input. This frame-sync. flag can be used to reset a decade divider which, when in its zero state, indicates the presence of a new 10-bit word. When the next complete word is available the counter will again have reached zero, thus dividing up the bit stream. The counter should stay synchronized but if through clock loss it does not, it will be corrected by the next sync. flag 11090 words later.

The frame-sync. flag can also be used by the data-handling computer to indicate the start of a new image line. If the data is very noisy, some sync. sequences will be missed and so the presence of valid data is signified by regular sync. If the computer also uses this flag to avoid a software word search, its presence must be guaranteed, so a second signal is generated called g sync., synchronized to the frame sync. (f sync.) by a similar reset counter method.

Fig. 15 shows a practical serial-to-parallel converter. Some of the circuit uses t.t.l. and some c.m.o.s. This change midway through the circuit was made so that an existing computer interface could be used but t.t.l. may be used throughout if convenient. The 10-bit words at the shift register output are only valid during the word-clock pulse; if there is a possibility of delay before collection by the computer, a latch should be used.

This completes the data decoding part of the system. The outputs comprise:

– 10 parallel-data lines
– 1 word clock at word rate (66.54kHz)
– 1 data-valid signal
– 1 frame-sync. pulse at line rate (6Hz)

Digital data must be processed and turned into images and the method used will depend to a great extent on the resources available to the constructor.

References
11. VHF Handbook, ARRL
12. VHF-UHF Handbook, RSGB
13. Analogue and digital Communications, W. D. Gregg, Wiley and Sons.

The address from which references 1 and 2 of last month's article were obtained will be given in the next article together with a further reference from the same source. Reference 15, which should have been added to last month's list, was Antenna and Receiving-System Noise-Temperature Calculation, L. V. Blake, US Naval Research Laboratory, Sept. 1961.

Displacement current

continued from page 70

together, causing the charge to move (via the displacement current) as shown in Fig. 5. This method uses much electrostatic energy as the masses of the electrodes are very large compared with the mass of the charge. The weight of 0.02 coulombs is 1.13×10^{-13}kg.

The second method for increasing capacitance is to transport the charges by a conduction current. This method is much more 'energy efficient' as the only losses are those associated with the collision of the charges with ions. Resulting ohmic losses are negligible in short capacitor leads.

The author disagrees with the previously mentioned oscillation explanation, despite the fact that the differential equation for a discharge can be very complex[4], and asks why the same charge is measured before and after the switch is closed? If the circuit did oscillate, the oscillation would obviously decay and the charge would be neutralized by recombination with an equal and opposite charge, with the liberation of heat. Secondly, since the capacitors are in parallel, the charge density will be the same. Consequently, once the charge has redistributed itself, the system will be static.

Finally, it is worth considering the magnitude of current that would have to be present if energy was to be temporarily stored in the inductor. For example, consider a capacitor of 5000μF connected to another of a similar value. Let the voltage be 10V. The energy stored in the capacitor, E, can be found by

$$E = \frac{1}{2}CV^2 = 0.25 \text{ joules}$$

If half this energy were to be stored in an inductor with very short leads of 1μH, then

$$0.125\text{J} = \frac{1}{2}\times10^{-6}\times I^2$$

so I is 500A.

Conclusion

The energy equation for a capacitor assumes that any change is brought about by letting the field do the work. Charge cannot be created or destroyed, although equal amounts of positive and negative charge may be simultaneously created, obtained by separation and lost by recombination.

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Jaguar tamed

Fly-by-wire Jaguar taking off on its first flight from Warton.

Said to be the first aircraft in the world to fly solely under the direction of all-digital, quadruplex, fly-by-wire controls, the Sepecat Jaguar made its first flight in this form at British Aerospace's Warton aerodrome on October 20, 1981.

One of the goals of an aircraft designer has always been stability, so that disturbances from the desired flying attitude are damped and corrected by the aerodynamics of an aeroplane, without excessive movement of the control surfaces. The work load imposed on the pilot is thereby kept within reason, but the more stable an aeroplane, the less manoeuvrable it becomes – it will try to maintain its neutral attitude.

Clearly, an unstable design would be more inclined to depart from the straight and narrow flight path on demand, but would also present the pilot with an impossible task simply to keep it in the air. Stability and agility are uneasy partners.

Military aviation, as is so often the case, is the stimulus for a technique which has been developed over the last ten years and which reaches a new level in the BAe equipment for the Sepecat Jaguar. The jargon term in common use is "Fly-by-wire", which means that the control surfaces are moved not by control rods and linkages but by actuators driven by the pilot's controls and by computers, which are capable of rapid response to disturbances to keep the aeroplane stable, and to the pilot's demands. Four computers and optical data links operate with considerable redundancy to maintain operation even when two of the computers or the gyro sensors that provide their inputs fail: the computers are programmed to prevent the aeroplane being forced into evolutions which would take it outside its designed capabilities. BAe have not thought it necessary to provide for manual control in emergency.

Jaguar will shortly be tested with wing-root forward extensions, which will move the centre of pressure forward of the centre of gravity and de-stabilize the aeroplane.

More letters

Microchips and megadeaths

Surely Tim Bierman (October Letters) is expecting too much from human beings. Nothing that is mass-produced by unskilled labour, as humanity is, can be expected to have outstanding quality.

Moreover, the design of human brains is so imperfect that it takes some 15 to 20 years to program them properly, and in so long a process it is inevitable that mistakes of a number of kinds are made. On top of this, evolutionary forces have produced human beings designed to work best in conditions of subsistence farming: it is to be expected that they will flounder and make mistakes in a highly technical society. Today's ultimate problem, in fact, is that this technical society has been created by the unusual members of the human race, while the ordinary everyday members of that race are unable to understand how to control it.

P. C. Smethurst
Bishop's Stortford
Herts

Mr Scroggie, in your September letters column, seems to assume that because unilateral nuclear disarmament will not necessarily stave off the ultimate bonfire it must therefore be a bad thing. I have torn up a two-page reply, preferring to address a single point. My respect for his intellect and his practicality left me surprised at his apparent paranoia.

The question is, even supposing his predictions to be true, would he *really* prefer to die in a nuclear conflagration (or, possibly worse, survive one) than to live under Soviet government?

It appears that the prospect of Soviet world domination fills us *both* with dismay, but I must remind him that it is the USA which currently threatens to escalate the arms race beyond its present already insane level.

Stephen Holden
Thornbury
West Yorkshire

I have been reading with great interest the letters you have been publishing under the heading "Microchips and megadeaths". While there are parts of letters with which I agree, I find that some correspondents appear to have missed the point.

I refer primarily to the writer who suggests that students following a sandwich type degree course should be actively discouraged from gaining their industrial experience in the defence industry. I am such a student, working for a major defence company, and would like to point out that the many students in my position do what they do because they want to become electronics engineers, not because they want to kill each other. What is usually forgotten when talking about the defence industry is the fact that weapons are not the sole output. Certainly they are important, but an equally important by-product is technological advancement. This means that we are becoming cleverer and capable of better things as we develop new skills. It is something we cannot do without.

The massive pocket calculator revolution did not start because someone decided it would be nice for school children to have them, but because the technology had been developed.

I am assuming the writer proposes that anyone involved in building weapons should give up his work and concentrate on a more socially useful activity. Does this include all the people who work in the canteens and on the sites, or even those who print the stationery? The list is endless, and yet they are all involved in warfare.

Tim Bierman pointed out in his letter in the October issue that the Americans are spending large sums of money on "weapons of death". We need a deterrent. Does Mr Bierman really believe that if the United States decided not to spend that money their enemies would disappear? I think not.

Instead, let us stand up for what we believe in, and not be intimidated by those who look on us as their enemy. If the worst *were* to happen, we would need everything we possess, and we must prepare now for what we will need.

T. C. Allen
Ash Vale
Hants

Correction

Figure 4 of "C.b. frequency synthesis", November 1981, contained one error. The earthed side of L_1 is shown connected to the anode of a Varicap diode. This connection should be replaced by a 1nF capacitor so that the anode is no longer directly connected to earth. Apologies for this omission.

Educating engineers

An ecological viewpoint

by Peter Hartley, Ph.D Colorado School of Mines, USA

This article argues that engineering education is on the wrong track and should be changed. Because it is rooted in the tradition of humanism and "the conquest of nature" it is having disastrous results in the world around us. Its aim of technical competence is not enough. The cure, says Dr Hartley, is for engineering education to use systems analysis – a method it already possesses – to examine critically the humanist assumptions that have dominated engineering so far.

The development of modern technology has been a great adventure that many people have justly regarded as the conquest of nature. Until recently, most engineers have prided themselves on making this conquest possible. Many, perhaps most, still do. What other attitude is possible for them? Can engineering be anything else but the conquest of nature?

Perhaps it is obvious from my tone that I find the conquest of nature questionable at best. Yet I must immediately make clear that I am not speaking from across a supposed gap between the so-called "two cultures"; I am not opposed to engineers or engineering, nor am I ignorant about them.

If I were a humanist, my problem would be immensely complicated and probably hopeless. Fortunately, I am not a humanist. I am a cultural ecologist with a literary background. Therefore, I can set to one side the "two cultures" approach, which completely blocks any resolution of the question. I can point out with no discomfort that the past attitude of engineers bears a close affinity, not to the vocabulary or preoccupations of those who consider themselves humanists, but to the dominant conception in our society about the supreme importance of strictly human interests in the general scheme of life. Humanism, if not the cause is certainly the essence of that ignorantly anthropocentric outlook.

The pressure of history allows us no choice but to use the term "humanism" for that ever increasing tendency to consider human life apart from all else – a tendency which inevitably becomes indistinguishable from the assumption that life has no value apart from human purpose. This humanist view displays and indeed constitutes humanism's inherently non-ecological character.

"Progress" promises a general amelioration of human life, making possible for everyone good education, cultivated sensibility, and not only the provision of bodily necessities but the addition of every material comfort. The education, insofar as it has been attainable, has of course been a humanist education singing the praises of human achievement through the power of human intellect, and defining the world as something for that intellect to exercise itself upon. Even material comfort itself is subsumed under the purposes which humanism in its more self-conscious moods likes to dwell upon; I have heard people maintain that material progress is necessary to provide us with energy slaves so that we can all be free to spend more time exercising our more purely human (i.e. mental) faculties.

Humanism is the dominant ideology of modern times, comprehending both capitalism and socialism, and being not merely an ideology but the practical commitment of every society that is modern or trying to become so. Its main practical effect is to increase without limit the per capita amounts of resource use, pollution, and environmental destruction. Its rationale is basically its commitment to human self-importance – a generalized egoism that encourages socially and environmentally corrosive egoism in every human individual.[2] In practice, this means that engineering has indeed been at the service of an outlook that at its foundation is humanistic. Modern engineering, in fact, has had no other purpose.[3]

The world as a manipulable object

Engineers follow notions of improvement set forth originally by poets and philosophers dreaming a world of perfect felicity for man. In its engineering manifestation, then, humanism contrives to manipulate the environment in ways that its philosophical and literary manifestations deem beneficial – to make improvements that accord with human purposes. In those terms we can even regard modern science as a creation of humanism. Operationally, modern science has been humanism's technique for defining the world as a manipulable object and for discovering the basis for effective procedures of manipulation. Engineers have simply applied those procedures in carrying out projects determined by humanistic notions of improvement.

The question of professional responsibility boils down to whether we can define full professional adequacy in engineering merely as technical competence to carry out such projects. This amounts to asking whether we should try to establish a radical separation between engineering and humanism to replace the fantasy separation that our cultural self-delusion has maintained. I started out by asking whether we had to identify engineering with the conquest of nature. In fact, *humanism* is the conquest of nature. This is humanism's fundamental arrogance and irresponsibility. Engineers like to think of themselves as being committed to responsibility. Can engineering turn away from the conquest of nature? Can engineering behave with full responsibility? Can there be a non-humanist engineering?

The most immediate difficulty in the project to conquer nature is its effect on *human nature* – its deleterious effect on society, and the concomitant diminution of human personality which results from the loss of sustaining interpersonal fabric. Humanistic egoism makes people unable to know society as anything but an aggregate of separate egos, or the earth as anything but an aggregate of mere non-human bits and pieces. But notwithstanding the vaunted importance of those isolated egos, they become objects of manipulation just as surely as the bits and pieces of estranged nature do – and by means of the same process. The industrial system is impossible unless most people in the industrial machine obey orders like robots. In *The Abolition of Man*, C. S. Lewis says: "Man's power over Nature turns out to be a power exerted by some men over other men with Nature as its instrument."[4] That, and not the environmental problem as usually conceived, is the most immediate professional dilemma of the engineer.

The exaggeration of separate human importance has created a general social estrangement such that the individual can have no real significance. There are no longer any transcendent interpersonal bonds that can confer fully differentiated individual significance.[5] Engineering has contributed to this situation not only because it has created the technological basis for industrial production as such, but also because industrial technology has been the means whereby the isolation of individuals in socially irrelevant modules has become possible. Survival – even comfort – has become possible without reference to others.

People's material needs are provided for not through binding human contact, but through mere distribution of standardized goods and services, which can be routed in any combination and at any speed to any number of individual customers whose

This article is a shortened version of one that originally appeared in the December 1980 issue of *The Ecologist* and is reprinted by kind permission of the editor of that journal.

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main relationship then is to the general productive mechanism rather than to other people as such. The mechanism requires that human behaviour must be compatible with the requirements of mass production; insofar as possible, individuals must be replaceable and interchangeable parts. Their relationship with each other becomes as exterior and standardised as their relationship to the mass system. Differentiated, unique personalities become as impossible as the differentiated social networks that once sustained them.

Quite simply, the energy that once flowed through those networks no longer does; energy now flows in wires and pipes. The effort to satisfy basic material needs that once gave urgency in social relationships and filled them with sustaining material content no longer exists. It has been engineered out of existence in an attempt to fulfil the humanist fantasy of liberation from mundane concerns deemed unworthy of the human intellect, or to realise the fantasy of pastoral felicity and effortless accommodation.

Engineering must be a social science

The point is that engineers do not merely design hardware; they design the material framework of society, and thus they design social relations as well. Its effect on social ecology is the greatest ecological impact of engineering. If engineers are to be fully professional, they must take full professional responsibility for their actions. Engineering must recognise and address its social science dimension; the engineer must be a social scientist as well as a designer of equipment and material processes.

The alternative view, still probably typical of most engineers, is that an engineer should merely *react* to situations or requirements that he must accept as given; he should not presume to make judgments except in terms of his technical expertise, which should be as narrowly specialized as possible so that he can be maximally expert at what he does. Social responsibility tends to be regarded in terms of adherence to government regulations. In practice, an engineer who is educated to react will tend to criticize those regulations only on the basis of whether they make his job more difficult. He will feel little professional obligation to evaluate and criticise policy on broader grounds, and certainly he will not feel obligated to take a public stand *as a professional* on questions of resource use and general ecological impact (including social impact) that go beyond the purview of the regulations.

To be sure, technical competence is a *sine qua non* of adequacy in any profession. But if technical competence is all we mean when we say an engineer is professional, then we cannot regard engineering as a profession on the same footing as other learned professions, which are ultimately based on standards of ethics and responsibility that go far beyond merely technical criteria. We are left with a conception of the engineer as no more than a high-grade technician, a functionary not fully professional – that is with no responsibility for his actions beyond their technical adequacy. A glorified mechanic. But someone who is professional in the fullest sense is responsible for taking into account the *ultimate* meaning of his professional actions, and is expected to have the background for doing so. We must assume that a real professional is the ultimate authority for all his own professional acts – then he can't pass the buck, can't define himself as someone who merely reacts to given situations.

In the past we have taken the unwarranted liberty of making radical changes in an environmental system that we did not understand; yet we have long known that random changes in any orderly system are likely to do harm. We are not dealing in vague sentiment here – from a strictly engineering point of view, it should appear most reasonable to hold suspect any proposed radical departure from conditions which prevailed at the time when the human species developed its present phylogenetic constitution.

Such practical questions of systemic integrity can show us how to establish a real separation between engineering and humanism. Unlike humanism, engineering can assimilate ecological thinking. To the extent that it does, we will have the non-humanist, responsible engineering we so badly need. At present, many engineers advocate a "broader" curriculum for engineering students. Naively, they suppose this would require a better grounding in the humanist tradition, which panders to their desire for cultural approval. Those of us in engineering education who have been immunized against the self-adulating rhetoric of humanism must disabuse our engineering colleagues before they overload the curriculum with humanist propaganda. Grounding in traditional humanism will merely deceive the students into feeling well-educated, while making them better able to rationalise their acts and fend off real systemic analysis.

To develop an adequate philosophy, engineering does not have to borrow from humanism. The principles of good systems design should provide an adequate basis, as long as engineering develops a broader perspective regarding the systems it deals with. Engineers must begin to apply good engineering analysis to issues that in the past they have pretended to ignore. Engineers have produced many unanticipated and undesirable effects not because they have failed to be humanists but because they have failed to be thoroughgoing as engineers. Adequate grounding in systems science will make obvious the fact that even a concern for medical effects as such is not good enough for good engineering; the social organization which brought about those effects is also part of the problem. This is why I emphasise the *social* aspects of the considerations to which engineering must pay attention.

In the long run, there is little point in merely designing ways to mitigate the bad effects of productive operations when such effects are the inevitable result of the principles constituting the organizations involved – principles that engineers have fostered without understanding the implications of what they were doing.

The activities of giant corporations dominate our lives, and as long as we accept the principles on which they operate, we shall be helpless before them. Engineers are the ones who have done most to help the development of industrial giantism, with its attendant transformations of community life, family life, and behavioural values generally, not to mention its virtual destruction of competitive free enterprise. Ironically enough, most engineers tend to view themselves as social conservatives. Yet their activities have made and continue to make inevitable the most radical kind of social change, all because they refused to examine the implications of what they were doing.

Even if engineers as a group would prefer to avoid the responsibility of full professionalism, society cannot allow them such a luxury any longer. What engineers do is too important; the effects of their activities are too profound. The advice of a physician affects one life at a time; the advice of an engineer may determine whether hundreds of people develop cancer ten or twenty years later. We can no longer afford the kind of ignorant specialization that hampered understanding in the past. We must insist on the most rigorous, fully developed, and comprehensive kind of professional standards in engineering, and we must give engineers an education that makes them capable of living up to standards of that kind.

Fundamental changes to curriculum needed

This involves some fundamental rethinking about the very nature of an engineering curriculum. The education I mean must be integral with technical instruction; it cannot be a mere addition to the technical curriculum. Courses aimed at giving "breadth" tend to be superficial, and to be regarded as extraneous by the students. If we cannot make the change an integral part of engineering instruction, we shall continue to graduate engineers who have only the technical skill to perform as narrowly based, irresponsible functionaries having no conception of the larger and more important effects of their activities.

Systems analysis is a basis of ecological study, which the ecologist tries to make as rigorous, as exact, as quantitative as it can be. Energetics is an essential topic for systems analysis in ecology, and along with the study of material and information flow it should be a basic topic for an approach to non-humanist engineering. Properly understood, this approach provides a tool for social analysis organized in a way clearly relevant to the technical considerations of engineering, couched in a language easily assimilable to the language that engineers already know. An engineer should know how to think about social organization as a control system. All engineering is essentially systems engineering of one kind or another; our aim must be to give every engineer a more generalised understanding of systems thinking and an ability to apply that thinking to a wider range of systems, making it possible for each engineer to relate his speciality to its broader systems context in a professionally meaningful way.

Present engineering education is in effect a method for training people to ignore insofar as possible everything that does not bear directly on the immediate technical problem. The main result of this is a tendency to suboptimize partial systems models in terms of very unrealistically defined criteria of "demand" and "need." These simplistic criteria enable planning to go forward without any analysis of systemic context and systemic alternatives. To proceed in such wilful ignorance is unprofessional.

Professional view is process-oriented

The systemic view, which we could also call the operational or realistic view, would enable the engineer to take a much more solid pride in his work. We could even call this view the *conservative* view, for a conservative in the best sense is someone who is process-oriented – that is, "concerned for the on-going inter-relationships and effects of elements within the system on each other." It is also the only conceivable professional view. At present, a technically competent engineer is in the position of designing good components for use in a badly designed overall system – a system that we could rapidly re-design for better energy efficiency, without any essentially new technology, and without radical social change.

Recent engineering has made everyone more and more dependent on distant sources over which they can have no direct influence. Engineering has designed a situation in which increasing control by centralized bureaucracies has become inevitable. The monstrous bureaucracy that fills conservatives with such disgust is a monument to the degree of impact engineers have had; their headlong rush to introduce technical innovation has completely revolutionised our political life, making local self-regulation and independence nearly impossible.

One of the worst problems is the general manipulation of society by the industrial-commercial bureaucracies, all pretending to offer choice while closing off options. Corporate economics really amounts to a collusion of private interests in a non-accountable private government controlling nearly every detail of our lives. The limited liability corporation defined as a juridical person is a new kind of control system, and as such it is a suitable topic for engineering analysis. From a systems point of view, the bad thing about such government is that it is unnatural – that is, it is badly designed and has to be maintained by an excessive energy flow. It is an attempt to deny systemic reality. It is inherently irresponsible, since it is set up precisely to allow those in control to affect others without paying attention to the full responses of those whom they affect. Thus to inhibit diversity of response from within a system is automatically to increase the energy cost of maintaining the system.[9] Any engineer should be at least minimally conversant with what systems analysis might have to say about such a problem, and should be ready to contribute to the analysis from his own point of view.

A still more profound effect of relentless technological change has been the fundamental re-design of basic personality – i.e. standard behaviour patterns – due to a complete change in the material basis for interpersonal relations and for the expectations that people have. We have engineered individual self-reliance out of existence. People who are cogs in a giant centralized corporate machine are not going to be self-reliant, though they may cling to the fantasy and soothe themselves with rhetoric. But they feel their helplessness, so they become addicts to the drug of consumerism, the endless purchase of endless trivial products. The systemic effects of technological innovation have created a population with an ever-increasing proportion of individuals who demand instant gratification, who have been programmed to "need" constant novelty. Such people represent a new kind of typical personality, incapable of restriction, incapable of permanent relationships, intolerant of life's ordinary demands. They are no longer differentiated individuals whose lives have unique value, but interchangeable components in jobs where replacements are always available, and one is as good as the next. The same inevitably becomes true of personal relationships. One worker is as good as another, one job is as good as another, one spouse is as good as another. This is freedom as designed by our present technology, the creation of engineers who just wanted to do their specialized thing, and let somebody else worry about the consequences.

In fact, we do not even need subtle analysis to prove that our system tends to maximize energy and materials consumption, nor do we need to argue about whether such a tendency is indefinitely sustainable. We need only ask how to decide on what energy and resource and organizational criteria we must use to indicate a consumption level that *is* sustainable, and how to apply those criteria. How should we go about designing a system that will stay at a sustainable level? This is clearly the engineering and social question for our times, and I should not have to ask it – any professionally responsible engineer should have thought of it ten years ago. Unfortunately, engineering has failed to develop real professional responsibility because, as I suggested at the outset, engineering has been dominated by humanist values, which are inherently antisystemic and, therefore, inherently irresponsible. The humanist dream of "progress" to which engineers have devoted themselves is a manifestation of humanism's fantasy concerning what it regards as human freedom, dignity, and power. Manipulation of the world both exhibits these things and proves that such manipulation is justified – if you are free, you have a right to act freely. There is a built-in tendency, therefore, to identify "progress" with anything that increases the amount of energy and material that people control.

When the inevitable ill results of such behaviour become too obvious to ignore, those non-engineers consciously devoted to humanism pat themselves on the back for being sensitive enough to notice the problem, while they chide engineers for creating it. The engineers then are supposed to take care of it. Non-engineering humanists are proud of themselves for having well-articulated noble sentiments, and they feel that they have fulfilled their obligation when they voice these sentiments. These non-engineers assume, however, that the solution to a problem will always allow them to retain unlimited control over energy and materials, and they humanely insist that all people should have such benefits. Thus the key to humanism – that is, to "progress" – is a belief that we can have our cake and eat it, too – that we can somehow ignore the second law of thermodynamics. That is the belief embodied in our society's basic design assumption that energy and materials use should increase every year – that we should attempt to maintain unlimited growth. The fact that engineers have accepted such a design assumption argues that engineers have been trained to be humanists first and engineers second.

Engineers by themselves cannot solve our problem, but if engineers will not take full professional responsibility for what they do, we will all continue to be helpless. Engineering education may be the key to the modern dilemma.

