wireless world

AUGUST 1981 60p

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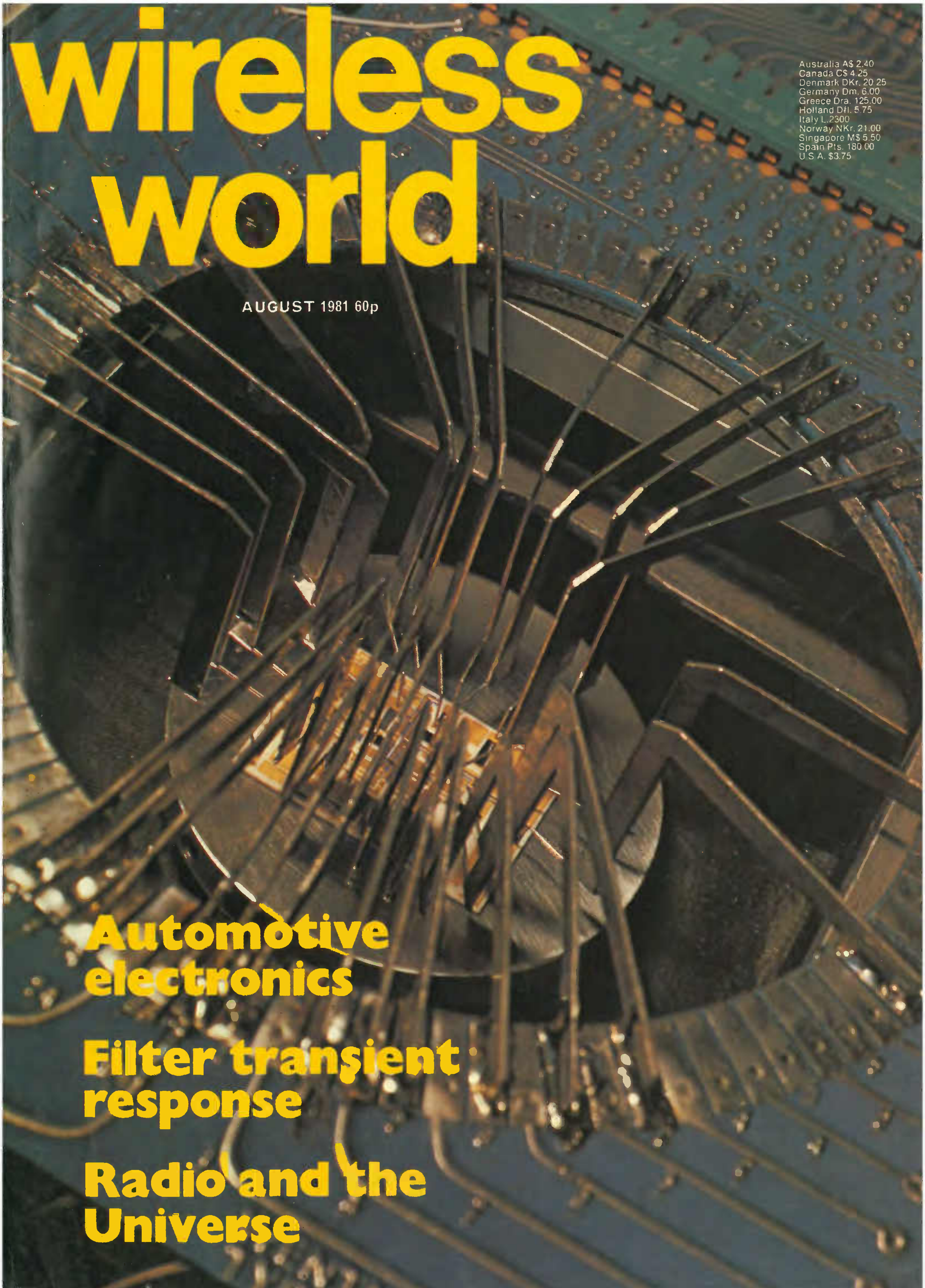

Automotive electronics

Filter transient response

Radio and the Universe

WIRELESS WORLD AUGUST 1981 VOL 87 NO 1547

wireless world

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Norway NKr. 21.00
Singapore M$ 5.50
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Filter transient response

Radio and the Universe

Front cover shows spider-like legs and contacts of a jig for testing integrated circuits, photographed at Wentworth Laboratories by Paul Brierley.

IN OUR NEXT ISSUE

Acceleration feedback speaker **uses a feedback signal from the bass driver cone to improve low-frequency response and reduce distortion at low frequencies.**

Direct memory access **in micro systems transfers information rapidly between memory and i/o without involving programme control and c.p.u. The principle is explained.**

Video discs update. **Now that several competing systems are being launched we report latest developments in this consumer electronics technology.**

Current issue price 60p, back issues (if available) £1.00, at Retail and Trade Counter, Units 1 & 2, Bankside Industrial Centre, Hopton Street, London SE1. Available on microfilm; please contact editor.
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wireless world

ELECTRONICS/TELEVISION/RADIO/AUDIO

AUGUST 1981 Vol 87 No 1547

Electronic Brokers

Electronic Brokers

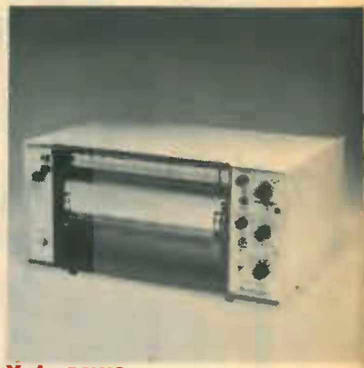
CURRENT USED TEST EQUIPMENT

Everything as new- except the price!

Marconi
TF2002B AM/FM Signal Generator. 10KHz-88MHz. 0.1μV-1V. 20Hz-20KHz Mod frequency. **£1200.00**

Tektronix
T935A Oscilloscope DC-35MHz 2mV-10V/div. Delayed sweep. **£595.00**

Solartron
7065 Microprocessor DMM. Scale length 1,400,000. AC/DC volts, resistance.
At Half New Price £695.00



Yokagawa
3047 2 Channel Chart Recorder. 0.5mV-100V. 2cm/hr-60cm/min. **£435.00**

Bruel & Kjaer
2203 Sound Level Meter C/W 4165 ½in Microphone. 26-140dBA. A,B or C weighting. Fast or slow response. **£395.00**
Bargain In Unused Condition

Tektronix
455 Dual Trace Portable Oscilloscope DC-50MHz. 5mV-5V/div. Full delayed sweep. Super condition. **£925.00**
Large Quantities Available

Marconi
TF2005R 2 Tone Signal Source.-20Hz-20KHz. 0-111dB in 0.1dB steps. **£295.00**

Wayne Kerr
RA200 Frequency Response Analyser. Frequency range 20Hz-30KHz or 200Hz-200KHz. 11in. crt display **£850.00**
Normal Price when new approx. £1906.00

ANALOGUE VOLTMETERS AND MULTIMETERS

Boonton.
93A True RMS Voltmeter 10Hz-20MHz. 1mV-300V £295.00

Fluke.
883AB AC/DC Differential Voltmeter. 20Hz-100KHz. 1mV-1kV. Very high accuracy £975.00

Hewlett Packard.
4815A Vector Impedance Meter. 500KHz-108MHz. 0-360° in 2 ranges. Z range 1Ω-100KΩ in 9 ranges £2150.00
8405A Vector Voltmeter. 1-1000MHz. 0-360° in 4 ranges £1985.00

Marconi.
TF2604 Electronic Voltmeter. AC 20Hz-1.5GHz. 300mV-1KV. DC 10mV-1KV. 0.2Ω-500MΩ £350.00

Philips.
PM2454B AC Millivoltmeter. 10Hz-12MHz. 1mV-300V £195.00

ANALYSERS

General Radio.
1911A Sound and Vibration Analyser. C/W Graphic leve recorder. 4.5Hz-25KHz. 1/3 or 1/10 octave. £950.00
8407A/8412A Network Analyser. C/W 8600A/8601A sweeper 0.1-110MHz £3500.00

Hewlett Packard.
141T-8552B-8554B Spectrum Analyser. 100KHz-1250MHz +10 to −122dBm. Variable percistence display £4950.00
141T-8552A-8554L Spectrum Analyser 500KHz-1250MHz Sensitivity −117dBM. Scan width 20KHz-1250MHz. 3500.00
310A Wave Analyser 1.5KHz-1.5MHz 10μV-100V F.S. Dynamic range > 75dB £1050.00
3581A Wave Analyser with Internal Sweep 15Hz-50KHz. 100nV-30V F.S. Dynamic range > 80dB Frequency indicated by 5 digit LED readout £1500.00

Tektronix.
491 Spectrum Analyser. 10MHz-2GHz direct. Up to 40GHz with optional mixers. £2700.00

BRIDGES & COMPONENT TESTERS

Boonton.
63H Inductance Bridge 0-110mH. Bridge frequency 5-500kHz £1250.00

General Radio.
1608A LCR Bridge. Accuracy 0.05%. 0.05pF-1100μF. 0.05μH-1100H. 0.05mΩ-1.1MΩ £925.00

Marconi.
TF1245-TF1246-TF1247 'Q' Meter and Oscillators. Q 5 to 500. 40KHz-300MHz £950.00

Rohde & Schwarz.
LRT (BN6100) Inductance Meter. 1pH-100μH. 2.2-285KHz £395.00

Wayne Kerr
B642 0.1% LCR Autobalance Bridge 10μΩ-100GΩ. 1fF-10F. 1nH-10MH £750.00

CALIBRATION EQUIPMENT

Fluke.
332A DC Voltage Calibrator. 0 to 1111.1110V. 0.1ppm resolution. 0.003% calibration accuracy £1495.00
760 Meter Calibrator. DC/AC Volts and current £2150.00

Tektronix.
191 Constant Amplitude Generator. 350KHz-100MHz £350.00

FREQUENCY COUNTERS

Advance.
TC15 & P1 Frequency Counter. DC — 500MHz. 9 digits £275.00

Fluke.
1900A-01 Frequency Counter 5Hz-80MHz. 6 digits. Mains / battery operation £195.00
1925A Frequency Counter. 5Hz-125MHz. 9 digits. EMI proof case £375.00

Philips.
PM6664 Fully Auto Frequency Counter 10Hz-520MHz. 8 digits £250.00

MULTIMETERS

Avo.
Test Set Number 4 20KΩ/volt, very robust £75.00
Full lead kit £6.25

S.E.I.
Super 50 Selectest. 20KΩ/volt £77.00

OSCILLOSCOPES

Hewlett Packard.
1223A Dual Trace Variable Persistance Storage Oscilloscope. DC-15MHz 2mV-10V/div. Max writing speed 1cm/μS. £950.00

Philips.
PM3212 Dual Trade Portable Oscilloscope. DC — 25MHz 2mV-10V/div £575.00

SE Labs.
SM121 6 Channel Monitor. 12" crt. Internal sweep £395.00

Tektronix.
432 Dual Trace Portable Oscilloscope. DC — 25MHz, 1mV sensitivity. 20nS-5S. Auto setting mains input 100-250V £510.00
454A Dual Trace Portable Oscilloscope DC — 150MHz 2mV-5V/div. Full delayed sweep. £1200.00
455 Dual Trace Portable Oscilloscope DC — 50MHz. 5mV-5V/div Full delayed sweep. Super condition. £925.00
464 Dual Trace Portable Storage Oscilloscope DC — 100MHz. 5mV-5V/div. Full delayed sweep. Max writing speed 110 div/μS £2250.00
465 Dual Trace Portable Oscilloscope. DC — 100MHz. 5mV-5V/div. Full delayed sweep P.O.A.
466 Dual Trace Portable Storage Oscilloscope Spec as per 464 but max writing speed 3000div/μS £2875.00
475 Oscilloscope DC-200MHz 2mV-5V/div Delayed sweep. £1495.00
521A PAL Vectorscope Measures Luminance Amplitude, Chrominance Phase, Chrominance Amplitude, Differential Phase and Gain. As new condition £2650.00
7704A Main Frame C/W 7A26, 7B80, 7B85. Dual Trace DC — 200MHz. £3550.00

Telequipment.
D34 Dual Trace Battery Portable Oscilloscope. DC-15MHz. 2mV-5V/div 24nS signal delay £445.00
D63 Dual Beam Oscilloscope c/w 2 Off V4 Modules. 4 Traces. DC-15MHz 5mV-20V/div £725.00
D83 Oscilloscope Main Frame C/W V4 and 52A plug-in units. DC — 50MHz. 5mV-20V/div. Full delayed sweep Very large CRT. £725.00
DM64 Dual Trace Split Screen Bistable Storage Oscilloscope DC-10MHz. 10mV-50V/div. Max writing speed 250 div/mS £715.00
1016 Dual Trace Portable Oscilloscope DC-15MHz 5mV-20V/div. XY Mode 1 only £310.00

OSCILLOSCOPE PROBES

EB90 X1 Probe. 1.2 mtr length DC — 20MHz £9.00
EB91 X10 Probe. 1.2 mtr length DC — 100MHz £11.00
EB95 X1, X10 Probe. 1.2 mtr length DC — 10MHz or DC — 100MHz £15.00

POWER SUPPLIES

Advance.
MG5-60 5V @ 60A switching £160.00
MG5-20 5V @ 20A switching £120.00
MG5-10 5V @ 10A switching £95.00
MG24-12 24V @ 12A switching £130.00

Weir.
762 Power Supply Unit 0-30V at 2A. Metered output. £90.00

RECORDERS

Hewlett Packard
7045A XY Recorder. Sensitivity 250μV-5V/cm. Electrostatic paper grip. A3 size £950.00
7045A-001 XY Recorder. As 7045A but with int. time base £1025.00

Racal.
Store 7D Tape Recorder 7 channels FM electronics DC — 20KHz. 1⅞-60ips. £4500.00

S.E. Labs.
6012 50 Channel UV Recorder. Servo paper drive upto 5 metrs/sec. 12" paper ... £1100.00

Watenabe.
MC641 6 Channel Chart Recorder. 1mV-100V, 250mm scan width £1495.00

SIGNAL SOURCES

Avo.
HF136 AM/FM Signal Generator. 4.0-120MHz. 0-100mV in 20dB steps plus fine control. O/P Z = 75Ω £410.00

Hewlett Packard.
203A Variable Phase Oscillator 0.005Hz-60KHz 0-360° £450.00
4204A Decade LF Oscillator 10Hz-1MHz 1mV-10V into 600Ω £695.00
606B AM Signal Generator 50KHz-65MHz AM 0-95% £850.00
616B UHF Signal Generator 1.8 to 4.2GHz Int pulse Mod. £1000.00
620B SHF Signal Generator 7-11GHz. 0.1μV-0.224V into 50Ω. Internal PM & FM £2100.00
651B Test Oscillator. 10Hz-10MHz. 0.1mV-3.16V £415.00
3310A Function Generator 0.0005Hz-5MHz. 15V pk-pk into 50Ω Sine, square, triangle, ramp and + or — pulse waveforms £385.00
3320A Frequency Synthesizer 0.01Hz-13MHz. O/P range 0— +13dBm into 50Ω. Long term frequency accuracy ± 10 parts in 10⁸ of setting per year £995.00
8600A + 8601A RV Sweeper + Markers 100KHz-110MHz £1500.00
8614A UHF Signal Generator 800-2400 MHz. Max O/P +10dBM into 50Ω. Int square wave mod. Ext AM-FM, pulse mod. £1950.00
8616A UHF Signal Generator 1800-4500 MHz. Max O/P +10dBM from 1800-3000 MHz, +3dBM 3000 MHz-4500 MHz. Mod as per 8614A. £1950.00
8640B Phase Locked Signal Generator 0.5 to 520MHz £3200.00
8654A AM/FM VHF Signal Generator 10-520MHz. 0.7μV-0.7V into 50Ω AM 0-90%. FM 0-100KHz Mod rate 400Hz and 1KHz £895.00
8690A/8699B RF Sweeper System. 0.1-4GHz in 2 ranges. Max O/P 10mW to 2GHz and 6mW to 4 GHz £2300.00

Marconi.
TF144H/4 AM Signal Generator 10KHz-72MHz. 2μV-2V £750.00
TF995B/5 AM/FM Signal Generator 200KHz-220MHz 1μV-200mV Narrow deviation for mobiles £695.00
TF1370A Wide Range RC Oscillator. 10Hz-10MHz. Sine wave, square wave upto 100KHz £275.00

Philips.
PM6456 Stereo Generator. Separate L and R Signals. Carrier frequency 100MHz ± 1%. RF O/P 3mV pk-pk £250.00

Radiometer.
SMG1C Stereo Generator. Separate L and R Signals. Carrier frequency 100MHz. RF O/P 10μV-100mV into 75Ω £375.00

SOUND LEVEL METERS

Bruel & Kjaer
2203 Sound Level Meter as per previous spec but also with 6613 octave filter set with centre frequencies of 31.5Hz-35.5KKz in 11 settings. 1 Only £565.00

General Radio.
1981 Sound Level Meter. 70-120dB. Digital and analogue reading. Peak hold. A weighting £300.00
1983 Sound Level Meter. 70-120dB. A weighting £195.00

TRANSMISSION MEASURING EQUIPMENT

Marconi.
TF2332 AF Transmission Test Set. 20Hz-20KHz £425.00

Siemens.

D2040 Selective Level Analyser and Voltmeter. 10Hz-60KHz —110dB to +50dB 3μV-300V Lin and log indication 5 digit frequency readout £1200.00
D2072 + W2072 Level Meter and Oscillator. 50KHz-100MHz —110dB-0dB. Receive bandwidth 3.1 and 10KHz £2200.00
W2006 + D2006 Carrier Level Test Set. 10KHz-17MHz —100 to +10dB. £1650.00
W2007 + D2007 Carrier Level Test Set 6KHz-18.6MHz. —120 to +20dB £1800.00

Wandel and Golterman.
PF-1 Digital Error Rate Measuring Set. Consisting of PFM-1 Digital Error Rate Meter and PFG-1 Pattern Generator £2490.00
PSO-5 and PMO-5 Level Measuring Set. 10KHz-36MHz. —110 to +20dB. C/W AZD-1 Scale expander £2050.00
SPM-6 and PS-6 Level Measuring Set 6KHz-18.6MHz. —110dB to +20dB Mains / battery operation £2150.00
PCM-1 PCM Test Set. PDA-64 PCM Signalling Analyser, PSM-4 Level Measuring Set Scanner. PDG-1 Digital Signal Generator. PDA-1 PCM Digital Signal Analyser P.O.A.

DVM's AND DMM's

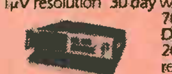
Datron.
1051 5½ Digit DMM. AC/DC Volts, Resistance. True RMS. 0.1μV resolution £750.00

Fluke.
8800A 5½ Digit DMM. AC/DC volts, resistance. 1μV resolution £450.00

Hewlett Packard.
3490A 5½ Digit DMM AC/DC volts, resistance, 1μV resolution. 30 day warranty £375.00

Philips.
PM2527 4½ Digit DMM. AC/DC volts, current and resistance. 10μV resolution. True RMS. £400.00

Solartron.
A243 5½ Digit DMM. AC/DC volts, resistance 1μV resolution 30 day warranty £375.00



7055 Microprocessor DMM. Scale Length 20,000. AC/DC volts, resistance. 1μV resolution £600.00
7055 plus processor control and RS232 interface £900.00
7065 plus processor control and RS232 interface £995.00

MISCELLANEOUS

Data Laboratories.
DL905 Transient Recorder with Pre-Trigger facility. Ideal for viewing single shot voltage transients 1 only £990.00

Ferrograph.
RTS2 Recorder Test Set Measures Wow & Flutter, Distortion, Gain £345.00
RTS2 + ATU-1 Recorder Test Set and auxiliary test set £375.00

Hewlett Packard.
331A Distortion Meter. 5Hz-600KHz. 0.1%-100% FS £615.00
432A Power Meter with 478A Thermistor Head. 10MHz-10GHz. 100μW-10mW £450.00
4329A Insulation Resistance Meter Range 500KΩ to 2 × 10¹⁶Ω £500.00
8745A S Parameter Test Set. Fitted with 11604A Universal Arms 0.1-2GHz £2750.00

Marconi.
TF791D Deviation Meter 4-1024MHz £195.00
TF2162 MF Attenuator DC — 1MHz 0-111dB Impedance 75Ω £135.00
TF2331 AF Distortion Meter 20Hz-20KHz. 0.1%-100% 1mV-30V voltage range. £395.00

Rohde and Schwarz.
MSC Stereo Coder. 30Hz-15KHz. £500.00

Tektronix.
TM515 Main Frame £150.00
TM504 Main Frame £100.00
DC503 100MHz Counter £195.00
DM502 3½ Digit DMM £150.00
FG503 0.1Hz-3MHz Function Generator £195.00
PS503A Power Supply £265.00
SC502 Dual Trace 15MHz Oscilloscope £575.00

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1 FULL GUARANTEE At Electronic Brokers we give you a TWELVE MONTHS WARRANTY on test equipment and 90 DAYS ON MOST COMPUTER PERIPHERALS. And we'll stand behind it all the way.

2 FAST DELIVERY When you buy used equipment from Electronic Brokers, it can be yours in a matter of only days. No waiting for manufacturers lengthy production schedules.

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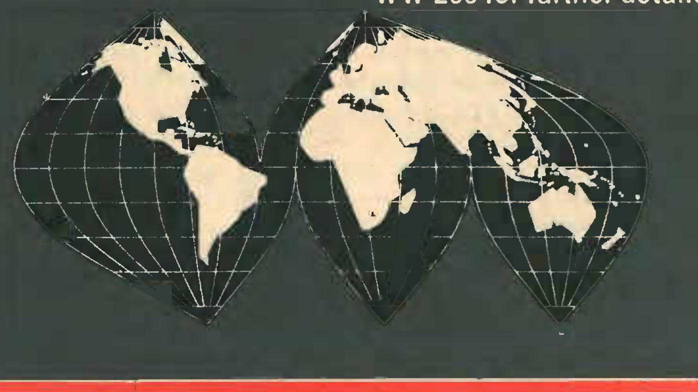

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CURRENT USED DEC EQUIPMENT

Computer equipment and peripherals by Digital Equipment Corporation


A section of our warehouse showing an extensive range of DEC components and systems available.


PDP11/70 Systems available from £22.000

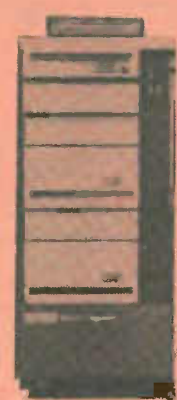

PDP11/34 inc RL01's, systems available now. Great savings.


PDP11/34 wide range of CPU's available from £4000


The VT100, Digital's high performance video terminal


A selection of our indepth range of DEC Terminals.

PDP11 SYSTEMS



DEC

VAX 11/780 with 1MB, RP06, TEE16, H9602, BA11, DD11, DZ11A, LA120. ..... £112,000.00

PDP11/34 System (non-A) with 256KB MOS, 2x RK06 Disk Drive and control, LA36 console £10,500.00

PDP11/34A 128KB MOS, KY11-LB Programmers Panel, DL11W Interface, 2x RL01 Disk Drives and Controller, 6ft. Cabinet, VT100 Console £11,500.00

PDP11/34A 128 KB MOS, KY11-LB Programmers Panel, DL11W Interface, RK05J and RK05F Disk Drives and Controller, 6ft. Cabinet, DECwriter IV Console £9,950.00

PDP11/34A 256KB MOS, KY11-LB Programmers Panel, DL11W Interface, 2 x RK02 Disk Drives and Controller, 6ft Cabinet, VT100 Console £19,750.00

PDP11/34A 128KB MOS, KY11-LB Programmers Panel, DL11W Interface, 2 x RL07 Disk Drives and Controller, 6ft. Cabinet, VT100 Console £12,750.00

PDP11/60 System with 2 RK07 Disk Drives and Controller, choice of Console ..... P.O.A.

PDP11 C.P.U.s

DEC.

PDP11/03-SD Processor in 3½" chassis complete with 16KW MOS memory and E15 option.
BRAND NEW — ONLY £1,495.00

PDP11/04 Processor in 10½" chassis complete with 16KW MOS memory and DL11W Interface.
BRAND NEW (can be enhanced to 28KW) £3,950.00

PDP11/34A Processor, 5¼in. Chassis, 128Kb MOS, KY11-LB Programmers Panel, DL11W Interface. £4,950.00

PDP11/34A Processor, 10½in chassis 128KB MOS, KY11-LB Programmers Panel, DL11W Interface. £6,250.00

PDP11 MEMORY

DEC.

KK11A 11/34A Cache Memory option £2,000.00
MF11LP 8KW core memory c/w 9-slot system unit £975.00
MK11CB 512Kb 11/70 expansion MOS memory including frame £14,500.00
MM11L 8KW core memory £795.00
MM11LP 8KW parity core memory £750.00
MM11DP 16KW core (ex DEC-maintained 11/34 systems) BARGAIN OFFER — ONLY £395.00
MM11UP 16KW Parity core memory complete with 9-slot system unit £1,500.00
MM11UP 16KW parity core memory (pre-requisite MF11UP) £1250.00
MS11JP 16KW MOS memory £395.00
MS11-LB 128KB MOS £1,995.00
MS11-LD 256KB MOS £3,500.00
MSV11C 16KW MOS memory (LSI 11) £495.00
MJ11-BE 64KW 11/70 memory £4,500.00
MK11-BE 64KW MOS memory for 11/70 ..... £3,950.00
MS11-MB 256KB ECC MOS memory for 11/44 (NEW) £3,942.00

DISKS

DEC.

RK05J add-on disk drive 2½ meg. Exchangeable-cartridge type From £1,500.00
RK06-ED Add-on 14 Meg disk drive £2,750.00
RK611-ED Unibus Controller + 1 RK06 drive £4,500.00
RK07-ED Add-on 28 Meg disk drive £4,750.00
RK711-ED Unibus Controller + 1 RK07 disk drive £6,500.00
RL01-AK Add-on 5 Meg disk drive £1,975.00
RL02-AK Add-on 10 Meg Disk Drive £2,500.00
RM03 Add-on 67 Meg disk drive £7,500.00
RP04-AB Add-on 88 Meg Disk Drive £4,950.00
RX11-BD RX01 Dual floppy + Unibus Controller £1,350.00
Controllers usually available for above drives

MAGNETIC TAPE

DEC.

Available from time to time — TU10, TU45, TE16 TS03 etc.

PDP11 OPTIONS

DEC.

AA11D VT01 Controller with 4-slot System Unit £125.00
BA11-KF expander Box £1,395.00
DD11A 4-slot System Unit £125.00
DD11B 4-slot System Unit £150.00
DD11-DK 9-slot backplane £465.00
DL11 Serial Interface £250.00
DL11WA/B Serial Interface/Line Clock £395.00
DR11C General Purpose Interface £250.00
DZ11A 8-line EIA MUX £1,395.00
DZ11-B 8-Line Expander MUX £995.00
FP11A Floating Point £1,750.00
KL11 TTY Interface £150.00
KW11L Real Time Clock £150.00
KW11P Programmable Clock £345.00
M792 ROM Diode Matrix £195.00
M9301-YB Bootstrap £325.00

POWER SUPPLIES

DEC.

H720 Power supply for BA11 Expander Box, BRAND NEW SURPLUS £175.00

PDP8A C.P.U.

DEC.

PDP8A Processors, systems and add-on memory usually available.

PDP8A MEMORY

DEC.

MM8AA 8KW Core £750.00
MM8AB 16KW Core £995.00

PDP8E CPU, MEMORY, OPTIONS

DEC.

DP8EB Communications Adaptor £395.00
KA8E Positive I/O Bus £95.00
KD8E Databreak £145.00
KL8E Asynchronous Interface £250.00
KL8JA Asynchronous Interface £275.00
KP8E Power fail/auto restart £95.00
MM8E 4KW Core memory stack £350.00
TA8E Dual Cassette Drive and Controller £525.00
VT8E Set graphics Control Modules £250.00

TERMINALS

DEC.

LA34 DECwriter IV 30cps desk-top terminal, 132 columns, upper/lower case ASCII £495.00

LA36 DECwriter II Keyboard Printer Terminal. The Terminal that has become an industry standard, with 132 column upper/lower case printing and switch-selectable speeds of 10, 15 & 30cps. Available with either 20mA or RS232 interface NOW ONLY £595.00

VT 52 SPECIAL PURCHASE of this outstanding Video Display Terminal featuring full upper/lower case ASCII character set, 24 x 80 display, auxiliary keypad, direct cursor addressing and tabulation, scroll or hold screen mode with X-off facility, 9 switch-selectable baud rates (75-9600 baud) choice of 20mA or RS232 interface. BRAND NEW SURPLUS. ONLY £450.00

VT55 Graphics VDU with integral hard copy unit, 20mA or RS232 Interface £1,250.00

LS-120 High speed keyboard terminal. 132-column printer with adjustable tractor feed and full upper and lower case ASCII printing (7 x 7 dot matrix) 180 cps print speed and operator-selectable baud rates up to 4800 baud. Integral stand, RS232 interface. BRAND NEW SURPLUS (limited quantity). ONLY £750.00

VT100 — limited quantity in as-new condition £650.00

DECwriter IV Desktop terminal complete with tractor feed, paper-out, cable and keypad options £495.00

KEYBOARDS

New ASCII Keyboards

KB756MF 56-station keyboard with full upper/lower case ASCII, parallel input, mounting frame for extra rigidity power requirements +5V, −12V £39.00
(mail order total ..... £47.15)

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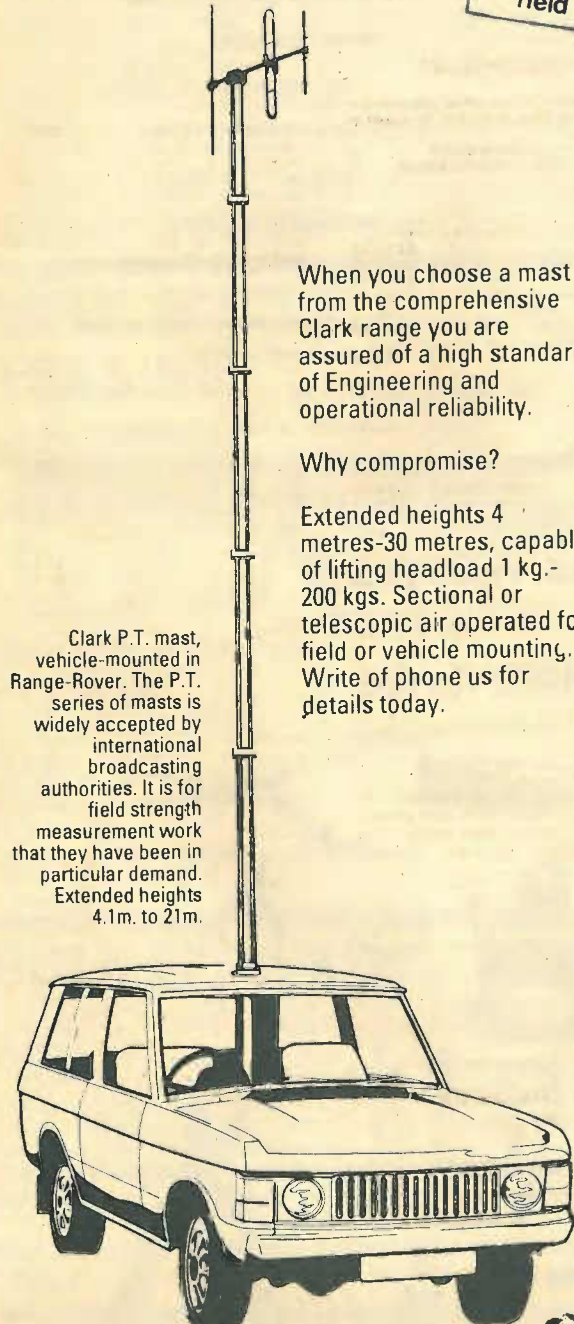

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4021	0.75
4022	0.68
4023	0.19
4024	0.45
4025	0.18
4026	1.05
4028	0.60
4029	0.75
4030	0.35
4035	0.75
4040	0.68
4042	0.65
4043	0.68
4043AE	0.93
4044	0.68
4046	0.69
4047	0.69
4049	0.30
4050	0,30
4051	0.65
4052	0.69
4053	0.69
4054	1.30
4055	1.30
4056	1.35
4059	5.75
4060	0.95
4063	1.15
4066	0.38
4067	4.30
4068	0.18
4069	0.18
4070	0.25
4071	0.22
4072	0.22
4073	0.22
4075	0.18
4076	0.60
4077	0.23
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40014	0.54
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40160	0.69
40161	0.69
40162	0.69
40163	0.69
40174	0.69
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40192	0.75
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40194	0.69
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7400N	0.10
7401N	0.10
7402N	0.10
7403N	0.11
7404N	0.12
7405N	0.12
7406N	0.22
7407N	0.22
7408N	0.15
7409N	0.15
7410N	0.12
7411N	0.18
7412N	0.19
7413N	0.27
7414N	0.51
7416N	0.27
7417N	0.27
7402N	0.13
7421N	0.28
7422N	0.20
7423N	0.22
7425N	0.22
7426N	0.22
7427N	0.22
7428N	0.35
7430N	0.13
7432N	0.23
7437N	0.22
7438N	0.22
7440N	0.14
7441N	0.54
7442N	0.42
7443N	0.62
7444N	0.62
7445N	0.62
7446N	0.62
7447N	0.62
7448N	0.56
7450	0.14
7451N	0.14
7453N	0.14
7454N	0.14
7460N	0.14
7470N	0.28
7472N	0.27
7473N	0.28
7474N	0.28
7475N	0.35
7476N	0.30
7480N	0.26
7481N	0.20
7482N	0.75
7485N	0.75
7486N	0.24
7489N	1.05
7490N	0.30
7491N	0.55
7492N	0.35
7493N	0.35
7494N	0.70
7495N	0.60
7496N	0.45
7497N	1.40
74100	1.10
74104	0.62
74105	0.62
74107	0.26
74109N	0.35
74110N	0.54
74111N	0.68
74112N	1.70
74116N	1.98
74118N	0.85
74119N	1.20
74120N	0.95
74121N	0.34
74122N	0.34
74123N	0.40
74125N	0.40
74126N	0.40
74128N	0.65
74132N	0.50
74136N	0.65
74141N	0.45
74142N	1.85
74143N	2.50
74144N	2.50
74145N	0.75
74147N	1.50
74148N	1.09
74150N	0.79
74151N	0.55
74153N	0.55
74154N	0.55
74155N	0.55
74156N	0.55
74157N	0.55
74159N	1.90
74160N	0.55
74161N	0.55
74162N	0.55
74163N	0.55
74164N	0.55
74165N	0.55
74166N	0.70
74167N	1.25
74170N	1.25
74173N	1.10
74174N	0.75
74175N	0.75
74176N	0.75
74177N	0.75
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74179N	1.35
74180N	0.75
74181N	1.22
74182N	0.70
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74193N	0.55
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74196N	0.55
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74284N	3.50
74285N	3.50
74290N	1.00
74293N	1.05
74297N	2.36
74298N	1.85
74365N	0.85
74366N	0.85
74367N	0.85
74368N	0.85
74390N	1.85
74393N	1.85
74490N	1.85

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74LS00N	0.11
74LS01N	0.11
74LS02N	0.12
74LS03N	0.12
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74LS08N	0.14
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74LS54N	0.15
74LS55N	0.15
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74LS139N	0.40
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74LS153N	0.35
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74LS377N	1.99
74LS378N	1.40
74LS379N	2.15
74LS384N	2.50
74LS385N	4.20
74LS386N	0.29
74LS390N	0.68
74LS393N	0.61
74LS395N	2.10
74LS396N	1.99
74LS398N	2.75
74LS399N	2.30
74LS445N	1.40
74LS447N	1.95
74LS490N	1.10
74LS668N	1.05
74LS669N	1.05
74LS670N	1.70

74CXX series

74C00	0.20
74C02	0.20
74C04	0.20
74C08	0.20
74C10	0.20
74C14	0.55
74C20	0.20
74C30	0.20
74C32	0.20
74C42	0.80
74C48	1.03
74C73	0.50
74C74	0.50
74C76	0.48
74C83	0.98
74C85	0.98
74C86	0.26
74C89	2.68
74C90	0.80
74C93	0.80
74C95	0.94
74C107	0.48
74C151	1.52
74C154	2.26
74C157	1.52
74C160	0.80
74C161	0.80
74C162	0.80
74C163	0.80
74C164	0.80
74C165	0.84
74C173	0.72
74C174	0.72
74C175	0.72
74C192	0.80
74C193	0.80
74C195	0.80
74C200	4.52
74C221	1.06
74C901	0.38
74C902	0.38
74C903	0.38
74C904	0.38
74C905	5.64
74C906	0.38
74C907	0.38
74C908	0.84
74C909	1.52
74C910	3.62
74C914	0.86
74C918	0.98
74C925	4.32
74C926	4.32
74C927	4.32

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4027	5.78
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4116 3	1.49
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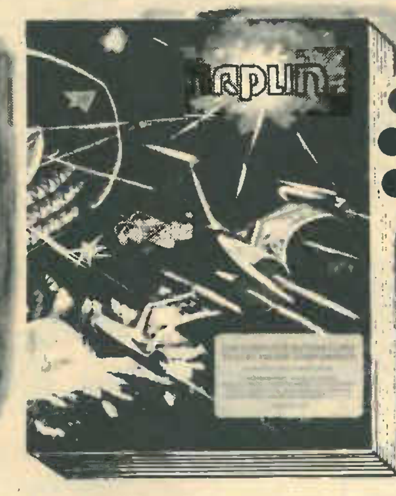

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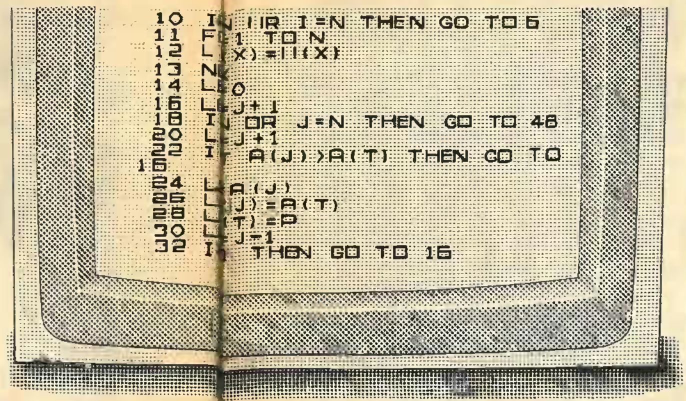


Reach advanced computer comprehension in a few absorbing hours

1980 saw a genuine breakthrough – the Sinclair ZX80, world's first complete personal computer for under £100. At £99.95, the ZX80 offered a specification unchallenged at the price.

Over 50,000 were sold, and the ZX80 won virtually universal praise from computer professionals.

Now the Sinclair lead is increased: for just £69.95, the new Sinclair ZX81 offers even more advanced computer facilities at an even lower price. And the ZX81 kit means an even bigger saving. At £49.95 it costs almost 40% less than the ZX80 kit!

Lower price: higher capability

With the ZX81, it's just as 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, or to select a program off a cassette through the keyboard.

Higher specification, lower price – how's it done?

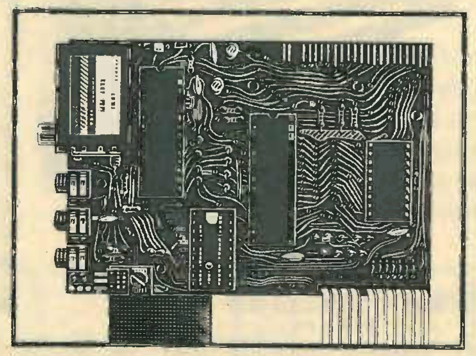
Quite simply, by design. The ZX80 reduced the chips in a working computer from 40 or so, to 21. The ZX81 reduces the 21 to 4!

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!

Kit or built – it's up to you!

The picture shows dramatically 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.



Proven micro-processor, new 8K BASIC ROM, RAM – and unique new master chip.

New Sinclair teach-yourself BASIC manual

Every ZX81 comes with a comprehensive, specially-written manual – a complete course in BASIC programming, from first principles to complex programs. You need no prior knowledge – children from 12 upwards soon become familiar with computer operation.

ew, improved specification

- Z80A micro-processor – new faster ersion of the famous Z80 chip, widely recognised as the best ever made.
- Unique 'one-touch' key word entry: the ZX81 eliminates a great deal of tiresome typing. Key words (RUN, LIST, PRINT, etc.) have their own single-key entry.
- Unique syntax-check and report codes identify programming errors immediately.
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- Up to 26 FOR/NEXT loops.
- Randomise function – useful for games is well as serious applications.
- Cassette LOAD and SAVE with amed programs.
- 1K-byte RAM expandable to 16K ytes with Sinclair RAM pack.
- Able to drive the new Sinclair printer not available yet – but coming soon!)
- Advanced 4-chip design: micro-rocessor, ROM, RAM, plus master chip – unique, custom-built chip replacing 8 ZX80 chips.

sinclair ZX81

inclair Research Ltd, 5 Kings Parade, Cambridge, Cambs., CB2 1SN. Tel: 0276 66104. Reg. no: 214 4630 00

If you own a Sinclair ZX80...

The new 8K BASIC ROM used in the Sinclair ZX81 is available to ZX80 owners as a drop-in replacement chip. (Complete with new keyboard template and operating manual.)

With the exception of animated graphics, all the advanced features of the ZX81 are now available on your ZX80 – including the ability to drive the Sinclair ZX Printer.

Coming soon – the ZX Printer.

Designed exclusively for use with the ZX81 (and ZX80 with 8K BASIC ROM), the printer offers full alphanumerics across 32 columns, *and* highly sophisticated graphics. Special features include COPY, which prints out exactly what is on the whole TV screen without the need for further instructions. The ZX Printer will be available in Summer 1981, at around £50 – watch this space!

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

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

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

How to order your ZX81

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

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

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

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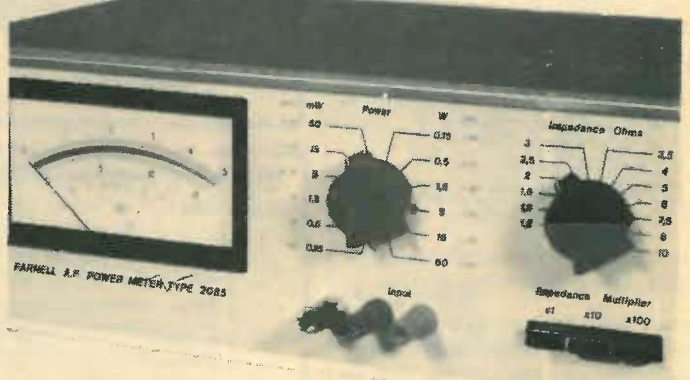

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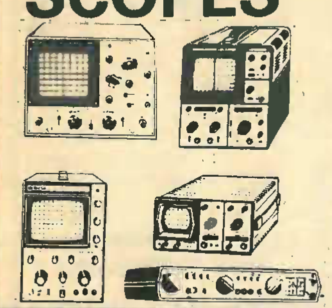

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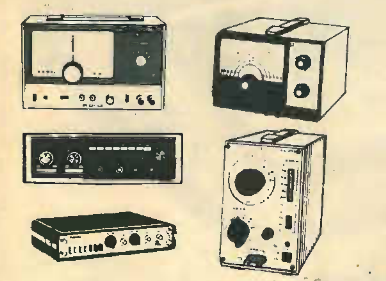

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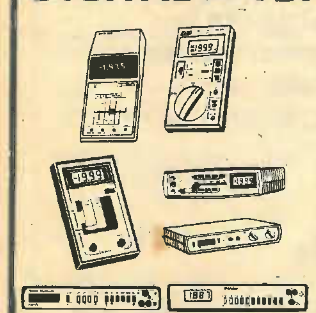

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DM450 4½ Digit LED 34 ranges AC/DC 10 amp £113.85
(DM series options. Carry case £8.86 Ni-cads £8.63 Mains adaptor £5.69)
1503 4¾ Digit LCD 28 range AC/DC 10 amp includes mains adaptor £159.95

MULTIMETERS (UK c/p 75p)

KRT101 1K/Volt 10 range pocket £4.60
ATM1/LT1 1K/Volt 12 range pocket £5.98
NH55 2K/Volt 10 range pocket £6.50
AT! 2K/Volt 12 range pocket de luxe £7.75
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AT1020 20K/Volt 19 range de luxe plus hfe test £16.95
7081 50K/Volt 36 range plus 10 amp DC £20.80
TR303TR 20K/Volt plus 12A DC plus hfe test £15.95
AT20 20K/Volt 21 range de luxe plus 10A DC and 5KV DC £21.95
AT205 50K/Volt 21 range de luxe plus 10A DC £24.95
7080 20K/Volt 26 range large scale, 10A DC plus 5KV AC/DC £26.95
AT2050 50K/Volt 18 range de luxe plus hfe test £28.50
AT210 100K/Volt 23 range de luxe 12A AC/DC £29.95
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KRT 500 1 50K/V range doubler 10ADC £16.50
ETC 500 0 As above with coloured scales £17.95
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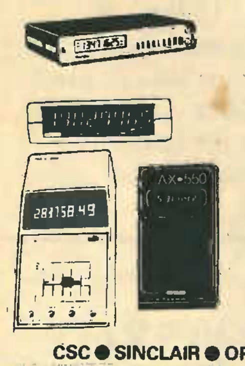

HAND HELD (UK post etc 85p)

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MAX550 30KHZ to 550mHZ 6 Digit LED £97.00

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CLAMP METERS/ INSULATION TESTERS

(All multirange except K2303)

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3101. 300 AMPS. 600 VAC. 1K OHM £32.95
K2803. 300 AMPS. 600 VAC. 2K OHM £53.95
K2903. 900 AMPS. 750 VAC. 2K OHM £77.95
K3103. Transistorised insulation/continuity tester. 100 MEG. 600 VAC. 0/2½K £95.00
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LCG-393V PAL 8VHF 6 patts £143.75
LCG-392U PAL B UHF 15 watts £228.85
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The EP4000 is not just an EPROM Programmer . . .

Not only does the EP4000 copy, store, program and duplicate the 2704/2708/2716(3) /2508/2758/2716/2516/2532 and 2732 EPROMs without personality cards or modules, but also includes a video output for memory map display to make the powerful editing facilities really useful (and this is in addition to the in-built LED display for stand-alone use), but it also comes as standard with comprehensive input/output – RS232, 20mA loop, TTL, parallel handshake, cassette, printer and direct memory access. Now the programming power can be expanded with our range of add-on accessories listed below.

Made in the U.K.

. . . but also a Real Time EPROM Emulator . . .

Real time EPROM Emulation is the second major function of the EP4000. This facility allows the machine to directly replace your in-circuit EPROMs during the process of program development – the EP4000 can be configured to look like any EPROM it is capable of programming. The press of a button isolates the external system so that data changes, entries, editing and downloading can be implemented. When the program is complete and working, the simulator cable can be replaced by an EPROM programmed by the EP4000.

. . . with real technical back-up and service.

The EP4000 comes with a technical manual describing every aspect of the machine – its purpose, its use, and how to use it. It also has a section describing the whole process of program development.
And if you ever need technical help or advice, you can now dial direct to our technical department for instant attention – Tel. (0803) 863380.
Finally, a full range of accessories in now available – these include Bipolar programming modules, multi-EPROM simulator adaptors, buffer pods, EPROM Erasers, video monitors, 2764/2564 programming satellite, printer and production programmers. The EP4000 is ex-stock. Price – £545 + VAT (+£12 for DATAPOST delivery). Telephone, telex, write or call for full data and Distributor list, or place your order for immediate despatch – Overseas customers, please telex or write for quotation and terms. Agents in some countries, and distributors in Britain required.

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Unit 6, Totnes Industrial Estate Totnes, Devon TQ9 5XL
Tel. *Sales* (0803) 863360. *Technical* (0803) 863380
Telex: 42596 GPELEC

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2215 Soundmeter inc Octave Filter	1095
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2305 Level Recorder	650
4230 Sound Level Calibrator	95
4424 Noise Dosemeter	375
CASTLE ASSOCIATES	
CS181A Sound Level Meter & Calibrator	325
CEL	
112 Environmental LEQ Meter Batt op	450
144 Improved version of 112 model	1050
BRIDGES & V and I STANDARDS	
FLUKE	
341 DC Voltage Calib 10μV to 1100V	1575
GENERAL RESISTANCE	
DAS56 DC V and I Calib 1μV-10V 30mA	600
HEWLETT PACKARD	
4342 QLC Meter 22 KHz-70 MHz	1100
MARCONI	
TF868A Universal LCR Bridge	250
TF1245 Q Meter 1 KHz-300 MHz	350
TF1313 Universal LCR Bridge	350
WAYNE KERR	
B224 LCR Bridge 0.1%	500
B500 LCR Bridge	240
B601 LCR Bridge RF Osc & Det not inc	125
COMMS & CABLE TEST EQUIPMENT	
CHASE	
35A Field Strength Meter 20-850 MHz	600
DYMAR	
8801S VHF Radio Telephone – Portable	295
883 VHF Radio Telephone – Portable	285
BC282 Batt Charger for 880/883	95
HEWLETT PACKARD	
3556A psophometer 20 Hz-20 KHz	250
MARCONI	
TF2333 Trans Test Set 30 Hz-550 KHz	600
PYE	
BC11A 10 way Batt chgr for PF2UB	150
PF2UB UHF Radio Telephone – Portable	125
STC	
74216A Noise Generator CCIT	275
74261A Psophometer CCIT	375
TEKTRONIX	
1502 TDR Cable Tester CRT + Recorder	2950
WANDEL & GOLTERMANN	
LDS2 200 Hz-600 KHz sender for gp Delay	2000
LDEF2 Filters for DLM1	250
COUNTERS & TIMERS	
FLUKE	
1910 125 MHz 7 Digit Counter	245
1911 250 MHz 7 Digit Counter	298
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.	99
5302A 50 MHz Counter Timer for 5300	80
5305B 1300 MHz Counter for 5300	325
5308A 75 MHz Counter Timer for 5300B	112
5345 500 MHz 11 digit Counter Timer	1350
10590A Adapter 5245 to 5345 Plug ins	225
RACAL	
9024 600 MHz 7½ digit Counter	250
9025 1 GHz 8 digit Counter	500
SYSTRON DONNER	
6053 3 GHz 9 digit Counter BCD O/P	790
6054 18 GHz 11 digit Counter BCD D/P	1950
5103B Strip Printer for 6053/6054	375
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HEWLETT PACKARD	
1600A Logic Analyser 16ch 20 MHz	2300
1607 Logic Analyser 16ch 20 MHz	1500
5011T Logic troubleshooting kit	125
TEKTRONIX	
7D01F Logic Analyser 16ch 50 MHz P/in	2650
832 Datacomm Test V24/RS232/I loop	1150
MAINS TEST EQUIPMENT	
COLE	
T1007 Volt/Freq/Spike Monitor Rec O/P	110

	Prices from £
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DL019 Mains Interface for DL905	300
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	75
N.B. Thermocouples not included	
DATALAB	
DL905 Digital Transient Recorder	1150
HEWLETT PACKARD	
X382A Rotary Vane Attenuator WG16	175
TEKTRONIX	
575 Semiconductor Curve Tracer	425
1485C TV Waveform Monitor PAL/NTSC	2300
NETWORK ANALYSERS/ PHASEMETERS	
DRANETZ	
305B/3001 Phasemeter 2Hz-700KHz	990

	Prices from £
D83/V4/S2A 50 MHz 1mV 2 Trace 2T Big CRT	900
D1010 10 MHz 5mV 2 Trace TV trig	235
D1015 15 MHz 5mV 2 Trace TV trig	295
D1016 15 MHz 1mV 2 Trace TV trig	340
S1A Single T/base Plug-in 50 MHz trig	135
S2A Dual T/base Plug-in 50 MHz trig	230
V1 15 MHz 1mV Single trace Plug-in	76
V4 50 MHz 1mV Dual trace Plug-in	180
TEXSCAN	
DU120 Large crt display unit	220
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
7834 400 MHz 4 Slot M/Frame 2500 cm/μs	5250
T912 10 MHz 2mV 2 Tr 1TB 250cm/ms	650
7313 25 MHz 3 Slot M/Frame split 5cm/μs	2100

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12 channel magnet block. Supplied with 6 channels of conditioning + 6 M3300 galvos.
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32 channel-clock to 20MHz. 4 addn'l qualifier channels. Table display 16 x 32 bit words + MAP and exclusive 'OR' display.
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1710/11/12/14 0.4-500 MHz 115dB range	2200
HEWLETT PACKARD	
8405A Vector Voltmeter 1–1000 MHz	2000
8414A Polar Display for 8410 N.W.A.	700
OSCILLOSCOPES & ACCESSORIES	
BRADLEY	
158 900 MHz Sampling Adaptor converts most scopes into UHF samplers	275
GOULD ADVANCE	
OS1000A 20 MHz 5mV 2 Trace TV trig	200
DS3300B 50 MHz 1mV 2 Trace 2T base	675
HEWLETT PACKARD	
1740A 100 MHz 5mV 2 Trace 2T base Trig View	1300
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
PM3214 25 MHz 2mV 2 Trace 2T base	640
PM3233 10 MHz 2mV 2 Beam Ch sig delay	425
PM3244 50 MHz 5mV 4 Trace 2T base	1675
PM3262 100 MHz 5mV 2 Trace 2T base Tr View	1300
TEKTRONIX	
326 10 MHz 1mV 2 Trace weight 13lb c/w re-chg batts. For harsh environment	540
453 50 MHz 5mV 2 Trace 2T Base	500
465 100 MHz 5mV 2 Trace 2T Base	950
465B 100 MHz 5mV 2 Trace 2TB inc Probes	1600
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
7603 100 MHz CRT r/out 3 slot M/Frame	1350
7704 200 MHz CRT r/out 4 slot M/Frame	1450
7A12 105 MHz 5mV 2 Trace Plug-in	390
7A18N 75 MHz 5mV 2 Trace Plug-in	420
7A19 500MHz 10mV 1 Trace Plug-in	950
7A22 1 MHz 10μV Differential Plug-in	630
7A24 350 mV 2 Trace Plug-in	1050
7A26 200 MHz 5mV 2 Trace Plug-in	690
7B53A 2 Timebase Plug-in 100 MHz Trig	550
7B80 1 Timebase Plug-in 400 MHz Trig	600
7B85 2 Timebase Plug-in 400 MHz Trig	700
7904 500 MHz CRT r/out 4 slot M/Frame	3900
P6013A X1000 12KV Probe	95
P6201 FET Probe DC-900 MHz	300
TELEQUIPMENT	
D34 15 MHz 2mV 2 Trace Mains + int batts	540
D63/V1/V1 15 MHz 2 Trace 1mV	600
D65 15 MHz 1mV 2 Trace TV trig sig delay	295
D75/V4/S2A 50 MHz 1mV 2 Trace 2T base	825

	Prices from £
POWER MEASUREMENT	
FLUKE	
8921A 10 Hz-20 MHz 4½ Digit & Analogue TRMS dBm/V meter 50Ω-1200Ω & 10MΩ	885
HEWLETT PACKARD	
8481A Type N Coax sensor for 435A	200
478A Type N Coax sensor for 432A	90
MARCONI	
TF2512 DC -500 MHz Powermeter	145
TF893A 10 Hz-20 KHz Powermeter	135
POWER SUPPLIES etc	
ADVANCE	
1V5S Inverter 24V DC to 240V AC 500W	300
FARNELL	
L30B 0-30V variable 1A Metered	65
FLUKE	
415B 0-3.1 KV variable 30mA Metered	550
ITT	
Powerlab Dual 15V variable 1A	80
MARCONI	
TF2154/1 0-30V variable Metered	75
VALRADIO	
B12/200S Inverter 12V DC to 230V AC 200W	110
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	
BS314 Chart 10" 4 Pen 16 speed	1950
BS316 Chart 10" 6 Pen 16 speed	2500
HEWLETT PACKARD	
7015A XY 1 pen A4 size	700
7046A XY 2 pen A3 size	995
MEDELEC	
M/scope Combined 4 ch scope + UV rec'dr	1900
PHILIPS	
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
SMITHS	
RE541 Chart 8" 1 pen 8 speed	250
RE501/4701 Cht 4" + XY 1ch 10 spd AC Batt	200

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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	425
TF2331 Distortion Meter BW100 KHz + Det.	340
Note: see also "Spectrum Analysers"	
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SG63D Generator 4-230 MHz AM/FM	200
GENERAL RADIO	
1362 Generator 220-920 MHz	375
GOULD ADVANCE	
SG70 Generator 5 Hz-125 KHz 600Ω/4W	85
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8690B Sweeper mainframe	650
8620B Sweeper mainframe	990
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
TF2171 Synchroniser for TF2015	525
TF2012 Generator 400-520 MHz FM	550
PHILIPS	
PM5127 Function 0.1 Hz-1 MHz Sin Sq Tri Rmp	450
PM5129 Func 1mHz-1 MHz Usual + swp/brst	645
RACAL	
9081 Gen Ø Lock 5-520 MHz AM/FM/ØM	1900
TEXSCAN	
9900 Sweeper 10-300 MHz 6/in CRT disp	525
VS60 Sweeper 5-1000 MHz	890
TV Markers 31.5 32.5 35 39.5 41.5 MHz	175
LN40A Log Amplifier	95
SPECTRUM ANALYSERS	
HEWLETT PACKARD	
141T/8552B/8555A Complete .01-18 GHz	8500
3580A 5 Hz-50 KHz with digi store disp	2950
8445A Pre-selector 0.01-18 GHz	1450
8558B 0.1-1500 MHz Plug-in for 180 series	3750
VOLT/MULTI-METER (ANALOGUE)	
AVO	
8 Mk4 AC/DC/—VI + Ω	70
BOONTON	
92C AC/RF 10 KHz-1.2 GHZ ½ mV-3V	350
HEWLETT PACKARD	
427A AC/DC/Ω AC-1 MHz	195
3400A 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
VOLT/MULTI-METER (DIGITAL)	
ADVANCE	
DMM7A 1999FSD AC/DC/V/I/Ω	115
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
HEWLETT PACKARD	
3490A 100000FSD AC/DC/V/Ω	625
SOLARTRON	
A200 19999FSD DC only 1μV-1 KV	85
A203 19999FSD AC/DC/V/Ω	175
A205 19999FSD TRMS AC/DC/V/Ω	195

Carston Electronics Ltd
01-267 5311
Shirley House, 27 Camden Road, London NW1 9NR. Telex: 23920.

