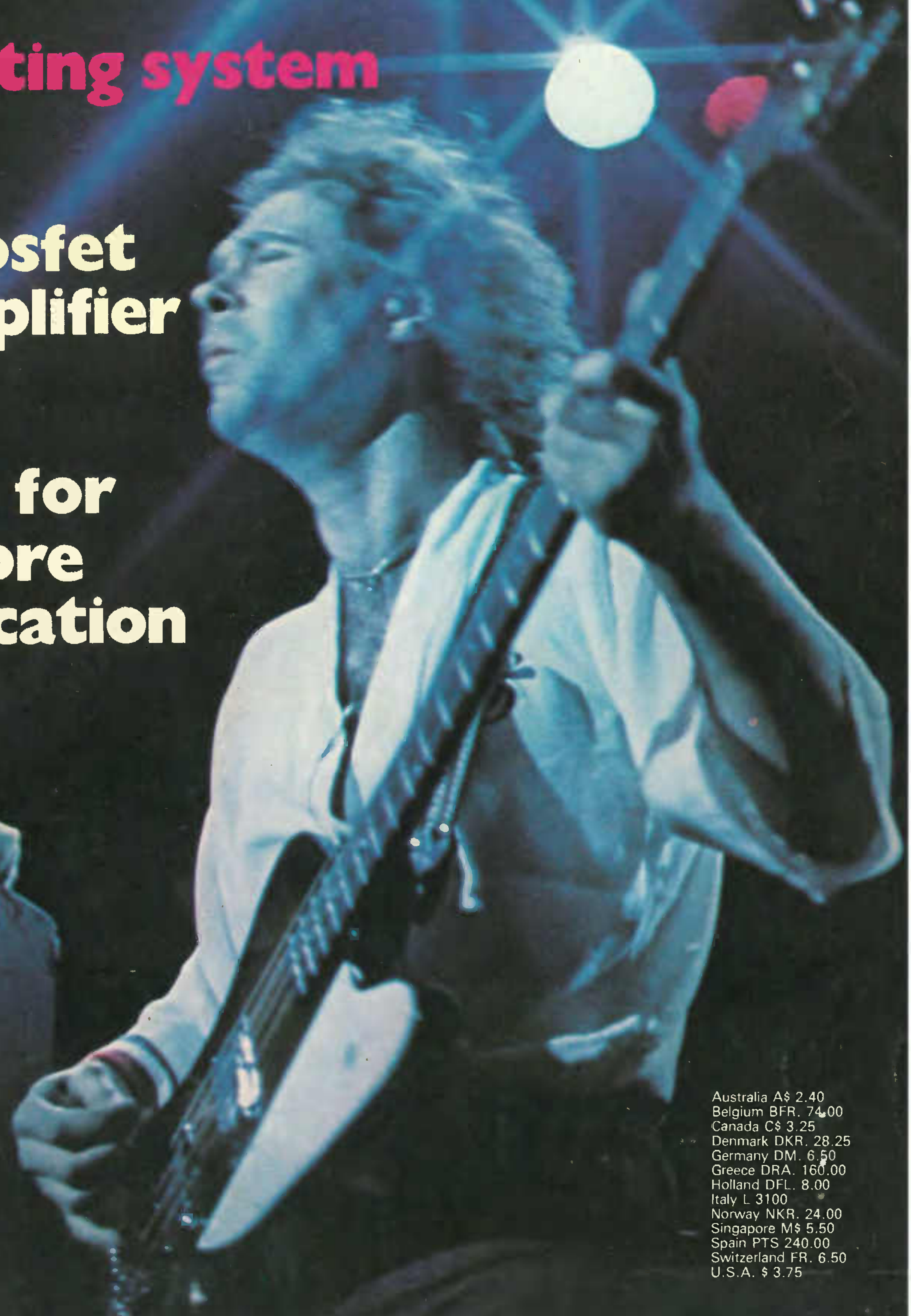
wireless world

APRIL 1982 70p

Stage lighting system

30W Dmosfet audio amplifier

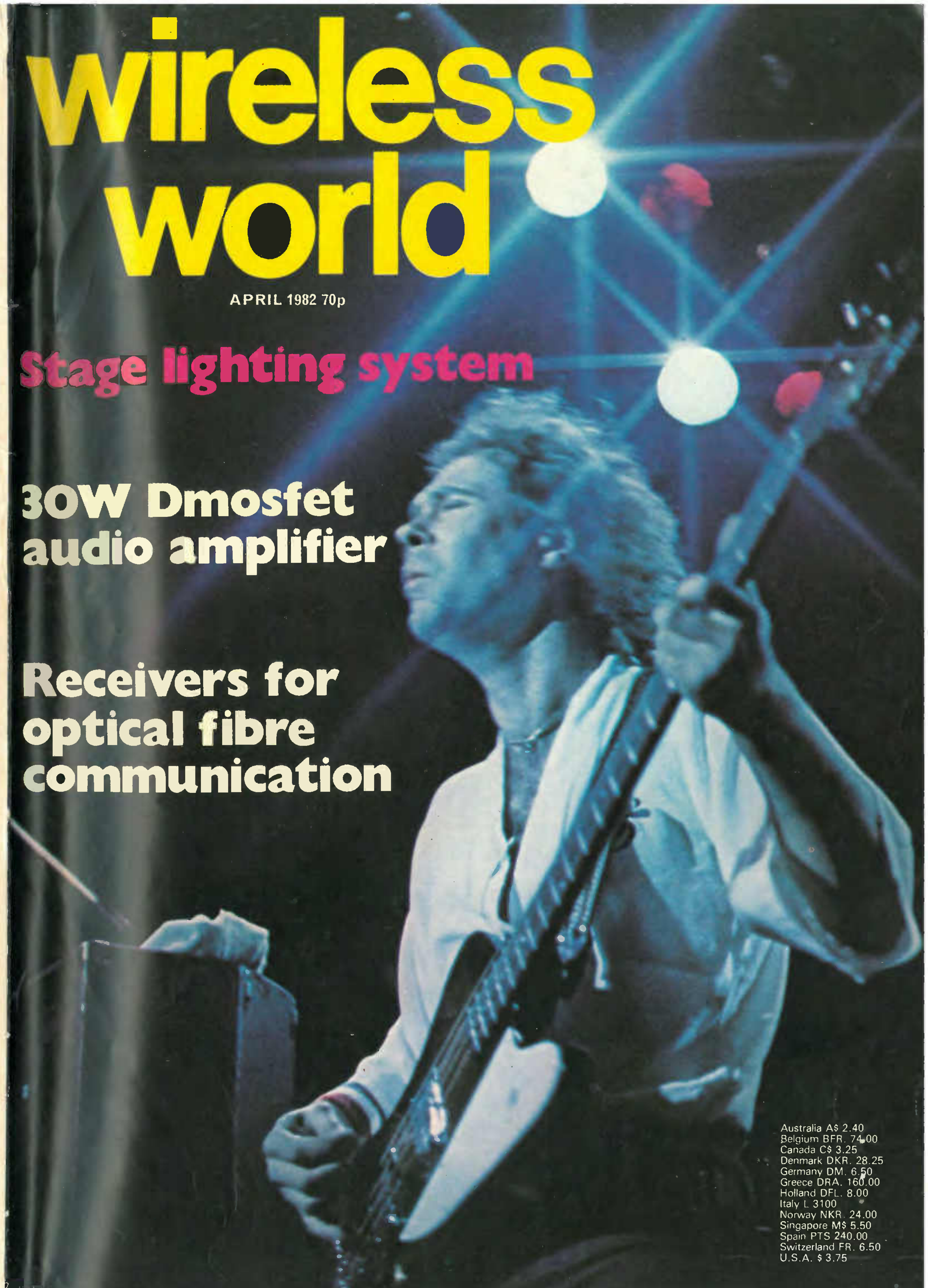
Receivers for optical fibre communication



Australia A$ 2.40
Belgium BFR. 74.00
Canada C$ 3.25
Denmark DKR. 28.25
Germany DM. 6.50
Greece DRA. 160.00
Holland DFL. 8.00
Italy L 3100
Norway NKR. 24.00
Singapore M$ 5.50
Spain PTS 240.00
Switzerland FR. 6.50
U.S.A. $ 3.75

WW—003 FOR FURTHER DETAILS

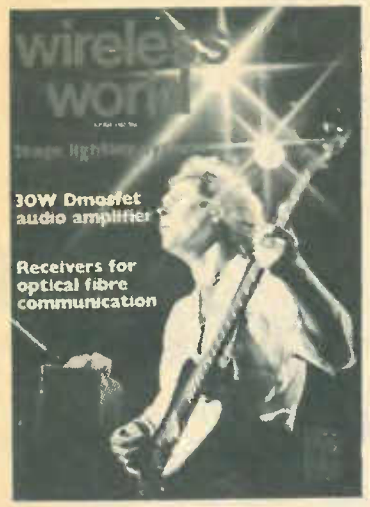
WIRELESS WORLD APRIL 1982 VOL 88 NO 1555



wireless world

ELECTRONICS
TELEVISION
RADIO
AUDIO

APRIL 1982 Vol 88 No 1555



Front cover picture illustrates the article on microprocessor stage lighting systems, starting this month.

NEXT MONTH

Digital filters – a new series giving theory, design techniques and microprocessor implementation.

Program exchange by telephone – design of software systems for loading source-code programs into memory.

Orchestral sound, halls and timbre – or 'Why does it sound so beautiful?' Denis Vaughan examines the Kingsway Hall and puts forward a theory to account for its excellence.

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

Telephones: Editorial 01-661 3500. Advertising 01-661 3130.

Telegrams/Telex: 892084 BISPRS G.

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

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USA: $39 surface mail, $98.30 airmail. US subscriptions from IPC B.P. Subscriptions Office, 205 E.42nd Street, NY 10017.

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ISSN 0043 6062

EP4000 EPROM EMULATOR PROGRAMMER

- ★ Programs 2704/2708/2716(3)/2508/2758 2516/2716/2532/2732
- ★ Emulates same devices with a single keypress
- ★ 300ns access time in emulation mode
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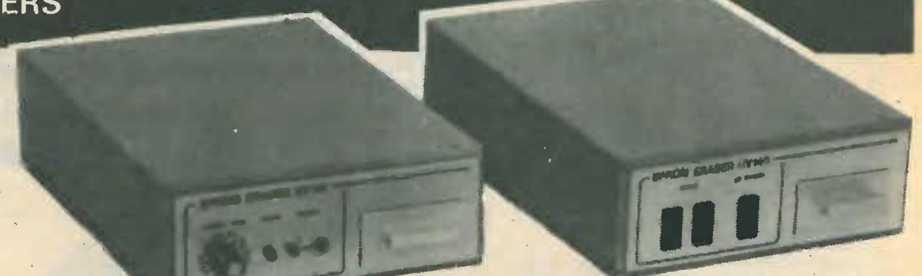
- ★ Fully buffered cold ZIF socket
- ★ Price £545 + VAT + £12 delivery

P4000 PRODUCTION PROGRAMMER

- ★ Program 1-8 devices simultaneously
- ★ Programs same devices as EP4000
- ★ No personality cards needed
- ★ Simple operation
- ★ Blank check & verify functions
- ★ Powered down master & copy sockets
- ★ Individual socket LED indicators
- ★ Mode indicators for blank check, program verify, and socket power down
- ★ Price £545 + VAT + £12 delivery

MODEL 14 EPROM ERASERS



- ★ 14 EPROM capacity
- ★ Safety interlocked
- ★ Convenient tray loading of devices
- ★ UV141 (with timer) £78 + VAT
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EA113 Electronic Multimeter. £115.00

Bruel and Kjaer
2409 TRUE RMS. Average and Peak 2Hz-200KHz £250.00

Hewlett Packard
3400A True RMS 1mV-300V 10Hz-10MHz £600.00

Marconi.
TF2603 RF Millivoltmeter 300µV Sensitivity. 50KHz-1.5GHz £525.00
TF2604 Electronic Voltmeter. AC 20Hz-1.5GHz. 300mV-1KV DC 10mV-1KV. 0.2Ω-500MΩ £350.00

ANALYSERS

Dymar.
1785 AM/FM Modulation meter 30-480MHz £295.00

Hewlett Packard
331A Distortion analysers 5Hz-600KHz to 0.1% voltmeter 300µV-300 volts at 2% £350.00
332A Distortion Meter 5Hz-600KHz £495.00
333A Distortion Meter with Auto null £675.00
8407A/8412A Network Analyser £1950.00
8555A Plug in. 10MHz-18GHz. £5000.00

Racal
9009 Automatic AM/FM modulation meter 30-150MHz manual tuning 8-1500MHz £395.00

Sound Technology
1700A measures distortion down to 0.002%. AC voltage 30µV-300V. S/N Ratio 100dB Dynamic range. power into 8Ω. 0.001% distortion Oscillator £950.00

Marconi
TF2303 AM/FM Modulation meter AM to 225MHz. FM to 520MHz £475.00
TF2370 Spectrum Analyser. 30Hz-110MHz. 0.1dB and 5Hz resolution £6500.00
TK2374 Zero loss probe for TF2370 £375.00

Tektronix
R491 Spectrum Analyser 10MHz-40GHz £3500.00
7603 Main Frame with 7L13 plug in 1KHz-1.8GHz. 30Hz-3MHz resolution. —128dBm sensitivity £9850.00

BRIDGES

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

Marconi
TF1245A + TF1246 'Q' meter £1100.00
TM4520 Set of Inductors £350.00

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

Wayne Kerr
SR268 Source and Detector £875.00

B642 LCR 0.1% £750.00

FREQUENCY COUNTERS

Fluke
[illegible] 7 digit 520MHz £425.00
1920A with Option 13 9 Digit 1GHz £750.00
1925A Multifunction, EMI Proof 9 Digit 125MHz £625.00
1953A Counter Timer Opt 04, 07, 14, 15. 0-1.25GHz with prescalers. I.E.E.E. interface £975.00

Hewlett Packard
5340A 8 Digit 10Hz-18GHz £3750.00

Marconi.
TF2430 unused condition. 7 digit 10Hz-80MHz 25MV Sensitivity £175.00
TF2432 10Hz-560MHz 10mV sensitivity £325.00

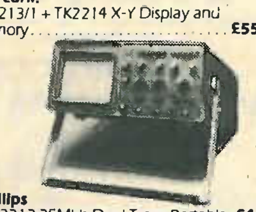
DVM's AND DMM's

Fluke
8022A 3½ digit hand held £65.00

Solartron.
7055 Microprocessor DMM. Scale Length 20,000. AC/DC volts, resistance. 1µV resolution £600.00
7065 Microprocessor DMM. Scale length 1,400,000. AC/DC volts, resistance £695.00

OSCILLOSCOPES

Marconi.
TF2213/1 + TK2214 X-Y Display and memory £550.00



Philips
PM3212 25MHz Dual Trace Portable. £475.00

SE Labs
SM1216 Channel Monitor. 12" crt. internal sweep £395.00

Tektronix.
465 Dual Trace Portable Oscilloscope. DC — 100MHz. 5mV-5V/div. Full delayed sweep £1395.00
465 with DM40 £1450.00
475 Dual Trace 200MHz Portable £2000.00
7603 100MHz Mainframe with 7A18N and 7B53N £3000.00
7704A 250MHz Mainframe c/w 7A22 Diff. Amplifier, 7A26 Dual Channel, 7B80 Timebase and 7B85 Delaying Timebase £4610.00
S1 Sampling Head. As New £450.00
7D14 Digital Counter plug-in 525MHz £850.00

Telequipment
D66A 25MHz Dual Trace £350.00

RECORDERS

Watanabe.
MC641 6 Channel 250mm Chart Recorder £1495.00

Yokagawa
3047 2 Channel 2 cm/HR — 60cm/MIN £435.00

SIGNAL SOURCES

Hewlett Packard.
4204A Decade LF Oscillator. 10Hz-1MHz. 1mV-10V into 600Ω £695.00
606B AM Signal Generator. 50KHz-65MHz. AM 0-95% £850.00
608F 10-455MHz AM/PCM Modulation 0.1µV-1V output £600.00
616B 1.8-4.2GHz int or ext PCM/FM 0.1µV-0.224V £1000.00
616B UHF Signal Generator. 1.8 to 4.2GHz. Int pulse Mod £1000.00
651B Test Oscillator. 10Hz-10MHz. 0.1mV-3.16V £415.00
3200B 10-500MHz Signal Source £475.00
3320A Frequency Synthesizer. 0.01Hz-13MHz. £995.00
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
TF2002B AM/FM 10KHz-88MHz £1200.00
TF2170B Synchronizer for TF2002B £450.00
TF995B/2 AM/FM 200KHz-200MHz £695.00
TF2005R 2 Tone Signal Source. 20Hz-20KHz. 0-111dB in 0.1dB steps £295.00
TF2008 AM/FM 10KHz-510MHz built in sweeper. Output 0.2µV-200mV £3500.00
6070 Signal Source 400-1200MHz £695.00

Philips.
PM5715 Pulse Generator 1Hz-50MHz £675.00
PM6456 Stereo Generator £250.00

Radiometer
SMG1 Stereo Generator £375.00

TRANSMISSION MEASURING EQUIPMENT

Siemens.
D2040 Selective Level Analyser and Voltmeter. 10Hz-60KHz. £1200.00
D2072 + W2072 Level Meter and Oscillator. 50KHz-100MHz £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 Pettern Generator £2490.00
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.

MISCELLANEOUS

Dymar
2085 AF Power meter 30Hz-30KHz 10µW-50W input imp 1.2-1000Ω £250.00

Fluke
3010A Logictester. Self Contained. Portable. Full Spec. on Request £8500.00

Hewlett Packard.
355E 12dB Programmable Attenuator unused £90.00
4329A High Resistance meter 500KΩ-2 × 10^{16} Ω test voltages 10-1000V £500.00
8405A Vector Voltmeter 1-1000MHz £2000.00
8403A Modulator Fitted With 8732B PIN MODULATOR £1500.00
8412A Phase Magnitude CRT display for network analyser £1500.00
8482H Power Sensor 100KHz-4.2GHz. AS NEW £250.00
8745A S Parameter Test Set. Fitted with 11604A Universal Arms 0.1-2GHz. £2750.00
59308A HP-IB Timing Generator £300.00

Marconi.
TF2162 M.F. Attenuator. 0-111dB £135.00
TF2163S UHF Attenuator 0-142dB 50Ω impedance DC-1GHz. £250.00
TF2331 AF Distortion Meter 20Hz-20KHz. £395.00
TF2500 AF Power Meter. 7 ranges 100µ watts to 25 watts £275.00
TF2807A PCM Multiplex tester £1500.00
TF2950/5 mobile Radio Test Set AM/FM £1550.00
TM8339 AC/DC mixer for use with TF2702 £250.00

Philips
PM5519 Colour TV Pattern Generator AS NEW £650.00
PM9380 Camera and Accessories (as new) £200.00

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

Tektronix
141A PAL Test Signal Generator £1750.00
1481C PAL TV Waveform Monitor. £2375.00
191 Constant Amplitude Sig. Gen. 350KHz-100MHz 5mV-5.5V £350.00
TM504 mainframe with SG503 + PG506 + DM501 + TG501 £3500.00

Please note: Prices shown do not include VAT or carriage.

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WIRELESS WORLD APRIL 1982

CMOS	
4000	0.11
4001	0.11
4002	0.12
4007	0.13
4008	0.50
4008AE	0.80
4009	0.25
4010	0.30
4011AE	0.24
4011	0.11
4013	0.25
4015	0.50
4016	0.22
4017	0.40
4019	0.38
4020	0.55
4021	0.55
4022	0.55
4023	0.15
4024	0.33
4025	0.15
4026	1.05
4027	0.26
4028	0.50
4029	0.55
4030	0.35
4035	0.67
4040	0.50
4042	0.50
4043	0.50
4043AE	0.93
4044	0.60
4046	0.60
4047	0.88
4049	0.24
4050	0.24
4051	0.55
4052	0.55
4053	0.55
4054	1.30
4055	1.30
4056	1.30
4059	5.75
4060	0.75
4063	1.15
4066	0.30
4067	4.30
4068	0.16
4069AE	0.14
4070	0.16
4071	0.16
4072	0.16
4073	0.16
4075	0.16
4076	0.55

4077	0.18
4078	0.18
4081	0.12
4082	0.18
4093	0.30
4099	0.80
4175	0.80
4502	0.60
4503	0.50
4506	0.70
4507	0.37
4508	1.50
4510	0.55
4511	0.45
4512	0.55
4514	1.25
4515	1.25
4516	0.60
4518	0.35
4520	0.60
4521	1.30
4522	0.89
4527	0.80
4528	0.65
4529	0.70
4531	0.85
4532	0.80
4534	4.00
4536	2.50
4538	0.85
4539	0.80
4543	0.60
4549	3.50
4553	2.70
4554	1.20
4555	0.35
4556	0.40
4557	2.30
4558	0.80
4559	3.50
4560	2.50
4561	1.00
4562	2.50
4566	1.20
4568	1.45
4569	1.70
4572	0.22
4580	3.25
4581	1.40
4582	0.70
4583	0.80
4584	0.27
4585	0.45
4702	4.50
4703	4.48
4704	4.24

4705	4.24
4706	4.50
4720	4.00
4723	0.95
4724	0.95
4725	2 24
40014	0.54
40085	0.99
40098	0.54
40106	0.69
40160	1.05
40161	1.05
40162	1.05
40163	1.05
40174	1.05
40175	1.05
40192	1.08
40193	1.08
40194	1.08
40195	1.08
TTL	**N**
7400N	0.10
7401N	0.10
7402N	0.20
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
7420N	0.13
7421N	0.28
7423N	0.22
7425N	0.22
7426N	0.22
7427N	0.22
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
74178N	0.90
74179N	1.35
74180N	0.75
74181N	1.22
74182N	0.70
74184N	1.20
74185N	1.20
74188N	3.00
74190N	0.55
74191N	0.55
74192N	0.55
74193N	0.55
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74195N	0.55
74196N	0.55
74197N	0.55
74198N	0.85
74199N	1.00
74221N	1.00
74246N	1.50
74247N	1.51
74248N	1.89
74249N	0.11
74251N	1.05
74265N	0.66
74273N	2.67
74278N	2.49
74279N	0.89
74283N	1.30
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
74LSN	
74LS00N	0.10
74LS01N	0.10
74LS02N	0.11
74LS03N	0.11
74LS04N	0.14
74LS05N	0.13
74LS08N	0.12
74LS09N	0.12
74LS10N	0.12
74LS11N	0.12
74LS12N	0.12
74LS13N	0.20
74LS14N	0.30
74LS15N	0.12
74LS20N	0.12
74LS21N	0.12
74LS22N	0.12
74LS26N	0.14
74LS27N	0.12
74LS28N	0.15
74LS30N	0.12
74LS32N	0.12
74LS33N	0.15
74LS37N	0.15
74LS38N	0.14
74LS40N	0.13
74LS42N	0.30
74LS47N	0.35
74LS48N	0.45
74LS49N	0.55
74LS51N	0.13
74LS54N	0.14
74LS55N	0.14
74LS73N	0.21
74LS74N	0.16
74LS75N	0.22
74LS76N	0.20
74LS78N	0.19
74LS83N	0.40
74LS85N	0.60
74LS86N	0.14
74LS90N	0.32
74LS91N	0.28
74LS92N	0.31
74LS93N	0.31
74LS95N	0.40
74LS96N	1.20
74LS107N	0.25

74LS109N	0.20
74LS112N	0.20
74SL113N	0.20
74LS114N	0.19
74LS122N	0.35
74LS123N	0.35
74LS124N	1.80
74LS125N	0.24
74LS126N	0.24
74LS132N	0.42
74LS133N	0.24
74LS136N	0.20
74LS138N	0.30
74LS139N	0.30
74LS145N	1.20
74LS151N	0.30
74LS153N	0.27
74LS154N	0.99
74LS155N	0.35
74LS156N	0.37
74LS157N	0.30
74LS158N	0.30
74LS160N	0.37
74LS161N	0.37
74LS162N	0.37
74LS163N	0.37
74LS164N	0.40
74LS165N	0.80
74LS166N	0.80
74LS168N	0.70
74LS169N	0.85
74LS170N	0.90
74LS173N	0.80
74LS174N	0.40
74LS175N	0.40
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74LS191N	0.45
74LS192N	0.45
74LS193N	0.42
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74LS195N	0.35
74LS196N	0.55
74LS197N	0.60
74LS200N	3.40
74LS202N	3.45
74LS221N	0.50
74LS240N	0.80
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74LS242N	0.70
74LS243N	0.70
74LS244N	0.60
74LS245N	0.80
74LS247N	1.35

74LS248N	1.35
74LS249N	1.35
74LS251N	0.35
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74LS259N	0.60
74LS260N	0.50
74LS266N	0.22
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74LS279N	0.35
74LS280N	2.50
74LS283N	0.42
74LS290N	0.50
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74LS295N	1.50
74LS298N	0.76
74LS365N	0.32
74LS366N	0.34
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74LS377N	0.85
74LS378N	0.65
74LS379N	0.60
74LS384N	2.50
74LS385N	2.05
74LS386N	0.29
74LS390N	0.68
74LS393N	0.61
74LS395N	2.10
74LS396N	1.99
74LS398N	2.75
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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
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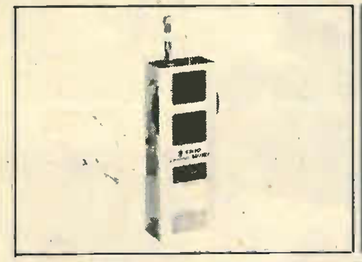

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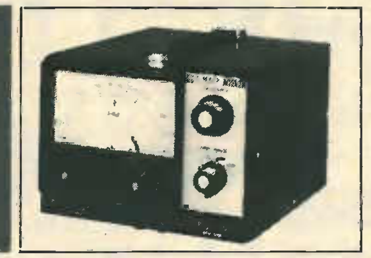

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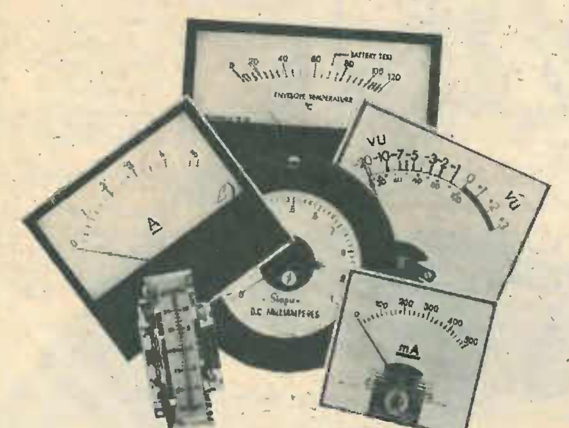

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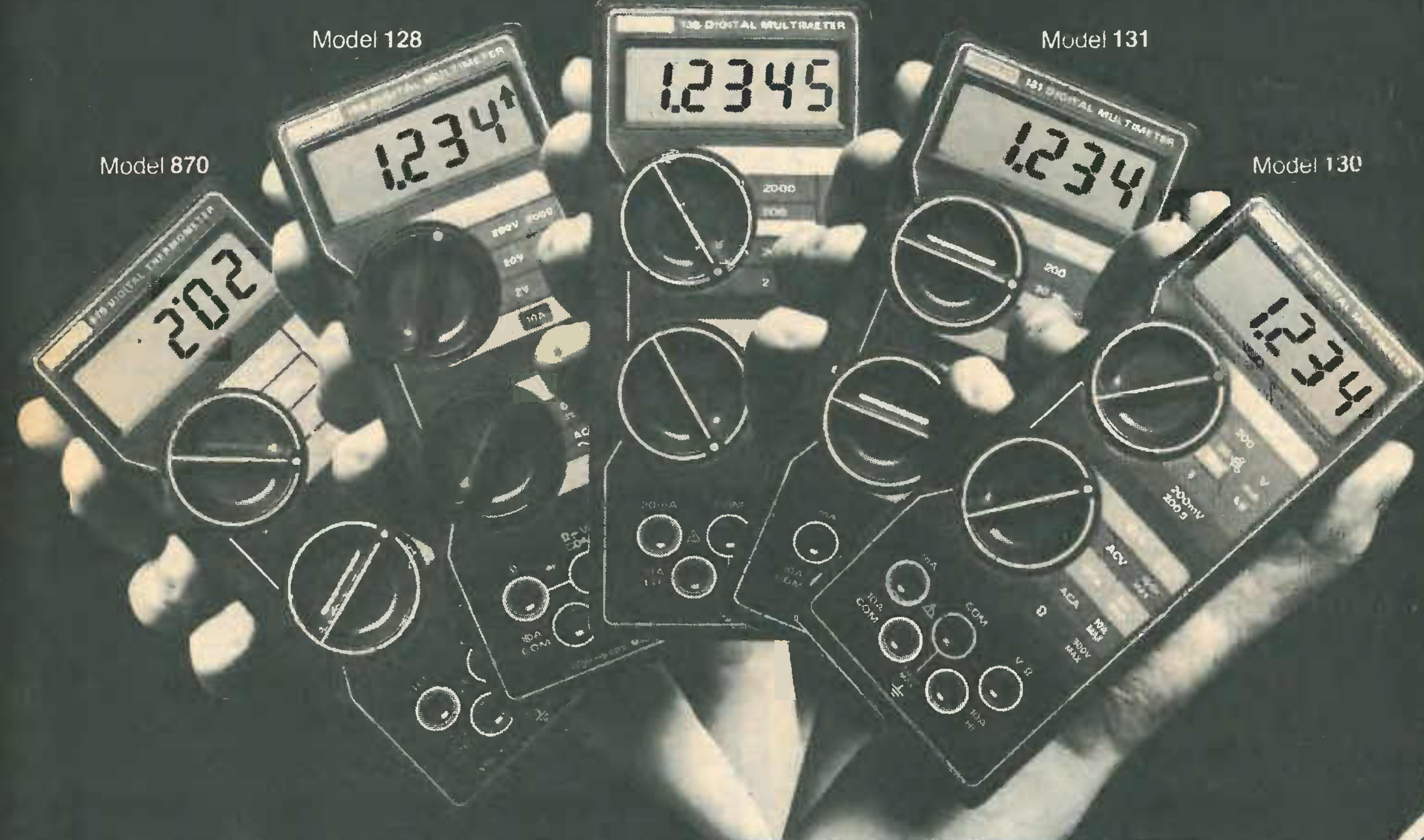

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WW4/82

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

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

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

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

Lower price: higher capability

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

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

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

New BASIC manual

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

Kit: £49.95

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

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

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

New, improved specification

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

Built: £69.95

Kit or built – it's up to you!