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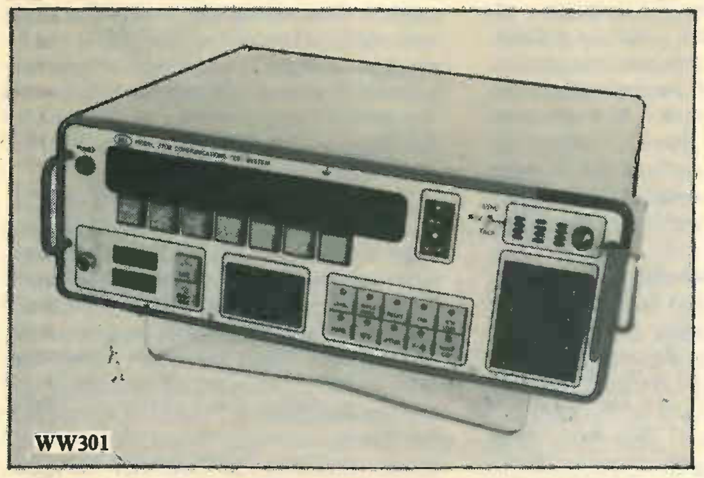
New Products



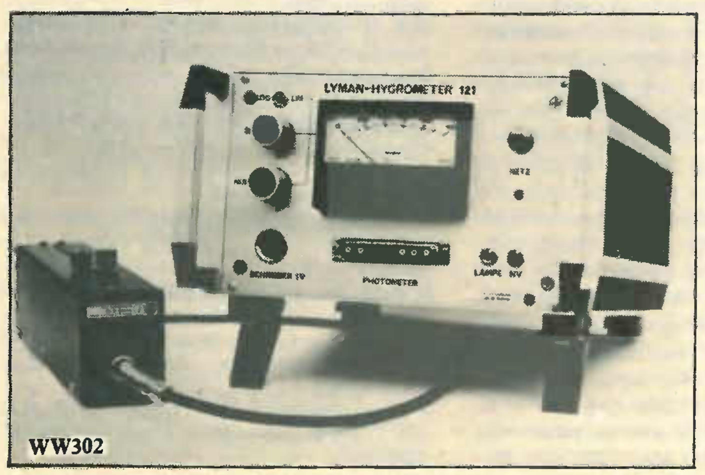
WW301

Communications test set

The latest addition to GADC's communications test equipment is the 3702 portable test unit with synthesized generator for level, noise, signal-to-noise ratio and frequency measurements to the relevant CCITT standard. A 40-character alphanumeric display shows control settings and measurements and gives indications from the instrument's self-test circuit. Plug-in cards are available for the following measurements, 3-level impulse noise, group delay, phase/amplitude jitter, sudden alterations in phase or level, i.m. distortion, peak/average ratio, 4-wire return loss and volts, ohms and capacitance. G.A.D.C. Ltd, 70/82 Akeman St, Tring, Herts HP23 6AJ.
WW301

Hygrometer

This instrument gives a readout of absolute humidity or water vapour content in air and other gases independent of temperature or pressure. A detector head, comprising a neon lamp, optical filter and photocell, is used to measure 121.59mm wavelength light absorption in water-vapour molecules. The standard version has a photocell for measuring humidity in the range 1 to 100g/m^3 and optional sensors are available for measuring down to 0.01g/m^3. Response time of the unit is said to be milliseconds and linear and logarithmic outputs are available for a chart recorder. Stability error is less than 1%/day. Rostol Ltd, Lysons Avenue, Ash Vale, Nr Aldershot, Hants GU12 5QF.
WW302



WW302

Visible-light laser diodes

Laser diodes with a peak wavelength of 780nm and 5mW maximum output power are manufactured by Hitachi. These devices can be used as light sources in videodisc and optical audio-disc players and have an anticipated operational life of 10^{5}h at room temperature. An integral p-i-n photodiode is included for use in automatic power-control circuits. Beam divergence is 15 by 30°, the polarization ratio is 70 and astigmatism is 15μm. Two versions of the HL7801 are available, differing only in mounting flange, and the price is under £100 for small quantities. Hitachi Electrical Components (UK) Ltd, 221/225 Station Rd, Harrow, Middx HA1 2XL.

WW303

Temperature controller

Digital-readout temperature controllers from Controls and Automation Ltd are available in 12 standard ranges to cover from 0° to 1600°C. The CAL7300 has a 1/8 DIN size front bezel (48 by 96mm) and is said to be capable of accepting almost any type of sensor; cold junction compensation is incorporated. Input drift is 3μV/°C and readout accuracy is ±0.15% f.s. The unit can operate in proportional or derivative mode with manual reset or in four terminal mode. On the standard version a relay rated at 10A, 250V (50Hz) is used for load switching but options are available with opto-isolated and triac/thyristor switching outputs. Both actual and set temperatures can be read from the display. Controls and Automation Ltd, Regal House, 55 Bancroft, Hitchin, Herts SG5 1LL.
WW304

20MHz oscilloscope

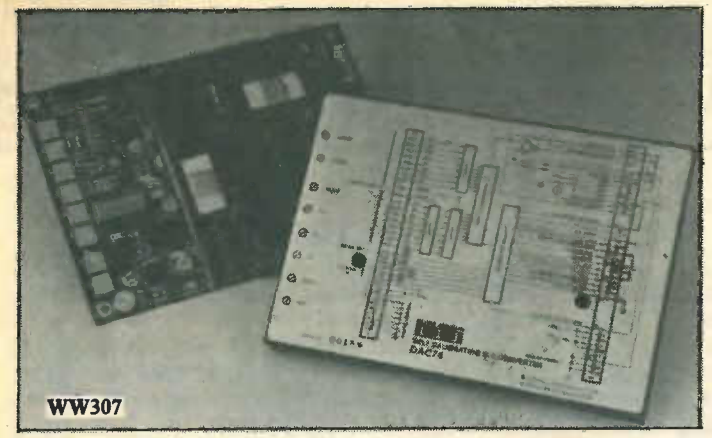
Sensitivity of Hitachi's V-202 dual-channel 20MHz oscilloscope is 1mV/div. This relatively low-cost instrument (£260 exc. v.a.t.) has 20ns/div maximum sweep speed and channel addition and subtraction facilities. Triggering modes include auto and 'tv', in which an active circuit is used for video signal sync. separation. The 51/2in rectangular c.r.t. has a graticule (with variable illumination) printed directly on it to give, it is claimed, parallax-free readings. Focus compensation for brightness changes is automatic. Reltech, Office Suite 1, Coach Mews, The Broadway, St Ives, Huntingdon, Cambs PE17 4BN.
WW305

Coaxial cable assemblies

Flexible p.t.f.e.-dielectric coaxial cables and cable assemblies can be supplied by Pascall for use in phase array systems, computer networks, microwave links and other such applications. 'Astro-super-flex' 32020 cable, designed by Astrolab Inc., has a loss figure of 13dB/100ft at 1GHz and an outside diameter of 0.163in. Loss of the 0.108in diameter 32013 type cable is 22dB/100ft at 1GHz. V.s.w.r. depends on the type of connectors used but is typically 1.25 at 12.4GHz using SMA and TNC terminations. Both cables have fused p.t.f.e. outer sleeves and can be bent to an inside radius of 1mm. R.f. leakage is given as −110dB minimum. Assemblies can be supplied with SMA, TNC, or BNC terminations. Alternatively, cable can be supplied unterminated. Pascall Electronics Ltd, Hawke House, Green St, Sunbury-on-Thames, Middx TW16 6RA.
WW306

16-bit d-to-a

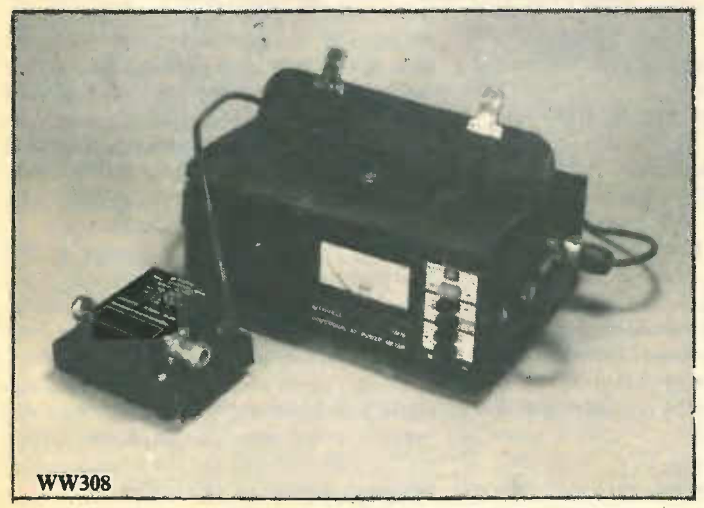
A self-calibrating 16-bit digital-to-analogue converter known as the DAC74 is available from Burr-Brown. Output can be either 0 to 10V or −10V to +10V and error specifications are ±0.5 l.s.b. maximum non-linearity, ±1 l.s.b. maximum differential non-linearity, ±7.5×10^{-4}% maximum gain error and ±40μV maximum offset (unipolar) for 15°C to 45°C. A microprocessor-controlled calibration circuit with a ±5 p.p.m/°C voltage reference trims the analogue output to compensate for temperature and long-term drifts. Calibration, initiated by a digital command, takes about 2.5s. The board has a steel housing measuring 127 by 178 by 18mm. Burr-Brown International, Cassiobury House, 11-19 Station Rd, Watford, Herts WD1 1EA.
WW307



WW307

Through-line power meter

Frequency response and power-measuring limits of the TM10 are 25MHz to 1GHz and 20mW to 100W respectively. This power meter, available through Farnell, has a detachable detector head (measuring 100 by 72 by 54mm) that covers the full measuring range and can be used at up to 1.5m from the readout unit. The basic reading error is ±3% and v.s.w.r. can be read directly on depression of a push button. One PP9 type dry cell will provide about 1000 operating hours according to the manufacturers. Dimensions of the measuring head are 100 by 72 by 54mm. Farnell Instruments Ltd, Sandbeck Way, Wetherby, West Yorks LS22 4DH.
WW308



WW308

Small linear op-amps

Most of the popular op-amp and comparator types such as the 741, 1458, 4558, 324 and 399 are included in NEC's Miniflat linear i.c. range for use on boards with tightly packed components and hybrid applications. 8-pin d.i.l. types measure 5 by 4.4mm and 14-pin types 10 by 4.4mm. Electrically, these devices are identical to their standard equivalents except in power dissipation. Both industrial and commercial grades are available. NEC Electronics (UK) Ltd, 116 Stevenston St, New Stevenston, Motherwell ML1 4LT, Scotland.
WW309

Versatile optical video link

No adjustment or alignment is needed in setting up OVID, an optical glass-fibre link for situations where microwave links cannot be used. Shown at the Berlin radio exhibition and claimed to be the first commercially-available optical system of its kind, it has a range of between 2 and 12km. Maximum range depends on the optical transmitter used and the signal-to-noise ratio required. For a transmission quality represented by a signal to weighted-noise ratio of 65dB an l.e.d. and avalanche photodiode would give a 2km range, but by substituting the l.e.d. with an 850nm laser 8km would be achieved. For tv distribution systems where 55dB is acceptable the equivalent ranges for the two cases are 3 and 10km and for surveillance, where 45dB will do, the figures are 4 and 12km. A p-i-n diode receiver option with laser can increase dynamic range as well as giving a range between the two extremes. Without h.f. emphasis, harmonic distortion of the sound circuits is less than 0.5%; video signal frame and line time distortion, intermodulation, luminance non-linearity, and differential gain are all below 1% with differential phase below 1°. It is a 19 inch rack-mounting transmitter and receiver, with interconnecting cable of 3.5dB/km attenuation. Standard Telephon und Radio AG, CH-8055 Zürich, Friesenbergstrasse 75.
WW310

Lightweight video recorder

Seen at last September's Berlin radio show, Grundig's VP100 portable video recorder uses a cassette only slightly larger than an audio cassette. Made by Futec (Future Technology) of Osaka but to Grundig specifications, the 110×70×10mm cassette contains enough ¼in tape to give 45min recording time. The head-to-tape speed of 4.7m/s is achieved with a linear speed of 22.5mm/s in conjunction with a 60mm dia. rotating head. A variable speed facility, both fast and slow, is provided as well as a freeze frame mode. At 25×6×18cm and weighing 2.3kg including batteries, Grundig expect it to be the smallest and lightest video recorder when it is marketed in the UK in the second half of next year (January in Germany). Grundig Ltd, Newlands Park, London SE26 5NQ.
WW311

WW311

Data concentrator

The technique of data multiplexing to improve the efficiency of a single data link is certainly not new; however, many systems comprise two or three units at each end of the system. The E series of data concentrators combines the necessary modules in a single case so that two units will allow a remote group of terminals to be connected to a central computer or processor via a serial data link. A standard data concentrator consists of a statistical multiplexer for between 4 and 16 programmable asynchronous channels and one synchronous channel using any protocol. The multiplexer output is fed to an integral high-speed modem which offers data rates up to 9,600 b.p.s. The unit also features a 16K buffer to cope with peak data transmission, together with a flow control to halt data from a computer or intelligent terminal if the buffer is nearly full. Data transmission is continuously monitored and if an error is detected the transmission is repeated, which provides automatic correction for errors introduced by, for example, noisy telephone lines. Because all of the functional blocks necessary for data concentration are housed in a single case, expansion and programming are straightforward. Timeplex Ltd, Timeplex House, 77 Boston Manor Road, Brentford, Middlesex.
WW312

Audible alarms

Two alarms from the American Sonalert range will emit a continuous or pulsating tone at 2.9kHz. SBM 616PC/JC is a 16mm deep, 42.7mm diameter device for board mounting, which produces a 68-78 dB(A) sound. A supply voltage of 6-16V d.c. at 1-4mA will drive the units, which pulse at 2-9Hz(PC) or 0.5Hz(JC) when one of the pins is connected to the positive rail. Highland Electronics Ltd, 8 Old Steine, Brighton BN1 1EJ.
WW313

I.c sockets with integral supply decoupling capacitors as described in September's New Products section are now available in the UK through Dage Eurosem, Rabans Lane, Aylesbury, Bucks HP19 3R9.

www.americanradiohistory.com

Waves

By Ariel

Adding up to a matter of time

The other day I was looking at a 1978 number of *Reader's Digest*. It would have been a more recent issue, but my suppliers – the church jumble sales that abound in our neck of the woods – tend to lag a bit behind W. H. Smith.

I had just finished a captivating piece on the courtship ritual of the pink-eyed okapi when it struck me that *RD* must be all things to all men. It offers tales of adventure on land, sea and air, stories of people triumphing over adversity, word-power tests, jokes, philosophical titbits . . . you name it. What's more, it doesn't take up a lot of room.

Additionally, it carries some of the best ads in the business. One in particular caught my eye. It was for 'a luxury leather briefcase for executives wishing to aspire to company chairman.' Now just you show me the chap with fires of ambition in his belly who could resist such a come-on. I almost succumbed myself.

Certainly it seems that manufacturers of electronic products, too, rate *RD* highly as an advertising medium. The digital watchmen, for instance, were there in strength, each trying to cap the rest. One was rapturizing about a timepiece (which looked a trifle too wrist-spraining for my delicate structure) which embodied no less than six main functions, including an audible signal to mark the passing of every hour on the hour. You could, if you felt the urge, convert it into a stopwatch. But the most confidence-building claim of all was that it was water-tested to 30 metres.

This made me wonder who the advertiser was aiming it. Obviously it wasn't just any old lad on the street who only wants to know how long he has to wait before the pubs open. So just how many people are there around who really need such a detailed monitoring of time? And how many more spend any appreciable time fully or partially immersed in all that H_2O?

Another enterprising merchant went distinctly bananas over his up-market combined digital watch and ballpoint pen. The watch half offered all the usual horological information and was – I was relieved to learn – accurate to within 60 seconds a year. But the pen half was a bit of a let-down: nowhere was there any mention of being able to write with it 30 metres down.

Pocket calculators were, of course, there in profusion, all offering a range of mind-boggling facilities. Again, I wondered (on the whole it was a rather wonderful afternoon) how widely they're actually used. All-in-all I reckon that this mania for personal electronic aids has got a little out of hand. Before the cult developed, the first thing young executives did when settling down to a meeting was to get out their fags and lighters. Now they plonk their calculators down on the deck instead.

The fad, moreover, has not remained confined to the business sector. I've seen housewives toting their instant adders round the supermarket.

I suppose there must have been a similar reaction back in the 6th century when the Chinese came up with their bamboo-rod abacus as an alternative to taking off their socks when they wanted to count up to 20. Or when clocks first gave sundials the big elbow. Nevertheless, I can't help feeling there's an urgent need for sweet reasonableness in these matters. Otherwise things are going to get worse. We may even reach the stage when you're out of date unless you're sporting a combined bath thermometer/pollen counter with a v.d.u. readout – worn on the wrist.

So let's not lose the capability of calculating with the most sophisticated device of all – the human brain. Nor let an obsession with hyper-accurate timing grab us too firmly by the forelock. Neither above the water nor under it.

Credit where credit is due

Can someone please tell me – and there must be a reason – why we have to endure at the end of tv programmes a long list of nearly everybody who has had some part in its making? Hardly a soul is left out. From the man who wrote the script based on an adaptation of the book of the film, to the girl who dabbed powder on the leading lady's damask cheek.

Given that these sycophantic references are necessary, they should at least be comprehensive. One glaring omission is British Telecom. The contribution made by their engineers is basic to every programme, whether it's the late night news or the most star-spangled spectacular.

An outstanding example of BT's role was the coverage of the Royal Wedding. This for BT was a landmark. As well as supporting BBC and ITV, British Telecom provided facilities for 100 foreign tv companies from more than 50 countries. Around 750 miles of cable, 15 microwave links, 80 vision circuits, 168 commentary links and 331 control circuits for tv production staff were provided. In fact, a BT spokesman said the whole operation represented about four months normal working for an o.b. team.

Now then, BBC and ITV, with this splendid example in mind, isn't there the strongest of strong reasons for giving BT an automatic place in your post-programme Hall of Fame?

And if you can get the credit in before the producer's – or at least before the assistant hairdresser's – so much the better.

Tv all around

Sit down for a minute and ponder on how far along the road in tv techniques we've come since the days of Baird's first flickering images.

Thanks to amazingly swift advances in component technology we have sets that are smaller, lighter, simpler to produce, need substantially fewer bits and pieces and virtually no routine adjustments. We have fast warm-up and touch tuning or remote control. Transmitted programmes can be recorded for deferred enjoyment and we can buy tapes (soon discs as well) for reproduction. The news and information services, Ceefax and Oracle, are but a button-push away. We can even link our sets to the telephone and interrogate the Prestel computer.

Direct broadcasting by satellite (d.b.s.) is, so to speak, very much in the air. And to complete the all-encirclement there appears to be a new and growing interest in the potentialities of cable tv.

In the June issue of *WW* I drew attention to the fresh attitudes we shall have to adopt in order to savour the delights of d.b.s. to the full, I also pointed out some of the initial inconveniences involved, like mounting a dish aerial on the roof or finding room for it indoors. The postcard I received from 'Relieved, Bath' convinces me my remarks were worth the making.

So far I haven't made such an in-depth analysis of cable tv, but I can well believe that here, too, there are practical points to consider.

Personally I've always had a mistrust – amounting to plain fear – of things underground. (It probably dates from the days of acting as a burial object for the kids during holidays by the sea.) And while I respect the competence of those on the technical side of cable distribution, I must point out that there are a lot of other people at it as well. The telephone, gas, water and electricity boys, for example.

Now, one of the disadvantages of this underground lark is that you can't see what's going on once you've replaced the earth. So if someone on an offday has done something silly with the various cables, you don't know about it until funny things begin to happen in the house. It would be a bit off-putting, for example, if you turned on the bath tap and got the soundtrack of Bonanza instead of hot water.

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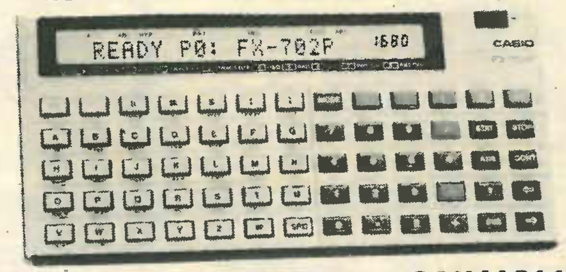

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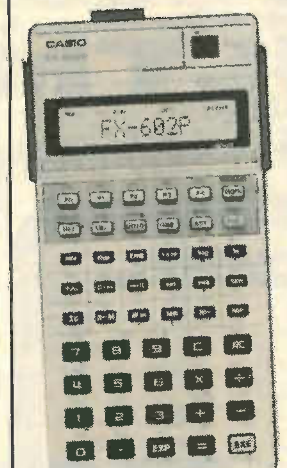

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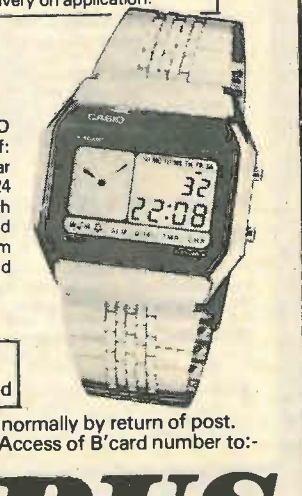

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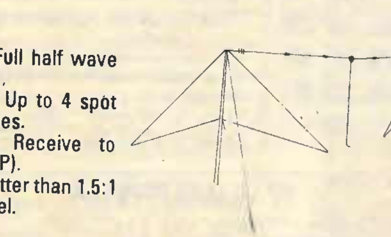
HF ANTENNA

MULTI FREQUENCY TRAP DIPOLES 2-30MHz



★ MODE; Full half wave operation.
★ BANDS; Up to 4 spot frequencies.
★ POWER; Receive to 800W (PEP).
★ SWR; Better than 1.5:1 on channel.

THE SMC TRAPPED DIPOLE ANTENNA
has been developed to satisfy the needs of commerical and military users. It is capable of operation between 2 and 30 MHz on as many as four spot frequencies – each capable of accommodating many channels. Excellent matching and efficiency with a single coaxial feed is offered by the use of SMC H1Q traps and the incorporation of a ferrite balun in a full half wave design. NB: Power absorbing terminating resistors are not employed. The antenna may be deployed using one or two support masts, installation (incorporating SMC light duty portable masts) can be easily effected by two people in half an hour.

Antennas
SMC/TDA/2 2 freq £125, SMC/TDA/3 3 freq £170, SME/TDA/4 PDA.

Complete Installation
2 freq antenna, 2 10m support masts, kit bags, erection equipment £434.
Exact specifications are to customers' requirements.
(Above include 30m UR67, balun etc).

SMC Masts and Towers; cost effective.
Support structures, 250 models available.

★ Tubular aluminium alloy masts 20-60ft.
★ Tubular steel masts 3-4.5" Dia. 20-100ft.
★ Self-supporting, telescopic, fold-over towers 20-60ft.
★ Self-supporting and guyed towers 20-160ft.

SOUTH MIDLANDS COMMUNICATIONS LTD.
OSBORNE ROAD, TOTTON
SOUTHAMPTON SO4 4DN
Telex: 477351 SMCOMM G
Tel: Totton (0703) 867333

WW – 070 FOR FURTHER DETAILS

COMPUTING TODAY: EDUCATING FOR TOMORROW

We look ahead to 1982, Information Technology Year, with a host of features on information handling, processing and storage of all kinds.
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PRESTEL; British Viewdata explained.
NASCOM DISCS; how one reader beat the problems by writing his own disc operating software.
PROGRAMS; we look at statistics, mathematical functions and data storage techniques.
You'll find all this and more in December's Computing Today. The magazine that keeps you in touch with personal computing every month. **ON SALE NOW ONLY 70p.**

HARDWARE .... SOFTWARE .... AT HOME .... IN BUSINESS
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ONLY 70p

WW – 062 FOR FURTHER DETAILS

U.K. RETURN OF POST MAIL ORDER SERVICE, ALSO WORLDWIDE EXPORT SERVICE

BSR DE LUXE AUTOCHANGER £20

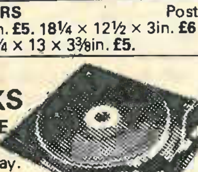
Plays 12", 10" or 7" records, Auto or Manual. A high quality unit backed by BSR reliability. Stereo Ceramic Cartridge. AC 200/250V. Size 13½ × 11¼in. 3 speeds. Above motor board 3¾in. Below motor board 2½in.
Post £2 Board £1 extra

HEAVY METAL PLINTHS Post £2

Cut out for most BSR or Garrard decks. Silver grey finish. Size 16x13¾in. **£4**
DECCA TEAK VENEERED PLINTH. Post £1.50
Superior finish with space and panel for small amplifier. Board is cut for B.S.R. or Garrard. 18¾in. x 14¼in x 4in. Black/silver facia trim. **£5**
Suitable plastic cover £6
WOOD PLINTH, TEAK EFFECT Size 15×15×3in. with board cut for B.S.R. (Post £1) **£3**
PIONEER and J.V.C. TEAK VENEERED PLINTH Post £2
19 × 14½in. with Plastic Cover 17¾ × 13in **£10.50**

TINTED PLASTIC COVERS Post £1.50
Sizes: 14½ × 12½ × 3in. **£5.** 18¼ × 12½ × 3in. **£6**
16¾ × 13 × 4in. **£6.** 14¼ × 13 × 3⅜in. **£5.**

BSR SINGLE PLAYER DECKS



BSR P172 RIM DRIVE QUALITY DECK
Manual or automatic play.
Precision ultra slim arm.
Cueing device. Bargain price
With stereo ceramic cartridge **£20** Post £2
BSR P207 BUDGET SINGLE PLAYER ideal for disco or small two-speed Hi-Fi system with stereo cartridge and cueing device. **£15** Post £2
BSR ready cut mounting board. Only £1 extra.