Full details and specification of equipment listed, available. Because of long copy dates this list is not comprehensive – ring for inventory update or tell us your SPECIFIC NEEDS. Hours Monday to Friday 9.00 am-5.30 pm (4.30 pm Fridays). **Prices exclude delivery and VAT.** We take Access or Barclaycard.

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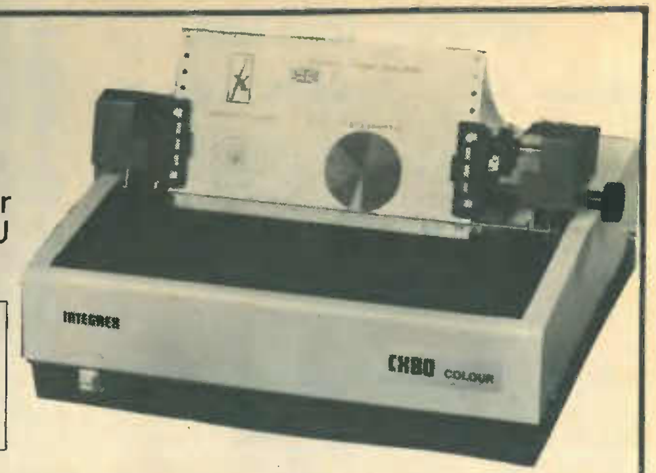
CX80 COLOUR MATRIX PRINTER



At last a low-cost Colour Matrix Printer for Text, Graphics, Histograms, Colour VDU Dumps, etc.

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Compatible with most microprocessors, prints in 7 colours – sophisticated internal programme makes the CX80 easy to use.

Dot Addressable + 15 user programmable characters, 96 ASCII and 64 graphics characters in rom. Centronics interface with RS232 and IEEE488 options.

The CX80 is a product of our own design and development laboratories. It represents a British breakthrough in colour printer technology. Colour brochure on request. OEM pricing available.

NRDC-AMBISONIC UHJ SURROUND SOUND DECODER

The **first ever** kit specially produced by Integrex for this British NRDC backed surround sound system which is the result of 7 years' research by the Ambisonic team, W.W. July, Aug., '77. The unit is designed to decode not only UHJ but virtually all other 'quadrophonic' systems (Not CD4), including the new BBC HJ. 10 input selections. The decoder is linear throughout and does not rely on listener fatiguing logic enhancement techniques. Both 2 or 2 input signals and 4 or 6 output signals are provided in this most versatile unit. Complete with mains power supply, wooden cabinet, panel, knobs, etc.

Complete kit, including licence fee **£57.70** + VAT or ready built and tested **£76.95** + VAT

INTRUDER 1 Mk. 2 RADAR ALARM

With Home Office Type approval

The original "Wireless World" published Intruder 1 has been re-designed by Integrex to incorporate several new features, along with improved performance. The kit is even easier to build. The internal audible alarm turns off after approximately 40 seconds and the unit re-arms. 240V ac mains or 12V battery operated. Disguised as a hard-backed book. Detection range up to 45 feet. Internal mains rated voltage free contacts for external bells etc.

Complete kit **£52.50** plus VAT, or ready built and tested **£68.50** plus VAT.

Wireless World Dolby noise reducer

Trademark of Dolby Laboratories Inc.

Typical performance
Noise reduction better than 9dB weighted.
Clipping level 16.5dB above Dolby level (measured at 1% third harmonic content)
Harmonic distortion 0.1% at Dolby level typically 0.05% over most of band, rising to a maximum of 0.12%
Signal-to-noise ratio: 75dB (20Hz to 20kHz, signal at Dolby level) at Monitor output
Dynamic range >90dB
30mV sensitivity

Complete Kit **PRICE: £49.95** + VAT (3 head model available)

Also available ready built and tested........................ Price £67.50 + VAT

Calibration tapes are available for open-reel use and for cassette (specify which) .... Price £2.75 + VAT

All kits are carriage free

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INTEGREX LIMITED

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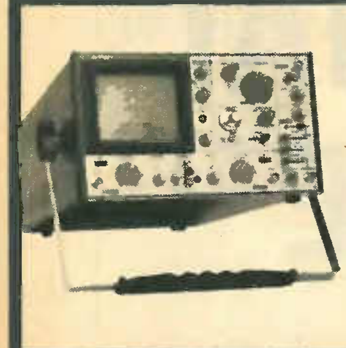
Burton-on-Trent (0283) 215432 Telex 377106

Hitachi Portable Oscilloscopes



A range of high quality 'scopes offering comprehensive specifications at very competitive prices and covering the frequency range 15MHz to 100MHz. The range includes Single and Double Beam and Quad-Trace types - all with a 2 year guarantee!
Illustrated is V550-B, a 50MHz 'scope with Variable Delayed Sweep, Trace Expansion to x1000, Jitter <1 in 20,000, TV Trigger Circuitry, 3rd Trace Trigger View, etc.,

ICD DMM's

Top quality keenly priced West European-made DMM's. Illustrated is the Hand-held 700D which together with 702D offers exceptional ruggedness combined with ease of handling and high operational safety. Model 600D is a truly pocket-sized DMM with large 3½ digit LCD display and 0.2% basic accuracy.

Multiplex® Nickel-Cadmium Cells

Multiplex Nickel-Cadmium Cells are made to high quality standards by a leading Japanese manufacturer. A wide range of standard cells is supplemented by a custom-built battery-pack facility. Also available is an extensive range of chargers and charger modules manufactured by Friemann & Wolf of West Germany to major European safety standards.

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6800	3.82
6802	5.74
6803	14.53
6809	12.00
8085A	8.02
Z80 CPU	4.00
Z80A CPU	5.92
SUPPORT CHIPS	
6520	3.15
6522	5.60
6532	7.75
6821	1.93
6840	5.87
68488P	9.38
6850	1.95
6862	7.09
6871A1T	20.90
6875P	4.16
6880	1.07
6887	0.80
8212	1.95
8216	1.95
8224	2.50
8228	4.20
8251	4.75
8253	9.90
8255	4.20
Z80 CTC	4.00
Z80A CTC	4.90
Z80 DMA	11.52
Z80A DMA	17.25
Z80 DART	7.20
Z80A DART	7.67
Z80 P10	4.00
Z80A P10	4.40
Z80 S10-0 / Z80 S10-1 / Z80 S10-2	17.90
Z80A S10-0 / Z80A S10-1 / Z80A S10-2	22.90
MEMORIES	
2101	3.68
2102	2.54
2114 200ns low power	1.35
2708	1.73
2716 (5v)	2.67
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74LS12	0.15
74LS13	0.29

DEVICE	PRICE
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74LS22	0.15
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74LS32	0.14
74LS33	0.17
74LS37	0.17
74LS38	0.17
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74LS47	0.42
74LS48	0.70
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74LS51	0.14
74LS54	0.15
74LS55	0.15
74LS73	0.22
74LS74	0.18
74LS75	0.30
74LS76	0.22
74LS78	0.25
74LS83	0.54
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74LS86	0.18
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74LS91	0.81
74LS92	0.40
74LS93	0.39
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74LS109	0.26
74LS112	0.26
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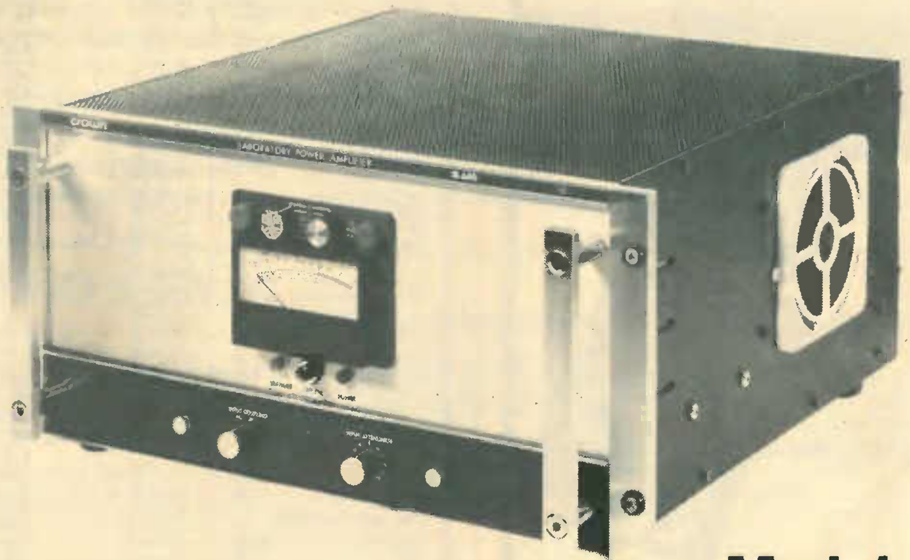

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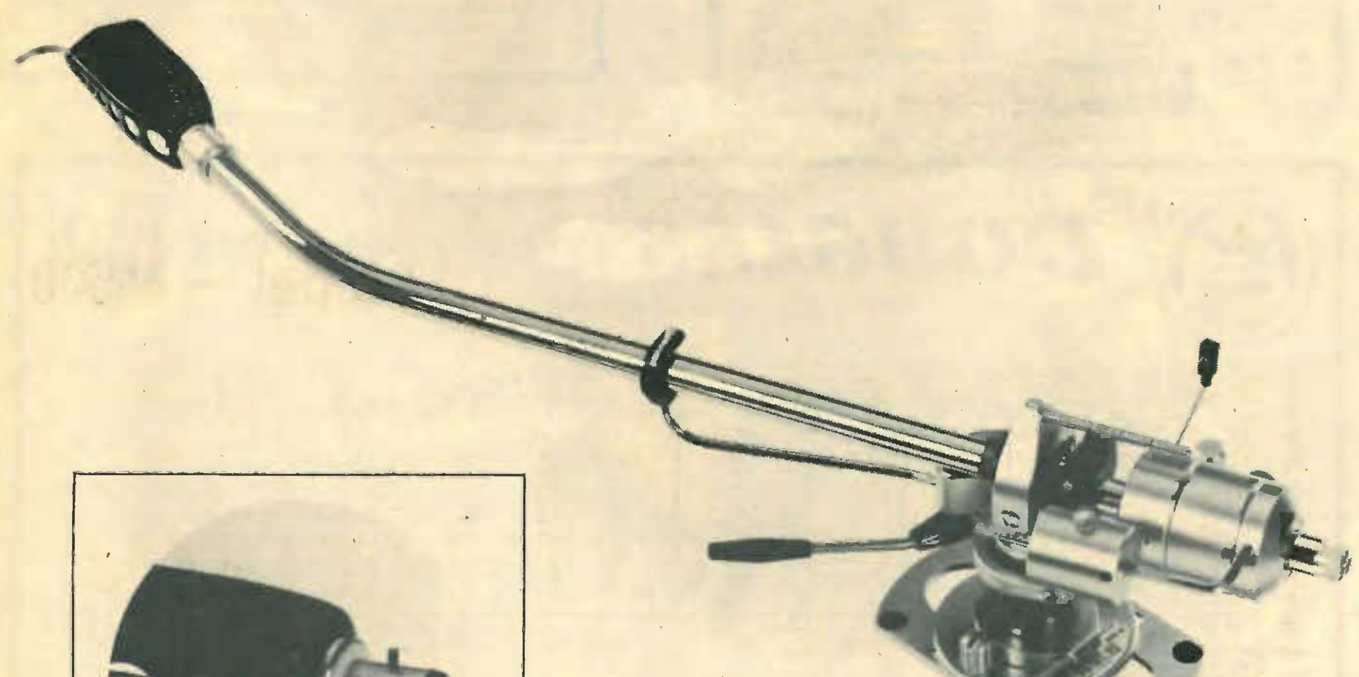

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Information versus emancipation

"Popular will can only express itself within the limits that technical necessities have fixed in advance." (Jacques Ellul in *The Technological Society*)

The ICL affair last May showed us that electronic information processing has become more than just a useful aid: it is a national issue. Some twenty government departments and several thousand British firms are dependent on the use of this company's machines. The Government was right to reject the proposal that ICL should be broken up, its customers sold off to a foreign firm and its research, development and manufacturing centres – constituting much of the country's strength in "information technology" – disposed of like unwanted chattels. If information technology (broadly the systems formed from digital computers and data communications) is an important part of the country's industry it must remain under British ownership. And the British organizations that use its products must not be abandoned to dependence on commercial decisions made by foreign computer firms who have no special concern about the future of any country, let alone this one.

Every nation, of course, wishes to maintain its independence by keeping control of the technical means by which its organizations function. In a democracy one would expect this control to be exercised by the popular will. But in modern industrialized countries the will of the people counts for less and less as officials in charge of specialized information, and of the means of handling it, become more influential in the ordering of events. Representative democracy, in fact, is giving way to oligarchy. The power of legislative assemblies in many countries has been declining relative to the power of the executive. This has happened because of the increasingly technical decisions which a modern government has to make. Such decisions are often beyond the competence of the ordinary representatives of the people, so they have to be made under the guidance of the technical experts in the permanent bureaucracy of the executive (e.g. the civil service). These bureaucrats always have better, more specialized information at their command than the legislators, and they keep it to themselves while it suits their purposes. Their guidance increasingly takes the form of the already prepared decision, the logical outcome of technical necessity, which the legislators cannot reasonably refuse to endorse. Much the same can be said of two other autocratic influences, the military and the large companies and public corporations. The first can keep information to itself on grounds of national security, the second on grounds of commercial secrecy. It is difficult for mere members of the public to contest their arguments because, without full information, the truth of the premises cannot be examined.

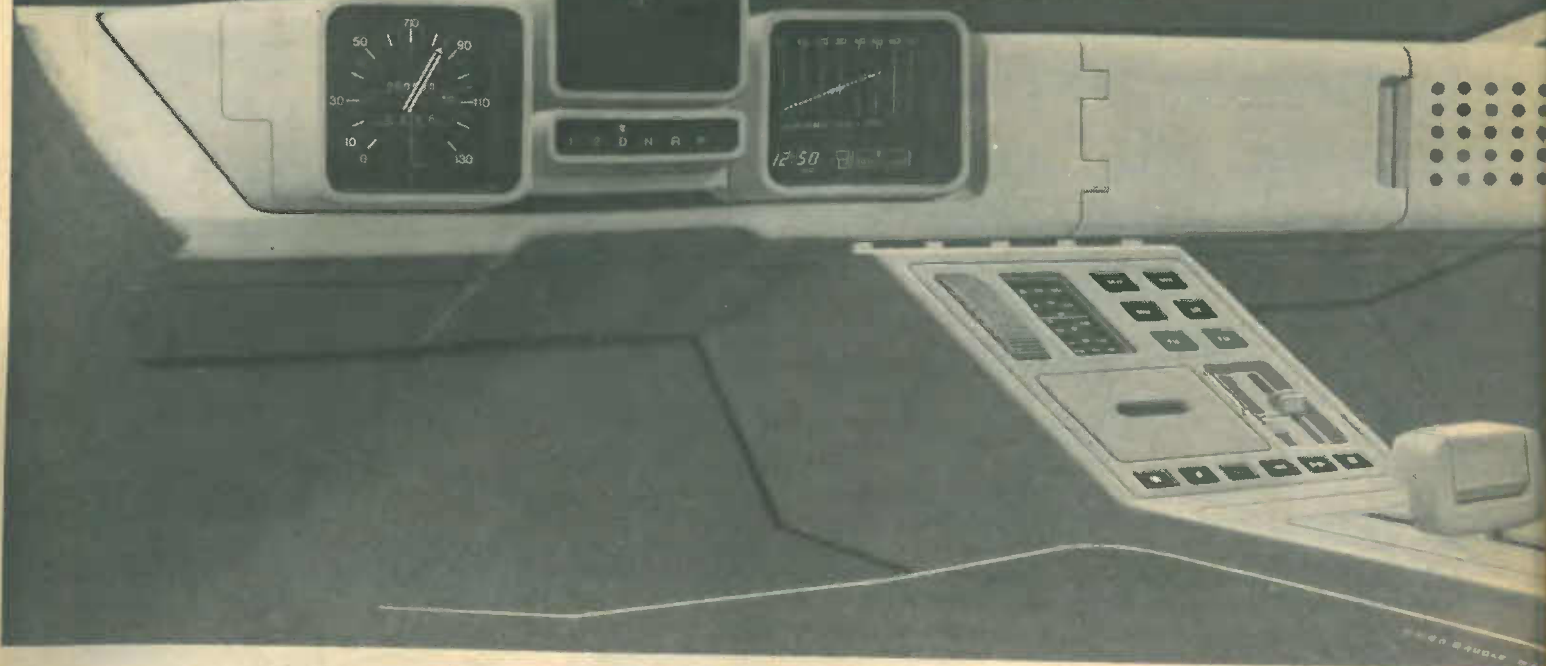
In all three groups, electronic data processing and data communication have become their central nervous system: without these machines the senior officers and managers would now fail to keep control. At the same time the very presence of such techniques allows the organizations continually to grow larger, in the resources and people they command, without danger of falling apart. They are integrated and secure. And the chiefs of these power structures, unelected by the people but using the technical products of their work, privately make decisions which can have profound effects on the economy or security of a whole country.

It's a sad fact for electronics engineers to digest that our contributions to information technology are now helping to undermine our own freedom to participate effectively in the public policy decisions which govern our lives. But at least it doesn't feel as bad when we know the machinery is our own design.

Electronics on the road – 1

An outline of the main applications of electronics to road vehicles

by J. R. Watkinson, B.Sc., M.Sc.



The peculiar circumstances of the world's motor industry, which produces vast quantities of technically conservative products for a market which is largely influenced by cosmetics, dictate that the equipment fitted usually lags the available technology by at least a decade. Accordingly, many of the applications to be described here may at present be found only on expensive vehicles, if at all.

Power units

Alternators. With the possible exception of radios, the alternator was the first quantity-produced automotive device to rely on semiconductors. The benefits of alternators are well known, but their use in road vehicles was only made possible by the development of low-cost reliable rectifiers[1]. For a long time the regulator remained mechanical in form, but now electronic regulators are becoming more common. Those using discrete components or thick film technology have been more successful than monolithic devices, primarily because of the adverse environment[2].

An alternator regulator basically controls the field current, as in Fig. 1, and the switching mode is often used to reduce dissipation.

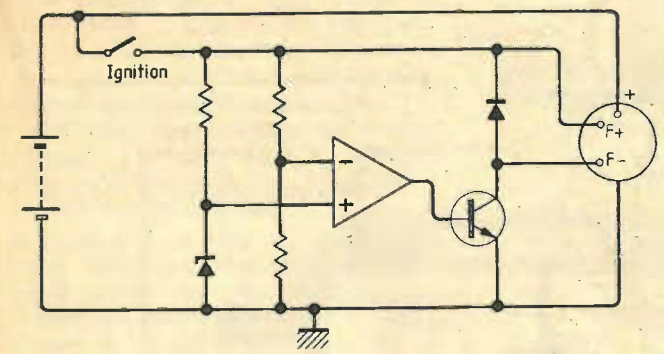


Fig. 1. Basic alternator regulator controls field current.

Electronic ignition. Electronic ignition is interesting in the way timing information is derived and in spark generation.

The source of timing has now generally polarized into two major groups, the magnetic pickup, where a rotating part of the engine modulates the flux linking a coil, and the optical system, where a light beam is interrupted[3]. Both of the above use the existing centrifugal advance mechanism, which is not devoid of drawbacks. A notable exception is the Bowstock system, which uses an r.f.-excited capacitance transducer to eliminate the advance mechanism[4].

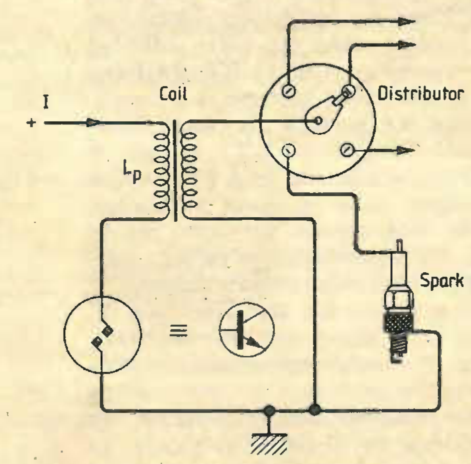


Fig. 2. Many inductive discharge systems simply replace points with transistor

There are now several variations in the spark generator design. In the inductive-discharge system of Fig. 2, the energy stored in the coil is $\frac{1}{2}L_pI^2$ joules. The primary current has to be limited to that which the mechanical contacts can handle without burning, so the inductance has to be relatively high to allow sufficient spark energy. The time taken for primary current to build up in that inductance reduces spark energy at high revolutions, even in the absence of points bounce. Replacement of the points with a transistor which can handle a higher current means that the inductance can be greatly reduced, allowing spark energy to be maintained to higher revolutions. It follows that the main benefit of an add-on inductive discharge ignition unit will not be realised if the appropriate low-inductance coil is not also fitted.

All commercial inductive-discharge systems are of similar design, with the exception of the Bowstock system, which employs some original thinking. As shown in Fig. 3, this system uses a matching transformer between the coil and the amplifier, which is of the push-pull type to give a more rapid rate of flux change. The matching transformer prevents the coil inductance from limiting the spark rate, and the makers claim 1200 sparks per second with undiminished energy. Also unique is the fact that no current flows from the battery except during the generation of a spark.

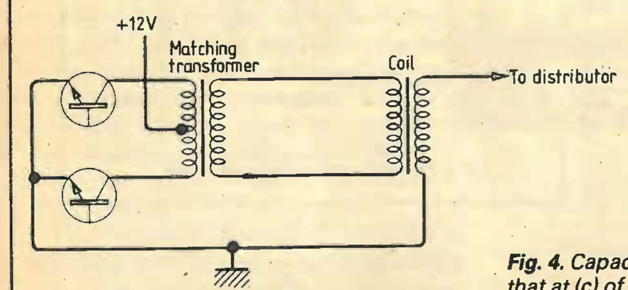


Fig. 3. Bowstock system uses matching transformer and push-pull amplifier to achieve rapid firing rate at full output. (1–coil, 2–transformer)

In a capacitor-discharge system, shown in Fig. 4(a), a high-voltage inverter charges a capacitor which, at the moment of firing, is discharged into the coil primary, which is used as a transformer. An equivalent circuit of the c.d. system is shown in Fig. 4(b). As the mutual inductance of the coil, L_m, is an order greater than the leakage inductances, it can be neglected, which simplifies the circuit to that of Fig. 4(c). The resonant frequency can be stated as

$$\omega_0=\frac{1}{\sqrt{LC_{ser}}}$$

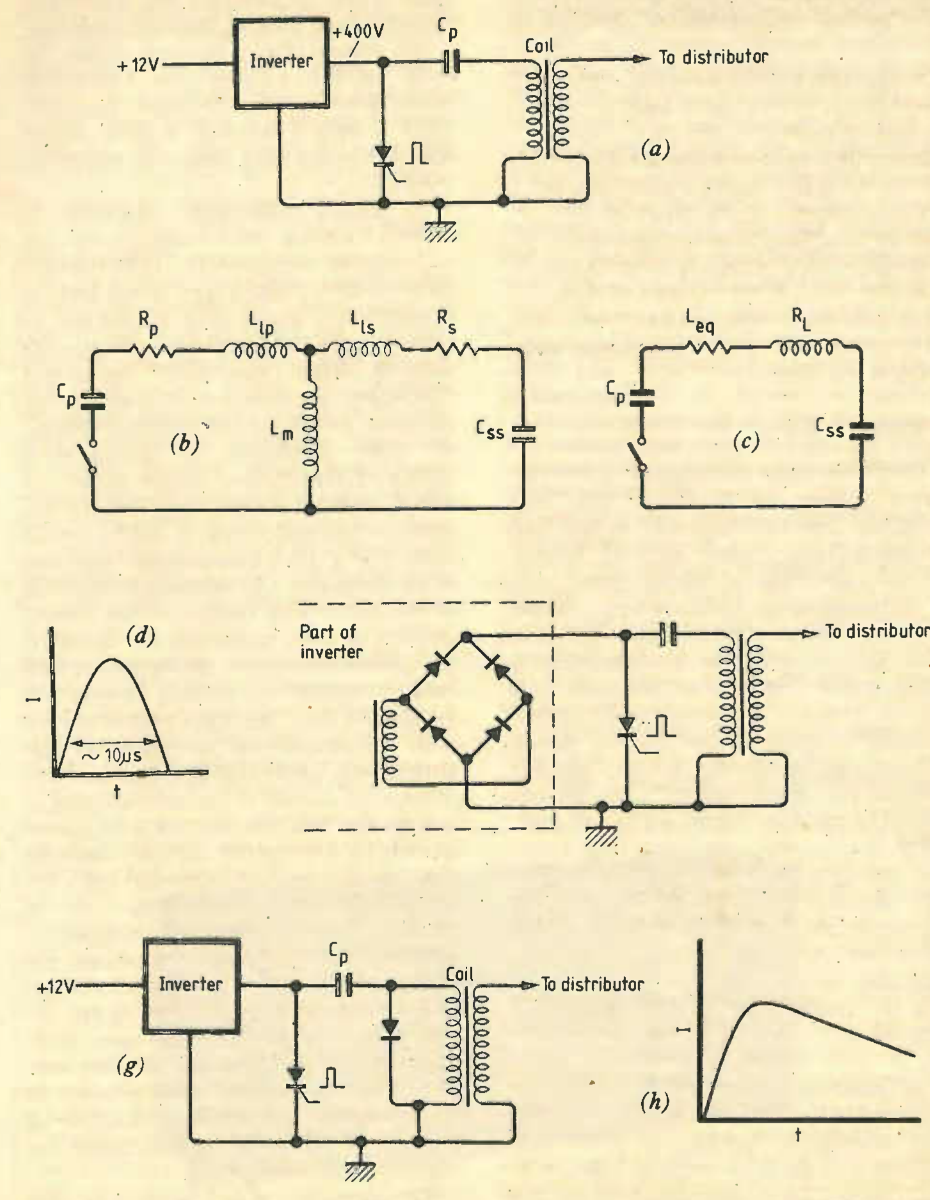
where $C_{ser}=\frac{C_p\,.\,C_{ss}}{C_p+C_{ss}}$

The primary current displays a half-sine characteristic, as in Fig. 4(d). The duration of this waveform, using figures quoted by Hoyer[5] is

$$\frac{2\pi\sqrt{31\mu H.240nF}}{2}\approx10\mu s$$

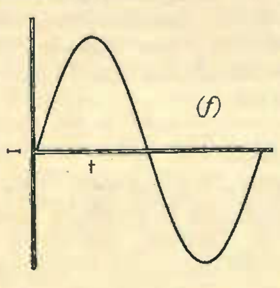
This is extremely short, and in fact the actual spark will be shorter than this. The rise time of the output voltage is correspondingly short, and as a result resistive losses before the spark gap breaks down are very small, which accounts for the unparalleled cold starting performance of the c.d. system. Unfortunately, the weak mixtures used in modern engines can find the spark too short. Simply stated, a weak mixture is not homogeneous, but consists of patches of strong mixture floating about in very weak stuff. If the spark arrives when no patch of mixture is adjacent to the electrodes, a misfire results. Turbulence in the cylinder means that a spark maintained for about 300µs will result in ignition, but this is obviously a function of engine design.

Fig. 4. Capacitor-discharge system, in basic form at (a). Equivalent circuit at (b) is simplified to that at (c) of coil mutual inductance is ignored. Current waveform produced by circuit at (a) is shown at (d), extended by circuit at (e) to waveform shown at (f). Flywheel diode in circuit at (g) allows long decay shown in (h)



In c.d. systems, the spark can be extended in a number of ways. Most common in constructors' circuits is the configuration of Fig. 4(e), where the inverter rectifier forms a return current path, giving a current waveform shown in Fig. 4(f). In Fig. 4(g), the flywheel diode across the coil primary allows the long current decay shown in Fig. 4(h). Obviously, the spark duration should be ascertained by oscilloscope before using a c.d. system on a lean-burning engine, particularly since the original coil is often used, and is not necessarily optimal for a c.d. system. Reputable manufacturers offer matching coils for their c.d. systems but, as with inductive discharge, the author has yet to see a reasoned argument for the use of matched coils in a motor magazine. The reader is referred to a better-than-average effort[6], which also gives an interesting insight into the motor fraternity's colloquialisms.

Enhanced-spark systems have been the subject of research for many years now, but commercial availability is relatively recent. The system depends upon the fact that the voltage required to maintain the spark is considerably less than the breakdown voltage of the spark plug.



A d.c. supply of several kilovolts is applied to the spark plug but, as this potential is below the breakdown voltage, no spark occurs until an e.h.t. pulse is superimposed upon the d.c. The spark gap then breaks down, and the d.c. supply maintains the arc until the charge is exhausted. The principle has long been in use in strobe tubes and flash guns, where the trigger pulse generates an intense electric field around the tube, which breaks down and discharges the h.t. capacitor until extinction voltage is reached[7].

The technique has also been used on electric arc welders to assist in establishing the arc. The components of such a system are under a great deal of stress, and it remains to be seen how reliable commercial systems are. It should be possible to design a system which keeps working on the trigger in the event of the h.t. failing.

A further concern is that erosion of the spark plug electrodes may be accelerated by the intense sparks generated by such systems. The greatest advantage would appear to be in application to lean-burning engines[8].

This type of spark generation has come to be known as the plasma system, an unfortunate term since it implies that the sparks generated by other systems are not also plasmic. Alongside the plethora of misnomers already perpetrated by the industry, such as fluid flywheels and shock absorbers, this latest is a drop in the ocean.

The distributor has a number of shortcomings, one of which is that condensation often forms inside the cap, which causes tracking, a surface breakdown of insulation. The rotor arm does not contact the segments inside the distributor cap, so a second spark spans the gap, causing erosion of the electrodes. The use of a conventional distributor dictates long h.t. leads, leading to radio interference, and extra leakage to ground to dissipate spark energy, as well as presenting a further spark gap which has to be broken down.

A system under investigation at the moment replaces the distributor with reed switches. This approach must reduce lead lengths and interference, but the reliability of such a system has to be questioned.

An alternative is to use one coil per cylinder, which is extravagant. There is, however, a compromise. In engines having single-plane crankshafts, whenever one piston rises on the compression stroke, another is rising on the exhaust stroke. There is no reason why the two cylinders should not spark together, as the exhausting cylinder would not be affected. With this approach only two coils would be required for a four-cylinder engine. Distributorless two-cylinder engines have used the principle successfully for many years now. As the two coils fire alternately, the effective dwell angle is doubled, making the simple inductive-discharge system attractive.

Fuel-injection systems eliminate the carburettor by injecting the fuel directly into the combustion chamber, or, more commonly, into the inlet manifold adjacent to the valve. Early fuel-injection systems were entirely mechanical, and their unreliability made them as popular as lead balloons; indeed the permanent repair for some was to fit a carburettor. The advent of electronic systems now means that reliability is more a function of what can be afforded rather than what was physically possible.

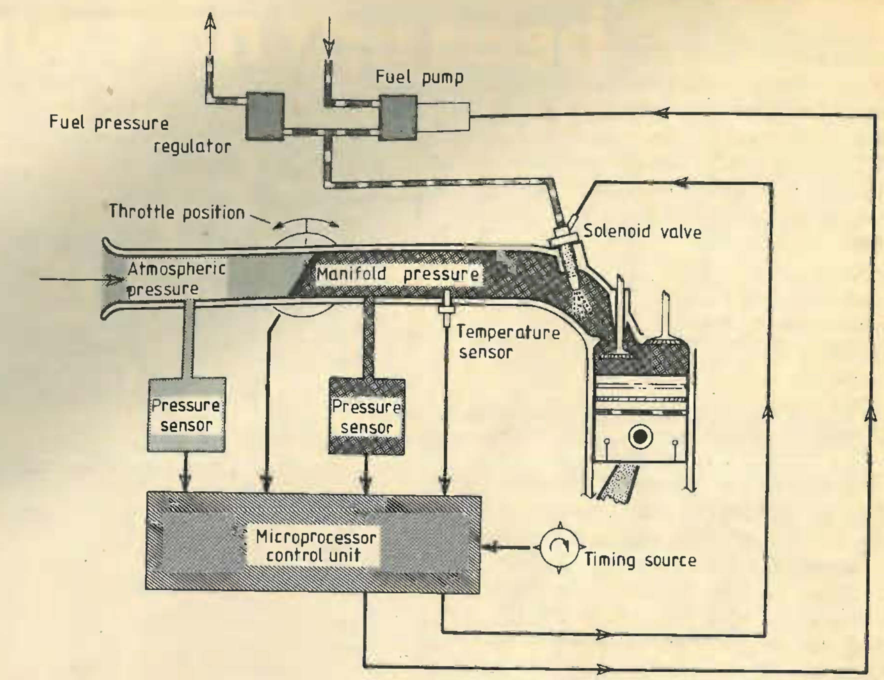


Fig. 5. *Basic electronic indirect fuel injection*

A normal carburettor responds to throttle opening, inlet manifold vacuum and engine temperature. Additionally, most modern vehicles have some form of temperature-controlled air intake to prevent icing and to eliminate yet another variable. Some carburettors[9] can adjust themselves for changes in atmospheric pressure. In a basic fuel-injection system, the input parameters are sensed by a variety of transducers (shown in Fig. 5) which feed the control unit. This device controls solenoid-operated valves which admit fuel from a pressure-stabilized line when energized. The injection must occur as the inlet valve opens, so the system requires an input to describe the rotational position of the engine: any of the devices used to replace the contact breaker are suitable for this. The input parameters are used to calculate the mass-per-unit-time airflow into each cylinder, because this dictates the amount of fuel to be injected in conjunction with the mixture strength required. By sensing the inlet air temperature, the temperature-controlled inlet becomes redundant. The system is an obvious application for a microprocessor, which can be programmed to account for transducer calibration constants, and can perform Gas Law calculations on the inputs to accurately assess the mass flow. Engine requirements under different conditions can be stored as lookup tables in r.o.m., so that one basic system could be adapted to a range of engines simply by blasting new r.o.ms.

The advantages of fuel injection are that high volumetric efficiency can theoretically be obtained in the absence of an inlet venturi, and that on multi-cylinder engines, much weight can be saved by replacing rows of carburettors, since the weight of a fuel-injection system grows little with the number of cylinders. These features are obviously only applicable to racing: more relevant to everyday motoring is the action of a fuel-injection system on the overrun, i.e. when decelerating with the throttle closed. With a carburettor system, the closed throttle causes high manifold vacuum which evaporates condensed fuel from the manifold walls. The resulting rich mixture causes a puff of black smoke to emanate from the exhaust. To meet U.S. emissions legislation, carburettors fairly bristle with devices to alleviate this problem. The fuel injection system simply does not inject any fuel at all under these circumstances, a trick which diesel engines have been doing for years. This may explain why both fuel injection and diesel engines are renascent in the U.S.A.

One interesting application of fuel injection, which is not possible with any other approach, is to change the number of cylinders in use, depending on the load. The argument for this is that by using, say, four cylinders of an eight-cylinder engine to generate half the maximum engine power, those cylinders are working at maximum compression and therefore maximum efficiency, whereas all eight cylinders would be working at part compression to achieve the same power output. The latest Cadillac V8,6,4 engine uses three different configurations, dependent on load, and a seven-segment indicator on the dashboard relays the number of cylinders in use.

Control

Automatic transmission. Theoretically, the advantages of automatic transmission are many, but they have to be weighed against the drawbacks of currently available units. Relieving the driver of gear

shifting means that the engine should always be running at an efficient speed, and that the driver can concentrate more on the road. In heavy traffic, the benefits of automatic transmission are compelling.

With some notable exceptions, current automatic gearboxes rely on a torque convertor in order to skimp on the number of ratios provided. A torque convertor is supposed to be a kind of variable-ratio torque transformer whose task is to pass engine power to the gearbox proper. Unfortunately, rather a lot of power is wasted as heat in current units. In order to prevent overheating, the convertor is deliberately designed to so load the engine that little power can be produced at low roadspeeds. As a result, the acceleration of three-ratio automatics from rest is pedestrian, and that of two-speed automatics can be measured with a calendar. The heat generated by the convertor represents wasted fuel, so as a palliative, recent units incorporate a lockup clutch which is used when cruising.

The exceptions to the above have been where the designer has kept the transmission within some efficiency guidelines. In this respect the French have a clear lead. The most efficient types use either a conventional clutch and gears, hydraulically operated, or electromagnetic powder clutches. Power losses in these systems should be no worse than in manual transmissions, and acceleration and economy are about the same. The most sophisticated are electronically controlled, using such input parameters as road speed and inlet-manifold vacuum, as well as manual override controls and kickdown switches. Current automatic transmissions have to be forced into low gear by the driver for long descents to avoid overheating the brakes: there is no reason why an intelligent transmission could not work out this condition itself. The narrow power band of modern o.h.c. engines, together with an extending motorway system, is dictating a trend to more gear ratios, five now being fairly common in manual transmissions. The future can be expected to bring automatic gearboxes with as many as eight ratios, controlled by microprocessors, as in Fig. 6. The gearbox itself need not be particularly complicated, since eight ratios can be obtained by cascading three epicyclic reducing stages, which could be engaged in binary combinations. In top gear, such a device would be extremely efficient, as all the stages would be locked up, with no relative movement of the gears.

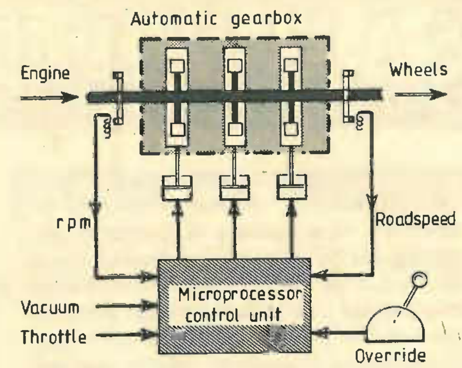


Fig. 6. *Eight-speed automatic gearbox with three stages combined in binary sequence. Micro processes inputs to arrive at correct ratio, controlling hydraulic clutches with solenoid valves*

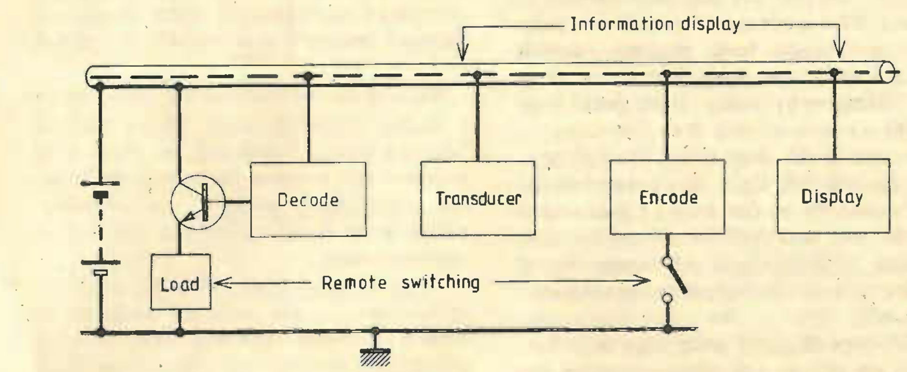


Fig. 7. *Common-bus vehicle wiring, showing load switching and transference of data to display*

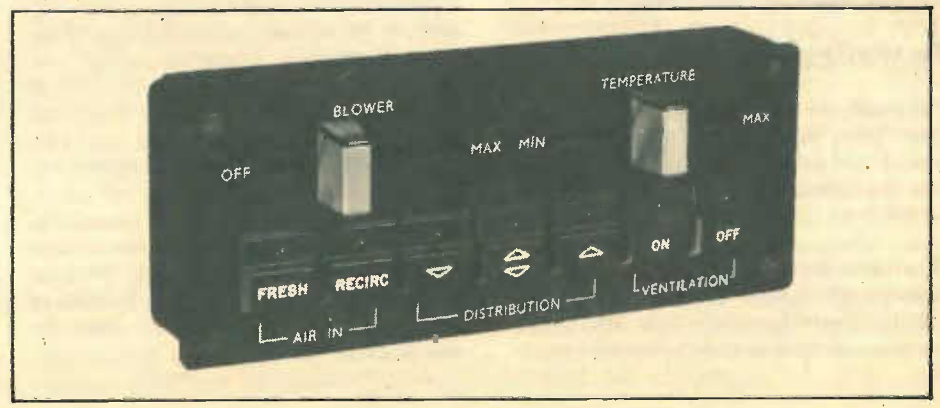
Electrical system. Legislation and social trends have made the electrical system of the modern car very complicated indeed, with devices like rear fog lights and hazard warning lights being introduced to counter today's conditions.

The driver has to be able to operate many different controls within easy reach, and to see instruments and the road. His body has to be kept warm, and supplied with fresh air, and his ears often require to be supplied with sounds of his choice. He needs to find his surroundings to his taste, as well as hoping that in the event of an accident he will not be injured by any of the hardware supplying these needs. The constraints of the above cause the dashboard area to be the most densely packed part of the whole vehicle. Not long ago, printed circuits were adopted to simplify some of the dashboard wiring, and multifunction stalk switches on the steering column also help to reduce the clutter, although the ergonomics of some leave a lot to be desired.

In an attempt to further simplify the physical arrangement of vehicle wiring, a system has been proposed whereby the battery is connected to every electrical device by one heavy coaxial cable running throughout the vehicle. The outer braid is used as the power conductor, the inner conductor being a serial, multiplexed control line, which is driven by a control unit situated next to the driver, as in Fig. 7. Using computer-type registered address techniques, devices connected to the cable are controlled by transmitting a unique address, followed by a control word. Data transmission in both directions would be possible, so that, for example, one node of the cable might be the engine-temperature transducer sending data to the dashboard display. In order to generate addresses and codes, to arbitrate line use and interface with driver controls, a microprocessor would be necessary, and needless to say, a great degree of both signal and hardware redundancy would be required to ensure reliability, as a failure would be rather crippling.

To be continued

Control panel for Smith's Industries electronic heater system. Mass of levers and cables is eliminated, giving flexibility in siting of panel. Heading picture is artist's impression of dashboard of the future, which uses both analogue and digital displays.



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WORLD OF AMATEUR RADIO

Record RAE entry

A record number of candidates, about 5500, sat the Radio Amateurs' Examination in May, and this is sure to be reflected in a continuing surge of new licences over the next few months. This year has seen the completion of the G8AAA sequence of Class B callsigns and the new G6-three-letter calls are already beyond G6CAA. Class A licences have reached beyond G4MAA and the total number of UK amateur licences by early June was over 32,500.

In terms of population percentage, however, the UK tends to lag well behind such countries as the USA, Japan, New Zealand etc. and the directly comparable position in West Germany (where for a number of years licence totals ran neck and neck with those of the UK) shows that country now ahead by more than 10,000.

In view of the criticisms I voiced of the RAE papers set in December 1980, it is only fair to report that significantly less adverse comment has been received on the questions set in May, and generally these do appear to have had rather more relevance to what people need to know to operate modern equipment without causing interference to other users of the radio-frequency spectrum. That having been said, there is no doubt that the inherent problems remain unsolved, and the technical level remains significantly higher than in the specimen questions issued by the City & Guilds Institute.

And what, for example, does one make of such a question as: "The advantage of keying the buffer stage in a telegraphy transmitter is: (a) no energy reaches the aerial during key-up; (b) spurious responses are minimized; (c) key-clicks are absent; (d) the oscillator frequency remains constant" (Paper 765-1-02, question 55)?

As someone who has spent much time keying oscillator stages, buffer stages, power amplifier stages (and various combinations of these in differential-keying arrangements) I have no hesitation in labelling this question, in this form, as meaningless and unanswerable in terms of modern practice! And, once again, the questions on radio propagation are confused and at too high a level.

Technical exams

The problems inherent in providing a sensible "entry examination" for what is intended to be a "self-training" service should not be underestimated; this is particularly true in countries such as the UK where only a single level of technical examination is held, without any form of "incentive" or "novice" licensing. In recent months, apart from my own criticisms, questions of the true aims, purposes and/or conduct of amateur examinations have been expressed by amateurs, or would-be amateurs, in a number of countries, including New Zealand, West Germany and the USA. One has to accept that the hobby has changed a great deal over the past two decades; that, whereas 30 years ago a high proportion of transmitters and aerials and ancillary equipment used by newly licensed amateurs was home-built, this is no longer true.

Some of the critics want examinations at a higher technical level; others want a "driving licence" approach in which it is accepted that it is possible to operate modern equipment without fully understanding the circuit design. A few typical comments are:

"The present form of examination is ludicrous . . . the syllabus needs to be looked at very carefully and perhaps trimmed to the *must* know level rather than including 'nice to know' parameters" (New Zealand).

"Exams should be designed so that, through memorization, those who take the tests will learn what they need to know to operate competently a station and to have an idea of how to fix one . . . amateur radio is effective in allowing thousands of untrained persons an opportunity to learn through *experience*" (USA).

"West Germany publishes a brochure containing questions and answers intended for the examining committee, but it is available to the public and most of the examination questions are exactly the same as in this official publication . . . we now have 'persons licensed to participate on amateur frequencies' " (West Germany).

There is another aspect of this matter. It could be argued that licensing and examination policy in the UK has led in recent years to undue concentration of amateur operation in the 144-146MHz (two-metre) amateur band, while at the same time many of the h.f. and u.h.f. bands are now relatively "underpopulated", a situation having many potential dangers and disadvantages.

From all quarters

The RSGB estimate that some 7000 people attended the 1981 National Amateur Radio Exhibition at Alexandra Palace, and certainly at times it was quite a struggle to get near the exhibits! About 50 traders supported the event and the 'talk-in' stations registered some 2000 contacts. The 1982 event is due to be held in the new Alexandra Palace Pavilion from April 22 to 24, 1982.

British amateurs will be watching closely to see whether prices of Japanese equipment increase as a result of recent changes in the exchange rates, in view of the lack of any noticeable effect when the rate became more favourable to the £ sterling. Many complaints have been heard about the lack of competitive pricing by British importers, although "price negotiating" is not unknown.

The Radio Amateur Old Timers Association, formed originally in 1949 as the British Old Timers Association, is opening its ranks to all those who can show evidence of having been interested in the hobby, either the receiving or transmitting side, for a minimum of 25 years. Previously membership has been open only to those who have held a transmitting licence continuously for 25 years. Current membership is over 550. RAOTA holds the callsign G2OT and a regular 3.5MHz net is held on Thursday mornings at 11a.m. President is Ken Alford, G2DX who was originally licensed as TXK before World War I. Vice-president is F. J. ('Dud') Charman, G6CJ.

Application forms from Miss May Gadsden, 19 Drummond House, Font Hills, Long Lane, East Finchley, London N2.

Radio-control modellers continue to have problems due to interference from illegal c.b. operation and are not convinced that all will be well when (and if) c.b. activity shifts to the higher "legal" channels. The alternative model-control frequency of 35MHz is available only for use with model aircraft.

Running IARU

Views in support of major changes in the future organization and administration of the International Amateur Radio Union have been put forward by the overseas liaison officers of the New Zealand Association of Radio Transmitters: Arthur Godfrey, ZL1HV and Fred Johnson ZL2AMJ. For over 50 years IARU headquarters has been administered by the American Radio Relay League with its officers "arbitrarily selected rather than democratically elected" the New Zealanders note. They suggest: (1) IARU should have an executive elected by the member-societies; (2) administrative work should be carried out by the regional organizations, who would implement policy "decided by the HQ executive after due consultation with regional executives who in turn have sought the opinion of their member societies and reached a consensus".

It is suggested that a measure of decentralisation would permit more use to be made of volunteers and so reduce the need for professional administrators. The recent Region 1 IARU conference at Brighton highlighted a rather different problem: important new recommendations and resolutions can be introduced at a very late stage and then adopted or rejected without reference back to member-societies.

PAT HAWKER, G3VA

Simplified design of dc power supplies

Design considerations and formulae for common circuit configurations

by J. C. S. Richards

Although capacitance smoothed dc power supplies are common electronic circuits, surprisingly little has been written on how to design them. Much of what has been published gives the impression that a reasonably accurate prediction of performance demands either a computer or an extensive set of graphs and tables such as those of Schade[1] which have been used for over thirty years. This article describes a few simple approximations to give formulae which are easy to use and accurate enough for most purposes.

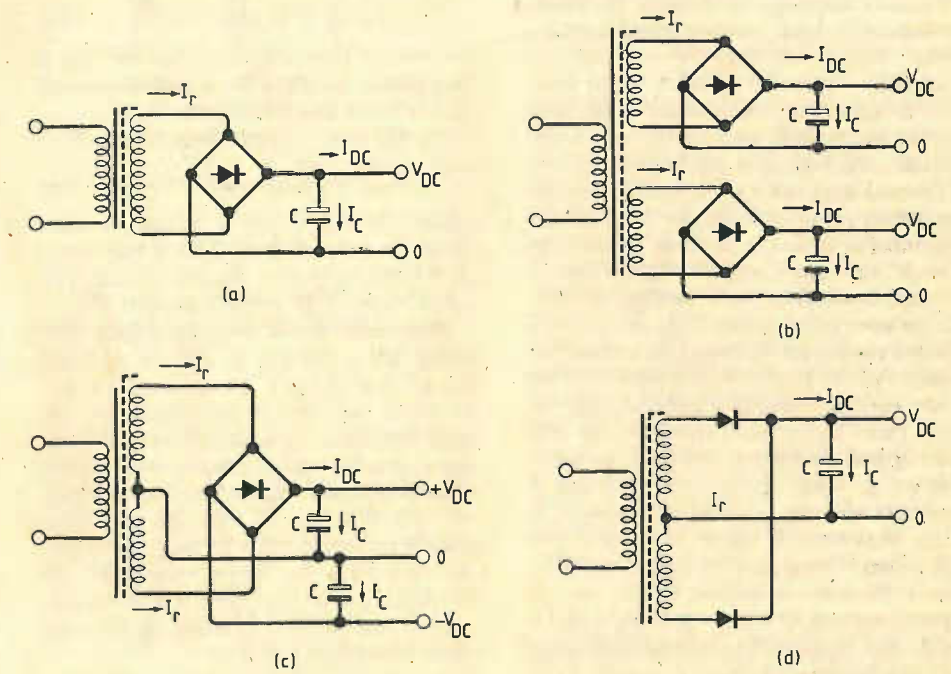


Fig. 1. Full-wave rectifier circuits. (a) bridge, (b) dual bridge, (c) centre-tapped bridge, (d) two phase. In the design formulae for the bridge circuit, V_R and I_R are the ratings for each secondary. For the two-phase circuit, the rating of each secondary is V_R, ½I_R.

To simplify the design procedure it is assumed that the direct output voltage and current in the system are independent of the size of the reservoir capacitance C, provided it is large enough for the peak-to-peak ripple voltage, V_{rip}, across it to be a small fraction, say 20%, of the dc voltage. As shown later, the performance can be easily calculated by taking C to be infinite. The ripple voltage is conservatively given by

$$V_{rip} \simeq nI_{DC}/(2fC) \qquad (1)$$

where I_{DC} is the dc output, f is the mains frequency, n is 1 for the circuits in Fig. 1, and 2 for the circuits in Fig. 2. A better approximation for V_{rip} is given in equation 11. With 50Hz mains, I_{DC}=1A and C=10,000μF, V_{rip} is about 1V for a full-wave circuit.

A second assumption concerns V_{rec}, the forward voltage drop in the rectifiers, which depends on the rectifier peak current but is unlikely to be more than 1.5V for a silicon device. The design procedure assumes that the rectifiers are ideal, infinite resistance in the reverse direction and zero resistance in the forward direction. When calculating the dc output voltage, V_{DC}, from a specified transformer, subtract V_{rec} from the value obtained with ideal rectifiers. When choosing a transformer, start by adding V_{rec} to the required value of V_{DC}. Except for very low currents, V_{rec} should be taken as 1V per diode, i.e. 2V for a bridge rectifier. Leakage in the electrolytic capacitor and in any reverse biased rectifiers causes a voltage drop of up to 0.5V in the forward biased rectifiers. However, V_{DC} is usually calculated at zero output current so that components with a suitable voltage rating can be chosen, and it is therefore advisable to consider V_{rec} as zero.

Transformer considerations

Copper losses are important when determining the transformer performance. Ready made transformers are usually described by some of the following parameters.