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

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

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

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

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

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

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

How to order your ZX81

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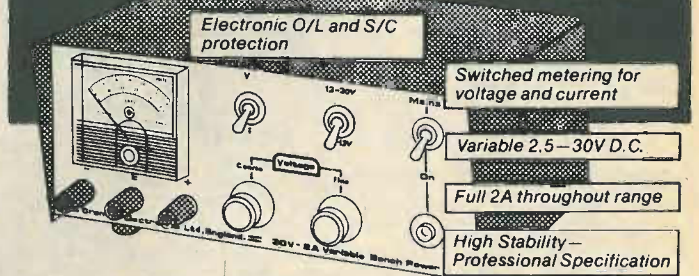

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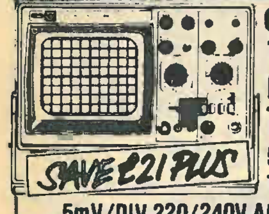

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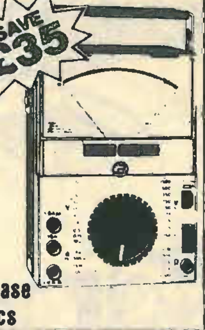

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100m 3½ digit LCD 30 range Rotary switch plus Hfe Tester 10A AC/DC £69.95

Callers will always find a range of low cost test equipment, accessories, tools, irons and boards in stock, also special offers for certain equipment which will vary from time to time.
Price correct at time of preparation E&OE.
All prices include VAT

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STOP PRESS Few only 8110 23 range 10A AC/DC, range hold, continuity buzzer plus much more. Rotary switch £59.95

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New reliable range of DMM's and frequency computers with those extra facilities and competitive prices. All battery operated (supplied). Except 5020A mains. Optional mains eliminators available.

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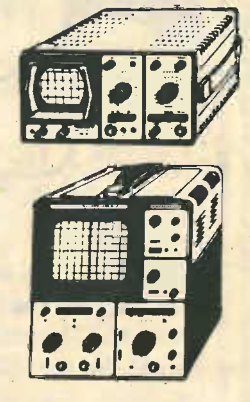

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4¾ Digit. 0.05% 7 Function LCD
30 ranges: 1200V DC, 750V AC, 10A AC/DC, 32 Meg ohm. Also includes frequency measurement to 4 MHZ and 4 KHZ output.
Made to exacting standards in the UK.
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AMATEUR/CB TESTING – Full lists send SAE

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All featuring AC/DC Volts/Current & Ohms ranges.
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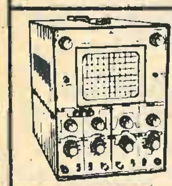
SAFGAN PORTABLE OSCILLOSCOPES



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'THE SHOW' is now at The Barbican, Tuesday to Thursday, April 20 to 22. 10 a.m. – 6 p.m. except Thurs. (When 5.00 p.m.)

TAKE A COACH TO THE SHOW!

A world-first in exhibition visitor attraction . . . unique to Britain.

Take the trouble out of travelling to 'The Show'

The All-Electronics/ECIF Show has moved to the City of London's new exhibition halls at The Barbican – **and** doubled in size!

That means 460 **stands** in all. (Grosvenor House had 220 – to give you a comparison of scale.)

And because it's now almost as big as its continental equivalents, it is the one event of the year that will give **you** a comprehensive analysis of the electronics industry as a whole.

As befits its new authority, the event is simplicity itself to get to.

For the organisers are providing you with first-class coaches to take you to 'The Show' at less cost than the equivalent public transport.

(As long as you live within a one-and-a-half hour's journey by road radius from the City of London.)

Just complete our coupon and indicate the town nearest you from which you'd be happy to depart at 9.00 a.m.-ish.

Enclose a cheque or postal order for the indicated sum – and you'll get a remarkable package in return!

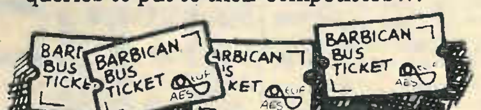
A) Your ticket to take you to the Barbican and back (in comfort – and with full documentation, by the way).

B) A **free** season pass to the exhibition.

C) A **free** copy of the 120-page 'Show' catalogue and yearbook.

D) Full details of all the events, seminars and receptions taking place during The All-Electronics/ECIF Show.

Need we mention that, with this kit, you can prepare for your visit by contacting those exhibitors you **must** see in advance and arrange a meeting 'on stand'. You can also prepare spec/cost/availability queries to put to their competitors . . .



Britain's No. 1 electronics event: created to take on the best in Europe

The All-Electronics/ECIF Show is **your** big, big one!

Four hundred and sixty stands for you to visit, no less.

And we couldn't make it easier for you to see them.

Just use the top coupon if you'd like to travel via our coach parties.

Or, if you'd prefer to make your own way there, use the bottom coupon.

All we need is a 20p stamp – and we'll send you tickets, catalogue, details – oh, everything! (But we must get your form by April 10th.)

Remember this: you can't afford to miss The All-Electronics/ECIF Show

It's true.

So big is 'The Show's' scale that virtually everyone will be there.

Your next employer, to be opportunistic.

And the manufacturer of components that will significantly alter your circuitry design.

Or the purveyor of products at significantly cheaper prices than you've been accepting.

Plus your colleagues from way back when . . .

Plus the chance recognition of an opportunity which, were it not for the product parade, the conflux of competitors, the state of the mart . . . well, you'd not pass Go, not collect £200!

So take two minutes **now** to prepare for very special opportunities.

1 Use this form if you're going to use our coaches . . .

They depart from the towns listed at 9 a.m.-ish. And they leave the Barbican between 5 and 6 p.m.

Please tick the appropriate boxes, return the form enclosing your cheque/P.O. made out to The All-Electronics/ECIF Show, and we'll send you **full** information (including the departure points, their nearby car parking facilities, luncheon alternatives, and so on).

If, by any chance, fewer than 30 people wish to journey from the town of your choice on the day of your choice, you'll get your money back a.s.a.p.

The cost includes the postage for a catalogue, a free season ticket. And we'll enclose a receipt.

"I require (insert quantity) ☐ packages and enclose cheque/P.O. for: £ ________

Name (please use clear capital letters) ________

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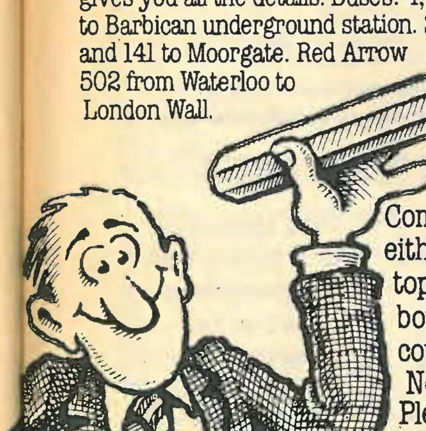
For the Barbican

Liverpool Street – and a seven-minute walk. Or take the Metropolitan or Circle Line tube from any of the rail termini to 'The Barbican' and it's a 1-minute walk! Your free ticket gives you all the details. Buses: 4, 277, 279 to Barbican underground station. 21, 43, 76 and 141 to Moorgate. Red Arrow 502 from Waterloo to London Wall.



Complete either our top or our bottom coupon. Now. Please.

2 Making your own way? Use this

Please attach a 20p stamp by its corner to cover postage and packing costs for your free season ticket to 'The Show.' **Plus** a 120-pp catalogue with full details of the event. **And** comprehensive details of the activities (seminars, receptions, etc.)

(please use clear capital letters)

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Name ________

Address ________

4776F

3 If you're just going to turn up . . .

Well, admission is £1 without a ticket. We're open between 10 a.m. and 6 p.m. on Tuesday and Wednesday. But between 10 a.m. and 5 p.m. on Thursday. (This – and other – information goes with the ticket, so **do** ask for one **now!**)

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X: Timebase 0.2s-0.5µs/cm (±5%) – Triggering 2Hz-30MHz (3mm) – Built in component tester – Calibrator – Screen 6 x 7 – 1kV.

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X: Timebase 0.2s-40ns/cm incl.x5 Magn. – Trigger 3Hz-30MHz (4mm) – X-Y operation – Calibrator – Screen 8 x 10cm – 2kV.

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Bandwidth DC-20MHz (-3dB) Sensitivity 2mV/cm - 20V/cm(±3%) Timebase 40ns/cm Triggering DC - 40MHz (5mm) Algebraic Add., Sweep Delay, x5 Mag., Overscan Ind., Var. Holdoff, Single Sweep.

HM705 £580
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2A Series BY 290
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3.7A Series C3700/2200
5A Series C5000/3300
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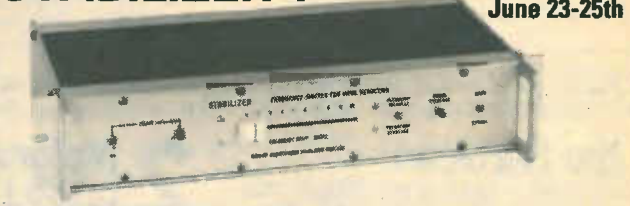
STABILIZER 4

APRS Stand 35 June 23-25th



The Stabilizer is a high quality frequency shifter for howl reduction on speech and music. It offers variable shifts either up or down between 1 and 10 Hertz so allowing choice of the optimum shift for the particular acoustics and sound sources involved in each installation. Rack and box versions.

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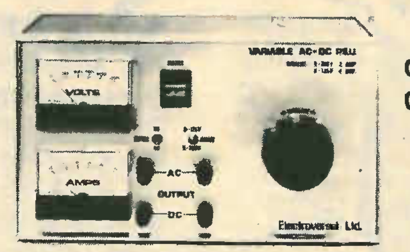

2 ranges:
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AC or DC
Continuously variable.

Output is fused and mains isolated.

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- ★ GREEN DISPLAY
- ★ BUILT IN AMPLIFIER AND SPEAKER
- ★ **£149.95** each excluding carriage (£10.00) and V.A.T. (15%)
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The NEC JB1201M is a 12" Video Monitor optimised for use as a computer video display terminal (unlike most CCTV monitors available). The green phosphor CRT display greatly reduces eyestrain. The built in audio amplifier and speaker make it specially suitable for personal computers.

EPROM PROGRAMMERS AND ERASER

EP4000 EMULATING PROGRAMMER

- ★ COPY/PROGRAMME/EMULATE 2704/2708 2716/2508/2516/2532/2732 EPROMS
- ★ 4K x 8 STATIC RAM
- ★ VIDEO O/P AND 8 DIGIT LED DISPLAY
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- ★ PROGRAMME UP TO 8 EPROMS SIMULTANEOUSLY
- ★ COVERS SAME EPROMS AS EP4000
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- ★ SIMPLE TO USE
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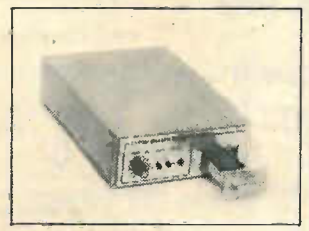
UV141 EPROM ERASER



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KEYBOARD AND ENCLOSURE

CASE Attractively styled personal computer enclosure constructed of structured foam top and steel base (similar to the top selling Apple). Finished in charcoal and black.
£49.95 excluding carriage (£10.00) and V.A.T. (15%)

KEYBOARD High quality electromechanical ASCII Encoded keyboard which can be fitted in above case or used separately. Full upper and lower case provided.
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TRANSFORMER Mains transformer suitable for +5V at 2.5A and ±12V at 1A. Mounts on special lugs inside enclosure.
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HEATSINK Heatsink for T03 Regulators which mounts inside rear of enclose.
£2.50 excluding V.A.T. (15%)

SPECIAL PRICE FOR CASE, KEYBOARD, TRANSFORMER & HEATSINK IF PURCHASED TOGETHER:
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Device	Price
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2708 450ns	1+2.25 25+1.99
2716 450ns (single +5V)	1+2.40 25+2.25
2716 350ns	6.95
2532 450ns	1+4.50 25+4.25
2732 450ns	1+3.99 25+3.80
2732 350ns	7.50
4116 200ns	1+0.74 25+0.70 100+0.67
4116 150ns	1+0.93 25+0.89
4118 200ns	1+3.90 25+3.45
4118 150ns	8.00
5516 200ns	12.50
6116 200ns	7.95
6116LP 200ns	10.00
6116LP 150ns	10.85
CRT CONTROLLERS	
EF6845P	9.50
EF9364P	5.94
EF9365P	62.90
EF9366P	62.90
EF9365/6 DATA AND APPLICATIONS	2.00
BUFFERS	
81LS95	0.90
81LS96	0.90
81LS97	0.90
81LS98	0.90
8T26A	0.99
8T28A	1.40
8T95	1.35
8T97A	1.35
8T98	1.45
DATA CONVERTERS	
ZN425E-8	3.45
ZN426E-8	3.00
ZN427E-8	5.99
ZN428E-8	4.75
ZN429E-8	2.10
ZN432CJ-10	28.09
ZN433CJ-10	2.59
ZN440	56.63
ZN432E-10	14.75
ZN447	9.14
ZN448	6.85
ZN449	3.20
NEW FLOPPY DISC CONTROLLERS	
FD1771	17.12
FD1791	32.81
FD1793	32.81
FD1795	35.33
WD1391	45.50
WD1393	45.50
WD1395	45.50
WD1397	45.50
WD2143-01	5.45
WD1691	10.87
MISCELLANEOUS SUPPORT CHIPS	
AY-3-1015	3.25
AY-3-1270	7.95
AY-3-8910	6.95
AY-5-1013	3.45
AY-5-3600	7.95
AY-5-2376	6.95
DP8304	4.50
MC1488	0.59
MC1489	0.59
MC3446	2.95
MC3448A	4.25
MC3480	7.95
MC3487	2.95
MC14411	6.94
MC14412	7.99
RO-3-2513L	6.99
RO-3-2513U	5.99
ULN2803A(L203)	0.84
DVM CHIPS	
ZN450e	7.81
ZN450E DVM KIT	25.00
NEW LINEARS	
LM301AN	0.25
LM308N	0.89
LM311N	0.69
LM319N	2.20
LM324N	0.30
LM348N	0.59

Device	Price
LM555CN	0.16
LM556CN	0.49
LM725CN	3.20
LM741CN	0.14
LM747CN	0.70
LM748CN	0.34
REGULATORS	
7805	0.39
7812	0.39
7815	0.39
78L05	0.29
78L12	0.29
78L15	0.29
7905	0.55
7912	0.55
7915	0.55
79L05	0.50
79L12	0.50
79L15	0.50
LM309K	0.99
LM317K	3.20
LM323K	4.95
LM338K	4.75
Z80 FAMILY	
Z80 CPU	3.49
Z80A CPU	3.99
Z80 CTC	2.99
Z80A CTC	2.99
Z80 DART	10.00
Z80A DART	12.00
Z80 DMA	9.95
Z80A DMA	11.95
Z80 PIO	3.49
Z80A PIO	3.75
Z80 SIO-0	10.99
Z80A SIO-0	11.99
Z80 SIO-1	10.99
Z80A SIO-1	11.99
Z80 SIO-2	10.99
Z80A SIO-2	11.99
MK 3886	11.00
MK 3886-4	14.47
6800 FAMILY	
6800	2.99
6802	3.99
6803C	11.80
6809	9.99
6810	1.25
6821	1.25
6840	4.20
6850	1.50
6852	8.91
6871AIT	18.70
6880	1.07
6887	0.80
68488	9.11
6875	4.16
6843	13.99
68B00	4.70
68B02	19.11
68B21	2.29
68B10	2.00
68B40	4.70
68B50	2.15
68000C4	110.00
6500 FAMILY	
6502	4.25
6520	2.99
6522	4.75
6532	6.95
8080 FAMILY	
8085A	5.50
8212	1.70
8216	0.99
8224	1.95
8228	3.95
8251	3.60
8253	7.95
8255	3.60

Device	Price
CMOS 4000 'B' SERIES	
4000	0.11
4001	0.11
4002	0.13
4006	0.60
4007	0.15
4008	0.55
4009	0.28
4010	0.35
4011	0.12
4012	0.15
4013	0.29
4014	0.58
4015	0.58
4016	0.25
4017	0.45
4018	0.58
4019	0.29
4020	0.58
4021	0.60
4022	0.62
4023	0.17
4024	0.35
4025	0.16
4026	0.90
4027	0.30
4028	0.55
4031	1.65
4033	1.60
4034	1.55
4035	0.72
4040	0.54
4041	0.60
4042	0.54
4043	0.59
4044	0.64
4045	1.65
4046	0.68
4047	0.68
4048	0.54
4049	0.20
4050	0.28
4051	0.59
4052	0.68
4053	0.59
4054	1.20
4055	1.20
4060	0.79
4063	0.95
4066	0.34
4068	0.17
4069	0.17
4070	0.17
4071	0.17
4072	0.17
4073	0.19
4075	0.17
4076	0.62
4077	0.22
4078	0.24
4081	0.14
4082	0.19
4085	0.63
4086	0.69
4093	0.39
4502	0.69
4507	0.39
4508	1.90
4510	0.60
4511	0.49
4512	0.60
4514	1.49
4515	1.49
4516	0.69
4518	0.40
4519	0.28
4520	0.69
4521	1.49
4522	1.20
4526	0.70
4527	0.88
4528	0.70
4532	0.85
4541	0.90

Device	Price
4543	0.99
4553	2.90
4555	0.39
4556	0.44
4585	0.82
74LS SERIES	
74LS00	0.10
74LS01	0.11
74LS02	0.12
74LS03	0.12
74LS04	0.12
74LS05	0.13
74LS08	0.12
74LS09	0.12
74LS10	0.12
74LS11	0.12
74LS12	0.12
74LS13	0.22
74LS14	0.39
74LS15	0.12
74LS20	0.12
74LS21	0.12
74LS22	0.12
74LS26	0.15
74LS27	0.12
74LS28	0.15
74LS30	0.12
74LS32	0.12
74LS33	0.16
74LS37	0.15
74LS38	0.15
74LS40	0.12
74LS42	0.34
74LS47	0.39
74LS48	0.60
74LS49	0.59
74LS51	0.14
74LS54	0.15
74LS55	0.15
74LS73	0.19
74LS74	0.16
74LS75	0.24
74LS76	0.20
74LS78	0.19
74LS83	0.44
74LS85	0.65
74LS86	0.15
74LS90	0.30
74LS91	0.75
74LS92	0.34
74LS93	0.34
74LS95	0.43
74LS109	0.21
74LS112	0.21
74LS113	0.23
74LS114	0.19
74LS122	0.39
74LS123	0.39
74LS124	0.99
74LS125	0.25
74LS126	0.25
74LS132	0.45
74LS136	0.28
74LS138	0.34
74LS139	0.35
74LS145	0.75
74LS148	0.90
74LS151	0.39
74LS153	0.29
74LS155	0.39
74LS156	0.38
74LS157	0.31
74LS158	0.31
74LS160	0.39
74LS161	0.39
74LS162	0.39
74LS163	0.39
74LS164	0.47
74LS165	0.99
74LS166	0.84
74LS173	0.70
74LS174	0.47
74LS175	0.49
74LS181	1.28

Device	Price
74LS190	0.49
74LS191	0.49
74LS192	0.49
74LS193	0.46
74LS194	0.39
74LS195	0.39
74LS196	0.59
74LS197	0.65
74LS221	0.54
74LS240	0.89
74LS241	0.89
74LS242	0.79
74LS243	0.79
74LS244	0.65
74LS245	0.89
74LS247	0.63
74LS248	0.63
74LS249	0.63
74LS251	0.40
74LS253	0.39
74LS257	0.40
74LS258	0.39
74LS259	0.79
74LS261	1.95
74LS266	0.23
74LS273	0.75
74LS279	0.30
74LS283	0.44
74LS290	0.54
74LS293	0.45
74LS365	0.34
74LS366	0.36
74LS367	0.34
74LS368	0.49
74LS373	0.74
74LS374	0.74
74LS375	0.47
74LS377	0.89
74LS378	0.69
74LS379	0.64
74LS386	0.28
74LS390	0.54
74LS393	0.59
DIL SOCKETS LOW PROFILE - TIN	
8 pin	0.07
14 pin	0.09
16 pin	0.09
18 pin	0.13
20 pin	0.14
22 pin	0.17
24 pin	0.19
28 pin	0.25
40 pin	0.29
NEW LOW PROFILE - GOLD	
8 pin	0.22
14 pin	0.29
16 pin	0.31
18 pin	0.33
20 pin	0.35
22 pin	0.40
24 pin	0.42
28 pin	0.54
40 pin	0.81
NEW ZERO - INSERTION FORCE DIL	
24 pin	6.30
28 pin	7.40
40 pin	8.80
CRYSTALS	
1 MHz	2.90
1.008 MHz	2.90
1.8432 MHz	2.20
3.6864 MHz	2.95
4 MHz	1.65
6 MHz	1.90
8 MHz	1.95
14 MHz	3.45
NEW UHF MODULATORS	
6 MHz	2.75
8 MHz	4.40
DATABOOKS	
THOMSON-EFCIS 6800 Data Book (Inc p&p)	5.95
Data Converter Handbook (Inc p&p)	1.58
DATASHEETS	
Photocopied Data Sheets available for most product at 6p per page ex. p&p and V.A.T. (Please telephone for details	

NEW CATALOGUE NOW AVAILABLE

Gives details of our full product range including price breaks and a voucher value £1. Please send SAE.

SPECIAL OFFERS

	1+	25+	100+
2114 Low Power 200 ns	0.84	0.79	0.74
6116 Low Power 200 ns	7.60	7.20	6.75
6116 Standard 200 ns	5.70	5.35	5.05

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ACOUSTIC & VIBRATION

Item	Prices from £
BRUEL & KJAER	
1621 Tunable Band Pass Filter	550
2113 Audio Frequency Spectrometer	1400
2203 Sound Level Meter	450
2215 Sound Level Meter inc. Oct. Filter	1050
2218 Sound Level Meter inc. Leq.	1475
2305B Level Recorder inc. 50 dB pot.	1350
2625 Vibration pick-up amplifier	350
2808 Power Supply/Mains Adapter	90
2972 Tape Signal Gate	200
4230 Sound Level Calibrator	95
4423 Noise Dosemeter	350
4424 Noise Dosemeter	375
CASTLE ACOUSTICS	
CS181 Sound Level Meter & Calibrator	295
C.E.L.	
112 Environmental Noise Analyser	300
144 Environmental Noise Analyser	500
DAWE	
419C Audio White Noise Generator	190
1461CV Vibration Analyser	350
1463B ⅓ Octave Filter	200
1465 Octave Band Filter	150
KISTLER	
504A Charge Amplifier	200
WAYNE KERR	
B731B Vibration Meter inc. probe	270

BRIDGES & V and I STANDARDS

Item	Prices from £
ADVANCE	
TI Q Meter 100 KHz-100 MHz	160
CINTEL	
2773 Inductance Bridge	160
HEWLETT PACKARD	
4261A Digital Automatic LCR Bridge	975
4342 QLC Meter 22 KHz-70 MHz	1600
MARCONI	
TF868A Universal LCR Bridge	250
MUIRHEAD	
D30A DC Bridge 0.15%	180
PHILIPS	
PM6302 RCL Bridge — direct reading	395
WAYNE KERR	
B224 RCL Bridge 0.1%	500
B521 LCR Bridge	115
B801/CU681/Q801/SR268 VHF Admittance Bridge with source and detector transistor adapter & D.C. Control Unit for transistor measurements	750

COMMS & CABLE TEST EQUIPMENT

Item	Prices from £
DYMAR	
BC282 Battery charger for 883 Radio Telephone	80
883 Radio Telephone — VHF band — hand held	245
HEWLETT PACKARD	
3556A Psophometer 20 Hz-20 KHz	250
MARCONI	
TF2809 Data Line Analyser	600
NORTHEAST ELECTRONICS	
TT537B Psophometer/VU Meter	200
SEIMENS	
U2033 Psophmeter	475
S.T.C.	
74184B Selective Level Measuring Set	600
74216A Noise Generator	300
74261A Psophometer	300
74262B White Noise Generator & Receiver	2000
74307C Level Measuring Set	175
74834C Distortion Measuring Set	500
96016 Selective Null Detector	200
GTA-2 Quantization Distortion Tester	800
GTA4B Pattern Generator	900
TEKTRONIX	
1502 TDR Cable Tester CRT + Recorder	2950

COMPUTER EQUIPMENT

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

DIGITAL TESTING EQUIPMENT

Item	Prices from £
HEWLETT PACKARD	
1600A Logic Analyser 16 ch 20 MHz	1400
1600S Logic Analyser 32 ch 20 MHz	2250
1602A Logic Analyser 16 ch 10 MHz	900
1607 Logic Analyser 16 ch 20 MHz	950
TEKTRONIX	
832 Datacom Tester R5232/V24	1150
833 As 832 plus BERT/BLERT feature	1300
7DOIF/DFI Logic Analyser/Formatter 16 ch 50 MHz P/in	2650
7603/7DOIF/DFI As above with display mainframe	3600

MAINS TEST EQUIPMENT

Item	Prices from £
COLE	
T1007 Volt/Freq/Spike Monitor Rec O/P	110
DATALAB	
DL019 Mains Interface for DL905	300

SPECIAL OFFER

PHILIPS PM2454B
£180

A.C. Analogue millivoltmeter.
Frequency range 10 Hz – 12 MHz.
12 ranges 1 mV-300 V F.S.D.
Voltage and dB scale provided.
D.C. output proportional to meter reading.

COUNTERS & TIMERS

Item	Prices from £
FLUKE	
1910A-1 125 MHz 7 digit Cntr. AC/Batt	300
1912 520 MHz 7 digit Counter	375
1912A01 As 1912A but inc. re-charging batteries	430
1920A 520 MHz 9 digit Counter inc. Brst. mode	575
1920A14 1250 MHz otherwise as 1920A	750
HEWLETT PACKARD	
5243L 20 MHz 8 Digit Counter	150
5245L 50 MHz 8 Digit Counter	200
5300A/5304A 10 MHz 6 Digit Counter Timer	250
5300A/5305B 1300 MHz 6 Digit Counter	425
5345 500 MHz 11 Digit Counter Timer	2000
MARCONI	
TF 2432 560 MHz 8 digit Counter	350
RACAL-DANA	
371 18 GHz 11 digit Counter with Source Locking facility	4950
8110 50 MHz 8 Digit Counter Timer	320
9024 600 MHz 7½ digit Counter	220
9025 1 GHz 8 digit Counter	450
9520 10 MHz 4 Digit	95
9905 200 MHz 8 digit Counter Timer	360
SYSTRON DONNER	
6053 3 GHz 9 digit Counter BCD O/P	790
5103B Strip Printer for 6053/6054	375
TEKTRONIX	
DC501 7 Digit 100 MHz Counter — TM500 Plug-in	180
DRANETZ	
606 3ch Volts Av/Spike/Time/Printer	2950
616 2ch AC 1ch DC Volts/Av/Spike/Time/Printer	3300
GAY	
LDM AC/DC/Spike/Time inc. Printer	1250

MISCELLANEOUS

Item	Prices from £
A.I. INDUSTRIES	
TCS General Purpose Gas Leak Detector — intrinsically safe	290
BRADLEY	
192 Oscilloscope Calibrator	825
COMARK	
1601BLS Thermom 10ch 87 + 1000°C type K	50
N.B. Thermocouples not included	
CROWCON	
71P Inflammable Gas Detector/Alarm	125
DATALAB	
DL905 Digital Transient Recorder/Display Storage	1050
FLANN	
16/11 Rotary Vane Attenuator WG16	250
HEWLETT PACKARD	
342A Noise Figure Meter	500
X382A Rotary Vane Attenuator WG16	175
MULTIMETRICS	
AF120 Dual H/Pass L/Pass active filter 20 Hz – 2 MHz	600
PHILIPS	
PM 5501 Colour TV Pattern Generator	199
PM 6455 Stereo FM Generator	
PM 6456 Stereo FM Generator	
RESEARCH INSTRUMENTS	
Micro manipulator — 4 Probes moveable in all planes. Adjustable test table — Watson Barnet optics. Complete system mounted in perspex enclosure	
ROHDE & SCHWARZ	
BN252 Transistor Y Parameter Test Set	
S.T.C.	
74600J Attenuator 0-9 dB 50Ω in 1 dB steps	
74616A Attenuator 0-100 dB 600Ω in 0.1 dB steps	
TEKTRONIX	
521PAL Vectorscope	
528 TV Waveform Monitor	
575 Semiconductor Curve Tracer	
1485C TV Waveform Monitor PAL/NTSC	
YELLOW SPRINGS	
YS157 Water Pollution Measurement System	

NETWORK ANALYSERS/ PHASEMETERS

Item	Prices from £
GENERAL RADIO	
1710/11/12/14 0.4-500 MHz 115 dB range	
HEWLETT PACKARD	
8405A Vector Voltmeter 1–1000 MHz	
8414A Polar Display for 8410 N.W.A.	
8745A S Parameter Test Set 0.1-2 GHz	
11570A Accessory Kit for 8405A	
11600A Transistor Test Fixtures TO18/TO-72	
11602A Transistor Test Fixtures TO5/TO-12	
11604A Universal extension arm for 8745A	
11605A Flexible arm for 8743A	

OSCILLOSCOPES & ACCESSORIES

Item	Prices from £
CROTECH	
(New CROTECH Oscilloscopes)	
3030 15 MHz 1 Trace 5mV built-in component tester	
3033 15 MHz 1 Trace 5mV battery operation	
3034 15 MHz 2 Trace 5mV battery operation	
3035 10 MHz 1 Trace 5mV built-in component tester	
3131 15 MHz 2 Trace 5mV built-in component tester	
3337 30 MHz 2 Trace 5mV with signal delay	
GOULD ADVANCE	
OS1000B 20 MHz 5mV 2 Trace	
OS3000A 40 MHz 5mV 2 Trace 2T base	
HEWLETT PACKARD	
182C 100 MHz Mainframe	
182T 100 MHz Mainframe with digital normaliser interface	
1804A 50 MHz 20mV 4 Trace Plug-in	
1825A Dual Timebase Plug-in	
1805A 100 MHz 5mV 2 Trace Plug-in	
PHILIPS	
PM3207 15 MHz 5mV 2 Trace TV trig	
PM3211 15 MHz 2mV 2 Trace TV trig	
PM3212 25 MHz 2mV 2 Trace TV trig	
PM3233 10 MHz 2mV 2Ch fixed delay Dual Beam	
PM3244 50 MHz 5mV 4 Trace 2T base	
PM3260 120 MHz 5mV 2 Trace 2T base	
PM3262 100 MHz 5mV 2 Trace 2T base Tr View	
TEKTRONIX	
465 100 MHz 5mV 2 Trace 2T base	
465B 100 MHz 5mV 2 Trace 2TB, inc Probes	
475 200 MHz 2mV 2 Trace 2T base	
475A 250 MHz 2mV 2 Trace 2T base	
485 350 MHz 5mV 2 Trace 2T base	
5B42 2 T/base plug-in 50 MHz Trig for 5000 series Mainframe	
DD501 Digital Events Delay — P/in for TM500 series	
661/4S3/5T1A 1 GHz Sampling scope	
7A12 105 MHz 5mV 2 Trace Plug-in	
7A18 75 MHz 5mV 2 Trace Plug-in	
7A19 500 MHz 10mV 1 Trace Plug-in	
7A22 1 MHz 10μV Differential Plug-in	
7A24 350 MHz 5mV 2 Trace Plug-in	
7A26 200 MHz 5mV 2 Trace Plug-in	
7B53A 2 Timebase Plug-in 100 MHz Trig	
7B80 Single Timebase 400 MHz Trig	
7B85 Timebase with delay 400 MHz Trig	
7403N 75 MHz 3 slot M/Frame	
7603 100 MHz CRT r/out 3 slot M/Frame	
7704A 200 MHz CRT r/out 4 slot M/Frame	
P6013A X1000 12KV Probe	
TELEQUIPMENT	
D63/V1/V1 15 MHz 2 Trace 1mV	
D63/V5/V5 15 MHz 5mV 2 Trace & fixed delay	440
D75/V4/S2A 50 MHz 1mV 2 Trace 2 T/base	650
D83/V4/S2A 50 MHz 1mV 2 Trace 2T Big CRT	750
D1015 15 MHz 5mV 2 Trace TV trig	295
S61 5 MHz 5mV 1 Trace	135
TEXSCAN	
DU120 Large CRT XY Display with z modulation	280
Note: we hold a range of cameras	P.O.A.