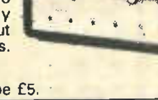
GARRARD 6-200 SINGLE PLAYER DECK
Brushed Aluminium Arm with stereo ceramic cartridge and Diamond Stylus, 3-speeds. Manual and Auto Stop/Start. Large Metal Turntable. Cueing Device and Pause Control. Ready cut mounting board £1 extra. **£20** Post £2

BATTERY ELIMINATOR MAINS to 9 VOLT D.C.
Stabilised output, 9 volt 400 m.a. U.K. made in plastic case with screw terminals. Safety overload cut out. Size 5 x 3¼ x 2½in. Transformer Rectifier Unit. Suitable Radios, Cassettes, models, **£4.50.** Post 65p.

DELUXE SWITCHED MODEL STABILISED VOLTAGES
3-6-7½-9 volt 400ma DC max. Universal output plug and lead. Pilot light, mains switch, polarity switch, **£7.50.** Post 65p.

DRILL SPEED CONTROLLER/LIGHT DIMMER KIT. Easy to build kit. Controls up to 480 watts AC mains, **£3.** Post 65p.
DE LUXE MODEL READY-BUILT 800 watts plus Photo Electric Sunset "On" feature. Front plate fits standard box, **£4.**

ECHO CHAMBER or REVERB



Good quality unit with endless play tape cartridge. Stationary play heads ensure good reproduction and echo variance is achieved by changing tape speed. Input imp: 50k and 600 ohms. Power: 240 volts A.C.
£68. Post £2. Spare tape £5.

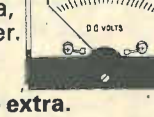
RELAYS, 12V DC **£1.25.** 6V DC **95p.** 18V **£1.25.**
BLANK ALUMINIUM CHASSIS. 6 x 4–**£1.45**; 8 x 6–**£1.80**; 10 x 7–**£2.30**; 12 x 8–**£2.60**; 14 x 9–**£3.00**; 16 x 6–**£2.90**; 16 x 10–**3.20.** All 2½in. deep. 18 swg.
ANGLE ALI. 6 x ¾ x ¾in. 18 swg. **25p.**
ALUMINIUM PANELS, -18swg, 6 x 4–**45p**; 8 x 6–**75p**; 14 x 3–**75p**; 10x7–**95p**; 12 x 8–**£1.10**; 12 x 5–**75**; 16 x 6–**£1.10**; 14x9–**£1.45**; 12 x 12–**£1.50**; 16 x 10–**£1.75.**
PLASTIC AND ALI BOXES IN STOCK. MANY SIZES
ALUMINIUM BOXES. 4 x 4 x 1½ **£1.** 4 x 2½ x 2 **£1.**
3 x 2 x 1 **£1.** 6 x 4 x 2 **£1.60.** 7 x 5 x 3 **£2.40.**
8 x 6 x 3 **£2.50.** 10 x 7 x 3 **£3.** 12 x 5 x 3 **£2.75.**
12 x 8 x 3 **3.60.** All 18swg with lids.
BRIDGE RECTIFIER 200V PIV 2a **£1.** 4a **£1.50.** 8a **£2.50.**
TOGGLE SWITCHES SP **30p.** DPST **40p.** DPDT **50p.**
RESISTORS. 10Ω to 10M. ¼W, ½W, 1W, 1p: 2W **10p.**
HIGH STABILITY. ½w 2% 10 ohms to 1 meg. **8p.**
Ditto 5%. Preferred values, 10 ohms to 10 meg, **3p.**
WIRE-WOUND RESISTORS 5 watt, 10 watt, 15 watt **20p**
PICK-UP CARTRIDGES SONATONE 9TA **£2.50.** 9TAC **£3.80**
BSR Stereo Ceramic SC7 Medium Output **£2.** SC12 **£3.**
PHILIPS PLUG-IN HEAD Stereo Ceramic AU1020 (G306 GP310 - GP233 - AG3306 - AG3310) **£2.**
LOCKTITE SEALING KIT DECCA 118. Complete **£1.**
SOLDERING IRON 240V 40W. 5mm bit **£2.95.**
JACK PLUGS Mono Plastic **25p**; Metal **30p.**
JACK PLUGS Stereo Plastic **30p**; Metal **35p.**
JACK SOCKETS Mono Open **20p**; Closed **25p.**
JACK SOCKETS Stereo Open **25p**; Closed **30p.**
FREE SOCKETS – Cable end **30p.**
2.5mm and 3.5mm **JACK SOCKETS 20p. Plugs 20p.**
DIN TYPE CONNECTORS
Sockets 3-pin, 5-pin **10p.** Free Sockets 3-pin, 5-pin **25p.**
Plugs 3-pin **20p**; 5-pin **25p.**
PHONE PLUGS and SOCKETS ea. **15p.**
Free Socket for cable end **20p.**
Screened Phono Plugs **25p.**
U.H.F. COAXIAL CABLE SUPER LOW LOSS. 25p yd.
COAX PLUGS 20p. COAX SOCKETS 20p.

POTENTIOMETERS Carbon Track
5kΩ to 2MΩ LOG or LIN. L/S **50p.** DP **90p.** Stereo L/S **£1.10.** DP **£1.30.** Edge Pot 5K, SP **45p.**

MINI-MULTI TESTER

Deluxe pocket size precision moving coil instrument. Impedance + Capacity – 2000 o.p.v. Battery included.
11 instant ranges measure:
DC volts 10, 50, 250, 1000.
AC volts 10, 50, 250, 1000.
DC amps 0-100mA.
Continuity and resistance to 1 meg ohms in two ranges.
£6.50 Post 65p
De-Luxe Range Doubler Model, 50,000 o.p.v. **£18.50.** 7 × 5 × 2in. Post £1

NEW PANEL METERS £4



50μa 100μa, 500μa,
1ma, 5ma, 50ma, 100ma,
25 volt, 50 volt, VU Meter.
500ma, 1 amp, 2 amp
Facia 2⅜ × 1¾ × 1½in.
Lighting kit 6 or 12v **90p extra.**
1ma (240° scale) 2¼in. sq. **£5** Post 65p

RCS SOUND TO LIGHT CONTROL KIT
Kit of parts to build a 3 channel sound to light unit 1,000 watts per channel. Suitable for home or disco. **£15** Post 95p
Easy to build. Full instructions supplied. Cabinet **£4.50** extra. Will operate from 200MV to 100 watt signal.
200 Watt Rear Reflecting White Light Bulbs. Ideal for Disco Lights, Edison Screw. 6 for **£4,** or 12 for **£7.50.** Post 65p.

RCS "MINOR" 10 watt AMPLIFIER KIT £14
This kit is suitable for record players, guitars, tape playback, electronic instruments or small PA systems. Two versions available: Mono, **£14**; Stereo, **£20.** Post £1. Specification. 10W per channel; input 100mV; size 9½ × 3 × 2in. approx. SAE details. Full instructions supplied. AC mains powered. Input can be modified to suit guitar.

RCS STEREO PRE-AMP KIT. All parts to build this pre-amp. Inputs for high, medium or low imp. per channel, with volume control and PC Board. Can be ganged to make multi-way stereo mixers **£2.95** Post 65p.

MAINS TRANSFORMERS

		Post
250-0-250V 70mA, 6.5V, 2A	£4.50	£2
250-0-250V 80mA, 6.3V 3.5A, 6.3V 1A	£5.00	£2
350-0-350V 250mA, 6.3V 6a C.T.	£12.00	£2
300-0-300V 120mA, 2×6.3V 2A C.T.; 5V 2A	£10.00	£2
220V 45mA, 6.3V 2A	£2.50	£1

AUTO WOUND 115V to 240V 150W **£9**; 400W. **£11**; 500W. **£12** £2

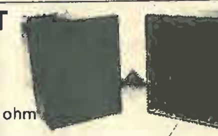
GENERAL PURPOSE LOW VOLTAGE
Tapped outputs available

2 amp. 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 25 and 30V	£6.00	£2
1 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£6.00	£2
2 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£9.50	£2
3 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£12.50	£2
5 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£16.00	£2

5-8-10-16V. ½ amp.	£2.50	80p	15-0-15V 2 amps	£3.75	£1
6V ½ amp.	£2.00	£1	17-0-17V 2 amps	£4.50	£2
6-0-6V. 1½ amps	£3.50	£1	18V 6a Twice	£11.00	£2
9V 250ma.	£1.50	80p	20V 1 amp	£3.00	£1
9V 3 amp.	£3.50	£1	20-0-20V 1 amp	£3.50	£1
9-0-9V 50ma	£1.50	80p	20-40-60V 1 amp	£4.00	£2
10-0-10V 2 amps	£3.00	£1	25-0-25V 2 amps	£4.50	£1
10-30-40V 2 amps	£3.50	£1	28V 1 amp Twice	£5.00	£2
12V 100ma	£1.50	80p	30V 1½ amp	£3.50	£1
13V 750ma	£2.00	80p	30V 5 amp and 17-0-17V 2a	£4.50	£2
12V 3 amps	£3.50	£1	35V 2 amps	£4.00	£1
12-0-12V 2 amps	£3.50	£1			

CHARGER TRANS	Post	RECTIFIERS	Post
6-12 volt 3a	£4.00+£2	6-12 volt 2a	£1.10+80p
6-12 volt 4a	£6.50+£2	6-12 volt 4a	£2.00+80p

OPUS COMPACT SPEAKERS



FLUTED WOOD FRONTS
TEAK VENEERED CABINET
11×8½×7in 15 watts
50 to 14,000 cps. 4 ohm or 8 ohm
£20 pair Post £2

LOW VOLTAGE ELECTROLYTICS ALL 10p
1 mf, 2 mf, 4 mf, 8 mf, 10 mf, 16 mf, 25 mf, 30 mf, 50 mf, 100 mf, 250 mf. All 15 volts. 22 mf/6v/10v; 25 mf/6v/10v; 47 mf/10v; 50 mf/6v; 68 mf/6v/10v/16v/25v; 100 mf/10v; 150 mf/6v/10v; 200 mf/10v/16v; 220 mf/4v/10v/16v; 330 mf/4v/10v; 500 mf/6v; 680 mf/6v/10v/16v; 1000 mf/2.5v/4v/10v; 1500 mf/6v/10v/16v; 2200 mf/6v/10v; 3300 mf/6v; 4700 mf/4v. **ALL 10p.**
500mF 12V **15p**; 25V **20p**; 50V **30p.**
1000mF 12V **20p**; 25V **35p**; 50V **50p**; 100V **70p.**
2000mF 6V **25p**; 25V **42p**; 40V **60p**; 1200mF 76V **80p.**
2500mF 50V **70p**; 3000mF 50V **65p**; 2000mF 100V **£1.20.**
4500mF 64V **£2.** 4700mF 63V **£1.20.** 2700mF/76V **£1.**

HIGH VOLTAGE ELECTROLYTICS

8/450V	45p	8+8/450V	75p	32+32+16/350V	90p
8/800V	£1.20	8+16/450V	75p	100+100/275V	65p
16/350V	45p	20+20/450V	75p	150+200/275V	70p
32/500V	75p	32+32/350V	50p	220/450V	95p
32/350V	50p	32+32/500	£1.80	80+40/500V	£2
50/500V	£1.20	50+50/300V	50p		

VALVE OUTPUT Transformers (small) **90p.**
TRIMMERS 10pF, 30pF, 50pF, **5p.** 100pF, 150pF, **15p.**
CAPACITORS Various 10pf to 100,000pf **5p.**
PAPER 350V-0.1 **7p**; 0.5 **13p**; 1mF 150V **20p**; 2mF 150V **20p**; 500V-0.001 to 0.05 **12p**; 0.1 **15p**; 0.25 **25p**; 0.47 **35p.**
MICRO SWITCH SINGLE POLE CHANGEOVER 30p.
SUB-MIN MICRO SWITCH, 30p. Single pole changeover.
TWIN GANG, 120pF **50p**: 500pF **£1.**
GEARED TWIN GANGS 25pF **95p.** 365pF **£1.**
GEARED 365 + 365 + 25 + 25pF **£1.**
TRANSISTOR TWIN GANG. Japanese Replacement **50p.**
NEON PANEL INDICATORS 250V 30p.
ILLUMINATED ROCKER SWITCH. Single pole. Red **65p.**
CASSETTE MONO REPLAY. Complete working **£12.50**
CASSETTE MOTOR. 6 volt **£1**
CASSETTE MECHANISM. 6 or 12v Stereo Heads **£5**

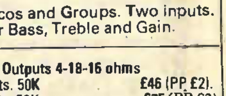
NEW baker Star sound

high power full range quality loudspeakers produced to give exceptional reproduction. Ideal for Hi-Fi, music P.A. or discotheques. These loudspeakers are recommended where high power handling is required with quality results. The high flux ceramic magnet ensures clear response.

MODEL	INCHES	OHMS	WATTS	TYPE	PRICE	POST
MAJOR	12	4-8-16	30	HI-FI	£14	£2
DELUXE MK II	12	8-16	15	HI-FI	£14	£2
SUPERB	12	8-16	30	HI-FI	£24	£2
AUDITORIUM	12	8-16	45	HI-FI	£22	£2
AUDITORIUM	15	8-16	80	HI-FI	£34	£2
GROUP 45	12	4-8-16	45	PA	£14	£2
GROUP 75	12	4-8-16	75	PA	£22	£2
GROUP 100	12	8-16	100	PA	£24	£2
GROUP 100	15	8-16	100	PA	£32	£2
DISCO 100	12	8-16	100	DISCO	£24	£2
DISCO 100	15	8-16	100	DISCO	£32	£2

BAKER 150 WATT MIXER/POWER AMPLIFIER £89 Post £2 **SLAVE VERSION £75**
For Organs, Discotheque, Vocal, Public Address. Three loudspeaker outlets for 4, 8 or 16 ohms. Four high gain inputs, each 20 mv, 50K ohm. Individual volume controls "Four channel" mixing. 150 watts into 8 ohms R.M.S. Music Power. Distortion less than 1%. Slave output 500 M.V. 25K.ohm. Frequency Response 25 Hz – 20kHz ± 3dB. Integral Hi-Fi preamp separate Bass & Treble. Compact – 16" x 8" x 5½". Lightweight – 14lb: Master volume control. Made in England. 12 months' guarantee. 200/250v A.C. mains or 120V to order. All transistor and solid state devices. 100 Volt Line £15 extra.
BAKERS NEW PA150 MICROPHONE PA AMPLIFIER £129. Post £3
4 channel 8 inputs, dual impedance, 50K-600 ohm 4 channel mixing, volume, treble, bass. Presence controls, Master volume control, echo/send/return sockets. Slave input/output sockets. 4/8/16 ohm.

BAKER 50 WATT AMPLIFIER



£69 Post £2
Ideal for Halls/PA systems, Discos and Groups. Two inputs. Mixer, Volume Controls, Master Bass, Treble and Gain.

RCS offers MOBILE PA AMPLIFIERS. Outputs 4-18-16 ohms
20-watt RMS 12v DC, AC 240v, 3 inputs. 50K £46 (PP £2).
40-watt RMS 12v DC, AC 240v, 4 inputs. 50K £75 (PP £2)
Mic 1; Mic 2; Phono, aux. outputs 4 or 8 or 16 and 100-line.
60-watt RMS, Mobile 24 volt DC & 240-volt AC mains. inputs 50K. 3 mics + 1 music. Outputs 4-8-16 ohm + 100 volts line £95 (PP £2).

FAMOUS LOUDSPEAKERS "SPECIAL PRICES"

MAKE	MODEL	SIZE	WATTS	OHMS	PRICE	POST
SEAS	TWEETER	4in	50	8	£7.50	£1
GOODMANS	TWEETER	3½in	25	8	£4.00	£1
AUDAX	TWEETER	3¾in	60	8	£10.50	£1
SEAS	MID-RANGE	4in	50	8	£7.50	£1
SEAS	MID-RANGE	5in	80	8	£12.00	£1
SEAS	MID-RANGE	4½in	100	8	£12.50	£1
GOODMANS	FULL-RANGE	5½in	15	8	£6.50	£1
GOODMANS	FULL-RANGE	8in	30	8	£12.50	£1
GOODMANS	AUDIOM 8p	8in	15	15	£8.50	£1
SEAS	WOOFER	8in	30	8	£14.00	£2
CELESTION	DISCO	10in	20	8/16	£11.50	£2
CELESTION	DISCO	10in	60	8/16	£21.50	£2
RIGONDA	GENERAL	10in	15	8	£5.50	£2
GOODMANS	AUDIOM PG	12in	60	8	£20.00	£2
GOODMANS	PP12	12in	75	8/15	£24.50	£2
GOODMANS	AUDIOM P	12in	50	8/15	£20.00	£2
GOODMANS	GR12	12in	90	8/15	£27.50	£2
EMI	HI-FI	13x8	10	3/8	£9.50	£1

CROSSOVERS. TWO-WAY 3000 c/s 3 or 8 or 15 ohm **£1.90.** 3-way 950 cps/3000 cps. 20 watt rating. **£2.20.** 3 way 60 watt **£6.**
LOUDSPEAKER BARGAINS
3 ohm, 4in, 5in, 7×4in, **£1.50**; 6½in, 8×5in, **£3**; 8in, **£3.50.**
8 ohm, 2⅝in, 3in, 5in, **£1.50**; 6½in, **£3**; 8in, **£4.50**; 12in, **£6.**
15 ohm, 3½in, 5×3in, 6×4in, **£1.50.**
25 ohm, 3in, 5×3in, 7×4in, **£1.50. 120 ohm,** 3¼in dia. **£1.**

MOTOROLA PIEZO ELECTRIC HORN TWEETER, 3⅜ square £5.00
100 watts. No crossover required 4-8-16 ohm, 7⅜ × 3⅛ £10.50

SPEAKER COVERING MATERIALS. Samples Large S.A.E.
B.A.F. LOUDSPEAKER CABINET WADDING 18in wide **25p** ft.

THE "INSTANT" BULK TAPE ERASER

Suitable for cassettes, and all sizes of tape reels. AC mains 200/250V. Hand held size with switch and lead (120 volt to Order).
Will also demagnetise small tools
£9.50 Post 95p
Head Demagnetiser only £5

RADIO COMPONENT SPECIALISTS

337 WHITEHORSE ROAD, CROYDON
Open 9-6. Closed all day Wed. Open Sat. 9-5.

Radio Books and Components Lists 28p stamps. (Minimum post/packing charge 65p.) Access or Barclaycard Visa. Please Tel: 01-684 1665 for same day despatch. Cash prices include VAT.

www.americanradiohistory.com

VALVES

Minimum Order £1

VALVES VAT IS INCLUDED

A1065 1.40
A2293 8.80
A2900 9.20
AR8 0.75
ARP3 0.70
ATP4 0.60
B12H 3.90
CY31 1.40
DAF96 0.70
DET22 26.95
DF96 0.70
DH76 0.75
DL92 0.60
DY86/87 0.65
DY802 0.70
E55L 14.90
E88CC 1.60
E88CC/01 3.10
E92CC 1.20
E180CC 2.80
E180F 6.30
E182CC 4.95
EA76 2.25
EABC80 0.60
EB91 0.60
EBC33 1.15
EBC90 0.90
EBF80 0.60
EBF83 0.60
EBF89 0.80
EC52 0.65
EC91 4.40
EC92 0.85
ECC81 0.65
ECC82 0.60
ECC83 0.65
ECC84 0.60
ECC85 0.60
ECC86 1.70
ECC88 0.80
ECC189 0.95
ECC804 0.90
ECF80 0.85
ECF82 0.65
ECF801 1.05
ECH34 2.25
ECH35 1.70
2.10*
ECH42 1.20
ECH81 0.70
ECH84 0.80
ECL80 0.70
ECL82 0.75
ECL83 1.40
ECL85 0.80
ECL86 0.90
EF37A 2.15
EF39 1.80
EF80 0.65
EF83 1.75
EF85 0.60
EF86 0.75
EF89 1.05
EF91 1.50
2.90*
EF92 1.80
EF95 0.60
EF96 0.60
EF183 0.80
EF184 0.80
EF812 0.75
EFL200 1.85
EH90 0.85
EL32 1.10
EL34 1.80
2.90*
EL37 4.40
EL81 2.45
EL82 0.70
EL84 0.80
EL86 0.95
EL90 1.00
EL91 4.20
EL95 0.80
EL504 1.70
EL803 5.90

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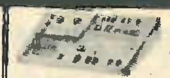

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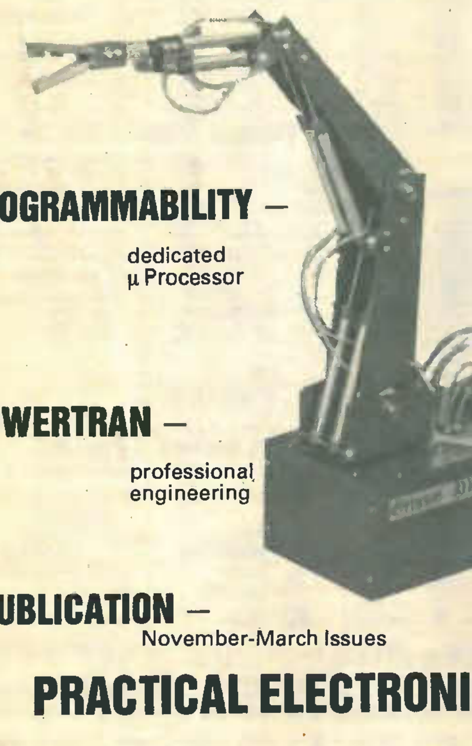

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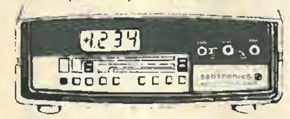

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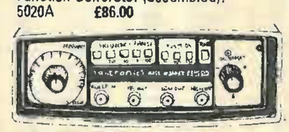

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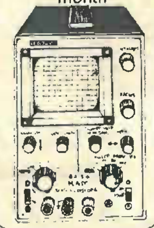

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	1X012	12+12	1 25		
	1X013	15+15	1 00		
	1X014	18+18	0 83		
	1X015	22+22	0 68		
	1X016	25+25	0 60		
	1X017	30+30	0 50		
50 VA 80×35mm 0 9 Kg Regulation 13%	2X010	6+6	4 16	£5 83 +£1 10 P/P	£4 93 +£1 10 P/P
	2X011	9+9	2 77		
	2X012	12+12	2 08		
	2X013	15+15	1 66		
	2X014	18+18	1 38		
	2X015	22+22	1 13		
	2X016	25+25	1 00		
	2X017	30+30	0 83		
	2X028	110	0 45		
	2X029	220	0 22		
	2X030	240	0 20		
80 VA 90×30mm 1 Kg Regulation 12%	3X010	6+6	6 64	£6 51 +£1 43 P/P	£5 47 +£1 43 P/P
	3X011	9+9	4 44		
	3X012	12+12	3 33		
	3X013	15+15	2 66		
	3X014	18+18	2 22		
	3X015	22+22	1 81		
	3X016	25+25	1 60		
	3X017	30+30	1 33		
	3X028	110	0 72		
	3X029	220	0 36		
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120 VA 90×40mm 1 2 Kg Regulation 11%	4X010	6+6	10 00	£7 55 +£1 43 P/P	£6 38 +£1 43 P/P
	4X011	9+9	6 66		
	4X012	12+12	5 00		
	4X013	15+15	4 00		
	4X014	18+18	3 33		
	4X015	22+22	2 72		
	4X016	25+25	2 40		
	4X017	30+30	2 00		
	4X018	35+35	1 71		
	4X028	110	1 09		
	4X029	220	0 54		
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160 VA 110×40mm 1 8 Kg Regulation 8%	5X011	9+9	8 89	£9 92 +£1 43 P/P	£8 44 +£1 43 P/P
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	5X013	15+15	5 33		
	5X014	18×18	4 44		
	5X015	22+22	3 63		
	5X016	25+25	3 20		
	5X017	30+30	2 66		
	5X018	35+35	2 28		
	5X026	40+40	2 00		
	5X028	110	1 45		
	5X029	220	0 72		
	5X030	240	0 66		