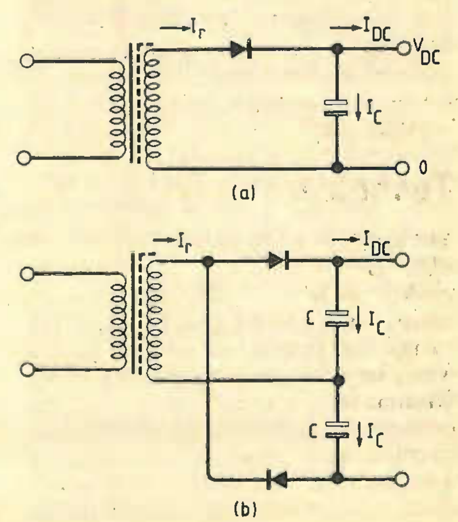
V_p – nominal r.m.s. primary voltage.
I_R – rated r.m.s. secondary current.
V_R – rated r.m.s. secondary voltage or the secondary voltage when the current is I_R.
V_{oc} – open circuit r.m.s. secondary voltage.
r – regulation or $(V_{oc}-V_R)/V_R$.

For a custom designed transformer or one whose parameters are found by measurement, the most readily available quantities are usually

R_1 and R_2 – primary and secondary resistances.
n – turns ratio, given by V_p/V_{oc}.
R_s – output resistance, given by (R_1/n^2+R^2).

Because simplified design methods are particularly useful when only a few items are needed and off-the-shelf transformers are used, the formulae below use the first set of parameters. If the second set is preferred, a conversion can be achieved using

Fig. 2(a). Half-wave circuit, (b) symmetrical voltage doubler.



the relations

$$(1+r)I_R/r = V_{oc}/R_s \qquad (2)$$

$$(1+r)V_R = V_{oc} \qquad (3)$$

Tolerances are rarely quoted for transformers and it is not uncommon for the open circuit secondary voltage to be 3% adrift and the regulation r, which is often given as a typical or a maximum value for a broad range of transformer, to be 10 or 20% different. However, these errors usually combine to make the full load voltage within about 2% of its nominal value.

When a transformer has more than one secondary winding, the variation of output voltage with load becomes more complicated because current drawn from one secondary affects the voltages on the rest. However, for a transformer with two similar secondaries each passing the same current, the behaviour can be described in terms of V_R, I_R and r as above. This covers the series and parallel connection of secondaries and the rectifier circuits in Fig. 1(b) and (c). For the two-phase circuit in Fig. 1(d), the r.m.s. current in each secondary is the same, but the current flows in only one secondary at a time. To compare this circuit with a bridge rectifier using both secondaries in parallel, suppose that V_R, I_R, r, R_1, R_2 and R_s are the transformer parameters when the secondaries are in parallel. In this case the rating of each secondary is $\frac{1}{2}I_R$ and its resistance is $2R_2$. If current is taken from only one secondary instead of from both in parallel, the total r.m.s. current which can be drawn without overheating is reduced to $I_R/k^{1/2}$ and the effective output resistance is increased to kR_s, where

$$k = (2R_2 + R_1/n^2)/(R_2 + R_1/n^2) \qquad (4)$$

The value of k must lie between 1 and 2, and is typically 1.5 when a transformer is designed to have equal primary and secondary copper losses in normal operation.

Design formulae

A characteristic of capacitance smoothed rectifier circuits is that the currents in the transformer and rectifier are pulsed. The performance is easily calculated if the angle of flow, 2θ, is known, and in the approximate formulae below, θ is expressed in radians.

To find the half angle of flow θ,

$$\theta = 1.494x^{1/3} + 0.111x \qquad (5)$$

where $x = A_1[r/(1+r)](I_{DC}/I_R)$
and $A_1 = 1$ for a bridge, $A_1 = k$ for a two-phase, and $A_1 = 2$ for a half-wave or doubler circuit. The second term may be ignored when $x < 0.05$.

For the dc output voltage V_{DC},

$$V_{DC} + V_{rec} = \sqrt{2}(1+r)A_2V_R \cos\theta \qquad (6)$$

where $A_2 = 1$ except for the doubler circuit where $A_2 = 2$.

For the r.m.s. transformer current I_T,

$$I_T/I_{DC} = 1.37\ A_3/\theta^{1/2} \qquad (7)$$

where $A_3 = 1$ for a bridge or two-phase, $A_3 = \sqrt{2}$ for a half-wave, and $A_3 = 2$ for a doubler circuit.

For the repetitive peak rectifier current I_p,

$$I_p/I_{DC} = 2.36\ A_4/\theta \qquad (8)$$

where $A_4 = 1$ for a bridge or two-phase, and $A_4 = 2$ for a half-wave or doubler circuit.

For the r.m.s. capacitor current I_C,

$$I_C/I_{DC} = (A_5 I_T^2/I_{DC}^2 - 1)^{1/2} \qquad (9)$$

where $A_5 = 1$ except for the doubler circuit where $A_5 = 1/2$.

For the maximum permitted dc current I_m, which occurs when $I_T = I_R$,

$$I_m/I_R = 0.87\ A_6[r/(1+r)]^{1/5} \qquad (10)$$

where $A_6 = 1$ for a bridge, $A_6 = 1/k^{2/5}$ for a two-phase, $A_6 = 0.76$ for a half-wave, and $A_6 = 1/2$ for a doubler circuit.

For the peak-to-peak ripple voltage V_{rip},

$$V_{rip} = A_7 I_{DC}(1 - 2A_8\theta/\pi)/(2Cf) \qquad (11)$$

where $A_7 = A_8 = 1$ for a bridge or two-phase, $A_7 = 2$ and $A_8 = 1/2$ for a half-wave, $A_7 = 2$ and $A_8 = 1$ for a doubler circuit. The r.m.s. value of the ripple is about $0.3V_{rip}$.

More exact forms of most of these formulae are given in, or can be deduced from the theory described later. However, any errors introduced by the approximations are nearly always <3%, and more usually <1%. Also, errors arising from the simplifying assumptions made in deriving the "exact" formulae and from inaccurate specification of the transformer are likely to be more significant. In practice the total discrepancy between calculated and measured values of V_{DC} has rarely exceeded 1V or 5%.

Choosing a circuit

The choice of circuit is usually between a bridge and a two-phase design. Overall the two-phase circuit is usually better and cheaper at low voltages and the bridge wins at higher voltages, but the differences in cost and efficiency are small and often less important than the availability of components.

For dual supplies the separate bridges of Fig. 1(b) allow flexibility in earthing etc, while the centre-tapped bridge of Fig. 1(c) is the most economic way of obtaining positive and negative rails. The only important advantage of a half-wave circuit as shown in Fig. 2(a) is simplicity. The transformer is used inefficiently, flux in the core has a dc component, the dc regulation is poor and the ripple voltage is double that of a full-wave type using the same capacitor.

The symmetrical half-wave doubler in Fig. 2(b) avoids dc polarisation in the transformer core, the fundamental ripple frequency is twice that of the supply, and a high dc voltage can conveniently be obtained using components with a relatively low voltage rating.

The available direct current I_m, the corresponding dc voltage V_m and the open circuit dc voltage V_o, with allowance for the rectifier voltage drop V_{rec}, are plotted against r in Fig. 3 for a full-wave bridge. The trend of the curves is the same for all

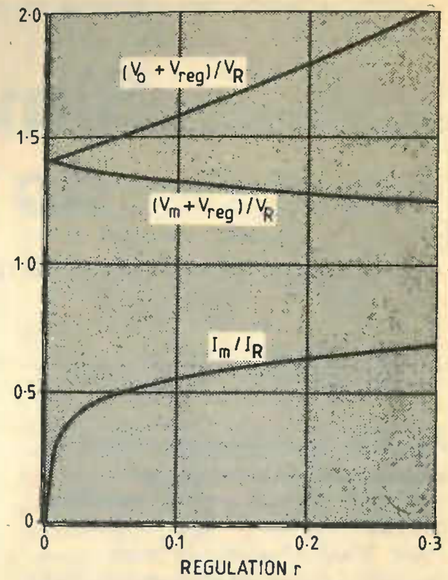


Fig. 3. Graph for a bridge rectifier circuit showing how the maximum available dc current I_m, the corresponding dc output voltage V_m, and the open circuit dc voltage V_o vary with the regulation of a transformer rated at V_R and I_R.

circuits. Regulation of the dc supply is $(V_o - V_m)/V_o$, therefore a transformer with poor regulation makes a power supply with even worse regulation. However, when r is very small, the transformer tends to be large and expensive for its VA capacity and I_m/I_R becomes small. Also, it may be necessary to introduce an external resistance to limit the peak rectifier current, thereby removing any advantage from a low r.

As a general guide, for outputs between 10 and 100VA, a regulation of about 0.1 (10%) is a good compromise and suitable transformers are readily available. Transformers with a low power rating, <10VA, are not much cheaper than larger types and, because the relatively larger cooling surface permits a higher current density in the copper, a larger fraction of the winding area is occupied by insulation which tends to make the copper losses and hence r relatively large.

For a bridge or a two-phase circuit which must provide V_{DC} at a maximum current I_{DC}, the transformer V_R should be about 0.8 $(V_{DC} + V_{rec})$ and I_R should be around $2I_{DC}$. When specifying V_{DC} for a supply which is to be stabilized, allow for the voltage drop in the stabilizer, typically 2 to 3V, variations in mains voltage, about ±10%, and the minimum voltage across the capacitor which is less the V_{DC} by about $\frac{1}{2}V_{rip}$ (0.5 to 1V). Considering all these factors, and allowing for a 1 to 2V drop in the rectifiers, a stabilized output usually requires a transformer with a V_R of about 0.9 $(V_{stab} + 5V)$. Therefore, for the popular stabilized values of 5, 12 and 15V, the transformer voltages must be around 9, 15 and 18V respectively. It is permissible for I_{DC} to exceed I_m for periods much less than the transformer thermal time constant, provided that I_{DC} is appropriately less than I_m at other times. Note that the thermal time constants of the rectifiers and

capacitor are relatively short and their ratings should be determined from the maximum value of I_{DC}.

When a supply is switched on a large current, up to $\sqrt{2}I_R(1+r)/r$, can flow into the capacitor, so the rectifiers must have an appropriate non-repetitive peak current rating. The repetitive peak voltage rating of the rectifiers should be at least $\sqrt{2}(1+r)V_R$ for the bridge circuits and twice that value for the other circuits, with an allowance for mains voltage variations. The voltage rating of the capacitors should not be less than $\sqrt{2}(1+r)V_R$, and these ratings should be increased by 30 to 50% for high reliability.

Design examples

For a supply with an output of 35V dc at 0.6A, less than 2V peak-to-peak ripple, and a bridge rectifier with $V_{rec} = 2V$, a transformer is needed with V_R about 0.8 × 37 or 30V, and I_R about 2 × 0.6 or 1.2A. From equation 10, the two secondaries in series can provide a dc current I_m of 0.85A, and from equations 5 to 11 the following values are found. The figures in brackets were measured on a prototype with C=2,200μF.

At $I_{DC} = 0$, $V_{DC} = 46.2V$ (45.8V)
At $I_{DC} = 0.6A$, $\theta = 0.473$,
$V_{DC} = 39.2V$ (38.4V)
$I_T = 1.2A$, $I_p = 3.0A$, $I_c = 1A$,
$V_{rip} = 1.9V$ (1.8V).

For a supply to provide 5V at 1A with less than 1V peak-to-peak ripple, a transformer with two secondaries each rated at 4.5V 1.3A, and a regulation figure of nominally 0.1 is suitable. The design equations for a bridge circuit with the secondaries in parallel give the values below; measured values are for C=10,000μF.

At $I_{DC} = 0$, $V_{DC} = 7V$ (6.1V)
At $I_{DC} = 1A$, $V_{DC} = 4.2V$ (4.1V),
$V_{rip} = 0.7V$ (0.6V).

For a two-phase circuit, assuming $k = 1.5$, the following values are obtained.

At $I_{DC} = 0$, $V_{DC} = 7V$ (6.6V)
At $I_{DC} = 1A$, $V_{DC} = 4.9V$ (5.1V),
$V_{rip} = 0.7V$ (0.6V).

These results clearly show that the two-phase circuit is superior.

Derivation of equations

An equivalent circuit for a bridge rectifier is shown in Fig. 4, together with some current and voltage waveforms. The transformer is represented by a sinusoidal generator, $v_1 = (V_1 \cos\omega t)$, and an output resistance R_s.

When C is large enough, the voltage across it can be taken as constant and equal to V_{DC}. Current i_1 flows into C whenever the magnitude of v_1 is greater than V_{DC}, i.e., when $|V_1 \cos\omega t| > V_{DC}$, or when ωt lies between $(n\pi - \theta)$ and $(n\pi + \theta)$, where n is 0, ±1, ±2 . . . etc. and 2θ is the angle of flow. In Fig. 4(b), $|V_1 \cos\omega t|$ and V_{DC} are shown together and

$$V_{DC} = V_1 \cos\theta \qquad (12)$$

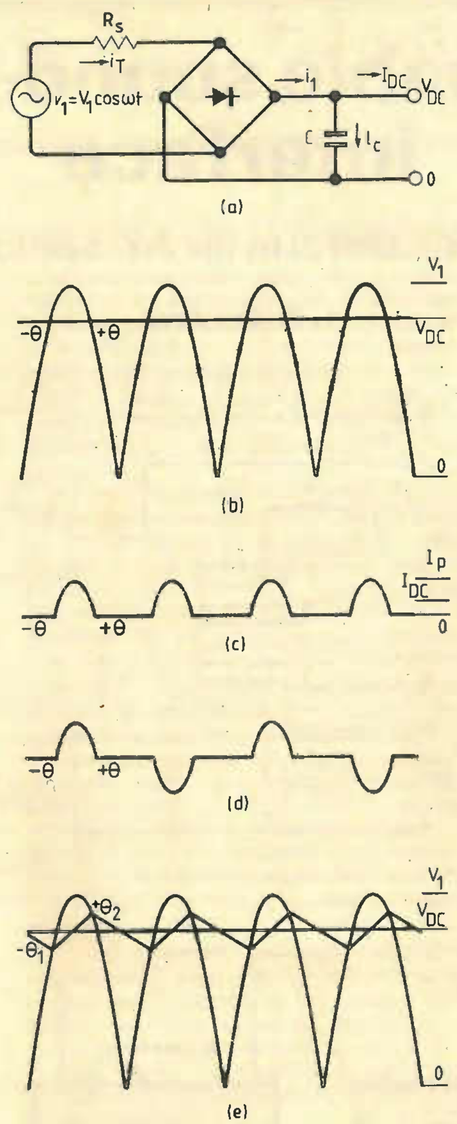


Fig. 4(a). Equivalent circuit of a bridge rectifier system. (b) Comparison of $|V_1\cos\omega t|$ and V_{DC} when C is infinite. (c) Waveform of current i_1 into the capacitor. (d) Waveform of transformer secondary current i_T. (e) Comparison of $|V_1\cos\omega t|$, voltage across a finite capacitance and the dc output voltage.

Current i_1 flows in pulses as shown in Fig 4(c), and is given by

$$i_1 = V_1(\cos\omega t - \cos\theta)/R_s \qquad (13)$$

Because the average value of i_1 must be equal to I_{DC},

$$\sin\theta - \theta\cos\theta = \tfrac{1}{2}\pi R_s I_{DC}/V_1$$
$$= \pi r I_{DC}/[2\sqrt{2}(1+r)I_R] \qquad (14)$$

This equation can be solved by trial and error or by expanding $\sin\theta$ and $\cos\theta$ as a truncated power series in θ and then using Newton's approximation to obtain equation 5 above.

The transformer current is shown in Fig. 4(d) and has the same r.m.s. value I_T and peak value I_p as i_1. Therefore,

$$I_T^2 = \frac{V_1^2(2\theta + \theta\cos2\theta - 1.5\sin\theta)}{(\pi R_s^2)} \qquad (15)$$

$$I_p = V_1(1 - \cos\theta)/R_s \qquad (16)$$

Expanding $\cos2\theta$ etc. as series in θ, and keeping the most significant term provides equations 7 and 8.

From Fig. 4(a), the current i_1 divides into two parts, I_{DC} and i_c in capacitor C. Because i_c has no dc component, the average value of $i_c I_{DC}$ is zero, and equation 9 follows. To find I_m, I_T is made equal to I_R and the equation is solved by series expansion to find θ_m, from which I_m follows by equation 13.

For circuits other than the bridge type, the constants A_1 to A_8 can be found by sketching the waveforms and making appropriate adjustments to the integration limits when taking averages.

Effect of finite capacitance

If the ripple voltage across capacitance C is assumed to be an exact triangle waveform, the diagram in Fig. 4(e) is produced where $|V_1\cos\omega t|$ and the voltage across C are shown together. The theory given above can be extended to find θ_1, θ_2 and hence V_{DC} etc.[2], but the improvement is small if the ripple is small. For example, the change in V_{DC} for a bridge system is around $6(V_{rip}/V_{DC})^2\ [I_r/(rI_{DC})]^{2/3}\%$, which is <3% provided that V_{rip}/V_{DC} <0.2 and a transformer with $r > 0.05$ is used at or near its maximum capacity. If such an improvement is justified, a more accurate method of predicting rectifier voltage drop should be used. The discharge current out of C is I_{DC} therefore, if C discharges for a time t_1,

$$V_{rip} \simeq I_{DC}t_1/C \qquad (17)$$

From Fig. 4(e) and because $(\theta_1 + \theta_2)$ is approximately 2θ, and the repetition time of the ripple is $1/(2f)$,

$$t_1 \simeq (1 - 2\theta/\pi)/(2f) \qquad (18)$$

so equation (11) follows, and (1) gives a rough overestimate.

Note that in the doubler circuit of Fig. 2(b), the voltage waveform across each capacitor is that of a half-wave circuit. However, the two ripple waveforms are displaced from each other by half a cycle and, when added, give a ripple waveform with a fundamental frequency of twice the mains frequency.

References

1. Schade, O. H., "Analysis of rectifier operation", *Proc. I.R.E.*, Vol. 31, pp 341-361, 1943.
2. Leiders, A., "Single-phase rectifier circuits with CR filters", *Electronic components and applications*, Vol. 1, pp 153-165, 216-225, 1979.

Tone filters for electronic organs – correction

On page 61 of Colin Pykett's article in the December 1980 issue, please transpose the first five lines in columns two and three. And on page 60, in column three, please read 82kΩ for R_1 and 1kΩ for R_2. Apologies for these errors.

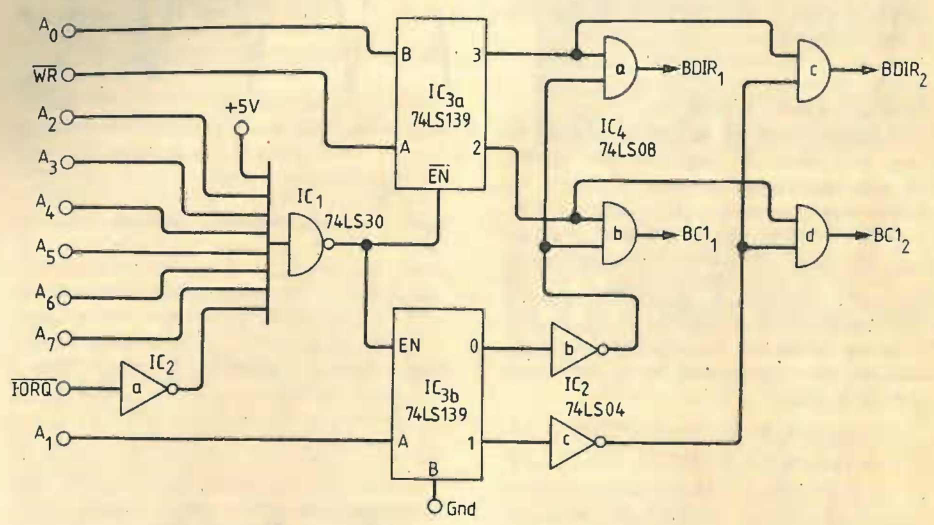
Programmable sound-generator interface

Z80 control of the AY-3-8910

by M. Shepherd

Although the AY-3-8910 programmable sound generator was designed for use with a microprocessor, it can only be directly used with CP1600/1610 devices. This inexpensive interface allows up to four generators to be controlled by the popular Z80 using i/o instructions.

The AY-3-8910 programmable sound generator, p.s.g., is a 40-pin i.c. containing 14 read/write registers which determine tone frequency, noise amplitude and envelope shape on three separate audio output channels. These features make the device suitable for computer control and, with simple programming, a wide range of musical and non-musical sounds can be produced.



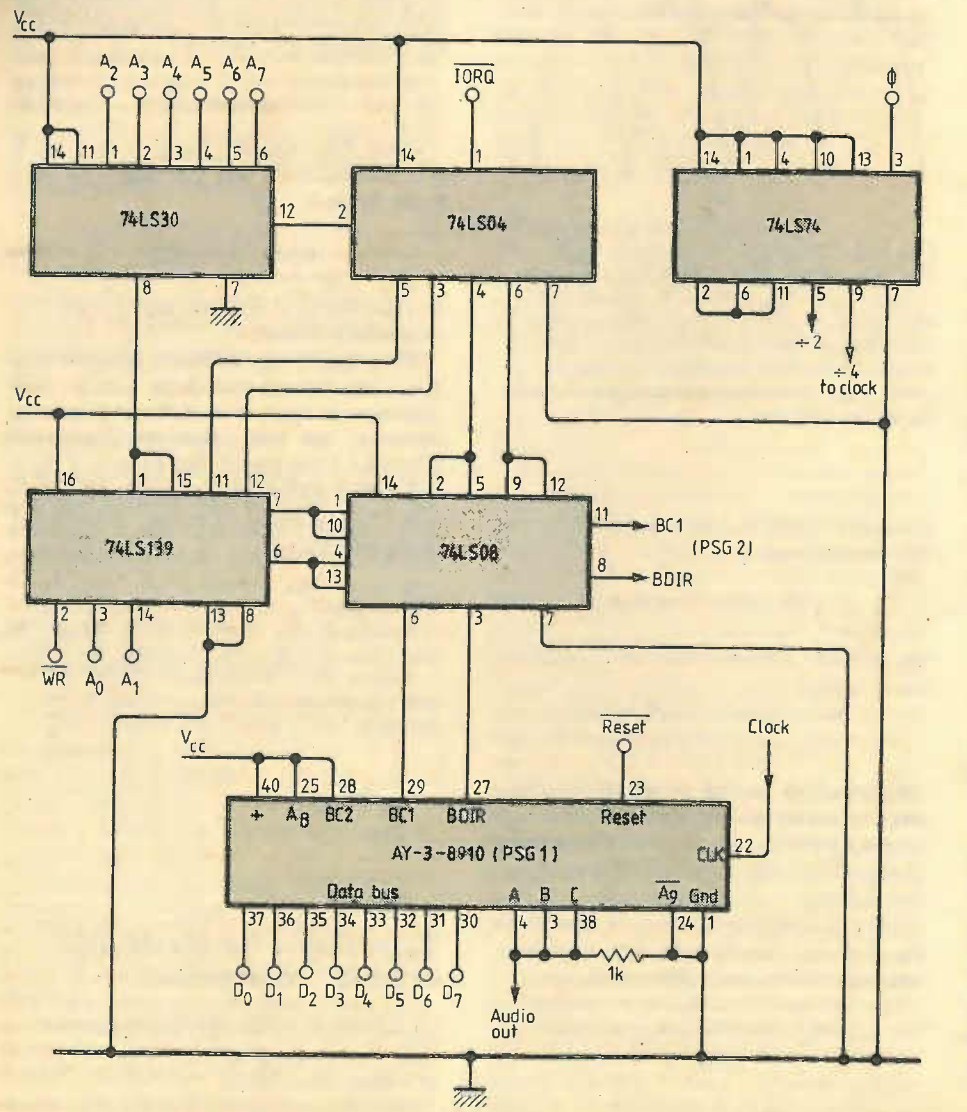


Fig. 1. Interface decoding logic for two programmable sound generators.

Fig. 2. Control circuit for one or two p.s.gs. Z80 connections are marked with a circle.

Once programmed, the p.s.g. can produce and sustain a particular sound without further control from the computer, and several devices can generate elaborate contrapuntal effects.

Individual registers in the generator are accessed and written/read via an 8-bit bidirectional bus which is controlled by BDIR, BC1 and BC2 signals. If BC2 is connected to +5V, bus control can be achieved with the signals shown below.

BDIR	BC1	Function
0	0	bus inactive
0	1	read data from latched p.s.g. register
1	0	write data to latched p.s.g. address
1	1	latch register address

The BDIR and BC1 signals are directly available from CP1600/1610 processors, but with other microprocessors they must be simulated and synchronized to allow data transfer between the processor and p.s.g. bus.

The AY-3-8910 also has two independent general purpose 8-bit i/o channels, registers 14 and 15, which have no effect on the sound generation. These are equivalent to a Z80 p.i.o. without the handshake lines and interrupt facility, and can be used, for example, to read a keyboard.

continued on page 54

LETTERS TO THE EDITOR

BETTER R.F.I. PROTECTION NEEDED

It is clear from my own observations that a.m. citizens' band equipment operating on the 27MHz frequency is now so firmly entrenched in this country that nothing, certainly not the belated appearance of a legal specification, will sweep it away. Whatever the rights and wrongs of the matter may be, there are just too many a.m. rigs in service for them to fade rapidly into obscurity come the glorious day.

I therefore issue a vehement plea for all manufacturers of domestic electronic equipment to start looking seriously at one aspect of its performance which is usually wholly neglected – immunity to strong radio-frequency fields. Manufacturers ought to be forcefully reminded that if their apparatus is not intended to respond to 27MHz a.m. signals it is a failing on their part if it does. The extra components needed to secure excellent r.f.i. protection are not expensive, and their presence would also assist in reducing the number of domestic problems arising from the use of amateur, p.m.r., broadcast or other radio transmitters close to ordinary households.

Perhaps reviewers might observe that an r.f.i. susceptibility test would be a useful addition to their array of measurements. A number of reputable hi-fi manufacturers produce amplifiers with appalling r.f.i. protection, and it seems that performance in this respect is haphazard – there being considerable differences between various models from the same manufacturer, and no apparent correlation between price and protection.

Norman McLeod
Brighton
Sussex

DISTORTION AT THE AMPLIFIER–SPEAKER INTERFACE

The two-part article "Intermodulation distortion at the amplifier-loudspeaker interface" by Otala and Lammasniemi in your November and December 1980 issues contains serious flaws.

This article began life as an Audio Engineering Society Convention preprint, No. 1336 of February/March 1978. Its authors are aware of at least three independent rebuttals of that preprint, one of which has already been published. This published rebuttal is by R. R. Cordell of Bell Telephone Laboratories, and is available as AES Convention preprint No. 1537 of November 1979, under the title "Open-loop output impedance and interface intermodulation distortion in audio power amplifiers". One of the unpublished rebuttals is by E. M. Cherry and G. K. Cambrell of Monash University; originally submitted to the *AES Journal* in February 1979, a revised manuscript was submitted in October 1980 under the title "Output stages for audio power amplifiers".

Cherry and Cambrell make the following points:

1. If an amplifier uses a common-emitter output stage then, if collector resistance can be varied without changing any other parameter, interface intermodulation distortion, i.i.m., increases monotonically as collector resistance is reduced.
2. If an amplifier using a given transistor has a common-emitter output stage, and if this is changed to the common-collector configuration and nothing else is changed except the phase of the feedback connection, i.i.m. at best remains constant but is more likely to increase.

Taken together, 1 and 2 run absolutely counter to the suggested "rule" of providing a low open-loop output resistance (*WW* Dec. 1980, p.56).

3. For practical purposes, a loudspeaker is passive and cannot inject a signal back into an amplifier. (a) The motional e.m.f. produced by sound incident on the loudspeaker cone from room or enclosure reflections of from other sources is minuscule compared with amplifier rated output voltage. (b) Substantial motional e.m.f. results from the signal applied to a loudspeaker. However the substitution (or compensation) theorem of network theory shows that an active network which models a loudspeaker and includes such a motional e.m.f. can be replaced identically by the passive LRC network that completely models the driving-point impedance of the loudspeaker. A loudspeaker is strictly passive so far as any applied electrical signal is concerned, and there is no possibility of i.i.m. as defined because there is no independent signal source in the load.
4. I.i.m. is proportional to a product of output current amplitudes in Fig. 4. The constant of proportionality depends on the detail of the circuit, but cannot exceed the constant in a standard two-tone intermodulation test. I.i.m. at given output current amplitudes cannot exceed the standard intermodulation at the same current amplitudes.

Taken together, 3(a) and 4 suggest that the distortion power produced in a real-life situation by the interface intermodulation mechanism is minuscule compared with the distortion power produced by the standard intermodulation mechanism.

Edward M. Cherry
Department of Electrical Engineering
Monash University
Clayton, Victoria, Australia

The authors reply:

We are not aware of any rebuttals of our AES paper. The paper of Cordell is based on different premises from ours, i.e., Cordell postulates the amplifier open-loop distortion to be constant in the comparison, whereas our analysis is based on the closed-loop distortion being held constant. This difference in boundary conditions taken into account, Cordell's results are in agreement with ours and the paper can hardly be considered a rebuttal. The two other references quoted are unknown to us, and will be considered if and when available.

The points the writer makes sound familiar to us as if they were our own results taken from our paper:

1. This conclusion is a corollary to our paper. We assumed the amplifier closed-loop distortion to be constant, which is a real-life engineering consideration, as discussed in our paper. The writer's assumption is that the open-loop distortion is constant and that the amount of overall negative feedback varies with the collector resistance. This leads to complete agreement with our results, if allowance is made for the different boundary conditions. However, we doubt if the writer's case could be realistic in practice.
2. Our theory shows that the i.i.m. in this case should in principle remain about the same just as the writer states. We cannot see any theoretical discrepancy here either. Nevertheless, this kind of a hat-trick would be impossible in practice, and practical measurements show the common-emitter stage to be inferior because of larger closed-loop distortion.
3. (a) We agree completely with this point, as is stated in our paper. (b) As far as the loudspeaker is concerned, this is just a matter of definition. We would wish to point out that the proposed i.i.m. measurement method was not conceived to simulate the physical *loudspeaker*, but just to expose the *amplifier* output port to such worst-case current and voltage relationships which might occur when real loudspeaker loads are being driven.
4. This is a rephrasing of the opening paragraph of Part 2 of our paper. In many cases, i.i.m. will be negligible as compared to the CCIF two-tone i.m. However, in a poorly designed amplifier, such as shown in our Fig. 14, it may equal in magnitude the two-tone i.m., as can be seen from our Figs. 15 and 17.

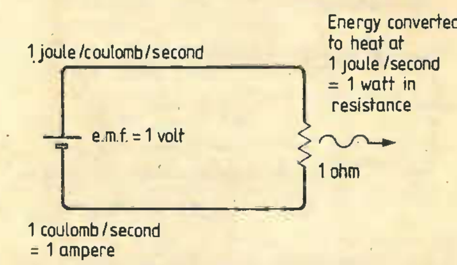
In conclusion, the letter does not seem to indicate any flaws in our paper, on the contrary. Many a thing may seem controversial if viewed from different positions. However, a more thorough examination which takes into account the different sets of boundary conditions shows no conflict to exist.

Matti Otala, Jorma Lammasniemi
Technical Research Centre of Finland
Oulu, Finland

THE DEATH OF ELECTRIC CURRENT

Mr Ivor Catt's very interesting article in your December 1980 issue obviously calls for some discussion, since, if he is correct in his analysis it would imply that a lot of our fundamental teaching in electronics is wrong.

Let me recapitulate first, simply, on the Normal theory of electric current flow. It is now widely taught that in the following circuit the electric current consists of a flow of electrons, between adjacent atoms which make up the material of the wires; the electrons either carrying, or being, elements of electric charge. The



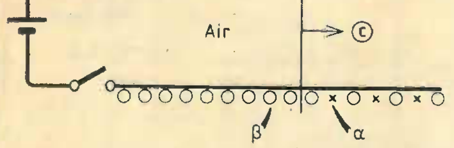
charges are given energy by the electromotive force of the battery, such that if 1 coulomb (6.24 × 10^{18} electrons) of charge is raised through a potential difference of 1 volt, it acquires 1 joule of energy; which is then expended when the current (rate of flow of charge) flows through the external circuit resistance. If the charge is flowing through the wire at 1 coulomb/s, then the current is said to be 1 ampere, and the resistance of the circuit would be 1 ohm; while the energy of the current would be dissipated (e.g. converted into heat) by resistance, at the rate of 1 watt, or 1 joule/s.

It would seem from the successes we have had, for example, in making colour television, radio and stereo systems available to so many people, that these circuit fundamentals must be quite a valid and useful way of thinking. I am also at a loss to see how Mr Catt can develop his theory of the battery and resistor, with the 'energy current' entering the resistor sideways (on p. 80, December issue) into giving such useful quantitative concepts as the above circuit does; but maybe he doesn't want to, at present. It would seem, however, that he is at least asking us to lay aside our hypotheses about the existence of protons, electrons, and therefore presumably even atoms; for we are told that electric charge does not exist, and nothing flows in a conductor. This could indeed be revolutionary.

As a philospher, I am only in sympathy with Mr Catt's initiative. Although I can't really follow the flight of his imagination at present, I have argued elsewhere ("Mind & Machine," *The Listener*, Oct. 17th, 1963) that the concepts and inventions of physics, and indeed the Universe itself, should be understood in terms of the concept of imagination, e.g. of the writing of scientists, and not vice versa. My attempt to argue this viewpoint however, i.e. that scientific knowledge does not have to be taken literally as ultimate truth, was not very well received, and I was accused of 'dangerous obscurantism'. It may, I suppose, one day be possible to explain the 'imaging' or 'imagining' function of the brain in physical concepts. However, although I wish Mr Catt every success in developing his imagination and new theories, I think he should be warned, or reminded, that the imagination of scientists does have to be supported, or tested, by observations and experiments. In short, it seems that he may be unwise in reviving a Heaviside theory, published in 1892, and in quoting J. A. Fleming (1898) and Clerk Maxwell (1831-1879), who lived before the discovery of the electron (1897), through the experiments of J. J. Thomson, had become well known and accepted.

Peter G. M. Dawe
Oxford

The author replies:
Mr Dawe's recapitulation, para. 2, deals with a so-called "steady state" situation. Conventional theory covers for these quite well; it was developed for that purpose. However, conventional theory cannot cope with the transient condition, as we shall see. Consider the situation ¼ nanosecond after we close the switches in the diagram below.



A voltage-current step has advanced three inches to the right. Behind the step, there is a voltage drop between the wires. The E lines must terminate on electrons in the lower wire. It follows that behind the step the lower conductor contains more electronics per inch than is contained in the uncharged section ahead of the step.

As the step advances further forward, extra electrons must appear in locations such as α to terminate the new E lines involved in the voltage difference which now exists in the next inch of transmission line.

Where does the electron come from to fill the next gap α as the step front advances forward? It cannot be one (say β) from behind the step, because this electron is not travelling at the speed of light. For β to arrive at location α in time, it would have to travel at the speed of light, since the voltage-current step is travelling forward at the speed of light (for the dielectric). A central feature of conventional theory (N or H) is that the drift velocity of electric current is slower than the speed of light. Therefore Theory N, where electric current is the *cause* and $E \times H$ field an effect, breaks down for the simple reason that a cause travelling slower than the speed of light cannot create an effect travelling *at* the speed of light. It seems clear that if we retain a dualistic theory (N or H), the present discussion forces us to conclude that Theory H obtains; the cause must be the $E \times H$ field in the dielectric, energy current, which does travel at the speed of light, and the slower electric current in the wire is merely an effect of that cause.

I would agree with Mr Dawe, para. 3, that practical success would tend to indicate that our fundamental theory is sound. However, counter-instances abound. Lacking sound theory, the Romans still built many impressive bridges. Like Mr Dawe, I shall use whatever suits me to calculate dissipation in resistors, etc. We do not have to use the theory we believe, when it is inconvenient, rather than travel by another more convenient path in our day-to-day affairs. Calculation of the steady current from a (car) battery to a resistor (car headlamp) will not become the stamping ground for theoretical discord. Similarly, I think quite happily about how to avoid "losing the cold" in my deep freeze. There is a time and place for theories. The policeman who charges you with driving without due care and attention should not have to bother with Newton's Laws of Motion, and is not charging you for ignoring them.

With regard to the last paragraph, the electron is not necessary (indeed, it creates major problems) in explaining the passage of a TEM step guided between two conductors. Should it be necessary in other situations, it can be expected to turn out to be a standing wave energy current. This was proposed by Schrödinger. Jennison's design of such a structure (*Wireless World* June 1979, pages 45-47) goes wrong because, like so many others, he is trapped within the conceptual confines of the sine wave. Once you drop the sine wave, it is not difficult to construct an "electron" out of energy current. (However, it would then be illogical to hold onto Theory N or Theory H, since energy current would then be bordered by energy current (i.e. electrons). Similarly, once it is realized that a capacitor is a transmission line, it is not logical to retain the alternate lumped L and C (transmission line) model for the transmission line.)

I think the first part of the last paragraph, like Osiander, is wrong. It is a tragedy that virtually all contemporary scientists are siding with the mediaeval church against Galileo. I stand with Galileo, Bruno and Kepler, but unlike Bruno I shall not be burnt alive for it. (See M. Polyanyi, "Personal Knowledge", RKP 1958, pp. 145-6.) As to the second part of the last para., I am making *discovery*, not indulging in imagination. As to the electron, although I may allow the existence of the standing-wave electron, I find the billiard-ball electron incomprehensible. Like Einstein, I do not accept the quantum. (Max Born, "The Born-Einstein Letters", Macmillan 1971, pp. 164, 168.) However, this does not bear directly on Theory C, which merely removes the (possibly in other situations surviving) electron from the theories of (a) the "steady charged capacitor" and (b) "electric current in a wire".

Ivor Catt

HERBERT DINGLE

Perhaps I may be permitted to make a brief reply to Dr Wilkie's lengthy attack in the June issue on my late uncle Professor Herbert Dingle. Dr Wilkie writes: "Professor Dingle is described as an expert on relativity". He makes no comment on this but later in his letter he says "Professor Dingle was a distinguished historian of science". The subtle implication is that he must be regarded as an historian who had no right to be delving into such abstruse matters as the Theory of Relativity. This impression can best be corrected by quoting from his obituary in *The Times* of September 6th, 1978.

"His 'Relativity for All' (1922) appeared at a time when it used to be said that only six men in the world understood the theory. If this had been true, Dingle must be rated high among the six for his little book showed a profound grasp of relativity as a physical theory combined with a capacity for presenting it, not as an esoteric mystery, but as a logical development of the mechanics of Newton".

To this might have been added the comment that he met and discussed scientific matters with Einstein, a privilege that was denied to most of his critics.

My other point concerns my uncle's love of good English. This was something he inherited from his father and shared with his brother. It led him to avoid jargon whenever possible. Dr Wilkie, who evidently loves technical language, finds this very tiresome; he holds the remarkable view that plain English is ambiguous and jargon is precise. I know from my own profession as a veterinary surgeon just how mistaken this is. Once people resort to jargon they make words mean whatever they want them to mean; one only has to recall what happened to 'parameters' to realise that.

I have not the knowledge to tell whether my uncle's beliefs were correct, but I confess I am not impressed by an opponent who admits to difficulty in expressing his case in plain English, and who links Herbert Dingle's supporters with people who believe the Earth to be flat. 'Flat Earthers', by the way, can be dealt with quite easily without resorting to technical language.

P. J. Dingle
King's Lynn
Norfolk

TELEVISION SETS FOR THE DEAF

I am glad that Mr Power has pointed out that hearing impaired people will not necessarily get satisfactory listening via a manufacturer's installed outlet socket (May letters). When 15 per cent of the adult population have hearing difficulties it seems appalling to me that none of the manufacturers pays attention to the problem.

I wrote my original letter to you with my tongue just a little in my cheek as I know more than a little about the problem. I was hoping to draw a hail of fire from the various manufacturers but only Decca had anything to say.

May I conclude by saying that the problem is not for the hearing impaired alone; it is a problem for their families and neighbours as well. One of the most common enquiries which I get from the area around Southend is: "Can you do something for my dear old Mum/Dad, he/she wants the television so loud it is driving us up the wall!"

Fred Holloway
Rayleigh
Essex

MAGNETIC RECORDING

As an academic who has for some years been teaching the above topic, I have been most grateful to *Wireless World* for this fairly regular feature which has been used as a source of update information. With reference to the review by J. Moir in the March issue, I would like to take up four points.

It is stated: "If the head gap is not at right-angles to the edge of the tape, the first zero in the response occurring at the frequency at which one edge of the recorded track is two half waves ahead of the other edge."

Whilst this is highly desirable, azimuth misalignment is most important for replaying prerecorded tapes. Slight mis-alignment goes unnoticed if the machine replays one of its own recordings.

"Though the actual bias frequency is not important . . . the waveform of this bias signal is very significant."

The frequency may be very critical in the case of a radio/recorder system. The latter part of the statement is inconsistent with the use of the frequency modulated luminance carrier used as bias signal for the chrominance component in v.c.r. systems. Have the effects of a non-sinusoidal bias signal on audio distortion been measured?

"Print-through will obviously be reduced by any increase in the thickness of either the tape or the coating."

Whilst I agree that an increase in base thickness reduces print-through, an increase in coating thickness alone will, if anything, increase print-through. The thicker coating may now carry a greater magnitude of magnetic flux, particularly at lower frequencies, which in turn will induce a greater print-through into adjacent layers.

Finally – a purely academic point – there is a continual interchange from imperial to metric measurements and the use of c.g.s. and SI units tended to detract attention from an otherwise most useful review.

G. E. Lewis
Canterbury College of Technology
Canterbury, Kent

The author replies:
Mr Lewis raises a number of points that justify some additional comment, though I am not quite clear as to the meaning of his first point.

Azimuth mis-alignment, i.e. the fact that the recorded track is not at right angles to the edge of the tape, is the situation responsible for the poor high frequency performance provided by many cassette recordings. As Mr Lewis comments, it is of no great significance if a recording is replayed on the machine on which it was recorded, but azimuth mis-alignment introduces considerable attenuation of the high frequencies if there is any significant difference in the gap alignment of the record and replay heads. Extensive experience in assessing the performance of many hundreds of domestic machines suggests that few of them have the gap azimuth at right angles to the track edge, the standardised alignment location.

The actual bias frequency is of no great importance as far as the magnetic recording process is involved, but there are often other (non-magnetic) reasons why one bias frequency has advantages over some other frequency. Beats between the bias frequency and a recorded frequency are a well known problem that can be reduced by shifting the bias frequency. Many of the better domestic machines actually include a control to allow the bias frequency to be shifted by a few kHz if 'birdie whistles' appear when the machine is used, particularly with an f.m. receiver that has inadequate suppression of the sub-carriers.

It is well established that a distorted bias waveform is responsible for an increase in tape noise. Even harmonics in the bias supply are substantially equivalent to the addition of a d.c. component to the record head current. I know of no evidence that the distorted bias current leads to any significant increase in the distortion of the audio signal.

The extent of any print-through is a function of the tape base thickness and the temperature dependence of the magnetic properties of the coating. The effect of an increase in coating thickness is to move the frequency spectrum of the print-through signal down the frequency spectrum where it is generally less significant.

The choice of units is a perpetual problem. We are in a transition stage where several systems of units are in general use, so we commonly find that some dimensions are currently quoted in imperial or metric units and others in c.g.s. or SI units. I quoted the parameters in the units in which they are currently commonly expressed.

James Moir

LOW-NOISE AMPLIFICATION

In his "Introduction to low-noise amplifier design" (April issue) Mr Foord falls into the old booby trap of basing his method on transistor parameters which are not often published – particularly remarkable in view of his introductory remarks which recognize that "manufacturers often fail to specify their transistor parameters in a convenient form". How many manufacturers specify $r_{bb'}$ in their ordinary data sheets? The Mullard technical handbook gives it in a "list of symbols for semiconductor devices" in the general explanatory notes, but never gives its numerical value; few other manufacturers even do that!

J.G.D. Pratt
Leatherhead, Surrey

The author replies:
I did appreciate the problem that manufacturers do not specify $r_{bb'}$. What I attempted to show in my article was that the collector current for the first stage of a pre-amp should always be chosen to be approximately correct for a given source resistance. If the source impedance is low, then $r_{bb'}$ does become significant. Unfortunately we have to use $r_{bb'}$, or similar noise constants. There is no other way. I gave the table covering a few transistors as a guide. For more detailed work where $1/f$ noise is important $r_{bb'}$ can be split into two parts, and a $1/f$ break point and slope added. Motchenbacher and Fitchen give a comprehensive table for 20 transistors, indicating four noise parameters for each[1]. They also give excellent design equations for noise and gain, with practical results, for a great variety of circuits. This is the best single reference on low-noise design I have read.

The most accurate measurement method for $r_{bb'}$ is by actually measuring thermal noise against frequency for different operating conditions. This is discussed by Unwin and Knott[2].

To give reasonable noise parameters in their data sheets the manufacturers might have to measure up to four parameters for each transistor. Under productions conditions this would introduce a lower yield (higher cost) if the parameters were guaranteed.

In their transistor data book Motorola do give comprehensive curves of noise figure against frequency for quite a number of their transistors. National Semiconductor publish a booklet which relates their type numbers with a particular process, and gives some noise curves for their processes.

A. Foord
Malvern
Worcs

References

1. Motchenbacher & Fitchen. Low-noise Electronic Design, John Wiley & Sons, 1973.
2. Unwin and Knott. Comparison of methods used for determining base spreading resistance, *Proc. I.E.E.*, vol 127, part 1, no. 2, April 1980, p.53-61.

INTERFERENCE FROM MICROS

As a radio amateur I encountered the same kind of trouble as Hugh D. Ford (March letters) when using my Motorola 6800 evaluation kit, Apple II and TRS80. I got rid of the interference by shielding the system completely, which is the least expensive measure in terms of time and money. Mains power is supplied through a filter and data ports are decoupled by by-pass capacitors.

In my opinion today's microcomputers are very prone to cause radio frequency interference. This is made worse by the use of plastic cabinets, large p.c. boards, simple power supplies and a minimum of components used (decoupling capacitors).

Suppliers of filters and shielding elements as, for instance, R.F.I. Shielding Ltd of Braintree, advise their customers on how to tackle the interference problem systematically. To my knowledge the only standardisation effort so far has been undertaken by Verband Deutscher Elektrotechniker (VDE Verlag GmbH, Bismarckstr. 33, D-100 Berlin 12) and details are discussed in VDE 0871 (radio interference suppression in high frequency equipment for ISM and similar purposes) and in VDE 1877 (measurement of interference voltage and field strengths).

The contribution "Controlling electromagnetic interference generated by a computer system" in the September 1979 issue of *Hewlett Packard Journal* gives an idea of the complexity of the problems involved.

Application of such standards to commercial products would, however, mean a higher selling price. The FCC in the United States is setting specifications obliging designers to pay more attention to e.m.i./r.f.i. problems (see *EDN*, 18 February 1981). Of course a lot of articles have been written on this subject, such as:

"FCC computing equipment e.m.i. standards", *EDN* March 5, 1980.

"E.m.i. susceptibility testing of computer system," *Comp. Design*, March 1980.

"Design digital equipment to meet FCC standard," *EDN*, June 5, 1980.

"Good shielding techniques control e.m.i. and r.f.i.", *EDN*, February 18, 1981.

"Microcomputers and radio interference", *QST*, March 19, 1980.

Yes, we must learn more in this widening field and training courses should be organized on e.m.i. control methods and procedures. A label "Approved by VDE" or "Meets FCC rules" would certainly be an advantage in today's highly competitive markets.

Decaunes Bernard
Epalinges
Switzerland

MICROCOMPUTERS FOR SCHOOLS

While I cannot claim to be an expert in the field of microcomputers (I am a final year physics student), I would like to comment on your "Microcomputers in school" article in News of the Month in the June issue. While I agree that a price of £1,650 seems high for a school system comprising a single user station, it is worth noting that this is the price for the 'top of range' system with dual double-sided mini-floppy disc drives. It is further worth commenting that Research Machines are developing a network system to allow a number of workstations to access the disc drives, printer, etc., via a network controller in the main machine. The workstations will be able to operate independently of the network. The approximate cost of each workstation is £500 for a 32K system; this I believe compares favourably with a system based around a number of Acorn Atoms. As yet the ZX81 does not, to my mind, offer sufficient sophistication, although there may well be a role for it as a secondary machine.

In relation to the Government scheme, it is unfortunate that the half price offer only applies to those schools which have not yet made any effort to obtain a computer, so that in effect a school which 'saved' £1,600 out of capitation/p.t.a. funds previously will be penalised.

I realise my comments may be biased towards the sophistication offered by the 380Z, first because I started in computing on the UMRCC mainframe system and secondly because, being a physicist, my programmes almost inevitably require the increased capability the larger machine offers. What is, I feel, of greatest importance is that, once certain machines are accepted as being standard, then this standard should be adhered to. At least it is important to keep to a common dialect in whatever language is used.

A. R. Corless
Department of Physics
University of Manchester

RADIO AMATEURS' EXAMINATION

Comments have been made about the last Radio Amateurs Examination, City & Guilds No. 765, both in *Wireless World* (Pat Hawker, May issue, p. 54, July issue letters) and elsewhere, particularly by radio amateurs over the air. These all tend to confirm my experience which casts serious doubt on the validity of the exam.

I and two other licensed amateurs, ran a short course here last autumn for ILEA science teachers for the RAE. All those who attended regularly passed and many of them now have licences. We had a post-mortem after the exam from which I collected evidence from these teachers. They are all professionally involved in teaching pupils for science exams and, as a body, well qualified to comment. Only if the exam is published could the following points be confirmed:

1. At least two questions had no right answers.
2. Some narrow topics were questioned more than once in the paper.
3. Some questions were badly phrased and ambiguous so that competent graduate physicists were not sure of the expected answer.
4. Some of the distractors of these multiple choice questions appeared too trivial, thus reducing the real validity of the exam.
5. Some questions were pointless, hence again reducing the validity. (I think one question referred to a nationality requirement for a Home Office licence – does it matter whether the candidate knows or not? His status will be examined by the Home Office in due course whether or not he knows the answer – unless he fails the exam for not knowing!)

As professionals from an examination standpoint, we feel this poor quality of examining will discredit those who hold a radio amateur licence. To have qualified from passing this exam means little in terms of radio expertise, rather more in terms of luck. It would be a pity if the matter were allowed to slip. The quality of operators coming on the air can be judged by listening in. It varies from excellent to disgraceful. What exactly is the exam achieving?

A stringent re-think leading to a rigorous exam is called for. The less serious amateur can now take refuge in the citizens bands.

J. M. Osborne, G3HMO
South London Science Centre
Inner London Education Authority
London SE5

MICROCHIPS AND MEGADEATHS

In your November 1980 editorial "Microchips and megadeaths" you advocate that electronics engineers pull out of military electronics. Some recent letters on this topic have come under the title of "Ethics in action". The subject and title are unrelated. There is nothing ethical or unethical in working on military electronics. There is, however, a painfully obvious ethical question in killing someone. Whether I use a piece of military electronics or a ball-peen hammer is neither here nor there.

I feel that those people arguing for disarmament are not really concerned about wars and the associated killing. Rather they are only concerned that their necks are now on a nuclear chopping block.

Some people say that peace at any price is better than war. Any family run by this particular ethic is not worth living in. Avoiding conflict in this manner results in intolerable situations being established that invariably lead to worse conflict at a future date. Military power exists for one reason. It is a tool of coercion. Its levers are the potential and actual death and destruction that it can and does deliver. Military power can be used (the Iranian embassy siege) and abused (Czechoslovakia in 1968). Any form of power can be used and abused, be it police power, government power or parental power. Its use or abuse lies totally with the user.

I am certain that if we did not have our military capability (and the will to use it when necessary) countries less scrupulous than ours would use their power to coerce us. However, if no person was willing to use death and destruction to further his own aims we would not need any form of military power on this earth.

So, the only way to a genuine peace is through the raising of the general ethic by which we all live together. My work in military electronics is (in its small way) buying time by maintaining the balance of power. It is just a pity that people seem to find it easier to throw away their swords than to beat them into ploughshares.

Adrien Belcourt
Rochester
Kent

It is the most important fact of modern life that until we get nuclear weapons firmly under control we are living on time borrowed from Armageddon. We like to dress the nuclear arms race up in nice safe-sounding words like 'deterrence' and 'security' and 'defence', but in reality the race is the mad dash of the lemming towards total destruction.

The points made by your correspondent L. G. Martin in the February issue require some response. His first point is that your leader should have 'balanced' the account of the horrors of Hiroshima with consideration of the Japanese treatment of prisoners of war. Does the concept of 'balance' really apply here and, if so, what is the relative 'weight' of fighting soldiers and innocent civilians, some of them young children. Does Mr Martin regard his children as responsible for the treatment of prisoners by the British army? In any case, surely the point was to illustrate the effects of nuclear weapons, not to comment on the morality of a particular instance of their use.

To move on to the second point in Mr Martin's letter, it is unlikely that engineers in any country would be asked to voice their opinion on the use made by their government of their expertise – but that does not release them from the responsibility to do so, or from their personal responsibility for their work. Our celebrated Western freedom is illusory if we so easily enslave ourselves to the militarists.

The rest of Mr Martin's letter consists of a highly simplistic analysis of the likely results of disarmament. The first point which should be made is that Britain is not a super-power and that many of the world's small countries manage to live in peace and freedom with only small, conventional defence forces. But granting that, for the present, Britain is going to remain within NATO, unilateral renunciation of nuclear arms would reduce the risk of the country becoming a target and would put pressure on the Americans to adopt a more constructive and urgent approach to arms control negotiations. However, even if Mr Martin's simplifications were correct, and we were faced with the stark choice between "keeping our weapons" (and hence the certainty probably sooner, possibly later, of nuclear war) and "world-wide communism complete with its psychiatric hospitals for dissidents" – I know which I would prefer. I think that if Mr Martin had the imagination to conceive what nuclear war – the ultimate denial of freedom – would really be like, he would agree with me.

Finally let me echo Mr Francksen's articulate praise of *Wireless World's* broadening of interest. But could we please have more full-length articles on the wider aspects of engineering? Some day engineers will realise that the difference in status between them and, say, doctors has more to do with breadth of interest, social conscience and ethics than with what they quaintly call 'remuneration'.

John Hind
Belfast
Northern Ireland

JAMES CLERK MAXWELL

I welcome your efforts to lead the mind of your reader beyond the technical through a discussion of e-m theory. The article on James Clerk Maxwell in the March and May issues is thought-provoking but I think it is a little out of contact with reality, as were previous ones. Should the article be serious, it might be acceptable as vulgarisation for readers without contact with physics and without the ability to understand the principles, but its standard does not do justice to engineers.

My criticism is directed towards the author's misrepresentation of facts and ideas, not the questioning of theories. A few examples: the reader is given a misleading picture of the Michelson-Morley experiment: he is side-tracked into Doppler effects instead of being presented with the important result: the absence of phase shift between beams upon rotation. It is pointless to state that the experiment proves nothing as experiments don't prove theories, they test them. Elsewhere the author incorrectly represents Lorentz contraction (second order in v/c and of constant sign) as derivable from the very different Doppler effect (first order in v/c and so potentially of both signs). I am also unable to find meaning in many of his statements on energy conservation and composition of velocities.

A good discussion of the implication of the Michelson-Morley experiment can be found in: A. S. Eddington, "The Mathematical Theory of Relativity", Cambridge University Press, 2nd edition.

The editor's problem might be to obtain or encourage criticism of existing theory which is honest and at least partly valid as well as being imaginative and attractive to his reader. The problem is a difficult one since more than a huff and a puff are needed to bring down modern physics. May we look forward to more substantial attempts?