Carston Electronics Ltd
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All items have a 12 month guarantee unless otherwise stated.

OSCILLOSCOPES (STORAGE)

Item	Prices from £
HEWLETT PACKARD	
181A 100 MHz Mainframe 5cm/μs	2500
1703A 35 MHz 10mV 2 Tr 2TB 1000 Div/ms	1400
TEKTRONIX	
466 100 MHz 5mV 2 Tr 2TB 1350cm/μs	2950
T912 10 MHz 2mV 2 Tr 1TB 250cm/ms	895
7313 25 MHz 3 slot M/frame split screen 5cm/μs	1700
7613 100 MHz 3 slot M/frame 4.5cm/μs	2700
7834 400 MHz 4 slot M/frame 2500 cm/μs	5300

POWER MEASUREMENT

Item	Prices from £
FLUKE	
8921A 10 Hz-20 MHz 4½ digit & Analogue Trms & dBm	825
HEWLETT PACKARD	
432A RF-Microwave Powermeter for use with 470 series sensors	430
478A Co-ax sensor for 432 meter 10 MHz-10 GHz	160
X486A Power sensor for 432 meter W.G. 16	160
432A/478A combined price	550
432A/X486A combined price	550
8481A Type N Coax sensor for 435A	250
8482H Co-ax sensor for 435/436 100 KHz-4.2 GHz	220
MARCONI	
TF893A 10 Hz-20 KHz Powermeter	135
2502 R.F. Powermeter DC-1 GHz 10W max	475
2503 R.F. Powermeter DC-1 GHz 100W max	800
6460/6421 Microwave Powermeter & sensor 0.01-12.4 GHz	500

POWER SUPPLIES etc

Item	Prices from £
ADVANCE	
MG5-20 Switching PSU module 5V-20A fixed	90
BRANDENBURG	
800 EHT Power supply 3-30 KV-1mA	450
FARNELL	
B30/5 0-30V-5A variable	110
B30/20 0-30V-20A variable	225
FFSL 5V – 20A PSU module	80
H60/25 0-60V-25A variable metered	420
L30B 0-30V variable 1A Metered	60
SB30/10 0-30V-10A variable	190
TOPS/2 Twin 5V @ 5A + 15-0-15V @ 1A	85
TSV70 0-35V-10A or 0-70V-5A variable metered	320
HEWLETT PACKARD	
6268B 0-40 V variable 30 A Metered V + I	575
6966A 0-36 V variable 10 A Metered	450
MARCONI	
2154 0-30V variable 2A metered	75
PHILIPS	
PE1646 0-75V variable 6A Metered V + I	495

PULSE GENERATORS

Item	Prices from £
ADVANCE	
PG52A Modular pulse generator system — wide range of configurations — cost dependent on modules — typical	650
PG5002D 0.1 Hz-1 MHz 50V 100Ω Double pulse R.T. 15ns	290
EH RESEARCH	
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Engineering – or dominoes?

During the 1940s, at a grammar school in the north of England, the most wonderful things on display in the glass case outside the science laboratories were a cloud of glass-fibre wool and some coal with a fossil leaf in it. The glass was impossible because everyone knew that glass was hard and brittle and yet here was this soft (though scratchy) stuff made from it, and the coal was just so unimaginably old – older, even, than the physics master who had, some said, discovered fire. Simple things, goodness knows, but worth a couple of lessons in the physics class.

In those days, there was little talk of wireless in the classroom, let alone 'electronics'; classes were taken up with interminable experiments on the latent heat of vaporization and the laborious plotting of magnetic fields. Then, one day, a visiting teacher told the class of his wartime work on radar, speaking of microwaves, 'metallic insulators' and times measured in microseconds. This was a great deal more wonderful than the glass wool and bits of coal and led to rather a lot of daydreaming for some of the class.

Science teaching has advanced greatly in the ensuing 35 years. Microcomputers are becoming commonplace and labs are stocked with oscilloscopes, signal generators and all the other impedimenta of the electronic '80s. Pupils handle circuitry switching at 3ns or oscillators working at several gigahertz or truly compendious i.cs with remarkable nonchalance, if the youngsters seen on television programmes or in the news as competition winners are anything to go by.

It is, it goes almost without saying, necessary for the modern pupil to have the use of advanced, modern equipment. It is right that programming microprocessors should have taken the place of connecting components, in school, as in the world of work. A micro, given the correct data and program, will do exactly what is expected of it very efficiently, as can be verified by a glance at the storage oscilloscope or logic display, but where is the striving? And, without the striving, where is the learning? Is there a danger of producing a great number of people who call themselves electronic engineers but whose knowledge of electronics stops short at an ability to program and an awareness of the cheapest supplier of interfaces?

The only answer to all these weedy, half-baked questions is that undoubtedly that is exactly what engineers will be like, and quite soon, too: there is no reason why they should be any different. It has been said for years that the microprocessor is a component, to be used as any other component. There can be little advantage to a user in knowing the precise details of the internal working of a micro – it can be regarded as a machine which will do its job when asked. It is not necessary to know the finer points of oscilloscope design to use one to its fullest extent: neither is it absolutely necessary to know more than the capabilities and characteristics of a micro, or any other i.c., to obtain the maximum performance from it. And when the remaining parts of circuits are also integrated, there will be no pressing need to understand the use of power transistors, or passive components, either, unless one has to design the i.cs. 'Systems engineering' will be supreme.

This is not, of course, to say that all engineers will be satisfied without a detailed knowledge of exactly what happens inside the i.cs. Perhaps these people will be the originators – the ones who, because they know more of the internal operation, will be able to apply i.cs with a greater imagination. But do not decry the simple user of modules: he will know all he needs to know.

MICROPROCESSOR-CONTROLLED LIGHTING SYSTEM

Stage and theatre lighting control is a complex task – yet a task easily handled by a microprocessor. As even the simplest of microprocessors can be programmed to provide and accept data for controlling a lighting system, these articles concentrate on using an existing microprocessor board to process and store complex lighting patterns set by conventional faders, and cover interfacing from digital data, to human input, to light dimmers. Software for the 8085A processor used in the prototype will be discussed in the third and final article.

by John D. H. White and Nigel M. Allinson

This system is designed to simplify the control of complex lighting patterns as used in theatres and studios or at pop concerts. The prototype described in these articles made use of a commercially available 8085A processor board to control up to 256 lighting channels with 8-bit accuracy phase control. Here, we discuss the system's hardware and its ability to linearize the relationship between lamp brightness and fader position.

Background

Before the introduction of high-power semiconductors the brightness of lamps in lighting systems was controlled by variable resistors or inductors. The cost and size of such inefficient power-control methods meant that systems were kept small and were usually difficult to operate. With high-power thyristors, it was possible to construct very compact dimmers which could be controlled remotely. Initially, this improved power control was used to copy the previous systems; however, the compact nature of the dimmers meant that much larger lighting systems could now be built and controlled. At present, "portable" lighting systems with 80 separate output channels are in common use for pop-group concerts and even larger systems are employed in tv studios and theatres.

All lighting-control systems may be split into two separate sections – the power-control section (the dimmers) and the control desk, which is used to control the dimmers. These are usually remote from each other, being connected by multi-core cable. Although the size of lighting systems has increased over the years, the control facilities available have remained rudimentary. A small number of digitally controlled desks are commercially available, though these are expensive and tend to be used in large, fixed installations.

The most common type of circuit used in an analogue control desk is outlined in Fig. 1. Each row of channel faders (presets) is voltage driven by a master fader (master preset). Outputs from each preset for a given channel are then gated together through diodes; thus the final output from the control desk is the largest preset voltage for each channel. In this way, each master preset can be used to recall a stored lighting pattern (i.e. stored in a row of presets). Because of the cost of faders, the number of master presets is usually fairly small. For pop-group concerts and certain stage applications, the ability to control continuously the brightness of each light is forfeited to allow the storage of a greater number of lighting patterns. The patterns are created and stored by positioning pins, containing diodes, in interchangeable matrix boards, as indicated in Fig. 2.

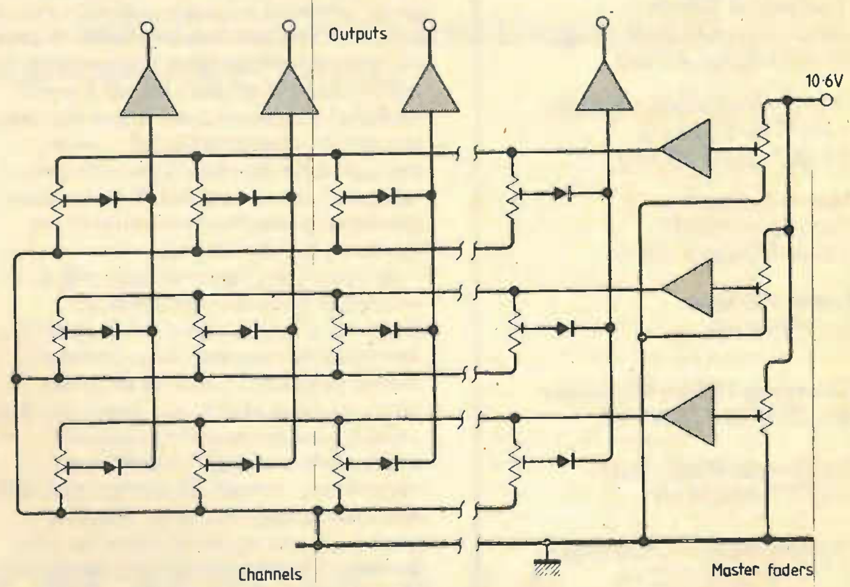


Fig. 1. This type of matrix is often used in analogue lighting-control desks. In this way, lighting patterns stored at preset fader positions can be recalled using the master faders.

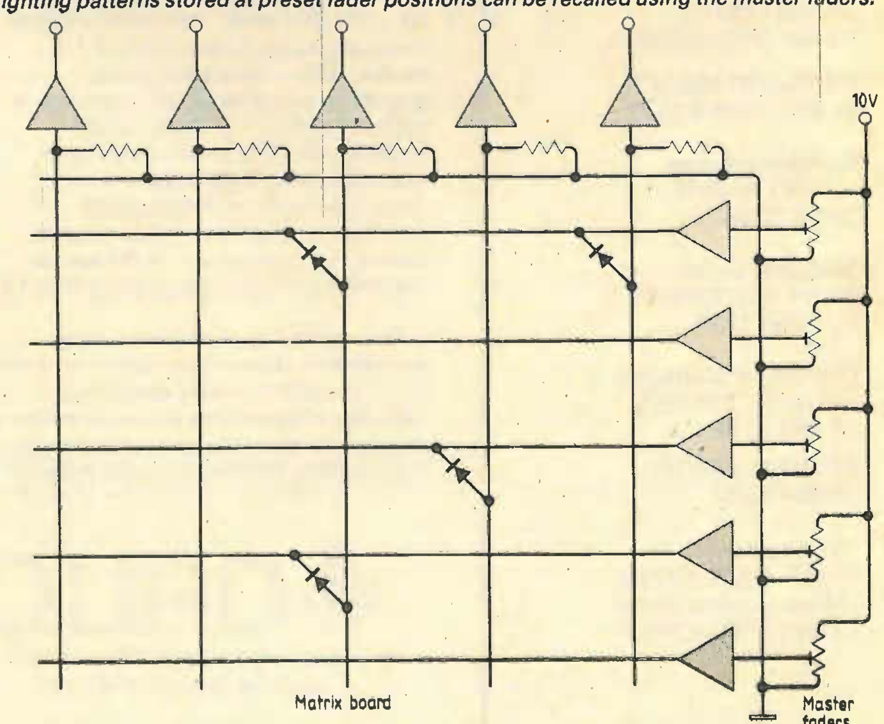


Fig. 2. Using this type of matrix, with plug-in diodes, a great number of lighting patterns can be stored cheaply but the ability to vary lamp brightness continuously is lost.

As the dimmers will use different mains phases (total power requirements may exceed 500kW for a large system), a standard interface format between the control desk and dimmers is necessary. A direct voltage of 0-10V has become the convention in most lighting systems, 0V corresponding to the lamps being off, and 10V to full brightness. Figure 3 shows the schematic lay-out of a typical dimmer module. The d.c. control voltage is compared with a ramp synchronized with the line frequency, hence phase-control of the load is possible.

Before considering the output hardware, one other question that needs answering; how many control bits are required to give apparently stepless light output variations? For a very wide range of lighting conditions, it was found that seven bits were sufficient for "stepless" light control. Since the microprocessor is an 8-bit device and most of the integrated circuits used to construct the system are 4-bit devices, it was decided to use 8-bit codes throughout. This also provides some immunity to the effects of truncation errors in the output code from software calculations.

Circuit description

Because of the large number of output channels each dimmer unit must be kept simple and economical. Also, since one may wish to increase the number of output channels in the future, a modular design is advantageous. The overall output-control layout is shown in Fig. 5. Each dimmer module is enabled so as to accept data from the microprocessor data bus by a 2-bit code derived from the 8 low-order bits of the address bus. Hence up to 256 dimmer modules can be given a unique address. Conventional output ports could have been used to enable data transfer to each dimmer module. However, the 8085A processor instruction set contains only one output-port instruction (OUT port) and this can only be used in a direct-addressing mode, i.e., the second byte of the instruction must contain the port address. The restriction of direct addressing makes this method unsuitable for use in a lighting-control desk because of the large number of outputs required. The solution is to employ mapped-memory output, which uses a section of "memory locations" for

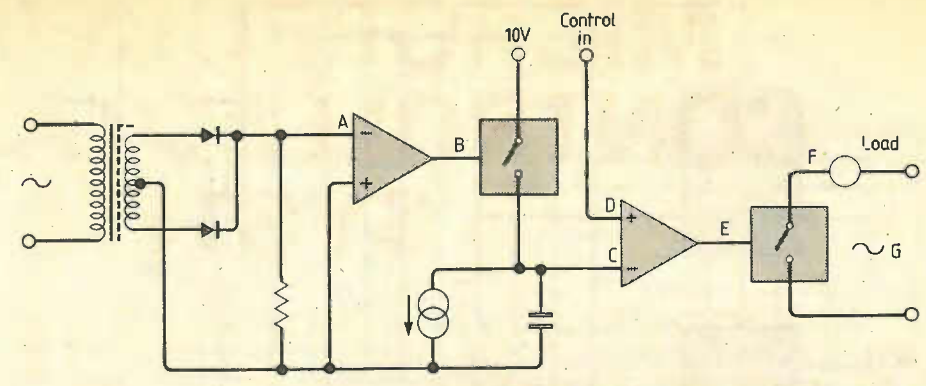


Fig. 3. Outline of a typical circuit. A d.c. control voltage is compared with a ramp synchronized with the line frequency, making phase control at the load possible.

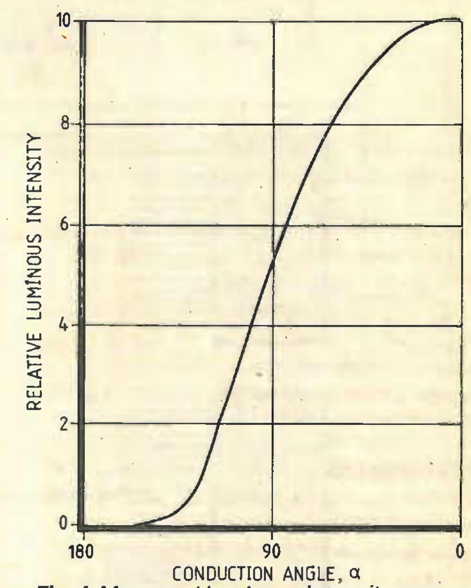


Fig. 4. Measured luminous intensity, as a function of conduction angle, for a 1000W lamp (see text).

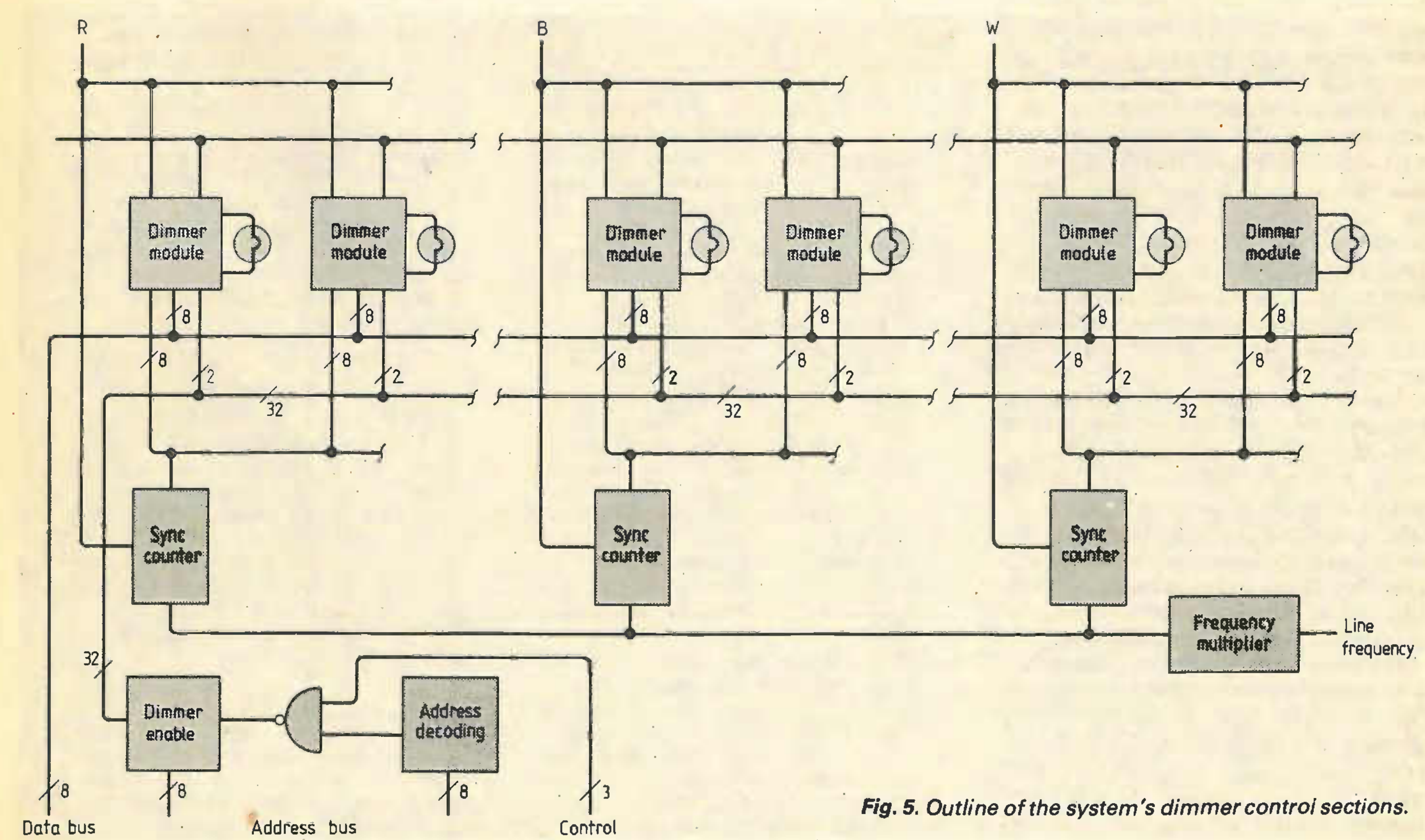


Fig. 5. Outline of the system's dimmer control sections.

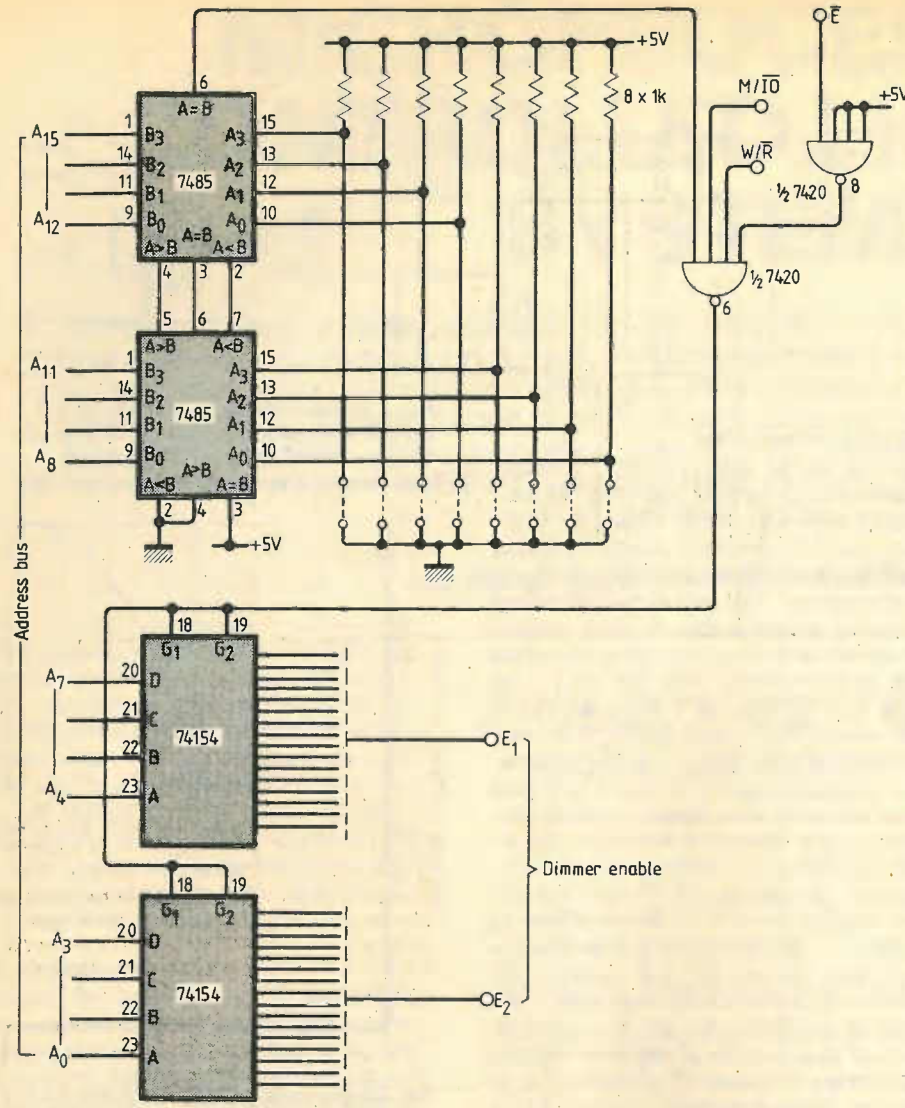


Fig. 6. *Address decoding and dimmer enable module.*

output. This arrangement allows any instructions which write to memory to be used as output instructions, giving considerable advantages in the software as indirect addressing is permitted. A small amount of extra hardware is, however, required to decode the address lines to enable the outputs.

The digital equivalent to the linear-voltage ramp in an analogue dimmer is an 8-bit binary code counting from 0 to 255 in each line half-cycle. The 8-bit synchronous counter is clocked by 51.2 kHz signal derived by multiplying the line frequency. The counter is reset every line half-cycle by a zero-crossing detector.

Each dimmer module compares the latched 8-bit code from the control desk to the 8-bit code from the counter. When the counter output is greater than the control-desk code, a 51.2 kHz signal is applied to gate the thyristors, hence accurate phase control of the lamps is possible.

The complete lighting system will contain one address-decoding and dimmer-enable module, one frequency-multiplier module, three counter and reset modules (one for each phase used), and one dimmer module per output channel.

Address decoding and dimmer enable module

The eight high-order bits of the address bus are compared with a bit pattern set by 8 wire-links to determine the location of the 256 output addresses in the memory map. Two cascaded 7485 4-bit magnitude comparators, see Fig. 6, generate a high-level signal when both inputs are equal. This signal, the M/IO and W/R control signals and the system enable signal, E, enter a NAND gate to give a signal which is high when valid output data is present on the data bus. The 8085A processor system employed in the prototype design was a Quarndon Electronics Ltd. QMS 85 8085 development system, which produces an overall system-enable strobe. E will be low whenever the WR, RD or INTA of the 8085A is low. For "write" cycles, the data bus is stable while E is active.

The valid-data signal is used to strobe the G1 and G2 inputs of two 74154 4-to-16-line demultiplexers connected to the eight low-order bits of the address bus. Two dimmer enable signals, E1 and E2, from the 32 outputs of the demultiplexers, give 256 unique addresses for the dimmer modules.

Frequency multiplier module

A 51.2kHz clock signal for the 8-bit counters, shown in Fig. 7, is obtained by multiplying the line frequency by 1024. The phase-locked loop (NE565) has a feedback divider chain consisting of five 7474 dual D-type flip-flops. The capture range is set at ±2Hz. The t.t.l. input signal to the phase comparator is at half-wave rectified mains frequency. Although t.t.l. compatible, the square-wave output of the v.c.o. will only provide a current of about 1mA, so the output is buffered to drive the counter and divider chain.

Synchronous counter and reset module

This circuit, shown in Fig. 8, generates a 8-bit binary code which counts from 0 to 255 in half a line period. The 51.2 kHz signal from the frequency multiplier is used to clock two cascaded 74161A 4-bit counters. The CLEAR inputs of these counters are used to reset them at the zero-crossing points of the mains. The full-wave rectified a.c. is applied to the voltage comparator (741). The output of the op-amp is inverted and converted to t.t.l. levels by the following common-emitter stage.

Dimmer module

The 8-bit code from the control desk, through the data bus, is stored in two 7475, 4-bit bistable latches, Fig. 9. These latches are enabled, i.e., data on the data bus is transferred to their Q outputs, when the dimmer module is addressed by its own 2-bit dimmer enable signal, E1 and E2. Data stored in the latches is compared to the output of the counter by two cascaded 7485s. When the count from the counter is greater than the latch data, the 51.2 kHz signal is gated to the thyristors through some buffer stage and pulse transformer. Some interference and transient protection is provided by the inductor and capacitor.

System performance

Some advantages of feeding data to a large number of channels have already been mentioned. Also, since the access time for each dimmer is less than the 410ns (the maximum data-bus access time permitted by the processor), no processor WAIT states are involved in transmitting data. This, of course, maximizes the data transference for updating the dimmers and

Subjective brightness control

For full-wave control using a triac or inverse-parallel connection of two thyristors, the r.m.s. output voltage, V_o, is;

$$V_O = V_S\left(\frac{\pi - \alpha + \frac{1}{2}\sin 2\alpha}{\pi}\right)^{1/2}$$

where V_S is the r.m.s. supply voltage and α is the conduction angle. This, of course, assumes a purely resistive load. Tungsten lamps have associated with them some inductance and a thermal inertia, which affects their transient behaviour. The perceived brightness of a controlled light source is a complex function of the voltage, and hence the position of the fader on the control desk. A number of factors contribute to this function:

– The resistance of the lamp filament increases over a range of about 20:1 for its entire operating range.

– As the temperature increases, the spectral distribution of the radiant energy changes, approximately in accordance with Planck's distribution law. With increasing temperature, the peak of the radiant energy moves towards shorter wavelengths (i.e, the light is "whiter"). A tungsten-filament lamp may be considered as a near-perfect universal radiator.*

– Due to the above, the fraction of the total radiant energy visible also changes. Mathematically, the visible output is the convolution of the modified Planck's distribution function and the standard luminosity curve of the human eye.

All these factors can be approximated, with reasonable accuracy, by the simple expression:

$$\text{luminous intensity, } I = kV_s^c$$

where k and c are constants for a particular type of tungsten lamp. The type of lamp (maximum voltage, wattage, etc.) has a slight effect on c. Most references consider c to lie between 3.2 and 3.5. Our experience suggests a slightly lower value for a wide range of lamp types. The measured luminous intensity as a function of conduction angle for a 1000W PAR64 lamp is given in Fig. 4. This general curve holds for all forms of tungsten lamp, and is used to linearize the relationship between lamp brightness and fader position in this system. It is worth noting here, that measured photometric brightness, L, of a surface (its luminance) is not generally the same as its subjective brightness, B. Subjective brightness is determined in part by the luminance of an object, and in part by the conditions of observation such as the state of adaptation of the eye and the luminance of surrounding areas. The relationship between luminance and subjective brightness is still an area of active psychophysical research. Engineers are often satisfied with approximate relationships, and, from accumulated experimental evidence, a simple though approximate relationship is:

$$B = aL^{\gamma}$$

where γ is ⅓ or ½, for dark or bright surroundings respectively. γ-correction is most commonly encountered in the design of tv displays. However, our experimental work with slowly increasing the brightness of lamps suggested that the best subjective linear increases in subjective brightness was obtained by ignoring γ-correction and simply using the relationship for luminous intensity. The inverse of the above function (i.e., the first two equations combined) is calculated for each discrete step in the dimmer control code.

*This term is used in preference to black body because a very hot object or surface radiator will radiate visibly; "universal" applies to both absorption and emission. – Ed.