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	6X014	18+18	6 25		
	6X015	22+22	5 11		
	6X016	25+25	4 50		
	6X017	30+30	3 75		
	6X018	35+35	3 21		
	6X026	40+40	2 81		
	6X025	45+45	2 50		
	6X033	50+50	2 25		
	6X028	110	2 04		
	6X029	220	1 02		
	6X030	240	0 93		
300 VA 110×50mm 2 6 Kg Regulation 6%	7X013	15+15	10 00	£13 67 +£1 73 P/P	£11 66 +£1 73 P/P
	7X014	18+18	8 33		
	7X015	22+22	6 82		
	7X016	25+25	6 00		
	7X017	30+30	5 00		
	7X018	35+35	4 28		
	7X026	40+40	3 75		
	7X025	45+45	3 33		
	7X033	50+50	3 00		
	7X028	110	2 72		
	7X029	220	1 36		
	7X030	240	1 25		
500 VA 140×60mm 4 Kg Regulation 4%	8X016	25+25	10 00	£18 17 +£2 05 P/P	£15 53 +£2 05 P/P
	8X017	30+30	8 33		
	8X018	35+35	7 14		
	8X026	40+40	6 25		
	8X025	45+45	5 55		
	8X033	50+50	5 00		
	8X042	55+55	4 54		
	8X028	110	4 54		
	8X029	220	2 27		
	8X030	240	2 08		
625 VA 140×75mm 5 Kg Regulation 4%	9X017	30+30	10 41	£25 10 +£2 20 P/P	£21 54 +£2 20 P/P
	9X018	35+35	8 92		
	9X026	40+40	7 81		
	9X025	45+45	6 94		
	9X033	50+50	6 25		
	9X042	55+55	5 68		
	9X028	110	5 68		
	9X029	220	2 84		
	9X030	240	2 60		

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DIN 41612 2 × 32 Way	300p	350p
2 × 32 Way (rt angled)		400p

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40 Way	525p	370p	
50 Way	575p	450p	

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74194	70p	74LS540	135p
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74196	60p	74LS670	170p
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74198	100p		
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TIP29C 55p
TIP30A 48p
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TIP31C 62p
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2N2907A 30p
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2N3053 40p
2N3054 65p
2N3055 48p
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(as described in "P.C.W." Oct. '81)

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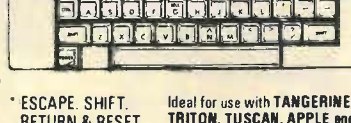

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2N3553	1.09	2N5071	12.10	BLX65	1.67	BLY55	9.40
2N3632	6.03	2N5090	8.44	BLX66	4.91	BLY83	7.45
2N3733	6.13	2N5102	9.44	BLX67	5.41	BLY84	7.25
2N3866	0.92	2N5590	7.85	BLX68	7.29	BLY85	6.02
2N3924	1.66	2N5591	10.21	BLX69X	21.15	BLY87A	6.43
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2N4429	9.89	2N6082	10.17	BLY33	1.87	BLY91C	6.90
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HY 60	30w/4-8Ω	0.015%	<0.006%	±25±30	76×68×40	240	£9.58	£8.33
HY 120	60w/4-8Ω	0.01%	<0.006%	±35±40	120×78×40	410	£20.10	£17.48
HY 200	120w/4-8Ω	0.01%	<0.006%	±45±50	120×78×50	515	£24.39	£21.21
HY 400	240w/4Ω	0.01%	<0.006%	±45±50	120×78×100	1025	£36.60	£31.83

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Model No.	Output power Watts rms	T.H.D.	I.M.D.	Supply voltage	Size mm	Wt gms	Price inc. VAT	Price ex. VAT
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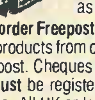
HD 200	120w/4-8Ω	0.01%	<0.006%	±45±50	120×78×60	620	£31.49	£27.38
HD 400	240w/4Ω	0.01%	<0.006%	±45±50	120×78×100	1025	£44.42	£38.63

HEAVY DUTY without heatsinks

Model No.	Output power Watts rms	T.H.D.	I.M.D.	Supply voltage	Size mm	Wt gms	Price inc. VAT	Price ex. VAT
HD 120P	60w/4-8Ω	0.01%	<0.006%	±35±40	120×26×50	265	£22.82	£19.84
HD 200P	120w/4-8Ω	0.01%	<0.006%	±45±50	120×26×50	265	£27.17	£23.63
HD 400P	240w/4Ω	0.01%	<0.006%	±45±50	120×26×70	375	£39.42	£34.28



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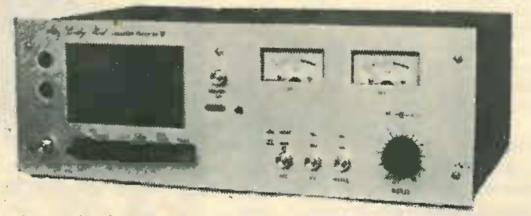
LINSLEY HOOD CASSETTE RECORDER 2



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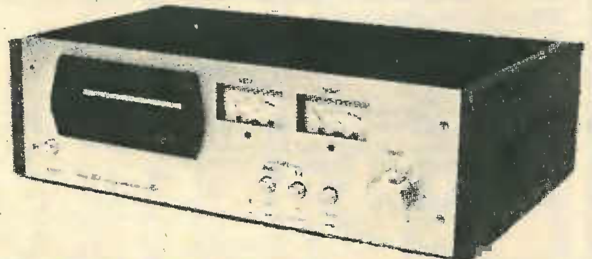
This latest version has the following extra features: Ultra low wow-and-flutter of .09% – easily meets DIN Hi-Fi spec. Deck controls latch in rewind modes and do not have to be held. Full Auto-stop on all modes. Tape counter with memory rewind. Oil damped cassette door. Latching record button for level setting. Dual concentric input level controls. Phone output. Microphone input facility if required. Record interlock prevents rerecording on valued cassettes. Frequency generating feedback servo drive motor with built-in speed control for thermal stability. All these desirable and useful features added to the excellent design of the Linsley-Hood circuits and the quality of the components used makes this new kit comparable with built-up units of much higher cost than the modest, **£94.90** + V.A.T. we ask for the complete kit.

LINSLEY-HOOD CASSETTE RECORDER 1



We are the Designer Approved suppliers of kits for this excellent design. The Author's reputation tells all you need to know about the circuitry and Hart expertise and experience guarantees the engineering design of the kit. Advanced features include: High-quality separate VU meters with excellent ballistics. Controls, switches and sockets mounted on PCB to eliminate difficult wiring. Proper moulded escutcheon for cassette aperture improves appearance and removes the need for the cassette transport to be set back behind a narrow finger trapping slot. Easy to use, robust Lenco mechanism. Switched bias and equalisation for different tape formulations. All wiring is terminated with plugs and sockets for easy assembly and test. Sophisticated modular PCB system gives a spacious, easily-built and tested layout. All these features added to the high-quality metalwork make this a most satisfying kit to build. Also included at no extra cost is our latest HS 16 Sendus Alloy super head, available separately at **£8.20** but included free with the complete kit at **£75** plus VAT.
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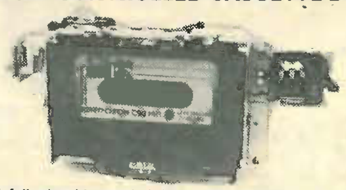

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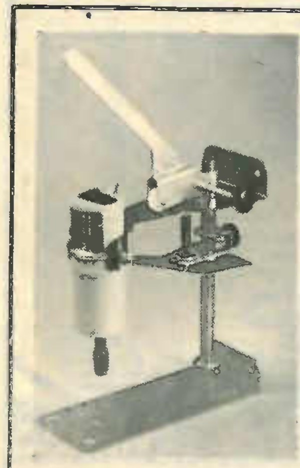

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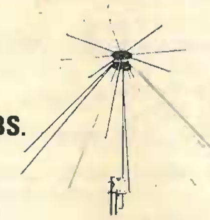

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RECEIVER UNIT R278 ground Mil UHF Rx 225/400Mc/s in 1750 chan. any 10 of these plus 1 service chan. can be selected from front of Rx triple conv. Rx uses 38 crystals, no ext. crystal req., for use on 230v 600 ohm 2 watt O/P with handbook for 19" rack mt. about 50Kg **£87.** PAN & TILT HEADS for 230v 360' pan 90' tilt HD for o/s use **£35.** RADIOSONDE UNITS MK. 2 3 valves unit Tx on 27Mc/s meas. Temp, Press, RH. new cond. with chart & circ. **£6.50.** also type M.60 more modern at **£12.50.** RADAR T.S. Q Band combination TS with W.M. 33/37 Gz, Tunable Klystron High power, Wattmeter, CW, Pulse or FM O/P as 3 WG swts. note 400c I/P **£85.** Sig. Gens CT480 X Band **£85,** CT538 C Band **£115,** UHF Glide Slope Sig. Gen. UHF 329/335Mc/s **£55.** X Band Spec. Analyzer Head unit with 2x Bal. Mixers, Atten. Waveguide Swt., Tunable filter, selection of WG.16 parts etc. **£85.** COAX RELAYS min. type 50 ohm 24v with conn. **£5.** TRANS AUTO 200/250v to 115v 560 watt enclosed **£14.50.** HT Trans. 230v to 1500-0-1500 at 750Ma **£25.** CT373 Audio bench TS 17c/s to 170Kc, Osc., Dist. meas. set & VTVM new cond. 240v **£80.** BATTERIES Nick. Cad. Type in 6v 550 Ma/Hr. at **£4.50** & 12v 550Ma/Hr. at **£6.50** both tubular type new. STANDARD CELLS Muirhead 1.01859 volts **£5.75.** HELIPOT DIALS Colvern 10 Tr. **£1.50.** Beckman 15 Tr. **£2.50.** DECCA NAV. Bench sig. gen. with freq. change ass **£115.** DRIFT RECORDERS old WW.2 A/C item **£12.50,** also G.P.I. Mk. 1c **£10.50.** MIKES FIST TYPE ex Navy nom. 25 ohm with press to talk swt. dynamic noise cancelling with ext. cord. **£3.80.** POWER UNITS Plessey 200/250v I/P reg O/P 28v DC at 15 amps made to run A/C RT units complete in case most have faulty control reactors (spare available) **£38** also C trans. from these with rect. **£25.** REC TAPE by Ampex 3600 ft. on 10½" SPOOLS ¼" Mil. Spec. new **£7.50.** HEAT & LIGHT UNITS 115v 500 watt 7" dia. new 2 for **£5.40.** BLOWERS H.D. type single ended 240v outlet 2½"x3½" new **£11.50.** BULK TAPE ERASERS for BCC A/Port recorders 230v **£65.** RF WATT METERS part of I.LS test equip. 75 ohm 0/60 watt **£12.50.**

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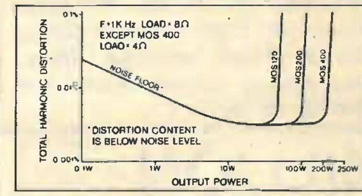

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Frequency response, all models 15Hz-50kHz-3db

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Model No.	Output power Watts rms	DISTORTION T.H.D. Typ at 1kHz	DISTORTION I.M.D. 50Hz/7kHz 4:1	Supply voltage Typ/Max	Size mm	Wt gms	Price inc. VAT	Price ex. VAT
MOS 120	60w/4-8Ω	<0.005%	<0.006%	±45±50	120×78×40	420	£29.76	£25.88
MOS 200	120w/4-8Ω	<0.005%	<0.006%	±55±60	120×78×80	850	£38.48	£33.46
MOS 400	240w/4Ω	<0.005%	<0.006%	±55±60	120×78×100	1025	£52.20	£45.39

MOSFET Ultra-Fi without heatsinks

Model No.	Output power Watts rms	DISTORTION T.H.D. Typ at 1kHz	DISTORTION I.M.D. 50Hz/7kHz 4:1	Supply voltage Typ/Max	Size mm	Wt gms	Price inc. VAT	Price ex. VAT
MOS 120P	60w/4-8Ω	<0.005%	<0.006%	±45±50	120×26×40	215	£26.82	£23.32
MOS 200P	120w/4-8Ω	<0.005%	<0.006%	±55±60	120×26×80	420	£32.81	£28.53
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HY 66	Stereo pre-amp	Two channels, with inputs for mic/mag. cartridge/tape/tuner/auxiliary, with volume/bass/treble/balance.	20 mA	£14.02	£12.19
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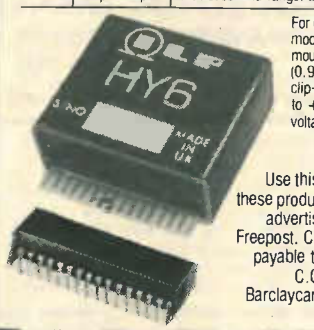

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4049	27p
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4503	65p
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74LS03	13p
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74LS30	14p
74LS32	14p
74LS38	16p
74LS42	39p
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74LS75	29p
74LS86	36p
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74LS93	38p
74LS107	40p
74LS112	70p
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74LS125	29p
74LS132	50p
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7912	12V	58p
	100mA	
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	500mA	
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79MO5	5V	62p
723		32p

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16 pin	14p
14 pin	12p
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HM 6116-3 (16K 150ns)	£15.50	£15.25

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6504	£7.25	8085A	£6.45
6802	£5.70	Z80	£4.00
6809	£15.00	Z80A	£5.85

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6520	£3.10	Z80 CTC	£4.25
6522	£5.55	Z80 PIO	£4.25
6532	£7.70	Z80ACTC	£5.40
6810	£2.50	Z80APIO	£5.40
6821	£1.90	Z80DMA	£14.95
6845	£15.00	Z80ADMA	£18.00
6850	£1.90	Z80S10/0	£17.50
6852	£3.25	Z80AS10/0	£22.50
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8216	£1.75	Z80AS10/1	£22.50
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MK3886 2½ meg. £19.50
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12/24V RANGE PRI 220/240V
SEC: 0 12V 0V 12V

TYPE	AMPS 12v	AMPS 24v	PRICE £	P/P £
242	0.3	0.15	1.70	0.40
213	10.50		2.65	0.87
71	2	1	2.77	1.10
18	4	2	3.98	1.43
68	3	1.5	3.46	1.43
85	5	2.5	6.06	1.43
70	6	3	6.67	1.43
108	8	4	8.03	1.43
72			8.66	1.73
116	12	6	9.31	1.90
17	16	8	11.46	2.05
115	20.10		13.69	2.05
187	30.15		19.23	2.35
232	40	20	27.61	4.50
226	60	30	35.35	4.00

15/30V RANGE PRI 220/240V
SEC: 0V 12V 15V 0V 5V 9V 15V
VOLTS AVAILABLE 3 ⟹ 15 — 0 — 15

TYPE	AMPS 15v	AMPS 30v	PRICE £	P/P £
112	1	0.50	2.84	1.10
79	2	1.0	3.29	1.10
3	4	2	6.18	1.43
20	6	3	7.19	1.73
21	8	4	8.52	1.73
51	10	5	10.57	1.90
117	12	6	11.94	2.05
88	16	8	16.14	2.20
89	20	10	18.54	2.35
90	24	12	20.57	2.55
91	30	15	23.63	2.65
92	40	20	33.21	4.50

25/50V RANGE PRI 120/220/240V
SEC: 0V 20V 25V 0V 8V 15V 25V
VOLTS OUT 5 ⟹ 25 — 0 — 25

TYPE	AMPS 25v	AMPS 50v	PRICE £	P/P £
102	1	0.50	3.29	1.43
103	2	1.0	4.09	1.43
104	4	2	7.65	1.73
105	6	3	9.09	1.90
106	8	4	12.24	1.90
107	12	6	16.15	2.20
118	16	8	22.46	2.55
119	20	10	27.05	2.55
109	24	12	32.44	3.50

30/60V RANGE PRI 120/220/240V
SEC: 0V 24V 30V 0V 10V 18V 30V
VOLTS 6 ⟹ 30 — 0 — 30

TYPE	AMPS 30v	AMPS 60v	PRICE £	P/P £
124	1	0.5	3.30	1.43
126	2	1	6.36	1.43
127	4	2	7.86	1.73
125	6	3	11.78	1.90
123	8	4	14.72	2.20
40	10	5	17.10	2.20
120	12	6	19.44	2.35
121	16	8	27.70	2.65
122	20	10	32.05	4.00
189	24	12	37.02	5.00

48/96V RANGE PRI 120/220/240V
SEC. 0V 36V 48V 0V 36V 48V
VOLTS 12 ⟹ 48 — 0 — 48

TYPE	AMPS 48v	AMPS 96v	PRICE £	P/P £
430	1	0.5	4.69	1.43
431	2	1	7.84	1.43
432	4	2	12.94	2.05
433	6	3	14.62	2.20
434	8	4	20.04	2.45
435	10	5	28.75	2.65
436	12	6	36.16	4.00
437	16	8	39.47	4.60

AUTOTRANSFORMERS 240/220 – 115V
65VA — 10 KVA
0V 115V 220V 240V

TYPE	VA	PRICE	P/P
25	65	3.90	1.10
64	80	4.62	1.10
4	150	6.21	1.43
69	250	7.54	1.43
53	350	9.73	1.90
67	500	11.70	2.20
83	750	13.51	2.05
84	1000	18.31	2.35
95	2KVA	34.36	5.00
73	3	64.74	5.00
57	5	97.85	6.50
101	10	179.05	10.00

CASED AUTOTRANSFORMERS
240V LEAD IN: 115V 2 PIN SOCKET OUT

TYPE	VA	PRICE £	P/P £
56W	20	6.60	0.87
64W	80	8.43	1.43
4W	150	10.86	1.73
69W	250	13.17	1.90
67W	500	20.46	2.20
84W	1000	30.24	2.55
95W	2000	54.83	5.00
73W	3000	78.67	6.50

LINE ADJUSTMENT AUTOTRANSFORMERS
0 200 210 220 230 240 250

TYPE	VA	PRICE £	P/P £
415C	50	2.31	0.87
416C	100	3.46	0.87
417C	200	4.00	1.10
418F	350	6.26	1.43
419F	500	6.74	1.73
420E	750	8.33	1.90
421F	1000	11.64	2.05

MAINS ISOLATORS (SAFETY SCREEN)
PRI 120/220/240V SEC 60V 55V 0V 55V 60V 60V 55V 0V 55V 60V

TYPE	VA	PRICE £	P/P £
149F	60	8.40	1.73
150F	100	9.71	1.73
151F	200	13.84	2.05
152F	250	16.69	2.20
153F	350	20.77	2.55
154F	500	26.03	2.65
155F	750	36.75	5.00
156F	1000	47.42	6.00

MAINS ISOLATORS (SAFETY SCREEN)
PRI 380/415/460V SEC 60V 55V 0V 55V 60V 60V 55V 0V 55V 60V

TYPE	VA	PRICE £	P/P £
243F	60	8.40	1.43
244F	100	9.76	1.73
245F	200	13.93	2.05
246F	250	16.69	2.20
247F	350	20.77	2.55
248F	500	26.03	2.65
249F	750	36.75	5.00
250F	1000	47.42	6.00

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LM311H High Perf. Volt. Comparator	£1.00
LM384N, 5-watt Amp	£1.20
LM393N Dual Com.	60p
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MINIATURE HIGH-QUALITY FANS "Whisper Model" by Rotron. Low-power consumption (less than 10 watts). Silent running. 115v. (two in series for 230v.). 50/60Hz. Size 4½ × 4½ × 1½in. ONLY £6.50 EACH. incl. V.A.T. BRAND NEW. 50% less than manufacturer's price.

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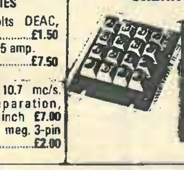

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16 pin	.10	.096	.085	.091	.078	.07
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20 pin	.14	.126	.113	.12	.10	.092
22 pin	.15	.135	.12	.143	.122	.111
24 pin	.15	.135	.12	.146	.132	.116
28 pin	.16	.145	.125	.155	.14	.12
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Model No.	Module	What it does	Current required	Price inc. VAT	Price ex. VAT
HY 7	Mono mixer	Mixes eight signals into one.	10 mA	£5.92	£5.15
HY 8	Stereo mixer	Two channels, each mixing five signals into one.	10 mA	£7.39	£6.25
HY 11	Mono mixer	Mixes five signals into one — with base/treble controls.	10 mA	£8.11	£7.50
HY 68	Stereo mixer	Two channels, each mixing ten signals into one.	20 mA	£9.14	£7.95
HY 74	Stereo mixer	Two channels, each mixing five signals into one — with treble and bass controls.	20 mA	£13.17	£11.45

AND OTHER EXCITING NEW MODULES

Model No.	Module	What it does	Current required	Price inc. VAT	Price ex. VAT
HY 13	Mono VU meter	Programmable gain/LED overload driver.	10 mA	£6.84	£5.95
HY 67*	Stereo head-phone driver	Will drive stereo headphones in the 4 ohm-2K ohm range.	80 mA	£14.20	£12.35
HY 72	Voice operated stereo fader	Provides depth/delay effects.	20 mA	£15.07	£13.10
HY 73	Guitar pre-amp	Handles two guitars (bass and lead) and mic with separate volume/bass/treble and mix.	20 mA	£14.09	£12.25
HY 76	Stereo switch matrix	Provides two channels, each switching one of four signals into one.	20 mA	To be announced	
HY 77	Stereo VU meter driver	Programmable gain/LED overload driver.	20 mA	£10.64	£9.25

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Typical Gain	: 25 dB
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Input Socket	: 50 Ohm 'N' Type
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240v 0.3A rpm 2,800 cont. rated, 14 blade fan. Brand new, boxed with 2.5 MFD capacitor. £7.50. P&P £2 + VAT £1.43.

WW – 090 FOR FURTHER DETAILS

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PRINTER BARGAINS

ICL Terminet Letter Printers.
These are high quality impact printers, not matrix, that cost over £1,500.
★ Micro-controlled intelligent printers
★ ACSII Upper and lower case, RS232 input
★ 10, 30 or 60 ch/sec selectable
★ Whisper quiet band mechanism
★ Print quality like a good electric typewriter
★ Attractive aluminium case.
Sold in good condition fully tested for the ridiculous price of £170!

CENTRONICS 101A MATRIX PRINTERS
Now available at a fraction of original cost — these heavy duty printers are the industry standard and will print at 165 cps for 24 hours a day. Standard parallel interface. Fully overhauled £250

DATAPRODUCTS 2230 LINE PRINTERS
For the professional user who wants the very best and fastest — printing at 300 lines/minute these world-famous line printers are used by nearly all the large computer companies. These units cost around £8,000 and are in perfect condition, only a few years old £950

QUME SPRINT 55 DAISY WHEEL
These need no introduction from us. Offered at only £650

MAGTAPES, DISKS, ETC....

PERTEC 9-TRACK MAGTAPE SYSTEMS
A complete Magnetic Tape system, with all electronics and parallel TTL in/out — easy to interface to a micro-system. Original cost over £4,000, these units are about four years old £200
DRE 4000 Disk Drives, 5 plus 5 Megabyte, as new £750
DRE Series 30 2.5 Megabyte Cartridge drives £450
Century Data 10 Megabyte in cabinet (Model 111) £300
DCS 3000 Data Cartridge system 2.5 Mb 3M Cartridge. New £300

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A Real Bargain! Two cards containing at least 350 ICs in DIL sockets. ICs all identifiable modern TTL and can be unplugged — none are soldered. Sockets are wire-wrap and easily removable. Hundreds of pounds worth of components for only £34.50, including VAT and postage.

PLEASE NOTE: Except where stated prices exclude VAT and carriage, please phone for transport costs on heavy items. All equipment may be viewed at our office near High Wycombe. Callers very welcome.

We stock a huge amount of DEC Systems and spares, and offer complete PDP8 and PDP11 computer systems from £200 upwards. We have lots of one-off bargains.

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STANDARD FREQUENCY RECEIVERS
CRYSTAL STANDARDS — FREQUENCY COUNTERS

CRYSTAL STANDARD TYPE 102 £148

OFF/AIR RECEIVER TYPE 103 £165

OUTPUTS 1 MHz, 10 MHz: OFF/AIR RECEIVER PHASED LOCKED TO DROITWICH, CRYSTAL STANDARD DRIFT LESS THAN 1 PART IN 10^8 PER DAY. MAINS POWERED WITH FITTED INTERNAL STANDBY BATTERY. DETAILS OF FREQUENCY COUNTERS ON REQUEST

RCS ELECTRONICS
WOLSEY ROAD
ASHFORD, MIDDX.
Phone 53661

WW – 087 FOR FURTHER DETAILS

WE PURCHASE

Surplus component stocks, redundant materials, obsolete computers, for cash.