T. de Limelette
London NW1

The author replies

T. de Limelette enjoys Eddington's mathematics. The author of any good book on physics will take his reader along a mathematical route from Newton's laws of motion to the law of the conservation of energy and return via a different mathematical route to Newton's laws, only if Newton's time and space and its one dimension length, are absolute or concrete. All units of Newton's laws can be derived from the three fundamental units of mass, time and length, and if their dimensions are not universally concrete, for any reason, the mathematical route from Newton's laws to the conservation law will mathematically either generate or destroy an infinite amount of energy. Maxwell said on page 2 of his *Treatise* "A knowledge of the dimensions of units furnishes a test which ought to be applied to the equations resulting from any lengthened investigation. The dimensions of every term of such an equation, with respect to each of the three fundamental units must be the same. If not the equation is absurd." Maxwell's mathematics were immaculate. I have merely applied Maxwell's test to the equations of modern theory. The equations are absurd. I fail to see how the adroit and deliberately secretive manipulation of the three fundamental units can be described as honest.

M. G. Wellard

SLOTTED CYLINDER AERIALS

In June letters Mr James referred to propagation tests carried out by Philips and suggested that better results would have been obtained at the higher frequencies (928MHz) if a form of slotted cylinder aerial had been used instead of a quarter wave whip.

Earlier this year the RSGB performed some similar propagation experiments in the 1296MHz amateur band using horizontal polarisation and the aerials to which Mr James refers in order to examine the potential of these frequencies; a copy of the resulting paper was sent to the Home Office for their information.

This aerial is also known as the Alford slot, and is in some ways analagous to the vertically polarised co-linear. It produces horizontal polarisation with an omnidirectional pattern in the horizontal plane, and achieves gain by reducing the beamwidth in the vertical plane. Those used in our tests were made from thin walled metal tube, 3cm diameter and 48cm long, with a slot about 0.5cm wide along their length.

The edges of the slot in fact form a twin wire transmission line which is continuously loaded by a shunt inductance formed by the rest of the cylinder. The phase velocity of a wave travelling along the slot can then be several times that of the free space velocity, in this case four times, and so the distribution of the electric field along the slot can be a single electrical half wave over a slot that is physically two wavelengths long. Thus the whole aperture is fed in phase, and a gain of about 6dBi was measured. Higher gains could be achieved by using a longer tube and higher phase velocity.

These aerials were used at each end of both fixed-to-mobile and mobile-to-mobile links with receivers with 2dB noise figures, and one watt transmitters giving an e.i.r.p. of 4W.

Typical ranges were as follows:

Central London	<1 to 3km
suburbs	2 to 5km
country	3 to 8km

Maximum range between well sited mobiles was about 20km.

N.b.f.m. (8kHz bandwidth) was used for most of the tests and was found to be superior at shorter ranges. S.s.b. increased the maximum range, but at short and medium ranges the severe multipath effects in urban areas rendered the s.s.b. almost unintelligible at times.

Throughout the tests 3W of 144MHz s.s.b. into ⅝ whips was used for talkback, and gave a more uniform coverage than the 1296MHz without suffering from the multipath effects.

The Alford slot aerials have also been in use for three years on a 1296MHz beacon (GB3IOW) on the Isle of Wight, and it is hoped that they will be used on some of the experimental repeaters proposed for the 1296MHz band.

J. N. Gannaway, G3YGF
Oxford

IS LIGHT VELOCITY A CONSTANT?

It would be difficult to imagine a more unscientific experiment than the one referred to in May letters by D.A. Bell in support of the theory of relativity. The four clocks were flown round the world by J.C. Hafele and R.E. Keating not separately but in one batch and not in one flight but in commercial aircraft from airport to airport, subject to landing and take-off at each stage. Hafele and Keating admitted that the time-keeping qualities of atomic clocks vary with varying physical conditions but claimed that there are no environmental effects which would uniformly decrease or increase all four clocks and that a random distribution for the time drifts would be expected unless relativity was active. In fact, since all four clocks were subject to exactly the same changing environmental conditions in the same aircraft, one would except their time drifts to be identical. All that the experiment showed is that atomic clocks will drift in changing physical conditions. If the four clocks had been flown separately over the same route in different aircraft at different times the experiment may have had some validity and a very different result would no doubt have been obtained.

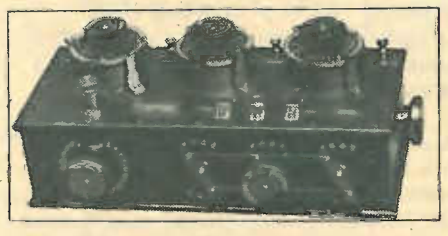
In the interminable argument about time-dilation it has always been claimed that time goes slower for a body in motion relative to the earth. In this case whatever correction may be applied to the aircraft's ground speed (there is no such thing as a stationary frame in Einstein's relativity) the airborne clocks had a velocity, the direction of which is immaterial since time-dilation is a function of v^2, relative to the earth. According to the Special Theory the airborne clocks should have lost on both occasions whereas on one flight they actually gained. As Alice might have said, what a strange sort of Through-the-Looking-Glass world where a contrary result is held to verify a theory!

Eric Holland
Kirkella, North Humberside

HISTORICAL EQUIPMENT STOLEN

During the morning of 25th February 1981 a man gained access, by deception, to the foyer of the New Street, Chelmsford, premises of The Marconi Company. He managed to remove a valuable exhibit from the permanent display of historical Marconi radio equipment. Challenged by security staff, he succeeded in breaking out into the street, where in the subsequent chase, he made his escape.

The stolen item is a 1907 Multiple Tuner (see photo). It is readily identifiable by the serial number 8015 beneath the legend 'Marconi's Wireless Telegraph Co Ltd'.



Should any collector be offered this item he should note that it is stolen. As such the police, or the Historian, The Marconi Company Limited, Marconi House, Chelmsford, England (telephone 0245-353221) would wish to hear about it.

W. T. T. Prince
Marconi House
Chelmsford, Essex

CB RADIO AND RC MODELS

Your columnist Pat Hawker is only partly correct when he states that radio control modellers have been offered alternative frequencies (World of Amateur Radio, April issue). It is true that a new frequency (35MHz) is now available but it is only for the use of model aircraft. Therefore all other radio modellers with 27MHz equipment have a continuing problem.

It is probably not widely known that because of increasing a.m. c.b. interference most radio control equipment is now f.m. The Government's proposals will therefore have the greatest effect on those who have purchased equipment in the last few years. These modellers will therefore have to convert to 35MHz if they fly aircraft (costing £20-30) or purchase 459MHz equipment (costing about £200) if they operate in an area where c.b. interference is obtrusive.

As it is unlikely that the illegal a.m. c.b. operators will change equipment then both model control and the paging systems are likely to become completely unusable.

I believe the only honourable course for the Government to take now would be to provide another radio control band for non-aircraft use. This should be as near as possible to the present band so that equipment can be re-tuned and re-crystalled at minimum cost. The c.b. operators should also be asked to pay a licence fee which would be used to reimburse modellers for the conversion costs.

T. E. Wakes
Lightwater, Surrey

Satellite tracking by home computer

Both software and aerial rotator interface for the scientific computer

by Neoklis Kyriazis, B.Sc.

This two-part article describes a tracking system for circular orbiting satellites using the Wireless World scientific computer. Part one, this issue, deals with the interface circuit for controlling the aerial azimuth and elevation angles, and with aerial rotators and their mountings. In the next section, the Basic/machine-code program will be presented. This program processes the satellite orbit parameters and converts data for use with the interface.

Many home computers are capable of handling the arithmetic necessary for tracking a satellite but they require large amounts of software to make them behave as a numeric calculator. The Z80/MM57109 combination used in the *Wireless World* scientific computer enables the complex trigonometry involved in satellite elevation and azimuth angle calculations to be processed with a minimum of software. For the program used here, the MkIII BURP interpreter must be installed in the computer.

Although the program was written for tracking the Amsat Oscar series, any satellite on a circular orbit can be tracked by inserting the relevant parameters in the BURP program.

Aerials and rotators

The aerial system used by the author for tracking Oscars 7 and 8 comprises two yagis; one of eight elements for 145.9MHz and one of 16 elements for 435.1MHz. One aerial is mounted at each end of a 1.5m long tube supported centrally by a rotator which controls the elevation angle. The rotator is mounted on a metal plate with a tube welded underneath it which is supported by a second rotator for controlling the azimuth angle.

The Alliance U-200 'Tenna rotor' type aerial rotators used by the author have a four-core control cable; two of these cores are for forward/reverse control of the motor, one for the ground connection and one is connected to a cam switch that closes and opens for every 10° rotation of the driven shaft. Semi-air spaced 75 ohm coaxial cable is used to feed the aerials. This type of cable is efficient even at u.h.f. but a masthead pre-amp is required for Mode J down-links. Note that in the system described here, aerial elevation is increased by counter-clockwise rotation of its rotator while the inverse applies for the azimuth rotator.

There is a mechanical stop in the rotators used by the author which prevents the aerials turning through more than 360°. This means that if the satellite's azimuth changes from 0° to 360° the rotator must turn through 360° before it can resume tracking. As it takes more than a minute for the rotator to make one full turn, the program is arranged so that it calculates orbits passing north of the ground station and adds 180° to the result while keeping 180° elevation so that the aerials rotate in the right direction. The same problem does not apply to the elevation rotator.

The interface

Digital information from the computer drives the two aerial rotators via an interface. This interface also conveys information relating to the positions of the aerials back to the computer. As mentioned earlier, a cam switch on the shafts of the rotators opens and closes for every 10° of shaft rotation. One contact of the switch is connected internally to ground and the other is tied externally to +5V via a 2k2 ohm resistor. A 100μF capacitor and a 220 ohm resistor are used at these connections as a.c. caused by switching high motor currents may affect the operation of the computer.

Each time the cam switch closes and opens, the voltage across one of the two 100μF capacitors shown in Fig. 1 produces an '0' level pulse which is fed into the computer via the 0 input port. The program counts these pulses to keep track of the aerial position and although resolution is only 10°, reception of Amsat Oscar 8 in Mode J using a 16-element yagi is not affected by the error. If a highly directional aerial is to be used, some more accurate method of feedback may be needed.

Each rotator motor has two windings at 90° to each other. One end of each winding is connected to ground and a 150μF non-polarized capacitor is connected between the other two supply inputs. The capacitor provides phase shift in the alternating current supplied to one of the rotor windings. Two relays are used for each rotator; one to switch the 24V supply from one winding to the other to determine the direction of rotation and one to switch the supply in and out. The serial output of the computer is used to control the motors via a CD4015 serial-in/parallel-out shift register which drives the relay coils through four buffer transistors.

An accurate timer is needed to provide the program with real-time information. For this purpose a mains-frequency divider chain consisting of a 7400 and three 7490 i.cs is used to produce a short pulse every 10 seconds. This pulse activates the maskable interrupt of the Z80 and sends the processor to a routine that increments the value of the real-time variable, named T in the BURP program, by 1/360 hours, i.e., 10 seconds. Since the INT pin of the Z80 is used by the MM57109 some simple modifications are necessary to give an OR function between the timer and the number cruncher, details of which will be given later.

Circuit details

Figure 1 shows the complete circuit diagram of the rotator controller. Transformer T_1 supplies 24V a.c. for the rotator motors and 10V a.c. for the rest of the circuit. Diode D_5 and a 2200μF capacitor provide 12V d.c. for the relay coils and for the 5V regulator which supplies the CD4015 c.m.o.s. shift register and the timer section i.cs. Logic signals to and from the computer are fed through a 6-way DIN socket and to and from the rotators via two 5-way DIN sockets. The buffered D7 line from the computer is connected to the data input of the CD4015 at pin 7 while a clock pulse to pins 1 and 9 of the i.c. is supplied from pin 10 of IC_2.

Thus, a control word from the computer is fed to the CD4015 in serial form from output port HEX A0. The parallel outputs Q0 to Q3 drive transistors Tr_1 to Tr_4 through 1k ohm resistors and any spurious pulses created during serial data transfer are bypassed through 47nF capacitors. Outputs $\overline{Q0}$ to $\overline{Q3}$ of the 4015 are not used but are available for controlling additional circuits if required. Transistors Tr_1 to Tr_4 drive the four relay coils from the c.m.o.s. shift register outputs so they should have a high h_{FE}. Darlington pairs can be used if necessary.

Relays RLA_1 and RLC_1 switch the direction of the elevation and azimuth motors respectively while RLB_1 and RLD_1 switch the 24V a.c. supply to the motors on or off. Each rotator cam switch output is tied to the +5V supply through a 2.2k ohm resistor and a 220 ohm series resistor and 100μF bypass capacitor in each line prevent a.c. from the motor ground returns passing through to the computer input. When a cam switch is closed a logic '1' is seen by the computer and when a switch is open a logic '0'. Switch S_2, between ground and the azimuth cam switch input

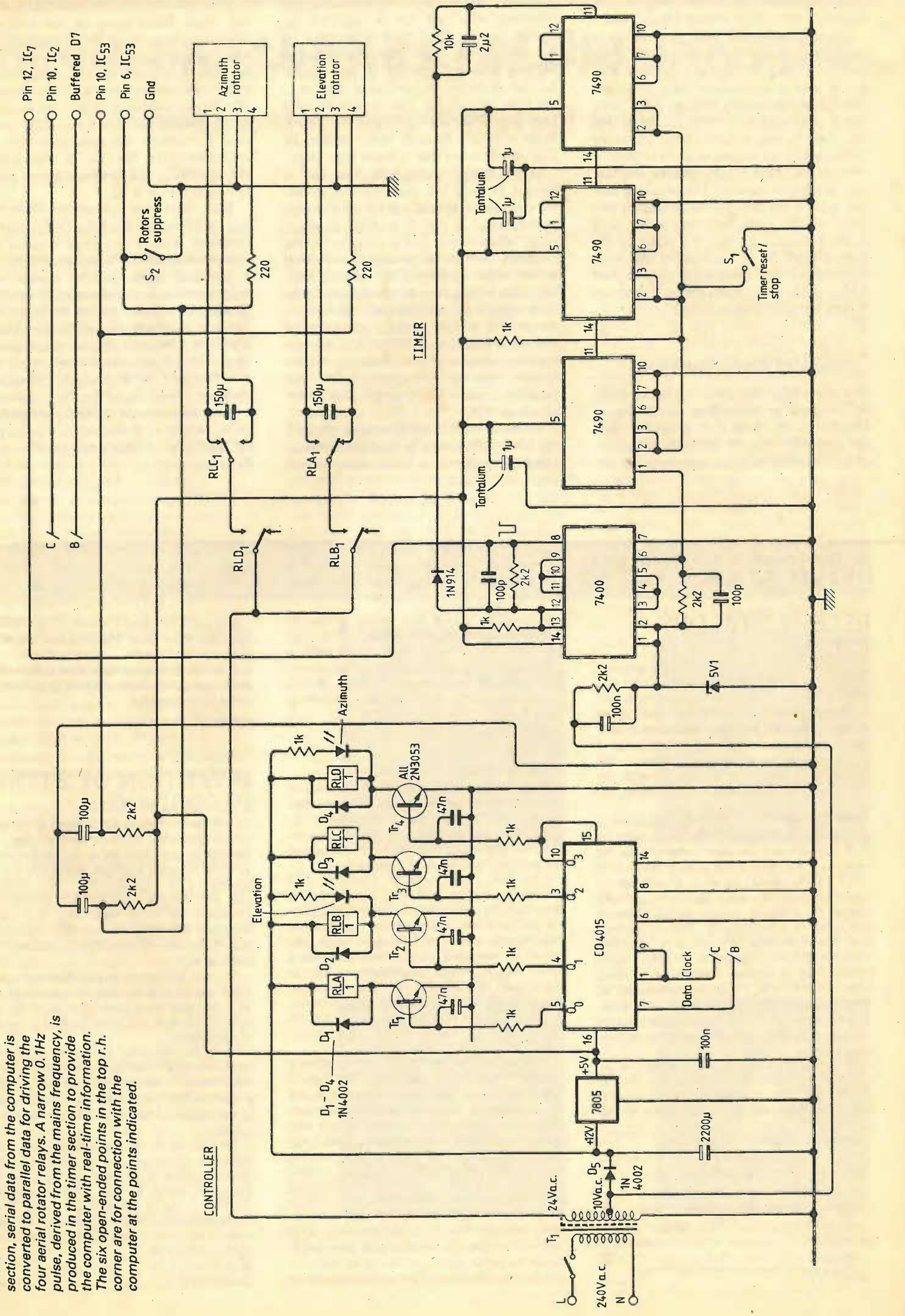


Fig. 1. The complete computer/aerial-rotator interface circuit. In the controller section, serial data from the computer is converted to parallel data for driving the four aerial rotator relays. A narrow 0.1Hz pulse, derived from the mains frequency, is produced in the timer section to provide the computer with real-time information. The six open-ended points in the top r.h. corner are for connection with the computer at the points indicated.

to the computer, signals the program not to operate the rotator motors when closed.

Mains frequency is used as a reference for the ten-second interrupt pulses. Two gates of a 7400 are used as a Schmitt trigger to give a rectangular wave from the transformer secondary voltage. This 50Hz signal is divided by five by the first 7490 and then by ten in both of the following 7490s to give an output of 0.1Hz which is differentiated by a 2.2μF capacitor and 10k ohm resistor in parallel. The resulting narrow pulse is fed through the remaining two gates of the 7400, also connected as a Schmitt trigger, to the INT input of the Z80. Switch S_1, connected to the reset input of the 7490 dividers, is used to start and stop the timer manually so that it can be synchronized with real time.

Computer modifications

As a pulse from the timer can occur while the program is controlling the rotators, IM2 (interrupt mode two) is used so that the processor can be directed to the interrupt service routine anywhere in the program. When IM2 is specified the processor will look for an eight-bit interrupt vector, which must be supplied by the interruptor. Since the RD/WR and MREQ lines are inactive during an interrupt cycle the bi-directional drivers at the data pins of the Z80 remain in their high-impedance state. Hence, the Z80 is liable to read a random vector unless the Z80 data lines are tied to either logic state.

In this design, the data lines are tied to ground through 10k ohm resistors so that the processor will read a HEX 00 interrupt vector, which is half of a 16-bit interrupt vector whose upper half is provided by the program. The 16-bit pointer thus formed is used as the address of the memory location from which the starting address of the interrupt routine is loaded into the instruction pointer. In this program, the interrupt register is loaded with HEX 16 so that the starting address of the interrupt service routine must be in location 1600. This location contains 02 16 so the routine begins from 1602.

With the MkIII BURP monitor the INT pin of the Z80 is used by the MM57109 for number transfer so it is necessary to provide an OR function between this pin and the timer. Spare gates on the computer board can be used for this purpose as follows. Connect pin 22 of IC_6 to pin 13 of IC_7 instead of to pin 16 of IC_1 using passive pull-down resistors of 10k ohm to ground. The timer's output is connected to pin 12 of IC_7 via one pin of a 6-way DIN socket used to connect the computer with the controller/timer. Pin 11 of IC_7 then goes to pin 13 of IC_{14} and finally, connect pin 12 of IC_{14} to pin 16 of IC_1.

With these connections the MM57109 and the timer can share the INT pin of the processor. Pins 6 and 10 of IC_{53} are also connected to the DIN socket and through a screened cable to the rotator cam switches. IC_{53} is wired to input port HEX 00 and provides six inputs to the processor, one of which is used by the cassette interface. The azimuth cam switch goes to bit 2 of the data bus and the elevation cam switch to bit 1. Bit 0 is used by the cassette interface. Two pins of the DIN socket are used by the buffered D7 line and the clock pulse, which is active when output port HEX A0 is used, from pin 10 of IC_2.

To be continued

MORE LETTERS

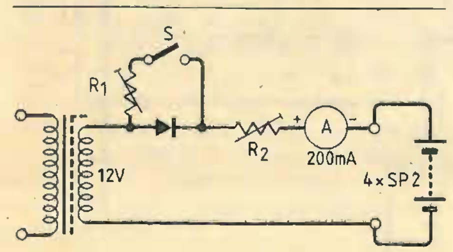
RECHARGING DRY CELLS

Mr Hickman, in his article "Battery powered instruments" (February 1981 issue), states that the recharging of dry cells is both futile and dangerous. I wonder what I have been doing wrong for the past six years. As a keen cyclist, with a preference for battery powered lamps, I have a potential use of zinc carbon primary cells amounting to about twelve sets through the winter months. Recharging reduced this to one set.

The method used was originally published in *Wireless World* in October 1955 in an article by R.W. Hallows and has more recently been the subject of a patent application (PCT/SE79/00091) by K.J. Rostlund. It involves the use of a leaky rectifier to partially reverse the charging current during alternate half cycles of an a.c. supply. For my application, that of charging SP2 cells, a net charging current of 100mA is applied to the cells. This is produced by a forward component of mean value 200mA and a reverse component of 100mA. Under these conditions the cell voltage does not exceed 1.55V – an important requirement in view of the over-run filaments in standard lamps.

An interesting aspect of the technique is the apparent reduction of internal resistance, the charged cells having similar characteristics to HP2 cells. The principle is illustrated by the accompanying sketch and, whilst it may be argued that the method is inefficient, with primary battery power at about £100 per kWh, it represents a considerable saving. With S open R_2 is adjusted for an indicated 200mA. With S closed R_1 is adjusted to reduce the indication to 100mA.

D.F. Caudrey
Newbury, Berks



The author replies:

My article did indeed discourage the idea of recharging zinc/carbon primary cells and batteries and I think that this is the 'fail-safe' approach for those who might otherwise have attempted recharging without first ascertaining the necessary techniques and precautions.

I too have a copy of R.W. Hallows's 1955 article, but it must be borne in mind that in those days the outer strength member of a primary cell was a very substantial zinc pot, alias the negative pole of the cell. Nowadays, single cells are all of 'leakproof' construction and wear a steel corset, allowing a considerable economy in the amount of zinc used. For this reason the author considered recharging by whatever means unlikely to be successful, and quoted the view of a major battery manufacturer on the topic.

It is interesting to learn of Mr Caudrey's successful results with recharging, but I guess that the cells are not nearly exhausted before being recharged. Hallows's original article described the spongy uneven redeposition of zinc with d.c. charging and contrasted it with the dense even thickness of the zinc pot even after frequent recharging with a larger a.c. component superimposed on the net d.c. charging layer type batteries (which I use more than single cells) though I fear this is likely to prove more difficult. The main problem with layer batteries is that any evolution of gas simply forces the layers apart, resulting in an open-circuit battery. However, if the a.c. component in "dirty d.c." charging prevents the evolution of free gas, even layer batteries may prove rechargeable.

It would be interesting to hear if any readers have successfully extended the life of layer batteries by recharging.

Ian Hickman

INVENTION OF STEREO RECORDING

One of the answers to the question of the priority of Blumlein's work, raised by Reg Williamson in your June issue, is straightforward enough. Blumlein's British Patent 394,325 was applied for on 14th December 1931. Both hill and dale/lateral and 45°/45° methods of recording are dealt with. One had always supposed that Blumlein was the originator of the whole idea of recording two signals on a single groove.

But was he? I now see that Blumlein's *provisional* specification contains this passage (p. 6: U 54 - 50) describing something which he presumably knew of and acknowledged at the time of application:

"For the purposes of television previous proposals have been made whereby a wax disc has a sound record as a hill and dale cut and a picture record as a laterally cut V-shaped groove at the bottom of the hill and dale groove or vice versa."

He goes on to say that this kind of record would be of no use for two unrelated sound signals because of crosstalk, but could be used for stereo signals because a small amount of crosstalk could be tolerated or allowed for. He is too polite to say that it would be of no use for sound and vision signals for television – even for low definition!

W.J. Cluff
London NW7

Radio and the birth of the universe

The cosmic microwave background in the Big Bang theory

by Eric Eastwood, F.R.S.

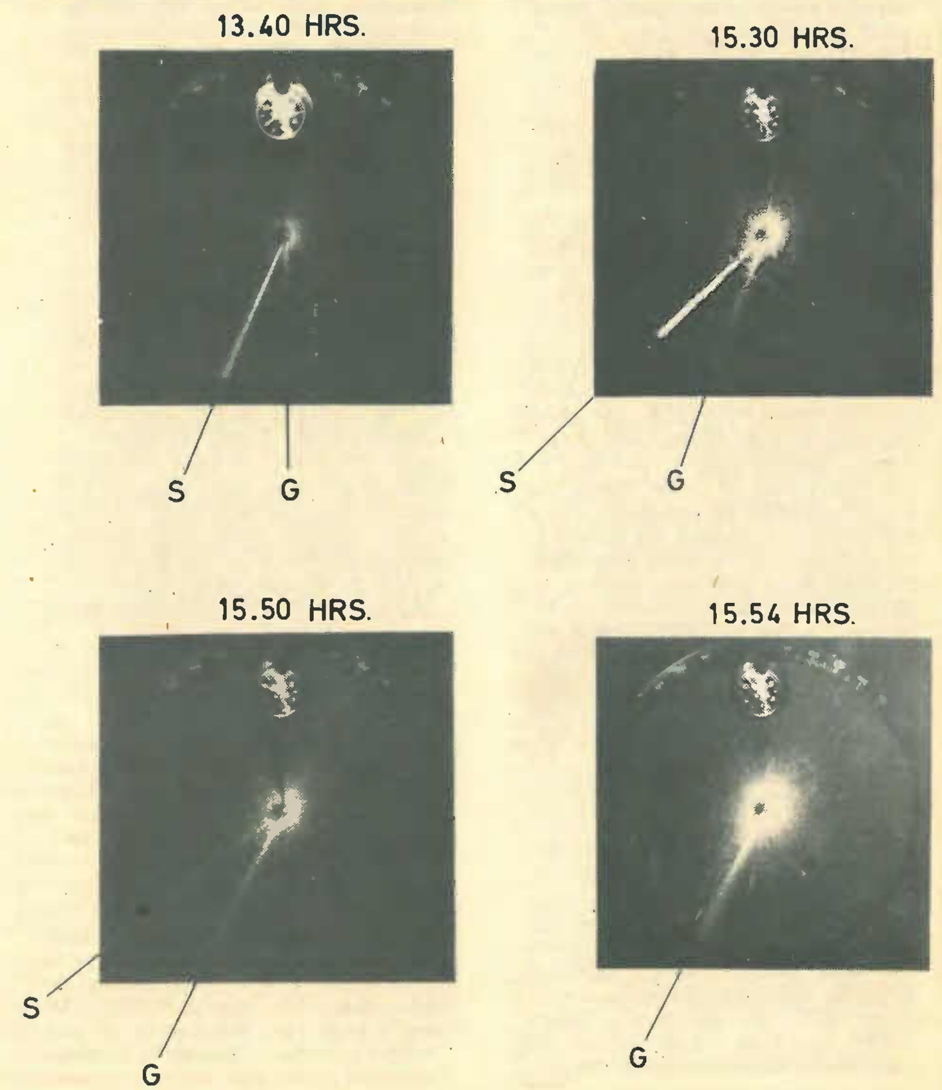
The radiation which mediated the processes of nucleosynthesis at the birth of the universe and controlled the helium/hydrogen radio prevailing ever since is that, cooled by adiabatic expansion, now described as the 3K cosmic microwave background. This article first reviews the growth of radio astronomy from the 1940s until 1964 when Arno Penzias and Robert Wilson made their momentous discovery of this cosmic radiation background. It outlines the measuring programme and the immediate explanation of the radiation offered by Dicke and his colleagues. Also it deals with the measurements performed to determine the degree of anisotropy in the radio background and describes how the antenna temperature variation led to a determination of the "peculiar" velocity of the galaxy. The theory of the "hot big bang" is touched upon and there is a summary of the modern state of the theory which has been able to build upon the essential fact supplied by the temperature measurement of 3K of the noise background – the ratio of the number of photons to the number of nucleons.

When Karl Jansky set up his aerial and receiver system at Holmdel, New Jersey, in August 1931, his purpose was not to launch the science of radio astronomy but simply to assess the interference from atmospherics that might occur with new radio circuits planned to operate in the h.f. band (2-30MHz). From the inception of wireless telegraphy in 1896 long waves had dominated world radio communications but in the 1920s Marconi showed that cost effective radio systems could be engineered using the so-called short waves. Jansky recognised that the commercial success of such high frequency radio communication circuits depended upon a good understanding of atmospheric interference effects. Such interference was familiar at long waves and varied with the seasons of the year and time of day; little experience of interference at short waves had been accumulated, however, and these were the effects which Jansky set out to investigate.

His aerial consisted of a wooden frame, rotatable about a vertical axis, on which was mounted an array of dipoles with reflectors. A horizontal aperture of two wavelengths at the operational frequency of 20MHz was employed and provided a rather broad beam radiation pattern but with useful suppression of the back lobe. The magnitude of the received noise signal was recorded together with time and azimuth of arrival. As he expected, Jansky found static attributable to both local and remote thunderstorms but what made his study justly famous was the detection of a weak but steady noise signal which "caused a hiss in the phones that could hardly be distinguished from the hiss caused by set noise". This signal was not isotropic and the directional variation which took place over the first three months of observation caused him to conclude that the sun was somehow involved[1]. When the observations had been maintained over a period long enough to establish the pattern of seasonal change, however, he was able to show that the radiation was coming from a fixed direction in space, in fact from the general direction of the central region of the galaxy, with the maximum signal being received from the direction of the constellation Saggitarius[2].

Jansky speculated upon possible causes of the radiation and considered radiation from the stars themselves but hesitated to urge this strongly since he had failed to

Fig. 1. Solar (S) and galactic (G) noise signals on the p.p.i. of a metric wave radar.



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detect any radiation from the sun (we now know that this was because the sun was in a quiet period). He appeared to favour an analogy with the Johnson noise developed by a resistor, pointing out that there was much interstellar matter in the galaxy, probably charged, and at a high temperature and therefore in thermal motion as with the electrons in a resistor. His proposal was not wholly incorrect but there the matter rested and this important first discovery of radioastronomy was not followed up for some years[3].

Jansky's observation is conveniently illustrated in Fig. 1 which shows the appearance of a p.p.i. radar tube displaying the signal from an experimental radar antenna used as a passive receiver which was not unlike the array originally employed by Jansky but giving a much sharper beam and with reduced side-lobes. An array of 96 horizontal dipoles was arranged in 24 vertical stacks and, at the operational frequency of 215MHz, yielded a horizontal beam width of 3° The purpose of this particular set of measurements was to assess the variation in the horizontal radiation pattern of the array using the sun as a noise source at infinity. Serendipity played its part in these observations, for in the p.p.i. record of Fig. 1 is shown the diurnal motion of the noise signal from a very active sun (marked with an S) but also the presence of a second signal designated G. This second signal showed a sidereal rate of revolution and was found to correspond to the general direction of the galactic centre, thus repeating very vividly Jansky's original observation – thanks to the excellent integrating power of the cathode ray tube phosphor[4].

Growth of radio astronomy

That the investigation of the radio emissions from the galaxy which had been observed by Jansky was not vigorously pursued by astronomers was probably attributable to their unfamiliarity with radio and electronic techniques. Radio scientists at that time who might have taken up the study were fully occupied on ionospheric and propagation studies and the related sun-earth relationships, including magnetic phenomena. It has also to be remembered that the decade of the thirties was the period when the principles of radar were being intensively but secretly researched by all the future participants in the second world war. These new radio techniques, developed for essentially military purposes by scientists and engineers working in close collaboration with the military services, would ultimately make an invaluable contribution to the science of radio astronomy.

Nevertheless some radio astronomical observations were made even during the war. Thus Reber in the USA working with a 30-foot parabolic antenna of his own construction plotted contours of noise emissions from the galaxy at a frequency of 160MHz and so greatly extended Jansky's original observations. Serendipity played a part through observations made from operational military radar stations. Thus

radio noise from the sun during a period of sunspot and flare activity was detected and measured in 1942 and again in 1945 over a band of radar frequencies (20-100MHz). Radars operating in the 20-80MHz band deployed by the RAF and the Army for detecting and tracking V2 missiles in 1944/45 also proved capable of performing the same function on meteors penetrating the earth's atmosphere, thus initiating the study of meteor astronomy by radar. Particularly important was the use of the army equipment to map with much greater precision the noise signals emitted by the Milky Way and this work by Hey led to the first recognition of the Cygnus radio source.

With the end of the war radio astronomy was rapidly developed in many laboratories all over the world. Many types of radiotelescopes were devised in order to enhance receiver sensitivity and antenna resolving power. Study of the radio emissions from stars, galaxies and the universe at large supplied new information which complemented the findings of the optical astronomers and our understanding of the universe and its contents had been greatly increased by the fruitful marriage of optical and radio methods. Similar increase in understanding will surely stem from the newer techniques of mounting sensors in satellites and space vehicles so that optical and microwave radioations, x-ray, γ-rays and cosmic rays may be studied without the attenuations produced by the earth's atmosphere. Radio has had the special advantage relative to the other radiations used in astronomy of using comparatively long waves which are better able to penetrate deeply into the "dusty regions" of the galaxy (as evidenced by dark clouds obscuring parts of the Milky Way). Coupled with this advantage has been the ability to detect line radiations from such emitters as atomic hydrogen (λ = 21cm) which has permitted the spiral arms of our own galaxy to be traced; or carbon monoxide (λ = 2.6mm) which is yielding valuable information on the presence of a great ring of cold star-forming clouds in the inner region of the galaxy.

Analyses by radio astronomers have been made, not only of our own local galaxy but also of the radio profiles of much vaster galaxies than our own. This has allowed detailed comparisons of these radio contours to be made with the star fields of these regions as recorded by the optical astronomers, with the result that identification of many radio sources with optical galaries with known spectral characteristics has proved to be possible. This work coupled with the results of the researches on the positions and distributions of radio sources over the whole of the celestial sphere have had profound implications for cosmology – the study of the evolution of the universe itself.

With all this post-war activity in observational radio astronomy, so successful in its prosecution and so fascinating in its consequences for our understanding of stars and galaxies, it seems astonishing in retrospect that one discovery so vital for

Theory of the expanding universe

Improvements in telescopes during the early 18th century were such that astronomers were able to distinguish clearly between the stars as point sources of light and other more extended luminous regions which appeared as small, faint "clouds", hence the name given to them – nebulae. The philosopher Immanuel Kant writing in 1755 held that many of the nebulae were probably assemblies of stars like our own Milky Way (the local galaxy, from galaxias ≡ milk) and should be regarded as "island universes".

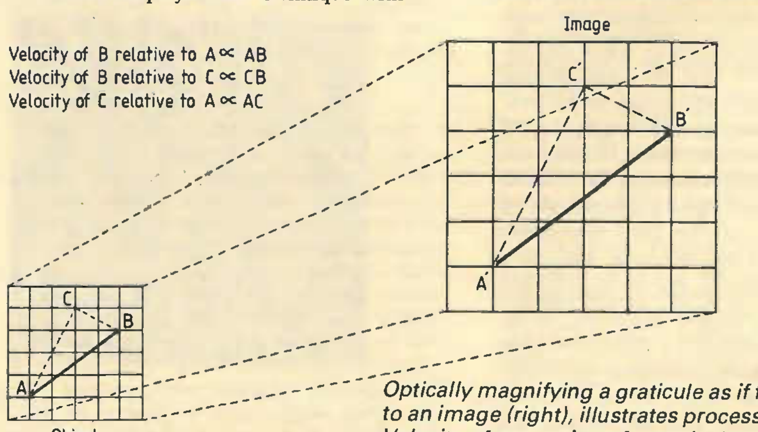
Kant's view did not prevail until 170 years later; meanwhile, nebula plotting was pursued with such good effect by Sir William Herschel, the musician turned astronomer who discovered the planet Uranus in 1781, and later by his son, Sir John Herschel, that by 1864 the Catalogue of Nebulae published by the latter contained over five thousand entries. Yet the nature and locations of the nebulae remained undecided, although some of them were by this time considered to be glowing gas clouds lying within the local galaxy. About this time the spectroscope was married to the telescope, to increase very significantly the astronomer's powers for obtaining information about the stars. In this way Sir Norman Lockyer in 1868 identified the element helium from the sun's spectrum, while Sir William Huggins, in the same year, detected the shift of the absorption lines in certain stellar spectra. He attributed the wavelength displacement to the Doppler effect so giving the radial velocity of the star with respect to the earth. By the turn of the century it had been established that while the more obviously cloud-like nebulae lying within the Milky Way gave bright line emission spectra, i.e. they were indeed glowing gas clouds, other nebulae showed spectra crossed by dark absorption lines similar to those of stars. It was found by Slipher that the absorption lines of most of the nebulae he observed were shifted towards the red and corresponded to quite high radial velocities of recession; this suggested that such nebulae must lie outside the local galaxy.

In 1923 Edwin Hubble, using the new 100-inch telescope of the Mount Wilson observatory, finally settled the matter by showing that portions of the Andromeda spiral nebula could be resolved into individual stars. More important still was his discovery of some Cepheid variable stars in the nebula which permitted him to assess its distance as about 800,000 light years and so well outside the local galaxy (diameter ~ 100,000 light years). Thus Kant's speculation on the nebulae as "island universes" was substantially vindicated.

The variable star Delta Cephei and similar stars were studied by Henrietta Leavitt in 1912 when she showed that the absolute luminosity correlated with its period of variation. It was later shown by the Doppler shift of the spectrum lines that the surface of such a star actually oscillates radially. Cepheid variables provide the astronomer with a very convenient means of measuring stellar distances, for determination of the period gives the star's absolute luminosity which, by comparison with the apparent luminosity as observed through the telescope, yields the distance.

Hubble employed this technique with great success to measure the distances of the nearer nebulae, but for fainter and more remote nebulae the Cepheids could no longer be identified and measured. Nevertheless, Hubble perservered with his distance measuring programme, basing it upon luminosity measurements of identifiable bright stars. By 1929 Hubble was able to combine his distance measurements with Slipher's spectroscopically determined radial velocities and showed that the velocity was roughly proportional to the distance. This work continued until 1936 with distances of still fainter galaxies being estimated from the luminosity of the galaxy as a whole (up to about 240 million light years) and with velocities provided by the spectroscopist Milton Humason. Nevertheless, the linear relation between velocity and distance was maintained, i.e. velocity equals constant times the radial distance, with the constant becoming appropriately known as Hubble's Constant (H). Apart from a few nearer galaxies, including the Andromeda spiral, all the velocities measured were velocities of recession, i.e. the spectrum lines were shifted towards the red.

When newer telescopes became available after the war, such as the Palomar 200-inch, the measurements were continued but the broad features of Hubble's



Optically magnifying a graticule as if from an object (left) to an image (right), illustrates process of expansion. Velocity of separation of a particular pair of points on the graticule is proportional to separation (Hubble's Law).

work remained. More detailed study of the Cepheid variables, in particular the recognition of two classes of variable, has changed the distance scale so that the Andromeda nebula, for example, is now put at 2,200,000 light years. In consequence the distance scale for the galaxies has been increased and the accepted value of the Hubble constant at present is 15 kilometres per second per million light years.

Hubble's law refers to distances and velocities measured relative to the earth and would seem to suggest that we on the earth are very privileged observers of the universe. It was quickly realised, however, that this was not so; all the galaxies are rushing apart from each other and Hubble's relation would be observed by an observer on any other galaxy who could equally well regard himself as the centre of the expansion.

Since the relative velocity between any pair of galaxies is proportional to their separation, i.e. $v = Hd$, then the time taken to achieve this separation is some value not greater than $d/v = 1/H$. In other words, the expansion of the galaxies in accordance with Hubble's Law implies that at a time in the order of $1/H$ in the past all the galaxies must have been in close proximity to each other. With H equal to 15 km sec^{-1} per 10^6 light years $1/H$ becomes 20,000 million years, but since the velocities must have been reduced by gravity during the expansion, the time taken must have been considerably less than this figure.

The expansion process can be simply visualised by considering, as shown in the diagram, a graticule imaged on to a television screen through a device giving controllable magnification of the picture (as by a zoom lens in television, or when a radar plan position display is expanded about *any* chosen centre). As the magnification is continuously increased, so the image points expand away from each other and, obviously, the velocity of separation of a particular pair of points AB is proportional to the separation as Hubble's Law states. An observer located at any image point A would see the same expansion as would be observed at B, and the "universe of points" would appear isotropic and homogeneous. The Cosmological Principle states that all observers in the universe are equivalent and will see the universe about them to be homogeneous and isotropic and to display similar motions.

The investigations of Hubble and his co-workers took place against a background of cosmological theory which included Einstein's General Theory of Relativity of 1916. This is still the best guide we have to the understanding of the interrelation of space, time and gravitation regarded as the essential elements of the universe which we observe. At first, solutions of Einstein's equations were sought which would describe a uniform and isotropic universe that was neither expanding nor contracting, but with the acceptance of Hubble's findings on the expanding universe cosmologists in their studies of the universe have relied mainly on Friedmann's solutions of 1922 which retained only the constraints of isotropy and homogeneity. These solutions lead to the concept of the universe being closed, i.e. oscillatory, with collapse following the present expansion, or open, i.e. all galaxies expanding to infinity, according as the average density of the present universe is greater or less than a certain critical value. This value is proportional to the square of the Hubble constant; if H = 15 km sec^{-1}/10^6 light years then the critical density is 5×10^{-30} gm cm^{-3}, which corresponds to about three hydrogen atoms per thousand litres of space. Estimates of the present density from known galaxies is about 10^{-30} gm cm^{-3} which would mean that the universe is open; this has prompted many astronomers to search for methods of detecting the "missing matter" that might "close" the universe.

It has to be emphasised that the explosion which launched the expansion is not to be thought of as merely projecting matter into an otherwise empty space waiting to receive it. General relativity suggests that the process must be viewed as an expansion of space itself, with matter and radiation being carried outward as it were like the co-ordinate points of the diagram. Thus every galaxy possesses a cosmological velocity relative to the co-ordinate system which is described as a "pecular" velocity. It was the peculiar velocity of our local galaxy which Muller's experiment detected and measured.

According to this view of the expanding universe of the galaxies the red shifts observed by Slipher and Humason may also be regarded as a consequence of the expanding space which is the co-ordinate system. In the simple case with the relative velocity of two galaxies such less than the velocity of light c and having separation d, then for radiation of wavelength λ the Doppler effect will produce a fractional increase in wavelength or red shift of $z = \delta\lambda/\lambda = v/c$. But the transit time of the signal is d/c and during this time the increase in separation of the galaxies is $(d/c)\ v$ so that the fractional increase in distance is $(d/c)\ v\ (1/d) = v/c = z$. In other words, the fractional increase in wavelength is equal to the fractional increase in distance between the transmitting and receiving galaxies; it is for this reason that such a Doppler shift is described as a "cosmological red shift". For large velocities, i.e. high values of the red shift z, then special relativity gives $1 + z = ((c+v)/(c-v))^{1/2}$ but the proportionality between wavelength and the expansion factor of the universe remains true[8], and also applies in the general relativity case.

The theory of the expanding universe outlined above is not accepted by all astronomers and so it is reassuring to find evidence from other branches of science which, at least, are not grossly at variance with the age of the universe derived as the reciprocal of Hubble's constant. Thus geological studies indicate a lower limit of four thousand million years for the age of the earth. Evidence on the age of the galaxy deduced from stellar studies suggests a figure well in excess of ten thousand million years. So $1/H$ is not a hopeless figure for the age of the universe, remembering that H itself has not been determined accurately by reason of the difficulty of measuring the distances of all but the nearer galaxies.

progress in cosmology should have had to wait until 1965 to be made – the existence of an all pervading radio noise background, having the spectrum characteristic of a low temperature black body radiator. Serendipity and radio communications research has helped to correct the omission.

Microwave radio noise background

Just as Jansky in 1931 was looking for sources and magnitudes of noise that might prejudice the performance of a h.f. radio communication circuit, so in 1964 two later Bell Laboratory scientists (working at the same Holmdel Field Station), Arno Penzias and Robert Wilson, were engaged on a not dissimilar task. Their operational interest related to satellite communication systems but the immediate scientific objective was the assessment of interfering noise emissions from the galaxy at microwave frequencies, and also propagation effects in the atmosphere.

In order to measure the received noise power absolutely a comparison method was employed whereby the receiver was switched between the incoming sky signal and the noise signal delivered by a resistive load cooled in liquid helium. In this way noise effects in the receiving system were eliminated but it was recognised that errors might still be introduced by noise signals generated in the antenna structure itself. In their experiment Penzias and Wilson employed a cornucopia type of antenna which had originally been set up by Bell scientists to study the reception of signals passively reflected from the Echo I satellite (a 100ft diameter balloon made of metalized fabric which was ejected from a canister after launch into orbit and inflated from a gas capsule). In effect the cornucopia was a shielded parabolic antenna which had a very low level backlobe; it was virtually immune from microwave radiation from the earth's surface since all the observations were made with the forward lobe directed to the zenith. It seemed most unlikely that such a well engineered structure would produce any interfering noise but to confirm that such an effect was totally absent they made their first observations at a wavelength of 7.35cm (the Telstar beacon frequency) when it was assumed that no noise power would be received from the galaxy. The magnitude of the inevitable interfering emissions from the atmosphere, mainly due to oxygen and water molecules, could be allowed for by taking measurements at various angles of elevation.

In spite of these precautions to eliminate all possible sources of error it was found that the noise power received was at a higher level than expected and corresponded to an excess antenna temperature of some 3.5 ± 1.0 K. The antenna temperature when directed to the zenith was 6.7 K, of which 2.3 K was attributable to the atmosphere and 0.9 K due to back lobe and ohmic losses. No diurnal nor seasonal variation of the signal could be detected. This was in sharp contrast to Jansky's original discovery of the radiation from the galaxy and eliminated the galaxy as a source of the isotropic signal. It appeared that the antenna and the earth itself were bathed in the radio flux and the conclusion seemed to be inevitable that the whole universe must be filled with this radiation. What was its spectrum? Could it be black body radiation and, if so, what was its significance and from whence had the flux originally derived[5]?

A possible answer to the last question was soon forthcoming and revealed the cosmic importance (literally) of the discovery which Penzias and Wilson had made. They learnt through contact with the astronomy group at Princeton University headed by Robert Dicke and which included Peebles, Roll and Wilkinson, that very recent theoretical research pursued by Peebles on the physical conditions that might have existed in the early "fireball" phase of the nascent universe (Dicke speculated that it might be the condensed state of a contracted previous universe) had indicated that an intense, high temperature field of radiation must then have been present. This field, being in thermal equilibrium with the matter, would have possessed a black body spectrum. Such a radiation field would have prevented the too rapid nucleosynthesis of helium and heavier nuclei from the primeval stock of protons and neutrons, for it is known from astronomical observations that hydrogen still forms about three quarters of the matter of the universe. It was suggested that the radiation which mediated at the genesis of the universe would preserve its black body spectral characteristics as the universe expanded but its temperature would fall progressively and inversely proportional to the "size" of the universe as the radiation, or "photon gas" as it may be regarded, cooled adiabatically[6]. If this were the radiation which Penzias and Wilson had detected it meant that the birth of the universe was being "seen" by radio waves as ancient as the universe itself.

Dicke and his colleagues had estimated that the present temperature of such a space expanded radiation field would be in the order of 10 K and concluded that it would be worth while to look for the radiation. Accordingly two members of the group, Roll and Wilkinson, proceeded to build a radiometer designed to detect the radiation on a wavelength of 3.2cm. At this point the Princeton group learnt of the Holmdel measurements on 7.35cm and the need was at once apparent for observations to be made at other wavelengths in order to establish whether the energy distribution of the background radiation conformed to a black body spectrum. Roll and Wilkinson's observations were immediately pressed to a conclusion and yielded a noise intensity that was indeed compatible with a black body spectrum of approximately 3 K. In other words the measurements of Penzias and Wilson, and Roll and Wilkinson fitted the black body curve shown in Fig. 2 which is described by the Planck formula:

$$u_\nu = \frac{8\pi h\nu^3}{c^3}\left(e^{\frac{h\nu}{kT}}-1\right)^{-1}$$

$$\text{or } u_\lambda = \frac{8\pi h\,c}{\lambda^5}\left(e^{\frac{hc}{kT\lambda}}-1\right)^{-1}$$

where: u_ν is the energy per unit volume per unit bandwidth at the frequency ν
u_λ is the energy per unit volume per unit of wavelength at wavelength λ
h is Planck's constant (6.625×10^{-34} Js)
k is Boltzmann's constant (1.38×10^{-23} JK^{-1})
T is the absolute temperature (K)
c is the velocity of light (2.99729×10^8 ms^{-1})

Thus the experimental evidence for the existence of a 3 K cosmic microwave radiation background (as it has come to be called) was already very good in 1965. As observations by later workers have accumulated the black body characteristic of the radio background has been given a probability bordering on certainty. For their discovery of the microwave background and the measurement of its temperature Penzias and Wilson were awarded the Nobel Prize in physics in 1978.

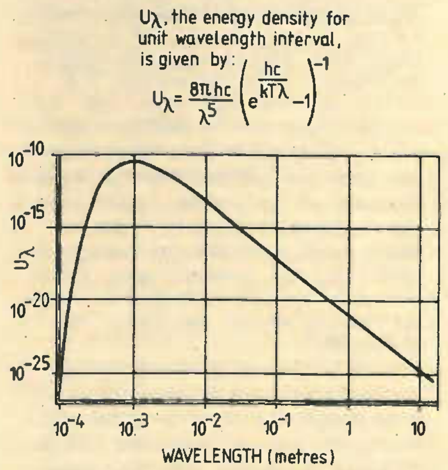


Fig. 2. The black body spectrum for 3K. The units of U_λ are joules per cubic metre of wavelength.

Anisotropy of microwave background

In the letter to the Astrophysical Journal[5] describing their measurement of the 3.5K excess antenna temperature, Penzias and Wilson stated, "This excess temperature is, within the limits of our observations, isotropic, unpolarized and free from seasonal variations". This question of isotropy was examined by a number of workers at the same time as the back body nature of the radiation was being established. By 1973 refinement of ground based experiments had permitted any anistropy that might exist to be shown to be less than one part in five hundred, which corresponds to a few millidegrees in the antenna temperature. In order to refine this measurement still further it was necessary to eliminate or reduce the main source of interference – which was Jansky type noise from the galaxy, but at microwave frequencies. Radio astromoners have

shown that such radiation is indeed produced by the motion of energetic electrons, not in the simple thermal agitation mode that Jansky speculated, but by spiralling about the lines of force of the galactic magnetic field – the so-called synchrotron effect.

Such synchrotron emission falls off with the wavelength so that by observing at shorter wavelengths this galactic noise interference would be reduced and, at the same time, the desired signal from the cosmic background would be increased. This was the design decision made by Muller and his colleagues at the University of California[7] when planning an experiment sensitive enough to measure the isotropy at the one millidegree level. They decided to operate at a wavelength of 9 millimetres and to avoid radiation from molecules of water in the atmosphere they designed the equipment to be operated in an aircraft flying at 50,000 ft. Compensation for the aerial temperature component arising from the oxygen radiation was achieved by switching a common receiver between two horns looking at different parts of the sky but at the same angles of elevation so that similar volumes of oxygen were included in their respective beams.

This is the principle of the Dicke radiometer which has been widely used in radio astronomy. A switching frequency of about one hundred hertz was employed and by filtering and amplifying the output from the receiver at this frequency any temperature difference between the two sky regions could be detected. Microwave signals from the sun and thermal effects on the antennae were avoided by making the flights at night. When sky temperature observations are conducted from the ground the portion of the celestial sphere examined is the region scanned by the beam of the antenna due to the diurnal rotation of the earth; the same is substantially true when the equipment is carried in an aircraft.

In order to study seasonal effects the flight programme extended over the whole of 1977 and clearly revealed that some anisotropy was indeed present. It was found that the temperature of the sky varied smoothly according to a cosine law from a maximum in the direction of constellation Leo to a mimimum in the reciprocal direction i.e. towards the constellation Aquarius. Temperature differences between these two directions and the average sky temperature was ±3.5 millidegrees and the effect was attributed to the velocity of the receiving antenna with respect to the radiation field and the Doppler shift that this produces. Apart from the cosine variation the radiation temperature was isotropic to one part in 3000 but in the direction 0 A (Fig. 3) where the antenna velocity is directly opposed to that of the radiation its spectrum will be displaced towards the blue i.e. its black body characteristics will be maintained but it will appear to be hotter. Now the mean wavelength λ will be shifted by an amount $\delta\lambda$ given by the usual Doppler relation $\delta\lambda/\lambda = v/c$, where v is the resultant velocity of the antenna. But according to

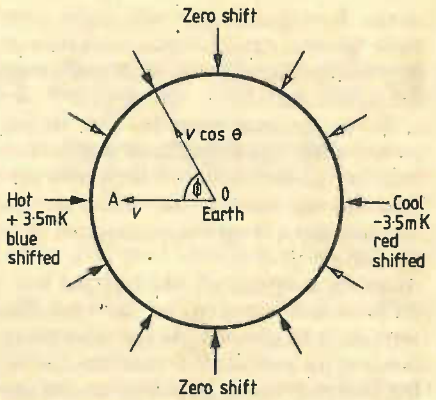


Fig. 3. The anisotropy of the cosmic microwave background due to the peculiar velocity of the galaxy.

Wien's law the typical wavelength is inversely proportional to the radiation temperature T i.e. $\delta\lambda/\lambda = -\delta T/T$ and the velocity v is given by $(\delta T/T)c$, with $\delta T = 3.5 \times 10^{-3}$ K the v is about 390 km/sec.

There are three vector components to this velocity:

(1) The orbital velocity of the earth about the sun at 30 km/sec.

(2) the orbital velocity of the solar system about the galactic centre at about 300 km/sec.

(3) the velocity of the galaxy as a whole with respect to the radiation field, or, as discussed later, with respect to those regions of the early universe from which the last scattering of the radiation occurred.

By appropriate combination of the velocity vectors Muller and his colleagues concluded that the velocity of the galaxy with respect to the radiation field is about 600 km/sec.

Cosmic role of radiation

When Lord Kelvin made his calculation of the age of the earth, based upon the cooling of a sphere from an inital high temperature, he recognized that his estimate was much too low to satisfy the geologists and so he included in his paper a caveat to the effect that there might be within the earth some undiscovered source of heat that would lengthen the time scale. We now know that certain nuclei dispersed in the rocks provide one such source.

Again, the Kelvin-Helmholz contraction theory of the sun as a means of supplying the energy it pours out as radiation proved quite inadequate to explain the age of the sun. But increased understanding of nuclear reactions in the 1930s led to the suggestions that the fusion of hydrogen to helium could easily supply the required energy and also provide a lead to the synthesis of the heavier nuclei which spectroscopy had shown to be present in the sun and other stars.

With geophysics and astrophysics already deriving support from applied nuclear physics, it was not surprising that cosmology should also be penetrated by the new physics. We have seen that there are good reasons for assuming that the myriad of galaxies which we now see widely distributed through space were probably in close proximity to each other some ten to twenty thousand million years ago. Certainly they did not then exist as galaxies for the universe must have been in a highly contracted and compressed state' In 1948 Alpher, Bethe and Gamow[9] put forward the first version of the so-called "hot big bang theory" which postulated just such a very dense state of the early universe in which the temperature was so high that thermonuclear reactions could take place in the primeval, wholly neutron "gas". Decay of neutrons to protons was assumed, followed by interactions to yield helium and other heavier elements, with the energy released fuelling the explosion and the subsequent expanding universe. It was recognized that radiation would be produced and it was even suggested that the cooled residue of this radiation should still be present in the universe. Curiously enough this paper did not prompt a search for the radiation, neither did it influence the discovery of the cosmic microwave background by Penzias and Wilson in 1964.