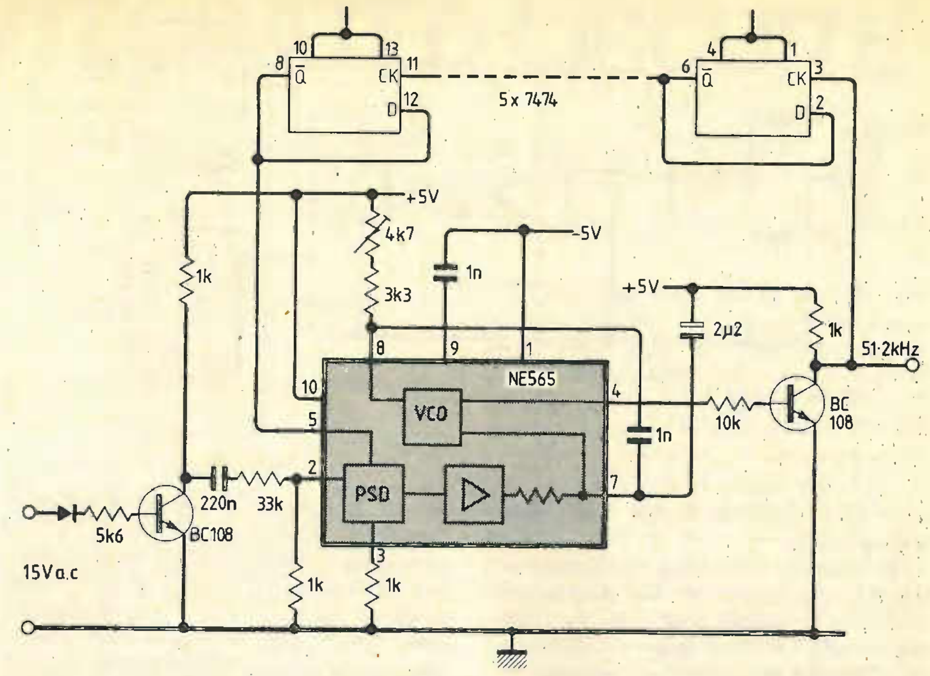
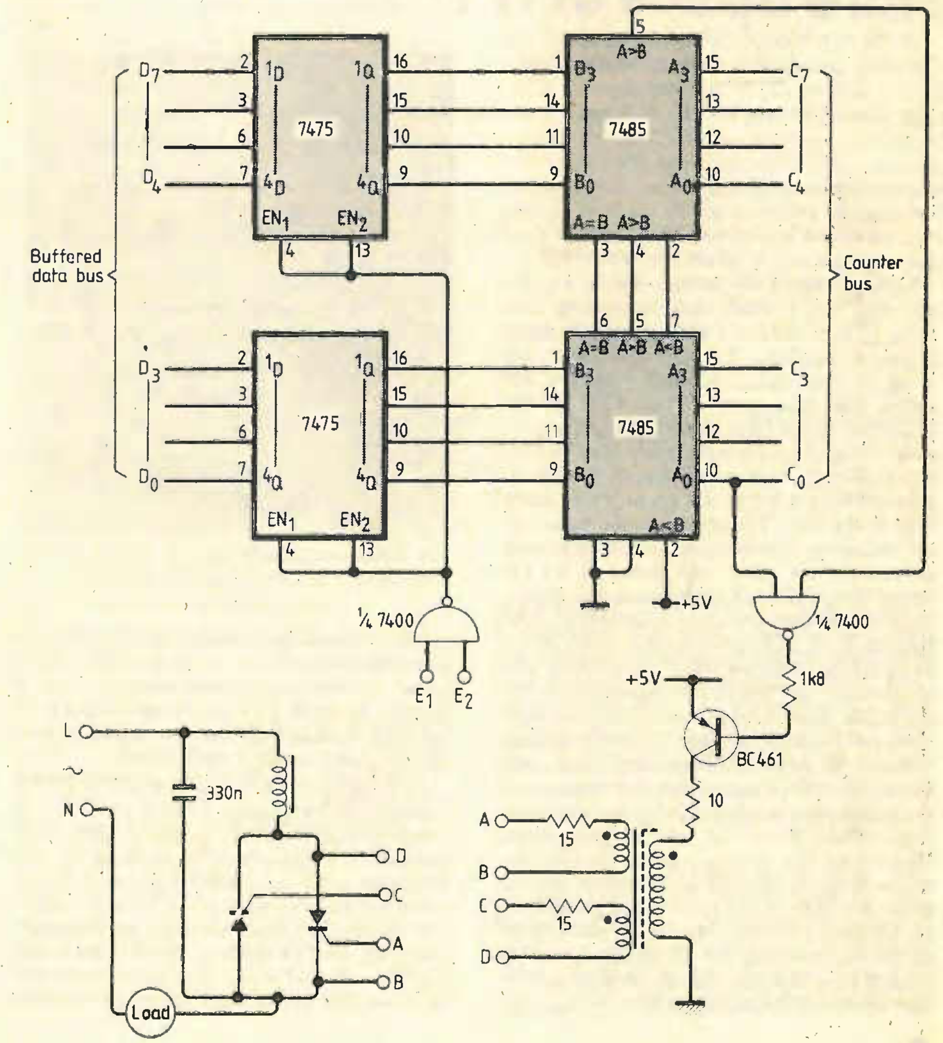


Fig. 7. *This circuit is used to multiply the ▲ line frequency by 1024 to provide a 51.2kHz clock signal for the 8-bit counters.*

Fig. 9. *A dimmer module. The 8-bit code from the control desk is stored in two 4-bit bistable latches, and passes to the outputs when the enable signal, derived from E1 and E2, is given. When the counter input to the comparators is greater than the latch output data, the 51.2kHz signal is passed to the thyristors through a buffer stage and transformer.* ▼



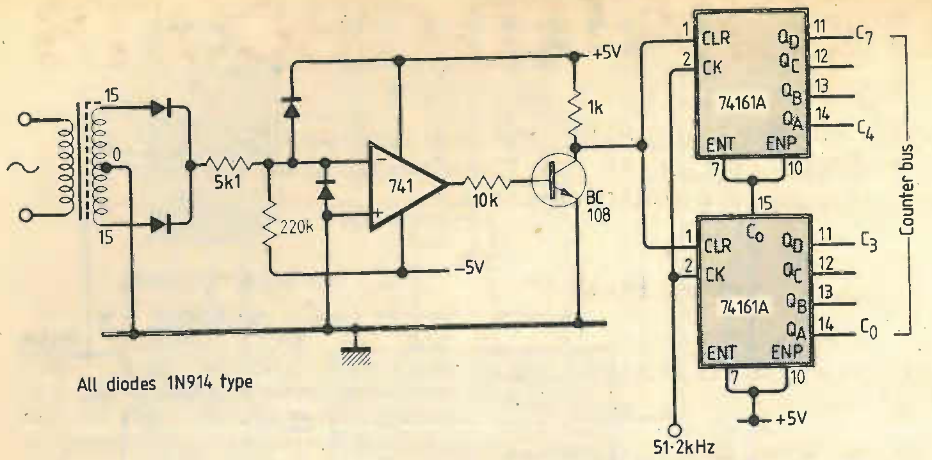
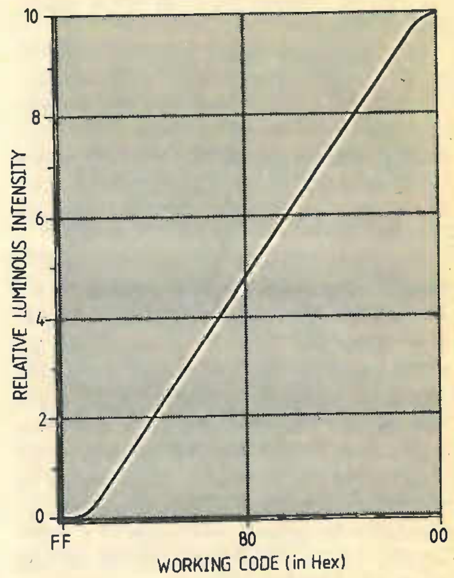


Fig. 8. *Synchronous counter and reset module. An 8-bit binary code counting from 0 to 255 in a half-line period is generated.*



helps to produce a highly interactive lighting system.

The effect of linearizing the luminous output of the lamps with the position of the faders is indicated in Fig. 10. The output code FF corresponds to the lamp being off, and the code 00 corresponds to full brightness. The slight delay at the start is due both to truncation errors in forming the inverse function mentioned earlier and to slight measurement difficulties. It could be removed by incorporating a suitable offset in the output coding, but from an operating point of view there are quite distinct advantages in having a definite "lamps off" position on the faders. In the system, the 256 values of this inverse function are held in a "look-up table" in the operating software. For a non-microprocessor system, there is no reason why these values could not be contained in a p.r.o.m.

The complete operating system not only provides routines for inputting and outputting data, but also various methods for processing the stored lighting patterns. In the next article, the control desk will be discussed. □

To be continued

Fig. 10. *The effect of linearizing the luminous outputs of the lamps in relation to the fader position.*

Fibre optics at ITT

Joining optical fibres, especially in the field, is very difficult. ITT have developed a fibre optic splicing kit, the OFSK-10. Primarily intended for the jointing of 50/125µm telecommunications grade fibres and other fibres of an all-silica construction, the kit uses an electric arc to fuse together the two ends. A V-groove jig has been developed to locate the ends accurately so that very high quality splices can be achieved.

Testing fibres in the field can also be a problem; it is very unlikely that the engineer has access to both ends of a cable but needs some method of locating a fault in a cable which can be up to 15km long, between repeaters. An answer has been provided by ITT in the OFR-3, an optical fibre reflectometer. If a short pulse of high intensity light is launched into an optical fibre, a small proportion of the light is reflected back towards the source from every point in the fibre. The reflections are 'backscatter' caused by imperfections in the molecular structure of the silica. The power of the reflected light, measured at the source end, decays exponentially with time, and by inference, with distance of the pulse into the fibre. The OFR-3 uses a laser to launch a pulse into the fibre and can measure and record the response from the reflections. Joins along the cable can cause extra reflections causing a peak in the response. Faults in the cable will cause drops in the response. The OFR-3 can display that response on an oscilloscope which includes an alpha-numeric display of all the relevant parameters. With the use of a cursor any part of the response can be looked at in more detail and the oscillogram with all the data display can be printed out for permanent record. The 'scope and printer are incorporated into the equipment which all fits into a portable case. All the controls and the laser are incorporated in the lid The laser fits behind a locked hatch and cannot be switched on unless connected to a cable. Any fault can be traced to within six metres resolution over a distance of 15km. ITT are already working on the OFR-4 which will be able to inspect a cable of even greater length – up to 100km.

The OFR-3 can trace faults in an optical fibre to within six metres over a length of 15000m.

ITT are particularly proud of two new applications for fibre optics. There is a plan to link the British and French electricity grids. One hour's difference between the clocks in the two countries means that peaks occur at different times and an extra boost can be provided across the channel. To avoid the need for frequency matching, the link will be d.c. G.E.C. are building the U.K. end of the link. Rectification will be by stacked thyristors each of which will work at a different potential and will therefore have to be isolated from the other in the stack. To avoid using a number of isolating transformers, the switching pulses will be carried to the thyristor gates by fibre optics cables. A special cable has been developed to withstand voltage potentials of up to 5kV/cm. In parallel with the development of the cable has been the design of an l.e.d. edge connector array for providing the individual pulse firing signals for each thyristor. The link is to be commissioned in 1985/86.

Another new application is a cable television link which is to be given a trial by British Telecom to 18 houses in Milton Keynes. The trial will use optical transmission based on p.f.m. (pulsed frequency modulation) in which the tv signal frequency modulates a square wave carrier which then drives an l.e.d. source. All the transmitter and receiver modules including the modulators and demodulators have been supplied by ITT Leeds.

BT are already running a cable tv service in Milton Keynes. For the trial, the programmes are down-converted into baseband and separated into individual channels (0 to 6 MHz PAL, video with sound). In addition a channel is formed consisting of the f.m. radio programmes on carriers in the range 0 to 7MHz. Each channel is fed to its own transmitter and a ten-fibre cable carries the channels to a distribution point. The cable used for the 3.5km primary link contains fibre of better than 4dB/km loss and 400MHz-km bandwidth-distance product. From the distribution point the secondary link of between 50 and 200m goes to each customer. Signal information and channel selection are transmitted back from the customer's end to a microprocessor control which provides the channel switching and can monitor information about transmission on both primary and secondary links. In the home the signal is received optically, demodulated to baseband and then up-converted to u.h.f. so that it can be fed into the aerial socket of an ordinary tv.

555-TYPE INTEGRATED CIRCUITS

The 555 group of i.cs is one of the most popular ever made, with an enormous variety of applications in oscillators and timers. John Linsley Hood explains its internal design and method of operation

If the 1950s were the decade in which linear electronic circuits, previously implemented using thermionic valves as their active components, were progressively taken over by transistors, then the '60s were the decade in which such circuits, built up from an assembly of discrete components and transistors, were increasingly constructed using one or two simple packages of purpose-built circuitry, containing all the necessary active and passive components in a single lump. The term 'integrated circuit' was coined at this time to describe this packaged assembly of components.

While it was the enormous progress in the field of digital computers; which convinced the i.c. manufacturers of the enormous benefits of scale, it was the consumer market which provided the chance of profitable manufacture away from the computer field.

The realization that there was a large potential market set the design departments of many of the larger semiconductor manufacturers exploring the possibilities for useful functional packages. Clearly, an i.c. functional block which could be used with a relay and a timing capacitor to provide time delays or timing cycles, as, for example, in a washing machine or a darkroom enlarger timer, would have a lot of uses, and several such i.cs were evolved at the end of the 1960s. Of these, by far the most successful was the Signetics 555. A number of manufacturers have copied it in identical form – in the process of what is known as 'second sourcing' – and produced in dual (556), quadruple (558) and c.m.o.s. (ICM7555) versions, along with sundry improved devices having the same pin configurations, such as the LM555C.

With the possible exception of the ubiquitous i.c. operational amplifier, few integrated circuits have had such an appeal

by J. L. Linsley Hood

to the hobby electronics constructor, with several complete books of circuits having been published showing possible applications for this device. Yet, in spite of this, to most of its users, its method of operation remains needlessly obscure, and many attempted applications founder on inadvertent incompatibilities between the internal and external circuitry.

Circuit description

The 555 is fundamentally intended to give an output voltage waveform, as a 'one-shot' or in a repetitive manner, at a low enough output impedance to operate a reasonably sensitive relay. To simplify calculations for the timing RC chain – in which the time constant RC, in seconds, is the time taken for a capacitor C to charge through resistor R to 63.2% of the applied voltage – the internal voltage switching levels are chosen so that the external timing capacitor charges through about this voltage differential. A simplified block diagram showing the internal arrangement is given in Fig. 1.

In this, the heart of the circuit is a bistable 'flip-flop' with an external overriding reset input R. The two normal inputs are the threshold and the trigger connexions, both of which are fed in through relatively high-impedance buffer amplifiers, connected, respectively, to reference voltages of $\frac{2}{3}V_{cc}$ and $\frac{1}{3}V_{cc}$, derived from the 15k resistor chain. Two buffered outputs from the flip-flop are provided through amplifiers A_1 and A_2, the first of which is a normal 'totem pole' output arrangement, as typically used in t.t.l. logic, to give a fairly low output impedance, and good current-sourcing characteristics. The second output, from A_2, is derived simply from a single transistor 'open collector' stage.

The way in which the 555 would normally be connected to operate as a 'one-shot' timer driving a relay, is shown in Fig. 2(a). In this the threshold input and the discharge (open-collector amplifier) output are joined together, and taken to the junction of timing resistor R and timing capacitor C; the timing cycle is initiated by

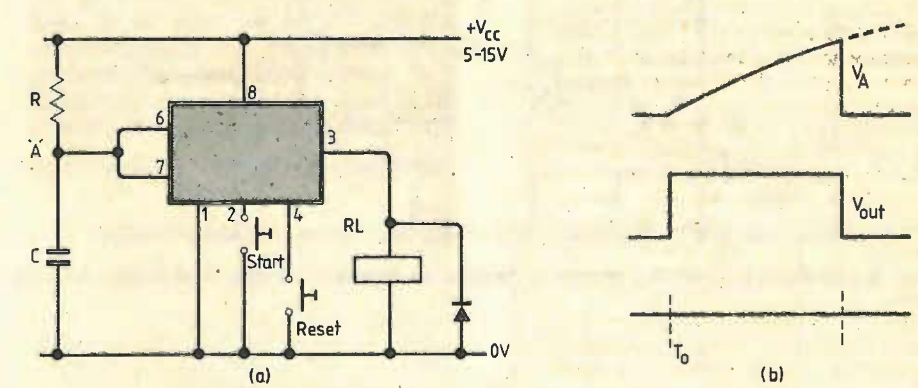


Fig. 2. *555 as a one-shot relay timer, with manual start and reset.*

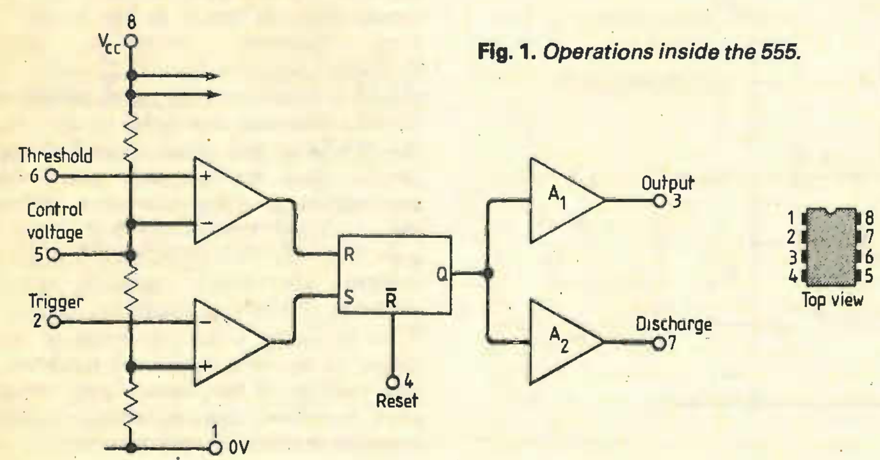


Fig. 1. *Operations inside the 555.*

a momentary operation of a push-switch connected to the trigger input. This sets the Q output from the bistable, and both of the non-inverted outputs from A_1 and A_2, to a high state. In the case of A_1, this will energize the relay RL_1, and in the case of A_2, the result will be that its output becomes an open circuit, so that the timing capacitor C is free to charge up towards the $+V_{cc}$ line.

Once the Threshold input level has reached $\frac{2}{3}V_{cc}$, the 'reset' input to the bistable, R in Fig. 1, is taken high, when it reverts to its initial state, with A_1 output 'low' – so that the relay is de-energized – and A_2 at a low impedance. This holds the

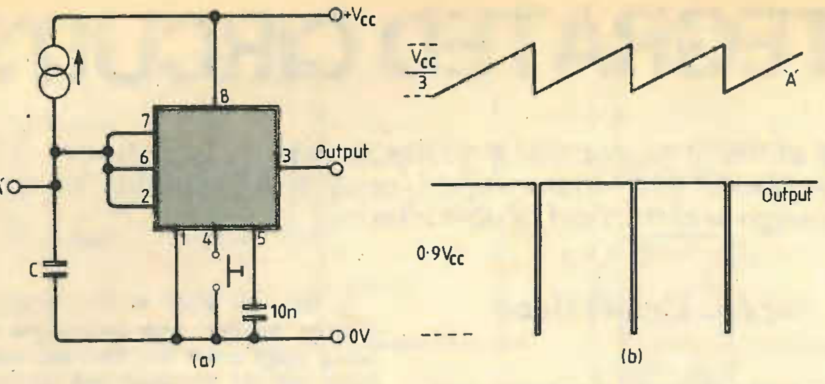


Fig. 3. *Connexion for a free-running oscillator, with a frequency determined by the constant-current source and the value of C.*

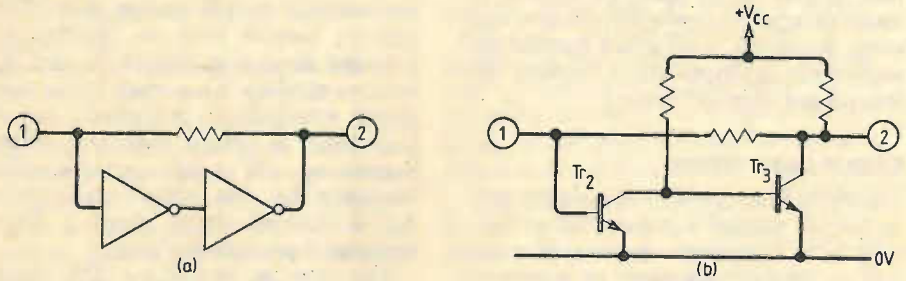


Fig. 4. *Flip-flop block of Fig. 1 in logical form at (a) and in its practical arrangement at (b).*

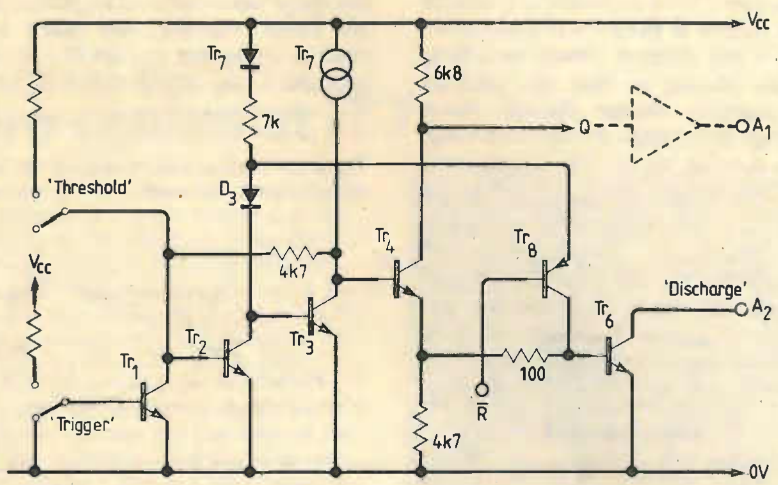


Fig. 5. *Flip-flop (Tr_2 and Tr_3) shown in relation to threshold, trigger and output circuitry.*

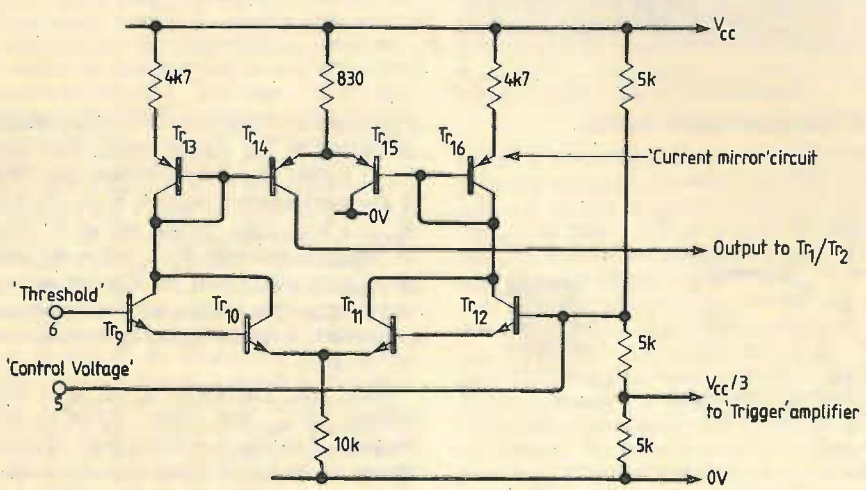


Fig. 6. *Input amplifier for threshold voltage.*

timing capacitor discharged and at a potential close to the 0 volt line level, ready for a further timing cycle to be initiated, by an input at a level less than $\frac{1}{3}V_{cc}$ being applied to the Trigger. The output waveforms are shown in Fig. 2(b).

Since the Trigger input is also taken to the bistable through a impedance buffer amplifier, it is practicable to connect this to the timing circuit as well, without imposing too much of a static load. This will convert the circuit into a 'free-running' sawtooth generator, with an output of $\frac{1}{3}V_{cc}$, as shown in Figs 3(a) and 3(b). Moreover, if the timing resistor *R* is replaced by an appropriate constant-current source, the output at point A will be a highly linear waveform, suitable for use in a time-base generator, and with a sync. input available at the override reset *R* of the bistable.

The bistable flip-flop is itself a very simple arrangement, shown schematically in Fig. 4(a) and in its practical form in Fig. 4(b). In this circuit, if the input (1) is taken high, even momentarily, the output will also go high and remain at that state. Similarly, if the input is taken low, the output will also follow, and remain. The fact that the transistor circuit of Tr_2 and Tr_3 can be made to behave like this depends on the characteristic that a transistor turned hard on will have a collector-emitter voltage drop of only some 0.1 to 0.4 volts, depending on construction and I_b and I_c, whereas the minimum voltage necessary at the base, for conduction, will be at least 0.5 volts in a silicon device.

The way in which this circuit is organized, with respect to its output circuitry, and its threshold, trigger, and reset inputs, is shown in Fig. 5. Because the transistor Tr_8, in the reset circuit, acts as a switch directly connected between the positive end of D_3 and the discharge circuit open-collector amplifier, this will cause Tr_3 to be turned off, with Tr_4 and Tr_6 turned on. This will reset both A_1 and A_2 outputs to the low level.

While this input, being connected later in the circuit than the trigger input, will over-ride the trigger signal, if the trigger input is held low, the circuit will revert to the operating condition, with A_1 high and A_2 open circuit, as soon as the reset signal is removed.

The two input amplifiers used in the threshold and trigger circuits, are of similar form, as shown in Figs 6 and 7, using Darlington connected, four-transistor, long-tailed pairs. However, it should be borne in mind, as explained in the first article of this series on the 741, that the integrated circuit manufacturing process does not normally allow the construction of p-n-p transistors, within the i.c., which have a very high current gain, except in the circumstance that their collectors are directly connected to the substrate, (which is normally the 0V line). Since the input p-n-p transistors of the trigger circuit do not meet this condition, they must be of the 'lateral' type, which gives an inferior input impedance to this amplifier to that of the n-p-n input devices

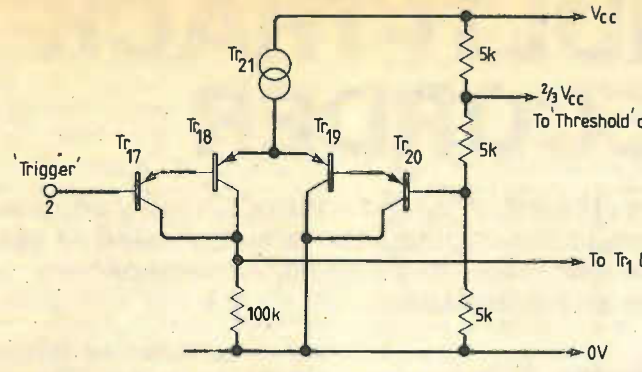


Fig. 7. *Trigger input amplifier, using p-n-p transistors.*

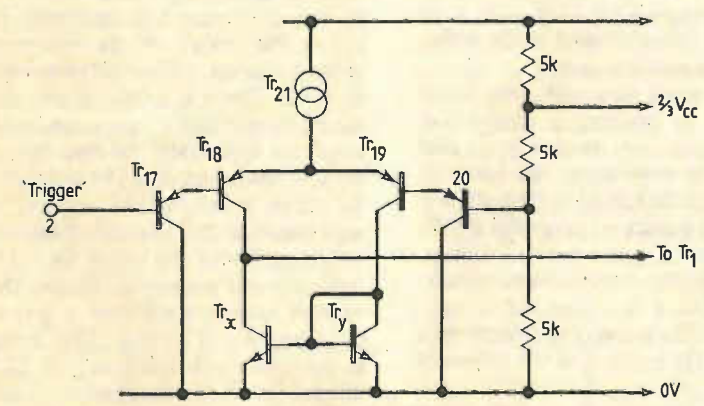


Fig. 8. *Improved trigger amplifier, using higher-gain p-n-p transistors and a current-mirror collector load for Tr_{18}.*

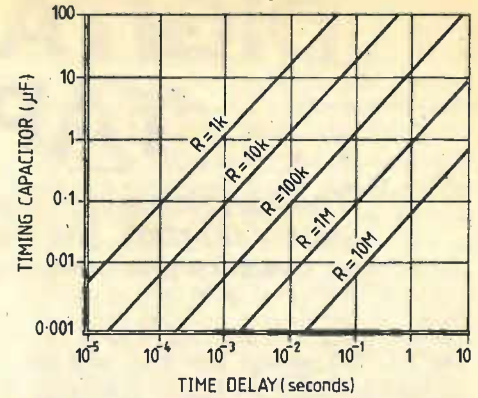


Fig. 10. *Time delay as a function of R and C in Fig. 1.*

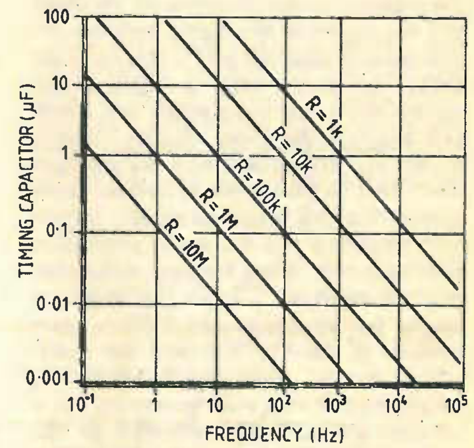


Fig. 11. *Variation of Fig. 3 oscillator frequency with R and C (constant-I source replaced by R if sawtooth linearity not important).*

used on the threshold circuit input. To compensate somewhat for this deficiency, the trigger amplifier input circuit is operated at a very low collector current. Nevertheless, the input impedance for this circuit is still some five times lower than for the threshold input. In the National Semiconductor LM555, this circuit is modified, and improved, as shown in Fig. 8, to use a better type of input p-n-p transistor, together with a current mirror collector load (Tr_x and Tr_y).

The complete circuit of the 555 is given in Fig. 9, to show how the separate elements are connected together. Although the circuit is referred to in the data books as linear, because its operation is essentially digital in form, switching rapidly from one stable state to another, there is no need for any of the h.f. compensation of the amplifier elements customary in normal linear devices. This allows very fast rise and fall times at the output, of the order of 100ns, and repetitive operation at frequencies approaching 1MHz.

Typical time delay and free-running frequency graphs are shown, for completeness, in Figs. 10 and 11. □

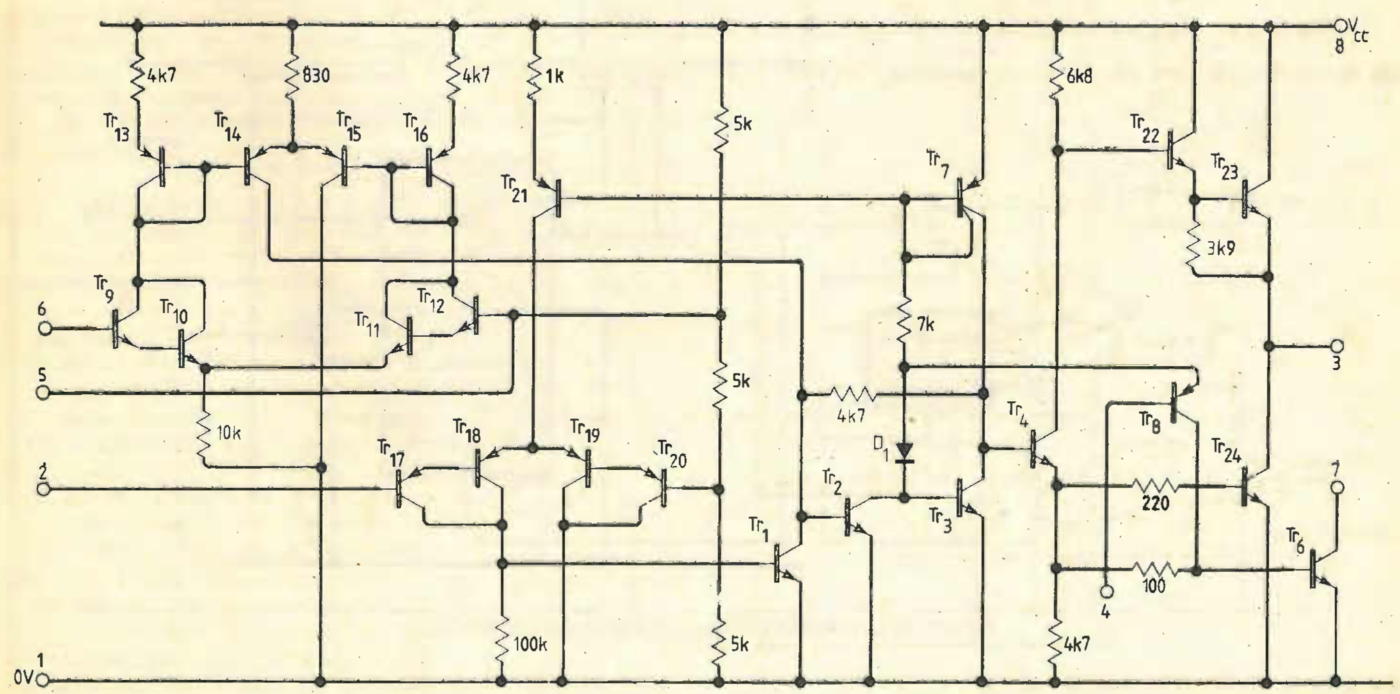


Fig. 9. *Complete circuit of Signetics NE555.*

DIGITAL, MULTI-TRACK TAPE RECORDER

The final article in this series describes the motor speed control circuitry and the power supplies. The few modifications to the original tape recorder, used as the basis for this design, are also presented, with advice on adjustment of bias, equalization and signal level.

by A. J. Ewins, B.Tech.