We also collect – distance no object. Just call:

C. T. Electronics (Acton) Ltd.

267 & 270 Acton Lane, London W4 5DG

Telephone 01-747 1555; 01-994 6275. Telex 291429

WW – 091 FOR FURTHER DETAILS

LANGREX SUPPLIES LTD

RST Climax House, Fallsbrook Rd., Streatham, London SW16 6ED RST

Tel: 01-677 2424 Telex: 946708

SEMICONDUCTORS

Type	Price
AA119	0.12
AAY30	0.20
AAY32	0.48
AAZ13	0.17
AAZ15	0.17
AAZ17	0.17
AC107	0.63
AC125	0.29
AC126	0.29
AC127	0.29
AC128	0.35
AC141	0.32
AC141K	0.40
AC142	0.32
AC142K	0.40
AC176	0.35
AC187	0.32
AC188	0.32
ACY17	1.50
ACY18	1.32
ACY19	1.27
ACY20	1.27
ACY21	1.32
ACY39	2.88
AD149	0.86
AD161	0.40
AD162	0.40
AF106	0.40
AF114	0.86
AF115	0.86
AF116	0.86
AF117	0.86
AF139	0.38
AF186	1.15
AF239	0.45
AFZ11	4.60
AFZ12	4.60
ASY26	1.61
ASY27	1.04
ASZ15	1.38
ASZ16	1.38
ASZ17	1.15
ASZ20	2.64
ASZ21	2.88
AU113	2.88
AU110	2.88
BA145	0.15
BA148	0.17
BA154	0.12
BA155	0.13
BA156	0.12
BAW62	0.06
BAX13	0.07
BAX16	0.07
BC107	0.18
BC108	0.18
BC109	0.18
BC113	0.17
BC114	0.17
BC115	0.21
BC116	0.21
BC117	0.26
BC118	0.21
BC125	0.21
BC126	0.21
BC135	0.17
BC136	0.22
BC137	0.22
BC147	0.14
BC148	0.14
BC149	0.15
BC157	0.15
BC158	0.15
BC159	0.15
BC167	0.13
BC170	0.13
BC171	0.12
BC172	0.13
BC173	0.13
BC177	0.32
BC178	0.16
BC179	0.32
BC182	0.35
BC183	0.13
BC184	0.13
BC212	0.13
BC213	0.13
BC214	0.13
BC237	0.13
BC238	0.13
BC301	0.38
BC303	0.39
BC307	0.13
BC308	0.13
BC327	0.14
BC328	0.14
BC337	0.14
BC338	0.14
BCY30	1.44
BCY31	1.73
BCY32	1.73
BCY33	1.27
BCY34	1.15
BCY39	3.91
BCY40	3.22
BCY42	0.35
BCY43	0.35
BCY58	0.22
BCY70	0.20
BCY71	0.21
BCY72	0.20
BCZ11	2.01
BD115	0.48
BD121	1.96
BD123	3.22
BD124	2.30
BD131	0.51
BD132	0.55
BD135	0.46
BD136	0.46
BD137	0.46
BD138	0.46
BD139	0.55
BD140	0.58
BD144	2.30
BD181	1.38
BD182	1.38
BD183	1.38
BD237	0.62
BD238	0.62
BDX10	1.05
BDX32	2.30
BDY20	1.73
BDY60	3.16
BF115	0.40
BF152	0.18
BF153	0.18
BF154	0.20
BF159	0.31
BF160	0.28
BF167	0.28
BF173	0.35
BF177	0.40
BF178	0.40
BF179	0.40
BF180	0.32
BF181	0.32
BF182	0.35
BF183	0.32
BF184	0.32
BF185	0.35
BF194	0.16
BF195	0.14
BF196	0.15
BF197	0.16
BF200	0.46
BF224	0.29
BF244	0.32
BF257	0.31
BF258	0.31
BF259	0.31
BF336	0.39
BF337	0.38
BF338	0.41
BFS21A	0.52
BFS28	2.58
BFS61	0.31
BFS98	0.31
BFW10	1.12
BFW11	1.10
BFX84	0.35
BFX85	0.35
BFX87	0.35
BFX88	0.35
BFY50	0.29
BFY51	0.29
BFY52	0.29
BFY64	0.35
BFY90	1.09
BSX19	0.31
BSX20	0.31
BSX21	0.33
BT106	1.38
BTY79/400R	2.30
BU205	1.50
BU206	1.73
BU208	2.30
BY100	0.46
BY126	0.15
BY127	0.16
BZX61 Series	0.20
BZY88 Series	0.12
CRS1/40	0.69
CRS3/06	0.52
CRS3/40	0.86
CRS3/60	1.04
GEX66	3.45
GEX541	5.75
GJ3M	1.73
GM0378A	2.02
KS100A	0.52
MJE340	0.69
MJE370	0.84
MJE371	0.82
MJE520	0.54
MJE521	0.84
MJE2955	1.50
MJE3055	1.27
MPF102	0.40
MPF103	0.40
MPF104	0.40
MPF105	0.40
MPSA06	0.30
MPSA56	0.32
MPSU01	0.61
MPSU06	0.75
MPSU56	0.79
NE555	0.52
NKT401	4.03
NKT403	2.88
NKT404	2.53
OA5	1.38
OA7	0.69
OA10	0.63
OA47	0.14
OA70	0.29
OA79	0.14
OA81	0.20
OA85	0.20
OA90	0.09
OA91	0.09
OA95	0.09
OA200	0.17
OA202	0.17
OA211	1.73
OAZ200	1.73
OAZ201	1.73
OAZ206	1.73
OAZ207	1.73
OC16	2.88
OC20	2.88
OC22	2.88
OC23	4.60
OC24	3.45
OC25	1.15
OC26	1.73
OC28	2.30
OC29	2.30
OC35	1.73
OC36	1.73
OC41	1.04
OC42	1.04
OC43	1.73
OC44	0.98
OC45	0.75
OC71	0.63
OC72	1.15
OC73	1.15
OC74	0.81
OC75	0.75
OC76	1.15
OC77	1.15
OC81	0.75
OC81Z	1.38
OC82	1.04
OC83	0.92
OC84	0.92
OC122	3.16
OC123	2.30
OC139	3.45
OC140	4.60
OC141	4.93
OC170	1.44
OC171	1.44
OC200	1.73
OC201	2.88
OC202	3.16
OC203	3.45
OC204	3.45
OC205	3.16
OC206	3.16
OC207	2.88
OCP71	2.30
ORP12	1.15
R2008B	2.30
R2009	2.59
R2010B	2.30
T1C44	0.31
T1C226D	1.38
T1L209	0.18
T1P29A	0.49
T1P30A	0.52
T1P31A	0.38
T1P32A	0.41
T1P33A	0.62
T1P34A	0.77
T1P41A	0.51
T1P42A	0.48
T1P2955	0.81
T1P3055	0.64
T1S43	0.49
ZS140	0.29
ZS170	0.24
ZS178	0.62
ZS271	0.26
ZS278	0.65
ZTX107	0.14
ZTX108	0.14
ZTX109	0.14
ZTX300	0.15
ZTX301	0.16
ZTX302	0.21
ZTX303	0.21
ZTX304	0.23
ZTX311	0.15
ZTX314	0.29
ZTX500	0.16
ZTX501	0.16
ZTX502	0.21
ZTX503	0.22
ZTX504	0.24
ZTX531	0.28
ZTX550	0.29
1N914	0.06
1N916	0.10
1N4001	0.07
1N4002	0.07
1N4003	0.07
1N4004	0.08
1N4005	0.10
1N4006	0.13
1N4007	0.14
1N4009	0.08
1N4148	0.05
1N5400	0.15
1N5401	0.15
1S44	0.05
1S920	0.09
1S921	0.10
2G301	1.15
2G302	1.15
2G306	1.15
2N404	1.50
2N696	0.37
2N697	0.37
2N698	0.37
2N705	1.44
2N706	0.29
2N708	0.29
2N930	0.29
2N1131	0.35
2N1132	0.35
2N1302	1.38
2N1303	0.92
2N1304	1.38
2N1305	1.15
2N1306	1.73
2N1307	1.27
2N1308	2.01
2N1309	1.38
2N1613	0.37
2N1671	1.73
2N1893	0.37
2N2147	4.60
2N2148	4.31
2N2218	0.37
2N2219	0.37
2N2220	0.23
2N2221	0.23
2N2222	0.23
2N2223	4.89
2N2368	0.29
2N2369A	0.29
2N2484	0.29
2N2646	0.58
2N2904	0.37
2N2905	0.37
2N2906	0.24
2N2907	0.24
2N2924	0.30
2N2925	0.25
2N2926	0.17
2N3053	0.30
2N3054	0.63
2N3055	0.75
2N3440	0.81
2N3441	0.98
2N3442	1.44
2N3614	2.53
2N3702	0.13
2N3703	0.13
2N3704	0.13
2N3705	0.13
2N3706	0.13
2N3707	0.13
2N3708	0.12
2N3709	0.13
2N3710	0.12
2N3711	0.12
2N3771	1.61
2N3772	1.84
2N3773	2.07
2N3819	0.35
2N3820	0.45
2N3823	0.69
2N3866	1.15
2N3904	0.20
2N3905	0.20
2N3906	0.20
2N4058	0.23
2N4059	0.23
2N4060	0.18
2N4061	0.18
2N4062	0.18
2N4124	0.18
2N4126	0.18
2N4286	0.17
2N4288	0.21
2N4289	0.21
2N5457	0.37
2N5458	0.37
2N5459	0.37
2S017	11.50
2S019	13.80
2S026	28.75
2S103	1.73
2S302	2.30
2S303	4.03
2S322	4.03
2S324	4.03
2S701	2.30
2S745A	1.09
2S746A	1.09

VALVES

Type	Price
A1834	10.35
A2087	13.58
A2134	20.13
A2293	8.62
A2426	17.63
A2521	24.38
A2900	14.43
A3343	51.75
AZ31	1.26
AZ41	1.32
BK448	110.27
BK484	149.09
BS90	52.27
BS810	86.25
BT5	58.13
BT17	106.89
BT19	36.17
BT29	327.69
BT69	333.50
BT75	102.46
BT95	127.02
CBL31	2.30
CL33	2.30
CY31	1.15
C1K	21.30
C3A	11.50
C3JA	23.23
DA41	28.75
DA42	21.51
DA100	97.93
DAF91	0.46
DAF96	1.15
DET22	32.78
DET24	52.90
DF91	0.46
DF96	1.15
DK91	1.21
DK92	1.44
DK96	1.26
DL92	1.26
DL94	1.38
DL96	1.26
DLS10	9.48
DLS15	12.37
DLS16	12.37
DLS19	12.37
DM70	1.44
DM71	1.44
DM160	3.96
DY87	0.74
DY802	0.96
E55L	25.17
E80CC	11.27
E80CF	12.96
E80F	14.19
E80L	13.98
E81CC	6.62
E81L	14.06
E82CC	7.03
E83CC	7.16
E86C	13.23
E88C	7.12
E88CC	3.86
E90CC	9.94
E90F	11.39
E91H	5.34
E92CC	9.40
E99F	10.16
E130L	19.39
E180CC	11.39
E180F	7.83
E182CC	13.80
E186F	12.58
E188CC	9.40
E280F	25.88
E283CC	9.02
E288CC	18.54
EA52	28.18
EA76	2.30
EABC80	1.38
EAC91	0.92
EAF42	1.44
EAF801	2.02
EB41	2.30
EB91	1.01
EBC33	2.02
EBC41	1.44
EBC81	1.26
EBC90	0.97
EBF80	0.58
EBF83	1.44
EBF89	0.97
EBL31	2.88
EC90	1.28
EC91	9.33
EC92	1.44
EC157	349.26
ECC33	4.02
ECC35	4.02
ECC40	2.30
ECC81	1.01
ECC82	0.82
ECC83	1.01
ECC84	1.36
ECC85	1.38
ECC86	2.30
ECC88	2.07
ECC89	1.88
ECC91	10.27
ECC189	1.90
ECC807	2.02
ECC808	2.59
ECF80	1.24
ECF82	1.38
ECF86	1.73
ECH35	2.30
ECH42	1.32
ECH81	1.38
ECH83	1.44
ECH84	1.47
ECL80	1.15
ECL81	1.73
ECL82	1.15
ECL83	1.73
ECL84	1.61
ECL85	1.28
ECL86	1.38
EF37A	4.02
EF39	3.16
EF40	3.45
EF41	2.30
EF42	2.30
EF50	1.73
EF54	5.75
EF55	2.88
EF80	0.92
EF83	4.03
EF85	0.92
EF86	1.74
EF89	1.84
EF91	2.07
EF92	6.68
EF93	1.15
EF94	1.24
EF95	6.27
EF98	1.44
EF183	0.92
EF184	0.96
EF804S	12.65
EF805S	12.65
EH90	1.61
EK90	1.24
EL32	1.73
EL33	4.02
EL34TH	2.53
EL34MUI	3.16
EL36	1.84
EL41	1.44
EL42	2.02
EL81	4.03
EL83	4.03
EL84	1.15
EL86	2.88
EL90	1.10
EL91	8.21
EL95	1.51
EL156	27.60
EL360	9.77
EL500/504	2.16
EL509	3.63
EL821	11.96
EL822	12.55
EM34	5.75
EM80	1.26
EM81	1.15
EM84	1.15
EM85	1.44
EM87	1.73
EN32	13.66
EN91	2.94
EN92	5.23
EY51	2.02
EY81	1.89
EY83	2.02
EY84	10.57
EY86	0.96
EY88	2.02
EY500A	2.23
EY802	94
EZ35	97
EZ40	1.44
EZ41	1.44
EZ80	0.96
EZ81	0.96
EZ90	1.38
FW4-500	2.88
FW4-800	2.88
G1.371K	41.40
G551K	12.65
G180.2M	18.42
G240.2D	12.85
G400.1K	19.28
GN4	8.62
GN4A	8.62
GS16	10.35
GT1C	14.38
GU50	14.31
GU51	13.62
GXU1	16.10
GXU2	28.43
GXU3	30.49
GXU4	32.77
GXU50	17.25
GY501	3.16
GZ32	1.44
GZ33	4.60
GZ34	2.88
GZ37	4.60
KT61	4.02
KT66	11.50
KT88	13.80
KTW61	2.02
KTW62	2.02
KTW63	2.02
M8079	12.29
M8080	9.49
M8081	11.30
M8082	9.87
M8083	8.54
M8091	11.99
M8096	4.31
M8097	4.09
M8098	5.50
M8099	5.98
M8100	9.49
M8136	9.98
M8137	9.73
M8140	5.17
M8141	5.52
M8142	7.77
M8144	4.31
M8149	5.86
M8161	9.11
M8162	10.36
M8163	5.17
M8190	5.29
M8195	4.25
M8196	7.47
M8204	6.57
M8212	12.47
M8223	3.80
M8224	4.66
M8225	2.99
M8248	13.32
MU14	1.73
MX119	58.65
MX123	67.85
MX145	62.10
MX151	17.25
MX152	143.75
MX161	166.75
MX163	23.11
MX164	27.95
MX166	161.00
MX168	48.30
N78	20.13
OA2	2.30
OA3	5.69
OA4	4.02
OB2	1.44
OB3	2.20
OC2	3.04
OC3	2.20
OD3	2.20
OZ4	1.84
PC86	1.61
PC88	1.61
PC95	1.49
PC97	1.38
PC900	1.38
PCC84	1.15
PCC85	1.38
PCC88	1.38
PCC89	1.56
PCC189	1.61
PCC805	1.51
PCC806	2.07
PCE82	2.07
PCF80	1.15
PCF82	1.15
PCF86	1.84
PCF87	1.84
PCF200	3.74
PCF201	2.45
PCF801	1.84
PCF802	2.19
PCF805	1.84
PCF806	1.84
PCF808	1.84
PCL82	1.15
PCL83	2.30
PCL84	1.15
PCL85	1.24
PCL86	1.24
PCL805/85	1.24
PD500	4.14
PE06-40N	31.40
PFL200	2.07
PL36	1.38
PL81	1.38
PL81A	1.38
PL82	1.38
PL83	2.55
PL84	1.24
PL504/5	1.61
PL508	2.07
PL509	3.73
PL519	3.73
PL801	1.27
PL802	3.40
PY33	1.27
PY81	0.97
PY82	0.92
PY83	0.81
PY88	1.01
PY500A	2.07
PY800	0.97
PY801	0.97
QQV02-6	16.17
QQV03-20A	20.13
QQV06-40A	47.15
QQV07-50	60.66
QQZ03-20A	59.80
QQZ06-40A	63.37
QU37	14.38
QV03-12	5.62
QV04-7	2.88
QV08-100	137.08
QY3-65	57.06
QY3-125	62.40
QY4-250	77.05
QY4-400	80.44
QY5-500	168.83
QY5-3000A	356.66
QZ06-20	34.16
R10	5.75
R17	1.89
R18	4.89
R19	1.38
R20	1.66
RG3-250	35.77
RG3-250A	37.49
RG3-1250	63.94
RG4-1250	43.13
RG4-3000	90.36
RR3-250	53.54
RR3-1250	94.83
S11E12	55.20
S130	3.45
S130P	4.03
STV280-40	11.50
STV280-80	24.15
SU41	2.88
SU42	10.35
TD03-10	32.78
TD03-10E	32.78
TD03-29F	33.93
TT15	34.50
TT21	16.98
TT22	16.98
TT100	59.51
TY2-125	69.01
TW4-400	74.07
TY4-500	105.97
TY5-500	187.45
TY6-800	193.20
TY6-5000A	356.50
TY6-5000B	264.50
TY6-5000W	316.25
TY7-6000A	368.80
TY7-6000W	322.00
TZ40	28.75
U18-20	2.88
U19	15.81
U25	1.33
U26	1.66
U37	10.35
UABC80	1.44
UAF42	1.44
UB41	1.44
UBC41	1.73
UBF89	1.38
UCC84	1.26
UCC85	1.38
UCF80	1.32
UCH42	1.38
UCH81	2.67
UCL82	1.20
UCL83	1.66
UF41	1.15
UF42	1.44
UF80	1.66
UF85	1.66
UF89	1.66
UL41	2.88
UL84	1.38
UM80	1.15
UY41	1.44
UY85	1.20
VLS631	15.24
XG1-2500	58.02
XG2-6400	113.50
XG5-500	28.23
XG2-6400	155.42
XR1-1600A	58.88
XR1-3200	87.15
XR1-3200A	93.15
XR1-6400	108.30
XR1-6400A	164.23
YD1120	264.50
YD1240	366.62
Z759	19.32
ZM1000	6.03
ZM1001	6.19
ZM1020	10.83
ZM1021	10.17
ZM1022	10.60
ZM1023	8.81
ZM1040	22.26
ZM1041	19.16
ZM1042	20.44
ZM1051	100.05
1B3GT	2.58
1B24	11.50
1B35A	28.75
1B63	57.50
1R5	1.21
1S5	0.46
1T4	0.46
2AS15	11.50
2C39A	21.85
2C43	20.70
2D21	2.94
2E26	17.86
2J42	109.25
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2J70B	418.34
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3B24	9.20
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6AB7	1.73
6AC7	1.61
6AF4A	1.84
6AG7	2.30
6AH6	5.52
6AK5	4.15
6AK6	2.81
6AL5	1.01
6AM4	2.65
6AM5	8.21
6AM6	2.07
6AN5	4.45
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6AQ5	1.10
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6AS7G	9.49
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6AU5GT	4.97
6AU6	1.24
6AV5GA	4.52
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6B8	2.02
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6BA7	5.89
6BA8A	4.31
6BC4	4.27
6BE6	1.24
6BH6	1.75
6BJ6	1.24
6BK4	4.84
6BL6	97.75
6BL7GT	4.44
6BM6	97.75
6BN6	1.89
6BQ7A	4.28
6BR7	4.60
6BR8	2.02
6BS7	4.60
6BW6	4.60
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6BX7GT	5.70
6BZ6	2.73
6C4	1.01
CB6A	2.86
6CD6GA	5.83
6CG7	2.62
6CH6	11.96
6CL6	4.12
6CW4	8.83
6D2	1.01
6DK6	3.00
6DQ6B	4.69
6EA8	3.38
6EB8	2.44
6EW6	1.73
6F6	2.02
6F23	1.84
6F28	1.33
6F33	34.50
6H1	14.38
6H2N	1.21
6H3N	1.21
6H6	1.73
6J4	6.10
6J6	6.21
6J7	2.88
6K4N	1.44
6K6GT	1.50
6K7	1.73
6K8	2.02
6KD6	7.31
6L6G	2.88
6L6GA	1.73
6L6GT	2.24
6L6GC	2.88
6L7	2.30
6N2P	1.21
6N3P	1.21
6N7	1.73
6P25	4.14
6Q7	2.53
6R7	2.07
6SA7	1.67
6SC7	1.73
6SF7	1.84
6SH7	1.73
6SJ7	1.84
6SK7	1.50
6SK7GT	3.08
6SN7GT	1.84
6SQ7	1.50
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6SS7	2.07
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30L15	2.07
30L17	2.07
30P4	1.06
30P19	1.38
30PL1	2.88
30PL14	1.93
30PL15	2.07
35W4	0.69
50C5	0.81
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75C1	2.70
85A1	8.63
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805	23.00
807	4.31
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2050	8.00
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5675	21.47
5687	6.31
5696	4.35
5718	7.87
5725	5.62
5726	3.62
5727	6.47
5749	5.14
5751	4.80
5763	4.66
5814A	4.28
5840	5.06
5842	13.90
5876A	19.55
5879	5.38
5886	12.08
5963	3.38
5965	4.00
6005	5.62
6021	5.13
6057	4.02
6058	12.47
6059	4.60
6061	4.89
6062	4.31
6063	4.20
6064	8.54
6067	4.02
6072	5.80
6080	7.88
6097AxBxC	166.75
6146A	12.24
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6159B	19.91
6189	10.03
6201	10.92
6442	17.25
6883B	14.64
6973	4.38
7025	2.73
7551	6.45
7586	11.66
7587	20.11
7609	36.57
7868	5.04
7895	13.25
8005	86.40
8068	6.33
8122	60.11
8136	2.48
8417	6.76
18042	8.63
18045	12.06

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Type	Price
B7G unskirted	0.25
B7G skirted	0.35
B9A unskirted	0.25
B9A skirted	0.35
Int Octal	0.40
Loctal	0.63
Nuvistor base	0.86
8 pin DIL	0.17
14 pin DIL	0.17
16 pin DIL	0.20
Valve screening cans/all sizes	0.35

CRTs

Type	Price
2AP1	9.78
2BP1	10.35
3BP1	11.50
3DP1	5.75
3EG1	8.05
3FP7	6.90
3GP1	6.90
3JP1	9.20
3JP2	9.20
3JP7	11.50
3KP1	17.25
3RP1	40.25
3WP1	23.00
5ADP1	40.25
5BP1	11.50
5CP1	11.50
5CP1A	46.00
5FP15A	17.25
5UP7	28.75
DG7-5	72.82
DG7-31	66.78
DG7-32	66.78
DH3-91	67.65
DH7-11	130.09
VCR97	13.80
VCR138	11.50
VCR138A	14.38
VCR139A	9.20
VCR517A	11.50
VCR517B	11.50
VCR517C	11.50

Tube Bases Prices on application

INTEGRATED CIRCUITS

Type	Price
7400	0.18
7401	0.20
7402	0.20
7403	0.20
7404	0.21
7405	0.21
7406	0.49
7407	0.49
7408	0.23
7409	0.23
7410	0.20
7412	0.33
7413	0.37
7416	0.37
7417	0.37
7420	0.21
7422	0.23
7423	0.38
7425	0.35
7427	0.35
7428	0.50
7430	0.20
7432	0.35
7433	0.46
7437	0.37
7438	0.37
7440	0.37
7441	1.04
7442	0.83
7447AN	1.35
7450	0.21
7451	0.21
7453	0.21
7454	0.21
7460	0.21
7470	0.44
7472	0.38
7473	0.44
7474	0.44
7475	0.62
7476	0.48
7480	0.64
7482	0.86
7483	1.15
7484	1.21
7486	0.45
7490	0.69
7491	0.94
7492	0.69
7493	0.69
7494	0.94
7495	0.84
7496	0.94
7497	3.62
74100	1.77
74107	0.52
74109	0.84
74110	0.59
74111	0.82
74116	2.13
74118	1.15
74119	1.77
74120	0.95
74121	0.49
74122	0.71
74123	1.36
74125	0.67
74126	0.67
74128	0.72
74132	0.83
74136	0.59
74141	1.02
74142	2.64
74143	2.99
74144	2.99
74145	1.15
74147	2.30
74148	2.02
74150	2.07
74151	1.08
74154	2.07
74155	1.04
74156	1.04
74157	0.86
74159	2.53
74170	2.76
74172	5.06
74173	1.63
74174	1.84
74175	1.17
74176	1.33
74178	1.56
74179	1.56
74180	1.38
74190	2.19
74191	2.19
74192	2.19
74193	2.19
74194	1.44
74195	1.38
74196	1.55
74197	1.55
74198	3.11
74199	2.64
76013N	2.02
TAA570	2.65
TAA630S	4.02
TAA700	4.50
TBA480Q	2.12
TBA520Q	2.65
TBA530	2.28
TBA540Q	2.65
TBA550Q	3.70
TBA560CQ	3.70
TBA673	2.52
TBA700	1.75
TBA720Q	2.65
TBA750Q	2.38
TBA800	1.38
TBA920	3.34
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2651	10.90
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2653	9.00
2661–1	12.00
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6100	9.25
6101	6.40
6102	17.75
6103	6.75
6402	3.80
6403	6.50
6800 FAMILY	
6800	3.70
6802	5.75
6808	4.45
6810	2.17
6821	2.52
6840	5.50
6850	2.00
6852	2.47
6854	4.60
68047	5.64
68488	5.43