The existence of the 3K microwave background is the major evidence in support of the modern Big Bang theory while the isotropy of the radiation argues strongly in support of the Cosmological Principle. The black body character of the spectrum indicates that at the time of its origin the radiation was in thermal equilibrium with matter. That point in the past can be identified as the time when the expanding fireball which was the universe was a thousandth of the size of the present universe and, correspondingly, was at a temperature of about 3000K, for that was the stage when the protons and the helium nuclei formed by thermonuclear processes could combine with the free electrons. Before that time (and at higher temperatures) the density of electrons, protons, etc., had been so high that scattering processes ensured that the universe was opaque to radiation. With the formation of atoms and the removal of the electron scatterers space became transparent to radiation; this was the so-called moment of decoupling, after which the adiabatic expansion of the radiation to its present state commenced, the black body character of the spectrum being maintained. Thus the radiation which is now received carries the imprint of those regions of the new universe where the last scattering occurred but, as already noted, Muller's work did not reveal any inhomogeneities in these regions that might have suggested that groupings of matter had occurred at that stage. Perhaps this conclusion was to be expected, for only after decoupling of electrons and radiation was the great pressure of the radiation released which hitherto had prevented any association of the matter into aggregations, so that the formation of the galaxies which we now see could then begin.

Most important of the contributions to cosmology which stem from knowledge of the cosmic microwave background and its temperature of about 3K is the fact that it permits the estimate of the ratio of the number of photons to the number of nuclear particles in the present universe. This ratio would have been maintained during the fireball era and knowledge of it is necessary to study the progress of the nuclear reactions which then occurred, and in particular, to monitor the production of deuterium as the essential intermediary to the formation of the helium nuclei. Because the present temperature of the radiation background is 3K, the Planck formula tells us that the wavelength of the peak emission is about 1mm. Now the photons, which are the quanta of the energy carried by such a radiation stream, are spatially distributed at roughly a wavelength interval, so that the number of photons per litre is in the order of a million; accurate calculations shows the figure to be 550,000. Estimates of the number of nuclear particles in the galaxies then permits the ratio of photons to nuclear particles to be put at between 100 million to 20,000 million, i.e. a ratio in the order of 1000 million. It is this dominance of the radiation which controls the reactions at the onset of nucleosynthesis. Calculations of the products of the various nuclear processes are obviously very complex and were first executed by Peebles, and independently by Wagoner, Fowler and Hoyle[10]. The main conclusion was that helium would be the major product and would represent 22% to 28% by weight with hydrogen comprising most of the remainder, the balance being made up of small amounts of deuterium and other light nuclei. Observational evidence on the abundance of various nuclei in our galaxy indicates that 8% of the atoms are helium, 0.1% heavier nuclei and the balance is hydrogen; thus the percentage by weight of helium is about 26.

One of the astonishing features of the theory is the very short time required to complete the nuclear processes that prepared the essential material from which the present universe has evolved. Perhaps even the slight knowledge that most scientific people now have of nuclear weapons should have prepared us for the rapid execution of the succession of reactions that the cosmological theory requires. If the initial ingredients of the early universe be taken as a mix of protons and neutrons at a temperature well above 10^{10}K, together with radiation of density of about 10^9 photons per nuclear particle, then there will be an accompanying flux of electrons, positrons, neutrinos and antineutrinos, since the temperature is well above the threshold temperature for the generation of electron + positron pairs from two "colliding" photons of the radiation (5.9×10^9K). The density of the universe at this early stage was enormous and so the frequency of the various particles would be very great and would ensure that the whole world system was in thermal equilibrium. The principles of statistical mechanics may therefore be applied to the assembly of particles and the densities of the various species calculated. In particular, the number of protons and neutrons must have been equal since the two reactions:

$$p + \text{antineutrino} \rightleftarrows n + e^+$$
$$n + \text{neutrino} \rightleftarrows p + e^-$$

would have proceeded with equal speed since thermal equilibrium would have ensured equal availability of neutrinos and antineutrinos.

As the universe expanded and the temperature fell, the slight mass excess of the neutron above the proton would have favoured the neutron conversion process, thus causing a progressive reduction in the proportion of neutrons – to 17% in fact, when the temperature had dropped to 3×10^9K, which occurred in the very short time of 13.82 seconds. By this time annihilation of the positrons by combination with the electrons would be well advanced since the threshold temperature was already passed. Although it was possible for stable helium nuclei to be formed at 3×10^9K, it would not occur since no nuclei of deuterium would yet have been available. Deuterium is formed by the combination of a neutron with a proton together with the emission of a photon, but this action is readily reversible at high temperature and in the presence of a strong radiation field of photons. Thus the reaction was not effective until the temperature had dropped just below 10^9K, when the dissociation of the deuterium would have slowed to the point that the deuterium lived long enough to be "burnt" into helium i.e. the remaining neutrons, whose proportion at this stage would have fallen to 13%, were rapidly converted into helium. Thus the helium to hydrogen ratio by weight is 26 to 74. The temperature of onset of successful nucleosynthesis of deuterium is dependent upon the photon/nucleon ratio; if this is 10^9 (as calculated from the 3K background) then the temperature is 0.9×10^9K, and the time taken to reach this stage is only 3 minutes 4 seconds according to Weinberg [11].

Nucleosynthesis was now complete, as was also the removal of the positrons, leaving electrons in number just sufficient to match the positive charges of the protons, whether free or combined into nuclei. Combination of the electrons with these nuclei to form stable atoms could not happen until the temperature had fallen to about 3000 K. This process took about 700,000 years and then occurred the moment of decoupling when the universe became transparent to radiation; expansion of the radiation and matter followed, together with the progressive grouping of the matter into the forms of our "familiar" universe.

The rate of expansion of this relativistic universe of galaxies is a function of the gravitational field, which is itself dependent not only upon the total mass of all the nuclei but also upon the energy of the cosmic microwave background and upon the neutrino/antineutrino flux. We have seen that the expansion may continue to infinity i.e. the universe is open, or the rate of expansion may fall to zero and then reverse i.e. the universe is closed. Whether the universe is open or closed depends upon whether its average density is less or greater than the critical density mentioned earlier. The measured temperature of the microwave radiation could provide a valuable clue to this question, for the figure of 3K supplies the present photon density while the ratio of photons/nuclear particles at nucleosynthesis is a factor which influences the production of the residual deuterium that escaped conversion to helium. If the abundance of deuterium relative to that of protons which obtained at the end of nucleosynthesis could now be measured then the present average density of particles could be derived more accurately than by the crude method of summing up the possible contents of all the galaxies! Deuterium estimates made so far tend to favour the open universe, but uncertainties in the methods of assessing deuterium are still too great for the open universe concept to be accepted as proven.

Conclusion

The modern version of the Big Bang cosmology has already achieved some notable successes, not least being the way it has been able to build upon the discovery of the cosmic microwave background. Steven Weinberg, awarded a Nobel Prize in 1979 for his work in particle physics, discusses in his exciting book "The First Three Minutes"[11] states of the early universe that may have preceded the 10^{10}K stage which was taken as the starting point of this survey and shows how many fundamental problems in particle physics are involved in the endeavour to look back still further in time. What is certain is that the present theory of the foundation of the universe provides a great stimulus for further research and establishes the need for more observations, many of which will have to be made from space vehicles. Thus the techniques at least of microwave communications will continue to be needed in order to make new data available to the cosmologists.

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Digital storage and analysis of speech

2 – Coding in the time domain

by **Ian H. Witten**, M.A., M.Sc., Ph.D., M.I.E.E., University of Calgary

There are several methods of coding the time waveform of a speech signal to reduce the data rate for a given signal-to-noise ratio, or alternatively to reduce the signal-to-noise ratio for a given data rate. They almost all require more processing, both at the encoding (for storage) and decoding (for regeneration) ends of the digitization process. The aim of this section is to introduce the ideas in a qualitative way: theoretical development and summaries of results of listening tests can be found elsewhere.

Syllabic companding

We have already studied one time-domain encoding technique, namely logarithmic quantization, or log p.c.m. (sometimes called "instantaneous companding"). A more sophisticated encoder could track slowly varying trends in the overall amplitude of the speech signal and use this information to adjust the quantization levels dynamically. Speech coding methods based on this principle are called adaptive pulse code modulation systems (a.p.c.m.). Because the overall amplitude changes slowly, it is sufficient to adjust the quantization relatively infrequently (compared with the sampling rate), and this is often done at rates approximating the syllable rate of running speech, leading to the term "syllabic companding". A block floating-point format can be used, with a common exponent being stored every M samples (with M, say, 125 for a 100 ms block rate at 8 kHz sampling), but the mantissa being stored at the regular sample rate. The overall energy in the block,

$$\sum_{n=h}^{h+M-1} x(n)^2 \qquad (M=125, \text{say})$$

is used to determine a suitable exponent, and every sample in the block – namely $x(h)$, $x(h+1)$, . . . $x(h+M\text{-}1)$ – is scaled according to that exponent. Note that for speech transmission systems this method necessitates a delay of M samples at the encoder, and indeed some methods base the exponent on the energy in the last block to avoid this. For speech storage, however, the delay is irrelevant. A rather different, nonsyllabic, method of adaptive p.c.m. is continually to change the step size of a uniform quantizer, by mulitplying it by a constant at each sample which is based on the magnitude of the previous code word.

Adaptive quantization exploits information about the amplitude of the signal, and, as a rough generalization, yields a reduction of one bit per sample in the data rate for telephone-quality speech over ordinary logarithmic quantization, for a given signal-to-noise ratio. Alternatively, for the same data rate an improvement of 6dB in signal-to-noise ratio can be obtained. However, there is other information in the time waveform of speech, namely, the sample-to-sample correlation, which can be exploited to give further reductions.

Differential coding

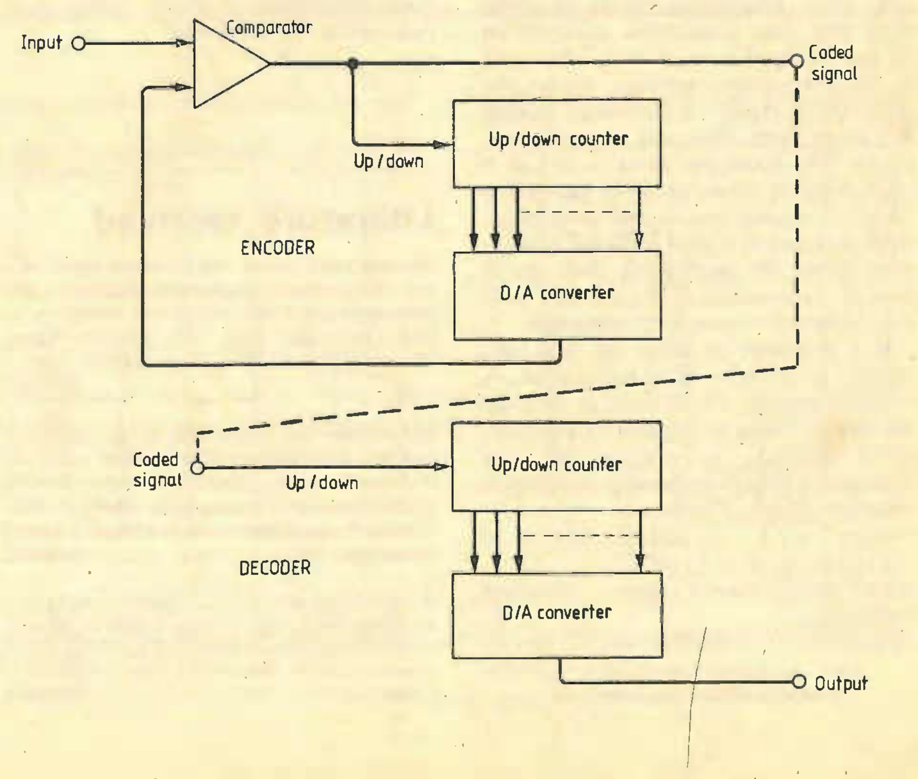
Differential pulse code modulation (d.p.c.m.), in its simplest form, uses the present speech sample as a prediction of the next one, and stores the prediction error – that is, the sample-to-sample difference. This is a simple case of predictive encoding. Referring back to the speech waveform displayed in Fig. 5, it seems plausible that the data rate can be reduced by transmitting the difference between successive samples instead of their absolute values: less bits are required for the difference signal for a given overall accuracy because it does not assume such extreme values as the absolute signal level. Actually, the improvement is not all that great – about 4-5 dB in signal-to-noise ratio, or just under one bit per sample for a given signal-to-noise ratio – for the difference signal can be nearly as large as the absolute signal level.

If d.p.c.m. is used in conjunction with adaptive quantization, giving one form of adaptive differential pulse code modulation (a.d.p.c.m.), both the overall amplitude variation and the sample-to-sample correlation are exploited, leading to a combined gain of 10-11 dB in signal-to-noise ratio (or just under two bits reduction per sample for telephone-quality speech). Another form of adaptation is to alter the predictor by multiplying the previous sample by a parameter which is adjusted for best performance. Then the transmitted signal at time n is

$$e(n) = x(n) - ax(n\text{-}1),$$

where the parameter a is adapted (and stored) on a syllabic time-scale. This leads to a slight improvement in signal-to-noise ratio, which can be combined with that achieved by adaptive quantization. Much more substantial benefits can be realized by using a weighted sum of the past several

Fig. 9. Conversion hardware for delta modulation.



(up to 15) speech samples, and adapting all the weights. However, this requires a great deal more computational power – both in the encoder and in the decoder.

Delta modulation

The coding methods presented so far all increase the complexity of the analogue-to-digital interface (or, if the sampled waveform is coded digitally, they increase the processing required before and after storage). One method which considerably *simplifies* the interface is the limiting case of d.p.c.m. with just 1-bit quantization, in which only the sign of the difference between the current and last values is transmitted. Figure 9 shows the conversion hardware. The encoding part is essentially the same as a tracking d-to-a, where the value in a counter is forced to track the analogue input by incrementing or decrementing the counter according as the input exceeds or falls short of the analogue equivalent of the counter's contents. However, for this encoding scheme, called "delta modulation", the increment/decrement signal itself forms the discrete representation of the waveform, instead of the counter's contents. The analogue waveform can be constituted from the bit stream with another counter and d-to-a converter. However, an all-analogue implementation can be used, both for the encoder and decoder, with a capacitor as integrator whose charging current is controlled digitally. This is a much cheaper realization.

It is fairly obvious that the sampling frequency for delta modulation will need to be considerably higher than for straightforward p.c.m. Figure 10 shows an effect called "slope overload" which occurs when the sampling rate is too low. Either a higher sample rate or a larger step size will reduce the overload; however, larger steps increase the noise level of the alternate 1s and −1s that occur when no input is present – called "granular noise". A compromise is necessary between slope overload and granular noise for a given bit rate. Delta modulation results in lower data rates than logarithmic quantization for a given signal-to-noise ratio if that ratio is low (poor-quality speech). As the desired speech quality is increased, its data rate grows faster than that of logarithmic p.c.m. The crossover point occurs at a much lower rate than would be needed for telephone quality speech, and so although delta modulation is used for some applications where the permissible data rate is severely constrained, it is not really suitable for speech output from computers.

It is profitable to adjust the step size, leading to *adaptive* delta modulation. A common strategy is to increase or decrease the step size by a multiplicative constant, which depends on whether the new transmitted bit will be equal to or different from the last one. That is,

stepsize $(n+1)$ = stepsize $(n)\times 2$ if $x(n+1)<x(n)<x(n-1)$ or $x(n+1)>x(n)>x(n-1)$ (slope overload condition);

stepsize $(n+1)$ = stepsize $(n)/2$ if $x(n+1), x(n-1)<x(n)$ or $x(n+1), x(n-1)>x(n)$ (granular noise condition).

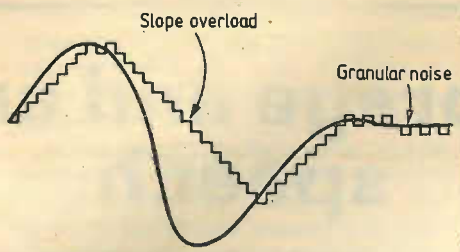


Fig. 10. Slope overload and granular noise in delta modulation.

Despite these adaptive equations, the step size should be constrained to lie between a predetermined fixed maximum and minimum, to prevent it from becoming so large or so small that rapid accommodation to changing input signals is impossible. Then, in a period of potential slope overload the step size will grow, preventing overload, possibly to its maximum value when overload may resume. In a quiet period it will decrease to its minimum value which determines the granular noise in the idle condition. Note that the step size need not be stored, for it can be deduced from the bit changes in the digitized data. Although adaptation improves the performance of delta modulation, it is still inferior to p.c.m. at telephone qualities.

It seems that a.d.p.c.m., with adaptive quantization and adaptive prediction, can provide a worthwhile advantage for speech storage, reducing the number of bits needed per sample of telephone-quality speech from 7 for logarithmic p.c.m. to perhaps 5, and the data rate from 56 kbits/s to 40 kbits/s. Disadvantages are additional complexity in the encoding and decoding processes, and the fact that byte-oriented storage, with 8 bits/sample in logarithmic p.c.m., is more convenient for computer use. For low quality speech, where hardware complexity is to be minimized, adaptive delta modulation could prove worthwhile – although the ready availability of p.c.m. codec chips reduces the cost advantage.

To be continued

Literature received

Monthly news sheets, which contain details of a host of electronic **components**, accessories and instruments, are sent out free of charge by J. Bull (Electrical) Ltd, 34/6 America Lane, Haywards Heath, West Sussex RH16 3QU. **WW401**

Instruments and **accessories** for measurement and test, and a number of instrument cases, are illustrated and specified in a catalogue from Global Specialities Corporation, Shire Hill Industrial Estate, Units 1 and 2, Saffron Walden, Essex CB11 3AQ. **WW402**

A large range of active and passive components for **thick-film** hybrid circuits is fully detailed in a new catalogue from Norsem Thick Film Components, Level 1, The Civic Centre, Hartlepool, Cleveland. **WW403**

Programmable sound generator interface

continued from page 38

The interface decoding logic, shown in Fig. 1, uses A0-A7, IORQ and WR signals from the Z80 and four i.cs to provide BC1 and BDIR signals for two p.s.gs. The two separately addressable p.s.gs require four Z80 i/o ports, 252-255, which can be relocated by using one or more of the three spare gates to invert the address lines before IC_1.

The p.s.gs are programmed by latching their relevant register and then writing or reading data, which can be achieved with the following instructions

LD A,R	R is the p.s.g. register address, R=0-15
OUT (252), A	latch register address R in p.s.g. 1
LD A, D	D is the output data, D=0-255
OUT (253), A	output data to latched register in p.s.g. 1
IN A, (253)	return contents of latched register in p.s.g. 1 to A.

Alternatively, the corresponding Basic commands can be used. The second p.s.g. is programmed in the same way using i/o ports 254 and 255 with the register addresses latched on port 254.

The 8-input NAND gate enables a dual 2-line to 4-line decoder when IORQ is active during i/o cycles involving ports 252-255. IC_{3a} decodes A0 and WR, and simulates BC1 and BDIR on data outputs 2 and 3 for all necessary p.s.g. bus functions except the inactive state. IC_{3b}, IC_4 and two inverters ensure that each p.s.g. bus is only active during the i/o operations listed above. Therefore, a p.s.g. bus can only be active when IORQ is active, which is sufficient to fulfil the timing requirements of the p.s.g. and a 4MHz Z80 system.

The construction of the interface is straightforward, and the complete circuit for driving one or two AY-3-8910 devices is shown in Fig. 2. The interface will also drive the smaller AY-3-8912 i.c., but the pin assignment is different and there is no A9 address line. Because the p.s.g. has a maximum clock frequency of 2MHz, an optional 74LS74 is included to divide a 4MHz clock by 2 or 4.

Although the three audio outputs in Fig. 2 are connected together, they may be amplified separately with an i.c. such as the LM 386 which uses a single 5V supply. The interface can be modified to control four p.s.gs by decoding both A1 and A2 with IC_{3b}. In this case, disconnect A2 from IC_1 and connect the NAND gate input to +5V, connect the B input of IC_{3b} to A2. The inverted data outputs from IC_{3b}, pins 9 and 10, then gate another 74LS08 to generate the BC1 and BDIR signals for two extra p.s.gs. Four devices are controlled via eight i/o ports, 248-255, which provides twelve independently programmable audio channels.

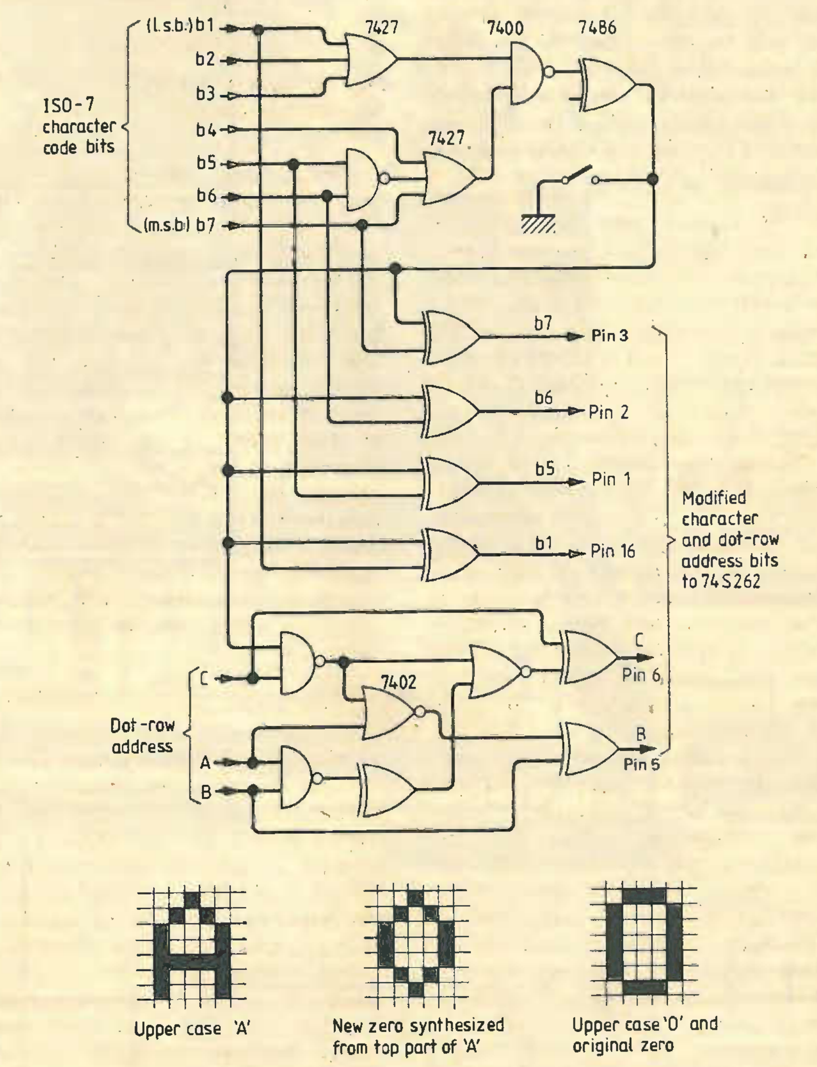
CIRCUIT IDEAS

Improving the 74S262 character generator

A disadvantage of the 74S262 character generator r.o.m. is that the displayed outputs for zero and upper-case O are identical. This circuit simulates the style of zero found in other r.o.ms.

The ISO-7 code for zero, 0110000, is converted to letter A, 1000001, and the dot-row address is modified so that the lower half of the displayed character is a reflection of the upper half. Because only the address inputs to the r.o.m. are modified, other functions such as character rounding are not affected. The switch can be included to disable the circuit if required.

A. Pemberton
Sheffield

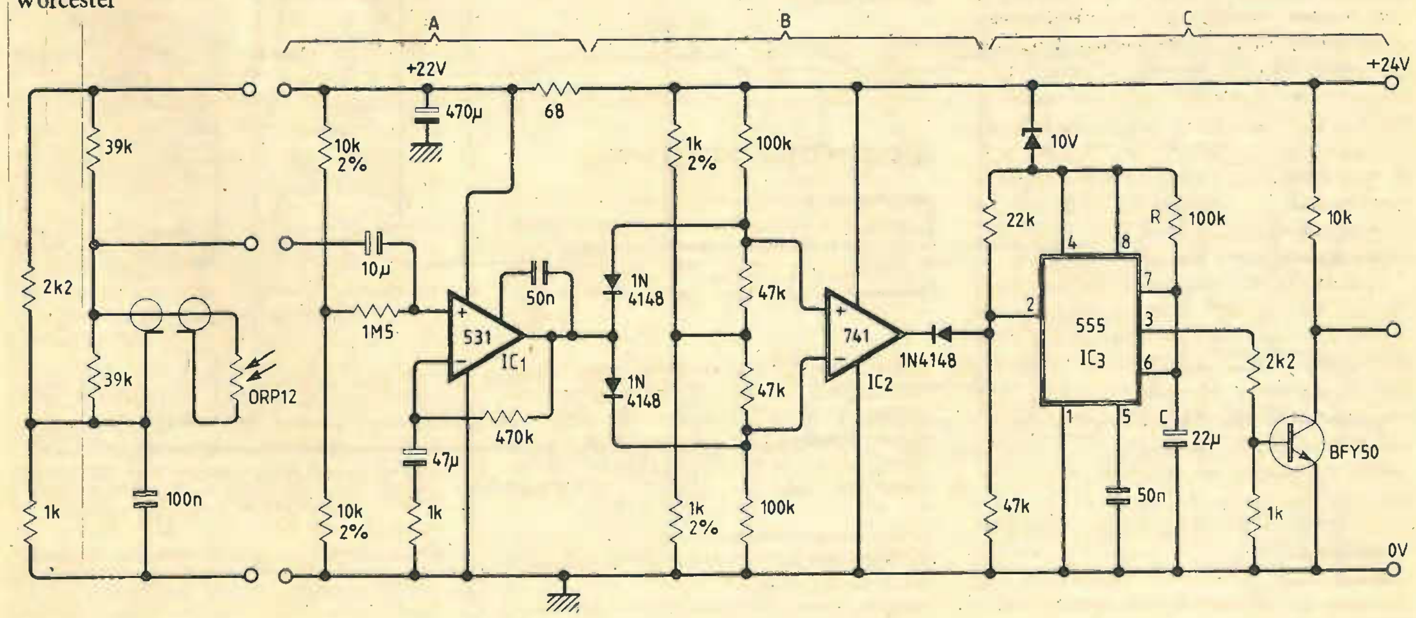


Voltage-change detector

This detector produces a negative pulse when the input voltage changes direction by more than about 15mV. The differentiator in section A detects and amplifies the leading edge of a voltage change and the output switches positive or negative. Section B converts any pulses from IC_1 which are 4.5V or greater to negative pulses. Section C is a standard monostable circuit with a delay of 5s set by the RC network.

The additional circuit at the input of section A is necessary if the detector is used with a cadmium sulphide cell or a thermistor. The voltage fed to the detector input is restricted to between 1/3 and 2/3Vcc. Other op-amps can be used for IC_1 provided they have an input impedance of around 20MΩ.

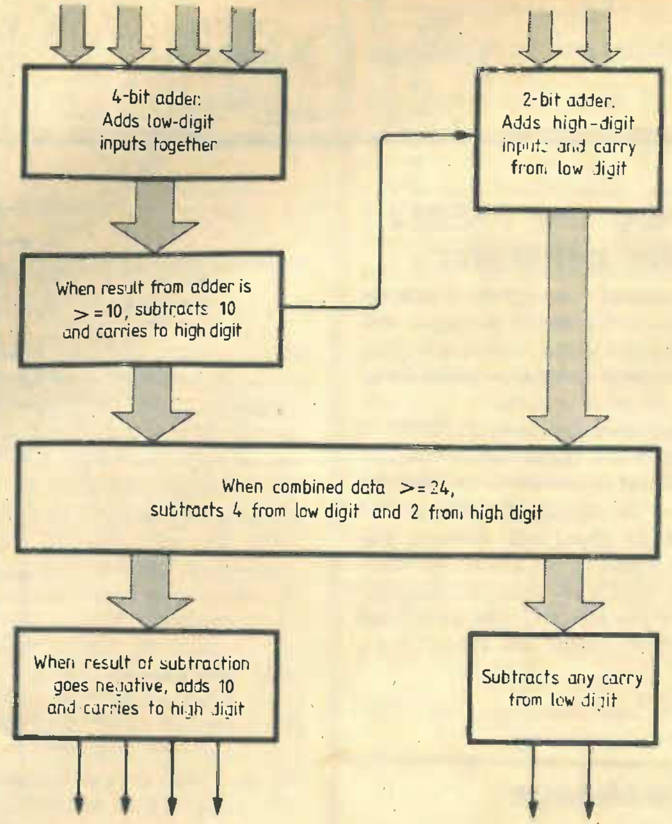
M. L. Ford
Worcester

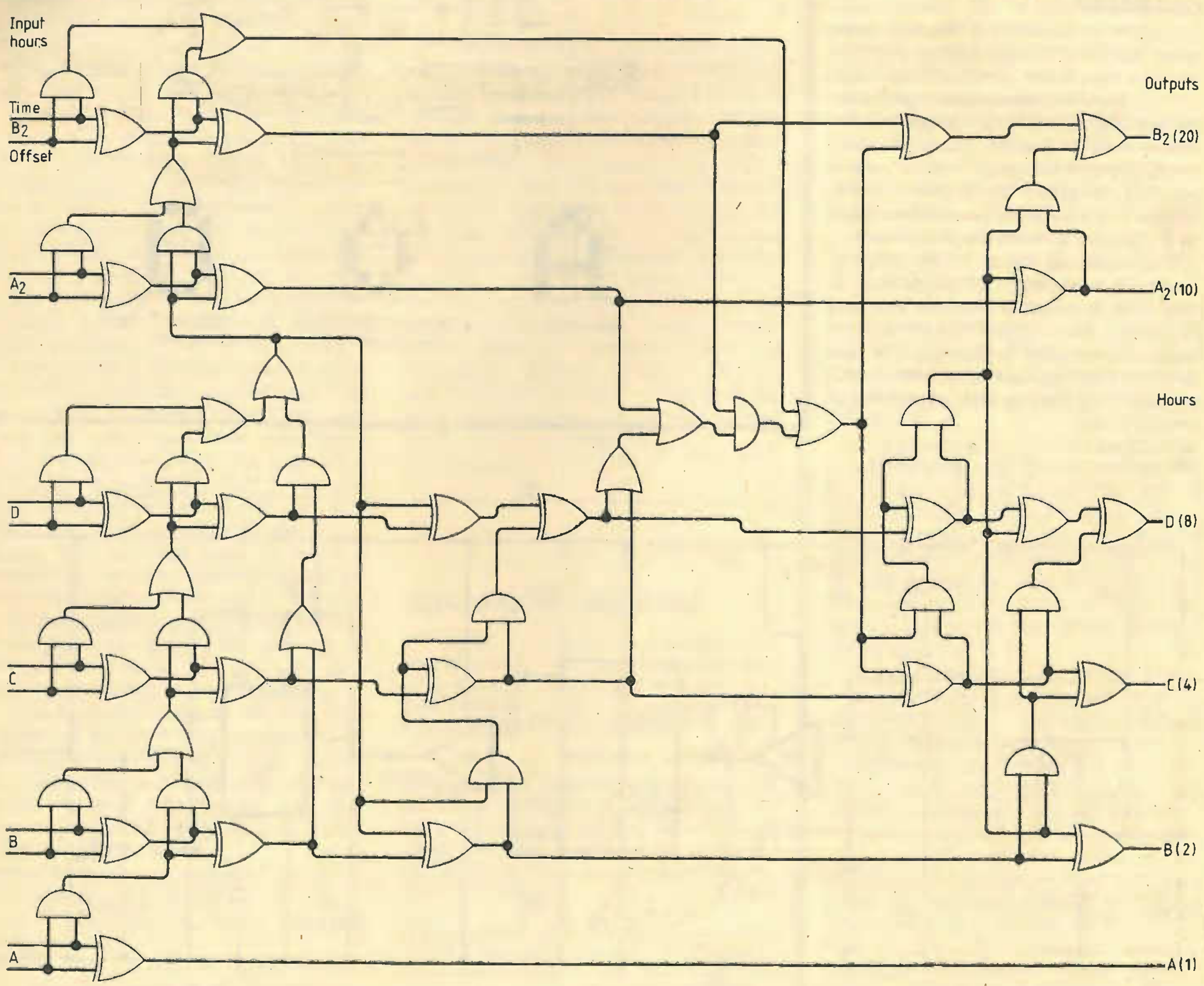


Variable time offset

By combining two sets of b.c.d. inputs, which represent the hours on a 24 hour clock and the time offset to be added, time shifts can be produced from 1 to 23 hours. Although this circuit uses discrete gates to reduce cost, parts of the design can be replaced by single i.cs such as adders.

N. J. Booth
Reading





Transient response of audio filters

Sharp cut-off filters are not always the best. Time domain considerations can lead to a reduction in coloration

by D. C. Hamill, M.Sc.

A filter with a sharp cut-off can cause an audible coloration which sounds like a resonance near the filter cut-off frequency. The sharper the filter cut off, the worse the coloration appears to become. It also seems to become worse as the cut-off frequency is moved further into the audible frequency range. This article sets out to explain this effect and suggests how it may be avoided, concluding with a practical design for a variable cut-off low-pass filter.

To try to understand the coloration effect noticed with sharp cut-off filters first think about the human hearing mechanism. As yet there is no single comprehensive theory of hearing which is generally accepted and which explains all the experimental phenomena, but it seems that the analysis of perceived sounds by the ear and brain is performed partially in the frequency domain and partially in the time domain. That is to say, it has been found that although certain parts of the basilar membrane in the ear respond to specific frequency bands, much of the experimental evidence refutes a "frequency analyser" description of the hearing process. If a signal is produced consisting of two pure tones with frequencies of 200 and 300Hz the ear hears a pitch corresponding to a frequency of 100Hz. This can be partly explained by the generation of a difference tone due to intermodulation in non-linear parts of the ear, but it also occurs at low sound pressure levels where it should be negligible. Looking at the combined waveform of the two tones, Fig. 1, this repeats itself with a period equivalent to 100Hz. The term periodicity pitch describes this sort of phenomenon which indicates that the ear uses a time-based pitch analysis which detects the repetition rate rather than a Fourier type of analysis which breaks the signal down into sinusoidal frequency components.

Another manifestation of periodicity pitch[1] can be demonstrated by producing a random signal and mixing a delayed version of this with the original. The ear hears a pitch which depends on the time delay. If this is done with a music signal and the delay is continuously varied one gets the effect known in pop music as phasing, better described as time separation pitch. Again, there is no Fourier component corresponding to the pitch heard.

A discussion of the various theories of hearing and the evidence which supports them is given by Licklider[2]: the time-domain-analysis explanation is becoming more widely known and studied, although it is not universally accepted.

Autocorrelation approach

The model of time domain analysis most commonly put forward is the autocorrelation process. Autocorrelation measures how similar a signal is to a delayed version of itself. Mathematically the autocorrelation function is

$$R(\tau)=\overline{x(t).x(t-\tau)}$$

the bar over the product representing a mean value taken over all time. The signal $x(t)$ is sampled, then again after a time delay τ, the samples multiplied together, and the product averaged over many samples to give $R(\tau)$. A schematic system for measuring autocorrelation functions is shown in Fig. 2. The function is generally normalized to one at $\tau=0$.

Autocorrelation functions of some simple signals are shown in Fig. 3. A periodic signal such as a sine or square wave has a regularly undulating autocorrelation function whereas white noise, a completely random signal, has an autocor-

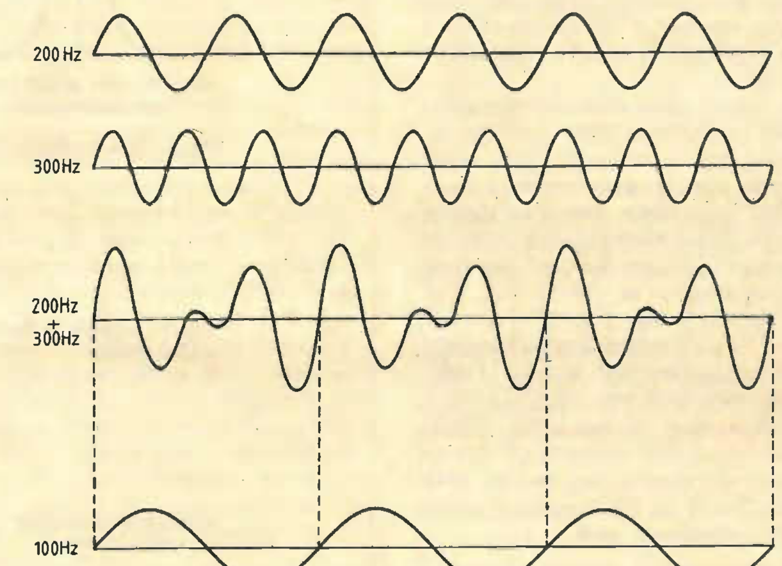


Fig. 1. Waveform produced by adding 200 Hz sinusoid to 300Hz sinusoid has a repetition rate of 100Hz, although there is no fundamental component at this frequency.

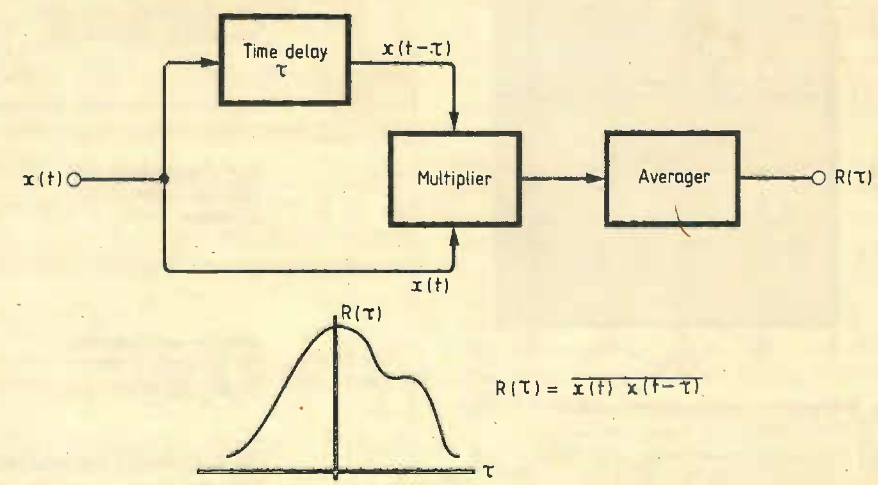


Fig. 2. Schematic method for measuring the autocorrelation function of a signal x(t).

relation function which is zero except at $\tau=0$. This makes white noise a useful signal for evaluating the response of systems because the degree of randomness of the output can easily be assessed. If white noise is passed through a low-pass filter with an ideal amplitude response – that is one which passes components below the cut-off frequency but completely stops those above cut off – a strong periodicity appears in the autocorrelation function. This indicates that the ideal frequency-domain filter is unsuitable for time-domain processing. For no audible ringing, the white-noise autocorrelation function of a network should show no ripple. Compare Fig. 3(d) with (f) which is for a simple low-pass RC section. This illustrates the fact that simple networks producing a 6dB/octave slope can be used without introducing coloration into the signal.

The autocorrelation function of a signal has been tied up with pitch and coloration by Bilsen[3], who found the experimental subjective weighting function $\rho(\tau)$ shown in Fig. 4. The pitch and coloration threshold, according to Bilsen, is given by

$$\frac{R(\tau)}{R(0)} > \frac{0.063}{\rho(\tau)}.$$

That is, if the normalized white noise autocorrelation function of the system exceeds $0.063/\rho(\tau)$ coloration may be detected in the signal.

The pitch of white noise fed through a high-pass or low-pass filter is closely related to its cut-off frequency. This would be expected from its autocorrelation function, Fig. 3(d), which shows substantial ripples of a period corresponding to the cut off frequency: compare this with the autocorrelation function of a sine wave, Fig. 3(a). This pitch and cut-off frequency relationship was confirmed experimentally by Small and Daniloff[4] and by Fastl[6]. However, with high-pass filters having a cut-off frequency below about 600Hz anomalous results are obtained which suggest that coloration is not audible with high-pass filters in the frequency range where they are usually used.

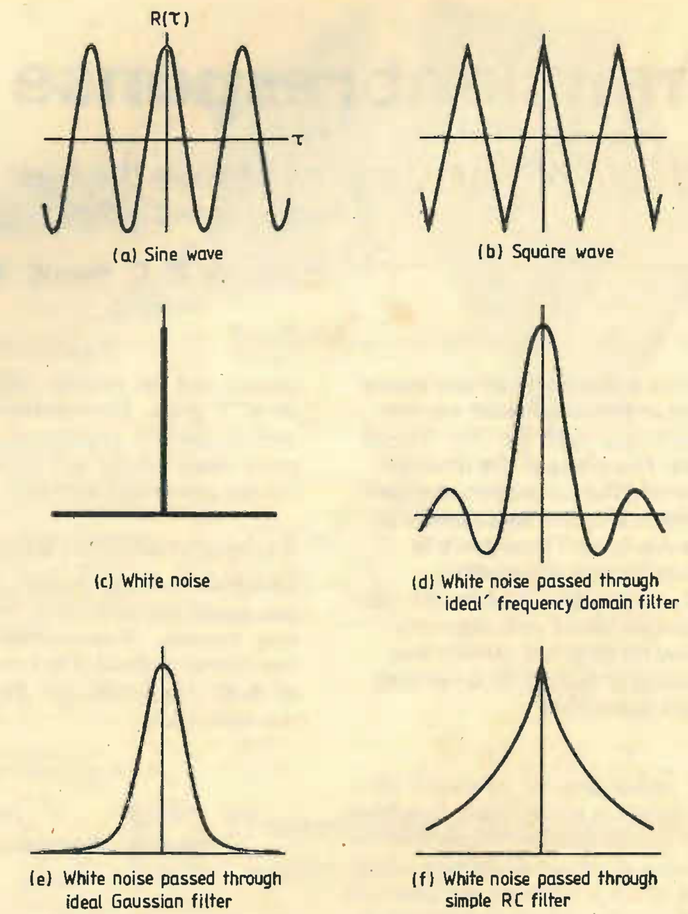


Fig. 3. Autocorrelation functions of various signals.

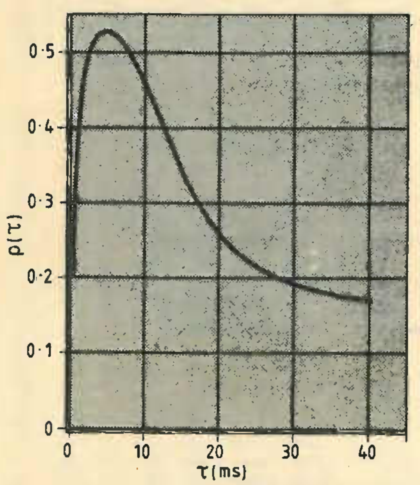


Fig. 4. Experimental autocorrelation weighting function is based mainly on work concerned with room acoustics, hence the time scale is in tens of milliseconds (after Bilsen, ref. 3).

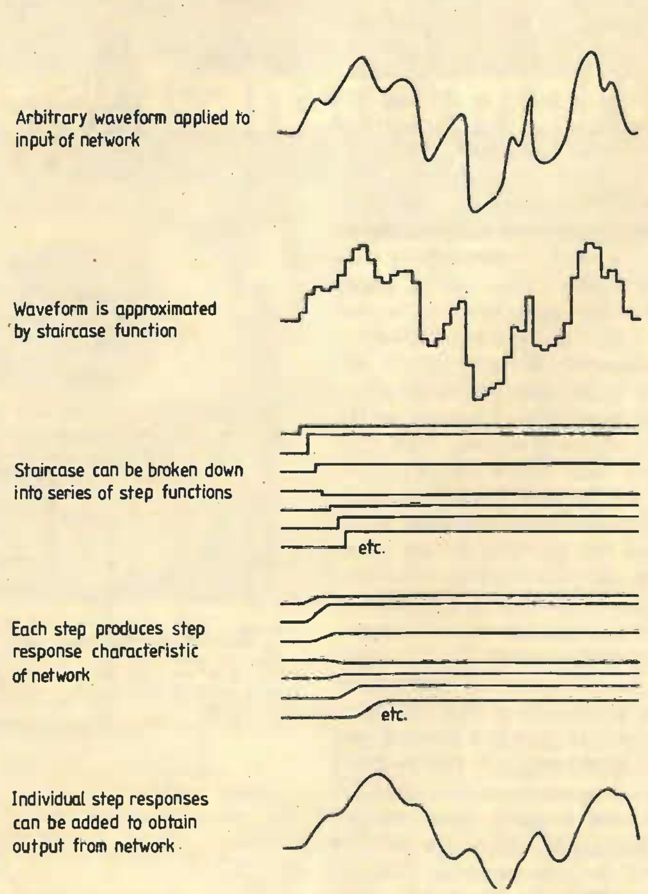


Fig. 5. Knowing the step response of a network the response to an arbitrary input waveform can be found.

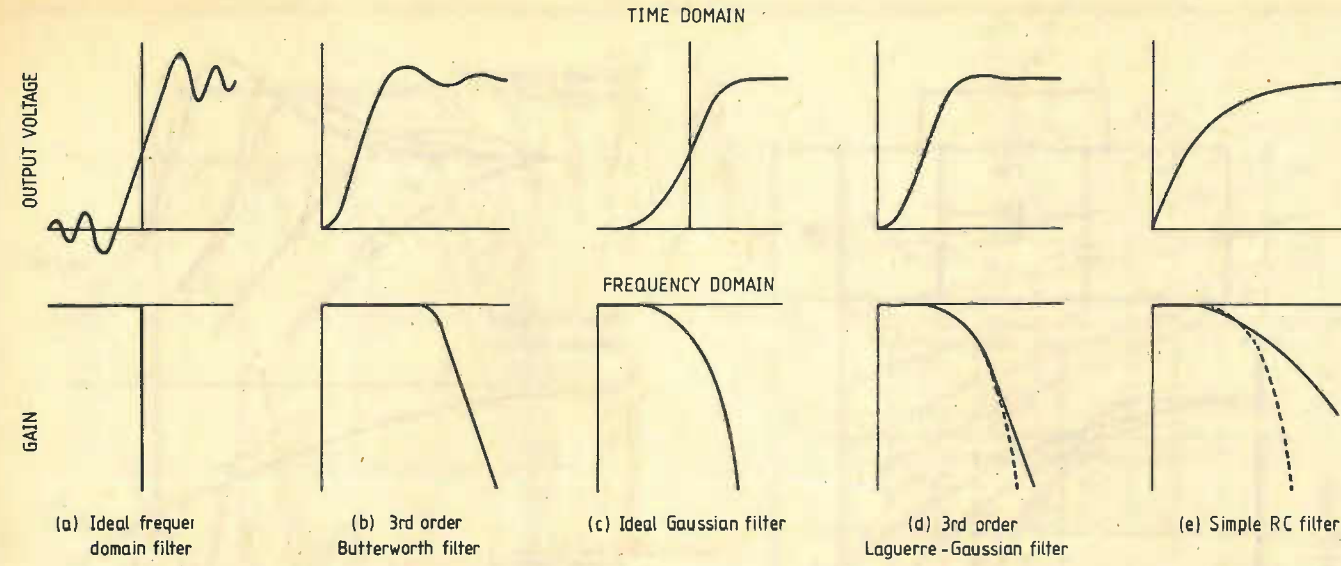


Fig. 6. Step response and amplitude response of some ideal and real filter. In (d) and (e) the true Gaussian shape is shown in broken line.

The sensation of pitch becomes more definite as the slope of a sharp cut-off filter is increased. Rakowski[6] has reported experiments with filters having slopes of 15, 50 and 150dB/octave above −3dB frequencies of between 200Hz and 5kHz. He found that "The accuracy of the pitch judgement decreases for extreme low and high frequencies. The increase in steepness of noise band skirts improves the accuracy of the pitch judgements but at 15dB/octave judgement may still be made with considerable consistency." This is in accordance with an autocorrelation theory, which predicts increased coloration as the filter becomes nearer to the ideal frequency-domain filter.

From the weight of experimental evidence then, an autocorrelation theory of hearing including a suitable weighting function appears to explain the phenomenon of filter coloration satisfactorily.

Step response

The white-noise autocorrelation function of a filter is not a very familiar quantity to many electronics engineers although they often use other time-domain descriptions of signals. (An oscilloscope is a time-domain display system, invaluable for studying the effect of networks on pulses.) The step response of a network is closely related to its white-noise autocorrelation function: the autocorrelation function of a signal is the time domain description of its power spectral density (its "frequency spectrum") and contains the same information. Given a white noise input, the power spectral density directly depends on the transfer function of the network. Taking this transfer function one can find the impulse response or the step response of the network by means of the Laplace transform. So the step response is a close cousin of the white-noise autocorrelation function and contains all its information, as well as additional phase information.

If the step response of a network is known, the response to an arbitrary signal, for example speech or music, can be found. The input signal can be approximated by a staircase function, as in Fig. 5, and by taking smaller and smaller steps one can get as close to the original as necessary. This staircase function can be decomposed into the sum of a large number of positive or negative steps of varying magnitude each of which has its own step response when passed through the network. If these are added together the resulting waveform is the response of the network to the input signal*. There is therefore a direct connection between the step response of a network and its response to real signals.

By studying the step responses of some idealized and real filters these can be related to their white-noise autocorrelation functions and criteria for audio filters can be established. Consider first the ideal frequency-domain filter shown in Fig. 6(a). The step response shows considerable ringing as would be expected. There is also a precursor, that is a response before the input step is applied, pointing to the non-realisability of this ideal filter. A real approximation to this type of response is the third-order Butterworth response shown in Fig. 6(b). There is now no precursor but there is still a lot of ringing. This sort of filter is common in audio equipment although it is by no means optimal for the application.

The ideal time-domain filter is one with a fast rise time and no overshoot or ringing. This is achieved if the amplitude response follows a Gaussian shape and if the phase response is linear. The step response of a Gaussian filter has a precursor, but a practical filter, a third-order Laguerre Gaussian approximation, gives a delayed response with no precursor and negligible ringing.

The subject of filter families such as Butterworth, Bessel, Chebyshev, is too wide to cover in one article but is well covered in the literature[7].

Design criteria

Basically, there is a need for as much attenuation as possible in the stop band with a flat amplitude response in the pass band. A steep slope in the stop band is not harmful in itself (the Gaussian filter approaches an infinite slope) but the shape of the response curve in the transition region between the pass band and the stop band is important. Looking at the Gaussian, Laguerre and simple RC filters, there is little or no ringing when the cut-off is approximately Gaussian over the first 10dB or so of attenuation. The phase response associated with this type of cut-off tends to be linear in the case of practical transfer functions, and this has sometimes led to the misconception that filters should be specified to have a linear phase response to minimize ringing. The step response contains information which is discarded in the autocorrelation response. This implies that a pure autocorrelation theory of hearing does not take account of the ears' sensitivity to phase information, but there has been considerable controversy over the degree to which phase shifts are detectable. What is important in the present context is that phase linearity, by itself, is no guarantee of adequate audio filter design.

One could choose a sharp cut-off response characteristic and then add an all-pass phase equalizer to give good phase linearity, but this would not give freedom from ringing. The ideal frequency-domain filter is a good example of this: even with zero phase there is bad ringing. Adjusting the phase response near the band edge can alter the symmetry between precursor and overshoot but can never remove the ringing.

The conclusion must be drawn that the main factor governing transient response is the shape of the amplitude response roll-off in the transition region. For best results this should have a Gaussian shape, that is it should follow

$$\left|\frac{v_{out}}{v_{in}}\right| = \exp\left[-\left(\frac{f}{f_{-3dB}}\right)\frac{\log_e 2}{2}\right].$$

* This is equivalent to convolution of the impulse response of the network with an arbitrary signal, and is known as the Duhamel superposition integral method.

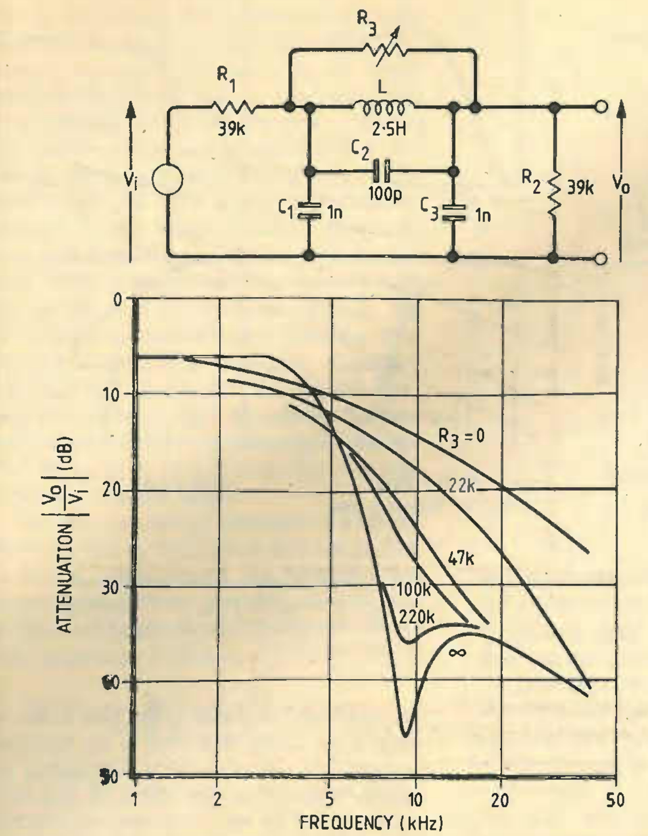


Fig. 7. Amplitude response curves for a simple variable slope filter (after Leakey, ref. 9).

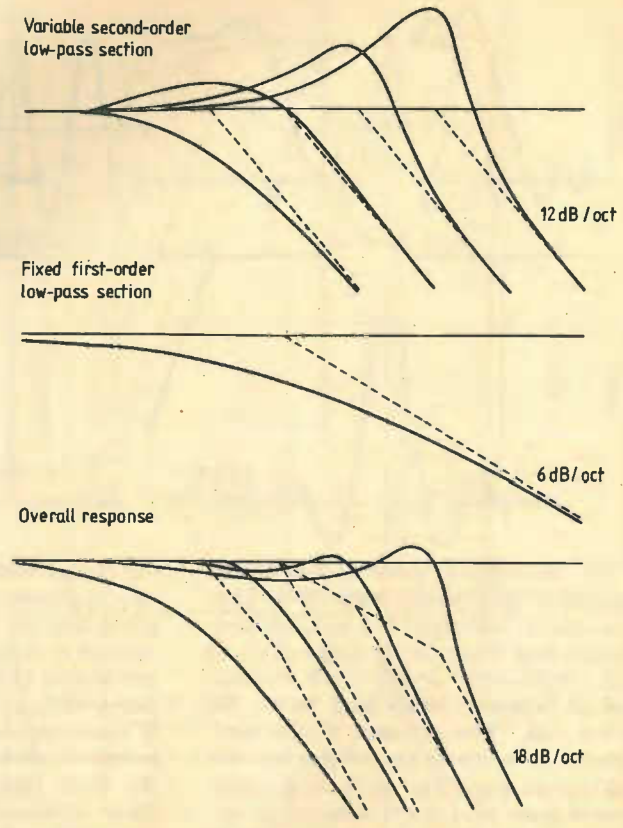


Fig. 8. In variable low-pass filter overall response is the sum of a first-order and a variable second-order response.

This is unrealisable as it stands but it can be approximated by either a Taylor or a Laguerre series expansion[8]. Several other filter approximations also produce a quasi-Gaussian roll-off, for example the well-known Bessel or Thomson family and the in-line pole approximations.