The VLF910 cassette tape-deck used in the Hart version of the Linsley Hood cassette recorder uses only one motor for the capstan drive, take-up spool and rewind spool. In spite of this, and though relatively cheap, its specifications are excellent and the success of the digital recorder design is due in no small part to this excellent deck. The motor used is called a frequency-servo type and consists of a motor unit and tachogenerator. Earlier versions of the VLF910 deck used a motor, type R14-7430, 03Y8D, with a built-in tacho generator which produced an a.c. output with amplitude and frequency proportion al to its speed. When running at the normal tape speed of 1 7/8 in/s, the frequency output was approximately 456Hz. Later versions of the VLF910 deck use a different motor, type MMX-6H2LSB, which, instead of a tachogenerator, has a rotating magnetic disc attached to the motor shaft and an associated Hall-effect i.c. When running at a tape speed of 1 7/8 in/s, the output on one of the pins of the Hall-effect i.c. is a pulse train of frequency about 912Hz. (Although the figure of 912Hz is claimed as approximate with respect to a tape-speed of 1 7/8 in/s, it is **exactly** double that produced by the tachogenerator of the earlier motor).

Research Department, London Transport.

Both motor types have additional built-in electronics to produce a closed-loop servo system. Although the motors are said to be frequency-servo types, the speed of the motor is not locked to a reference frequency: the frequency so produced by the 'tachogenerators' is converted to a voltage, using a pulse-width discriminator circuit, and then compared to a reference voltage. The stability of the speed of the motor thus depends upon the stability of the reference voltage.

For accurate speed control of the tape-recorder, the motor speed must be locked to a reference frequency. The importance of this speed control is not so great during the recording process, but absolutely vital during playback to ensure that the temporary storage buffers are filled with data at precisely the same rate as they are emptied. Short-term wow and flutter content of the data is not important because the number and length of the temporary storage buffers are designed to cope with this short-term variation.

The block circuit diagram of the tape-recorder speed control circuit was shown in Fig. 11 in part 2 of the series: Fig. 47 shows the circuit of the reference frequency selector, v.c.o. and phase sensitive detector. The v.c.o. and p.s.d. are contained within the c.m.o.s. phase-locked-loop i.c., type 4046. So that the tape-recorder speed control can be self-contained, the v.c.o. is used as the frequency reference source in the absence of any external reference. Using the values for the timing capacitor and resistor as shown, the 5kΩ variable resistor is adjusted to give an output frequency of 455Hz. (This is the same as the tape-clock frequency of 22,755Hz divided by 50.) In the absence of an external frequency input, the reset input to the 4017 counter will be at the logic 0 level. The output from the v.c.o. clocks the counter so that evntually the '5' output becomes logic 1, disabling the counter. In this condition, the carry-out, CO, is at logic 0. The output from Nand 2 is thus at logic 1 and the output from Nand 3 is the inverted v.c.o. signal. Nand 4 inverts this signal yet again, presenting a non-inverted v.c.o. signal to the input of the Ex-Or p.s.d., whose other input is that from the tachogenerator pulse shaper. When the phase-locked loop of the speed-control system is in lock, the frequency from the tachogenerator pulse shaper is exactly that of the v.c.o., but it leads it in phase by about 90°. Consequently, the D input to the D-type flip-flop is at the logic 1 level when the Ck input goes positive, putting a logic 1 on the Q output of the flip-flop, lighting the l.e.d. and giving a visual 'in-lock' indication. With logic 0 on the $\overline{Q}$ output, the audible indicator is silent. In the event of a loss of lock the l.e.d. will flash and the audible indicator will warble at a frequency dependent upon the rate of slippage between the two frequencies.

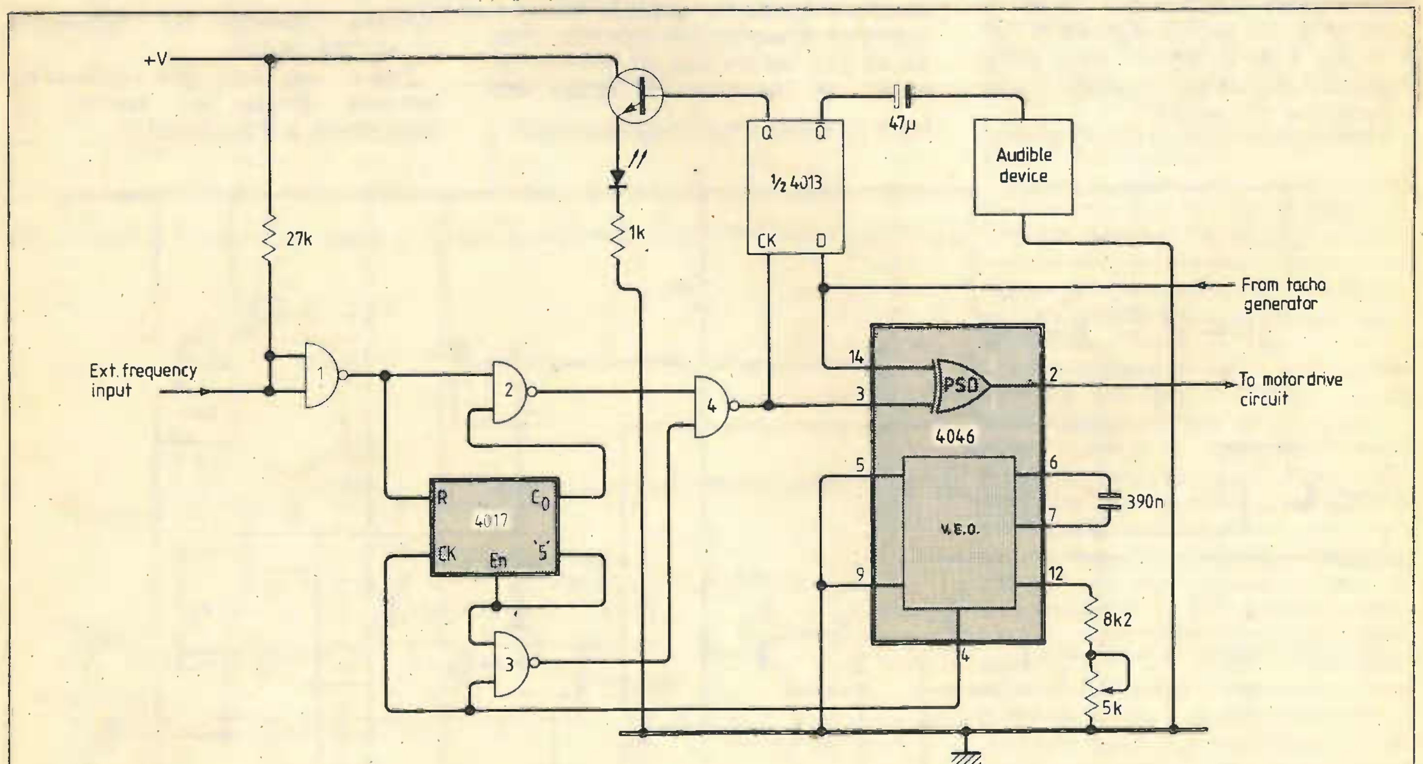


Fig. 47. *Motor speed control circuit and 'in-lock' indicator.*

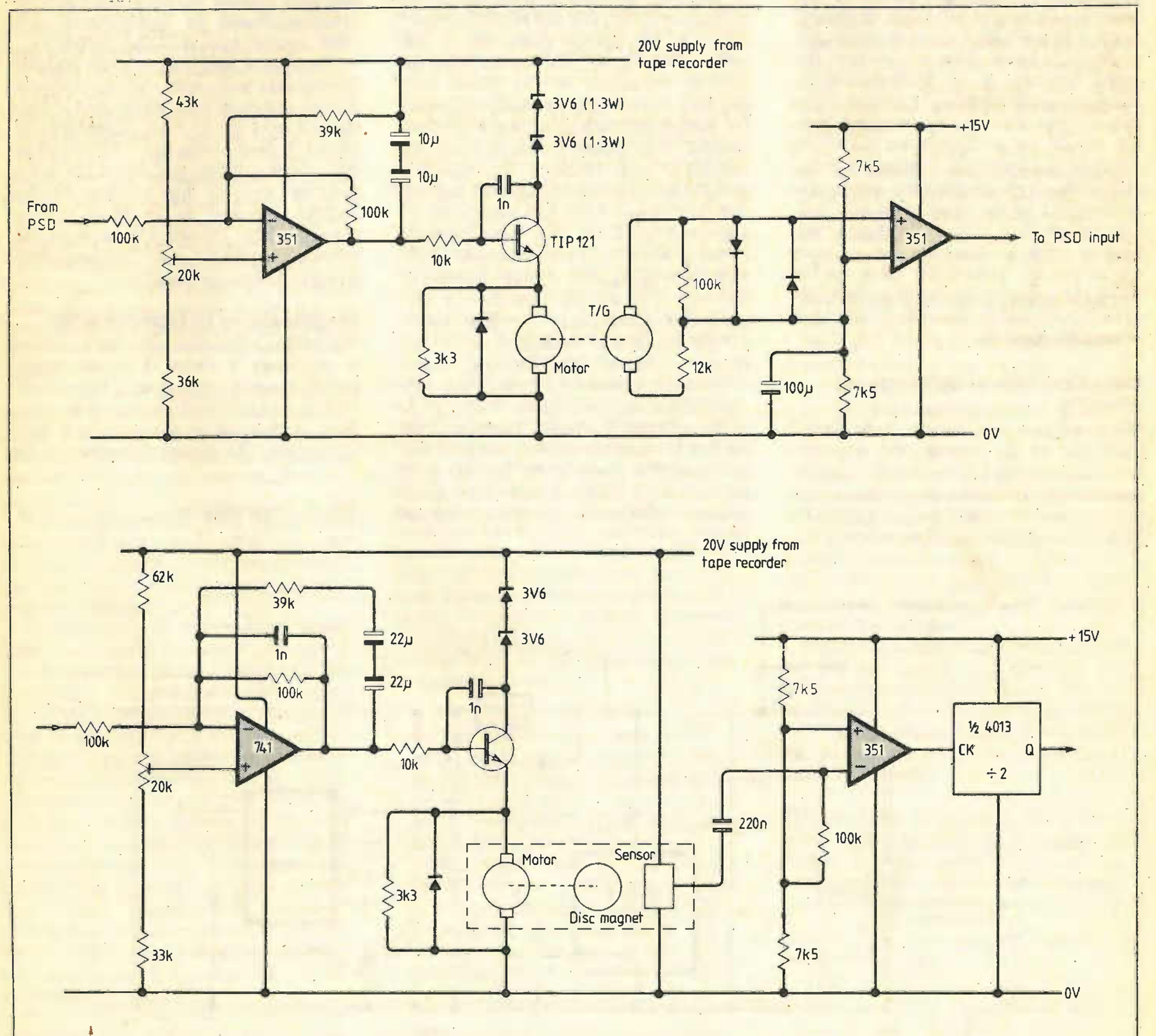
The output from the p.s.d. is passed to the motor drive circuit of Fig. 48(a) or (b). It is filtered by a lead-lag low-pass filter, consisting of the 100k input resistor to the 351 op-amp and the 39 k plus 5µF capacitor (11µF in Fig. 48(b)) feedback loop. The low-frequency gain of the inverting op-amp is limited to unity by the 100k feedback resistor. The resulting output from the op-amp drives the motor via the emitter-follower circuit using a Darlington power transistor, TIP121. The 10k resistor and base-collector feedback capacitor of 1nF provide some necessary high-frequency cut-off to the emitter-follower stage. The values of the filter components were found by trial and error to produce a stable and trouble-free p.l.l. servo system under all conditions of Play, Rewind and Fast Forward operation of the deck.

The direct offset voltage produced at the output of the op-amp by the potential divider circuit on the non-inverting input is essential to the self-starting action of the servo system. The 20k resistor should be adjusted such that the p.l.l. finds lock in one or two seconds after pressing the Play, Rewind or Fast Forward keys. If the voltage on the non-inverting input is too low, the p.l.l. will not find a 'lock', the motor speed remaining too low; if it is too high, the loop will find and lose its 'lock', the motor speed ending up too high. When a satisfactory setting for the 20k resistor has been found it will be observed that the tachogenerator waveform leads the v.c.o. output by a little more than the ideal 90°. This phase difference will change a little under varying load conditions but should not vary so much as to lose lock.

The tachogenerator pulse shaper circuit shown in Fig. 48(a) is that for the motor with the built-in tachogenerator, while that in Fig. 48(b) is for the motor with the mechanically coupled magnetic disc and Hall-effect sensor. Because the output from the speed sensing circuit of Fig. 48(b) is exactly double that of Fig. 48(a), the output from the pulse shaper is divided by 2.

C.m.o.s. circuits of Fig. 47 and the pulse shapers of Figs. 48(a) and (b) are powered from a 15V supply, which is provided by a 15V, 100mA regulator powered by the cassette recorder's 20V stabilized supply line. The 20V supply powering the

Fig. 48. *Motor drive circuit and tacho pulse shaper. Version for motor Type R14-7430, 03Y8D is at (a), while that used for motor Type MMX-6H2LSB is shown at (b).*



motor drive circuit is that normally supplied to the positive lead of the motor, switched by the various keys of the cassette deck.

Motor modifications

Both types of motor may be removed from their outer casings by careful removal of the back-plate. For motor type R14-7430, 03Y8D, the built-in electronics should be completely removed. The tachogenerator output is identified by two yellow leads, whilst the motor contacts are two terminal posts to which the internal p.c.b. is soldered. The two yellow leads should be extended, and two wires, red and black, should be soldered to the two terminal posts of the motor, making certain which is the positive and negative terminal. Reversal of these two motor connections will result in the motor running backwards, but no damage will be done.

With the back off the motor type MMX-6H2LSB, the frequency output of the Hall-effect sensor should be identified before any modifications are carried out. This is done by running the motor from a nominal 12V source and using an oscilloscope to identify the frequency output pin of the i.c. Having done this, remove the power transistor of the built-electronics: this automatically breaks the internal servo loop. A low-value resistor from the positive supply line to the positive pin of the motor drive should then be removed, and a link made from the negative pin of the motor drive to the negative supply line. Connections then need to be made to the positive supply line of the built-in electronics, the positive pin of the motor drive, the negative supply line of the built-in electronics and the frequency output pin of the Hall-effect i.c.

Use of the reference frequency circuitry

When operated with the rest of the digital electronics of the recorder, the reference frequency for the speed control circuit is supplied by the 'reference frequency circuitry', shown in block form in Fig. 11 of part 2. During the recording process, the reference frequency is the TC frequency of 22,755.5Hz divided by 50, i.e. 455.1Hz. When this source is connected to the external frequency input of the motor speed control circuit, the internal v.c.o. source is automatically 'knocked-out'. The 4017 counter of Fig. 47 is continually reset by the presence of the external frequency source with the result that CO remains at the logic 1 level and the 5 output at logic 0. The external frequency source thus passes through Nands 2 and 4 to the input of the p.s.d., the output of Nand 3 being permanently maintained at logic 1.

On playback, the reference frequency presented to the speed control circuit is that from a v.c.o. whose output frequency is dependent upon the average voltage at its input, which is the filtered output of a p.s.d. comparing the crystal-controlled TC with the recovered TC from the recorded data of one track of the tape-recorder. Thus, on playback, the speed control of the tape is maintained by a p.l.l. servo system within another p.l.l. Some readers may think this a very curious system and wonder why the output from the p.s.d. comparing the crystal and recovered tape-clocks is not simply connected to the motor driver circuit. The answer to this is that the dynamics of the record and playback servo loops are totally different. On record, the tachogenerator is directly coupled to the motor, but on playback the recovered tape clock is mechanically coupled to the motor through the capstan and belt drive. It is not impossible to achieve a p.l.l. by the more obvious method, but it is very unstable and easily disturbed, losing lock, by any vibration of the deck. The solution used here is very much more satisfactory, offering as it does a very convenient method of switching from one reference frequency (on record) to another (on playback). by having a very much lower natural frequency for the p.l.l. of the reference frequency generator than for that of the motor speed control circuit, the instability produced by the belt drive mechanism is removed and there is no instability produced by one p.l.l. upon the other.

Power supplies

The Hart version of the Linsley-Hood cassette recorder is mains-powered but can very conveniently be made to operate from a 24 volt d.c. source. Because there was a requirements for the recorder to be operable independently of a mains supply it was decided that it, too, should be capable of operating from 24 volts d.c. As a result, the power supply of Fig. 49 was designed and constructed. Since a very large number of c.m.o.s. i.cs are used in the digital circuitry it was decided that they were worth protecting from any over-voltage spikes. Consequently the 'crowbar' circuit was added: in the event of an over-voltage spike, the thyristor is triggered, causing the fuse in the positive supply rail to the 7815 regulator to blow. An over-voltage of approximately 16 volts is needed to trigger the 'crowbar' circuit.

A switching inverter circuit, shown in Fig. 50, is used to generate the negative rail voltage. The heart of the circuit is the 78S40 switching inverter. Using the values indicated, the output voltage from the switching inverter circuit across the 47µF capacitor should be approximately −18 volts, at a load current of about 120 mA.

This type of switching inverter does not operate very well under varying load conditions, so a shunt regulator is used to drop the −18 volts to −15 volts. Approximately 100mA is drawn from the −15 volt rail by the various analogue and digital i.cs in the circuitry: there is thus no need for the 2N3053 transistor to be fitted with a heatsink. The 2N2905 transistor of the switching regulator also dissipates little power and needs no heatsink.

Modifications to tape-recorder

The Miller-coded data recorded onto tape is effectively a series of square-shaped pulses, ranging in frequency from about 5.5kHz to 11kHz, which should be modified, or distorted by the recorder as little as possible. The transient response of the tape-recorder is more important, in its present use, than a flat frequency response.

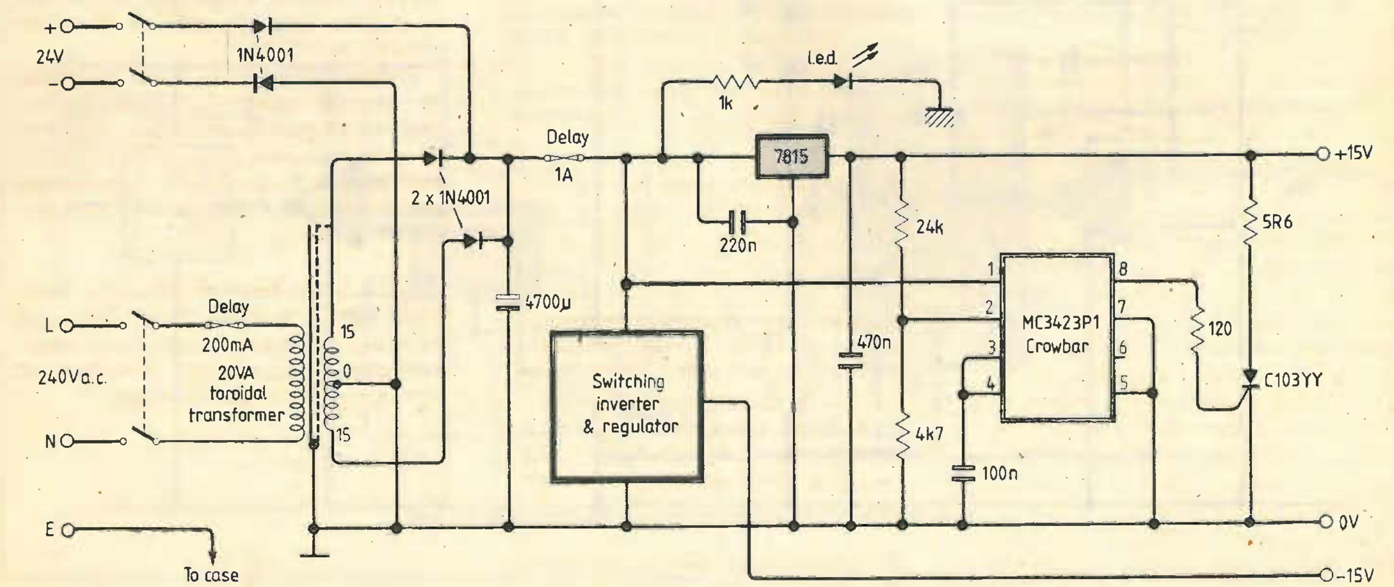


Fig. 49. Power supplies.

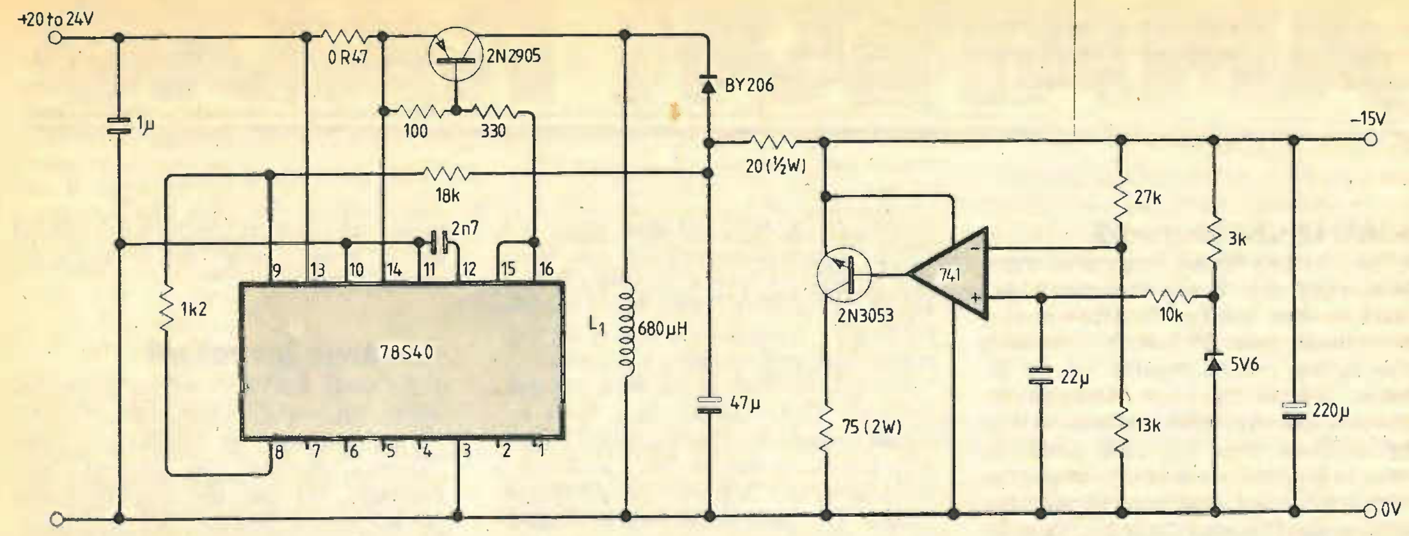


Fig. 50. Circuit diagram of switching inverter and regulator block seen in Fig. 49.

To obtain the desired record/replay characteristics, the signal level, bias level and equalization must be adjusted. Firstly, the frequency response of any tape-recorder is the wider, the lower the signal level recorded. In normal use, the level of the signal to be recorded is a compromise between frequency response, distortion and signal-to-noise ratio: too high a level results in distortion and too low a level results in a poor signal-to-noise ratio. Signal-to-noise ratio is not a problem in the present use of the tape-recorder since the Miller-coded data is recorded at a constant signal level with no amplitude variation. The recording level can thus be reduced, improving the quality of the signal in terms of frequency response and distortion, provided, of course, it is not reduced to a level where noise imposes itself on the signal.

The level of the high-frequency bias can have a considerable effect upon the recorder's frequency response; high levels of bias producing an attenuation to the high frequency signals but some reduction in distortion.

Finally, adjustment of the equalization characteristic has a great effect upon the amount of high-frequency pre-emphasis and modifies considerably the transient response of the recorder.

In addition to all the possible adjustments mentioned, it must not be forgotten that the quality of the tape used is of prime importance. The author formed a considerable liking for Maxell UDXL II cassette tapes, both C60s and C90s. It is a CrO-type tape, requiring a high bias level and a 70µs equalization characteristic and has all the usual advantages of good frequency response, etc. The cassettes are also very sound mechanically. This is not the only suitable tape available – other tapes may perform just as well – but the tape recorder should be set-up using this tape. Having satisfactorily adjusted the tape-recorder to operate with the digital electronics, other brands of tape may be tried to determine their suitability.

When I began recording the Miller-encoded data on to tape to discover how well the recorder performed, a problem occurred with the transport mechanism that was not immediately appreciated. The replayed signal, having passed through the peak detector and Miller decoder, was found to contain errors in the data stream which were initially thought to be due to the recorder's limited frequency response. Consequently, I experimented at length with the various adjustments mentioned earlier. Subsequently, the main reason for the errors in the replayed and decoded data was found to be due to jerkiness in the take-up spool of the tape-recorder, which was caused by incorrect operation of the slipping-clutch mechanism driving the take-up spool. The slipping-clutch was not, in fact, slipping, but the brass bush on the end of the slipping-clutch spindle, in contact with the rubber-tyred pulley of the take-up spool mechanism, was slipping jerkily. The problem was effectively cured by taking the slipping-clutch mechanism apart and 'weakening' its compression spring. The author is pleased to be able to say that a second tape-recorder, bought from Hart electronics at a later date, has a cassette deck with a modified slipping-clutch mechanism that gave no such problems. However, as a result of this fault, the author discovered a number of adjustments that should be made to the recorder to improve its record/replay characteristic of the Miller waveform.

- The 0dB recording level of 2.25 volts r.m.s. at the output of the recording amplifier should be reduced by about 4dB to 1.42 volts r.m.s., which corresponds, on playback, to an output from the replay amplifier of about 250 mV r.m.s., i.e. 4dB down on the original 400mV level. The 'VU' meter circuit sensitivity should be adjusted accordingly for a 0dB reading when the output from the recording amplifier is 1.42 volts r.m.s.
- The amount of high-frequency pre-emphasis should be reduced to a minimum by adjustment of Vr_2 to maximum resistance on the recording amplifier board.
- The bias oscillator frequency should be raised from about 55kHz to nearer 80kHz by replacing the capacitor, C_{23} (10nF), of the bias oscillator circuit with one of 6.8nF and by changing R_{50} from 150 ohms to about 200 ohms.
- The 70µs record/playback equalization characteristic should be used and a slight improvement may be obtained by changing the valve of C_6, on the replay board, from 27nF to 18nF.
- The bias level should be high with the 47k variable resistor adjusted for the highest level possible. This should result in a bias voltage, as measured at the junction of the 47k variable resistor, and the 220pF capacitor C_{20} (L or R), of about 10V r.m.s.

The actual bias level does not appear to be very critical, but a high level produces a steadier signal, on replay, with less amplitude flutter. As the recorded signal has no low-frequency content below 5.5kHz the erasing effect of a high bias is of little consequence and the reduced distortion probably beneficial.

With all the above adjustments carried out, and the cassette deck operating in a mechanically satisfactory manner, little or no errors should be observed in the resulting replayed decoded data. Those errors that do occur should be due only to imperfections in the tape.

This concludes the series of articles. Stripboard layouts prepared by Mr Ewins are available in photocopy form: please write, including a large, stamped and addressed envelope, if you would like copies. □

AMATEUR RADIO

50MHz stays good

In the February WoAR I suggested rather prematurely that "fewer transatlantic signals have been heard on 50MHz this winter although some 28/50MHz cross-band working has proved possible". J. R. R. Baker, GW3MHW, near Aberystwyth, Dyfed, a devoted 50MHz enthusiast, feels my comment does less than justice to what, in his view, has proved to be an even more fascinating period than two years ago at the peak of Sunspot Cycle 21. Then, he admits, there were outstandingly strong 50MHz signals that enabled a number of British amateurs to work all ten American "call areas". Altogether some 150 British amateurs and more than 20 other Western European stations participated in the transatlantic cross-band working. A few European stations, including about a dozen in Holland, were permitted to transmit on 50MHz.

Good results were also achieved during the 1980-1 season, with rather more Central American and Caribbean signals. No high hopes were held for the 1981-2 season, yet GM3MHW considers it has proved as good, in its way, as the two previous years: a few openings in late October, daily openings throughout November (except November 7), almost daily in December, and occasional openings in January 1982. On January 27, GW3MHW made his 449th cross-band contact for the season, compared with about 400 in each of the two preceding years, including many Caribbean and South American stations. Ken Ellis, G5KW contacted 48 of the American States. Several British amateurs made 70/50MHz contacts with Canadian VE1ASJ.

These results, two years after the peak of Cycle 21, are being regarded as so encouraging that it is proposed to publish a regular newsletter for 50MHz enthusiasts (from G4JCC or G4JLH for modest payment to cover postages and stationery).

The GaAs mosfet

The current availability of lower cost gallium arsenide f.e.t. devices, including dual-gate mosfets at around £5 or less, means that receivers with noise figures of under 1dB and with good dynamic range can now be achieved by amateurs on 144 and 432MHz. Devices include the 3SK97 and 3SK98 developed in Japan for use in television receiver tuners but it is believed that comparable devices will soon become available from European firms. For example, D. J. Robinson, G4FRE, has measured 0.9dB noise figure with 18dB gain (circuit, not total system figures) at 430MHz. On 144MHz the French amateur F6CER has described a receiver front-end comprising a 3SK97 r.f. amplifier, MD151 doubly-balanced diode mixer and P8000 impedance-converting grounded-gate amplifier, followed immediately by a 9MHz crystal filter. These GaAs mosfets are roughly one-quarter or less of the cost of most high-performance s.h.f. gasfets.

Further advances in the field of super low-noise GaAs mosfets have been reported recently by Hughes Aircraft who, with laboratory devices, have achieved a noise figure of 1.3dB with 10.3dB gain at 12GHz. The GaAs mosfet seem destined to play an increasingly important role at frequencies from about 100MHz upwards.

From all quarters

Following the example of the British teletext services, the Dutch Teletekst service by NOS now includes a page of information for the transmitting amateur.