DEVICE	PRICE
8080 FAMILY	
8080A	3.50
8085A	8.00
8155	8.75
8156	8.75
8212	1.95
8216	1.80
8224	2.25
8226	1.80
8228	5.50
8238	5.50
8251	3.85
8253	9.00
8255A	3.55
8257	7.95
8279	10.50
TMS5501	15.00
Z80 FAMILY	
Z80 CPU	4.10
Z80A CPU	6.25
Z80 CTC	4.40
Z80A CTC	5.25
Z80 PIO	4.25
Z80A PIO	4.95
Z80 SIO-0	17.50

DEVICE	PRICE
Z80 SIO-1	17.50
Z80 SIO-2	17.50
Z80 SIO-9	11.50
Z80A SIO-0	23.50
Z80A SIO-1	23.50
Z80A SIO-2	23.50
Z80A SIO-9	15.50
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9900	32.50
9980A	20.00
9981	29.30
9901	9.94
9902	8.52
9903	25.55
9911	28.46
9914	19.29
9927	27.39
MEMORIES	
2101	1.65
2102	1.15
2111	1.25
2112	1.65
2114	3.25
2708	3.45
2708–4	1.50

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74LS01	0.13	74LS113	0.25	74LS244	1.10
74LS02	0.14	74LS114	0.25	74LS245	1.60
74LS03	0.14	74LS122	0.42	74LS247	0.80
74LS04	0.15	74LS123	0.59	74LS251	0.45
74LS08	0.15	74LS124	1.15	74LS253	0.45
74LS09	0.15	74LS125	0.30	74LS257	0.50
74LS10	0.14	74LS126	0.30	74LS258	0.50
74LS11	0.15	74LS132	0.50	74LS261	1.98
74LS12	0.15	74LS136	0.27	74LS266	0.25
74LS13	0.30	74LS137	0.75	74LS273	1.10
74LS14	0.50	74LS138	0.40	74LS279	0.42
74LS15	0.15	74LS139	0.40	74LS280	2.15
74LS20	0.14	74LS145	0.80	74LS283	0.70
74LS21	0.15	74LS147	1.20	74LS290	0.60
74LS22	0.15	74LS148	1.08	74LS293	0.60
74LS27	0.15	74LS151	0.42	74LS295	1.05
74LS28	0.20	74LS153	0.42	74LS298	1.05
74LS30	0.15	74LS155	0.55	74LS299	2.50
74LS32	0.15	74LS156	0.55	74LS365	0.39
74LS33	0.17	74LS157	0.38	74LS366	0.39
74LS37	0.18	74LS158	0.38	74LS367	0.39
74LS38	0.18	74LS160	0.45	74LS368	0.39
74LS40	0.15	74LS161	0.45	74LS373	1.05
74LS42	0.45	74LS162	0.45	74LS374	1.05
74LS43	0.50	74LS163	0.45	74LS377	1.05
74LS44	0.50	74LS164	0.62	74LS378	0.75
74LS47	0.55	74LS165	0.95	74LS379	0.95
74LS51	0.15	74LS166	1.40	74LS386	0.27
74LS54	0.15	74LS170	1.50	74LS393	0.75
74LS55	0.15	74LS174	0.72	74LS395	1.15
74LS73	0.25	74LS175	0.71	74LS668	0.67
74LS74	0.20	74LS181	1.45	74LS669	0.67
74LS75	0.30	74LS183	1.96	74LS670	1.65
74LS76	0.25	74LS190	0.60	81LS95	1.32
74LS78	0.30	74LS191	0.60	81LS96	1.32
74LS83A	0.55	74LS192	0.65	81LS97	1.32
74LS85	0.75	74LS193	0.65	81LS98	1.32
74LS86	0.20	74LS194	0.65	8T26A	1.60
74LS90	0.35	74LS195	0.60	8T28	1.60
74LS91	0.35	74LS196	0.65	8T95	1.50
74LS92	0.35	74LS197	0.65	8T96	1.50
74LS93	0.35	74LS221	0.60	8T97	1.50
74LS95	0.50	74LS240	1.10	8T98	1.50
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Type	VA	Secondary Volts RMS	Secondary Current RMS	Dimensions Dia.	Dimensions Height	Weight Kg	Price
C1000	30	6+6	2.50	70mm	30mm	0.45	
C1001	30	9+9	1.67	70mm	30mm	0.45	£6.38
C1002	30	12+12	1.25	70mm	30mm	0.45	
C1003	30	15+15	1.00	70mm	30mm	0.45	(+£1.10
C1004	30	18+18	0.83	70mm	30mm	0.45	p.p.)
C1005	30	22+22	0.68	70mm	30mm	0.45	
C1006	30	25+25	0.60	70mm	30mm	0.45	
C1007	30	30+30	0.50	70mm	30mm	0.45	
C1010	60	9+9	3.33	87mm	33mm	0.75	
C1011	60	12+12	2.50	87mm	33mm	0.75	£7.31
C1012	60	15+15	2.00	87mm	33mm	0.75	
C1013	60	18+18	1.67	87mm	33mm	0.75	(+£1.43
C1014	60	22+22	1.36	87mm	33mm	0.75	p.p.)
C1015	60	25+25	1.20	87mm	33mm	0.75	
C1016	60	30+30	1.00	87mm	33mm	0.75	
C1017	60	110	0.55	87mm	33mm	0.75	
C1018	60	220	0.27	87mm	33mm	0.75	
C1019	60	240	0.25	87mm	33mm	0.75	
C1020	100	12+12	4.17	88mm	40mm	1.00	
C1021	100	15+15	3.33	88mm	40mm	1.00	£8.15
C1022	100	18+18	2.78	88mm	40mm	1.00	
C1023	100	22+22	2.27	88mm	40mm	1.00	(+£1.43
C1024	100	25+25	2.00	88mm	40mm	1.00	p.p.)
C1025	100	30+30	1.67	88mm	40mm	1.00	
C1026	100	110	0.91	88mm	40mm	1.00	
C1027	100	220	0.45	88mm	40mm	1.00	
C1028	100	240	0.42	88mm	40mm	1.00	

NOTE: All types normally supplied with 240 V primary 110 V. 220 V or other voltage supplied on request.

Type	VA	Secondary Volts RMS	Secondary Current RMS	Dimensions Dia.	Dimensions Height	Weight Kg	Price
C1030	160	18+18	4.44	108mm	42mm	1.5	
C1031	160	22+22	3.64	108mm	42mm	1.5	£12.26
C1032	160	25+25	3.20	108mm	42mm	1.5	
C1033	160	30+30	2.67	108mm	42mm	1.5	(+£1.73
C1034	160	35+35	2.29	108mm	42mm	1.5	p.p.)
C1035	160	110	1.46	108mm	42mm	1.5	
C1036	160	220	0.73	108mm	42mm	1.5	
C1037	160	240	0.67	108mm	42mm	1.5	
C1040	230	25+25	4.60	115mm	50mm	2.2	
C1041	230	30+30	3.83	115mm	50mm	2.2	£14.87
C1042	230	35+35	3.29	115mm	50mm	2.2	
C1043	230	40+40	2.88	115mm	50mm	2.2	(+£1.73
C1044	230	110	2.09	115mm	50mm	2.2	p.p.)
C1045	230	220	1.05	115mm	50mm	2.2	
C1046	230	240	0.96	115mm	50mm	2.2	
C1050	330	25+25	6.60	130mm	52mm	2.8	
C1051	330	30+30	5.50	130mm	52mm	2.8	£17.36
C1052	330	35+35	4.71	130mm	52mm	2.8	
C1053	330	40+40	4.13	130mm	52mm	2.8	(+£1.90
C1054	330	45+45	3.67	130mm	52mm	2.8	p.p.)
C1055	330	110	3.00	130mm	52mm	2.8	
C1056	330	220	1.50	130mm	52mm	2.8	
C1057	330	240	1.38	130mm	52mm	2.8	
C1060	530	30+30	8.83	145mm	60mm	3.8	
C1061	530	35+35	7.57	145mm	60mm	3.8	£22.57
C1062	530	40+40	6.63	145mm	60mm	3.8	
C1063	530	45+45	5.89	145mm	60mm	3.8	(+£2.05
C1064	530	50+50	5.30	145mm	60mm	3.8	p.p.)
C1065	530	110	4.82	145mm	60mm	3.8	
C1066	530	220	2.41	145mm	60mm	3.8	
C1067	530	240	2.21	145mm	60mm	3.8	

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Ref.	12v Amps	24v	£	P & P
111	0.5	0.25	2.42	.95
213	1.0	0.5	2.90	1.00
71	2.0	1.0	3.86	1.00
18	4.0	2.0	4.46	1.20
85	5.0	2.5	6.16	1.20
70	6.0	3.0	6.99	1.20
108	8.0	4.0	8.16	1.44
72	10.0	5.0	8.93	1.60
116	12.0	6.0	9.89	1.60
17	16.0	8.0	11.79	1.72
115	20.0	10.0	15.87	1.84
187	30.0	15.0	19.72	2.04
226	60.0	30.0	40.41	OA

30 VOLT RANGE (Split Sec)
Pri 220-240V. Volt available 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30V or 12V-O-12V or 15V-O-15V

Ref.	Amps 30v	Amps 15v	£	P & P
112	0.5	1	2.90	1.00
79	1	2	3.93	1.00
3	2	4	6.35	1.20
20	3	6	7.39	1.44
21	4	8	8.79	1.60
51	5	10	10.86	1.60
117	6	12	12.29	1.72
88	8	16	16.45	1.96
89	10	20	18.98	1.84
90	12	24	21.09	OA
91	15	30	24.18	OA
92	20	40	32.40	OA

SCREENED MINIATURES Pri 240V

Ref.	mA	Sec Volts	£	P&P
238	200	3-0-3	2.83	.50
212	1A, 1A	0-6, 0-6	3.14	1.00
13	100	9-0-9	2.35	.50
235	330, 330	0-9, 0-9	2.19	.60
207	500, 500	0-8-9, 0-8-9	3.05	.95
208	1A, 1A	0-8-9, 0-8-9	3.88	1.20
236	200, 200	0-15, 0-15	2.19	.60
239	50MA	12-0-12	2.88	.50
214	300, 300	0-20, 0-20	3.08	1.00
221	700 (DC)	20-12-0-12-20	3.75	1.00
206	1A, 1A	0-15-20,0-15-20	5.09	1.20
203	500, 500	0-15-27,0-15-27	4.39	1.20
204	1A, 1A	0-15-27,0-15-27	6.64	1.20

AUTO TRANSFORMERS
Voltages available 105, 115, 190, 200, 210, 220, 230, 240. For step up or step down.

Ref.	VA (Watts)	TAPS	£	P&P
113*	15	0-10-115-210-240V	2.77	1.00
64	80	0-10-115-210-240V	4.41	1.20
4	150	0-10-115-200-220-240V	5.89	1.20
67	500	0-10-115-200-220-240V	12.09	1.84
84	1000	0-10-115-200-220-240V	20.64	2.20
93	1500	0-10-115-200-220-240V	25.61	OA
95	2000	0-10-115-200-220-240V	38.31	OA
73	3000	0-10-115-200-220-240V	65.13	OA
80	4000	0-10-115-200-220-240V	84.55	OA
57	5000	0-10-115-200-220-240V	98.45	OA

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MAINS ISOLATORS (screened)
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Ref. VA	(Watts)	£	P&P
07★	20	4.84	1.20
149	60	7.37	1.20
150	100	8.38	1.44
151	200	12.28	1.72
152	250	14.61	2.04
153	350	18.07	2.12
154	500	22.52	2.20
155	750	32.03	OA
156	1000	40.92	OA
157	1500	56.52	OA
158	2000	67.99	OA
159	3000	95.33	OA
161	6000	203.65	OA

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Pri 0-220-240V.

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Ref.	Amps 50v	Amps 25v	£	P&P
102	·5	1	3.75	1.20
103	1	2	4.57	1.20
104	2	4	7.88	1.44
105	3	6	9.42	1.60
106	4	8	12.82	1.72
107	6	12	16.37	1.84
118	8	16	22.29	2.20
119	10	20	27.48	OA
109	12	24	32.89	OA

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400/440 to 200/240 (screens)

VA	Ref.	£	P&P
60	243	7.37	1.20
250	246	4.61	2.04
350	247	18.07	2.04
500	248	22.52	OA
1000	250	45.94	OA
2000	252	67.99	OA
3000	253	95.32	OA
6000	254	189.02	OA

60 VOLT RANGE (Split Sec) Pri 220-240V.
Voltages available 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48 60V, or 24V-0-24V or 30V-0-30V

Ref.	Amps 60v	Amps 30v	£	P&P
124	·5	1	4.27	1.20
126	1	2	6.50	1.20
127	2	4	8.36	1.60
125	3	6	12.10	1.72
123	4	8	13.77	1.96
40	5	10	17.42	1.84
120	6	12	19.87	2.04
121	8	16	27.92	OA
122	10	20	32.51	OA
189	12	24	37.47	OA

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75	£8.50	1.20	64W
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200	£12.02	1.44	65W
250	£13.38	1.44	69W
500	£20.13	2.04	67W
1000	£30.67	2.20	84W
2000	£54.97	OA	95W

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Ref.	Amp	Price	P&P
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172	1A	3.26	.90
173	2A	3.95	.90
174	3A	4.13	.99
175	4A	6.30	1.10

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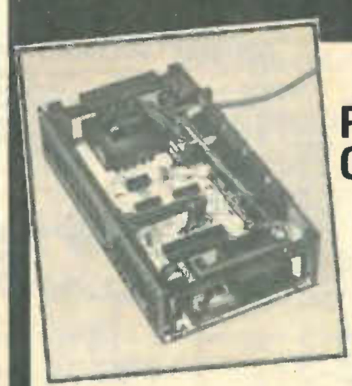

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AF125	0.32
AF126	0.32
AF127	0.32
AF139	0.42
AF150	0.42
AF239	0.42
AU106	2.08
AU107	1.75
AU110	2.00
AU113	1.48
BC107	0.10
BC107A	0.10
BC107B	0.10
BC108	0.10
BC108A	0.10
BC108B	0.10
BC108C	0.10
BC109	0.10
BC109B	0.10
BC114	0.11
BC116A	0.12
BC117	0.19
BC119	0.24
BC125	0.12
BC140	0.31
BC141	0.25
BC142	0.21
BC143	0.24
BC147	0.09
BC148A	0.09
BC148B	0.09
BC149	0.09
BC157	0.10
BC158	0.09
BC159	0.09
BC160	0.28
BC161	0.28
BC170B	0.10
BC171	0.08
BC171A	0.10
BC171B	0.10
BC172	0.09
BC172B	0.10
BC172C	0.10
BC173B	0.10
BC174	0.09
BC182	0.09
BC182LB	0.10
BC183	0.12
BC183L	0.09
BC184LB	0.09
BC204	0.10
BC208B	0.13
BC212	0.09
BC212L	0.09
BC213	0.09
BC213L	0.09
BC237	0.09
BC238	0.09
BC251a	0.12
BC252A	0.15
BC258A	0.39
BC300	0.30
BC301	0.30
BC303	0.26
BC307	0.09
BC327	0.10
BC337	0.10
BC338	0.09
BC461	0.30
BC478	0.20
BC547	0.10
BC548	0.10
BC549A	0.08
BC550	0.07
BC557	0.07
BC557B	0.07
BC558	0.07
BD115	0.30
BD116	0.52
BD131	0.32
BD132	0.35
BD133	0.40
BD135	0.30
BD136	0.30
BD137	0.28
BD138	0.30
BD139	0.32
BD140	0.30
BD159	0.65
BD166	0.46
BD179	0.72
BD182	0.70
BD201	0.83
BD202	0.65
BD203	0.78
BD204	0.70
BD222	0.46
BD223	0.48
BD225	0.46
BD233	0.35
BD234	0.35
BD236	0.45
BD237	0.30
BD238	0.33
BD410	0.55
BD434	0.55
BD437	0.50
BD517	0.60
BD520	0.65
BDX32	1.50
BF115	0.35
BF127	0.24
BF158	0.18
BF160	0.27
BF167	0.24
BF173	0.22
BF177	0.38
BF178	0.26
BF179	0.34
BF180	0.29
BF181	0.29
BF182	0.29
BF183	0.29
BF184	0.28
BF185	0.28
BF194	0.11
BF195	0.11
BF196	0.11
BF197	0.11
BF198	0.10
BF199	0.14
BF200	0.30
BF241	0.15
BF256	0.28
BF256/LC	0.28
BF257	0.28
BF258	0.25
BF259	0.26
BF271	0.26
BF273	0.13
BF336	0.34
BF337	0.29
BF338	0.32
BF355	0.37
BF362	0.38
BF363	0.31
BF371	0.20
BF394	0.19
BF457	0.23
BF458	0.23
BF459	0.36
BF595	0.23
BF597	0.25
BFR39	0.23
BFR41	0.28
BFT42	0.28
BFW92	0.85
BFX29	0.30
BFX84	0.26
BFX85	0.28
BFX86	0.30
BFX88	0.25
BFY50	0.21
BFY51	0.21
BFY52	0.25
BFY90	0.77
BR100	0.19
BR101	0.30
BRC4443	0.85
BT106	1.00
BT108	1.22
BT116	1.20
BU105	1.22
BU108	1.69
BU124	1.00
BU126	1.22
BU204	1.55
BU205	1.30
BU208	1.39
BU208A	1.52
BU208/02	1.89
BU326A	1.42
BU407	1.24
BU500	1.75
MJ3000	1.98
MJE340	0.40
MJE520	0.48
MRF450A	11.50
MRF477	10.00
MRF475	2.50
R2008B	1.70
R2010B	1.70
R2322	0.58
R2323	0.66
R2540	2.48
RCA16334	0.90
RCA16335	0.80
TIP29	0.40
TIP29C	0.42
TIP30C	0.43
TIP31C	0.42
TIP32C	0.42
TIP33B	0.75
TIP41C	0.45
TIP42C	0.47
TIP47	0.65
TIP2955	0.84
TIP3055	0.66
TIS91	0.20
2N2219	0.28
2N2905	0.40
2N3054	0.59
2N3055	0.52
2N3702	0.12
2N3703	0.12
2N3704	0.12
2N3705	0.12
2N3706	0.12
2N3708	0.12
2N5294	0.38
2N5296	0.48
2N5298	0.52
2N5496	0.66
2SA715	0.95
2SC495	0.80
2SC496	0.80
2SC1096	0.80
2SC1172Y	2.20
2SC1173	1.15
2SC1306	1.25
2SC1307	1.85
2SC1449	0.80
2SC1678	1.25
2SC1945	2.10
2SC1953	0.95
2SC1957	0.80
2SC2028	1.15
2SC2029	1.60
2SC2078	1.45
2SC2091	0.85

INTEGRATED CIRCUITS

AN214Q	2.50
AN240	2.80
HA1151	2.50
LA4031P	2.70
LA4400	4.15
LC7120	3.50
LC7130	3.50
LC7131	5.50
MB3712	2.50
MC1307P	1.00
MC1327P	0.95
MC1330P	0.76
MC1349P	1.20
MC1350P	0.76
MC1351P	1.00
MC1352P	1.00
MC1495	3.00
ML231B	1.75
ML232B	1.75
ML237	1.95
ML238	4.20
ML239	2.10
ML920	4.12
ML922	3.29
ML928	1.65
SAS560S	1.60
SAS570S	1.60
SAS580S	2.85
SAS590S	2.85
SL490	1.96
SL901B	4.35
SL917B	6.25
SL1310	1.80
SL1327	1.10
SL1327Q	1.10
SL1431	1.37
SN76003N	1.65
AC76013N	1.15
SN76003ND	1.50
SN76023N	1.45
SN76033N	1.65
AC76033N	1.65
SN76110N	0.89
SN76131N	1.30
SN76226DN	1.55
SN76227N	1.05
SN76532N	1.40
SN76533N	1.30
SN76544N	1.30
SN76650N	1.05
SN76660N	0.80
SN76666N	0.70
SW153	2.74
TA7205AP	1.95
TA7120	1.85
TA7130	1.50
TA7204	2.15
TA7205AP	1.95
TA7222AP	1.80
TA7310P	1.80
TAA550	0.25
TAA570	1.80
TAA621	3.00
TAA661B	1.20
TAA700	1.70
TBA120B	0.70
TBA120S	0.70
TBA120SQ	0.70
TBA120U	1.00
TBA395	1.50
TBA396	0.75
TBA440N	2.55
TBA480Q	1.25
TBA510	1.65
TBA510Q	1.65
TBA520	1.10
TBA520Q	1.10
TBA530	1.10
TBA530Q	1.10
TBA540	1.25
TBA540Q	1.35
TBA550Q	1.45
TBA560C	1.45
TBA560CQ	1.45
TBA570	1.00
TBA641-B11	3.00
TBA720AQ	2.45
TBA750	1.85
TBA750Q	1.85
TBA800	0.89
TBA810S	1.35
TBA810AS	1.35
TBA820	1.45
TBA920	1.65
TBA920Q	1.65
TBA950-2X	2.35
TBA990	1.49
TBA990Q	1.49
TCA270	1.10
TCA270S	1.10
TCA270SQ	1.10
TCA800	2.15
TCA940	1.65
TDA440	2.20
TDA1004A	2.20
TDA1170	1.95
TDA1190	2.15
TDA1270Q	3.95
TDA1327	1.70
TDA1327Q	1.70
TDA1352B	1.43
TDA1412	0.85
TDA2002	1.95
TDA2020	2.45
TDA2030	2.80
TDA2522	1.95
TDA2523	1.95
TDA2530	1.54
TDA2532	1.95
TDA2540	2.15
TDA2541	2.15
TDA2560	2.15
TDA2581	1.15
TDA2590	2.95
TDA2591	2.95
TDA2593	2.95
TDA2600	2.95
TDA2611A	1.95
TDA2640	2.60
TDA2690	1.35
TDA3950	2.50
UPC566H	2.95
UPC575C2	2.95
UPC1025	2.50
UPC1156H	2.95

7v Power Mike batteries TR175 £1.40 each.