While a Gaussian roll-off is ideal from the point of view of step response, the ear is not so critical of ringing as the cut-off frequency is raised. This implies that a sharper cut may be used at high frequencies without being objectionable.

As filters can be broken down into first and second-order terms, the last being responsible for ringing, the maximum allowable Q-factor of the various terms in the transfer function could be related to frequency as a criterion for audio network design**.

High-pass filters are less critical in their design. As previously mentioned, although at high cut-off frequencies ringing is noticeable, below about 600Hz this effect subjectively disappears. The design of high-pass filters can be based on conventional frequency-domain considerations. For example, a typical rumble filter might have a third-order Butterworth response with a −3dB frequency of 24Hz, giving 1dB drop at 30Hz.

** Research into the effect of similar transfer functions in introducing audible coloration has been carried out at the University of Surrey by J. M. Bowsher and K. Moulana.

Variable low-pass filter

One solution to the problem of ringing adopted in some high fidelity preamplifiers is to use a switched cut-off frequency and to add another filter control known as a slope or roll-off control. In one type[9] a slope control mainly affects the rate of fall-off in the stop band, thus sacrificing wanted attenuation to reduce the unwanted coloration, Fig. 7. The provision of three switched frequencies plus a slope control gives a comprehensive filtering facility in the sense that the user has a wide choice of filter characteristics. I believe this is unnecessarily complicated and that a single control can be adequate for most applications if correctly designed.

Essentially what is required is a steep final rate of attenuation, say 18 dB/octave, but with a gradual initial roll-off approximating a Gaussian shape. Finer control is possible if the cut-off frequency is made smoothly variable rather than switched. Secondly, the ear is less sensitive to ringing at the upper end of the spectrum than toward the middle and a sharper cut-off is more permissible (and desirable) near the band edge. The object of this design was therefore to obtain an 18 dB/octave slope which could be shifted along the frequency spectrum whilst automatically changing its shape in the transition region to give the maximum amount of attenuation without coloration at any setting. This aim has been achieved in the following way.

A second-order low-pass section has a peak in its response which depends on its Q-factor. If the Q-factor is allowed to increase as the cut-off frequency is increased, curves like those of Fig. 8 are obtained. If this rising response is offset by a first-order response falling at 6 dB/octave the result is an almost-flat pass-band response with a variable cut-off frequency, the initial roll-off becoming steeper with increasing cut-off frequency. (In practice, the first-order section must also have a variable cut-off frequency to avoid a peaked response.)

The filter was designed to be variable between a Bessel response with a cut-off at 6.3 kHz, and a 0.5 dB ripple Chebyshev response with a 20kHz cut-off. The subjective sensation of pitch is approximately linear with logarithmic frequency and as there is evidence[10] to show that the subjective effect of reducing the bandwidth of a signal is also nearly proportional to the logarithm of the cut-off frequency, this law has been incorporated in the variable control. The resulting circuit is analysed in the Appendix and its computed response curves are given in Figs 9 & 10.

Practical circuit

A practical circuit suitable for use in a high-fidelity preamplifier or in professional audio equipment is given in Fig. 11. In addition to the variable low-pass facility there is a fixed rumble filter built around the input stage which cuts off at 18 dB/octave with a Butterworth characteristic.

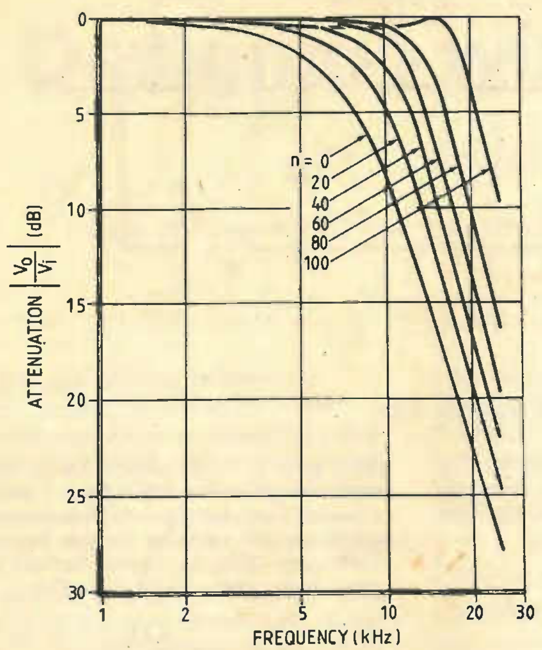


Fig. 9. Amplitude response of the variable low-pass filter. Parameter n is percentage potentiometer rotation.

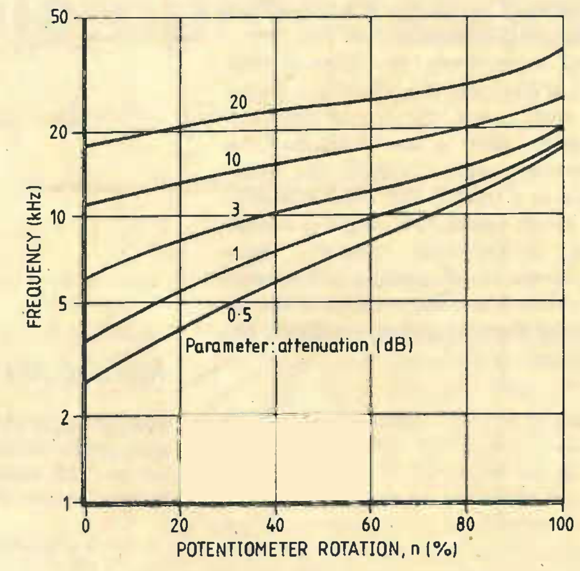


Fig. 10. Variation of cut-off frequency with potentiometer setting for various values of attenuation.

The second amplifier is a push-pull arrangement which was found necessary because of capacitive loading effects; a single-ended amplifier would give rise to considerable second harmonic distortion at high frequencies. Capacitor C_2 is included for stability, while C_1 and C_5 bypass r.f. without affecting amplitude response. For best results the source resistance should be low, preferably less than 100Ω, but up to 1kΩ is permissible if R_1 value is reduced to compensate. A load resistance of 4.7 kΩ or greater is recommended but the circuit will drive lower resistances at a higher distortion figure. Capacitors 3 and 4 should be low-leakage types such as tantalum bead to reduce noise from the control potentiometer. As a single potentiometer is used per

Measured performance of the variable filter

Amplitude response	Very close to computed curves −1 dB at 36 Hz and −15 dB at 15 Hz
Max. input level	+15 dBm (4.4V r.m.s.) at any frequency
Noise level	−93dBm max. (measured in noise bandwidth 20 Hz to 20 kHz, input shorted)
Gain	−0.5 dB at 1 kHz
Max. load impedance	4.7 kΩ (but see text)
Max. source impedance	100Ω (but see text)
Distortion	0.1 % t.h.d. at any frequency and input level up to +15dBm with 4.7kΩ load

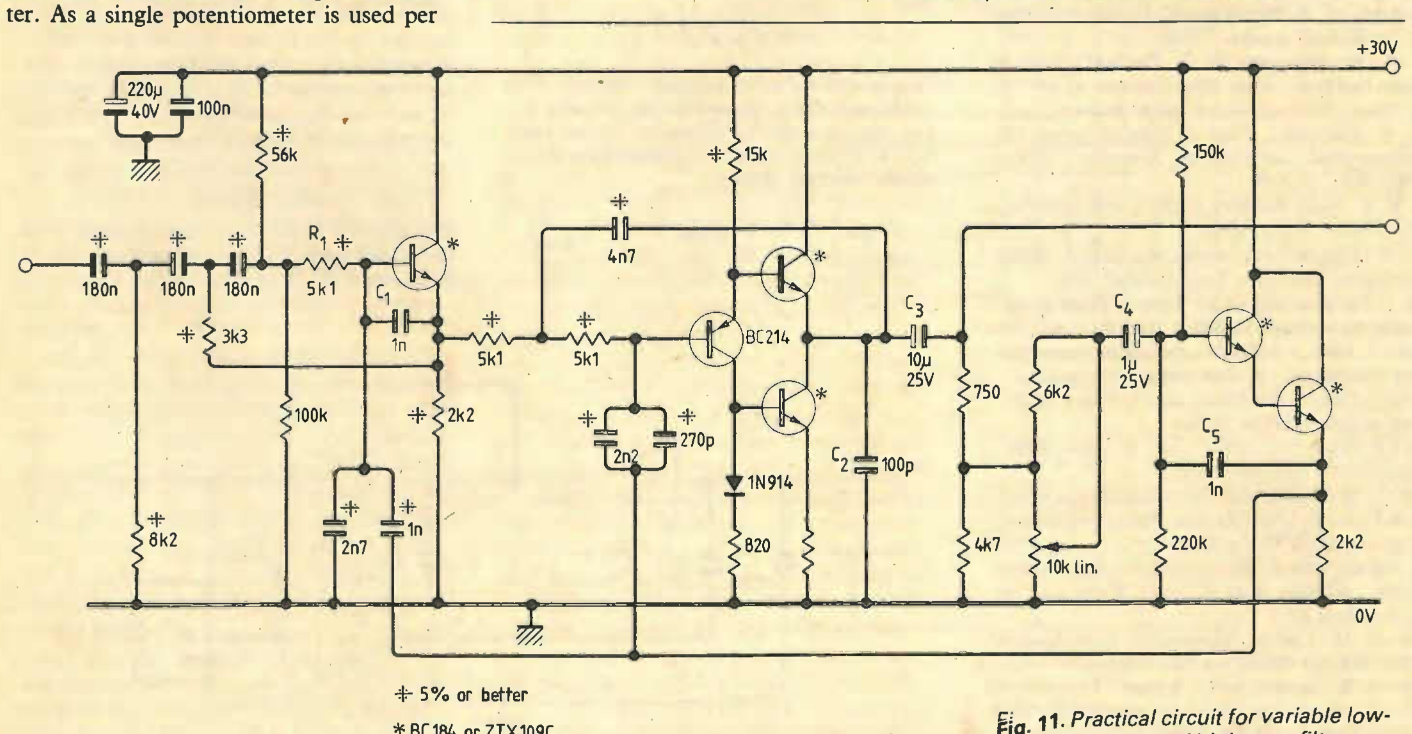
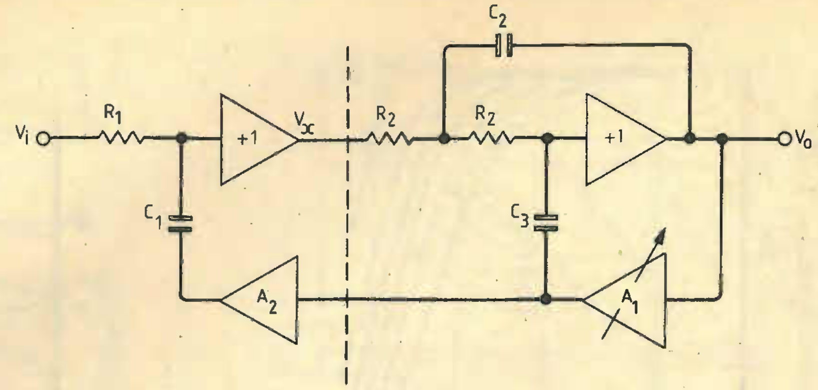


Fig. 11. Practical circuit for variable low-pass filter and fixed high-pass filter.

channel, stereo ganging is very easily achieved. (A version of the circuit was built using 741 op-amps as unity-gain amplifiers but their limited gain-bandwidth product caused deviations from the theoretical amplitude response.)

Judged subjectively, the filter is very effective in obviating the coloration. Using a pink noise input, the circuit does not significantly colour at any setting and the potentiometer seems to control the filtering action in a smooth and linear manner. With a music signal, lowering the cut-off frequency progressively removes "edginess" from the sound, causing instruments such as cymbals and harpsichord to recede and making the sound duller without being coloured.



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Appendix: Analysis of variable low-pass filter

The right-hand part of the circuit, Fig. A1, is a second-order Sallen and Key section with variable feedback controlled by the gain A_1. The transfer function of this part, V_o/V_x, is

$$\frac{1}{1+2sC_3R_2(1-A_1)+s^2C_2C_3R_2^2(1-A_1)}$$

This has a natural frequency

$$\omega_0=\frac{1}{R_2\sqrt{C_2C_3(1-A_1)}}$$

and

$$Q=\tfrac{1}{2}\sqrt{\frac{C_2}{C_3(1-A_1)}}$$

As A_1 increases, both ω_o and Q increase. The left hand part of the circuit has a response given by

$$V_x=\frac{V_i+sC_1R_1A_1A_2v_0}{1+sC_1R_1}$$

Combining the two transfer functions gives the overall function

$$\frac{v_o}{v_i}=\frac{1}{1+\alpha s+\beta s^2+\gamma s^3},$$

where

$$\left.\begin{aligned}\alpha&=2C_3R_2(1-A_1)+C_1R_1(1-A_1A_2)\\ \beta&=(C_2C_3R_2^2+2C_1C_3R_1R_2)(1-A_1)\\ \text{and}\quad \gamma&=C_1C_2C_3R_2^3(1-A_1)\end{aligned}\right\}\ 1.$$

This is a third-order low-pass function with coefficients which depend on the variable A_1. The minimum natural frequency occurs when $A_1 = 0$. Suppose this is to correspond to a Bessel transfer function. Then

$$\alpha=\frac{1}{\omega_1}\qquad \beta=\frac{0.400}{\omega_1^2}\qquad \gamma=\frac{0.067}{\omega_1^3}$$

which gives a –3 dB point at $\omega = 1.76\omega_1$. Normalizing to $\omega_1 = 1$, $R_1 = R_2 = 1$, gives $C_1 = 0.431$, $C_2 = 0.541$, $C_3 = 0.285$, which can be substituted into equations 1. Now suppose a 0.5dB ripple Chebyshev transfer function is required for the other extreme of A_1. Then

$$\alpha=\frac{2.53}{\omega_2}$$

$$\beta=\frac{2.44}{\omega_2^2}$$

$$\gamma=\frac{2.30}{\omega_2^3}$$

which gives a –3 dB point at $\omega = 0.989\omega_2$. Comparing these coefficients with those of equations 1, three equations in the variables A_{1max}, A_2 and $\omega_2/\omega_1 = 5.65$.

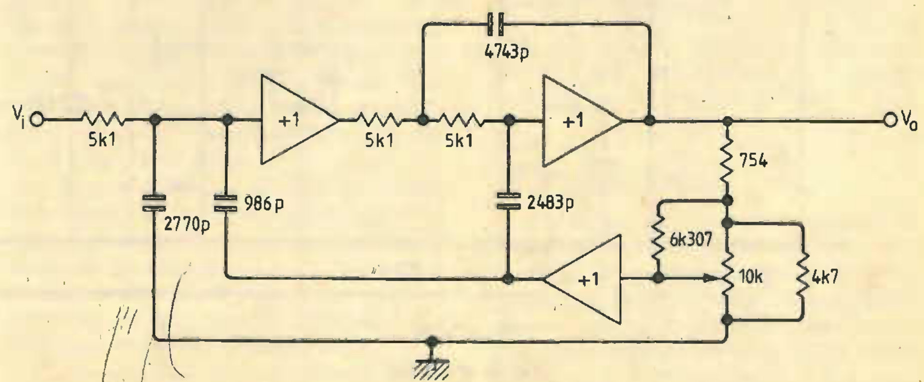
Notice that the cut-off frequency range is now defined by the ratio $0.989\omega_2/1.76\omega_1 = 3.18$, which can be denormalized to give a range of 6.28 to 20 kHz. This frequency range is determined solely by the choice of transfer functions; the two used here give a large range and useful response curves. For comparisons, a Butterworth transfer function when A_1 is at its maximum gives a denormalized range of only 11.8 to 20kHz.

The plot of log cut-off frequency versus A_1 is almost linear, as required; however, the addition of a resistor between the top of the potentiometer and its wiper improves the law. The use of an amplifier for A_2 is avoided by splitting C_1 into two, C_1' connected to earth and C_1'' connected to the output of A_1, such that

$$C_1'=(1-A_2)C_1$$

$$\text{and } C_1''=A_2C_1$$

The final schematic circuit denormalized to an impedance level of 5.1 kΩ and an upper cut-off frequency of 20kHz is shown in Fig. A2.



Designing with microprocessors

10 – Concluding interrupt-driven circuits

by D. Zissos and G. Stone Department of Computer Science, University of Calgary, Canada

The last two articles on interrupt driven circuits, June and July 1981, described operation, applications and design procedures. This article covers interrupt controllers and outlines the operation and use of two common interrupt chips.

The function of interrupt controllers is to generate an interrupt request, IRQ, signal when one or more flags are present, and to provide the microprocessor with information which will allow it to identify the source of interruption. Fig. 1 last month showed the basis of interrupt systems, and the step-by-step operation is described in reference 1. Interrupts are classified as **vectored** or **non-vectored** depending on the type of information made available to the microprocessor. In vectored interrupts, the vectoring address is generated externally prior to program interruption. In non-vectored types, the controller provides the microprocessor with the state of the individual flags, and it is left to the programmer to identify the source of interruption. For describing interrupt controllers, it is assumed that the higher the suffix of an interrupt flag, the higher its priority unless otherwise specified.

Controllers for non-vectored interrupts

The controller for non-vectored interrupts in Fig. 2(a) consists of an i/o port and two gates. The IRQ signal is generated by OR-ing the flag signals. When program interruption occurs, the programmer saves the processor status and reads the flag bits into the accumulator by simply executing an Input instruction with address Ap in this case. The processor status is saved to allow the interrupted program to continue correctly.

After the flag bits are stored in the accumulator, the programmer tests the value of each bit in turn by shifting left one position the contents of the accumulator through the carry flip-flop, and checking whether it is set, C=1, or reset, C=0, see Fig. 2(b). If the flip-flop is set, control of the program is transferred to the appropriate interrupt routine, otherwise the shift-and-test operation is repeated as shown in Fig. 3.

At the end of each service routine the processor status is restored, the interrupts are enabled and the interrupted program is resumed by executing a Return instruction. This method, commonly called software polling, involves no special hardware and is often favoured by people familiar with software. However, it is slow and if a large number of interrupts are necessary, the response time may be too slow for certain real-time applications.

Controllers for vectored interrupts

The function of controllers for vectored interrupts is to identify the source of interruption before generating the interrupt request signal, and to load the program counter with the appropriate vectoring address when the microprocessor is interrupted. Fig. 4 shows two methods for generating vectoring addresses. In (a), the vectoring address is generated directly by the interrupt controller but in (b), the interrupt controller sets a pointer to the memory location which holds the appropriate vectoring address and releases it. The first method is used by the Intel 8259 and the basic operation of this device depends on the execution of the three-byte Call instruction which allows direct access to the program counter[2]. This is because the data bus is linked to the program counter during the last two machine cycles as shown in Fig. 5. The 8259 issues an interrupt request signal when the microprocessor operation is to be interrupted, and waits for the processor to respond with INTA. When this occurs it feeds the data bus with the opcode of the Call instruction and then the two-byte vectoring address. The opcode is loaded into the instruction register and the vectoring address into the program counter as shown in Fig. 5. Before the vectoring address is loaded, its contents are automatically stored in stack[4].

The second method of generating vectoring addresses is used by the Motorola 6828[3]. In common with all interrupt controllers, the 6828 generates an interrupt request signal in response to external flags and waits for the microprocessor to respond. The processor responds by outputting consecutively addressed signals

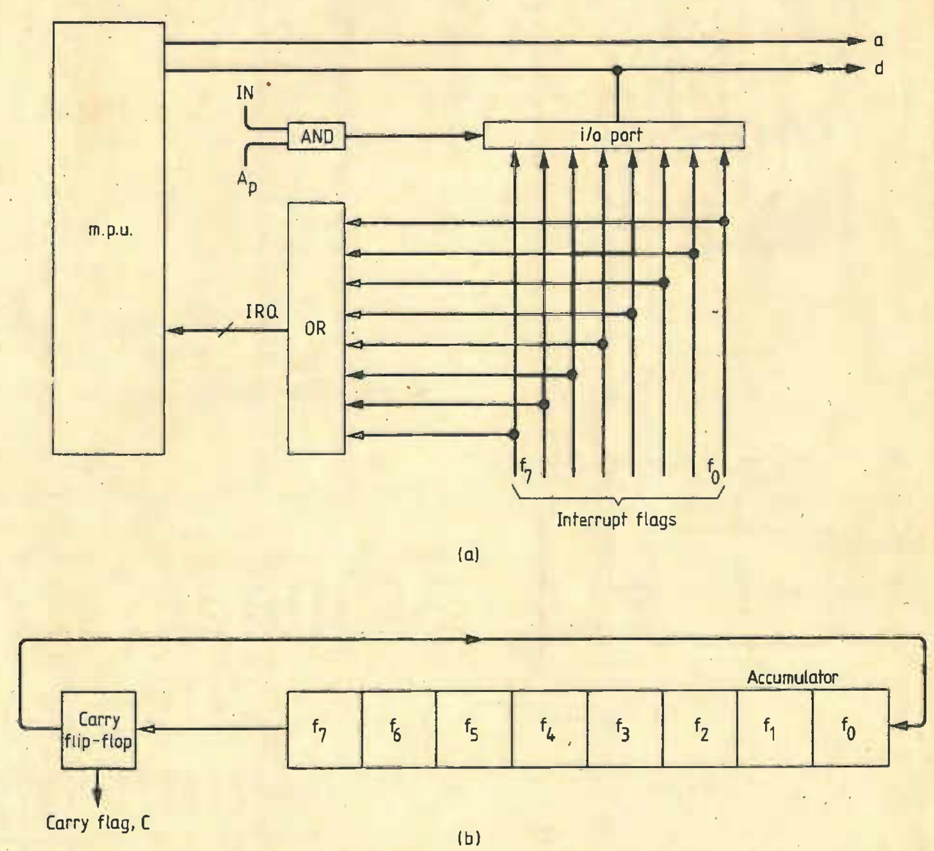


Fig. 2(a). Block diagram of an interrupt controller for non-vectored interrupts. (b) Accumulator contents prior to shift operation. (For Fig. 1 see last month.)

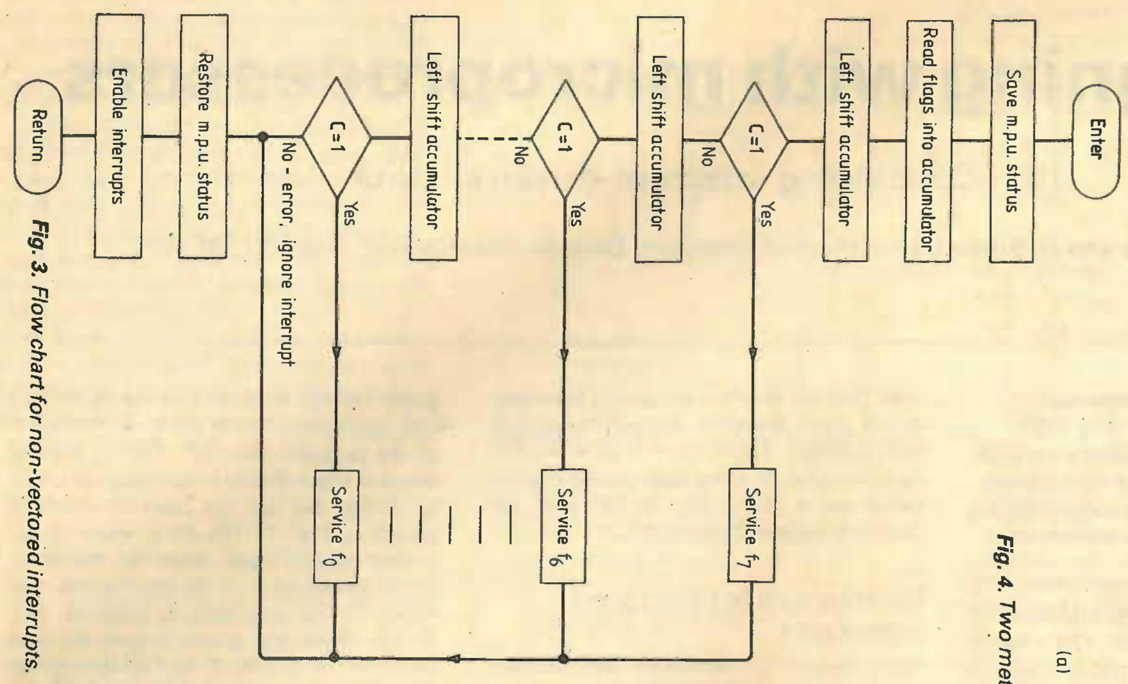


Fig. 3. Flow chart for non-vectored interrupts.

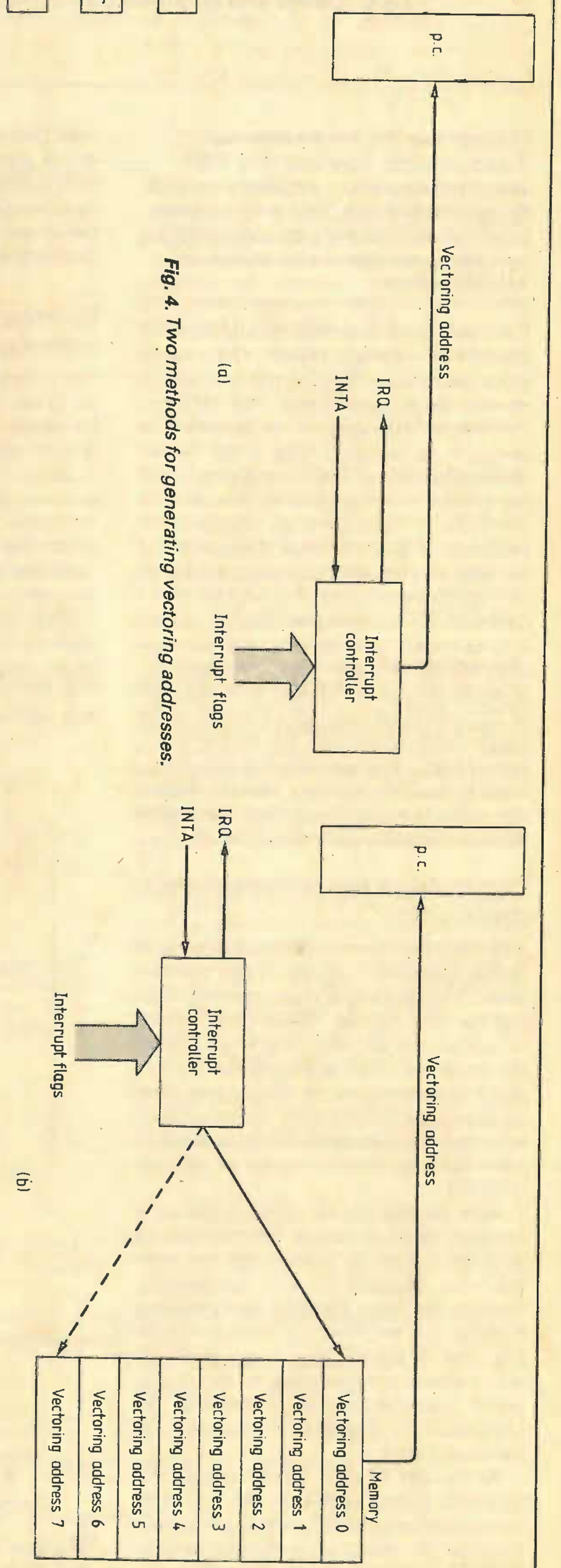


Fig. 4. Two methods for generating vectoring addresses.

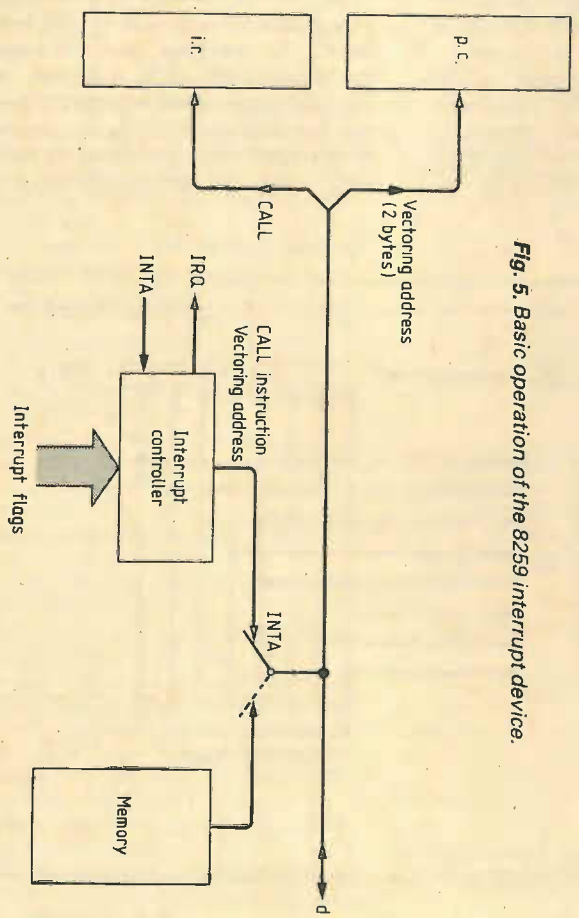


Fig. 5. Basic operation of the 8259 interrupt device.

FFF8 and FFF9. The presence of these signals on the address bus activates the interrupt controller, which then modifies their values in accordance with the interrupt flags, as shown in Fig. 6. Address bits 1 to 4 are replaced by four new bits z1 to z4. One method of achieving this, using a priority encoder (flag sorter) and some logic, is shown in Fig. 7[4]. The priority encoder identifies the flag with the highest priority, see Fig. 8. For example, q2q1q0=010 when flag 2 is identified and q2q1q0=111 if flag 7 is present. The values of the modified address bits are also given in Fig. 8 which shows

$$z1=q0 \qquad z3=\overline{q2}$$
$$z2=q1 \qquad z4=q2$$

A priority encoder and inverter circuit is shown in Fig. 9.

Restarts

Restarts are one-byte instructions whose format is 11ddd111 where ddd are variables. When this instruction is executed, the program counter is pushed on stack, and bytes 00000000 and 00ddd000 are written into it. This means that the execution of a restart instruction transfers program control to one of eight locations specified by 00000000 00ddd000, see Fig. 10. The restart instruction can be generated by a priority encoder and, because it is loaded into the instruction register rather than the program counter, all that is required is an i/o port and one AND gate.

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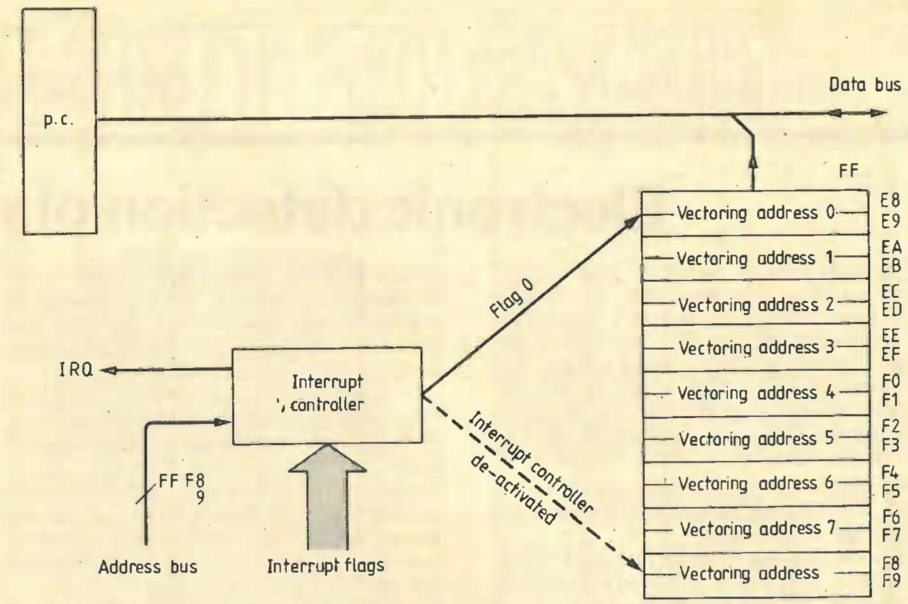


Fig. 6. Basic operation of the 6828 interrupt device.

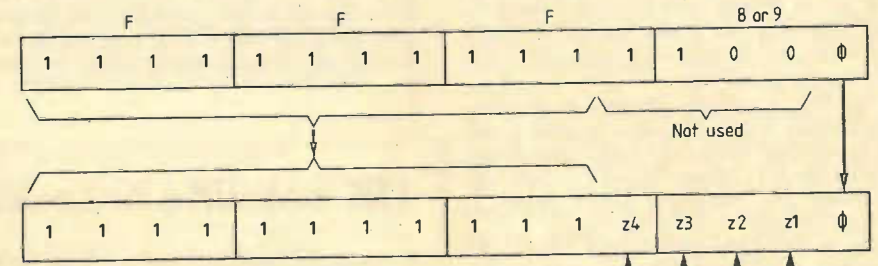
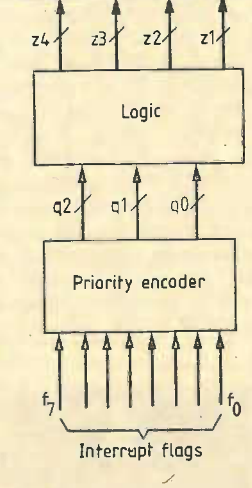


Fig. 7. Modification of the 6800 address signals FFF8/9 during interrupt cycles.



	Flag with highest priority			Modified address			
	q2	q1	q0	z4	z3	z2	z1
Flag 0	0	0	0	0	1	0	0
1	0	0	1	0	1	0	1
2	0	1	0	0	1	1	0
3	0	1	1	0	1	1	1
4	1	0	0	1	0	0	0
5	1	0	1	1	0	0	1
6	1	1	0	1	0	1	0
7	1	1	1	1	0	1	1
No flags	Priority encoder inoperative			a4	a3	a2	a1

Fig. 8. Modified vectoring addresses, see Fig. 7.

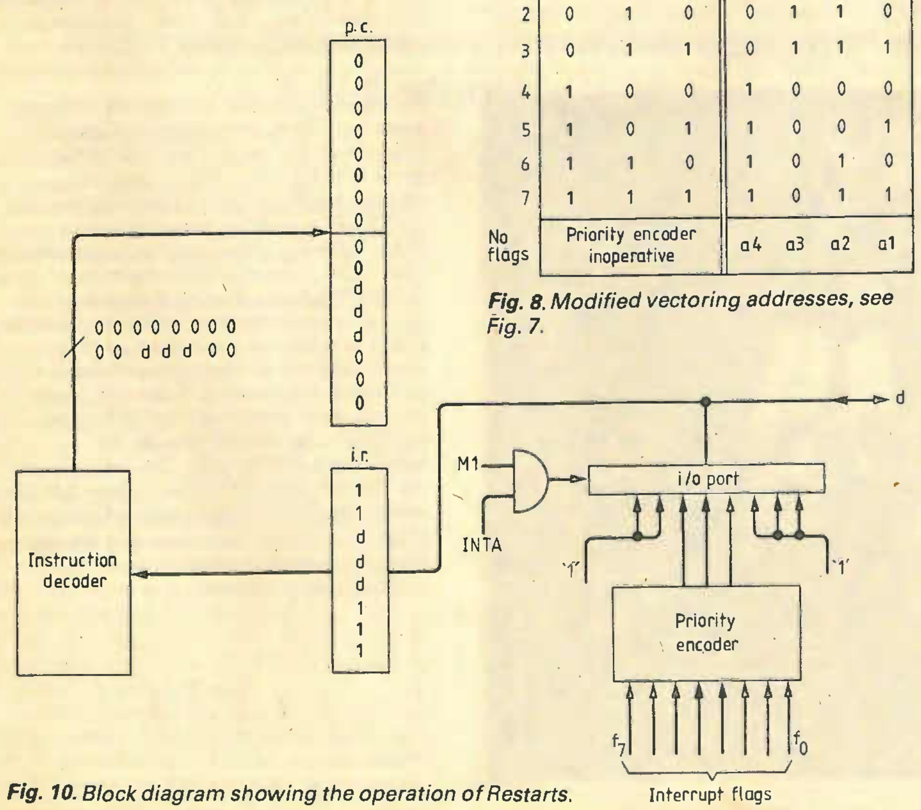


Fig. 10. Block diagram showing the operation of Restarts.

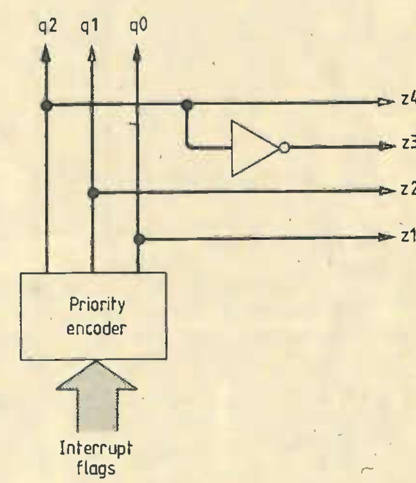


Fig. 9. Practical circuit for modifying address signals as shown in Fig. 7.

NEWS OF THE MONTH

Electronic detection of meteors

Two young avionics engineers, armed with a keen interest in astronomy, plus material help from their company, are making a contribution to an international scientific experiment this August, involving a comet which appears once in every 119 years. David Fosberry BSc, 25, Project Engineer with Marconi Avionics Limited and his partner Joe Cardwell, 22, Development Engineer, have designed an electronic detection instrument, the first of its kind, which can tell the presence of meteors and count them automatically.

The new Electronic Meteor Detection System (EMDS) is to be used as part of an international experiment, organised by the Meteor Section of the British Astronomical Association. Known as Project Perseid, it involves studying the appearance of the Perseid meteor stream, which is associated with the comet known as Swift-Tuttle 1862 III, recorded only once before and due to reappear this year.

The EMDS has been designed to meet the requirements of Europe's largest amateur group for meteor observation, the South Downs Astronomical Society, whose President, celebrated astronomer and broadcaster Patrick Moore, is taking a personal interest in the Project.

The South Downs Astronomical Society's 80 members are combining their efforts to observe the comet and its many thousands of rapidly-moving meteors, as their paths cross the earth's orbit. In addition to the new electronic means of detection, the Society is using visual observation and photographic methods, to gain important information about the behaviour of meteors, which can yield a better understanding of the nature and origin of the solar system itself.

The two Marconi Avionics engineers, and some 20 other young scientists from schools and universities, are travelling with the South Downs team to the Aubrac mountains in the Massif Central of France, where, at an altitude of 1200 metres, the best possible conditions will be obtained for their observations. Data will be acquired by the Society's team from late July until mid August, when the number of meteors is expected to be at a maximum.

Usually, meteors are observed by eye, as brief streaks of ionised gas, radiating in all directions, as if from an invisible point. Projecting the tracks back towards their apparent source, (known as the "radiant"), indicates which meteors are of the Perseid stream. To aid the human observers, an "all-sky camera" system is used and it is with this that the new electronic equipment is associated.

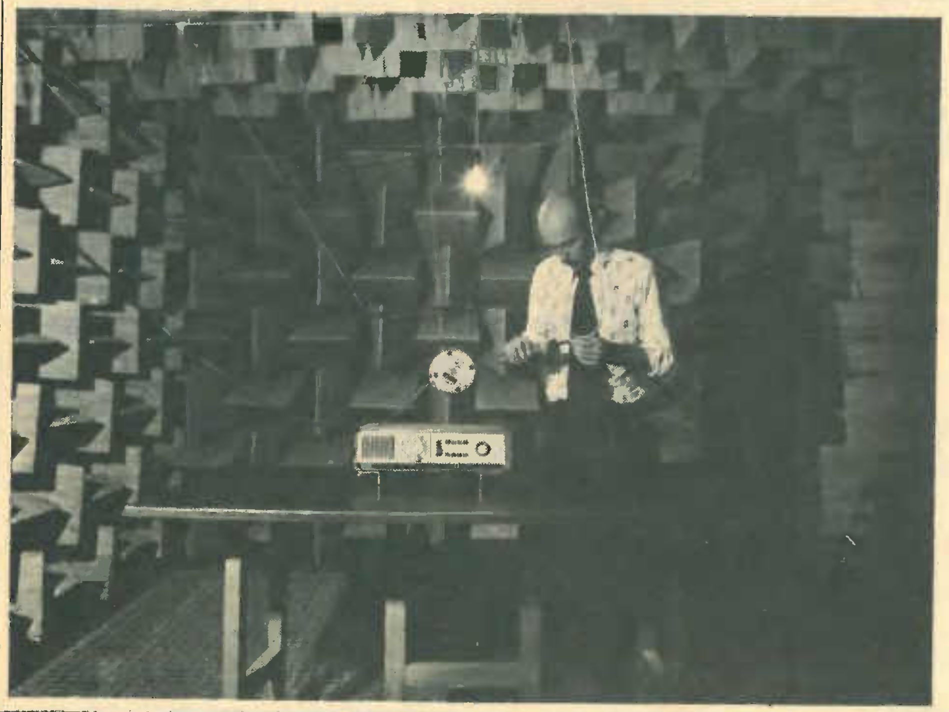
The EMDS responds to the transient streaks of light which characterise part of each meteor's path. The relatively constant background light from stars and planets is cancelled out automatically and an electronic tally is kept of the total number of meteors, together with the times between each occurrence, to an accuracy of 10 msec (one hundredth of a second). All the human observer has to do is detect which are Perseids and which emanate from other sources. The results will help to determine whether or not the Perseid meteors are occurring at random and if dense "knots" of more recent material are present in the stream – questions of particular importance to the better understanding of comets and their meteors.

About the size of a small shoe box, the EMDS is the first automatic meteor counting equipment to be built, and its use is expected to encourage the more widespread use of electronic detection and counting techniques among amateur astronomers everywhere. The new unit is to undergo official trials at the South Downs Astronomical Society's Observatory site on the Trundle, Goodwood, near Chichester, before being taken to France.

UK satellite broadcasting company formed

Following the Home Secretary's approval for an early start to satellite broadcasting in the UK (in the recent Home Office Study – News, July issue), a British company, probably the first of several, has been formed to provide the hardware for this new medium. Called the Satellite Broadcasting Company, it has been formed jointly by N. M. Rothschild, the merchant bankers, and British Aerospace, who are already involved in the construction of satellites. The new company plans to produce and launch satellites capable of transmitting programmes on two channels. These will be modified versions of the ECS – European Communications Satellite (see *Wireless World*, December 1978), a satellite which is similar to the OTS2 now in operation which is manufactured by British Aerospace Dynamics Group for the European Space Agency.

The project is still subject to official approval and plans need to be worked out in detail. It is thought that the minimum time before such a system became operational would be five years. To receive the broadcast in the home a one-metre dish antenna would be needed which with the associated electronic equipment could add £200 to the price of a tv receiver. Community receiving stations with cable distribution to homes is another possibility.



When one considers that British Telecom spends millions of pounds each day on equipment for installation, it becomes apparent that they need to keep close quality checks on what appears to be very mundane apparatus. Here the sound output is being checked on a loudspeaking telephone in the anechoic chamber of British Telecom's Quality Assurance laboratories in Islington, London. Facilities at the laboratories include an artificial mouth and ear for testing telephones, a photometry laboratory for testing lamps ranging from those used for industrial lighting to the miniature bulbs for telephone switchboards. The laboratories are listed by the British Calibration Service and carry out calibration tests on electrical measuring equipment, including testing, servicing and calibrating some 4,000 oscilloscopes each year.

New Quad electrostatic loudspeaker

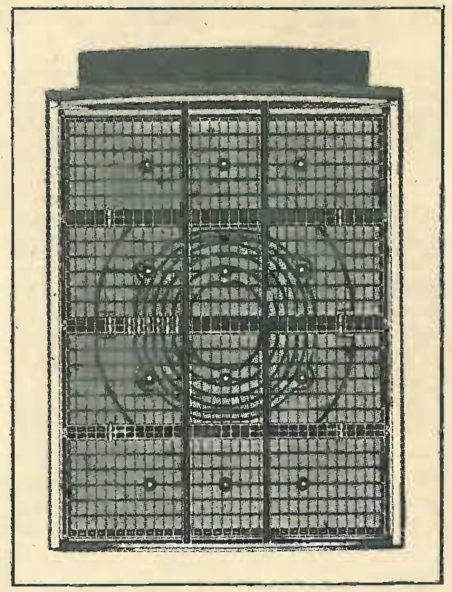
For many years, whenever one read a review of a new loudspeaker, the 'standard' speaker used in a/b comparisons was always the Quad ESL. Now Quad have announced the ESL-63 (named because development began in 1963) known to its engineers as FRED (full range electrostatic doublet).

Peter Walker postulated that if a very light diaphragm could be made to reproduce the air particle motion found at an imaginary plane some distance from, and normal to the direction of propogation from a theoretical ideal source, the result to the listener would be the same as if he were hearing that ideal source. The Quad ESL-63 achieves this by means of a very light electrically polarised diaphragm suspended between two sets of rigid and acoustically transparant (they have hole in them) concentric annular electrodes to which the signal is fed through sequential delay lines. The sound pressure pattern produced is a replica of that from an ideal source placed some 30cm behind the plane of the diaphragm. The motion of the diaphragm is roughly analogous to the wave motion which results when a stone is dropped into a still pool.

This configuration, says Quad, gives the designer complete control over the directivity of the loudspeaker. As a dipole with a figure-of-eight dispersion pattern, there is no radiation in the plane of the diaphragm and the ratio of direct to reflected sound is much higher than from an omni-directional source so there is a great improvement in the localisation of the stereo image.

Visually the ESL-63 is a great improvement over the old ESL and does not look like a room heater. It has a height of 92.5cm and a width of 66cm. The depth of 27cm includes the base containing all the electronics. It requires an ac mains supply.

The nominal resistance is 8Ω and this is almost purely resistive. It has a sensitivity of 1.5μbars/V referred to 1M, which is 86dB/2.83Vrms. The maximum input is 10Vrms continuous, 40V for undistorted maximum peak output with a maximum permitted peak input of 55V. The maximum output is $2N/m^2$ at 2m on axis. The bandwidth with reference to −6dB limits is 35Hz to over 20kHz. It is expected that the ESL-63 will be sold at £1,000 a pair.



The Quad ESL-63 Electrostatic Loudspeaker with the grille cloth removed. The concentric annular electrodes which 'spread' the sound pressure pattern across the diaphragm can be clearly seen.

Microprocessors and product design – a self-study course

The Open University is now offering a new self-study course for engineers and designers on microprocessors and product design.

It shows how to use microprocessors in product design and covers the complete sequence from customers' specification to final design stage.

Microprocessors and Product Design: A course for Engineers does not assume or require previous knowledge of microprocessors and involves between 60 and 70 hours study.

It comprises five books specially written for self-study; a file of date sheets and technical literature; a fully assembled microcomputer system based on the Intel 8085 microprocessor with full alphanumeric keyboard which interfaces with students' own tv sets and cassette recorders; a prototype development board to be driven by the microcomputer in various configurations; a user manual for the microcomputer and an experiment book containing practical work. The course fee is £395. There are no tv broadcasts or tutorials, so allowing students to fit study in as best suits them.

The course follows through the complete design sequence for microprocessor-based products: customer specification; overall system design; hardware and software development; prototype evaluation and production design. Case studies are brought in to illustrate points made and short self-assessment questions allow students to check progress.

The experimental work does not have to be done at the same time as reading the texts. The initial experiments familiarise students with use of the microcomputer and peripherals, while later ones follow the design sequence for a microprocessor-based product.

The course follows an earlier one from the Open University aimed at managers to give them insight into how the process of product development is affected by microprocessors. This was bought by 3,800 managers drawn from all industrial sectors. A survey showed that students on average passed on the course to five colleagues and found it to be relevant and of high quality.

The course is written by microelectronic experts at the University and is funded by the Microprocessor Application Project of the Department of Industry.

For course details and order form, write to MPO, Centre for Continuing Education, The Open University, PO Box 188, Milton Keynes, MK3 6HW or telephone 0908 79058 (24-hour service).

Viewdata oils capital's wheels

Stockbrokers in the UK can now turn to electronics to speed up the transmission of financial information to their clients and so compete more effectively with their business rivals. A private viewdata service set up by a new company, Videotex International Ltd, will enable them to send pages of textual information, such as share prices, company news, commodity prices and research material, to any client equipped with a standard viewdata terminal of the type used by the Prestel public service.

This development, the first of its kind, is in fact an extension of a large private viewdata system already in use at the London Stock Exchange. Called Topic (Teletext Output of Price Information by Computer) it presents the latest stock market prices on 1500 stocks and shares and also company announcements, exchange rates, interest rates and commodity prices. But Topic is a one-way system, providing information only to members of the Stock Exchange. To enable its stockbroker members to send private information to their clients, the Stock Exchange is now allowing them to become providers as well as recipients of information. They will be able to create and maintain, in the Topic database, their own pages of information specifically compiled to suit the needs of their clients. They can also specify precisely the recipients of this information. These can be individual clients or groups of clients, and groups with common interests can be members of a "closed user group" – a concept already pioneered by the British Telecom for Prestel. By the end of 1981 the Stock Exchange expects to have about ten such information providers.

To make use of this new facility, stockbrokers can apply directly to the Stock Exchange's technical services department or they can become a "sub information provider" to an already established information provider. This second alternative means joining a viewdata service bureau – which is what the new company Videotex International is offering, from a room within the London Stock Exchange. Formed by Hambros Bank, Modcomp (who provided the Topic computer) and Telemachus (makers of editing and other equipment), the company undertakes consultancy, database design, training and the supply of hardware, but, perhaps most important, it offers a variety of methods by which stockbrokers can feed in their pages of textual information. These range from filling in forms, through supervised and unsupervised editing, to the use by a stockbroker at his own premises of his own editing terminal, which can either be connected on-line to the bureau's database or be operated off-line, working into a local magnetic disc store. In the off-line case the contents of the disc store can be transferred in bulk either directly to the Topic database or to the bureau's database.

In introducing the service, Harry Fitzgibbons, a director of Hambros Bank, claimed that one advantage of viewdata type information systems over earlier data processing systems was the familiar appearance of the viewdata terminal. In the past businessmen had been somewhat repelled by the "high technology" appearance of computer terminals, but because the viewdata terminal was superficially the same as a domestic television set – and indeed could be used as such – they felt much more comfortable with it in their offices and more ready to operate it themselves.

Recharging dry batteries

With a flourish on trumpets Fidelity have announced their new portable radio, The Battery Saver, which runs on an ordinary PP9-type battery or from the mains. When connected to the mains, an automatic battery charger operates and continues to do so even if the set is switched off. Fidelity claim that the battery will last four times as long and that the radio would almost pay for itself in the cost of batteries over a five-year period.

Recharging Leclanche cells is a subject which has recurred many times; as long ago as 1953 *Wireless World* published an article by R. W. Hallows on 'Reactivating the dry cell'. In 1955 we published a description by the same author of the Elektrophoor reactivator. This used a half-wave rectifier with a resistor in parallel to provide 'dirty' dc and proved to be very successful in redepositing the zinc in the cells. In a follow-up article in 1958, Mr Hallows reported: "One's biggest surprise on opening the can of a cell which has been many times discharged and subsequently reactivated by the Elektrophoor is to find as a rule no trace of lumpy or spongy deposits, but a hard, even inner surface. The superimposed ac (on the dc recharging supply) not only produces this most desirable result, but also speeds up the process of depolarisation and makes it more complete." The Elektrophoor was the invention of a Dutch engineer, Mijnheer Beer.

An Ever-Ready spokesman has told us that their PP9 batteries can be recharged as long as they are not discharged by more than 10 to 15% and as long as the charging current is very carefully controlled. Any overcharge would lead to the production of gases which would lead to the layers of the battery being forced apart giving a very high internal resistance or open circuit within the battery. The circular leakproof batteries (with which Mr Hallows was so happy in the 1950's) are very well sealed and any production of gas inside could lead to a build-up of pressure and a possible explosion with the central carbon rod becoming a lethal weapon. The Spokesman also pointed out that the idea was not original; Telefunken have produced equipment which recharged its batteries, but the round cells were chosen and the equipment was withdrawn from the market very rapidly. Cinema usherettes used to hand in their torches after their shift to have the batteries recharged. That was thirty or forty year ago. He doubted that the Fidelity radio would be as successful as was claimed. Fidelity assume that the set would normally be used on the mains with occasional use at different locations when powered by the batteries. Ever-Ready surveys showed that portable sets were mostly used on battery power.

The Fidelity Battery Saver portable radio set which incorporates a battery charger for the dry cell battery.

After the crash

When a mammoth corporation crashes a lot of the dependent companies are affected and in the case of Rank many offshoots, some of them older than the Rank corporation were involved. We have heard that the Bush Radio brand name has been acquired by Interstate Electronics, who market radios, cassette players and electronic clock-radios manufactured in the Far East. They have changed their company name to Bush Radio but will continue to market their existing product ranges under the Insterstate label.

Following the closure of Rank-Toshiba, their Plymouth factory for the production of tv receivers is to be re-opened by Toshiba Consumer Products (UK) Ltd. The company is operated through Toshiba (UK) Ltd, the British-based marketing company of the Toshiba Corporation. The company has recruited its employees almost entirely from former Rank-Toshiba personnel.

Meanwhile one of the surviving branches, Rank Hi Fi, have appointed a new research and development manager, Mr Ken Russell, who will be responsible for co-ordinating all research at Wharfedale, the loudspeaker manufacturers, and at Heco, the West German sister company.

Mr Russell will also be in charge of speaker development and new product co-ordination for the Rank Hi Fi group.

Ken Russell, newly appointed research and development manager of Rank Hi Fi.

News in brief

Technomatic has opened a new retail shop at 305 Edgware Road, London W2 in the centre of 'component land'. At the same time they have become an official distributor for the Texas Instrument range of components.

End of public broadcasting now in sight? is the provocative title of the Royal Television Society's Convention to be held in Cambridge, 17-20 September 1981. The Convention will examine the transformation of broadcasting which is already under way. The upheaval resulting from satellite transmission, cable distribution and home video is likely to have a profound effect on the course of broadcasting. The convention will also consider the financing of broadcasting, the effect of the fourth channel and will take a look at the broadening of television access and relate this to the work of the new Complaints Commission. Details are available from the Royal Television Society, Tavistock House East, Tavistock Square, London WC1H 9HR.

Wilmslow Audio who supply loudspeakers and kits for loudspeaker designs, have moved to new premises at 35/39 Church Street, Wilmslow, Cheshire SK9 1AS. Telephone: 0625 529599. One of their latest offerings is a range of Wharfedale kits, the E50, E70 and E90. The kits are supplied with all panels accurately cut to size and the baffle boards have the necessary speaker apertures cut and rebated as required. All the available kits are on demonstration at the new location.

When a home computer becomes popular enough, its users get together to form a users club to exchange experiences, share programs and news. The **ZX80/ZX81 Users' Club** is an independent user group for those who have a Sinclair computer. The club caters for all types of user from the beginner to the more experienced user who may wish to expand his system. There is a regular newsletter containing articles on basic computing, various aspects of computing and hardware. There is a 'software bank' to provide software to members at minimal cost. The club provides technical support for its members. The address of the club is PO Box 159, Kingston upon Thames, Surrey KT2 5UQ.

Zilog have announced another of the Z series of microprocessors. The **Z800** is an 8-bit microprocessor which is code compatible with the Z80 and includes multiply and divide instructions, a three-times performance improvement over the Z80A, it is available in 8- or 16-bit bus versions and includes an on-board memory mapper for addressing up to 4 megabytes of memory. The Z800 will be available in mid-1982.