When last November an incendiary set fire to a key telephone exchange in the Lyons area of France, some 50,000 telephone and telex lines, including trunk lines, were put out of action, local radio amateurs provided a special emergency communications service, handling urgent calls filtered through the police to ensure that all calls were of a non-commercial nature. They used h.f. bands and the FZ8VHF repeater.

Kathy Marsh, VK5NKM, the only amateur in Coober Pedy, an opal-mining town in central South Australia, operates from an unusual "dug-out" home some 20-feet underground. Such buried homes fashioned from former mines are popular in the township since they avoid the high summer surface temperatures (almost 50°C) yet remain comfortably warm in winter. Australia has some 15,000 licensed amateurs in a population of about 15 million people.

Shortly after Australian amateur Ray Naughton, VK3ATN, had climbed to the 45ft level of his 110-foot mast to make everything secure during a gale, a 100mph gust collapsed the tower. He escaped with some broken bones and a stay in hospital.

The Reseau des Emetteurs Francais has warned its members that some French c.b. associations are making demands on amateur frequencies in the 28, 144 and 432MHz bands. The society recommends that amateurs should show that they are making full use of these bands.

IARU Region 1 reports that the Irish Radio Transmitters Society will be 50 years old in June but can trace its beginnings to the Dublin Wireless Club founded in June 1913. First president of IRTS was Colonel J. M. C. Dennis, EI2B (formerly DNX) who is widely believed to have been the owner of the world's first non-professional experimental wireless station, established in 1898. During World War II, those Irish amateurs who were not enlisted in the Forces, offered their services as listening stations.

Awards knocked

Bill Verrall, VK5WV, writing in *Amateur Radio*, has strongly attacked many aspects of the emphasis on DXCC and other "award collecting" by amateur radio operators. He feels that country-chasing has led to such abuses as: "dx nets" claiming exclusive occupancy of spot frequencies; an increasing amount of deliberate jamming and interference; use of illegally high power; split-frequency operation by "rare" stations that spreads interference over many channels; blatant soliciting for "dx-pedition" funds and extraction of payment for QSL cards; and the use of QSL cards bearing political or "religious" messages. He also condemns the recognition of uninhabitable rocks and reefs as "countries" and the risks that this involves for those who set up stations at locations which may at times be entirely covered by the sea; "bootleg" QSL cards that may be entirely fake, or sent or sold to stations with which no contact has been made; and the widespread use of a standard RS(T) report of 59(9).

P. A. Wolfenden, VK3KAU, Federal president of the Wireless Institute of Australia, has pointed out that despite the growth in the number of training courses by clubs and educational bodies, newcomers still need more practical assistance from active and competent amateurs of experience: "the newcomer has to learn the ways of amateur radio, the procedures and the standards, and the various gentleman's agreements about such matters as band plans, correct repeater operating, etc . . . only a few clubs provide practical 'hands-on' experience".

In brief

Gerald Stancey, G3MCK identifies the "Early French Resistance suitcase set" in Toulon museum ("Clandestine Radio – the early years" February issue) as an early SOE equipment Type A, Mk II and raws attention to a book published in France "Armement Clandestin" by Pierre Lorain, F2WL which includes details and circuit diagrams of a number of British and German suitcase sets. The photograph by the way was taken by Dick Rollema, PAoSE . . . The 1982 RSGB VHF Convention is at Sandown Park, Esher, on March 20 . . . The Northern Amateur Radio Societies Exhibition is at Belle Vue Leisure Park, Manchester, on April 4 . . . Plymouth Radio Club has its third annual rally at Tamar Secondary School, Paradise Road, Millbridge, on May 30 . . .

PAT HAWKER, G3VA

E.P.R.O.M. PROGRAMMER

Most commercially available e.p.r.o.m. programmers are expensive as they include software and other facilities to enable them to be used on their own. The cost of a programmer can be significantly reduced if it is designed for use with an existing microprocessor system, as will be shown in these articles. The design presented is for 2708, 2716 and 2532 e.p.r.o.ms, but with small modifications other devices may be programmed.

by H. S. Lynes

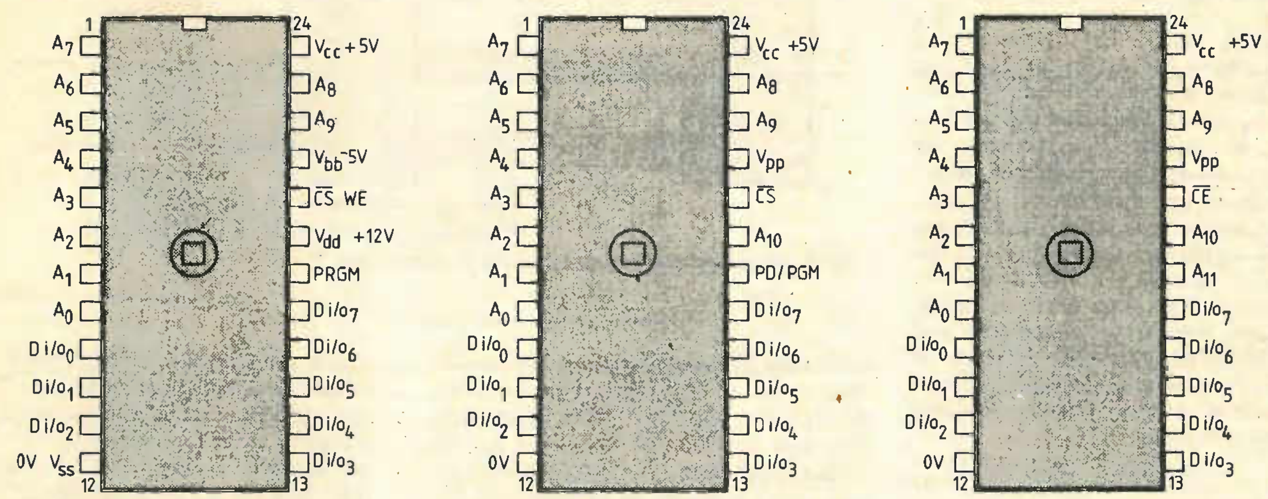
Sooner or later, probably all serious microcomputer system users in the hobbyist field will consider incorporating a program in e.p.r.o.m. (erasable programmable read-only memory). Unfortunately, commercial e.p.r.o.m. programmers are expensive and include facilities not essential for the enthusiast, who usually only wants to program the occasional device.

Commercial programmers fall into two main categories: those in the first category are expensive, have built-in data/address display and use 'personality' cards for programming different e.p.r.o.m. types. Units in the second category are very expensive. They have all the facilities of programmers in the first category but also include built-in v.d.u., tape interface, printer port, etc. All these programmers use comprehensive software and have large random-access memories to enable e.p.r.o.ms to be copied or modified at will. But if an existing microprocessor system is used to control an e.p.r.o.m. programmer, these facilities are unnecessary.

I therefore explored the possibility of adding e.p.r.o.m. programming hardware to an existing system. The first problem

Port C connections	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0	Hex
2708									
Function	logic	n.c.	26V	12V	n.c	n.c.	address		
I.c pin numbers			18	20			22	23	
Read	0	–	0	0	–	–	×	×	00
Write									
pulse off	0	–	0	1	–	–	×	×	10
pulse on	0	–	1	1	–	–	×	×	30
2716									
Function	logic	*	25V	n.c.	*	address			
I.c. pin numbers		20	21		18	19	22	23	
Read	0	0	0	–	0	×	×	×	00
Write									
pulse off	0	1	1	–	0	×	×	×	60
pulse on	0	1	1	–	1	×	×	×	68
2532									
Function	logic	*	25V	n.c.	address				
I.c. pin numbers		20	21		18	19	22	23	
Read	0	0	0	–	×	×	×	×	00
Write									
pulse off	0	1	1	–	×	×	×	×	60
pulse on	0	0	1	–	×	×	×	×	20

Notes: The hex. value is the code, or 'pin-profile', used for port C, ignoring the address. When programming 2716 and 2532 e.p.r.o.s, pin 21 is held high during the read cycle. Functions marked with an asterisk indicate that the port is used as a logic, i.e., the port is tied directly to the e.p.r.o.m. pin. Where × is given, both logic levels are used for addressing. PC7 is used to detect the high-impedance state after reset.



Fairchild F2708DC — Hitachi HN462716 — Hitachi HN462532

Fairchild F2708DC

Mode	18	19	20	21
READ	0V	+12V	0V	−5V
WRITE	26V*	+12V	+12V	−5V

Hitachi HN462716

Pin numbers	18	19	20	21
READ	0V	x	0V	+5V
WRITE	+5V*	x	+5V	+25V

Pin 19 is used for the address

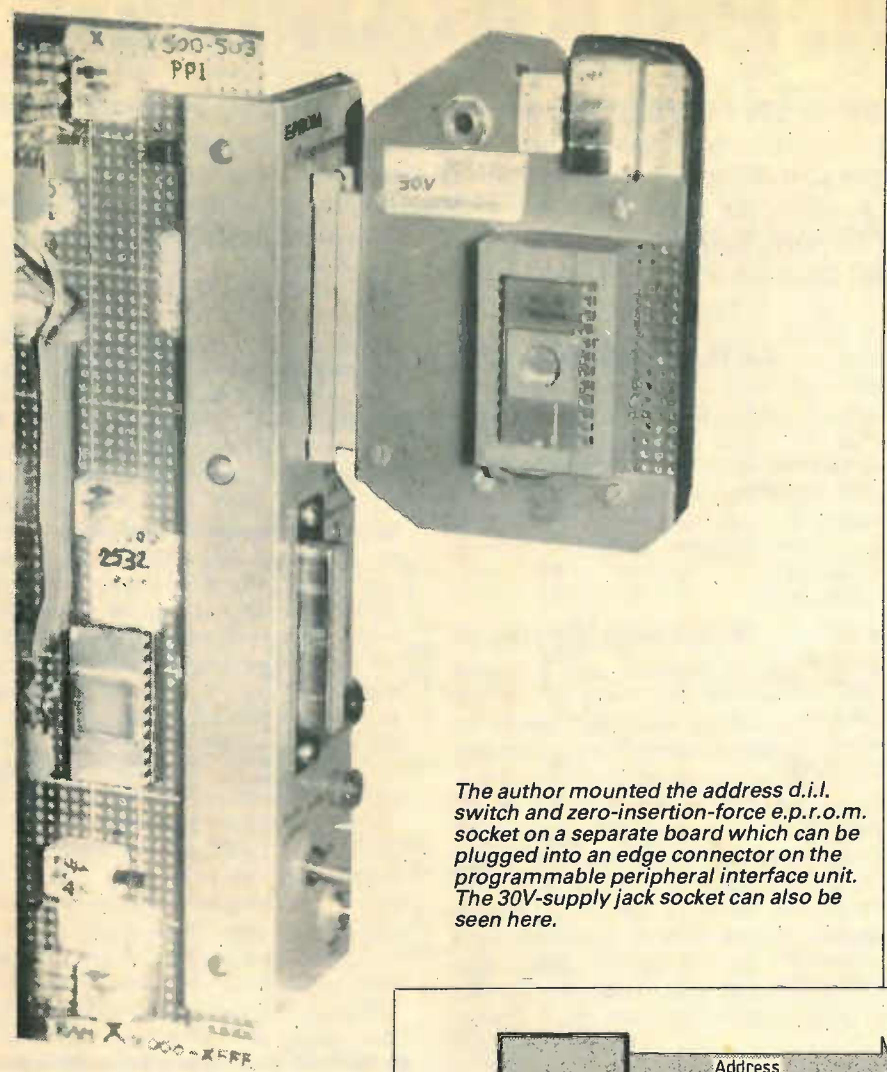
Hitachi HN462532

Pin numbers	18	19	20	21
READ	x	x	0V	+5V
WRITE	x	x	+5V*–0V*	+25V

Pins 18, 19 are used for the address
Pin 20 is LOW during during WRITE, with 25 volts applied to pin 21.

* pulsed

Fig. 1. The three e.p.r.o.ms for which the programmer was designed with tables showing control and programming logic requirements.



The author mounted the address d.i.l. switch and zero-insertion-force e.p.r.o.m. socket on a separate board which can be plugged into an edge connector on the programmable peripheral interface unit. The 30V-supply jack socket can also be seen here.

Table 1: Wiring from the 8255 p.p.i. and supplies to the e.p.r.o.m. programming board. Lines with prefix PA are for addressing and lines with prefix PB are for data. Prefix PC denotes lines used for both address and data.

E.p.r.o.m. socket pin numbers		Supply and p.p.i. lines
1		PA7
2		PA6
3		PA5
4		PA4
5		PA3
6		PA2
7		PA1
8		PA0
9		PB0
10		PB1
11		PB2
12		0V
		0V
13		PB3
14		PB4
15		PB5
16		PB6
17		PB7
18	for 2708s	PC5
19	for 2708s	+12V
20	for 2708s	PC4
21	for 2708s	−5V
22		PC1
23		PC0
24		+5V
(18)	for 2716/2532s	PC3
(19)	for 2716/2532s	PC2
		+30V
		PC7
(20)	for 2716/2532s	PC6
(21)	for 2716/2532s	PC5
		PC4
		Reset
		R/W
		+5V
		02
		spare

encountered was that programming requirements for different types of e.p.r.o.m. can be vary considerably. Also, there is no standardization in pin configurations. So, taking into account the popularity, price and availability of various e.p.r.o.ms, it was decided that the programmer should be designed for 2708 and 2716 (5V supply) e.p.r.o.m. types. As the 2532 looked promising at that time it was also included. The latter device is similar to the 2716 both in pin assignments and programming requirements, although its inclusion meant that an additional address line would be needed. Design objectives were thus as follows:

E.p.r.o.m. type	Organization	Requirements
2708 (3-rail)	1024 × 8	500µs programming pulse, sequential programming
2716 (5V)	2048 × 8	50ms t.t.l. programming pulse, bit-selectable programming
2532	4096 × 8	50ms t.t.l. programming pulse, bit-selectable programming

For the 2708, I used data published by Intel, which covers the subject of e.p.r.o.ms at length. This data was used to define the programming pulse rise-and-fall time limits of 0.5µs-2µs. For the 2716, Mostek data was used (which agrees with Fairchild and Hitachi data), and for the 2532, Hitachi data. The latter manufacturer's data was easiest to understand*. Pin configurations and level requirements are given in Fig. 1.

Although these three devices are at present the most popular, readers designing new systems using e.p.r.o.ms might want to omit the 2708 programming facility, since one 2716 can be obtained for less than the price of two 2708's. Furthermore, the 2708 must be programmed in small stages sequentially – a process often called 'spray-coat' programming. This is inconvenient when developing using 1K × 8 devices but if 2 or 4K devices are used, the method is intolerable. Fortunately, later devices may be programmed bit-by-bit as required. Inclusion of the 2532 programming facility is now justified, since it can be obtained for less than the price of two 2716's. The reasons for not including the 1702 among the chosen e.p.r.o.ms are that in my view, programming of it requires twisted logic, it is relatively expensive and it cannot be used with the software for the chosen devices in read mode.

The programmer was designed for use with a 6800 microprocessor system but is based on an 8255 programmable peripheral interface (Intel or National Semiconductor). Some extra logic is required to drive the 8255 control pins but this p.p.i. provides three 8-bit ports and programming is relatively simple. If the 6821 had been chosen, two i.cs would have been required and programming would, in my view, have been more difficult: there is no reason why support devices should not be chosen for their ability to fulfil objectives.

The 8255 is used in mode 0 (see manufacturer's data for further information) with the 8-bit ports A and C as outputs and port B as either input or output depending on the control word stored in one of the device's four memory locations. By changing port B from output to input it is possible to check that data entered into the e.p.r.o.m. has been correctly received. This function corresponds to the verify function of expensive programmers.

Since e.p.r.o.m. bits are all at logic 1 when the memory is empty, it would be possible to check the amount of memory available in partly full 2716/2532 devices. Unfortunately, the 6800 uses instruction FF to store the index register so confusion could result if the end of the existing program used FF as an instruction or address.

It is advisable to finish programs with three 00's to avoid the risk of placing a new program over the top of an existing one.

** This could be a useful tip for aspiring technical writers – Ed.*

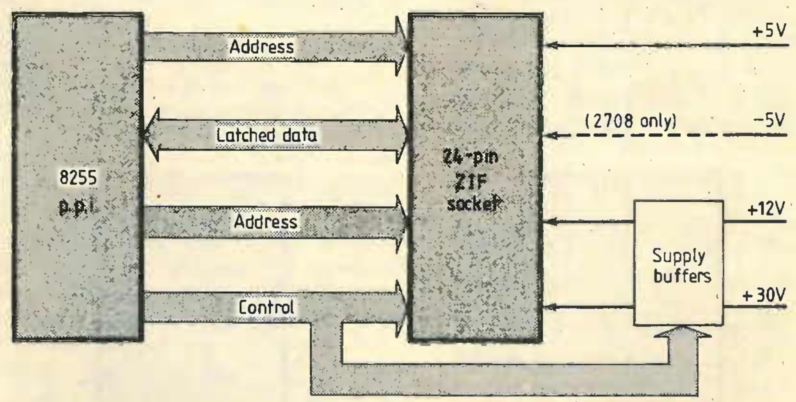


Fig. 2. Simplified block diagram of the programmer.

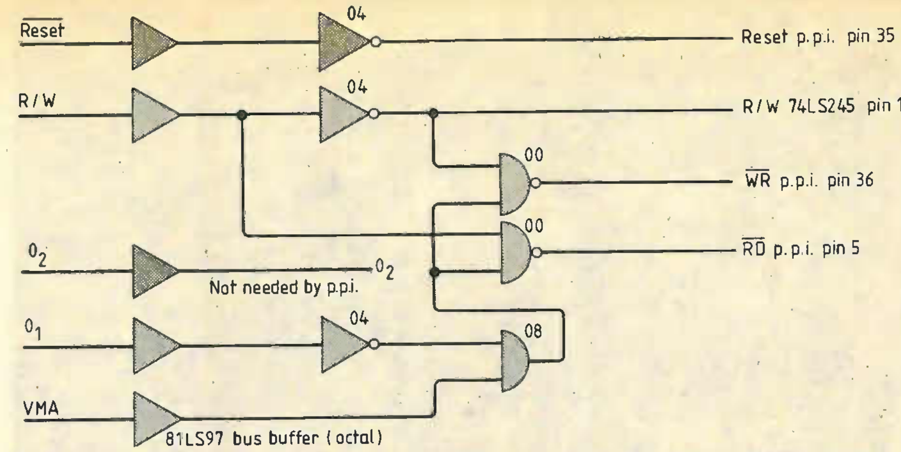


Fig. 3. Logic for converting outputs from a 6800 processor for use with an 8255 p.p.i. If an 8080 processor is used to control the programmer, this conversion is not required.

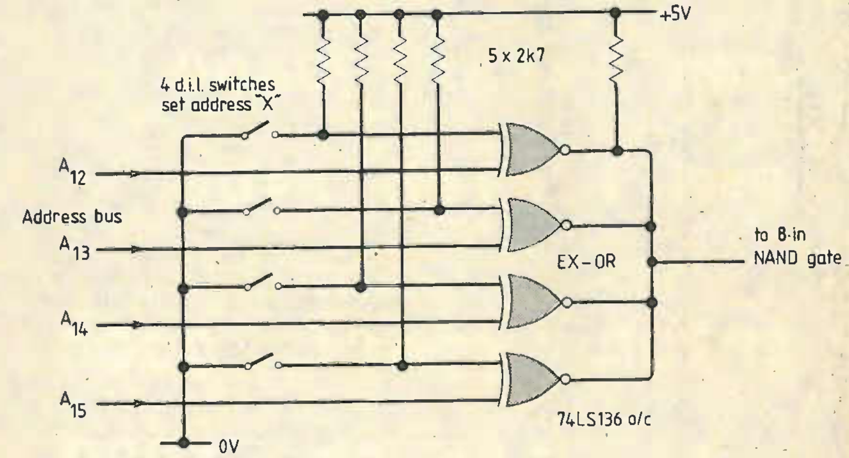


Fig. 5. Circuit for selecting the most significant digit of the p.p.i. address (see Fig. 4).

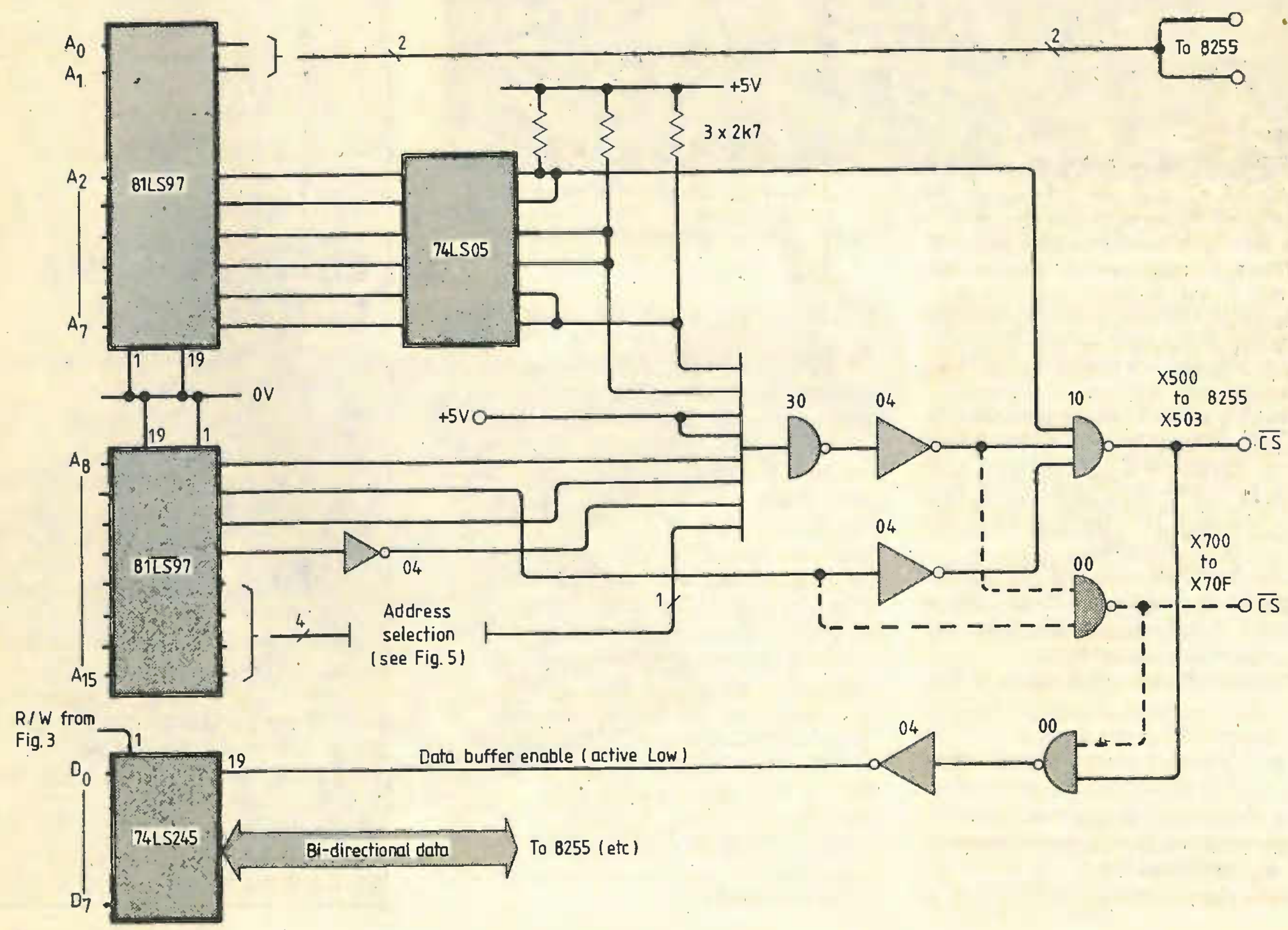
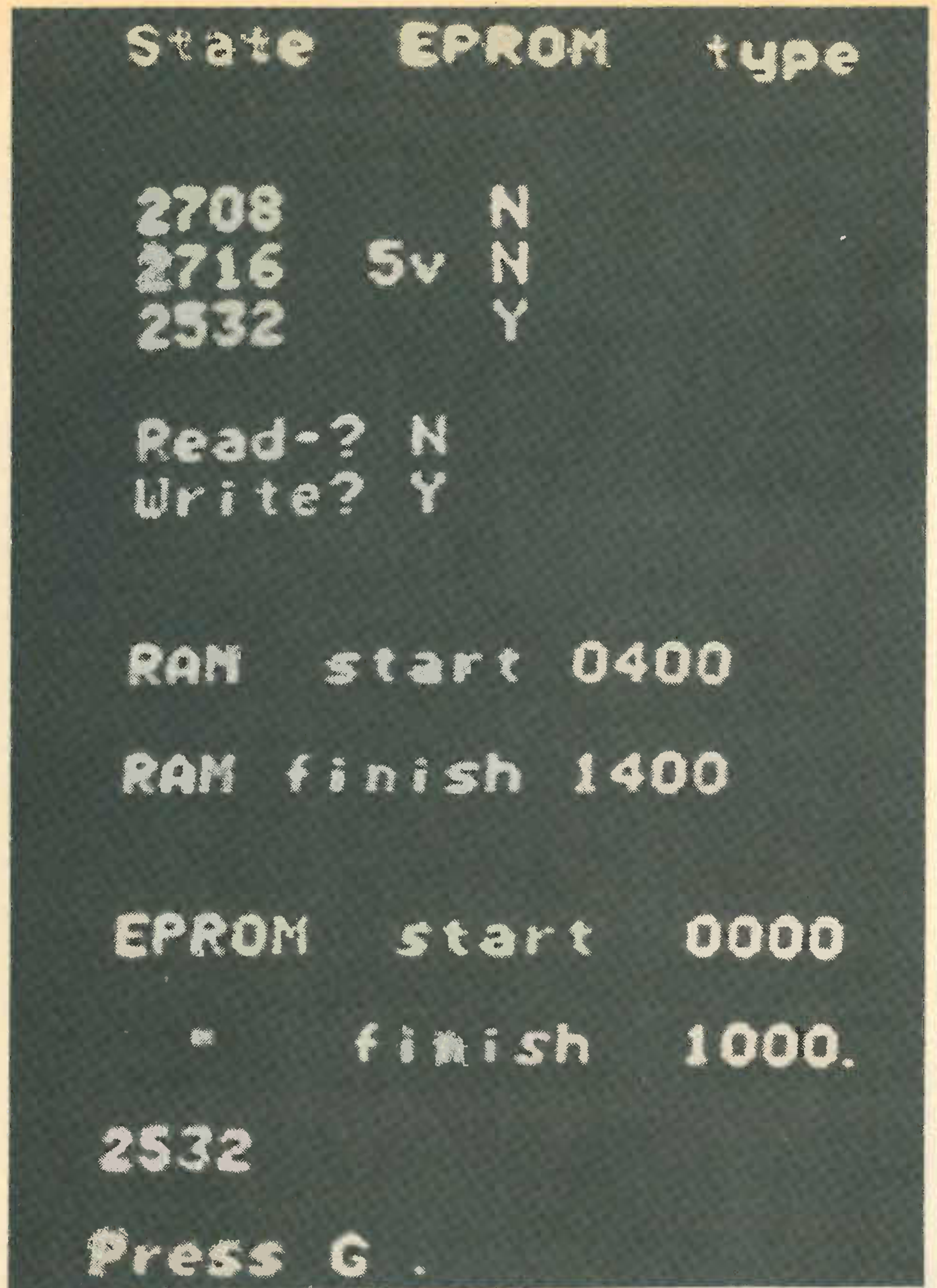


Fig. 4. Address decoding for the 8255 and one other device (see text).



This photo is an example of the author's display and illustrates the type of prompting that may be used. Because of the differences between microprocessor systems, a full software listing is not given, but a 'scratch-pad' and software outline will be included in the next article.

Also, a careful note of the current program state of each e.p.r.o.m. should be made. Colour coding the i.cs makes it easy to log their history.

Figure 2 is a block diagram of the programmer, and logic conversion for driving the 8255s $\overline{RD}$ and $\overline{WR}$ lines from the 6800 is shown in Fig. 3. If an 8080 processor is used to control the programmer, this conversion is not required.

The 8255 address, see Fig. 4, requires four consecutive locations. In my system the address is fully decoded, but the four most significant address lines can be altered using a d.i.l. switch as shown in Fig. 5. The four locations are from X500 to X503, where X may be from 0 to F depending on the d.i.l. switch setting. Being able to change the address is useful if the 8255 is to be used as a general purpose port, as opposed to being dedicated to e.p.r.o.m. programming.

Table 1 shows lines from the p.p.i. to the board on which the programming socket, switching between 2708 and 2716/2532 functions, and a voltage regulator were mounted. In the table, pins 18 to 21 of the programming socket are shown connected for programming the 2708. In practice, pins 18 to 21 are connected to a 4-pole, 2-way d.i.l. switch so that they may be taken to PC3, PC2, PC6 and PC5 respectively when 2716/2532 e.p.r.o.ms are to be programmed. PC5 is a 25V signal and PC4 a 12V signal, the conditioning circuits of which will be shown later. PC7 is used to check logic but it could be used to detect changes on pins 18 to 21, or even omitted to reduce the number of lines from the p.p.i. circuit to the programming board. 37 lines were used, as shown in the table but by omitting unwanted lines, combining the 0V rail and bringing in the 30V supply separately, the total may be reduced to 30. □

To be continued

IN OUR NEXT ISSUE

Digital filter design

Accuracy, versatility and a rapidly declining cost will ensure that digital filters take over from their analogue counterparts. A new series gives their theory, design techniques and microprocessor implementation.

Program exchange by telephone

There is a growing need to facilitate the easy exchange of programs and data from one person to another. Philip Barker discusses program distribution and the design and implementation of software systems capable of loading source code programs into memory.

Orchestral sound, halls and timbre

Taking the Kingsway Hall as a model, Denis Vaughan investigates the effect of concert hall shapes and sizes, and the working of the filtering of the outer ear on timbre and perceived directionality.

On sale April 21

NEWS

Polytechnical computer

The opening of the new computer centre at Coventry Lancester Polytechnic was accompanied by a civic reception and a protest demonstration by some of the students. The centre has been constructed to house two Harris computers which provide impressive processing power with storage capabilities for a high volume of batchwork and can service some 100 terminals distributed over the Polytechnic campus.

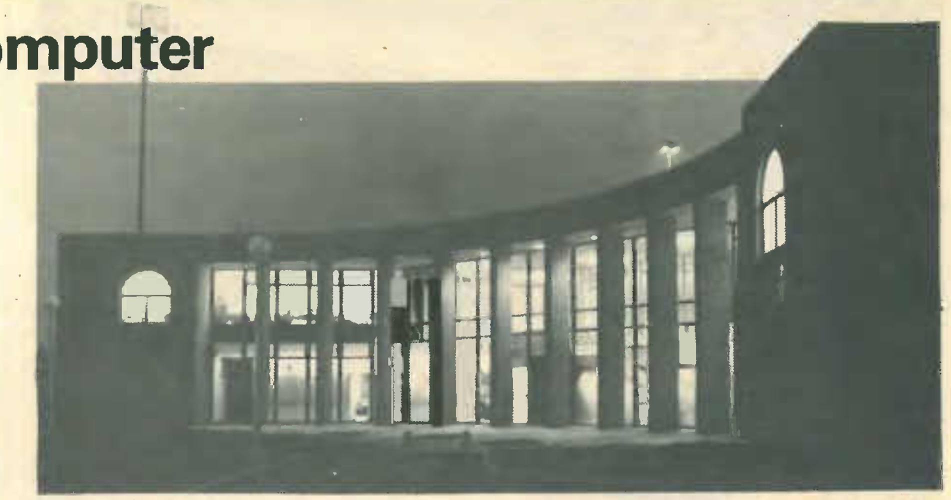
The centre incorporates a Harris 800 computer system which has 2 megabytes of memory, with four 300-megabyte disc drives and one 80-megabyte disc drive, a line printer, card reader, a 9-track magnetic tape unit and a CIL plotter.