THERMISTOR
VA1104 0.70
VA8650 0.45

★ 20MM ANTI-SURGE FUSES ★
£1 per pack of 10: 500 Ma, 1 A, 1.6 A, 2 A
£1.30 per pack of 10: 2.5 A, 3.15 A, 5 A
20MM QUICK BLOW FUSES
30p PER PACK OF 10
250MA. 500MA. 1A. 2A. 5A

NEW BRANDED VALVES

A1998	11.50
A2087	11.50
A2134	9.00
A2293	7.20
A2521	19.00
A2900	10.90
ACP	3.00
AC/HL/DD	3.00
AC/PEN	3.50
AC/SP3	4.50
ACVP1	3.50
ACVP2	1.50
AH221	31.00
AR8	0.70
AZ31	1.00
ARP12	0.70
ARP34	2.00
ARP35	1.50
ARP37	1.00
BT5B	43.50
BT17A	95.00
C1K	14.00
C3JA	10.00
DAC32	1.20
DAF91	0.45
DAF96	0.65
DC70	1.75
DC90	1.20
DCX4-1000	35.00
DET10	6.00
DET22	28.00
DF91	0.45
DF92	0.60
DF96	0.65
DF97	1.50
DH63	2.20
DH77	0.90
DK91	0.90
DK92	1.20
DK96	1.00
DL73	2.50
DL92	0.60
DL94	1.20
DL96	1.00
DLS10	9.00
DLS16	10.00
DM70	1.10
DM160	2.50
DY51	1.00
DY80	1.20
DY86/87	0.55
DY802	0.60
E1T	15.00
E55L	14.00
E80CC	4.75
EABC80	0.56
EAC91	0.90
EAF42	1.40
EAF801	1.40
EB41	2.30
EB34	1.50
EB91	0.52
EBC33	1.00
EBC41	0.85
EBC81	0.85
EBC89	0.85
EBC90	0.75
EBC91	0.75
EBF80	0.55
EBF89	0.70
EBL1	1.50
EBL21	2.00
EC52	0.70
EC86	1.00
EC88	1.00
EC90	0.60
EC91	7.00
EC93	0.80
EC8010	6.00
ECC33	4.00
ECC40	2.30
ECC81	0.55
ECC82	0.55
ECC82 Mullard	1.10
ECC83	0.60
ECC83 Mullard	1.10
ECC84	0.60
ECC85	0.60
ECC88	0.65
ECC91	0.65
ECC189	0.78
ECC2000	12.00
ECC803S	1.50
ECC804	0.40
ECC807	1.30
ECF80	0.65
ECF82	0.60
ECF86	1.50
ECF802	1.20
ECF804	6.00
ECF812	1.20
ECH3	2.50
ECH4	3.00
ECH35	1.50
ECH42	1.00
ECH81	0.58
ECH83	0.78
ECH84	0.93
ECL80	0.66
EF94	0.55
EF95	0.60
EF96	0.65
EF97	0.95
EF98	0.95
EF183	0.65
EF184	0.65
EF731	1.80
EH90	0.72
EK90	0.72
EL32	0.95
EL33	4.00
EL34	1.54
EL34 Philips	2.45
EL36	1.60
EL37	9.00
EL38	4.50
EL81	2.05
EL82	0.58
EL84	0.66
EL85	3.85
EL86	0.80
EL90	0.82
EL91	6.00
EL95	0.70
EL360	9.00
EL504	1.40
EL519	4.50
EL821	10.00
EL822	10.00
EM1	4.00
EM4	4.00
EM80	0.70
EM81	0.70
EM84	0.70
EM85	0.85
EM87	1.10
EMM803	2.50
EN10	8.00
EN32	14.00
EN91	0.95
EN92	4.00
ES1500	115.00
EY51	0.80
EY83	1.50
EY84	8.00
EY86/87	0.50
EY88	0.60
EY500A	1.50
EZ41	1.20
EZ80	0.60
EZ81	0.60
EZ90	0.96
FW4-500	2.00
G1/371K	30.00
GZ34	2.00
GZ37	4.00
HL41	1.50
HL42DD	2.00
HL92	1.50
HL133/DD	1.50
HP6	1.50
HY90	1.00
KT36	2.00
KT44	3.00
KT45	3.00
KT61	4.00
KT63	2.00
KT66 USA	6.00
KT66 UK	9.00
KT67	2.00
KT77	5.00
KT81	2.50
KT88 USA	7.00
KT88 UK	11.50
KTW61	1.50
L63	1.00
L102/2K	8.00
L120/2K	12.00
M502A	135.00
M537A	160.00
M8079	6.00
M8083	3.25
M8100	2.85
M8136	7.00
M8137	5.50
M8162	3.85
M8195	3.00
M8196	3.25
M8225	1.20
ME1400	4.00
ME1402	4.50
ME1403	10.00
ME1501	14.00
MH4	2.10
MH41	2.10
MS4B	5.00
MU12	1.50
MU14	1.50
N37	3.00
N78	8.90
NR14	9.00
NR73	3.50
NU3	1.50
NU17	1.50
NU18	1.50
OA2	0.60
OA3	3.00
OB2	0.65
OC3	1.05
OD3	1.15
OM4	1.00
OM5B	3.60
PCF805	2.00
PCF806	0.60
PCF808	1.48
PCH200	1.10
PCL82	0.80
PCL83	2.00
PCL84	0.80
PCL85	0.80
PCL86	0.80
PCL200	1.60
PCL805	0.90
PD500	3.50
PEN4DD	1.50
PEN25	1.50
PEN45	3.50
PEN46	1.50
PENA4	2.50
PFL200	1.13
PL33	0.75
PL36	1.05
PL81	0.75
PL81A	0.74
PL82	0.60
PL83	0.52
PL84	0.65
PL95	1.00
PL500	1.12
PL504	1.20
PL508	1.48
PL509	2.95
PL519	3.15
PL802	2.75
PL820	3.00
PT4	4.00
PT15	4.50
PY31	0.60
PY32	0.60
PY33	0.60
PY81	0.70
PY82	0.55
PY83	0.70
PY88	0.74
PY500A	1.45
PY800	0.70
PY801	0.70
QB3-300	30.50
QE03-10	3.50
QP25	1.00
QQE03-12	4.50
QQE06-40	13.95
QQV02-6	10.50
QQV03-10	3.75
QQV03-20A	12.25
QQV06-40A	13.95
QQZ06-40A	45.25
RG3-1250	45.00
RG4-1000	10.00
RK-20A	12.00
RPL16	12.00
RR3-250	37.00
RR3-1250	65.00
S6F33	25.00
S130	2.50
S130P	3.00
SP41	4.00
SP42	2.50
STV280/40	8.00
STV280/80	30.00
T41	2.00
TB2-300	45.00
TBW7-900	315.00
TD03-10F	23.00
TP25	1.50
TT11	1.50
TT21	19.50
TY2-125A	45.00
TY4-350	90.00
TY4-400	60.00
TY4-500	60.00
TY8-600W	315.00
TYS2/250	750.00
U10	1.50
U15	1.50
U17	1.50
U18-20	2.00
U19	11.95
U22	1.00
U25	0.68
U26	0.90
U37	12.00
U41	0.70
U191	0.70
U193	0.65
U281	1.00
U282	1.00
U291	0.60
U301	0.60
U309	0.60
U801	0.80
UABC80	0.65
UAF42	1.00
UBC81	1.00
UBF80	0.60
UBF89	0.60
UBL21	1.20
UC92	0.80
VR102	1.50
VR105/30	1.05
VR150/30	1.15
VT25	5.00
VT75B	3.00
VT120	1.15
VT138	4.25
VU39	1.50
VX6120	5.00
VX9133	5.00
X65	0.85
X66	0.85
X719	0.58
XG5-500	19.50
XR1-1600A	29.00
XR1-6400A	128.00
YL1020	29.00
YL1060	15.00
YL1370	5.50
Z63	1.00
Z77	1.20
Z303C	9.00
Z502C	12.00
Z504S	13.50
Z700U	1.00
Z749	0.48
Z759	16.00
Z803U	13.50
ZA1002	1.48
ZC1040	8.00
ZM1001	5.00
ZM1005	8.00
ZM1020	4.00
ZM1021	8.00
ZM1023	6.00
ZM1041	13.00
ZM1202	98.00
ZM1262	7.00
1AC6	1.20
1B22	10.00
1B3GT	1.00
1B5	2.50
1D5	1.00
1G3GT	1.00
1G5	1.00
1L6	1.50
1LA6	1.00
1U5	1.00
1X2B	1.15
4CX350A	52.00
4DT6	2.00
5A163K	10.00
5A-170K	5.25
5A/206K	9.00
5AN8	1.20
5B-254M	14.50
5B-255M	14.50
5D6	4.00
5D21	15.50
5D22	38.00
5R4GB	2.80
5U4G	0.85
5U4GB	1.50
5V4G	0.85
5Y3GT	0.85
5Z4G	0.85
6/30L2	0.70
6A/203K	9.00
6A6	1.50
6A8G	1.50
6AB7	0.60
6AB8	0.66
6AC7	1.00
6AF4A	1.20
6AG7	1.20
6AH6	1.00
6AJ7	1.00
6AK5	0.60
6AK6	2.00
6AL5	0.52
6AM4	2.50
6AM5	6.00
6AM6	1.30
6AN5	2.00
6AN8A	2.50
6AQ5	0.82
6AR8	2.00
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	0.80
6AV5GTA	1.50
6AU6	0.55
6AV6	0.72
6AW8A	2.50
6AZ8	1.80
6B10	2.50
6BA6	0.50
6BA7	3.75
6BA8A	3.50
6BZ8	0.95
6C4	0.60
6C6	0.50
6C8G	1.25
6C11	2.50
6C15	2.50
6C18	2.50
6C31	1.50
6CB5	1.50
6CB6	1.50
6CD6GA	4.00
6CF6	1.50
6CG8A	1.00
6CH6	10.00
6CL6	1.50
6CZ5	2.00
6DC6	2.00
6DW4	1.20
6EA8	1.80
6F1	2.00
6F6G	2.00
6F8G	1.50
6F12	1.30
6F14	1.00
6F22	0.70
6F23	0.48
6F24	1.25
6F25	1.25
6F26	0.48
6F28	1.25
6F33	9.00
6FG5	1.50
6FH5	1.50
6FN5	1.50
6FL2	1.50
6GH8A	0.60
6GK5	1.00
6GK6	2.00
6H2N	0.70
6H3N	0.70
6H6	1.00
6HF5	4.50
6HG8	1.50
6HZ6	1.00
6J5GT	0.75
6J6	0.55
6J7	1.05
6JB6	3.95
6JE6	2.10
6JS6C	2.55
6K4N	1.00
6K7	0.70
6KD6	3.95
6L1	2.50
6L6GC	1.90
6L6GT	1.20
6L7	0.55
6L15	1.50
7S7	2.00
7Y4	1.00
8D8	2.75
8FQ7	1.40
9BW6	1.20
91AG	10.00
10C1	5.50
10C2	0.70
10D2	1.25
10F1	0.75
10F9	0.75
10F18	0.60
10GK6	1.95
10P14	2.50
11E2	16.50
12A4	2.50
12AC6	0.80
12AD6	0.80
12AE6	0.85
12AG8	1.50
12AH7GT	0.85
12AH8	5.50
12AT6	0.59
12AT7	0.55
12AT7WA	2.50
12AU6	0.60
12AU7	0.55
12AV6	0.80
12AX7	0.55
12AX7WA	2.50
12AY7	4.00
12AZ7A	1.50
12B4A	1.60
12BA6	0.75
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BA154	0.06
BA155	0.13
BA156	0.15
BAX13	0.04
BAX16	0.06
BB105B	0.30
BY126	0.10
BY127	0.11
BY133	0.15
BY164	0.45
BY176	0.85
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BY210.800	0.33
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BY298.400	0.22
BY299-800	0.22
BYX10	0.20
BYX55/600	0.30
BYX71/600	0.30
OA47	0.09
OA90	0.05
OA91	0.06
IN914	0.03
IN4001	0.04
IN4002	0.04
IN4003	0.04
IN4004	0.05
IN4005	0.05
IN4006	0.06
IN4007	0.06
IN4148	0.02
IN4448	0.10
IN5401	0.12
IN5402	0.14
IN5403	0.12
IN5404	0.13
IN5405	0.13

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B7G Skirted	0.30
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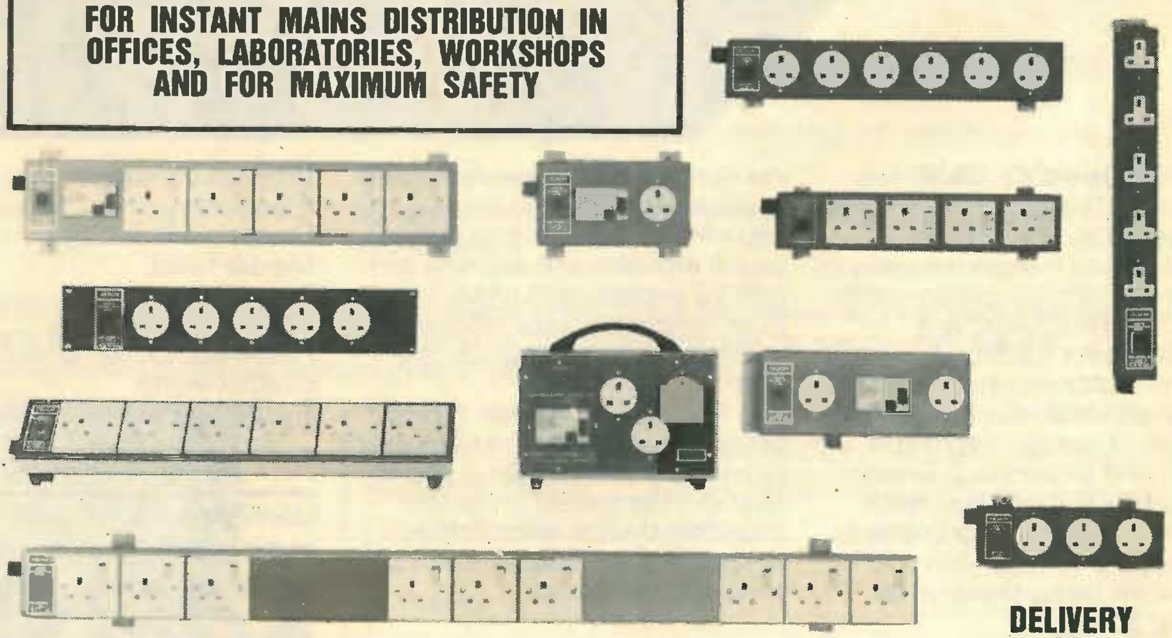

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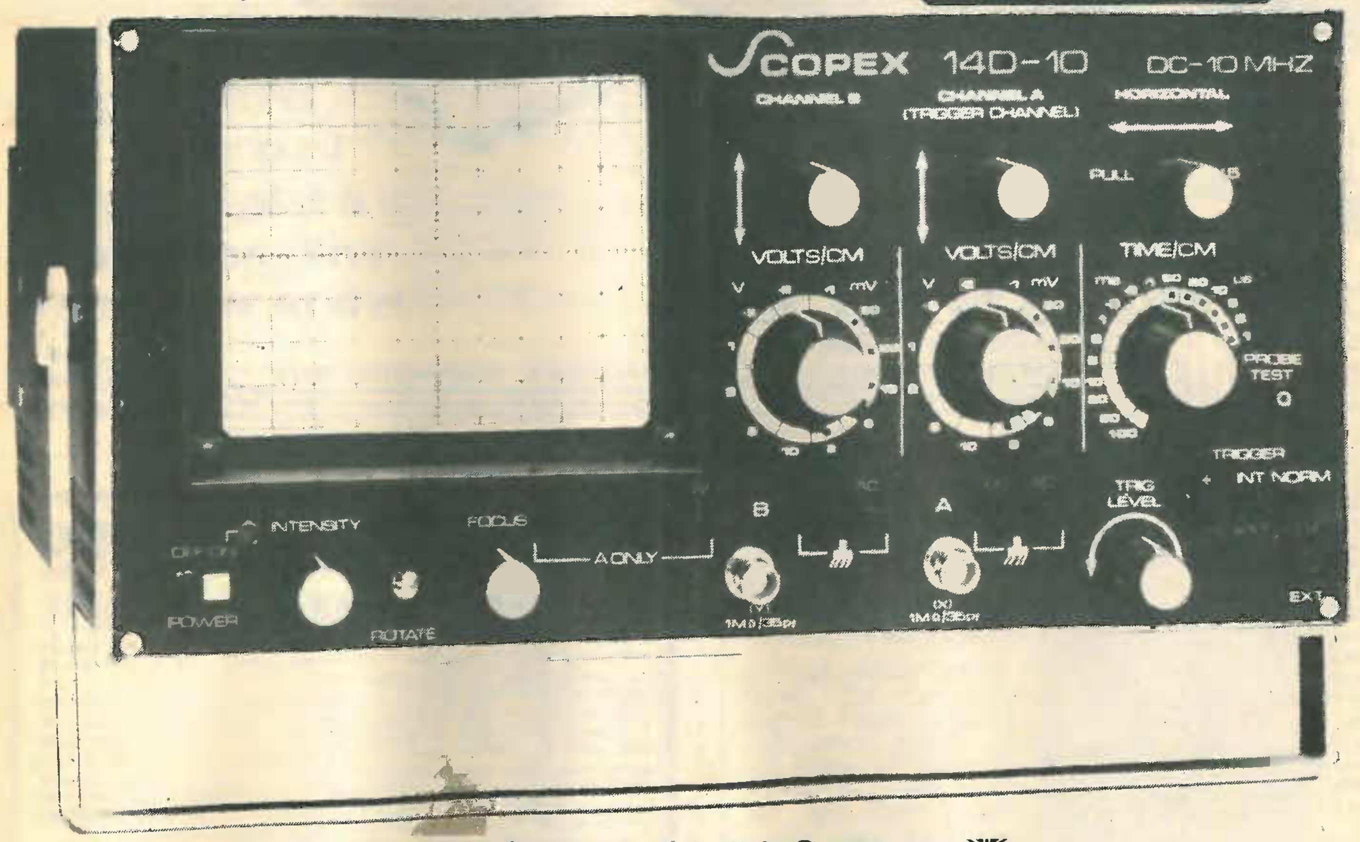

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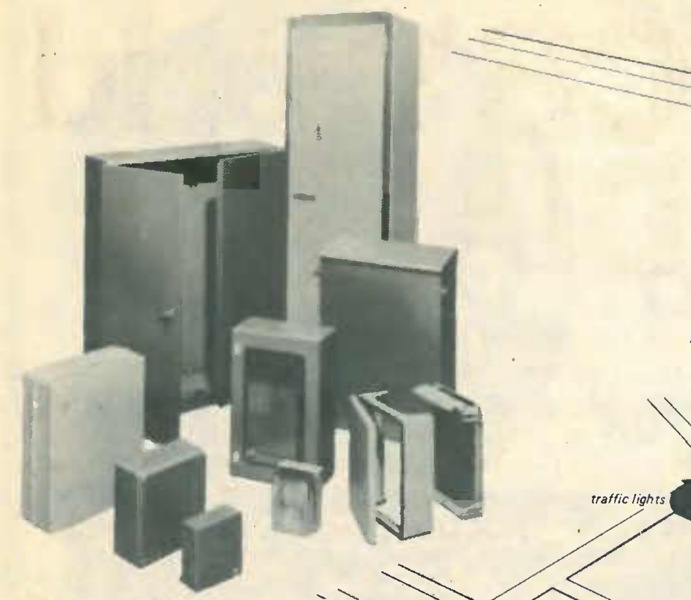

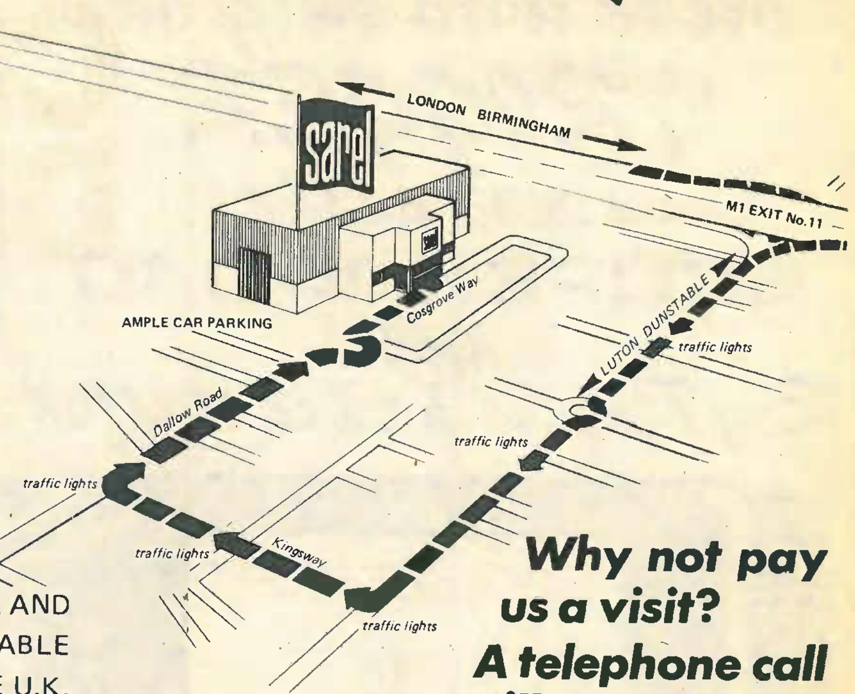

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4116 200NS	65p	60	55p	50p	45p
4116 150NS	75p	70p	65p	60p	55p
2114L 200NS	£1.00	95p	90p	85p	80p
6116 16K CMOS RAM 150NS	£6.50	6.00	5.50	5.00	4.50
4164 64K Dynamic RAM – No refresh on Pin 1 – 200NS	£6.50	6.00	5.50	5.00	4.50
4164S 64K Dynamic RAM with Pin 1 refresh 200NS	£8.00	7.50	7.00	6.50	6.00
2716 5V 450NS	£2.00	1.90	1.85	1.80	1.75
2732 450NS	£4.50	4.00	3.75	3.25	3.00
2532 450NS	£4.75	4.50	4.25	4.00	3.50

FLOPPY DISK CONTROLLERS

FD1771	£18
FD1791	£29
FD1797	£32
FD1691	£13
Set of FD1797 and FD1691	£40

BAUD RATE GENERATOR

COM 8116	£9.95
5.06MHz crystal for above	£3.50

ORDERING INFORMATION: For orders under £50 add 50p P&P. Please add 15% VAT to total value of order including postage and packing. All devices are prime, brand new, full spec and fully guaranteed. All items are subject to availability. Prices are subject to change without notice. CALLERS WELCOME.

VINCELORD LTD.

Suite 2
26 Charing Cross Road
London W.C.2
Tel: 01-625 6533 Telex: 27486 Equity G

WW098

WW – 098 FOR FURTHER DETAILS

CB World DIARY

By arrangement with Charles Letts, the famous diary people, we are to sell through *CB World* a limited number of CB Diaries. These diaries would normally be sold through bookshops and main newsagents but to introduce them for 1982, Letts have agreed that we should market them through the publication. Contents include:

- How c.b. works
- SWR your c.b. radio
- Setting up a Home Based c.b. unit
- Setting up a mobile c.b. unit
- c.b. fault finder guide
- 10-code
- Q-code
- Phonetic alphabet

Plus section for your Good Buddies, their handles, their home 20s and their land lines.
£2.45 (inclusive)

To: CB World, General Sales Dept., Room 205, Quadrant House, The Quadrant, Sutton, Surrey.

Please send me . . . . copy(ies) of *CB World* 1982 Diary at £2.45 each. My remittance is enclosed for £. . . . . . made payable to IPC Business Press Ltd.

These Diaries will be available towards the end of November 1981. Please send now to avoid disappointment.

Name ____________________

Address ____________________

www.americanradiohistory.com

COMPUTER WAREHOUSE

NOW OPEN MONDAY-SATURDAY 9.30-5.30

BULK BUY SPECIALS — RAM SCOOP 4116 200 NS 8 for £12.95; 2102-650 NS 8 for £5.50 INC VAT

25 WAY "D" CONNECTORS: 50+ / 100+ — 25p 1.70 1.10 0.95; 25S 1.90 1.20 1.00. ALL + VAT

WIRE WRAP SKTS. 24 Pin Vero 28p; 14 Pin Gold 22p; 16 Pin Gold 24p; 100 PCS Min Ord.

C10 DATA CASSETTES 10 for £5.75 Inc. VAT

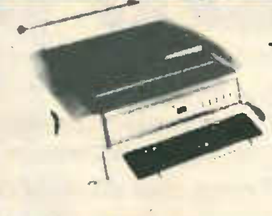
RF CONNECTORS 50Ω BNC PLG 50p; 75Ω BNC PLG 50p; PL259 PLG 40p; SO239 SKT 35p; 100 PCS MIN ORD.

TELETYPE ASR33 I/O TERMINALS

From £195 + CAR + VAT

Fully fledged industry standard ASR33 data terminal. Many features including: ASCII keyboard and printer for data I/O, auto data detect circuitry, RS232 serial interface, 110 baud, 8 bit paper tape punch and reader for off line data preparation and ridiculously cheap and reliable data storage. Supplied in good condition and in working order. Options: Floor stand £12.50 + VAT. Sound proof enclosure £25.00 + VAT

ICL TERMIPRINTER 300 BAUD TERMINALS



REDUCED TO CLEAR NOW ONLY £80 +CAR +VAT

Made under licence from the world famous GE Co. The ICL Termiprinter is a small attractive unit with so many features it is impossible to list them in the space available! Brief spec. as follows; RS232 serial interface, switchable baud rates 110, 150, 300, (30 cps), upper and lower case correspondence type face, standard paper, almost silent running, form feed, electronic tab settings, suited for word processor applications plus many more features. **Supplied complete, in as seen condition, no guarantee.**

MPU EXPERIMENTORS +5v +12v -12v +24v POWER SUPPLY

Once again we are very pleased to offer this superb Power Supply Unit, and hope to satisfy most of our previous customers who were disappointed when we sold out due to demand last time they were advertised!!! These units may just have well been made for your lab., they consist of a semi-enclosed chassis measuring 180mm x 120mm x 350mm containing all silicon electronics to give the following fully regulated and short circuit proof outputs of: +5v @ 2 amps DC, +12v @ 800 ma DC, -12v @ 800 ma DC, +24v @ 350 ma DC and if that's not enough a fully floating 5v output @ 50 ma DC which may be seriesed to give a host of other voltages. All outputs are brought out to the front panel via miniature jack sockets and are also duplicated at the rear on short flying leads. Units accept standard 240v mains input. They are ex GPO and may have minor scratches on the front panels, they are sold untested but in good internal condition. £16.50 each + £2.50 p+p complete with circuit and component list. Transformer guaranteed. HURRY WHILE STOCKS LAST!!