Inmos are ready to sell

Described recently in the *Guardian* as the world's biggest venture capital operation, Inmos have announced that they have appointed Rapid Recall and Hawke Cramer to distribute its products in the UK. At the same time they have launched the Inmos IMS1400 a 16K × 1 static r.a.m.

The IMS1400 has 45ns access time and a maximum power dissipation of 660mW, which allows for high-density packing. It is the first commercially available product, claims Inmos, to incorporate redundancy, allowing the replacement of memory cells. Currently manufactured in the US, European production of the IMS1400 will commence in the large scale 'manufacturing facility' due to go into operation in Newport, Gwent in mid-1982.

Considering that £50 million of public money has been spent to set up Inmos, we wish it all success.

Is radiation resistance real?

A real resistance produces thermal noise and absorbs power, but does radiation resistance? And why does it depend on the ratio of aerial size to wavelength?

by D. A. Bell, F.Inst.P., F.I.E.E.

One is tempted to think of resistance as being a property of resistors, the latter being typified by lengths of wire of high resistivity, thin films of carbon or metal and suitable bodies of high-resistivity material like carbon, germanium or silicon. But resistance can be more generally defined either as "that element of a circuit which absorbs power" or as "that element of a circuit which is the seat of Johnson (thermal) noise in accordance with Nyquist's theorem". These two are in fact equivalent, because there is a "fluctuation-dissipation" theorem which says that everything which is capable of dissipating energy will exhibit the fluctuations which we call thermal noise.

Johnson noise

Look first at the second criterion, the Johnson or thermal noise, which in material resistors is often described as the Brownian motion of electrons. This is particularly appropriate to receiving aerials. Starting with the work of Lorentz[1] using classical physics and continuing with Bakker and Heller[2] using quantum mechanics, it was possible to show that the application of established kinetic theory of gases to the conduction electrons in a metal leads to the well-known relations between mean-square noise voltage or current and resistance or conductance:

$$V^2_{\mathrm{df}}=4RkT\mathrm{d}f \qquad (1a)$$
$$I^2_{\mathrm{df}}=4GkT\mathrm{d}f \qquad (1b)$$

Here V^2_{df} or I^2_{df} is the mean square of the random (noise) voltage or current within bandwidth df, R or G the resistance or conductance involved, T the absolute temperature and k Boltzmann's constant. The equations 1 give the mean-square voltage or current components in a narrow frequency band df. A fact which is most easily derived by the mathematical technique of contour integration of a complex variable is that the mean-square of the total voltage or current (including components of all frequencies from zero to infinite frequency) is

$$V^2_{\mathrm{tot}}=kT/C \qquad (2a)$$
$$I^2_{\mathrm{tot}}=kT/L \qquad (2b)$$

where C and L are the residual reactive components to which the circuit reduces at infinite frequency. Formula 2b was derived by Brillouin[3] from a theoretical investigation of the behaviour of conduction electrons in a metal. But radiation resistance arises from the launching of electromagnetic waves into space, so it would appear not to have any system of conduction electrons in random motion which could be the seat of Johnson noise.

One must therefore back-track to the origin of the idea of Brownian motion and follow a fresh track that leads eventually to Nyquist's derivation[4] of equations 1, which is independent of the internal mechanism of the resistance. The botanist Brown observed through a microscope that pollen grains suspended in water were in continual random motion. At the time there was controversy as to whether this was due to the pollen being alive, but we know now that it was not – given a sufficiently high power microscope the same effect occurs with a dilute suspension of Indian ink in water – rather it was due to collisions between the pollen grains and the molecules of water.

To take a simple case, suppose a quantity of mercury vapour is mixed with lighter gas, such as the nitrogen and oxygen of air. At equilibrium, how will the energy of the heavy molecules of mercury compare with that of the lighter molecules of gas? The answer given by statistical mechanics is that it will be the same, and that every object of whatever mass or nature will have an average energy (in thermal equilibrium) of ½kT per degree of freedom*. This rule is equally true of gas molecules, suspended particles, larger mechanical systems and electric circuits. As an example of a large mechanical system Kappler[5] made a torsion pendulum by suspending a small slip of silvered glass on a quartz fibre. The angular movement of this mirror corresponded to a mean energy kT and could be explained by the unequal random bombardment with air molecules of different parts of its surface. So would the effect be eliminated by suspending the mirror in a vacuum? Reducing the pressure to 4×10^{-3} atmosphere altered the waveform (because the reduced damping led to sharper resonance) but did not alter the total energy. If the system were perfectly evacuated, the mirror could still receive thermal energy via its suspension, or in the last resort by radiation pressure on it. The point of this last suggestion is that as long as a system is *observable* it must by definition be able to exchange energy in some form with its surroundings.

Then at the beginning of the century Lord Rayleigh[6] suggested in connection with black-body radiation that a box full of radiation would have a number of degrees of freedom equal to the number of modes of standing wave which could be established in it. (This led to prediction of the "ultra-violet catastrophe" and to the introduction of quantum theory.) In due course Nyquist adopted the similar idea that the number of degrees of freedom of a transmission line was determined by the number of standing-wave modes which it will support, and matching the characteristic impedance of the line to a resistive termination then leads to equations 1. A slightly modified version of Nyquist's derivation is given in Appendix 1. The important point is that as this only depends on matching R to the Z_0 of the transmission line, anything which behaves circuit-wise as a resistance will satisfy the equation, regardless of its internal mechanism.

Thinking of a receiving aerial, from Nyquist it need only appear circuit-wise to have a resistance, e.g. as seen from impedance measurements at its feeder terminals. Secondly from general equipartition theory the noise power in that resistance will depend on its exchange of energy with the outside universe. For example, if the aerial of a satellite ground station is pointed at an empty region of space (empty meaning a region which does not contain any distinguishable radio sources) the temperature of the radiation resistance will be very low; but if it is pointed very near the horizon its temperature will be approximately that of the earth's surface or atmosphere. (At lower frequencies it is customary to add in various forms of interference from thunderstorms etc. by attributing a higher equivalent temperature to the radiation resistance.)

* In case the concept of "degree of freedom" causes difficulty, the number of degrees is equal to the number of co-ordinates which must be specified to define the motion of the object or system. A spherically symmetrical body – the idealized monatomic gas molecule – has three degrees of freedom corresponding to the x,y and z components of motion. An harmonic oscillator has two degrees of freedom corresponding to the amplitude of oscillation and the speed with which it passes through the point of zero displacement, or to the voltage and current in an electrical resonant circuit.

Biographical details of Professor Bell appeared in the January issue, page 60.

Absorption of power

For the radiation resistance of a transmitting aerial one can use the alternative definition: that element of a circuit which absorbs power. It is then said that if r.m.s. current i flows in an aerial of radiation resistance R_r to radiate power W, then $i^2R_r=W$. There are then two methods of calculating R_r when the geometry of the aerial is known.

The first, the Poynting vector method, is to calculate the field from a given current and hence the power density at all points on a sphere surrounding the aerial, and so by integration of the power density over the surface of the sphere to find the total power radiated. The mathematics is tedious, but radiation resistance is usually proportional to the square of h/λ where h is the length of aerial and λ the working wavelength: for a straight wire with $h \ll \lambda$, $R_r=80\pi^2(h/\lambda)^2$.

The second method is to calculate the in-phase e.m.f. which is induced in all parts of the aerial by its own current. In many practical cases this also involves mathematical complexity, but a circular loop can provide a simple example which gives some insight into the reason for R_r depending on the ratio of size of aerial to wavelength. In the figure a current $i=i_0 \sin(2\pi c/\lambda)t$ is supposed to circulate round the loop, having the same phase at all points. The magnetic field adjacent to dl' but due to the current in dl will be delayed by the time taken for it to travel between the two points and so will be slightly out of phase with the current in dl'. If there were no delay the e.m.f. induced in dl', proportional to the rate of change of magnetic field, would be exactly in quadrature with the current and the effect would be described as inductive; but the delay produces an in-phase component, which results in power dissipation and so is resistive. That is why all aerial systems have a radiation resistance which is a function of the ratio of aerial size to wavelength.† The mathematical evaluation for the circular loop leads to $R_r=20\pi^2(2\pi a/\lambda)^4$, Appendix 2.

The radiation resistance of an aerial is, of course, the same for both transmission and reception. It satisfies both the essential criteria of a "real" resistance, namely that it is the seat of Johnson noise and it absorbs power. Radiation resistance is therefore a real resistance in the same way, for example, as the high-frequency loss resistance of an air-cored inductor (largely due to eddy currents) or the loss resistance of a capacitor. Both of these resistances, like radiation resistance, vary with frequency. Resistance is a circuit concept which can be applied to anything which satisfies the two criteria of fluctuation and dissipation.

† The constancy of phase of the current around the loop might be questioned, but it is not essential. If the magnetic field at dl' is not later than the current at dl', because of the time taken for current to travel round the loop between the two points, then conversely the magnetic field at dl due to current in dl' will be still further behind the current at dl; and provided the effects are small, which follows from postulating that $a \ll 190$, the overall effect will be the same as though the current were in constant phase.

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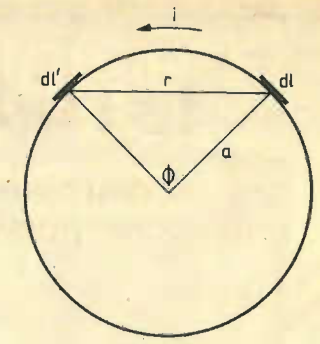


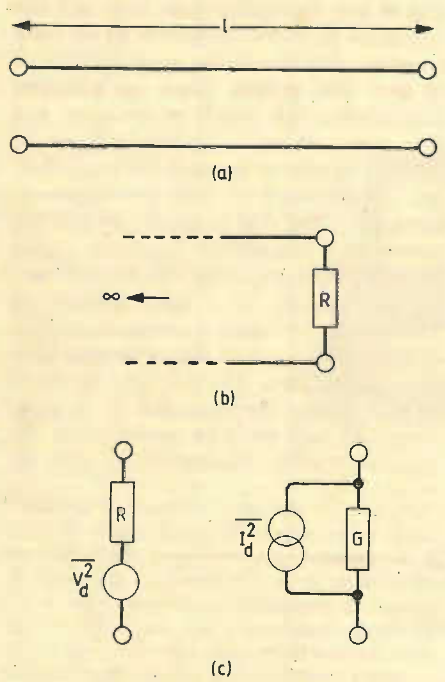
Method of calculating radiation resistance for simple circular loop aerial assumes uniform current. Interaction between elements dl and dl' is calculated and then extended to the whole periphery by integration in Appendix 2.

Appendix 1: Nyquist's transmission line

Figure (a) represents a loss-free transmission line of finite length l, open-circuited at its ends. This will support a standing wave of every wavelength such that l is an integral multiple of $\lambda/2$, and the number of such within a narrow frequency band df is $2ldf/c$ where c is the velocity of propagation. Each standing wave, like a harmonic oscillator, has two degrees of freedom and therefore mean thermal energy kT. The energy per unit length of line is then $2kTdf/c$. This is the resultant of two travelling waves moving in opposite directions with velocity of propagation c and therefore carrying power $kTdf$ each. Now let the line be extended to infinite length, but cut at the position of the observer and the right-hand part replaced by a resistor R matched to the characteristic impedance Z_0 of the line. Because the termination is matched, conditions in the remaining half of the transmission line are unchanged. Therefore power $kTdf$ will flow along the transmission line into R and equal power must flow from R into the line. As indicated in figure (c) this can be represented by combining with a noise-free resistor or conductor a voltage or current generator having the respective values

$$V_{df}^2=4RkTdf$$
$$I_{df}^2=4GkTdf.$$

This treatment departs slightly from Nyquist's original derivation.



Nyquist's formula for Johnson (thermal) noise is deduced from consideration of standing waves on a transmission line.

Appendix 2: Radiation resistance of small circular loop

The e.m.f. induced in an element dl will be obtained from the magnetic vector potential **A** at that point according to

$$-e=-\mathbf{E}\,.\,\mathrm{d}\mathbf{l}=(\mathrm{d}\mathbf{A}/\mathrm{d}t)\,.\,\mathrm{d}\mathbf{l} \qquad \text{(A1)}$$

where a negative sign has been added on the left because the e.m.f. is opposed to the current. (Bold-face type is used for vectors and $\oint$ means "integral around the circle".) If the current in the loop is $i=i_0\exp j\omega t$ equation A1 leads to

$$e=j\omega i_0\exp j\omega t(\mu/4\pi)\oint\oint\frac{\exp(-j\omega r/v)}{r}\mathrm{d}\mathbf{l}\,.\,\mathrm{d}\mathbf{l}' \qquad \text{(A2)}$$

where the double integration around the loop arises as follows. First find the e.m.f. in $\mathrm{d}\mathbf{l}'$ due to current in dl and integrate dl' round the circle to find the total e.m.f. due to current in dl; and then integrate dl round the circle to find the total effect for the whole of the current. The part of e which is in phase with the current is the real part of equation A2, but because of the initial j this comes from the imaginary part of the integrand, replacing $\exp(-j\omega r/v)$ by $-\sin(-\omega r/v)$. Now expand the sine as a series of powers of $\omega r/v$ and discard the first power because division by r will make it constant and $\oint\oint \mathrm{d}\mathbf{l}.\mathrm{d}\mathbf{l}'\equiv 0$. The cubic term is then the leading term and

$$R_r=e/i=\frac{\mu}{4\pi}\oint\oint\frac{\omega^4r^2}{3!v^3}\mathrm{d}\mathbf{l}\,.\,\mathrm{d}\mathbf{l}' \qquad \text{(A3)}$$

Now from the geometry shown above $\mathrm{d}\mathbf{l}\,.\,\mathrm{d}\mathbf{l}'=\mathrm{d}l\,\mathrm{d}l'\cos\phi$, $\mathrm{d}l'=a\mathrm{d}\phi$ and $r=2a\sin\phi/2$. Substituting these expressions in equation A3,

$$R_r=\frac{\mu}{4\pi}\frac{\omega^4}{3!v^3}\int_{l=0}^{2\pi a}\int_{\phi=0}^{2\pi}4a^3\sin^2(\phi/2)\cos\phi\,\mathrm{d}l\,\mathrm{d}\phi \qquad \text{(A4)}$$

Remembering that $\omega/v=2\pi/\lambda$ and μv is "the intrinsic impedance of free space" which equals 120π, equation A4 evaluates to $R_r=20\pi^2(2\pi a/\lambda)^4$.

Correlator for angles

Measures rotary effects such as timing scatter in vehicle ignition

by T. Spencer, B.Sc.(Eng.), M.Sc.(Eng.), M.Sc., M.I.E.E.

This digital correlator, operating by the coincidence of pulses representing angles of rotation, gives the instantaneous cross-correlation between a selected and a measured angle and also its frequency of occurrence. It can be used for checking timing scatter in automobile ignition systems, but is also suitable for converting a continuous electronically scanned omnidirectional surveillance radar receiver into one with a variable scanning rate.

Engineers may wish to compare the performances of automobile ignition systems under laboratory and field conditions in order to select the best system. This might be done, for example, before applying closed-loop control to engines to optimize performance and efficiency under variable load and environmental conditions while minimizing exhaust emissions. Doubts have been expressed about the reliability and consistency of spark ignition at some specified angle of advance and it would seem reasonable to expect a spread in the ignition time, particularly when using the conventional mechanical ignition system. The elimination of spring-operated point contacts, with their inherent contact bounce, high erosion rate, variation of dwell time with speed and other characteristics of the cam-operated mechanical switch, including backlash, friction and wear, should reduce the probability of spread in the ignition time. A high degree of consistency in ignition time can therefore be expected from electronic ignition systems not using mechanically operated contacts.

Because of the statistical nature of the problem, a measure of the spark scatter about a modal value can be obtained by cross-correlating the firing angle with a selected angle (i.e. summing the product of their instantaneous values with time) to produce an angular frequency distribution. This could be defined in terms of the standard deviation, if a theoretical distribution can be determined from the measurements at a given speed. The system having the greatest frequency at the nominal, or modal, angle will have the smallest standard deviation or spread, determined by counting (or integrating) the cross-correlator output over a range of angles about the modal value. By selecting the most suitable ignition system on this basis, the type of distribution associated with it could be determined, to give a suitable performance criterion.

Cross-correlation

The principle of the correlator used in this technique is as follows. Two independent inputs $j(t)$ and $i(t)$ are applied to a coincidence circuit or AND gate, whose output $K(t)$, a function of their product, is then summed over a time T. A continuous train of such outputs may be formally stated as:

$$R_{ij}(\tau)=\lim_{T\to\infty}\frac{1}{T}\int_0^T j(t)i(t+\tau)\mathrm{d}t$$

a cross-correlation function. τ is an arbitrary time delay between the two inputs, which for reasonable co-incidence, may be considered to be zero.

If $j(t)$ and $i(t)$ are known and unknown inputs corresponding respectively to a selected three-digit encoder output and a test pulse (e.g. an internal combustion engine spark ignition pulse at a preset or required angle of advance) the output $K(t)$ or $R_{ij}(0)$ after summing (counting or integrating) over a finite time, equals the frequency of $i(t)$ when coincidence is perfect. This process of cross-correlation is effected in Fig. 1 by the two-input NAND gate with waveforms (j) and (i) in Fig 2 applied to it. After inversion, its output (K) is eventually summed in a digital counter as a measure of the frequency of the ignition trigger or test pulse (i).

The digital correlator

In Fig. 1, a train of 360 equally-spaced pulses per engine revolution, independent

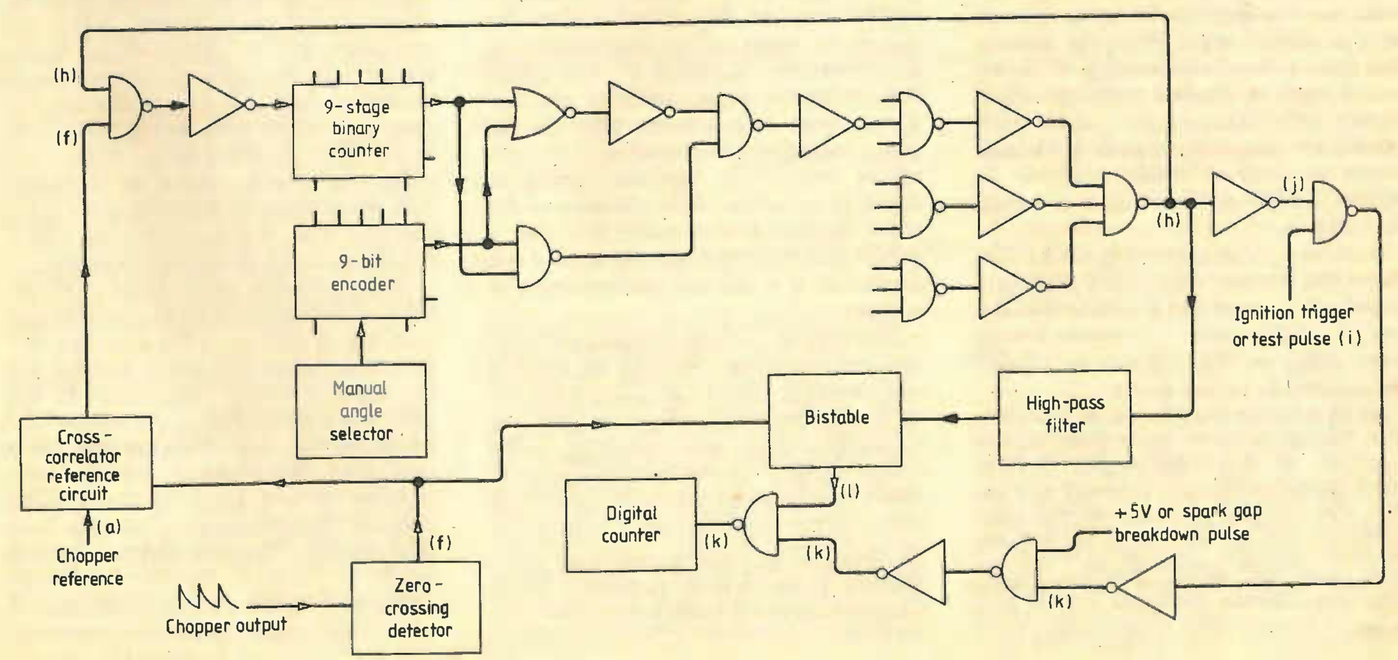


Fig. 1. Schematic of a cross-correlator channel. Waveforms at the reference points (a), (b), (c) etc. are shown in Fig. 2.

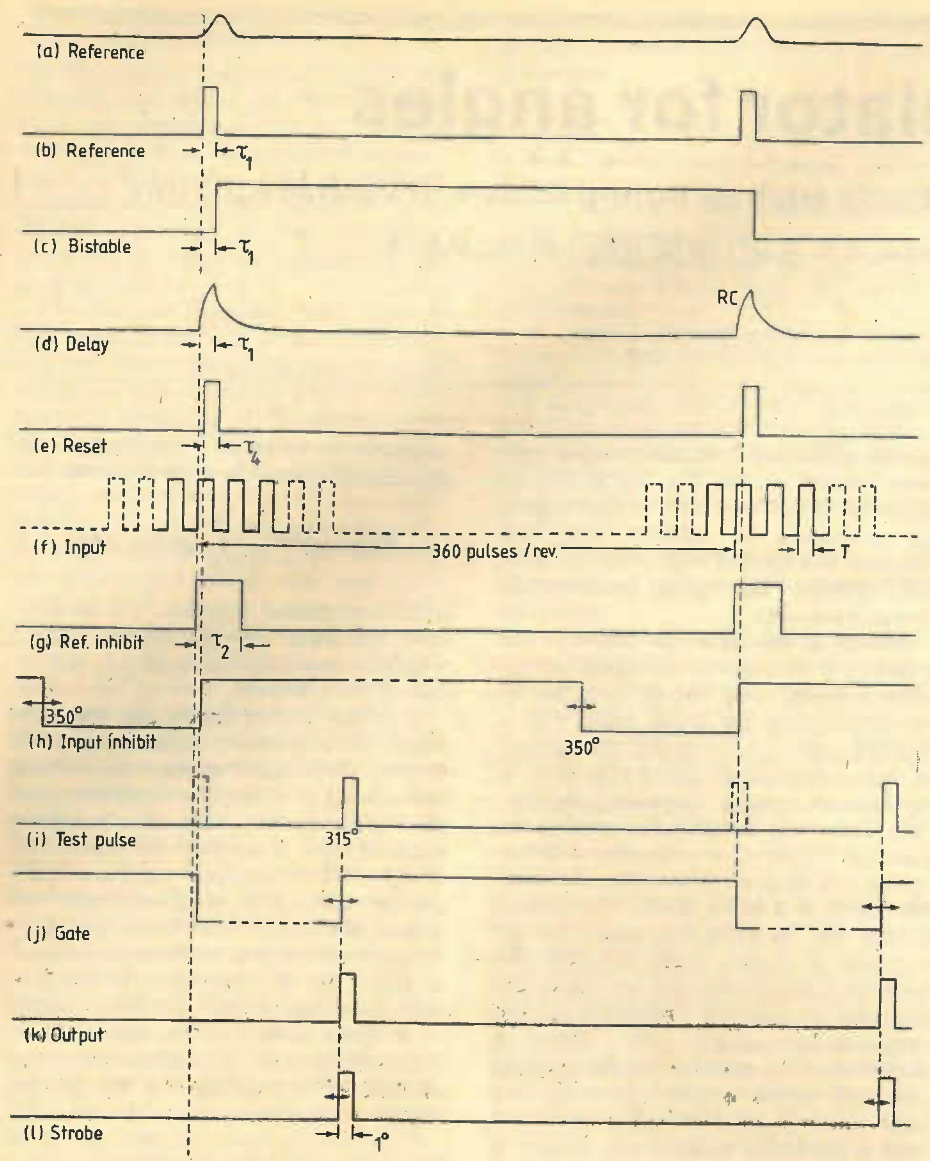


Fig. 2. Waveforms of the cross-correlator indicated by reference letters in Figs. 2 and 3.

of speed, is applied to a 9-stage counter used as a comparator for a 9-bit binary word. Corresponding collectors of each comparator stage are simultaneously applied to one input of nine two-input NAND and NOR gates in parallel. The second inputs of these accept from an encoder one of nine bits defining the selected word or ignition angle. When the comparator input pulse corresponding to the required angle of advance produces simultaneous coincidence at each of the nine parallel two-input gates, each NOR gate output is inverted before enabling its parallel NAND gate output at a second NAND gate.

Reference to the respective truth tables shows that whether coincidence is positive or zero, this second gate is inhibited with a positive output using t.t.l. circuits for positive logic; in the absence of parallel coincidence, its output is zero.

At coincidence the nine respective positive channel outputs are applied simultaneously to three three-input NAND gates whose outputs are inverted and applied to a single three-input NAND gate. Its output inhibits the comparator input pulse train and, when inverted, simultaneously enables a two-input NAND gate to which is applied the trigger pulse of the ignition system being tested. At coincidence, its output defines the instantaneous angular cross-correlation.

By counting these angular outputs, the average cross-correlation is obtained, that is, the angular frequency. If coincidence occurs within the 1° resolution, correlation will be complete. Any spread in either the instant of triggering or, alternatively, of gap-breakdown exceeding 1°, will reduce the correlation below 100% or the frequency from its maximum value. the degree of correlation or frequency of the correlator output at constant speed is therefore a measure of the efficiency of the spark ignition system under test over a period long compared with the time of one revolution at a selected ignition angle of advance.

Although the output frequency defines the cross-correlation between the selected and measured angle of advance, if the latter was the angular trigger pulse, then the correlator output, after inversion, could enable another two-input NAND gate to which is applied the spark-gap breakdown pulse, thereby simultaneously cross-correlating the ignition system trigger and gap-breakdown pulses with the selected angle. Provision is actually made for this in the correlator. The angular resolution is determined by the number of slots on an input chopping disc and is halved by using a zero crossing detector; for a 1° resolution, only 180 slots are required on the chopping disc.

The inhibit pulse cannot be used to reset the comparator, because in doing so, the comparator input will no longer be inhibited and counting will again begin immediately. The comparator must remain inhibited at the selected angle of ignition until a reference pulse resets it with monostable τ_3 in Fig. 3; the comparator reset pulse must be negative relative to the positive supply potential.

Since the comparator will begin counting pulses immediately the chopping disc begins to rotate, with only those input pulses following the reference pulse being significant, it will be necessary to inhibit any input pulses preceding it. In the system diagram of Fig. 3, the correlator input pulses from a zero-crossing detector are applied to a positive NAND gate (preceding the comparator input) which may or may not be inhibited by the bistable output Q. If Q enables the NAND gate, its output after inversion is simultaneously applied to the comparator and a 360-pulse counter, whose output using monostable τ_2 is applied to an Exclusive-OR circuit which will reset Q to $\overline{Q}$ and inhibit the positive NAND gate if 360 pulses are applied to it. Had this gate been initially inhibited, there would be no counter output to enable it with the Exclusive-OR and bistable circuits.

When a reference pulse from the chopping disc, using monostable τ_1, is applied to the Exclusive-OR input in the absence of a coincident counter output, it will trigger the bistable (on the trailing edge) and enable the NAND gate, if initially inhibited. Simultaneously the reference pulse, coincident with the 360th input pulse from the zero-crossing detector, reset the counter and comparator with a low-pass delay filter and monostable τ_3 before the next or first pulse of the sequence is applied to them; for the counter this is a precautionary measure since it resets itself at the end of the 360th pulse. At the 360th pulse, the counter output is coincident with and inhibits the reference pulse at the Exclusive-OR input, with the input NAND gate now permanently enabled.

If the reference pulse initially inhibits the correlator input NAND gate, then one complete revolution of the chopping disc will occur before this gate is enabled and the sequence begins. A maximum of less than two and a minimum of almost one revolution of the chopping disc will therefore be necessary for periodic selection of the required ignition angle of advance: if 360 pulses are counted after one revolution, selection will have already begun.

The 9×41 diode encoder matrix has 41 input angular position switches from 310° to 350° with 1.8 kΩ resistors connected across the +5V supply to ground at each of the nine encoder outputs. Each output is applied to an inverting buffer whose output is again inverted for enabling each of the nine parallel two-input NAND and NOR gates connected to the comparator collectors in Fig. 1.

The correlator operating waveforms are shown in Fig. 3. Waveform (h) is the output of the single three-input NAND gate used for inhibiting the comparator input of Fig. 2 and, when inverted, for gating the ignition trigger or plug gap-breakdown pulse in Fig. 1. Its trailing edge is locked to the encoder output, shifting to the left or right with the angular switch positions, and occurs at the instant the measured and selected angles are coincident. The leading edge occurs at reset, that is, at the leading edge of (e) inverted.

Waveform (i) is a test pulse obtained by locating a light source and detector at the 157th slot; an output is obtained when the reference aperture below the 180th slot passes through this position. This test pulse is amplified and gated by (h), inverted and shifted to 315° (j) at a two-input NAND gate whose inverted output (k) is applied to the final two-input NAND gate of the correlator, enabled by (l) to provide a direct measure of the disc speed.

By applying the derivative of (h) to the set (or preset) terminal of a J-K master-slave SN7472N flip-flop and (f) to its reset (or clear) terminal, a bistable output (l) 1° wide and independent of speed is available for strobing the final NAND gate of the correlator. This permits the frequency distribution of its output to be scanned at the 1° angular resolution of the correlator, instead of obtaining a cumulative distribution having a point of inflexion difficult to determine if (k) is gated by (j).

Input pulse generation

As the method of measurement depends on the amplitude of a pulse train the correlation between laboratory and field measurements should be good and independent of the respective prime movers for a constant angular resolution. The ignition systems being tested should also be independent of angular velocity perturbations, particularly when using different distributors and an encoder reference. The distributor automatic advance and retard mechanism could cause angular or timing errors because of velocity perturbations; their effectiveness should vary inversely with angular resolution. Variations in dwell and ignition timing through spring inertia and contact bounce, heel wear, points erosion and mechanical imperfections could be comparable with the timing over 1° at speeds approaching 3000 r.p.m., without being aggravated by velocity perturbations, which also affect the kinetic energy of the system.

To meet this requirement for constant speed, an electro-mechanical or velodyne speed control system, in which speed of rotation is held closely proportional to an input voltage by feedback methods, was used with a conventional six-way distributor and 7-in diameter, 180 slot, 0.25-in thick steel chopping disc coupled directly to the velodyne shaft (Fig. 4).

As the viscous friction damping in the

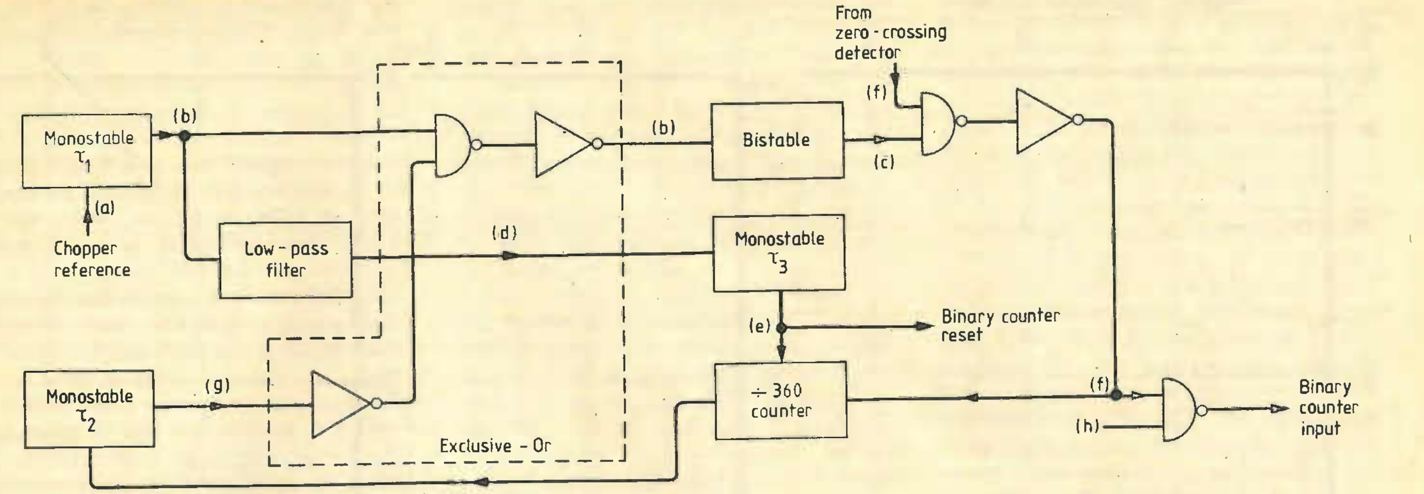


Fig. 3. Reference circuit for cross-correlator. See Fig. 2 for waveforms indicated by letter symbols.

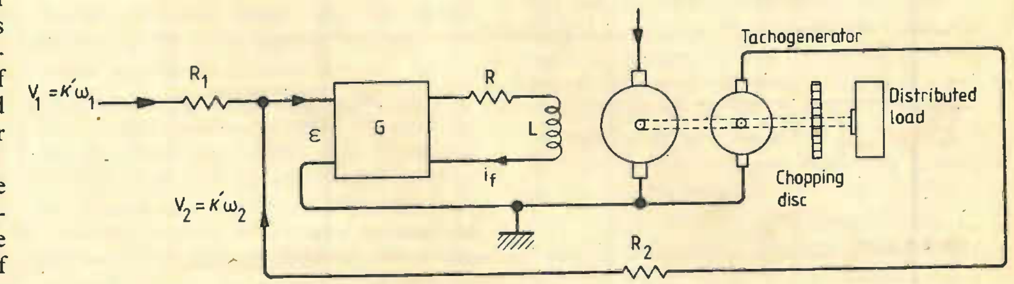


Fig. 4. Velodyne speed control system.

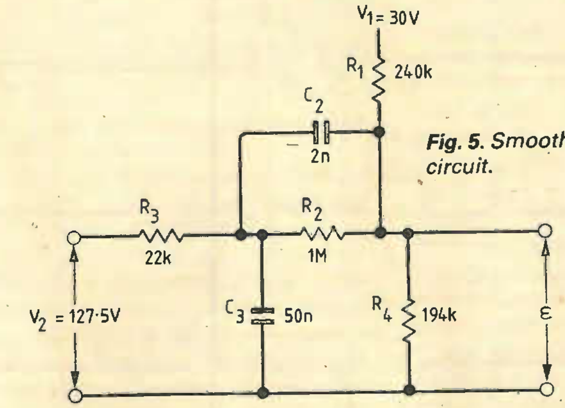


Fig. 5. Smoothing and phase advance circuit.

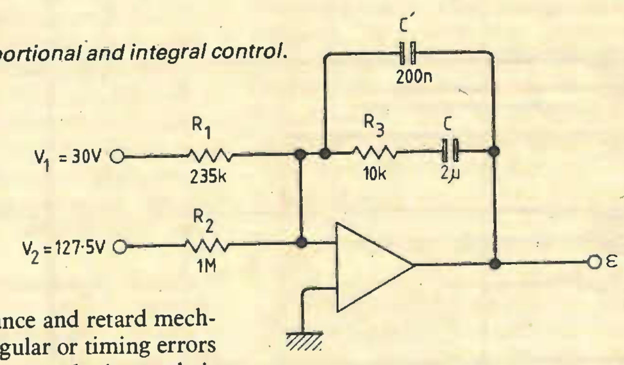


Fig. 6. Circuit for proportional and integral control.

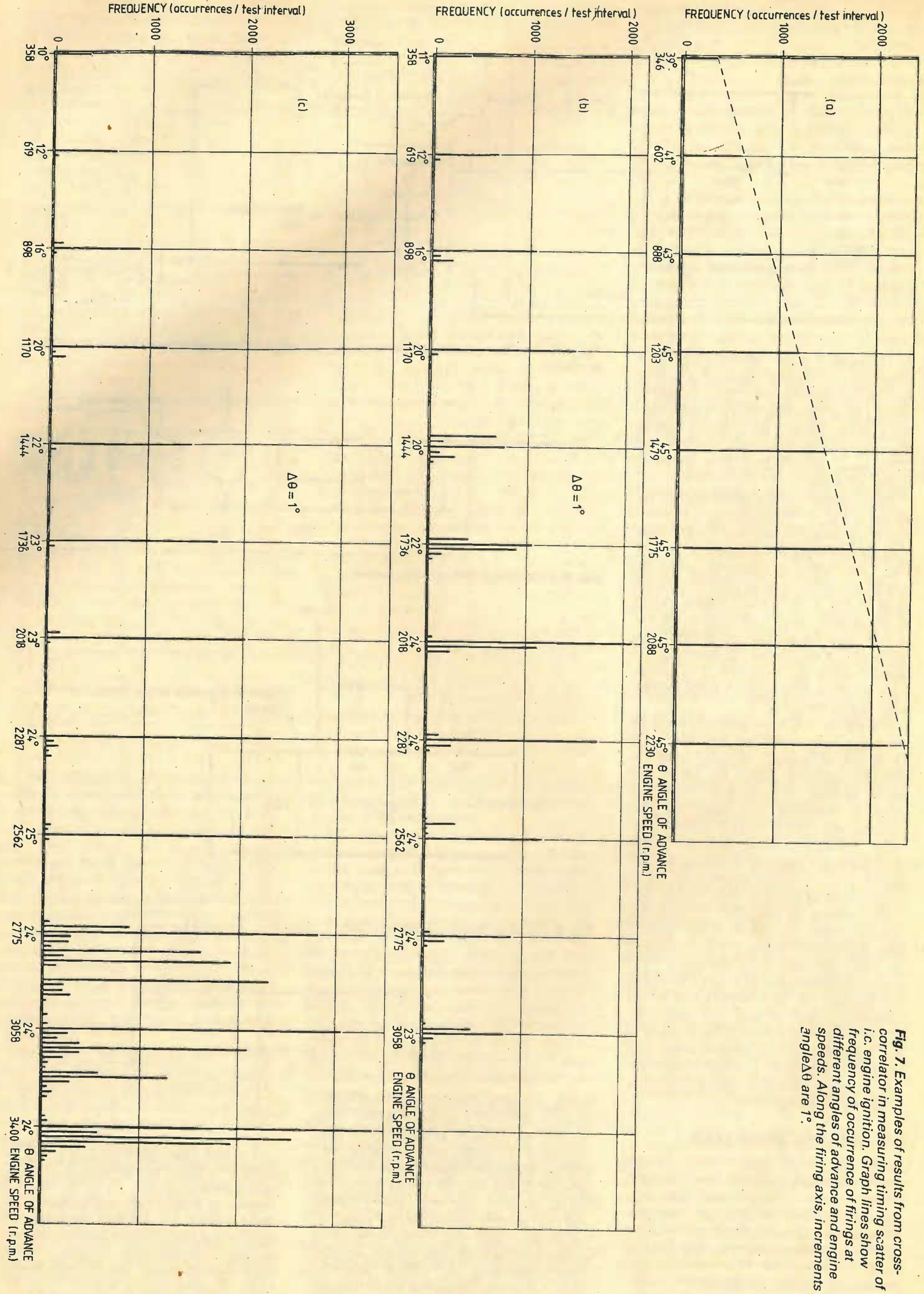


Fig. 7. Examples of results from cross-correlator in measuring timing scatter of i.c. engine ignition. Graph lines show frequency of occurrence of firings at different angles of advance and engine speeds. Along the firing axis, increments of angleΔθ are 1°.

speed control system of Fig. 4 may be negligible, its response will be highly oscillatory, which is definitely unacceptable for this application, so the damping must be artifically increased. Both smoothed and phase-advanced output control, together with proportional and integral control, have been considered. An analysis of the former gives a velocity error of approximately 35 r.p.m. using the constants of a modified Type 73 AP11084 velodyne with control amplifier gain G=306mA/V. That is, with a constant input, an output shaft deflection exceeding 3.6 radians/s will overload the amplifier.

Velocity error or lag can be completely eliminated by the introduction of a term proportional to the integral of the error, in the system differential equation. A circuit suitable for use with the two-lag system of Fig. 5, and providing a control amplifier input proportional to the error and its integral, is given in Fig. 6. (The component values of this have been derived in an appendix which can be obtained by sending a large s.a.e. to *Wireless World's* editorial office). In the steady state, the velocity error has been completely eliminated.

An obvious advantage of integral control is that input perturbations, or interference of duration short compared with this response time, will not affect the control system. In determining the step response, the inertia of the distributor and chopping disc load were neglected and, provided the control amplifier gain G is sufficiently high, these should be of no consequence. It can be shown that the peak overload velocity overshoot is only 5 r.p.m.; with a constant input, an output deflection of 29°/sec relative to the input will overload the control amplifier.

The stability of the velodyne speed control system of Fig. 4, with proportional and integral control, is assured by the rapid logarithmic decrement of the step-response, which has a value of 0.64, given by $\delta=\psi\pi/\sqrt{1-\psi^2}$, where the damping factor $\psi=0.2$.

Alternative gating

The parallel NOR and NAND circuits of Fig. 1, in each correlator channel, can be gated directly by the trigger pulse of the ignition system under test, thereby eliminating the encoder. By inhibiting the comparator input as before and decoding the 9-bit word stored in it, the angle of advance using either a visual or tape read-out will be known. However, an encoder provides the cross-correlator with a self-test capability without an ignition trigger pulse; it is thus able to synthesize a trigger pulse as well as measure it, which is not possible otherwise.

Comparison of ignition systems

Fig. 7 shows some results from using the cross-correlation technique to test and compare different ignition systems. At (a) are the results from an opto-electronic triggered capacitor-discharge system with variable spark duration; at (b) from a typical contact-operated c-d system; and at (c) from a transistor-assisted contact system. In the graphs the positions of the graph lines along the "angle of advance" axes show the spreads of ignition timing (at 1° intervals of angle of advance) at different engine speeds (in r.p.m.). Thus the bunches of lines can be regarded as spectra. The length of each graph line shows on the "frequency" scale, the frequency or number of occurrences in the test interval, of firing (spark plug gap-breakdown) at a particular firing angle.

The frequency spectrum of Fig. 7 (c) has an angular spread exceeding 10° at the highest speeds; the system (a) distributor with its light-chopper could reduce or eliminate these angular distributions. The bandwidth seems adequate with no reduction in modal value with speed: the increased scatter with speed is due to distributor contact bounce and inertia as well as spring inertia. The use of a 22kΩ suppressor resistor in system (b) could contribute to the increased scatter and low modal values at the lower speeds because of a larger breakdown current.

In a four-cylinder engine, such high distributor speeds as are used for checking the correlator are unlikely, and for engine speeds up to 5000 r.p.m. the performance of system (c), a standard 12V inductive ignition system, is superior to that of system (b) which is more complex. If the current switch was optically rather than mechanically triggered to eliminate the point contacts, its performance should equal that of system (a), which is complex and impracticable. While the use of long or short pulses seem irrelevant here, their effect on engine performance is most important[3]; a fast rise-time is essential, that is, adequate system bandwidth.

The linear speed characteristic of Fig. 7(a) for 100% correlation establishes the accuracy and reliability of the cross-correlator within its 1° resolution. It could be tested without a synthesized trigger pulse by enabling waveform (j) in Fig. 1, with a 5V supply and gating the nine respective comparator outputs at any selected angle within the encoder's range. However, an external pulse source checks the pulse amplifier and the correlator's stability or ability to respond to a test pulse at the set angle of advance and discriminate against spurious pulses over a realistic speed range. The results are confirmed by the uniform correlator angular output of Fig. 7(b) over a 9:1 speed range generated by the photo-optic distributor of system (a) even though the absolute angular values measured change in accordance with Fig. 7(a).

As the correlator's performance is independent of the prime mover, any discrepancy between laboratory and field measurements can only be due to prime mover velocity perturbations, caused by wear and backlash in the mechanical transmission from the engine to the distributor, together with the mechanical imperfections of the spring-loaded point contacts, aggravated by the kinetic energy of the advance and retard mechanism.

A quick method of selecting an ignition system is to apply the voltage proportional to the ignition system spark plug gap-breakdown current, i.e. the ignition scatter, to a two-input NAND gate enabled by the zero-crossing detector. The NAND gate output, after inversion, will consist of a train of discrete equally-spaced positive pulses at the gating repetition rate, having the same envelope as the scattered ignition input, i.e. a discrete spectral distribution of the ignition energy per revolution. By integrating this discrete spectrum to give a continuous distribution envelope or sampling and holding it with a box-car circuit to give a discontinuous distribution envelope with time, it may be applied to a c.r.o. triggered by the chopping disc reference pulse. It may then be photographed, for example after one minute, for comparison with other ignition system energy distributions. Unfortunately this method does not provide angular information or permit the measurement of the distributor spark-advance characteristic. However, the standard deviation by inspection of the distribution envelope will immediately indicate the best ignition system at one particular speed, repeating the comparison if necessary over the whole speed range. This kind of selection is an example of the "ensemble" method of averaging while that using a cross-correlator is one of "time" averaging. In system (a) the statistical processes are stationary since from Fig. 7(a) the frequencies at a given speed are the same.

Finally, although the correlator has been designed for selecting an ignition system by measuring the standard deviation of its angular distribution at a given speed, it would be a useful addition to a radar receiver for determining precisely the bearing of a return pulse. It would be particularly suitable for use in a within-pulse scanning system[4,5], with its fixed modulation or scanning frequency. By squaring the sinusoidal modulation waveform and dividing it electronically into equal parts, depending on the angular resolution required, the chopping-disc and velocity-control loop will be eliminated. Using a synchronized omnidirectional encoder with the same resolution, attention can be focused on a stationary return pulse from any known direction exceeding the threshold level. The encoder effectively converts the continuous electronically-scanned omnidirectional surveillance radar receiver into one with a variable scanning rate, since it could be switched sequentially manually or electronically in either direction at any frequency.

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NEW PRODUCTS

'Fingernail' switches

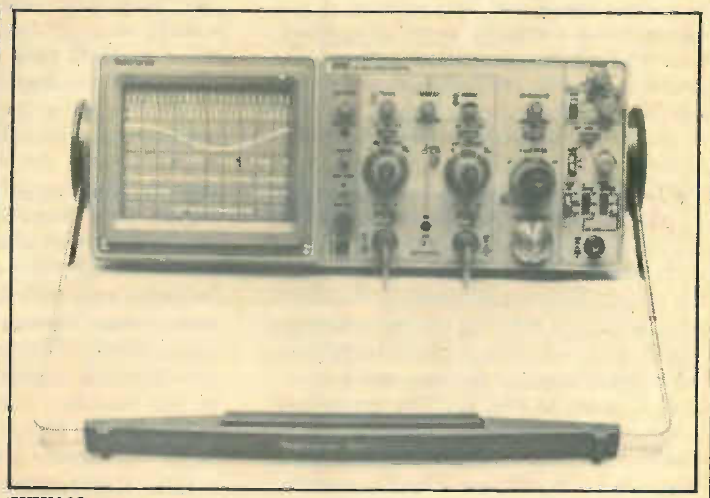
These 10 position binary coded decimal units, called fingernail switches rather than thumbwheel switches because of their small size, have wire-wrap pins and can be joined together to form a solid unit for mounting at the rear of a panel. Switching capacity of the Super Miniature series is 50mA at 28V d.c. (resistive load) with a continuous rating of between 100μA and 10mA. Contact resistance is 250mΩ maximum and insulation resistance at 250V d.c., 100MΩ. Temperature range of the series is −20 to 80°C and applications include computers, automatic control and measurement equipment and any situation where a numeric value needs to be adjusted periodically but space is limited. Cosmocord Ltd, Eleanor Cross Rd, Waltham Cross, Herts.
WW301

50MHz oscilloscopes

Growing demands for low-cost, general-purpose oscilloscopes have led Tektronix to design the 2200 series instruments, the first two versions of which have been recently announced. The 2213 at £617 and 2215 at £785 both have 50MHz bandwidth, 2mV sensitivity and dual trace. Basic differences between the two are that the 2215 has a dual timebase and calibrated delay, whereas the 2213 has a single timebase and uncalibrated delay. As switched-mode power supplies are incorporated, consumption is kept low and mains input variations from 90 to 250V and 48 to 62Hz can be accepted without adjustment. Both units have beam-finding, automatic intensity and focus facilities and weigh 6.1kg each. For sensitivity settings above 20mV/cm, the bandwidth is increased to 60MHz. These portable oscilloscopes are designed for use in service departments, educational establishments and other such sectors and will be available through Electroplan. Tektronix UK Ltd, Beaverton House, PO Box 69, Harpenden, Herts.
WW302

High-voltage probe

Availability of a probe with a built in meter for measuring up to 40kV d.c. has been announced by Sinclair Electronics Ltd. The LHM-80A, from the Japanese company Leader, has an analogue meter built into its handle which gives readings in 2kV steps with a maximum error of ±3%. The LHM-80A weighs 300g and costs £16 excluding v.a.t. Sinclair Electronics Ltd, London Rd, St Ives, Huntingdon, Cambs PE17 4HJ.
WW303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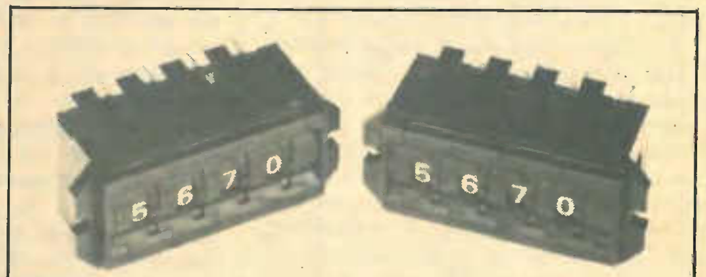

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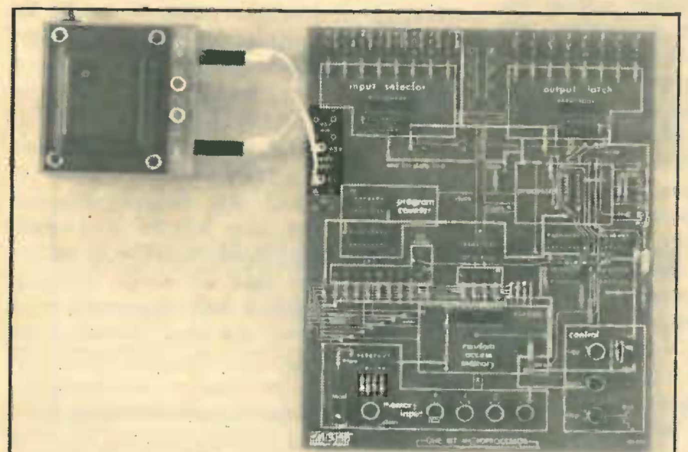
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WW303

Microprocessor trainer

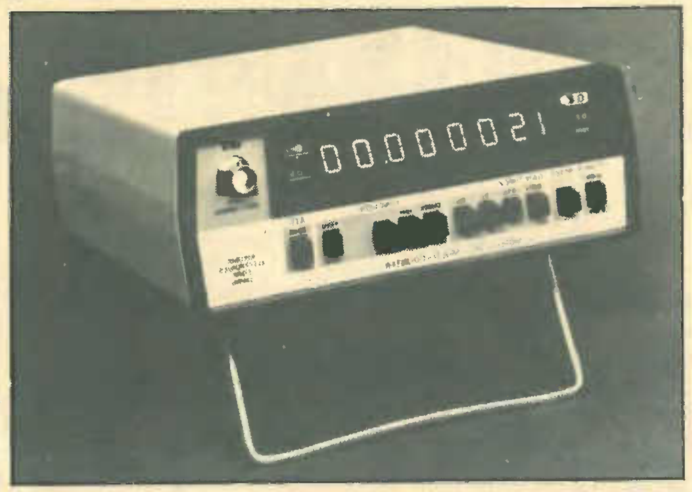
Many people with a knowledge of logic gates find difficulties when they come to trying to understand the microprocessor. Unilab, with their microprocessor trainer, hope to make the transition easier by providing a board which functions as a common microprocessor but using one-bit operation. Instruction notes describe microprocessor concepts and how they can be illustrated using the board. The One Bit Microprocessor is divided into sections and 35 l.e.ds distributed round the board show the states of lines between these sections and at the eight i/os. The i/os can be used for controlling simple demonstration models from programs entered as binary numbers and stored in a 256 × 4-bit r.a.m. Each unit costs around £66 and requires an external 5V supply. Unilab Ltd, Clarendon Rd, Blackburn, Lancs BB1 9TA.
WW304

Low-power r.a.ms

Two 256 × 4-bit c.m.o.s. static r.a.ms with 50μW power consumption in standby mode are available from Rapid Recall. The IM65X51 has 22 pins and separate i/o data lines, whereas the IM65X61 has 18 pins and multiplexed data lines. Both types are t.t.l. compatible, have internal address registers and can be supplied with either 300ns or 220ns access times. A third option is available with 4.5 to 10.5V maximum operating range. These i.cs can be supplied for various operating temperature ranges. Rapid Recall Ltd, Rapid House, Denmark St, High Wycombe, Bucks HP11 2ER.
WW305

Frequency counter

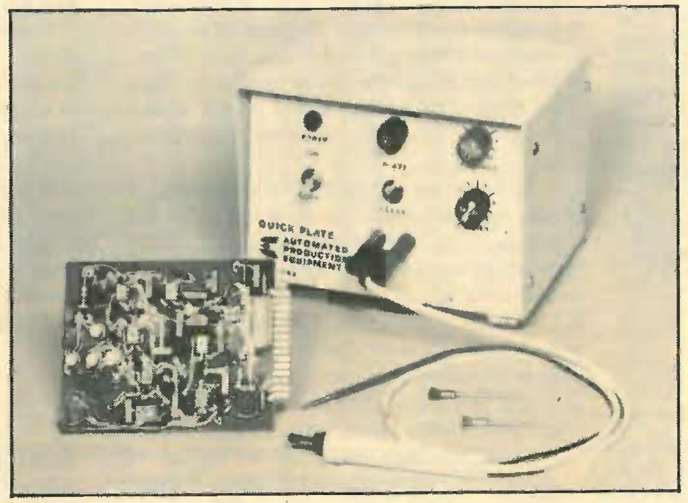
An eight-digit 10Hz to 150MHz counter for measuring frequency, period and r.p.m. is available through Telonic Berkeley. The 1MΩ resistance frequency/period input of the Kikusui 255 has 20mV sensitivity and automatic limit control when measuring large signals. Gate times are 10, 1, 0.1 and 0.01μs for frequency measurement and 60, 0.6, and 0.06s in tachometer mode for measuring up to 100,000 pulses/s. Periods from 100ms to 1μs can be measured. The 10MHz time-base, a t.t.l. compatible output of which is available at the rear of the unit, is stable to within ±1 × 10^{-6}/month. A more stable version of the 255, the 256, is available with an error of ±3 × 10^{-7}/month maximum at £265 plus v.a.t. The 255 costs £200 plus v.a.t. Telonic Berkeley UK, 2 Castle Hill Terrace, Maidenhead, Berks SL6 4JR.
WW306



WW306

Electro-plating repair kit

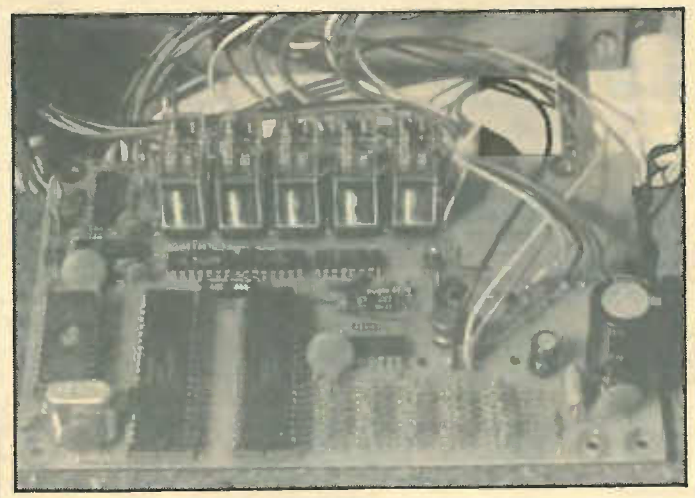
Small-area breaks, wear and blemishes in plated surfaces can be repaired using a unit from Automated Production Equipment along with plating solutions supplied by the same company. The SRS-069 unit is basically a variable voltage-regulated/current-limited power supply designed to provide power for two brush-tipped probes, one for cleaning the surface to be repaired and one for applying the plating solution. A third pointed probe provides the earth return from the surface. Various plating compounds are available for use with the unit, including gold, nickel, copper, aluminium, tin-lead and tin. Automated Production Equipment Corp, 142 Peconic Ave., Medford, NY 11763, USA.
WW307



WW307

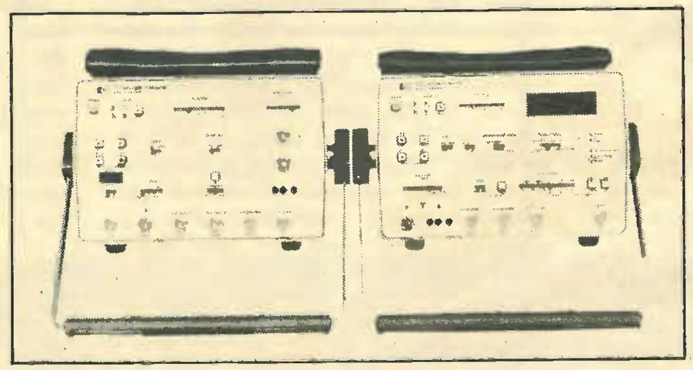
Industrial controller

Smallest in a range of industrial microprocessor controllers from EME is the TIM 01 for use in timing and sequencing applications. Four debounced t.t.l. compatible inputs and seven outputs are provided. Of the seven outputs, five use relay changeover contacts for loads up to 3A and two are open collector outputs for up to 1/2A. Eight t.t.l. compatible lines can be selected by programming to operate as either inputs or outputs. Locations for up to six 8-way d.i.l. switches are available so that parameters such as time periods, counts, limits and values can be set. The controller uses a 6802 microprocessor and can store programs of up to 2K. A single a.c. supply (either mains or low voltage) is required. Various options from the basic board to a unit tailored to customers' requirements and housed with screen printed legend can be supplied. EME Ltd, 5 Port Hill, Hertford, Herts SG14 1TJ.
WW308


WW308

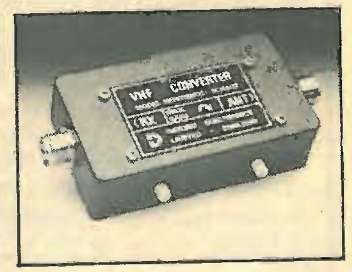
Error measurement system

Testing and performance evaluation of digital transmission and terminal equipment are the purposes of the 3781A/3782A combination from Hewlett-Packard. The 3781A pattern generator and 3782A error detector provide a system for testing error susceptibility that can be used with four levels of digital hierarchy at up to 50Mb/s. With the 3781A, errors can be injected singularly or at 1 in 10^{-3} or 1 in 10^{-5} error rates into a range of pseudo-random binary sequences and 16-bit word test patterns in a.m.i. or h.d.b.-3 line codes. Both 75Ω unbalanced and 120Ω balanced pseudo-ternary outputs and t.t.l. compatible monitor outputs are provided. Binary and code errors detected by the 3782A can be displayed as error rates, error counts, errors/second and seconds between errors over various gating periods. All four parameters are updated simultaneously over the same gating period. A printer output and real-time clock are included in the 3782A. Applications of the system are in research and development field trials and production testing where remote testing via an IEEE-488 bus is required. Hewlett-Packard Ltd, King Street Lane, Winnersh, Wokingham, Berks.
WW309


WW309

V.h.f./h.f. converter

Conversion of 144/146MHz band signals down to the range 28/30MHz for use with h.f. band receivers is the function of Datong's DC144/28 converter. At maximum gain, 18dB, the unit's noise figure is less than 3dB and the third-order input intercept typically -6dB. Separate gain controls are provided for the 50Ω impedance input and output. The DC144/28 incorporates a high-level



Schottky-diode balanced mixer, m.o.s.f.e.t. input, j.f.e.t. post-mixer amplifier, and fifth-overtone crystal oscillator. SO239 (u.h.f.) type connectors are used at both input and output. An external d.c. supply of between 10 and 14V is required to power the unit via a jack socket. Two versions of the converter are available, one with case and input/output connectors costing £31 exc. v.a.t. and one without costing £25 exc. v.a.t. The same company has introduced a unit for converting signals in the range 50kHz to 30MHz to the range 144 to 145MHz so that they can be received on 2-metre transceivers or v.h.f. scanners. Datong Electronics Ltd, Spence Mills, Mill Lane, Bramley, Leeds LS13 3HE.
WW310

SIDEBANDS
By Mixer

How's that again?