Also housed in the same building is a Harris H500 computer, a separate system with one megabyte of memory and one 300-megabyte disc drive with a line printer, a card reader, a magnetic tape unit and a paper-tape reader/-punch.

Elsewhere on the campus is a Harris H100 for the polytechnic's Electrical and Electronic Engineering department. Eventually it is planned to connect all three computers together by synchronous links into one processor network.

The system is the biggest Harris system outside the United States and is claimed to be the largest available to any further educational establishment in the UK.

The student protest was very civil and was not about student grants, despite the presence of the Parliamentary Under-secretary of State, Department of Education and Science, Mr William Waldegrave; it was about the delay in getting the computer actually working, their work was being delayed by the lack of terminal time as only a few were actually running. Harris assured us that these were teething problems and that they were flying a team of specialists from their factory in Florida to assist in the initialisation of the system.



The Computer Centre at Lanchester Polytechnic, Coventry, specially built to house the computer facilities, including the two Harris Computers and some special terminals.

Timex to sell Sinclair in the U.S.A.

You may know that the Sinclair ZX81 Microcomputer is manufactured under a subcontracting agreement by the Timex Corporation in their Dundee factory. The current production rate is about 30,000 units each month, which some clever mathematician has worked out to be one unit every ten seconds. Timex seem to be impressed by the sales and have come to an agreement with Sinclair Research, whereby they can sell a Sinclair/Timex computer in North America. Sinclair are at present selling in the U.S. by mail order at a rate of 15 thousand a month; Timex have about 170,000 retail outlets in North America, and could sell at a phenominal rate.

The agreement is for Sinclair to provide the technical expertise and for Timex to manufacture a computer which will include their own brand name. The name is not to be more prominent than the Sinclair marque which will remain on the equipment.

Timex will pay Sinclair a 5% royalty on all hardware that is related to the Sinclair microcomputer, even if it is not originated by Sinclair. They will also pay a 5% royalty on any Sinclair originated software. And they will even pay 2½% on software from any other source as long as it is intended for use on the Sinclair equipment. There will be a cross-licensing agreement for any hardware that Timex may develop themselves.

Clive Sinclair says that he has been looking for a large marketing outlet for his products for some time. He intends to keep Sinclair Research as a compact research and development team, concentrating on improvements to existing products and development of new ones. The date for the probable launch of the Microvision flat tv is given as the last quarter of 1982. It has already been announced that the tv is being incorporated into a desk-top terminal for ICL, and there may be some clue as to the likely format of the next-generation ZX computer in that. Sinclair's research into electric vehicles is continuing.

The Sinclair ZX81 which is to be manufactured, and marketed in North America, by Timex. The ZX81 is shown together with the add-on 16K RAM pack and the ZX Printer.

Having produced new versions of their pre- and power-amplifiers and their electrostatic loudspeakers, Quad have come up with an f.m. tuner, the Quad FM4. It has been styled to match the Quad 44 pre-amplifier with which it is shown. It incorporates a microprocessor which can recall the preset stations from memory and also controls inter-station muting and a.f.c. Manual tuning is used to program the seven preset stations and occasionally to tune in to a station not already programmed. A bar graph displays signal strength and centre tuning. The preset buttons and the tuning knob are the only controls: the microprocessor takes care of everything else.

Teletext, a new campaign

One way to mass market viewdata is believed to be the growth of private viewdata systems which are compatible with Prestel; used by companies for in-house systems. Another way is the development of a more attractive Prestel package for the consumer.

It was decided at the conference that Prestel could be made more attractive to the consumer by:

– working towards a consumer package, providing an overall viewdata service which would include transactional applications, i.e. the ability to order goods by pressing the appropriate buttons;
– including entertainment and communications as well as 'straight' information;
– examining the tariff structure;
– working towards a reduction in the cost of viewdata receivers;
– improving the quality and attractiveness of the information provided;
– promoting new applications of business viewdata;
– working towards the acceptance of viewdata as the principle means of communication between business and industry.

Further analysis of the view expressed at the conference will lead to the publication of another 'action document'. October has been selected as National Teletext Month as was October last year, this will be used for an intensive campaign to promote teletext.

1982 is Information Technology Year, and as part of the Government's commitment to IT, the Department of Industry is promoting further awareness of Teletext and Viewdata.

According to a survey published in Prestel (page 19191), 65% of the population now know what Ceefax is; for Oracle it's 55%, teletext, 50% Prestel 30% and viewdata 15%. There are still 20% who have no knowledge of any of these. Television viewers with facilities to receive teletext numbered over 300,000 at the end of 1981.

This is a result, claims the DoI, of the promotion campaign launched at a 'Commitment Conference' in January 1981, which brought together the manufacturers of the equipment with the information providers, with television rental and retail traders, software suppliers, trade associations and with representatives from British Telecom, the DoI and the NEDO. One of the chief aims of the campaign was to familiarize consumers with the process of obtaining information from the tv screen. It is believed that such familiarization could lead to more recognition for Prestel, BT's telephone viewdata system.

In February of this year, another Commitment Conference was held in London to plan a further campaign for 1982. Once again the accent would be on promoting teletext to the general public and Prestel to the business community.

Free specifications and standards

London Information have started a free consultancy service to help engineers identify and acquire the specs and standards or other documentation they may need for their projects. Enquiries are already running at hundreds of 'phone calls a week. The documents are not confined to the electronics industry and London Information have told us that they have recently supplied copies of quarantine regulations for Australian wallabies and building regulations for a middle east sports complex. They provided an electronics firm with the relevant US Mil specs and this resulted in a big export order to the US.

London Information claim to be able to get any available document from anywhere in the world. If they cannot supply the information then they will put companies in contact with a source that can. Further details can be obtained from: London Information (Rowse Muir) Ltd, Index House, Ascot, Berks SL5 7EU. Telephone: 0990 23377.

Arthur C. Clarke honoured

The science writer, Arthur C. Clarke has been chosen to receive the eighth Marconi Fellowship Award by the Marconi Fellowship council.

The $35,000 award is given annually in recognition of scientific achievement for the benefit of humanity in the field of communications science and technology.

Clarke predicted the geosynchronous communications satellite as early as 1945 in the *Wireless World* article "Extra-terrestial relays: can rocket stations give world-wide radio coverage?". We issued a reprint of the article with our October 1981 issue. In it, he addressed very specifically the technical issues involved in such satellites, which have since become such a significant part of the earth's communications.

Clarke's other innovations include the use of satellite platforms for observing the earth in a quantitative manner, the concept of the manoeuverable solar sail for low-acceleration interplanetary flight, and the concept of the 'space elevator' for reaching orbital altitudes using materials of very high strength/weight ratio which are likely to be developed soon.

Recently, Arthur C. Clarke has been strongly supporting proposals for the use of satellites for communicating with remote communities. Many such systems have been installed in villages in Alaska and Canada.

As far as the general public is concerned, Clarke is best known for his science fiction writings, especially for his collaboration with Stanley Kubrick on *2001: A Space Odyssey*. Rumour has it that they are to work together again on another s.f. film.

Mr Clarke is now the Chancellor of the University of Moratuwa in Sri Lanka.

● The Marconi International Fellowship was founded in 1974 by Gioia Marconi Braga, daughter of the Italian inventor, Guglielomo Marconi. It is sponsored by companies and instititutions from ten different countries.

Licence sensation

There is a belief that the Home Office has made another "snafu" and will be forced to rescind part of a new schedule which appears to contain a host of technical errors and misreading of the International Radio Regulations. A four-page Home Office announcement appeared in the London Gazette on February 12 addressed to "all holders of Amateur (Sound) Licence A and Amateur (Sound) Licence B" setting out a new schedule of frequencies, classes of emission and power limitations "as from January 1, 1982." These are regarded as "unacceptable" by the R.S.G.B. which immediately called for urgent discussions with the Home Office. The new schedule, as printed, not only introduces the new international symbols and defines power in terms of output to the aerial in dBW, But also removes 10kHz from the British 1.8MHz band, restricts 3.5MHz transmission to the very low power of 9dBW (carrier power), compared with 20dBW for other h.f. bands, and also introduces an entirely new form of power restriction (30dBW maximum equivalent isotropically radiated power) for all bands above 1.2GHz. There are also many other apparent technical anomalies that are inexplicable in any rational technical terms.

A Home Office spokesman has told us that it was all a terrible mistake based upon a series of mis-prints. It must be pointed out however that publication in the London Gazette makes it a legal announcement.

Computers in the field

The Husky 144 by DVW Microelectronics is a sturdy, waterproof microcomputer for data entry in the field

The computer industry at the moment seems obsessed with 'the man in the field', the roving executive, salesman, engineer or even the journalist. The theory is that these peripatetic representatives can feed in the latest information, deal, sales figures or stories down the line to their parent companies.

One approach to this is illustrated by the new protable terminal by Digital Equipment Corp. The Correspondant is a hard copy printer terminal about the shape and size of an electric typewriter. It can handle plain paper and can have tractor feed as an additional option. It offers 132-column printing with a range of typefaces and because it is bit-map addressable it offers high resolution graphics (132 × 72 dots per inch) and can be used in conjunction with Digital's visual display terminals. What makes it portable is the 'universal' power input which will accept any a.c. mains supply of any voltage or frequency. It may be fitted with an acoustic coupler to communicate with the base computer. Digital are eager to point out however that it is also highly suitable as a fixed printer terminal with an RS232 interface.

The Digital Correspondant is a terminal and must be connected, by whatever means, to a computer to be of any use. An alternative approach is the portable computer. This has the advantage of being able to collect data 'in the field' and one example, the Husky 144, made by DVW Electronics, has been designed with a tough case and a flat, touch-sensitive keyboard. It can be used literally in the field, out of doors. It has a liquid crystal display of up to 128 characters in four lines. It is battery powered and thus can include an internal memory which does not lose its data and real-time calendar and clock so that entries can be 'tagged' with collection time automatically. The Husky 144 is provided with 144K-bytes of memory and has 'user-friendly' software. A key marked 'Help' may be pressed at any time during operation and a part of the internal 'manual' is displayed on the screen giving information on what to do next.

To communicate with the outside world the Husky 144 can use an RS232 interface for direct communication with a host computer or a printer. It can use an acoustic coupler for telephone contact. It can also be used as its own base station and may be plugged into an optional disk drive for storage and retrieval of files. With a disk drive it can also be operated under CP/M which gives it access to a large library of commercial programs.

Correspondant – Digital's plain paper portable terminal designed 'for executives on the move'

Xenix and the supermicro

Xenix is the name of a computer operating system for use on 16-bit microcomputers. It has been developed by Microsoft and is an implementation of Unix, a software system originally developed by Bell Laboratories for use on DEC minicomputers, first on the PDP-7 and later on the PDP-11. Xenix is the 16-bit operating system which seems likely to become a standard, much as CP/M has become for the 8-bit processor. One advantage it has is that there are comparatively few codes which are specific to a particular processor; so it can be fairly easily implemented on many 16-bit processors.

All this is by way of introduction to the Bleasdale 600 Xenix computer which uses the Zilog Z8001 16-bit microprocessor. The Z8001 runs at 4Mhz and can address up to 8 megabytes of memory through a 23-bit address bus. The Bleasdale computer is a general-purpose applications for professional system designers and engineers and may be used in simulation, process control, image processing, instrumentation, scientific workstations. It may also be used for office automation equipment, communications networks, banking/financial systems etc. The first customers are the Monotype Corporation, who will use the computer for typesetting, and Precision Software, a financial information services company.

The 600 computer is of modular design, constructed from a range of plug-in p.c.bs which offer a wide range of different configurations. The boards are interconnected using the Multibus system with 24 address lines for up to 16 megabytes of memory.

The computer is manufactured at Bleasdale's factory in Lutterworth, Leicester, and is to be marketed through a network of distributors throughout Europe. The majority of the computers are likely to be sold to O.E.Ms. A version of the computer based on the Motorola M68000 processor is being produced and this will also operate on Xenix.

Eddie Bleasdale the managing director of Bleasdale Computer Systems believes that Xenix will be very popular in scientific and educational applications because of the widespread use of Unix in DEC computers. As Bleasdale are in the forefront of users of Xenix, he intends that his company will maintain that position and become a leading centre of expertise in Xenix/Unix.

● Zilog have given their official blessing to CP/M and Unix have warned that manufacturers should be wary of 'lookalike' systems. Traditionally a new computer system engendered a new operating system which became 'machine-dependent'. So if a computer system was selected the operation system went with it and the user became stuck with it. If, however, the operating system were selected first then a number of manufacturers could offer computers which operated the system. CP/M and Unix are suitable candidates but some systems are being marketed as 'Unix-like', for example, but do not have the universal application or constant development of the original. One has a feeling that the warning may not be entirely altruistic; CP/M and Unix both operate on Zilog equipment.

SIMPLE POWER AMPLIFIER

Complementary Hexfet devices offer improved performance over the equivalent bipolar output stage and allow simplified drive circuitry. This design delivers 60 watts into a four-ohm load, 32 watts into an eight-ohm load, from a simple ±30V supply.

by Peter Wilson
International Rectifier Co

The split power supply rails of this design give good rejection of supply voltage ripple allowing both a simple supply circuit to be used and the load to be directly coupled. The output devices operate in the source follower mode, which offers a two-fold advantage: the possibility of oscillation in the output stage is reduced as voltage gain is less than unity, and signal feedback through the heatsink is eliminated as the drain terminal, which is electrically connected to the tab on the TO-220 package, is at a direct voltage.

Symmetrical output is achieved by providing a "boot-strapped" drive to the gate of the n-channel device from the output. The use of the bootstrap circuit, C_4, R_8,R_9, also allows the driver transistor to operate at near constant current, which improves the linearity of the driver stage. The diode clamps the bootstrap circuit, restricting the positive voltage at the gate of Tr_5 to $+V_{DD}$ to maintain symmetry under overload conditions.

Transistor Tr_3 and resistors 11, 12 & 13 provide gate-source offset voltage for the output device with R_{12} variable to adjust quiescent current for variation in threshold voltage. A degree of temperature compensation is built into the circuit as both the emitter-base voltage of Tr_3 and the combined threshold voltages of the f.e.ts have a temperature coefficient of −0.3%/deg C.

The class A driver transistor operating at a nominal bias current of 5mA set by R_8, R_9 is driven by the p-n-p differential input pair biased at 2mA by R_3. Components R_7, C_2 set the closed-loop gain of the amplifier R_6/R_7 and provide low-frequency gain boosting. Additional components R_{15}, C_7 connected between the output and ground suppress the high-frequency response of the output stage, allowing the h.f. performance of the amplifier to be determined by the input circuit. Component R_1, R_2, C_1 at the input of the amplifier define the input impedance and suppress noise.

To achieve 60 watts into a four-ohm load, the current in the load is 3.9A r.m.s. or 5.5A peak. To sustain this source current, the n-channel Hexfet, IRF533, requires a gate-source voltage of 5V.

As peak load voltage is 22V, gate bias voltage to achieve peak power in the positive sense is $V_{pk} + V_{gs}$ = 27V. A similar calculation for the negative peak, using the p-channel device IRF9533, shows that a negative gate bias supply of − 28V is required. Consequently, a ± 30V supply is adequate for a 60 watt output, provided that the supply voltage does not fall below ± 28V when loaded: a source impedance of one ohm or better. When the supply voltage impedance is high, use a higher voltage supply together with complementary Hexfets of a higher voltage rating − IRF532/IRF9532.

When an eight-ohm load is used, 32 watts output power can be achieved from a ± 30V supply with source impedance better than two ohms.

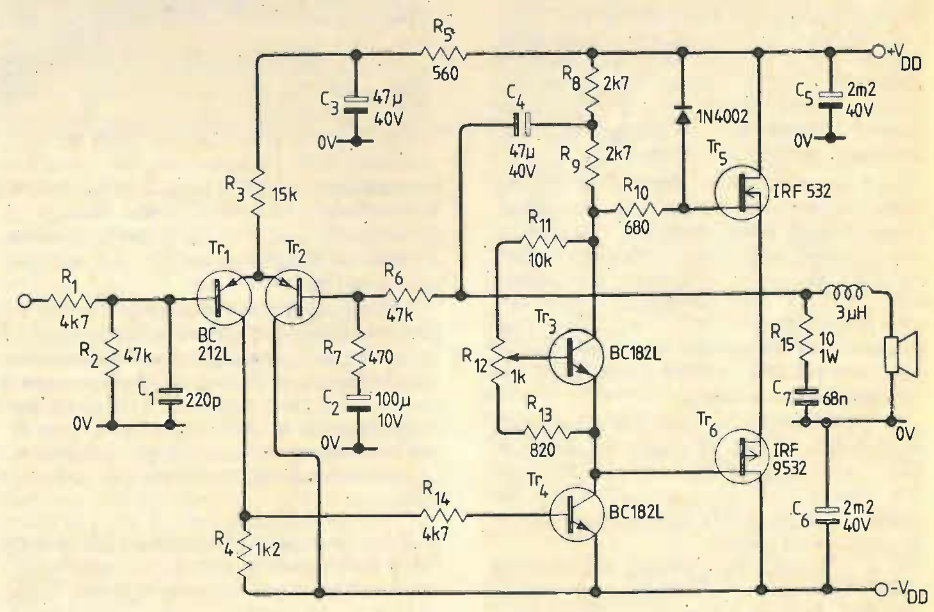
The curves drawn in Fig 1 show the power consumption of the amplifier, output power and power dissipated in the f.e.ts as a function of r.m.s. output current with ± 30V supplies and four and eight-ohm loads. It can be deduced that the maximum power dissipated in the devices is 56 watts and 28 watts with four and eight ohm loads respectively. Limiting the case temperature to 90°C and making an allowance for the thermal impedance of insulating washers, heatsink requirements are 0.5°C/watt with a four ohm load and 1.67°C/W with eight ohm load. Smaller heatsinks may be tolerated if the amplifier is not operated continuously at rated output power.

Open-loop gain measured with gate and source connections to the f.e.ts broken is 30 dB, − 3dB points occuring at 15Hz and 60kHz, Fig. 2. Closed-loop curves are shown for amplifier gains of 100 (R_7 470Ω) and 20 (R_7 2.2k). In both cases the curves remain flat to within ± 1dB between 15Hz and 100 kHz with an eight ohm load. The slew rate of the amplifier, measured with a 2V pk-pk square wave input is 13V/µs positive-going and 16V/µs negative-going. The discrepancy could be balanced out by addition of a series gate resistor for Tr_6.

Reduction of the closed-loop gain from 100 to 20 produces a significant improvement in distortion figure, Fig 3. Considering the simplicity, performance is quite acceptable. The output stage quiescent current was adjusted to 100mA and can influence the distortion measurement significantly if allowed to fall below 50mA.

The dependence of the quiescent current in the output stage and of the output offset voltage on power supply voltage are illustrated in the Table. Current is set by first adjusting the potentiometer R12 for minimum offset voltage − turned fully anticlockwise if the p.c.b. layout shown is used − and apply the power supply voltage, the positive supply passing through an ammeter with 1A f.s.d. It is then adjusted until the meter reading is 100mA with a ± 30V supply. Remove the meter from the circuit before applying an input signal to the amplifier.

When assembling the printed circuit board, mount the passive components first, ensuring the correct polarity of electrolytic capacitors. Then solder in bipolar transistors, checking for correct pin identification. Finally mount the f.e.ts, avoiding static discharge by shorting the pins together to ground and using a grounded soldering iron. Check the assembled board for correct component placement. Check the copper side of the board for solder bridges between tracks, and remove them. Check for dry solder joints visually and electrically using a resistance meter and rework if necessary.



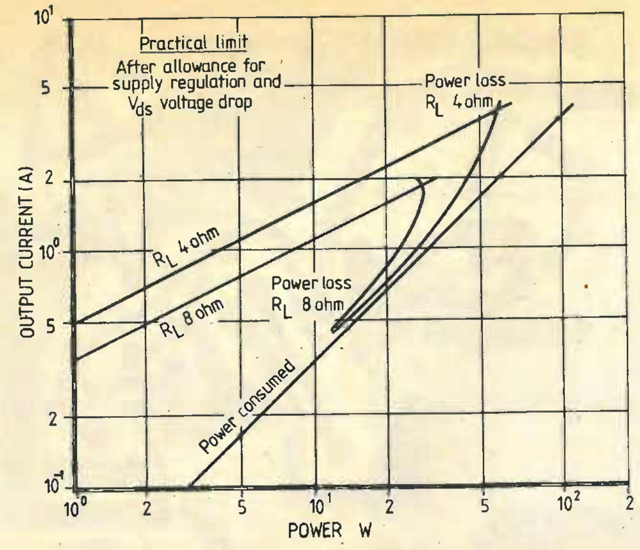


Fig. 1. *Power curves of the amplifier with four and eight ohm loads and ±30V power supplies.*

Variation in output offset voltage and quiescent current with supply voltage.

Supply voltage (V)	Output offset (mV)	Quiescent current (mA)
35	−40	135
30	−20	100
25	+ 4	75
20	+30	54

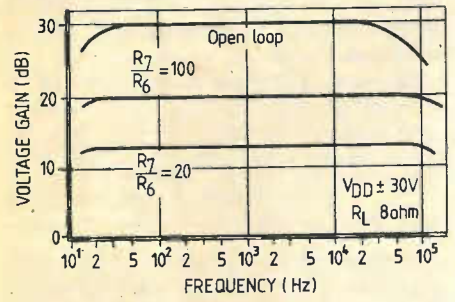


Fig. 2. *Frequency/amplitude curves for open-loop, 20 and 100× gain connections.*

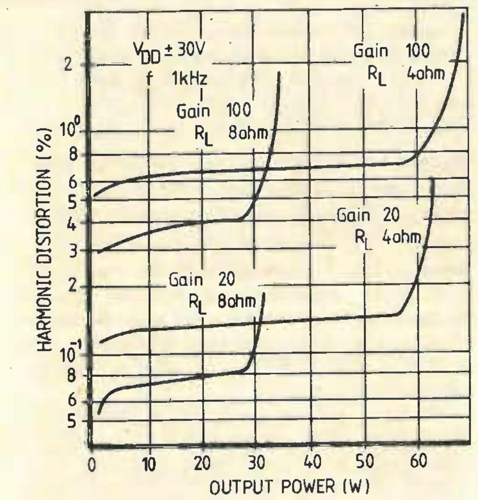


Fig. 3. *Distortion curves for gains of 100 and 20 with loads of four and eight ohms.*

Now apply power to the amplifier with heat dissipators fitted. Adjust potentiometer R12 for minimum offset (fully anticlockwise on the p.c.b. layout) connect an ammeter in series with the positive supply and adjust R_{12} for a reading between 50 and 100mA.

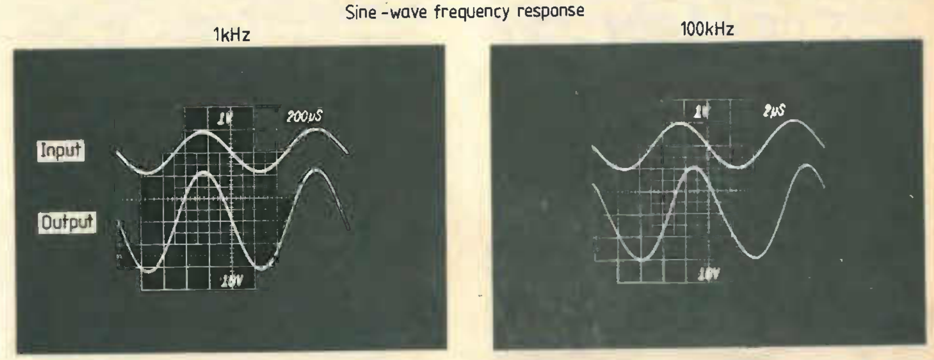
If a loudspeaker load is connected in circuit, protect it from d.c. overload with a fuse.) With the quiescent current set, confirm the output offset voltage is zero ± 100 mV. Excessive and erratic variation in quiescent current as R_{12} is adjusted indicates circuit oscillation or faulty wiring. Oscillation can only be satisfactorily identified and suppressed using an oscilloscope. Also, supply decoupling capacitors should be mounted close to the amplifier output stage and load ground point.

Additional circuit components have been added to ensure high-frequency stability of the complete amplifier. Placement and values depend to some extent on the printed-circuit board layout. Observe the following points when designing the printed circuit board.

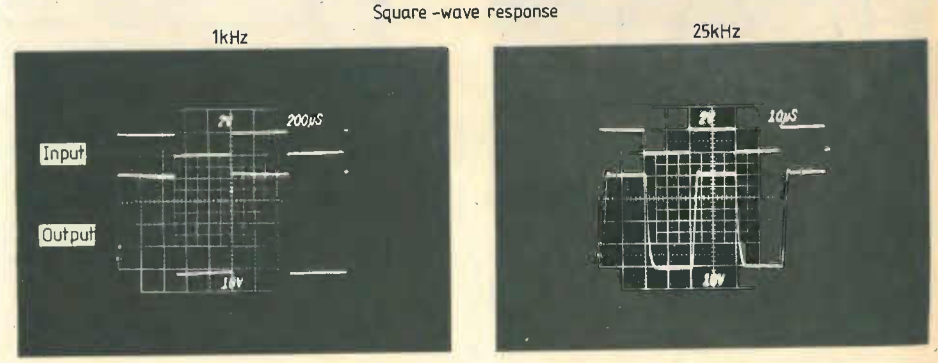
- Adopt a common ground principle, i.e. take power supply decoupling capacitors, load and input stage bias components to ground in close proximity, eliminating the effects of common-mode ground current. Similarly use a common output node, the load, feedback resistor and h.f. suppression components being taken from a common point on the board.
- Keep the length of connecting lead to the gate terminals of Hexfets to an absolute minimum to avoid oscillation of the power output stage. Series gate resistor R_{10} suppresses oscillation, but too high a value limits slew rate. Series resistor R_{14} suppresses amplifier oscillation caused by capacitive coupling to the base of Tr_4.
- Phase shift in the amplifier when driving a reactive load can lead to high-frequency instability. With a capacitive load, the addition of a small air-cored choke − 3µH with an 8Ω, 2µF load − restores stability. The final value of the choke is defined by experiment.

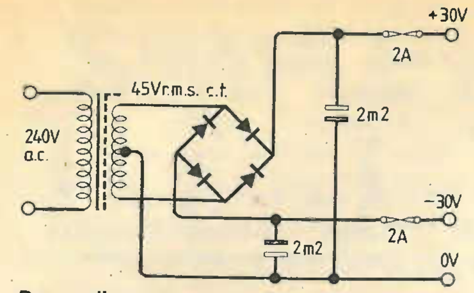
With the current set, remove the ammeter from the positive supply and apply a signal to the amplifier input. Signal level required for full rated output is 150-160mV for a gain of 100, and 770 to 800mV for a gain of 20. Clipping of the output waveform when operating at rated power indicates poor supply regulation and is remedied by reducing the input signal amplitude and derating the amplifier. Alternatively use a lower-impedance supply. Amplitude response of the amplifier can be checked over the frequency

Sine-wave frequency response



Square-wave response





Decoupling capacitors reduce the supply frequency ripple to 5.5V pk-pk at full load. Off load, the supply voltage should not rise significantly above ± 35V.

range 15Hz - 100 kHz with the aid of an audio test set or signal generator and oscilloscope. Distortion of the output waveform at high frequency indicates a reactive load: adjust the output choke to restore the waveform. Tailor h.f. frequency response with a compensation capacitor in parallel with R_6. The l.f. response is controlled by R_7, C_2.

Supply-frequency breakthrough is most discernible in a high-gain circuit. Minimize pick-up at the high-impedance input by a screened cable, grounded at the signal source. Supply-frequency ripple injected through the supply to the input stage of the amplifier can be detected across capacitor C_3. This is normally attenuated by the common-mode rejection of Tr_1 and Tr_2 before being amplified but if this is the source of breakthrough, adjust the values of C_3, R_5 to suppress the signal amplitude.

If the output stage is destroyed either through short-circuit load or h.f. oscillation, replace *both* Hexfet devices; it is unlikely other circuit components will have been affected. Repeat set-up procedure with the new devices in circuit. □

A glass-fibre printed circuit board for the heating-fuel saver will be available for £4.50 inclusive of VAT and UK postage from M. R. Sagin, Nancarras Mill, The Level, Constantine, Falmouth, Cornwall.

R.f. radiation hazards

Last year we published a news item[1] briefly pointing out the controversy surrounding the r.f. radiation-exposure safety limits accepted by most western countries. In America, the ANSI and ACGIH (American Conference of Governmental Industrial Hygenists) have both suggested new frequency-dependent standards based on the same work and both assuming 0.4W/kg as a safe maximum absorbed energy rate, and it is expected that the Americans will revise their existing 10mW/cm^2 maximum safe level in the near future.

Although we in the UK originally based our maximum safe level (10mW/cm^2) on that decided in the US some 20 years ago, whether or not we will again follow suit is not clear. According to Mr S. Allen of the NRPB, one possible point of contention is that the two proposed standards mentioned above are based on results from far-field radiation tests. It is accepted that measurements in the near field, and hence assessment of potential health hazards, are more complex than in the far field. Taking into account near-field effects when determining maximum safe-level standards would nevertheless be sensible.

An article recently published in Radio Communication[2] gives a good account of r.f. radiation hazard, as far as the radio amateur is concerned. The authors state that reports of "non-thermal" effects of r.f. radiation, mostly emanating from Eastern Europe, should be "regarded with suspicion", and go on to say, "there is no evidence that r.f. radiation produces long-term damage of the kind associated with ionizing radiation, i.e., cancer or genetic damage." Not a hint is given that the authors feel the accepted maximum level might be too high.

But not everyone is happy with the situation. Mr Herbert Goldwag, for one, summarizes the opposing point of view in an article called 'Microwave hazards' published in the IEEE *Spectrum*[3]. □

The first of these graphs provided by Mr Harlen of the NRPB shows r.f. radiation penetration and absorption versus frequency for a plane slab. Combined effects of penetration and 'focussing' (or geometry and high refractive index) in a potato are illustrated in the two other graphs taken from the Journal of Microwave Power.

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1 Small wavelengths – large doubts, *Wireless World*, October 1981, p42.