HIGH SPEED DATA MODEMS

A superb piece of engineering made by SE Labs Ltd. to a "no cost spared" spec for the GPO, the Modem 12 is a synchronous Modem for use on DATEL 2412 services, or other data links. Many features include switchable V26 modulation, 2400 baud full duplex 600/1200 standby, auto answer, 4 wire or 2 wire operation. Self test, LED status indication, CMOS technology, modular construction, original cost over £700 each. Believed brand new, supplied complete with PSU etc. £185.00 + £9.50 carriage + VAT. *Permission may be required for connection to PO lines.

PERTEC

PERTEC TAPE DRIVES
7 track 6840 — 75-25 £175.00 + VAT
9 track 6840 — 9-25 £295.00 + VAT
Phone for more details

DIABLO S30 DISK DRIVES

Another shipment allows us to offer you even greater savings on this superb 2.5 MB (formatted) hard disk drive. Two types are available both fully refurbished and electronically identical, the only difference is the convenience of changing the disk packs.
S30 front loader, pack change via front door £550 + vat
S30 fixed, pack change via removal of top cover £295 + vat
+ & — 15v PSU for 2 drives £125 + vat
SPECIAL OFFER new, 12 sector packs £20 + vat carriage & insurance on drives £15.00 + vat fully DEC RK05, NOVA, TEXAS compatable further info on controllers etc on request.

THE PRINTER SCOOP OF THE YEAR

SAVE OVER £1400

THE LOGABAX Z80 MICROPROCESSOR CONTROLLED LX180L MATRIX PRINTER

A massive bulk purchase enables us to offer you this superb professional printer at a fraction of its recent cost of over £2000. Utilising the very latest in microprocessor technology, it features a host of facilities with all electronics on one plug in P.C.B. Just study the specification and you will instantly realise it meets all the requirements of the most exacting professional or hobbyist user.
STANDARD FUNCTIONS ★ Full ASCII character set ★ Standard ink ribbon ★ RS232/V24 serial interface – 7 total controlled baud rates up to 9600 ★ 194 characters per line ★ Parallel interface ★ Handshakes on serial and parallel ports ★ 4 Type fonts, italic script, double width, italic large, standard ★ Internal buffer ★ Internal self test ★ 170 CPS ★ Variable paper tractor up to 17.5" wide ★ Solid steel construction ★ All software in 2708 eproms easily reconfigured for custom fonts etc.
All this and more, not refurbished but BRAND NEW At Only £525 +VAT
Also available identical to above LESS Electronics Card £250 + VAT + carriage and ins. £18.00 + VAT
OPTIONAL EXTRAS ★ Lower case £25.00 ★ 16K buffer £30.00 ★ Second tractor for simultaneous dual forms £85.00 ★ Logabax maintenance. P.O.A.

SOFTY 1 & 2

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Software development system invaluable tool for designers, hobbyists, etc. Enables open heart surgery on 2716, 2708 etc. Blows, copies, reads EPROMS or emulates EPROM/ROM/RAM in situ whilst displaying contents on domestic TV receiver. Many other features. £115 + carr. + VAT. Optional 2716, 2716 Function Card £40 + VAT. PSU £20 + £1.50 carr. + VAT.
Softy 2 for 2716/2732 £169 + VAT
Write of phone for more details.

9" VIDEO MONITORS

Ex-equipment 9" Motorola Video Monitors 75Ω composite input, tested but unguaranteed. £39.99 + £7.50 carriage + VAT. Complete with circuit.

NATIONAL MA1012 LED CLOCK MODULE

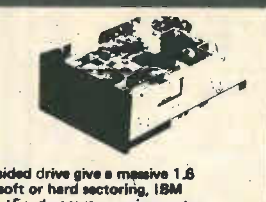
★ 12 HOUR ★ ALARM ★ 50/60 HZ

The same module as used in most ALARM/CLOCK radios today, the only difference is our price! All electronics are mounted on a PCB measuring only 3" × 1½" and by addition of a few switches and 5/16 volts AC you have a multi function alarm clock at a fraction of cost. Other features include snooze timer, am pm, alarm set, power fail indicator, flashing seconds cursor, modulated alarm output etc. Supplied brand new with full data only. Suitable transformer £1.75. £5.25

SEMICONDUCTOR 'GRAB BAGS'

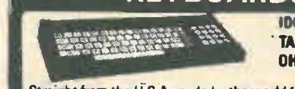
Mixed Semis amazing value contents include transistors, digital, linear, I.C.'s, triacs, diodes, bridge recs., etc. etc. All devices guaranteed brand new full spec with manufacturer's markings, fully guaranteed. 50+ bag £2.95 100+ bag £5.15
TTL 74 Series
A gigantic purchase of an "across the board" range of 74 TTL series I.C.'s enables us to offer 100+ mixed "mostly TTL" grab bags at a price which two or three chips in the bag would normally cost to buy. Fully guaranteed all I.C.'s full spec. 100+ £6.90 200+ £12.30 300+ £19.50

8" FLOPPY DISK DRIVES



Yet again we've managed to secure a large shipment of tomorrows technology at prices as yet unheard of!! And as with most of our purchases can pass these savings direct to you!! The DR 7100 & 7200 8" floppy disk drives have many inbuilt features to provide literally any BUS configuration with full daisy chain via internal jumpers 77 tracks on the single sided 7100 give upto 0.8 MB of data and 154 tracks on the 7200 double sided drive give a massive 1.6 MB of data. Many other features such as soft or hard sectoring, IBM or ANSI standards, only 240v AC, +24 & +5 v dc power requirements, and our unbelievable prices make these drives a snip.
Supplied BRAND NEW and boxed complete with user manual:
7100 single sided £225.00 + 8.50 ins. & carr. + vat.
7200 double sided £295.00 + 8.50 ins. & carr. + vat.
Full technical manual available £7.50 write or phone for more details.

RCA FULLY CASED ASCII CODED KEYBOARDS



IDEAL – TANGERINE, OHIO ETC.

Straight from the U.S.A. made by the world famous R.C.A. Co. the VP600 Series of cased freestanding keyboards meet all requirements of the most exacting user, right down to the price! Utilising the latest in switch technology. Guaranteed in excess of 5 million operations. The keyboard has a host of other features including full ASCII 128 character set, user definable keys, upper/lower case, rollover protection, single 5V rail, keyboard impervious to liquids and dust, TTL or CMOS outputs, even an on-board tone generator for keypress feedback, and a 1 year full R.C.A. backed guarantee.
VP601 7 bit fully coded output with delayed strobe, etc. £43.95
VP611 Same as VP601 with numeric pad. £54.95
VP606 Serial, RS232, 20MA and TTL output, with 6 selectable Baud Rates. £64.26
VP616 Same as VP606, with numeric pad. £84.34
Plug and cable for VP601, VP611 £2.25
Plug for VP606, VP616 £2.10
Post, Packing and Insurance. £1.95
ORDER NOW OR SEND FOR DETAILS.

MAINS FILTERS

Professional type mains filters as used by "Main Frame Manufacturers" ideal for curing those unnerving hang ups and data glitches, fit one now and cure your problems! Suppression Devices SD5 A10 5 amp £6.95. Corcom Inc F1900 30 amp £13.95 + pp £1.00

MUFFIN FANS

Keep your equipment Cool and Reliable with our tested ex-equipment "Muffin Fans" almost silent running and easily mounted. Available in two voltages. 110 V.A.C. £5.05 +pp 90p OR 240v A.C. £6.50 +pp 90p. DIMENSIONS 4¾" x 4¾" x 1½"

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LMC C5V 5V 10 AMP PSU, 240V NEW £45 + VAT + £2.50 P&P

— DEC CORNER —

DEC TU60 TWIN CASSETTE DRIVE ... £375 + VAT
PDP1105 MINI I/O MEMORY, CPU ETC. £450 + VAT
LSI1132K BYTE CMOS MEMORY CARDS £295 + VAT
RK05 MEMOREX DISK PACKS (12 sector) £20.00 + VAT
LSI1102 PROCESSOR CARD £275.00 + VAT
• • All types of DEC equipment purchased for cash • •

ELECTRONIC COMPONENTS & EQUIPMENT 66% DISCOUNT

Due to our massive bulk purchasing programme which enables us to bring you the best possible bargains, we have thousands of I.C.'s, Transistors, Relays, Cap's., P.C.B.'s, Sub-assemblies, Switches, etc. etc. surplus to our requirements. Because we don't have sufficient stocks of any one item to include in our ads., we are packing all these items into the "BARGAIN PARCEL OF A LIFETIME" Thousands of components at giveaway prices! Guaranteed to be worth at least 3 times what you pay plus we always include something from our ads. for unbeatable value!! Sold by weight
2.5kls £ 4.75 + pp £1.25 — 5kls £ 6.75 + pp £1.80
10kls £11.75 + pp £2.25 — 20kls £19.99 + pp £4.75

DISPLAY ELECTRONICS

Dept. W.W. 64-66 Melfort Rd., Thornton Heath, Croydon, Surrey. Tel: 01-689 7702 or 01-689 6800

MAIL ORDER INFORMATION
Unless otherwise stated all prices inclusive of V.A.T. Cash with order. Minimum order value £2.00 Prices and Postage quoted for UK only. Where post and packing not indicated please add 60p per order. Bona Fide account orders minimum £20.00. Export and trade enquiries welcome. Orders despatched same day where possible. 3% surcharge on Access and Barclaycard orders.

5v D.C. POWER SUPPLIES

Following the recent "SELL OUT" demand for our 5v 3 amp P.S.U. we have managed to secure a large quantity of ex-computer systems P.S.U.'s with the following spec.: 240 or 110v A.C. input. Outputs of 5v @ 3-4 amps, 7.2v @ 3 amps and 6.5v @ 1 amp. The 5v and 7.2v outputs are fully regulated and adjustable with variable current limiting on the 5v supply. Unit is self contained on a P.C.B. measuring only 12" x 5" x 3". The 7.2v output is ideal for feeding "on board" regulators or a further 3 amp LM323K regulator to give an effective 5v @ 7 amp supply. Supplied complete with circuit at only £10.95 + £1.75pp. Believed working but untested, unguaranteed.

WW – 096 FOR FURTHER DETAILS

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Advertisements accepted up to 12 noon Monday, November 30 for January issue, subject to space being available.

DISPLAYED APPOINTMENTS VACANT: £13.50 per single col. centimetre (min. 3cm).
LINE advertisements (run on): £2.50 per line, minimum 5 lines. (Prepayable).
BOX NUMBERS: £1.50 extra. (Replies should be addressed to the Box Number in the advertisement, c/o Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.)
PHONE: OPHELIA SMITH, 01-661 3033 (DIRECT LINE)
Cheques and Postal Orders payable to IPC Business Press Ltd.

A HOST OF ELECTRONICS APPOINTMENTS

£5,000-£15,000 p.a.

3	Essex	[illegible]			
	Glos	Design Engineers	Control/Comp Sys	Z80/8080/H&S'ware	£6-10K
3	Hants	Design Engineers	Datacomms	Dig/Analogue/Line	£7-[illegible]K
40	Hants	Software Engineers	[illegible]	[illegible]	[illegible]
	Herts	Consultant	Computer Systems	[illegible] R/T Mini-Micro H/S'ware	£7-15K
42	Herts	Design Engineers	Several	6800, 68000; AMD2900; Z80	£6-12K
44	Herts	H/S'ware Engineer	Control Systems	68000/Z80 H'ware + R/T Assembler	£8-12K
46	Herts	Sales Manager	Test Equipment	[illegible] test instruments	c£12K+c
48	Herts	Test Technician	Telecine	Test of Analogue/Digital/Video	£6K+
	Holland/Scotland	Software Engineer	Telemetry	Z80/8080 Macro Assembler	c£11K
50	Lancs	Sen Design Eng	Micro Systems	Z80/6502/2650 etc	£9-10K
52	London	Design Engineers	Many	Large/Small Co's; all levels exp	£5-13K
54	London	Sales Engineers	Test Insts	HNC/BSc + 2 yrs Sales exp	c£10K+c
	London	Service Engineers	Computer/Perip	Sev for good mini/micro/perip exp	£6-11K+c
56	London	Service Supervisor	Micro Terminal	RAIR or similar useful	c£8.5K+c
58	Middx	Design Engineer	Several	BSc/HND & Dig/An/RF	£8-10K
60	Middx	Software Engineer	Process Control	Des/25+ R/T Software RSX11 etc	to £10K
	Middx	Systems Engineer	Control	BSc+ Real time Control exp	£7K+
62	Northants	Service Engineer	Mini Computers	Good Digital/Mini/Peripherals	£8K+c
64	S.England	Commercial Manager	Communications	Good Admin & Export Experience	c£13K
	S.England	Marketing Director	Weapon Systems	Sev. years exp MOD Negotiation	c£15K+c
	S.England	Mechanical Designer	Radar	Senior Appoint Good Allround exp	to £12K
2	S.England	Procurement Exec	Radar	Several years Procurement exp	c£12K+c
4	S.England	Production Controller	Radar	MOD Environment	c£8K
	S.England	Sales Managers	Communications	Export Sales & Naval Systems	to c£14K
	S.England	Systems Engineers	Communications	HF/UHF/VHF/Microwave UK & OS	£neg
	S.England+ O/S	Installation Engineers	Communications	UHF/Microwave UK & OS	c£10-11K
10	Surrey	Applications Engineer	[illegible]	Modem/MUX/Line Comms	£8-10K+c
12	Surrey	Des/Dev Engineer	Several	Digital/RF/Analogue/Micro	£7-10K
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14	Surrey	Field Service	Computer Sys	Mini/Micro & periph experience	c£8K+c
16	Surrey	Field Service	Datacomms	Dig/[illegible] Modems-MUX-Telecomms	£6-8K+c
	Surrey	Sales Engin[illegible]	Data Loggers	Micr[illegible] Telecomms etc	~£10K+c

✲ We are aware of c2000 electronics companies throughout the U.K.
✲ These are just a few of their recently notified vacancies.
✲ If you are a qualified & experienced engineer seeking a new opportunity – or interested in discussing your potential contact either MIKE GERNAT or PETER BROWN on 076 384 676/7 (Till 8pm most Evenings).

ELECTRONIC COMPUTER AND MANAGEMENT APPOINTMENTS LTD 148-150 High St. Barkway Royston Herts SG8 8EG

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If you would like to develop your potential in the exciting future of Europe's leading test equipment specialist, complete the coupon and send it to us at the address below:-

marconi instruments

Return this coupon to John Prodger, Marconi Instruments Limited, Freepost, St. Albans, Hertfordshire, AL4 0BR. Telephone: St. Albans 59292

A GEC-Marconi Electronics Company

Name ____________________ Age ____

Address ____________________

Telephone Work/Home (if convenient) ____________

Years of experience	☐ 0-1	☐ 1-3	☐ 3-6	☐ Over 6
Present salary	☐ £4000-5000	☐ 5000-6000	☐ 6000-7000	☐ Over 7000
Qualifications	☐ None	☐ C&G	☐ HNC	☐ Degree

Present Job ____________________

(1234)

We've Made a Name for Ourselves and you could do the same

As EaE, we earned a reputation for the quality of our work in oilfield communications.

And now that we are part of the Palmer EaE Group, our activities are expanding faster than ever. Which is why we require

Radio Technicians and Communications Engineers

We are looking for seasoned professionals – Technicians with experience of HF, MF, VHF and UHF, and Engineers familiar with Microwave Transmission, Multiplexing and Scada Systems (and with HNC qualifications under their belt).

In the North Sea, earnings are up to £14,000, while overseas posts could be worth up to £20,000, plus tax concessions and generous home leave.

If you'd like to make a name for yourself, in one of the best jobs in the business, please write to Mike Futter, Palmer EaE Limited, Offshore House, 284-285 Southtown Road, Gt. Yarmouth, Norfolk, NR31 0JB.

PALMER EaE

1400

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The selected engineers will be operating or maintaining Rank Cintel MKIIIs with Topsy and Digiscan, and consequently only people with the necessary experience and skills need apply.

Salaries within the range £10,511-£11,793, according to experience, plus the opportunity for a considerable amount of overtime working. The Company benefits from an attractive contributory Group Pension Scheme, which includes free Life Assurance.

Please write or 'phone for an application form to:
Alan Edwards, Director of Operations
Television International Operations Limited
9-11 Windmill Street
London W1P 1HF
Tel: (01) 637 2477

1411

Test Engineers and Technicians – Wembley, Middlesex

Racal-BCC are members of the highly successful Racal Electronics Group and are world leaders in the design and manufacture of tactical radio communications equipment. We require a number of test technicians and test engineers to fill a variety of grades within the Test Department. The department is responsible for the manual and automatic testing and fault finding of the Company's equipments at various stages of manufacture.

Applicants should be qualified to HNC/HTC level and have experience of radio communications equipment.

We offer excellent conditions of service including good basic pay and a Group Productivity scheme.

Please apply in writing to:
The Personnel Officer.
Racal-BCC. South Way.
Wembley. Middlesex.

Racal-BCC

RACAL

World leaders in electronics

(1376)

Dolby

ELECTRONICS PRODUCTION ENGINEERS

South London **c. £7000**

Dolby Laboratories, the successful and progressive manufacturers of professional audio noise reduction equipment require Production Engineering staff. Those appointed will join a small team who are responsible for the introduction of new products into production, liaison with the R. & D. team, product improvement and component specification.

Ideal applicants will have several years' experience in electronics manufacturing. However, less-experienced electronics graduates will be considered who would find this an excellent opportunity to learn the details of electronic design from a production viewpoint. The ability to work projects through to successful conclusions without close supervision is essential.

Competitive salaries and excellent employment conditions are offered.

For application form, contact Phil Marshall

DOLBY LABORATORIES INC.
346 Clapham Road
London, S.W.9
01-720 1111

(1406)

PRODUCTION MANAGER

KILLALOE, COUNTY CLARE

IR. £12,500

Peak Electronics Limited is a private Irish Company with international subsidiaries which manufactures intruder detector and traffic control equipment using Infra-Red and Microwave technology. About 60 people are employed in total 50 of whom are engaged directly in production. The workforce is predominantly female.

Due to an expanding range of products and increasing sales, the company now wishes to appoint an experienced Production Manager.

Reporting to the Operations Director the Production Manager will be responsible for meeting **production output requirements** to required **quality** and **cost** standards; will be expected to contribute substantially in such areas as **production engineering, industrial engineering** and **quality** monitoring procedures, and will be capable of instituting and developing the necessary systems for the effective management of the department.

Candidates will ideally have had a number of years' experience in electronic and light mechanical assembly. This experience having been gained in production line management or through production engineering/quality control.

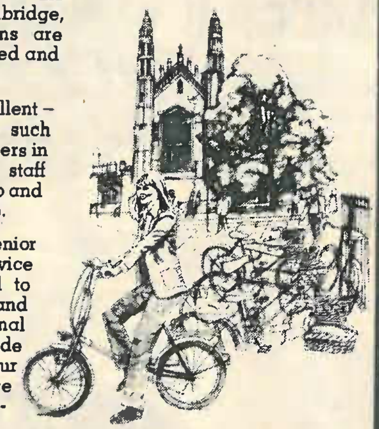
Salary is likely to be in the region quoted but would not be a limiting factor for the right candidate and normal benefits will apply.

Applications in writing, giving personal and career details, should be sent to the Managing Director, Peak Technologies Limited, Sunley House, 57 High Street, Edgware, Middlesex, HA8 7XA.

(1379)

www.americanradiohistory.com

Broadcasting in Cambridge



Here at Pye TVT Ltd, based in the beautiful University city of Cambridge, broadcast engineering positions are available for suitably experienced and mature people.

The working conditions are excellent – a large modern building with such facilities as befits the world leaders in broadcasting equipment, a staff restaurant and canteen, staff shop and a thriving sports and social club.

Two positions are available – a senior installation engineer, and a service engineer. The former will lead to management of installation and commissioning of professional broadcast systems, and a wide knowledge of broadcast colour studio operation and maintenance with appropriate technical qualifications to at least HNC level are preferred. Plus, of course, essential practical experience, a sense of responsibility, self motivation, and the ability to work as part of a team anywhere in the world for up to 6 months at a time.

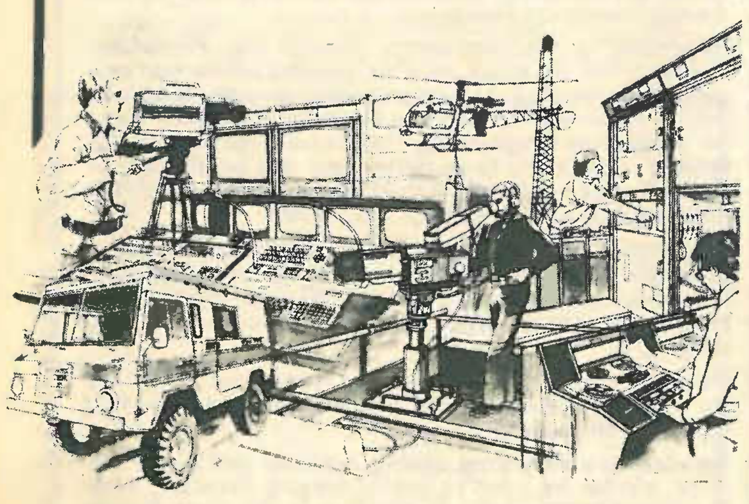
The principal duties involved with the post of service engineer are;liaison with development departments on technical matters arising from service activities, and investigation and correction of any problems that may arise on equipment sold by Pye TVT Ltd. A good general standard of education to HNC or equivalent is required, together with a current driving licence and a working knowledge of professional broadcasting colour TV studio equipment and current measurement instruments and techniques. Communication at all levels and self-motivation are essential.

For further details of these broadcasting engineering opportunities, please contact Lynn Osborne at Pye TVT Ltd., PO Box 41, Coldhams Lane, Cambridge, enclosing a full curriculum vitae and asking for an interview.

PHILIPS

Pye TVT Limited
The Broadcast Company of Philips

(1390)



TELECOMMUNICATIONS ENGINEERS

MULTIPLEX/MICROWAVE ENGINEERS
Saudi Arabia • Nigeria

RADIO SYSTEMS ENGINEERS
Saudi Arabia • Nigeria • Malta • Aberdeen
– on or offshore

Experienced in either HF/VHF/UHF or Troposcatter/ Telemetry.

TELEPHONE SWITCHING ENGINEERS
Saudi Arabia • Nigeria

Preferably with electronic exchange experience.

TECHNICIAN INSTRUCTORS and PLANNING ENGINEERS
Saudi Arabia

With a minimum of 5 years' experience in any of the above disciplines.

Applicants for all positions should hold a minimum of a final City and Guilds. Salaries are negotiable dependent on qualifications and experience.

For further information and to arrange immediate interview, telephone Windsor (07535) 57926. Chemsult, George V Place, 4 Thames Avenue, Windsor, Berks.

CHEMSULT

(1403)

B&W

manufacturers of
monitor loudspeakers
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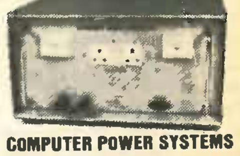

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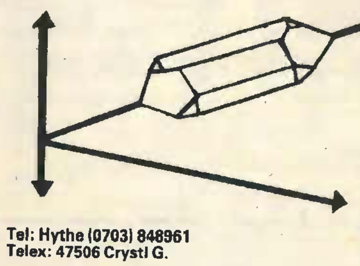

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Printed in Great Britain by QB Ltd., Sheepen Place, Colchester, and Published by the Proprietors IPC ELECTRICAL-ELECTRONIC PRESS LTD., Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS, telephone 01-661 3500. *Wireless World* can be obtained abroad from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd. INDIA: A. H. Wheeler & Co, CANADA: The Wm. Dawson Subscription Service Ltd, Gordon & Gotch Ltd. SOUTH AFRICA: Central News Agency Ltd: William Dawson & Sons (S.A.) Ltd. UNITED STATES: Eastern News Distribution Inc., 14th floor, 111 Eighth Avenue, New York, N.Y. 10011.

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