"... to inform a wide general public about the superordinate relationships of new technologies. It is ... a matter of showing trends and tendencies, of creating transparency and of promoting understanding for a life with controlled electronics by means of relevant information." (Ineltec 81 press handout).

I think I know what it means, Mr Fowler; it's all about telling Joe Public that electronics is wonderful. There's this big Swiss electronics exhibition in Basle whose purpose, aside from a "mediator function between manufacturer and user" (selling gear), is to "eliminate the layman's fear of excessive mental demands, to help him throw a bridge to (at?) the new technologies." Simple, really.

If it's all going to be like that, though, I'm not going. I think one of the younger end should be sent – they have no fear of excessive mental demands.

Yaiplecc Yopld

Near enough, anyway. That, in case you thought the printer was losing his touch, is what you ask for when you go to a bookstall in Russia to pick up the latest *Wireless World*. It isn't a translation, just a transliteration (Ooairless Ooorld). What happens is that the Russians buy a few copies from us, copy and reprint them with the above on the cover, and send them out. I don't know how many they print, but it must be quite a lot, or it wouldn't be worthwhile doing it at all. It loses a bit in the process – the drawings are all right, but the pictures come out looking a bit wan. And it's all in black and white, so that Paul Brierley's colour photos on the cover suffer direly.

What puzzles me is why we don't receive a few more contributions from the U.S.S.R. They're pretty bright people over there – brighter than most in many ways – but I can only remember two contributors in the last decade or so. It would be good to hear a bit more about what goes on in their electronics – they can't spend *all* their time orienteering, although they do seem extraordinarily keen on it, judging by their magazine *Radio*.

Long-felt want

It begins to look as though I'll have to acquire a computer of some sort, even if it's only to guard against abuse from the younger element here. Three of them have got them now and their conversation has taken a turn towards the grotesque already: it is not easy to maintain my front of omniscience when all around people are chatting amiably about daisy wheels, acorns, apples and various other intelligent vegetables.

I still have to solve the problem of what I'm going to do with it when I've got it, but that isn't the vital thing. What is important is that I must put on a bit of a spurt to catch up with the language, at least. It's moving so fast now: one hardly dares speak in case one is unwittingly guilty of a computerspeak solecism. If Shakespeare were writing today, he wouldn't dare make a character say "Go to, . . . " in case it was taken as an instruction to jump to the next scene. It's even got to the stage now where, when I mention the world 'program,' they all think I'm talking about Radio 4, not being able to credit that I've heard about computers yet.

Still, having got myself a computer, it will have to work for its living. On the whole, I really think I'd like to use it as a word-processor – I can probably live without a list of all the prime numbers up to several million, and I know the state of my bank account because the manager keeps writing bitter little notes to tell me. No, I think a word-processor might well be a great help: the typewriter I use makes a lot of mistakes and I get so fed up of correcting them that sometimes I don't bother and they get printed. When I do scribble all over the typescript the printers can't read my writing anyway, so mistakes still appear.

All this, so I'm told, will not be a problem with a w.-p. All you do is type the stuff in, press a few buttons, and it all leaps into position, mistakes corrected, paragraphs re-ordered on demand and the right-hand edge straight as a die. Another keystroke and the printer fires it all off at some unbelievable speed, ready for sending off to the printers. Yes, I think that's for me. It might even do the index every year, so you'll be able to have it before the end of the succeeding year.

Breaker breaking

It's started already. There I was, driving peacefully along between Sutton and Cheam, when a disembodied voice rudely interrupted Frederika von Stade, who was singing a Canteloube song from the Auvergne, to announce that if any breaker so desired, he was ready to hold converse with them. I think that's what he said, at any rate – I can't claim absolute certainty on this point, because the request was couched in such an unlovely combination of South London whine and Texas drawl that it might have been anything.

I wasn't able to hear the replies (I suppose he was breaking into the front end because of his proximity) and, in any case, I was trying to listen to Miss F. von S. singing her television commercial, but he must have received a reply from someone who was similarly baffled by the double talk, since he suddenly went all posh, and began to say things I could understand. It was at this point I realised that the c.b. freak was in the car behind, referring to this old creep in front of him who was driving too slowly. The impudence of the fellow! I was in progress at the maximum speed at which I feel safe – nearly 25 m.p.h., fast enough for anyone.

It wasn't the reflection on the verve and dash of my driving that hurt, though, nor the slighting reference to my noble vehicle as a heap, but the fact that the car behind him was a police car, full to the brim with impassive Woodentops who didn't take the slightest bit of interest in this verbal assault on me. I suppose they must have had a radio and been as vulnerable to interference as I was, but they didn't turn a hair. All the same, I bet if I'd put my foot down and gone past 32 m.p.h., they'd have had me.

Little boxes

People keep telling me that the audio boom is coming to an end. I dare say it must be if the experts say so, but I haven't seen much indication of it myself. The magazines which concern themselves with audio are still with us and I haven't noticed any diminution in the number of impressive-looking boxes with knobs on in the shop windows.

But if the experts are right and the boom is fading to a thin shriek, I can't say I'm surprised. The public can be taken for a ride by anyone with enough nerve, but not for ever. There is in most of us a hankering to have the 'latest' of anything, and when it is impressed on us that the row of l.e.ds on the new cassette deck is so much better than the meters on the old one that the expenditure of a wad of fivers is as nothing compared to the enhanced quality of music we can now enjoy, we fall for it – for a time, at any rate.

Comes the time, though, when a chap begins to wonder. How can it be, he (or she) will muse, that the new amplifier doesn't sound any different to the old one, even though it cost twice as much and has a pair of meters. Meters? If the thing sounds as though it's overloading, you turn the wick down, and if it doesn't, you don't. Who needs meters?

The truth is that manufacturers have exploited the public's weakness for gimmickry for years, and if the time has come to cool it, they ought not to grumble. Maybe they could start on video machines next – there's a fortune to be made there.

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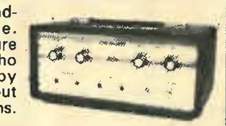

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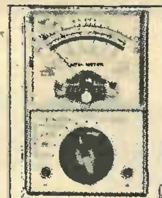
Sockets 3-pin, 5-pin **10p.** Free Sockets 3-pin, 5-pin **25p.**
Plugs 3-pin **20p;** 5-pin **25p.**
PHONO PLUGS and SOCKETS ea. **10p.**
Free Socket for cable end ea. **15p.**
Screened Phono Plugs ea. **15p.**

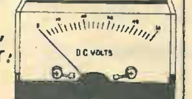
POTENTIOMETERS Carbon Track
5kΩ to 2MΩ. LOG or LIN. L/S **50p.** DP **90p.** Stereo L/S **£1.10.** DP **£1.30.** Edge Pot 5K. SP **45p.** Sliders Mono **65p.** Stereo **85p.**

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.
Facia 2⅜ × 1¾ × 1½in.
Fixing hole 1½in. dia.
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** Easy to build. Full instructions supplied. Cabinet Post 95p **£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.

"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 65p. 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 **£2.95**
Can be ganged to make multi-way stereo mixers 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 4A, 4A CT, 5V 2A	£14.50	£2
300-0-300V 120mA, 2×6.3V 2A C.T.; 5V 2A	£10.00	£2
220V 45mA, 6.3V 2A	£2.50	£1

GENERAL PURPOSE LOW VOLTAGE
Tapped outputs available

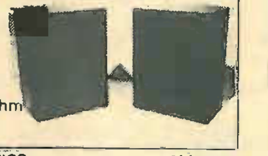
2 amp. 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 25 and 30V	£6.00	£2
1 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£6.00	£2
2 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£9.50	£2
3 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£12.50	£2
5 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£16.00	£2

12V, 100mA	£1.30	80p	20V, 40V, 60V, 1a	£4.00	£2
12V, 750mA	£2.00	80p	12V, 3a	£3.50	£1
10-0-10V 2a	£3.00	£1	10V, 30V, 40V, 2a	£3.50	£1
30V, 5a and 17-0-17V 2a	£4.00	£2	2 of 28 volt 1a	£5.00	£2
			20V, 1a	£3.00	£1
0.5, 8, 10, 16V, ½a	£2.50	80p	20V-0-20V, 1a	£3.50	£1
9V, 3a	£3.50	£1	9-0-9V 50ma	£1.50	80p
25-0-25V 2a	£4.50	£1	2 of 18V, 6a	£11.00	£2
30V, 1½a	£3.50	£1	12-0-12V, 2a	£3.50	£1
6V ½a	£2.00	£1	9V, ¼a	£1.50	80p
15-0-15V, 2a	£3.75	£1	32-0-32V, 6½a	£11.00	£2

AUTO WOUND 115V to 240V 150W **£8** 400W **£10** 500W **£12** £2

CHARGER TRANSFORMERS	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.**
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 MOTOR. 6 volt **£1**
CASSETTE MECHANISM. 12v Stereo Playback only **£5**
U.H.F. COAXIAL CABLE SUPER LOW LOSS. 25p yd.
COAX PLUGS 20p. COAX SOCKETS 20p.

NEW baker Star sound

high power full range quality loudspeakers produced to give exceptional reproduction. Ideal for electric guitars, organs, public address or discotheques. These loudspeakers are recommended where high power handling is required with quality results. The high flux ceramic magnet assembly ensures clear treble response so necessary for the music of today.

MODEL	INCHES	OHMS	WATTS	TYPE	PRICE
MAJOR	12	4-8-16	30	HI-FI	£14
DELUXE MK II	12	8-16	15	HI-FI	£14
SUPERB	12	8-16	30	HI-FI	£24
AUDITORIUM	12	8-16	45	HI-FI	£22
AUDITORIUM	15	8-16	80	HI-FI	£34
GROUP 45	12	4-8-16	45	PA	£14
GROUP 75	12	4-8-16	75	PA	£22
GROUP 100	12	8-16	100	PA	£24
GROUP 100	15	8-16	100	PA	£32
DISCO 100	12	8-16	100	DISCO	£22
DISCO 100	15	8-16	100	DISCO	£34

BAKER 150 WATT MIXER/POWER AMPLIFIER £89 Post £2
All purpose for Guitars, Discotheque, Vocal, Public Address. Amplifier "Mains Switch" for instant sound or muting. Three loudspeaker outlets for 4, 8 or 16 ohms operation. Four high gain outputs each 20 mv, 50K ohm. Individual volume controls with "Four channel" mixing. 150 watts into 8 ohms R.M.S. Music Power. Distortion less than 1% at full output. Slave output 500 M.V. 25K.ohm. Frequency Response 25 Hz – 20kHz ± 3dB. Integral Hi-Fi preamp 32dB. Variation on wide range separate Bass & Treble. Compact – 16" x 8" x 5½" approximately. Lightweight – only 14lb – approximately: White wording on Black facia and Cabinet. Made in England. 12 months' guarantee. 200/250v A.C. mains or 120V to order. All transistor and solid state devices.

BAKER 50 WATT AMPLIFIER

£69 Post £2
Ideal for Hi-Fi/PA systems, Discos and Groups. Two inputs. Mixer, Volume Controls, Master Bass, Treble and Gain.

RCS offers
Mobile PA Amplifiers
20 watt RMS 12v DC, AC 240v, 3 inputs **£46** (PP £2).
40 watt RMS 12v DC, AC 240v, 4 inputs **£75** (PP £2).
Mic 1; Mic 2; Phono; aux; Outputs 4 or 8 or 16 and 100v line. 60 watt RMS. Mobile 24 volt DC & 240 volt AC mains. Input 3 mics + 1 music. 4-8-16 ohm + 100 volts line **£95** (PP £2)

FAMOUS LOUDSPEAKERS "SPECIAL PRICES"
Post £2 ea.

MAKE	MODEL	SIZE	WATTS	OHMS	PRICE
SEAS	TWEETER	4in	50	8	£7.50
GOODMANS	TWEETER	3½in	25	8	£4.00
AUDAX	TWEETER	3¾in	60	8	£10.50
SEAS	MID-RANGE	4in	50	8	£7.50
SEAS	MID-RANGE	5in	80	8	£12.00
SEAS	MID-RANGE	4½in	100	8	£12.50
GOODMANS	FULL-RANGE	5½in	15	8	£6.50
GOODMANS	FULL-RANGE	8in	30	8	£9.50
GOODMANS	AUDIOM 8p	8in	15	15	£8.50
SEAS	WOOFER	8in	30	8	£14.00
CELESTION	DISCO	10in	20	8/16	£11.50
CELESTION	DISCO	10in	60	8/16	£21.50
RIGONDA	GENERAL	10in	15	8	£6.50
GOODMANS	AUDIOM PG	12in	60	8	£20.00
GOODMANS	PP12	12in	75	8/15	£24.50
GOODMANS	AUDIOM P	12in	50	8/15	£20.00
GOODMANS	GR12	12in	90	8/15	£27.50
EMI	HI-FI	13x8	10	3/8	£9.50

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.**
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. **£1.50.**
MOTOROLA PIEZO ELECTRIC HORN TWEETER **£5.00**
Handles 100 watts. No crossover required. 4-8-16 ohm.
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. Will also demagnetise small tools. **£8**
Head Demagnetiser only £5 Post 95p

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20 POWER AMPS

19 FUNCTIONAL MODULES

DAWN OF A NEW ERA

ILP

POWER UP TO 480 WATTS RMS SINGLE CHANNEL

AMPLIFIER WITH HEAT SINK

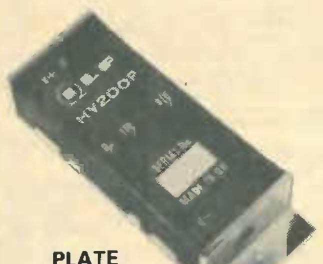

PLATE TYPE

PSU

Which amplifier?

I.L.P. Amplifiers now come in three basic types, each of which is available with or without heatsink. Having decided the system you want – home hi-fi (models HY30, 60 or 120 for example), super quality hi-fi with extra versatility (MOS120, MOS200) or Disco/PA/Guitar (HD120, HD200 or HD400) you will then decide whether amplifiers housed within their own heatsinks or plate amplifiers for bolting to a metal chassis will suit. With choice such as this and a brilliant new range of I.L.P. functional modules to choose from you now have the chance to build the finest audio system ever offered to the constructor.

BIPOLAR Standard, with heatsinks / Without heatsinks

MODEL NUMBER	OUTPUT POWER Watts rms	DISTORTION T.H.D. Typ at 1kHz	DISTORTION I.M.D. 60HZ/7kHz 4:1	SUPPLY VOLTAGE TYP/MAX	SIZE mm	WT gms	PRICE	VAT	MODEL NUMBER	SIZE in mm	WT gms	PRICE	VAT
HY30	15w/4-8Ω	0.015%	<0.006%	±18±20	76x68x40	240	£7.29	£1.09					
HY60	30w/4-8Ω	0.015%	<0.006%	±25±30	76x68x40	240	£8.33	£1.25					
HY120	60w/4-8Ω	0.01%	<0.006%	±35±40	120x78x40	410	£17.48	£2.62	HY120P	120x26x40	215	£15.50	£2.33
HY200	120w/4-8Ω	0.01%	<0.006%	±45±50	120x78x50	515	£21.21	£3.18	HY200P	120x26x40	215	£18.46	£2.77
HY400	240w/4Ω	0.01%	<0.006%	±45±50	120x78x100	1025	£31.83	£4.77	HY400P	120x26x70	375	£28.33	£4.25

Protection: Load line, momentary short circuit (typically 10 sec) *Slew rate:* 15V/μs *Rise time:* 5μs
S/N ratio: 100db *Frequency response (–3dB):* 15Hz – 50kHz
Input sensitivity: 500mV rms *Input impedance:* 100kΩ *Damping factor:* (8Ω/100Hz)>400

HEAVY DUTY with heatsinks / Without heatsinks

HD120	60w/4-8Ω	0.01%	<0.006%	±35±40	120x78x50	515	£22.48	£3.37	HD120P	120x26x50	265	£19.84	£2.98
HD200	120w/4-8Ω	0.01%	<0.006%	±45±50	120x78x60	620	£27.38	£4.11	HD200P	120x26x50	265	£23.63	£3.54
HD400	240w/4Ω	0.01%	<0.006%	±45±50	120x78x100	1025	£38.63	£5.79	HD400P	120x26x70	375	£34.28	£5.14

Protection: load line, PERMANENT SHORT CIRCUIT (ideal for disco/group use should evidence of short circuit not be immediately apparent).
The Heavy Duty range can claim additional output power devices and complementary protection circuitry with performance specs. as for standard types.

MOSFET Ultra-Fi, with heatsinks / Without heatsinks

MOS120	60w/4-8Ω	<0.005%	<0.006%	±45±50	120x78x40	420	£25.88	£3.88	MOS120P	120x26x40	215	£23.32	£3.50
MOS200	120w/4-8Ω	<0.005%	<0.006%	±55±60	120x78x80	850	£33.46	£5.02	MOS200P	120x26x80	420	£28.53	£4.28
MOS400	240w/4Ω	<0.005%	<0.006%	±55±60	120x78x100	1025	£45.39	£6.81	MOS400P	120x26x100	525	£38.91	£5.84

Protection: Able to cope with complex loads, without the need for very special protection circuitry (fuses will suffice).
Ultra-fi specifications:
Slew rate: 20V/μs *Rise time:* 3μs *S/N ratio:* 100db. *Frequency response (–3dB):* 15Hz – 100kHz
Input sensitivity: 500mV rms *Input impedance:* 100kΩ *Damping factor:* (8Ω/100Hz)>400

POWER SUPPLY UNITS

MODEL NO.	FOR USE WITH	PRICE	VAT
PSU30	± 15V combinations of HY6/66 series to a maximum of 100mA or *one* HY67 The following will also drive the HY6/66 series except HY67 which requires the PSU30.	£4.50	£0.68
PSU36	1 or 2 HY30	£8.10	£1.22
PSU50	1 or 2 HY60	£10.94	£1.64
PSU60	1 x HY120/HY120P/HD120/HD120P	£13.04	£1.96
PSU65	1 x MOS120/1 x MOS120P	£13.32	£2.00
PSU70	1 or 2 HY120/HY120P/HD120/HD120P	£15.92	£2.39
PSU75	1 or 2 MOS120/MOS120P	£16.20	£2.43
PSU90	1 x HY200/HY200P/HD200/HD200P	£16.20	£2.43
PSU95	1 x MOS200/MOS200P	£16.32	£2.45
PSU180	2 x HY200/HY200P/HD200/HD200P or 1 x HY400/1 x HY400P/HD400/HD400P	£21.34	£3.20
PSU185	1 or 2 MOS200/MOS200P/1 x MOS400/ 1 x MOS400P	£21.46	£3.22

All models except PSU30 and PSU36 incorporate our own toroidal transformers.

FP480
BRIDGING UNIT FOR DOUBLING POWER

Designed specially by I.L.P. for use with any two power amplifiers of the same type to double the power output obtained and will function with any I.L.P. power supply. In totally sealed case, size 45 x 50 x 20mm, with edge connector. It thus becomes possible to obtain 480 watts rms (single channel) into 8Ω. Contributory distortion less than 0.005%.
Price: £4.79 + 72p. V.A.T.

ILP ELECTRONICS LTD.

FREEPOST 2 Graham Bell House, Roper Close, Canterbury, Kent CT2 7EP.
Telephone (0277)54778 (Technical (0227) 64723) Telex 965780
Available also from MARSHALLS, TECHNOMATIC, WATFORD ELECTRONICS and certain other selected retailers.

Which modules?

In launching eighteen different units all within amazingly compact cases to help make complete audio systems using I.L.P. power amplifiers, we bring the most exciting, the most versatile modular assembly scheme ever for constructors of all ages and experience. Study the list – see how these modules will combine to almost any audio project you fancy – and remember *all I.L.P. modules are compatible with each other*, they connect easily. Modules HY6 to HY13 measure 45 x 20 x 40mm. HY66 to HY77 measure 90 x 20 x 40mm. They are so reliable that all I.L.P. modules carry a 5 year no quibble guarantee.

MODEL NO.	MODULE	DESCRIPTION/FACILITIES	CURRENT REQUIRED	PRICE	VAT
HY6	MONO PRE AMP	Mic/Mag. Cartridge/Tuner/Tape/ Aux + Volume/Bass/Treble	10mA	£6.44	£0.97
HY7	MONO MIXER	To mix eight signals into one	10mA	£5.15	£0.77
HY8	STEREO MIXER	Two channels, each mixing five signals into one	10mA	£6.25	£0.94
HY9	STEREO PRE AMP	Two channels mag. Cartridge/ Mic + Volume	10mA	£6.70	£1.01
HY11	MONO MIXER	To mix five signals into one + Bass/Treble controls	10mA	£7.05	£1.06
*HY12	MONO PRE AMP	To mix two signals into one + Bass/Mid-range/Treble	10mA	£6.70	£1.01
*HY13	MONO VU METER	Programmable gain/LED overload driver	10mA	£5.95	£0.89
HY66	STEREO PRE AMP	Mic/Mag. Cartridge/Tape/Tuner/Aux + Volume/Bass/Treble/Balance	20mA	£12.19	£1.83
HY67	STEREO HEADPHONE	Will drive headphones in the range of 4Ω – 2KΩ	80mA	£12.35	£1.85
HY68	STEREO MIXER	Two channels, each mixing ten signals into one	20mA	£7.95	£1.19
HY69	MONO PRE AMP	Two input channels of mag. Cartridge/ Mic + Mixing/Volume/Treble/Bass	20mA	£10.45	£1.57
HY71	DUAL STEREO PRE AMP	Four channels of mag. Cartridge/Mic + Volume	20mA	£10.75	£1.61
*HY72	VOICE OPERATED STEREO FADER	Depth/Delay	20mA	*To be announced*	
*HY73	GUITAR PRE AMP	Two Guitar (Bass/Lead) and Mic + separate Volume/Bass/Treble + Mix	20mA	£12.25	£1.84
†HY74	STEREO MIXER	Two channels, each mixing five signals into one + Treble/Bass	20mA	£11.45	£1.72
†HY75	STEREO PRE AMP	Two channels, each mixing two signals into one + Bass/Mid-range/Treble	20mA	£10.75	£1.61
†HY76	STEREO SWITCH MATRIX	Two channels, each switching one of four signals into one	20mA	*To be announced*	
†HY77	STEREO VU METER DRIVER	Programmable gain/LED overload driver	20mA	£9.25	£1.39

* Ready August – may be ordered now
† Ready September – may be ordered now

All the above modules operate from ±15V minimum to ±30V maximum – higher voltages being accommodated by use of dropper resistors. HY67 can only be used with the PSU 30 power supply unit.

The modules are encapsulated and include latest design high quality clip-on edge connectors.

For easy mounting we recommend
B6 Mounting board for modules HY6 – HY13
78p + 12p. V.A.T.
B66 Mounting board for HY66 – HY77
99p + 13p. V.A.T.

All I.L.P. modules include full connection data.

I.L.P. Products are of British Design and Manufacture.

See also our ad. on page 107

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Signature ....

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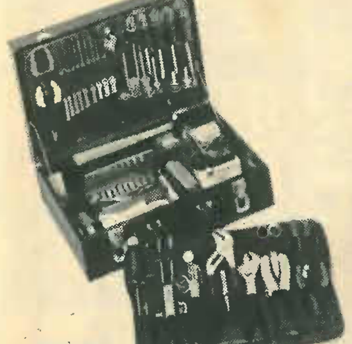

JTK 17

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Deluxe attache case of hardwood construction, llama grain covering and solid brass fittings.
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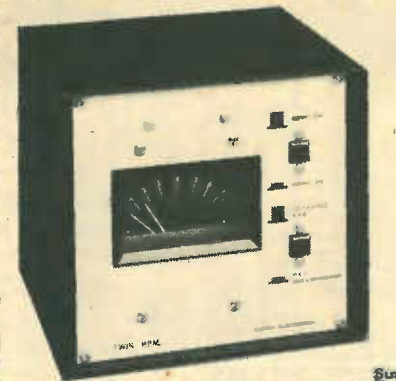
WW–009 FOR FURTHER DETAILS

TWIN PPM BOX



High quality **Ernest Turner** TWIN movement in a mains powered unit. The illuminated coaxially mounted pointers of the TWIN offer an unrivalled method of monitoring stereo Left and Right, or Sum and Difference controlled by a front panel switch. Meets IEC65-2, BS415 safety. Also single version and boards for building into equipment.

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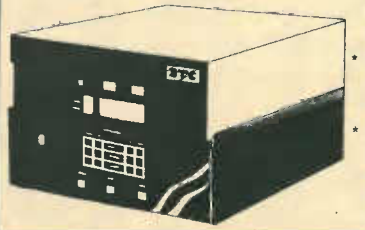

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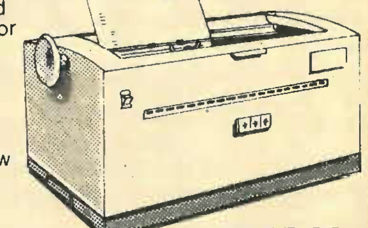

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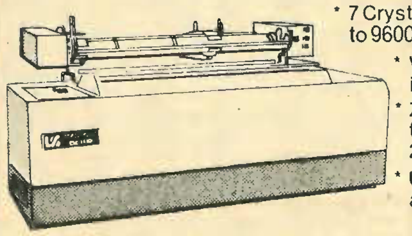

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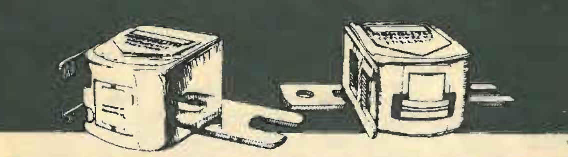
SOUND INVESTMENT



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MAINS ISOLATORS

Pri 0-120; 0-100-120V (120, 220, 240V) Sec 60 55-0-55 60 twice to give 55, 60, 110, 115, 120, 125, 175, 180, 220, 225, 230, 235, 240V.

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

★115 or 240v sec only. State volts required. Pri 0-220-240V.

12 or 24-VOLT

Separate 12V windings Pri 220-240V

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

50 VOLT RANGE

Pri 220-240V. Voltages available 5, 7, 8, 10, 13, 15, 17, 20, 25, 30, 33, 40 or 20V-0-20V and 25V-0-25V

Ref.	Amps 50v	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

30 VOLT RANGE (Split Sec)

Pri 220-240V. Voltages available 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30V or 12V-0-12V and 15V-0-15V

Ref.	Amps 30v	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

60 VOLT RANGE

Pri 220-240V (Split Sec)
Voltages available 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60V, or 24V-0-24V and 30V-0-30V

Ref.	Amps 60v	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

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, 2-20	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

MAINS ISOLATORS

400/440 to 200/240

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

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	0-115-210-240V	2.17	1.00
64	80	0-115-210-240V	4.41	1.20
4	150	0-115-200-220-240V	5.89	1.20
67	500	"	12.09	1.84
84	1000	"	20.64	2.20
93	1500	"	25.61	OA
95	2000	"	38.31	OA
73	3000	"	65.13	OA
80s	4000	0-10-115-200-220-240	84.55	OA
57s	5000	"	98.45	OA

* 0, 115, 220, 240. Step Up or Step Down

CASED AUTOS

240V cable input USA 115V outlets

VA	Price	P&P	Ref
20	£6.55	.95	56W
75	£8.50	1.20	64W
150	£11.00	1.44	4W
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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SPLIT BOBBIN TRANSFORMERS

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End of Line offers – **M679** 120V-2; 36V 1 6A **£3** pp 78p + VAT. **BE7** 0-110-120 220 240V Sec 20V 1 Amp **£1.80.** P&P 32p + VAT

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TRANSCENDENT 2000 single-board synthesizer

Complete Kit £168.50

Designed by consultant Tim Orr (formerly synthesizer designer for EMS Ltd.) and featured as a constructional article in ETI, this live performance synthesizer is a 3-octave instrument transposable 2 octaves up or down giving sweep control, a noise generator and an ADSR envelope shaper. There is also a slow oscillator, a new pitch detector, ADSR repeat, sampe and hold, and special circuitry with precision components to ensure tuning stability amongst its many features.

The kit includes fully-finished metalwork, fully assembled solid teak cabinet, filter sweep pedal, professional quality components (all resistors either 2% metal oxide or ½% metal film), and it really is complete – right down to the last nut and bolt and last piece of wire! There is even a 13A plug in the kit – you need buy absolutely no more parts before plugging in and making great music! Virtually all the components are on the one professional quality fibreglass PCB printed with component locations. All the controls mount directly on the main board, all connections to the board are made with connector plugs and construction is so simple it can be built in a few evenings by almost anyone capable of neat soldering! When finished you will possess a synthesizer comparable in performance and quality with ready-built units selling for many times the price.

Comprehensive handbook fully describes construction and tells you how to set up your synthesizer with nothing more elaborate than a multi-meter and a pair of ears!

TRANSCENDENT POLYSYNTH

expandable polyphonic synthesizer

Complete Kit £320
(single voice)

Plug-in extra voices **£52** (or £48 – if ordered with kit)

By brilliant design work and the use of high technology components the Polysynth brings to the reach of the home constructor a machine whose versatility and range of sounds is matched only by ready-built equipment costing thousands of pounds. Designed by synthesizer expert Tim Orr and published in Electronics Today International, this latest addition to the famous Transcendent family is a 4-octave transposable over 7½ octaves) polyphonic synthesizer with internally up to 4 voices making it possible to play simultaneously up to 4 notes, whereas conventional synthesizers handle only one at a time.

The basic instrument is supplied with 1 voice and up to 3 more may be plugged in. A further 4 voices may be added by connecting to an expander unit, the metalwork and woodwork of which is designed for side-by-side matching with the main instrument. Each voice is a complete synthesizer in itself, with 2 VCOS, 2 ADSRS, a VCA and a VCF (requiring only control voltages and power supply, the voice boards are also very suitable for modular systems). One of these voices is automatically allocated to a key as it is operated. There are separate tuning controls for each VCO of each voice. All other controls are common to all the voices for ease of control and to ensure consistency between the voices.

Although using very advanced electronics the kit is mechanically very simple with mininal wiring, most of which is with ribbon cable connectors. All controls are PCB mounted and the voice boards fit with PCB mounted plugs and sockets. The kit includes fully finished metalwork, solid teak cabinet, professional quality components (resistors 2% metal oxide or metal film of 0.5% and 0.1%), nuts, bolts, etc.

TRANSCENDENT DPX MULTI-VOICE SYNTHESIZER Complete Kit £299

The Transcendent DPX is a really versatile 5 octave keyboard instrument. These are two audio outputs which can be used simultaneously. On the first there is a beautiful harpsichord or reed sound – fully polyphonic, i.e. you can play chords with as many notes as you like. On the second output there is a wide range of different voices, still fully polyphonic. It can be a straightforward piano or a honky tonk piano or even a mixture of the two! Alternatively you can play strings over the whole range of the keyboard or brass over the whole range of the keyboard or should you prefer – strings on the top of the keyboard and brass on the lower end (the keyboard is electronically split after the first two octaves) or vice versa or even a combination of strings and brass sounds simultaneously. And on all voices you can switch in circuitry to make the keyboard touch sensitive! The harder you press down a key the louder it sounds – just like an acoustic piano. The digitally controlled multiplexed system makes practical touch sensitivity with the complex dynamics law necessary for a high degree of realism. There is a master volume and tone control, a separate control for the brass sounds and also a vibrato circuit with variable depth control together with a variable delay control so that the vibrato comes in only after waiting a short time after the note is struck for even more realistic string sounds.

To add interest to the sounds and make them more natural there is a chorus/ensemble unit which is a complex phasing system using CCD (charge coupled device) analogue delay lines. The overall effect of this is similar to that of several acoustic instruments playing the same piece of music. The ensemble circuitry can be switched in with either strong or mild effects.

Although the DPX is an advanced design using a very large amount of circuitry, much of it very sophisticated, the kit is mechanically extremely simple with excellent access to all the circuit boards which interconnect with multiway connectors, just four of which are removed to separate the keyboard circuitry and the panel circuitry from the main circuitry in the cabinet.

The kit includes fully finished metalwork, solid teak cabinet, professional quality components (all resistors 2% metal oxide), nuts, bolts, even a 13A plug!

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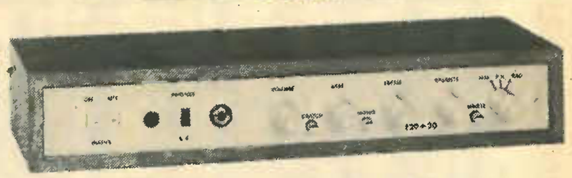
DE LUXE LINSLEY HOOD 75W STEREO AMPLIFIER

Complete Kit £85

This easy-to-build version of our world-wide acclaimed 75W amplifier kit based upon circuit boards interconnected with gold plated contacts resulting in minimal wiring and construction delightfully straightforward. The design was published in Hi-Fi News and Record Review and features include rumble filter, variable scratch filter, versatile tone controls and tape monitoring while distortion is less than 0.01%.

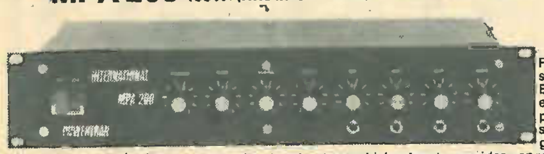


T20 + 20 20W STEREO AMPLIFIER £33.10

This kit, based upon a design published in Practical Wireless, uses a single printed circuit board and offers at very low cost, ease of construction and all the normal facilities found on quality amplifiers. A 30 watt version of this kit (T30 + 30) is also available for **£38.40**+VAT. MATCHING TUNERS – See our FREE CATALOGUE!

MPA 200 100W. (rms into 8 ohms) MIXER/AMPLIFIER

COMPLETE KIT £49.90



Featured as a constructional article in ETI, the MPA 200 is an exceptionally low priced – but professionally finished – general purpose high power amplifier. It features adaptable input mixer which accepts a wider range of sources such as microphone, guitar, etc. There are wide range tone controls and a master volume control. Mechanically the MPA 200 is simplicity itself with minimal wiring needed making construction very straightforward.
The kit includes fully finished metalwork, fibreglass PCBs, controls, wire, etc – complete down to the last nut and bolt.

SP2-200 2-CHANNEL 100W. AMPLIFER

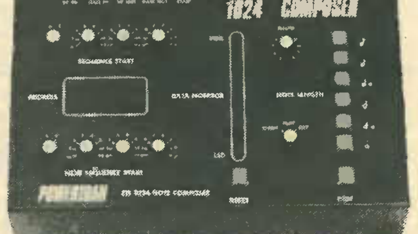
COMPLETE KIT £64.90

The power amplifier section of the MPA 200 has proved not only very economical but very rugged and reliable too. This new design uses two of these amplifier section powered by separate power supplies fed from a common toroidal transformer. Input sensitivity is 775mV.
Even simultaneously driven, each channel delivers over 100W rms into 8 ohms. The kit includes fully finished metalwork, fibreglass PCBs, controls, wire, etc. – complete down to the last nut and bolt!

NEW KITS!

1024 COMPOSER
Complete Kit £89.50

Programmed from a synthesizer, our latest design to be featured in ELECTRONICS TODAY INTERNATIONAL, the 1024 COMPOSER controls the synth. with a sequence of up to 1024 notes or a large number of shorter sequences e.g. 64 of 16 notes all with programmable note length. In addition a rest or series of rests can be entered. It is mains powered but an automatically trickle charged Nickel-Cadmium battery supplying the memory, preserves the program after switch off. The kit includes fully finished metalwork, fibreglass PCB, controls, wire, etc. – Complete down to the last nut and bolt!



DJ90 DISCO SYSTEM – READ ALL ABOUT IT!
in Electronics Today International July/August issue

All kits also available as separate packs (e.g. PCB, component sets, hardware sets, etc.). Prices in our FREE CATALOGUE.

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SALES COUNTER: If you prefer to collect your kit from the factory. Call at Sales Counter. Open 9 a.m. to 12 noon, 1 to 4.30 p.m. Monday to Thursday.

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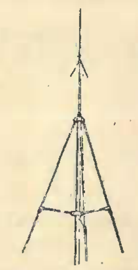

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22 pin	.15	.135	.12	.143	.122	.111
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SPECIFICATIONS

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	0.0035%	1.5Hz—50KHz	80—120—25
CPR1X	output	775mV	REG1	—	30VuS	110dB	775mV	0.008 %	1.5Hz—50KHz	161—102—35
MC1X	output	2mV	REG1	—	3VuS	70dB	2.8mV	0.008 %	10Hz —50KHz	138— 80—35
XO2/3	output	775-2500mV	REG1	—	3VuS	65dB	70/150uV	0.008 %	10Hz —50KHz	80—120—35
					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.

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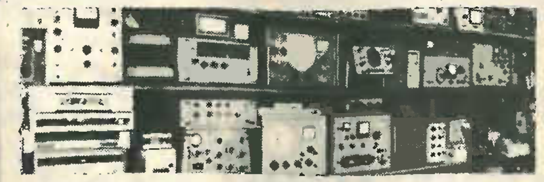

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	1X014	18 - 18	0.83	
	1X015	22 - 22	0.68	
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	1X017	30 - 30	0.50	
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	2X013	15 - 15	1.66	
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	2X015	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	
80VA, 90 · 30mm, 1Kg, Regulation 12%	3X010	6 - 6	6.64	£5.47 · £1.43 P/P · £1.04 VAT
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	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	
	3X030	240	0.33	
120VA, 90 · 40mm, 1.2Kg, Regulation 11%	4X010	6 - 6	10.00	£6.38 · £1.43 P/P · £1.17 VAT
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	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	
	4X030	240	0.50	
160VA, 110 · 40mm, 1.8Kg, Regulation 8%	5X011	9 - 9	8.89	£8.44 · £1.43 P/P · £1.48 VAT
	5X012	12 - 12	6.66	
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	5X014	18 - 18	4.44	
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225VA, 110 · 45mm, 2.2Kg, Regulation 7%	6X012	12 - 12	9.38	£10.06 · £1.73 P/P · £1.77 VAT
	6X013	15 - 15	7.50	
	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	
	6X028	110	2.04	
	6X029	220	1.02	
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300VA, 110 · 50mm, 2.6Kg, Regulation 6%	7X014	18 - 18	8.33	£11.66 · £1.73 P/P · £2.01 VAT
	7X015	22 - 22	6.82	
	7X016	25 - 25	6.00	
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	7X018	35 - 35	4.28	
	7X026	40 - 40	3.73	
	7X025	45 - 45	3.33	
	7X033	50 - 50	3.00	
	7X028	110	2.72	
	7X029	220	1.36	
	7X030	240	1.25	
500VA, 140 · 60mm, 4Kg, Regulation 4%	8X017	30 - 30	8.33	£15.53 · £2.05 P/P · £2.64 VAT
	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	
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	9X026	40 - 40	7.81	
	9X025	45 - 45	6.94	
	9X033	50 - 50	6.25	
	9X042	55 - 55	5.68	
	9X028	110	5.68	
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Home Office

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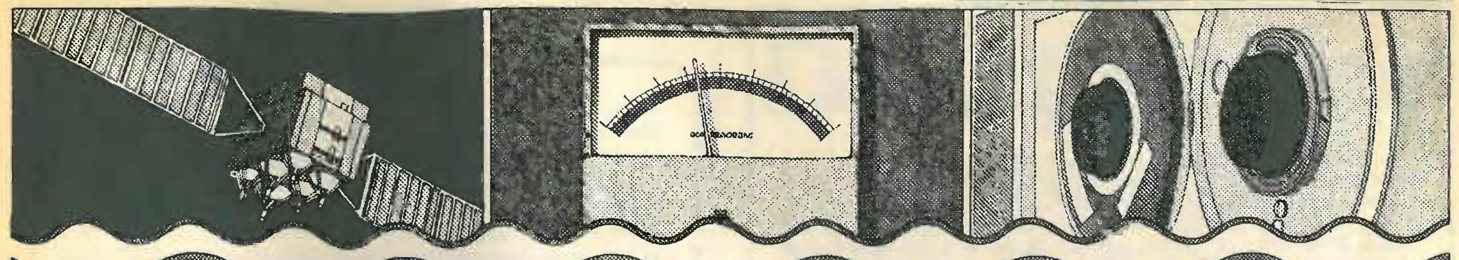


ELECTRONICS TECHNICIANS

Total involvement across the spectrum of advanced communications

The Government Communications Headquarters at Cheltenham is one of the world's foremost centres for research, development and production in the fields of voice and data communications and communications security. Its comprehensive facilities, some of them unique, are geared towards producing creative solutions to complex communications problems using state of the art techniques including computer/microprocessor applications.

There are currently opportunities for those with proven practical experience in electronics to become totally involved in complex systems spanning the whole spectrum of electronics technology. As a Telecommunications Technical Officer you will supervise a team of technicians involved in the management, construction, installation, testing, commissioning and maintenance of advanced technology systems in the UK and abroad. Alternatively you will provide vital support for project engineers and research scientists involved in planning, research and engineering development.

You will take part in most areas of activity and typical examples of current projects include:–

Space communications
Equipping and maintaining new earth stations.

Microwaves
Designing special aerials and electronics for mobile units.

Computer Systems
Providing advanced, automated office systems and high speed computers.

Digital Communications
Providing a complex and comprehensive computer network system.

Analogue Communications
Designing and equipping radio stations.

Most of these opportunities are in Cheltenham but there are others elsewhere in the UK and your preference for location will be taken into account. There are also many opportunities to work overseas.

Cheltenham

A significant advantage for people working at GCHQ in Cheltenham is its location in this elegant Regency town set in the heart of the Cotswolds. You can choose to live in the town itself, or in one of the delightful villages that surround it. Either way, you will have easy access to good shops, schools, sports facilities and cultural amenities in Cheltenham and nearby Gloucester, and also enjoy fast road/rail links to London, the Midlands and the West Country. RELOCATION ASSISTANCE MAY BE AVAILABLE.

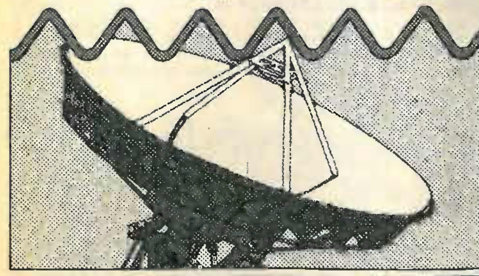
Qualifications

Candidates must possess a TEC Certificate in Electronics, Telecommunications or similar disciplines; or a City & Guilds Part II Telecommunications Technicians Certificate or Part I plus Mathematics B, Telecommunication Principles B, and either Radio Line Transmission B or Computers B; or an equivalent or higher qualification. In addition, all candidates must have had appropriate training and will normally be expected to have had 4 years "hands on" or proven managerial experience in radio, telecommunications, computers and microprocessors. There are also opportunities to join GCHQ at Radio Technician level.

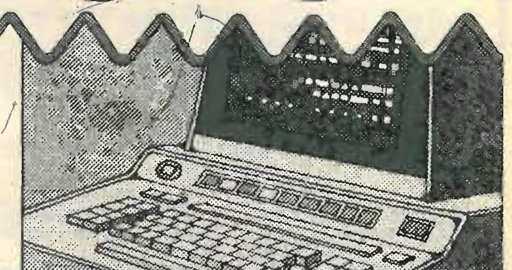
Starting salary will be in the range £5310-£7170 depending upon qualifications and experience. There are good prospects of promotion to posts with salaries of up to £11,100. **Salaries under review.**

For further information and an application form (to be returned by 6 August 1981) write to Civil Service Commission, Alencon Link, Basingstoke, Hants, RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours).
Please quote ref: T/5547/2.

(1228)



GCHQ in the heart of the Cotswolds



ELECTRONICS TECHNICIAN required by Department of Pharmacology, UCL, to work in the Electronics Workshop. Duties would include the design, construction and maintenance of a wide range of sophisticated equipment used in teaching and research laboratories. Candidates should hold HNC or equivalent and have good knowledge of electronics, including digital circuitry. Salary will be either Grade 5, £6,711 to £7666; or Grade 6, £7,548 to £8,818 inclusive of London Weighting, according to qualifications and experience. Application form from Personnel Officer (Technical Staff FE4WW), University College London, Gower St WC1E 6BT. (1211

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REPAIR ENGINEERS for high-level technical support on mpu development systems, single board computers and memories. To £8,000. West Country.

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OF THE SCOTTISH OFFICE

Wireless Technicians

(£5,300-£7,060)

Applications are invited for 4 posts of Wireless Technician in the Central Services Department of the Scottish Office. The posts are based in Inverness, Edinburgh, East Kilbride and Montreathmont, Forfar. Candidates must hold an Ordinary National Certificate in Electronic or Electrical Engineering **or** a City and Guilds of London Institute Certificate in an appropriate subject or a qualification of a higher or equivalent standard and have 3 years' appropriate experience.

A clean current driving licence and ability to drive private and commercial vehicles are essential.

Application forms and further information are obtainable from Scottish Office Personnel Division, Room 110, 16 Waterloo Place, Edinburgh EH1 3DN (quote ref PM(PTS) 2/5/81 (031-556 8400 Ext. 4317 or 5028).

Closing date for receipt of completed application forms is 10th August, 1981.

(1214)

OLDCHURCH HOSPITAL
ROMFORD, ESSEX RM7 0BE

Electronics Technician

Salary scale, Medical Physics Technician III, commencing £5,750 (or at 23 years or over £6,832) rising to £7,277 per annum including London Weighting.

Electronics Service Technician to work in the new District Department of Bio-medical Engineering.

Applicants should hold a minimum of ONC in a relevant subject and have held a post at Technician IV, or equivalent, for at least three years. They should have experience in the running of a planned preventive maintenance programme and in the day-to-day service requirements of the increasingly complex technological environment to be found in a General Hospital.

For further information contact: Mr. R. North, Head of Bio-medical Engineering Department, at the Hospital. Tel: Romford 46090, Ext. 3326.

Closing date 12th August, 1981.

(1221)

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ENGINEERS

We urgently require a Logic Engineer with practical experience of fault-finding on microprocessors and T.V. monitors.

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(1224)

NORTHERN REGIONAL HEALTH AUTHORITY

ELECTRONICS TECHNICAL ASSISTANT

Required for Regional Engineer's Division, based at Walkergate, Newcastle upon Tyne.

The appointment will be at Technical Assistant Grade 1. Salary £6633-£7824 per annum.

The post offers technologically interesting and varied work, with excellent working conditions and well-equipped laboratories, and involves visits to hospitals throughout the Region, for which financial reimbursement is made.

Applicants must be of high calibre and have had considerable and broad experience with modern electronic equipment.

Minimum qualifications: HNC or City and Guilds Full Technological Certificate in Electronic Engineering or equivalent.

Application form and job description from the Regional Personnel Officer, Northern Regional Health Authority, Benfield Road, Newcastle upon Tyne NE6 4PY.

Closing date: 31 July 1981.

(1203)

TRANS VIDEO

We, a progressive Broadcast TV facilities company, require an experienced and capable Electronics Engineer to take responsibility for the maintenance and development of our electronic equipment and CMX computer system.

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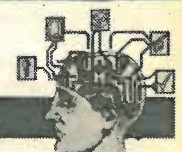
(291)

Notting Dale Technology Centre



NOTTING DALE TECHNOLOGY CENTRE in West London, trains young unemployed people in electronics, computing, and the development and production of electronic devices – particularly aids for disabled persons. The training workshop part of the Centre is run through the YOPS programme. A major thrust is being made to float both co-operatives and small businesses, employing ex-trainees in both commercial and need-based areas.

Two staff vacancies have arisen:

WORKSHOP MANAGER

An electronics engineer is required to set up and run the new workshop. The post involves some teaching of employees; a close relationship with Centre staff; the development and organisation of production of aids for the disabled and liaison with concerned organisations. Experience in small scale production and/or teaching would be an advantage.

INSTRUCTOR

To work with 16-18 year-old trainees in the workshop. Instruction is provided in electronics and computer programming. Ideally the person appointed would have some experience in both fields, and possibly also have been involved in teaching. A concern for the welfare of trainees and a willingness to take part of a collective responsibility for the running of the Centre would be essential.

Salaries for both posts around £7,500. Please apply in writing enclosing full c.v. to:

Reg Ellwood
NOTTING DALE TECHNOLOGY CENTRE
191 Freston Road, London W10 6TH

(1240)

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Piccadilly Radio require a

Broadcast Engineer

to be involved in all aspects of station engineering. Preference will be given to people having experience in this field. Salary will be in the grade I.L.R.2 and the company also runs a bonus scheme

Apply: Phil Thompson
Chief Engineer
Piccadilly Radio
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(1204)

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Miss Alison Newel
Personnel Manager
Visnews Limited
Cumberland Avenue
Park Royal
London NW10 7EH

(1229)

VISNEWS

Exeter Health Care District

Basic Grade Electronics Engineer/ Physicist

to join a team of graduates and technicians responsible for the overall management of electronic equipment used to monitor and treat patients. The person appointed would be expected to partake in the routine p.p.m. and servicing of a wide range of instruments. There will also be scope for some design and development work.

Applications are invited from those who possess a Degree or equivalent qualifications and have an interest in this type of important work and also wish to assist in developing an association with the Audiological Service. Added to this are the benefits of living in a very pleasant area with excellent sailing facilities, etc.

Starting salary £5,346-£5,958 p.a. according to qualifications and experience.

Contact either Dr. D. James, ext. 2278 or Mr. J. Burgess, ext. 2240 for further details.

Application form and job description from Personnel Department, Royal Devon and Exeter Hospital (Wonford), Barrack Road, Exeter. Tel. 77833, ext. 2188.

(1230)

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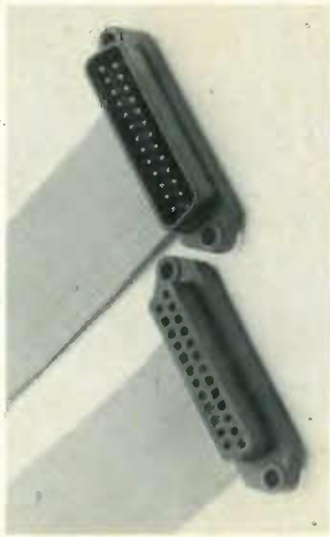

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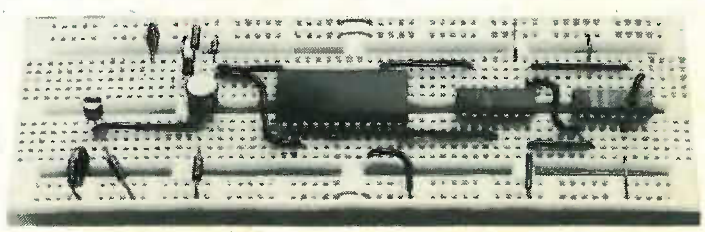

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