2 R.f. hazards and the radio amateur, Blackwell, R. P. and White, I. F., *Radio Communication*, February 1982, p136.

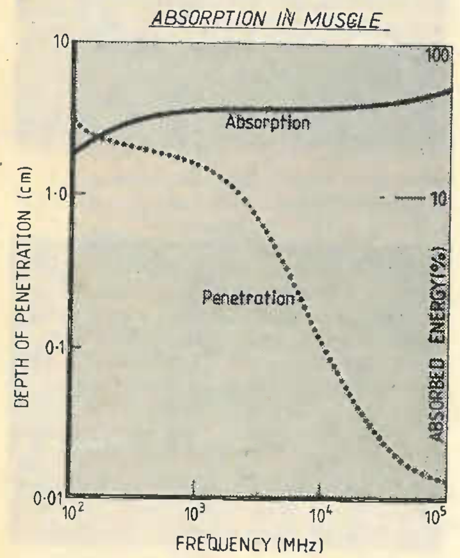
3 Microwave hazards, *IEEE Spectrum*, May 1979, p66.

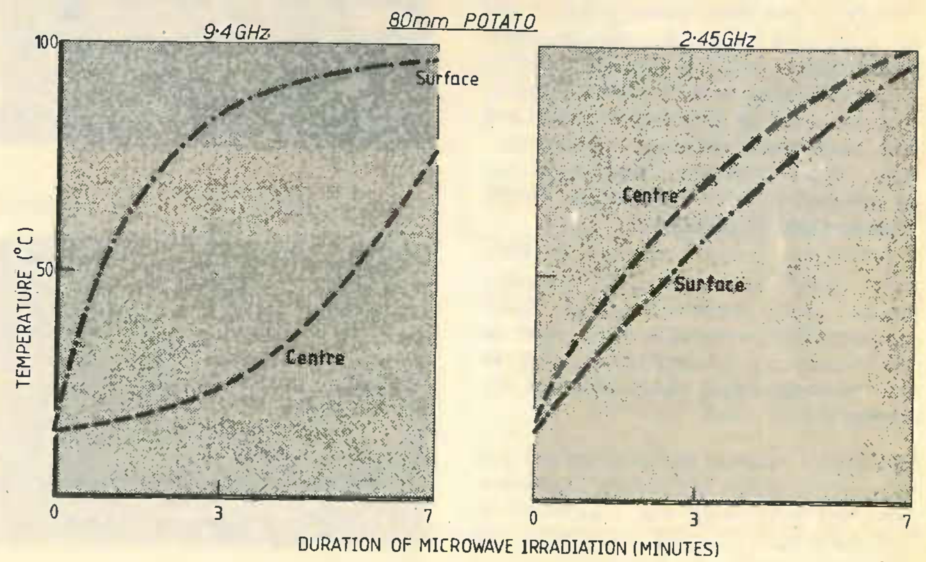
Further reading

Reference Data for Radio Engineers, Howards W. Sams and Co., Inc., p27-46.

Handbook for Radio Engineering Managers by J. F. Ross, Butterworths, pp372-387.

Radio hazards in the m.f./h.f. band, Rogers, S. J. and King, S. R., *Non-Ionizing Radiation*, vol. 1, No. 4, pp178-189.





LETTERS

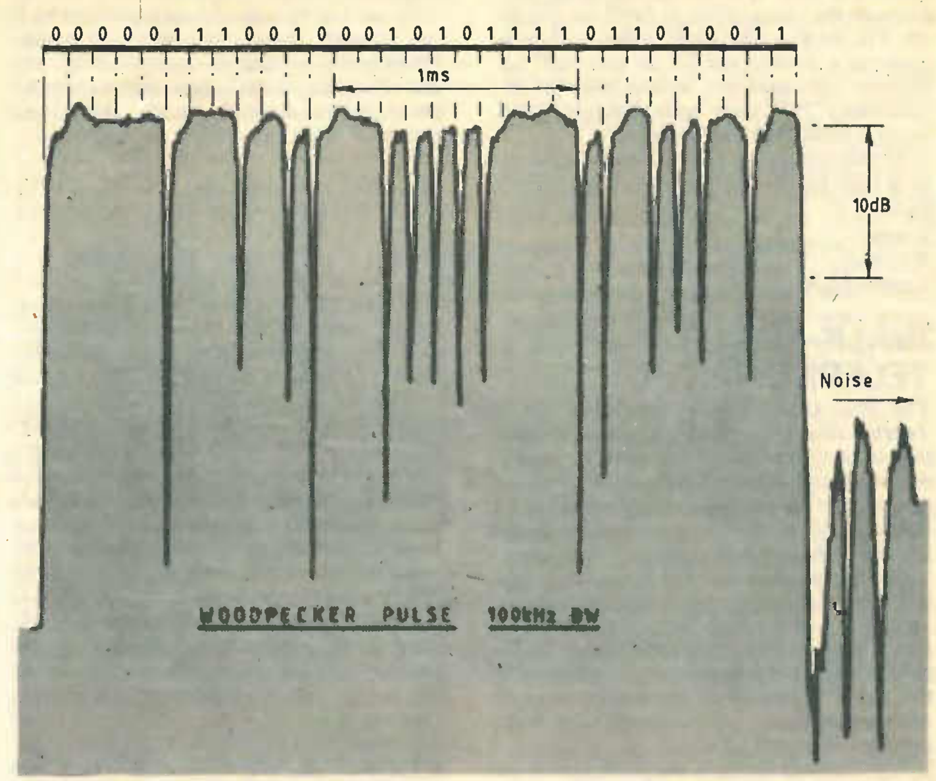
SITUATION NORMAL...

In your February issue, Pat Hawker mentions "SNAFU" as a coinage of War II. I think he and your readers may be interested to know its pre-war origin.

During the said war it was my pleasure to work for a time with two clever and humorous American Western Electric telephone engineers, and they told me that their pre-war jobs had been to go to telephone exchanges where there was trouble and rectify it. Upon arrival at the site an engineer would make a brief estimate of how serious was the trouble, establish a telephone link to his headquarters and send back a code word. His home base would therefore know he had arrived where the problems were, have a rough idea of how long it would take to clear them and have a telephone number where he could be contacted if need be. There were three code words: SNAFU – Situation normal, all fouled up" (or words to that effect); TARFU – "Things are really fouled up"; and FUBAR – "Fouled up beyond any repair". The latter would be sent if, for instance, a telephone exchange had been seriously damaged by fire or flood, while SNAFU would be used for a situation where cables or machinery had been damaged but where repairs or replacement would be relatively straightforward.

SNAFU became widely used in many situations during the war, but strangely the other code words were rarely used or were unknown. It would be a pity if this bit of folk lore was lost.

C. H. Banthorpe
Northwood
Middlesex



WOODPECKER

As a radio amateur, I have often been annoyed by the Russian "woodpecker" pulse transmissions which have plagued the h.f. bands for many years[1]. There has been no official explanation of the purpose of these transmissions, and various theories have been expounded in the media, ranging from spy communications to death rays. However, as a result of accidentally coming across some of these signals on a laboratory spectrum analyser, and storing the waveforms on a transient recorder, I think I can shed a bit more light on their structure and purpose.

Figure 1 is based on a printout of a typical pulse, plotted as logarithmic amplitude versus time. The overall duration of the pulse is 3.1ms. The interesting feature is the presence of "glitches" in the top of the pulse, the pattern of which remains the same from pulse to pulse, and they occur at intervals which are multiples of 100 μs. This led me to suppose that the glitches formed a binary sequence of length 31 bits.

I also guessed that the glitches arose from phase reversals in the transmitted signal, the finite width of the glitches resulting from the effect of the finite bandwidth of the transmitter and/or spectrum analyser. Thus, arbitrarily assigning a zero to the first data bit, the original modulation pattern could be reconstructed, with 0 representing 0 degrees and 1 representing 180 degrees. This gave the pattern 0000011100100010101111011010011.

This sequence turns out to be a maximum-length, pseudo-random binary sequence[2], which can be generated by a 5-bit shift register with feedback formed from the parity function of the contents of stages 3 and 5. I subsequently observed other pulse transmissions with different sequences of the same length, and was able to match these to p.r.b. codes from shift registers with feedback from stages 2,5 2,3,4,5 and 1,2,3,5. Four different codes, implying four different transmitters, agreeing with observations previously reported[1].

The interesting point about this use of p.r.b. codes arises from the shape of their autocorrelation function. If such a sequence is compared bit-for-bit, with a shifted version of itself, at all possible shifts, then, apart from the position where all 31 bits match, at all other shifts no more than 1 bit matches between the two sequences. Thus, if a woodpecker pulse is fed through a 3.1 ms delay line with 31 equally spaced taps, and the outputs of the taps are vectorially combined with appropriate inversions, so that the inversion pattern itself is the same sequence as the transmitted phase-inversion sequence, then the combined output will be a single pulse of 100μs duration, 31 times the amplitude of the input signal, with virtually no sidelobes.

The conclusion from all this, it seems to me, is that the woodpecker must be simply a pulse compression radar system, with a resolution of 100μs (10 miles), but the sensitivity 31 times that of a 100μs radar of the same power. Not only does the p.r.b. sequence cancel out shifted versions of itself in order to achieve its performance, but it has a high immunity to other codes in the same family, thus reducing cross-interference between separately sited radars on the same frequency. The use of four different sites presumably enables the target to be pinpointed in three dimensions in spite of the poor directivity of h.f. antennas and the variabilities of the ionosphere which is used to extend the range beyond the horizon.

Although this information leads to the possibility of jamming these signals, or at least puzzling the distant radar operator, whether we shall ever be rid of these wretched signals is another matter altogether.

J. P. Martinez G3PLX
Gosport

References

1. Mystery Soviet over-the-horizon tests. *Wireless World*, February 1977 p.53.

2. Pseudo-random binary sequence generators. F. Butler, *Wireless World*, February 1975 p. 87.

POOR DEAL FOR AMATEUR RADIO

I wish to congratulate you for publishing a letter (February 1980) criticising the RSGB: at last someone has dared to make public the feelings of many RSGB members. I myself have written to the RSGB on several occasions but I have never been privileged with an acknowledgement, not to mention an explanation of their actions.

Whilst the RSGB has been trying desperately to prevent the introduction of c.b. (I, like many, see through their claims of neutrality), radio amateurs have ended up with a very raw deal. Firstly, we have lost 200 kHz of 70 MHz; secondly, only one of the h.f. bands has been introduced; thirdly, despite the introduction of c.b. on 27 MHz (with no Morse), B licencees still need Morse for 70 MHz to 28 MHz. Whilst pip/kay tones are not to everyone's taste, they are used freely on c.b. but are severely restricted on the amateur bands. Selcal type signals are not permitted on the amateur bands whilst they are on c.b. I must add at this point that I am totally pro-c.b. and I am not some jealous, sour-grapes radio amateur.

Furthermore, whilst expending its energy on anti-c.b. propaganda, the RSGB have totally ignored the decline of amateur radio. Little mention is even made in *Rad-Com* of the illegal operation on London repeaters. Why does the

RSGB not close them down or, better still, persuade the Home Office to catch the offenders. The RAE is now a joke. Amateur radio is meant as a technical hobby; the new RAE has virtually eliminated any serious technical requirements. How many radio amateurs repair, let alone build, their own equipment?

As radio amateurs, we have virtually sold our birth right and the RSGB has stood by and let it happen.

B. Reay
Woolwich
London SE18

WALK-ABOUT TELEPHONES

The Post Office and its successor British Telecom have in the past been accused of being slow to meet the demand for telephone instruments other than those of the standard type, but this has now been to a large extent corrected by the availability of types ranging from the elegant baroque to the frivolous Mickey Mouse.

One facility which does not appear in the lists is the hand-held device which allows the user to make and receive calls while at the same to be free to roam about his house and garden. Radio linkage is one way of making this possible and is the means employed in certain instruments which are obtainable by the general public from suppliers other than Telecom.

This may be because of the possibility of the radio signals involved being received by someone who is not a member of the subscriber's household.

It is unlikely that the prospective user of one of these devices will have been warned that his future conversations may be overheard and even if the point is made he may shrug off the matter and say that he does not mind. A more important factor is that even if the user is indifferent to being overheard this may not apply to those with whom he is in communication and who may have objections to what they are saying being broadcast.

It may be argued that the threat to one's privacy is pretty small since suitably equipped listeners may be thin on the ground in the immediate neighbourhood. However, a single eavesdropper of less than good intent could be at least an embarrassing nuisance or there could be legal implications in a situation where a stranger might seek to profit as a result of information received.

Finally, there may very well be a real need for this type of telephone facility but there are pitfalls in the use of unauthorized equipment. One assumes that a Telecom-approved system awaits the provision of suitable safeguards and defences against illicit tapping of the telephone network.

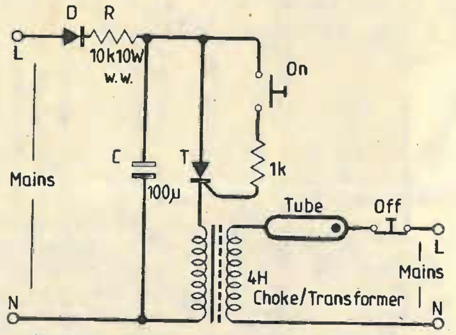
G. Dann
Chipstead
Surrey

NANOCOMP E.P.R.O.M. PROGRAMMER

I have been experimenting recently with a photographic flash tube and am concerned about inductive flashes and their erosion of the button in Fig. 1. on page 30 of the January 1982 *Wireless World*.

I think that problem could be reduced by having a low-voltage, high-current winding on the choke core in addition to the 4H. This would make the choke a transformer as well. A suggested outline for a circuit accompanies this letter and a description follows.

On the left the main voltage is rectified by D and charges C through R to mains peak voltage. Mains is also applied permanently to the tube and 4H winding in series but, since the tube has not stuck, no current flows: the tube is open-circuit.



When the On button is pressed, C discharges via the low-voltage winding, inducing an inductive voltage of, say, 2kV in series with the mains across the open-circuit tube. But as soon as the 2kV causes the tube to strike, it is anticipated that mains current will flow through the tube, using the 4H winding now as the choke. When the Off button is pressed, the tube should go off. In the event of a thyristor short-circuit or capacitor short-circuit the 10kΩ resistor would get warm and only consume a few watts. Normally, when off, only capacitor leakage current should be taken. The operation would depend on a real difference between striking voltage and maintaining voltage in the tube.

J. R. D. Powell
Harlow
Essex

DATA STORAGE

I would like to comment on two articles in the February 1982 issue: "Data recording on audio cassette" and "Economical Z80 development system". To start with, I would like to introduce myself as the designer of SOFTY, which appears in the latter article, and the inventor of TRANSWIFT, a software modem used in SOFTY to store data on cassette tape. The point that I will try to illustrate is that there are more ways of killing a cat than choking it with cream.

Data storage using audio tape is like a serial transmission in a medium of limited bandwidth (forget that the data stays in the medium for an indefinite time). The low-frequency limitations are the bigger nuisance – so why not use a system which has no low-frequency components? If the data recording is for a microsystem why not do it with software? If you are willing to ignore convention you can use a simplified recording and playback circuit.

Most microsystems have a bit of i/o going spare, either on the microprocessor itself or via an 8255 or similar. You could use a separate port for input and for output. You could add some sort of signal conditioning – but it isn't necessary. This circuit will store data using the cheapest cassette recorder at well over 3000 baud-equivalent.

Transmit a zero by putting the port high for a jiffy, then low for the same jiffy. A 1 is transmitted by using bigger jiffies. All binary transmissions are 0s and 1s strung together and the low-frequency components have vanished. You can put this transmission through a capacitor, for instance, without degrading it. You can also store it on tape and get it back unchanged. Recovering the succession of 0s and 1s is a matter of measuring the intervals between zero crossings. The resistors suspend the port at the transition point. You might recover the data in one of two ways: either you take a positive transition as a starting point, delay for a step interval and then input the bit, or you measure the time between similar transitions and decide whether it represents 1 or 0.

Examination of this transmission shows two important properties: turning it upside down makes no difference to reception, and clock-speed errors don't accumulate – each bit contains a clock. 10% or more difference in speed won't baffle it.

A TRANSWIFT transmission doesn't use start, stop or parity bits. The speed of the transmission is more likely to be restricted by the processor's agility in handling the data than by the bandwidth of the recording system. It is up to the processor to make an intelligent decision about whether it has a valid transmission or not, and where that transmission starts. If the input is to an interrupt this process can be automatic.

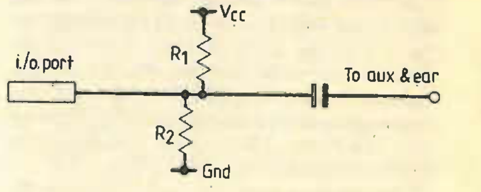
SOFTY2 uses 500µs and 1000µs as the transmission times for a 0 and a 1. To show that a transmission is coming, and to get over the bounce period of the recorder's automatic gain control, a leader of 20 bytes of 'AA' bytes are sent. (AA in hex. is 10101010). Then a hex '69' (which is 01101001), and the data, with no extra bits of any kind.

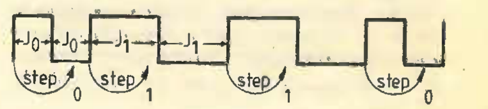
Recovery uses a routine which samples forward from each positive transition by 750µs and shifts the sample bit into a register. The word in the register is then compared with '55' and 'AA' and either are accepted as valid leaders. A leader counter with a starting value of perhaps 40 is decremented for each valid leader byte, but restored to starting value if an invalid leader is received. When the counter reaches zero the program starts looking for the '69'. The '69' is there for alignment – so that you can chop the succession of bits into bytes in the right places.

To establish the best form of error checking it is necessary to anticipate how the recorder will mess up the data. The usual system of adding a parity bit to each word fails because lateral displacement is common. All error checking systems use redundancy – they transmit extra information to catch errors. SOFTY uses a single byte appended to the transmission which is formed by exclusive-ORing all the data bytes with AA. (I used AA because it happens to be the leader and in the right register at the right time). The reception routine exORs the transmission and shows you the result – if it isn't AA then you have errors. I call this parallel parity.

In case you're wondering how much programming space this takes: A Z80 device (MENTA), designed later, uses 147 bytes for the cassette interface. SOFTY uses about 300.

The article "Economical Z80 development system" supports my claim that the combination of any assembler and a SOFTY makes a powerful design tool. However the process of linking a Nascom to SOFTY described is un-





necessary. Leaving aside the fact that SOFTY2 already has a parallel interface with normal handshake, plus serial routines for 110, 300, 600, 1200 and 2400 bauds, all of which ignore all ASCII characters except 0 to 9 and A to F – by far the simplest solution is to write a TRANSWIFT routine for the assembler's processor to dump the code into SOFTY using the cassette jack-socket. This reduces the hardware to a piece of wire and a jack-plug. In fact, I use a similar system from my Sharp MZ80K. The port used is the Sharp's keyboard l.e.d. – mainly because the connector is provided on the p.c.b.

TRANSWIFT is the simplest and most economical method of implementing a serial data transmission system, and is especially useful if the bandwidth of the medium is limited.

B. Savage
Dataman Designs
Dorchester

THE DEATH OF ELECTRIC CURRENT

Ivor Catt's latest letter suggests that some progress has been achieved in an uphill struggle, for he seems to acknowledge that we are discussing models of reality and not reality itself. However, there is some way still to go, for he seems to regard models as "true" or otherwise. Models can be bad or good or better in relation to their accord with observation, but never true or false. So it is fatuous to assert that a model shows that electric current does not exist.

Certainly, there is much to be said for keeping models simple, but I think that other correspondents have shown that the "insurmountable difficulties" introduced by ρ and $\mathcal{J}$ exist only in Mr Catt's mind. Further, simple models are not always best: albedo measurements had shown the shortcomings of the green-cheese model of the moon, long before Armstrong arrived to test the flavour!

I was interested by Mr Davidson's achievements with discharging capacitors, but I suspect that those of us not fortunate enough to have a capability for time-domain reflectometry will continue to use the exponential model. This model does have a shortcoming in that it suggests that the discharge current continues for an infinite time, whereas observation shows that it does not. Of course, if we use an electric current model we can account for this by supposing that the discharge current becomes submerged in the noise, currents generated by random motion of the electrons within the conductors. Presumably there is a means of describing the effect using an e.m. wave model?

R. T. Lamb
College of Engineering Studies
British Telecom

DANGERS OF LOW-FREQUENCY SOUND

I have just read the letter of S. Frost of Edinburgh, who replies to my earlier letter concerning my invention and operation of a hi-fi speaker system whose response is flat down to four Hz, suggesting that I should be careful. He quotes from the paperback "Supernature" by Dr Lyall Watson and suggests that my speaker could be harmful to certain people, due to its infrasound output.

I know that infrasound of very high intensity can give temporary effects which might be termed uncomfortable or disquieting by some people. However, the subject of infrasound in general is now much better understood that it was in 1974 (the date quoted by Mr Frost which applies to the above publication) and it is now known that even prolonged exposures to infrasound of even very high intensities up to that experienced, say, in a rapidly moving railway carriage with the window open (which I believe in the order of 135-138dB?) do not cause lasting deleterious effects. My speakers at present have a maximum output on transients of around 15-20dB less than this, or around the level of v.l.f. caused in a house by a very strong wind blowing outside. There is *no* risk of permanent harm arising from their use as hi-fi speakers. Infrasound produced by helicopter blades, pneumatic drills, heavy trucks, etc. (from the driver's seat) can be louder that this and are still not harmful. It takes sound loud enough to physically shake one out of one's seat before even temporary damage is caused (note sound pressures, not structure-borne vibrations). Levels such as those of a full sized fog horn (marine, shore-based) at 3ft are at the danger area.

G. Holliman
Watford
Herts

MICROCHIPS AND MEGADEATHS

Further to Mr P. C. Smethurst's letter in the December issue, may I suggest that the only way in which the technical society will become a reality is by a major evolutionary development of the human species.

The nearest approach the average homo-erectus makes to the technical society is to buy a digital wrist watch with alarm and graphic display, kidding himself that he will be able to tell the time with it. Such mistakes are inevitable with our present learning process.

Until our DNA reorganizes itself a little so that accumulated knowledge (only the facts, of course) can be passed directly to offspring, our ability will depend on Mr Smethurst's learning period of 15-20 years. Few people will reach his 'unusual' standard and buy watches with hands.

R. G. Brown
Watnall
Notts

Tim Bierman (October Letters) and Roy C. Whitehead (January Letters) are wrong to imagine that refusal to fighting wars will avert their occurrence. Modern technological warfare, involving nuclear and space-based weapons, does not depend upon the recruitment of willing and gullible warriors. A small, minority elite now possesses the power to destroy the earth and, if competition over markets, trade routes and natural resources necessitates it, will sacrifice millions of human lives to the god of profit. If the threat of war is to be removed, political action must be taken to transfer power away from the possessing minority into the hands of the democratically organized world community. If the weapons are used, there will be no hiding places for conscientious objectors; the time for objecting is now.

Instead of listing names of *Wireless World* readers who would refuse to fight in the event of a future war, may I suggest that a better course would be to list the names of readers who have taken the step of extending their scientific interest in technology into a scientific analysis of society?

Steve Coleman
Clapham
London SW4

THE NEW ELECTRONICS

The article by Hugh Jaques in your January edition prompts me to add my own comments on the subject of "The new electronics".

It is all very well to decry falling standards, but I find the tone of that article rather counter-productive. The standard in Germany, if we wish to draw comparisons, is far lower – yet the number of "Diplomingenieure" (dipl – Ing) and Doctors of Science is far greater. Previous *Wireless World* editorials have covered the question of status – and one gets the clear impression that British engineers are developing an inferiority complex with regard to the Germans.

Yet, years ago, I attended a conference in Frankfurt when Cosmos and l.c.ds were introduced. The meeting began with German engineers pounding the table Kruschev-style; everyone was quite unruly. When I pointed out that l.c.ds, with a quoted life-expectancy of fifty thousand hours, could not complete for longevity with l.e.ds (up to one million hours), everyone was on his feet screaming "l.c.ds no good." The meeting broke up in chaos and I never did find out if one could prolong the life of l.c.ds by interposing ceramic capacitors in the leads to block the d.c. components of the signal, which causes electrolysis of the liquid crystals.

Dipl-Ing colleagues were forever asking me such questions as "What is the difference between a p-n-p and an n-p-n transistor", and a doctor of physics never answered any question without his "schlaue Buch" (clever book) which was his real brains.

No – the Germans are dishing out high-level qualifications in every branch of science almost like the free-gifts with chewing-gum. Yet the television programme "Bilder aus der Wissenschaft" (pictures from science) complained that Germany was not winning any Nobel Prizes.

To improve standards one must set an example through excellent work – rather than trying to catch people out. Indeed, there is nothing very wrong in a newly-qualified engineer being a little "green". The real education is the work itself, and if the British withhold their qualifications whilst the Germans mass-produce them, Britain will not be well represented at future international congresses, will lose presence in the world and cease to sell goods.

It would appear that Mr Jaques was not so "word-perfect" as he claims. In his Fig. 2, the gain is only – R_2/R_1 if the source – impedance at point X is zero, which is what one would infer from the "gain between X and Z", because any generator impedance would be added to R_1. Secondly, the input-impedance at Y is $R_2/(1+A)$ only if the source – impedance at X is infinite. Otherwise R_1 and the source impedance form a series-string in parallel with $R_2/(1+A)$. What source impedance does Mr Jaques have in mind?

Perhaps you can see how destructive such a style of cross-examination can be. We all make mistakes which are not mistakes at all unless we want them to be. "What is the input impedance at Y with X open-circuit" would have been a better question, which would have saved Mr Jaques face. But I am just picking him up on words – as he was doing.

In the final analysis, engineers are paid for engineering – not for passing tests. Given the chance, many will succeed and many will fail. Be over selective and all will fail.

C. Wehner
London, W2

RECEIVERS FOR OPTICAL FIBRE COMMUNICATION

During the next few years optical fibre systems will be used increasingly for long-distance telecommunications with emphasis on achieving greater bandwidth and greater spans between repeaters. In this rapidly developing subject it is essential to be aware not only of the latest published results but also of the underlying principles to fully appreciate the potential of optical communication. With this in mind, Dr Garrett reviews both the best reported performance in detectors and receivers and the areas where there is still room for improvement.

Optical fibre communication systems are beginning to be used extensively for data links and for long-haul systems. The first "generation" of systems operates in the near infrared – a wavelength of about 0.85μm – where light sources may be made from gallium arsenide and detectors from silicon. At slightly longer wavelengths, 1.3 to 1.6μm, glass fibre is a better transmission medium, having enormous bandwidth and extremely low attenuation – 0.5dB/km or even lower. Fibre systems are being used to carry telephone traffic at 140 Mbit/s over unrepeatered spans of 10 to 12 km in the UK. Within the next few years it will be possible to operate at ten times that rate over at least five times that distance. As the market for fibre grows and the cost comes down, it will become economic to use fibre systems at lower data-rates as well, and also to transmit video either for entertainment or for teleconferencing.

The three basic functions of an optical receiver are to convert the signal from an optical to an electrical form, to amplify the signal, and to regenerate the transmitted message. The first of these is performed by an optical detector. Amplification is not specific to optical systems except for the special design of the front-end of the receiver, which is inseparable from the detector in determining the sensitivity. Estimation and regeneration of the message involves dealing with the noise and various system impairments; only the

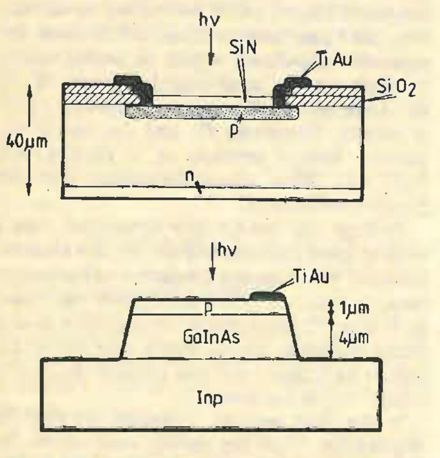


Fig. 1. Silicon p-i-n photodiode is suitable for wavelengths from 0.8 to 1μm (top), while InGaAs/InP p-i-n diode covers wavelengths from 1 to 1.6μm (bottom).

by I. Garrett

more basic ideas are covered; for more depth refer to the bibliography. In these functions, an optical receiver seems similar to a radio receiver. However, current optical receivers are quite different in the way in which they perform. Heterodyne detection, universal in radio practice because of its excellent sensitivity and rejection of adjacent channels, is at present impractical in optical receivers. It requires a local oscillator which matches the arriving signal in frequency, phase, and polarization. Today's semiconductor lasers have spectral line-widths of 25MHz to 1000GHz, and current fibres do not preserve a predictable polarization at the output end. Although the possible advantages of increased sensitivity and use of frequency and phase-shift keying have stimulated research into overcoming these and other problems, today's systems use incoherent (direct) detection, in which only the variations in optical power are sensed.

Unity-gain detectors

The device which converts the optical signal to an electrical form must be efficient at the operating wavelength and must respond at a speed appropriate to the message data rate or frequency band. One may also require a linear response, operation at ambient temperature from a convenient voltage supply, and a preference for a small, light, cheap and reliable device. Semiconductor photodiodes fit all these requirements remarkably well, and there is little interest in other types of detector for optical telecommunication, at least in normal terrestial environments. Photoconductive detectors have inferior noise performance except when the incident optical power level is high; pyro-electric detectors can only be made fast at the expense of sensitivity, and photomultipliers offer no advantage in sensitivity when, as is normally the case in fibre optic systems, the optical power level on zero bits is not zero. Phototransistors are convenient devices for low-speed data links, but are

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generally not sufficiently fast and sensitive for telecommunication.

A photodiode is a reverse-biased p-n junction formed in a semiconductor material. Photons are absorbed in the semiconductor and create electron-hole pairs. These carriers can be separated by an electric field, such as exists in the depletion region of a p-n junction, and then give rise to a current in the external circuit. To convert light efficiently, the semiconductor material must have a high absorption coefficient at the wavelength of the light so that different materials are appropriate for different wavelength ranges.

The speed of response is governed by the time taken for the photogenerated electrons and holes to reach the terminals of the device, and by the RC time constant of the measuring circuit, which may be affected or even dominated by the junction capacitance. Photo-generated carriers travel across the device to the terminals from the points at which they are generated by diffusion and by drift in any internal field. The rate of diffusion is generally so slow that except in very thin layers most carriers are lost by recombination and do not contribute to the photocurrent. The device is made fast and efficient by ensuring that the incident photons are absorbed in the high-field depletion region of the junction.

Figure 1 illustrates a photodiode structure used in practice. It is a silicon device designed for the wavelength range 0.8 to 0.9μm, and has a thick depletion region 30 to 100μm thick formed in low-doped material. The absorption coefficient of silicon in this wavelength range is 950 to 350cm^{-1}, so that several tens of microns of material are needed for almost complete absorption. Very little of the incident radiation is absorbed in the undepleted n$^+$layer at the surface, which is only about 1μm thick. The device is designed so that the field required to deplete it fully is well below the breakdown field strength, but sufficiently high to accelerate the carriers to their scattering-limited velocity (around 10^{7}cm s^{-1} in many semi-conductors at room temperature) resulting in a response time of about 10 ps per micron of depletion region. Depletion region doping is very low so that fast response is obtained with a moderate applied voltage. Such a device is known as a p-i-n photodiode, the i-region

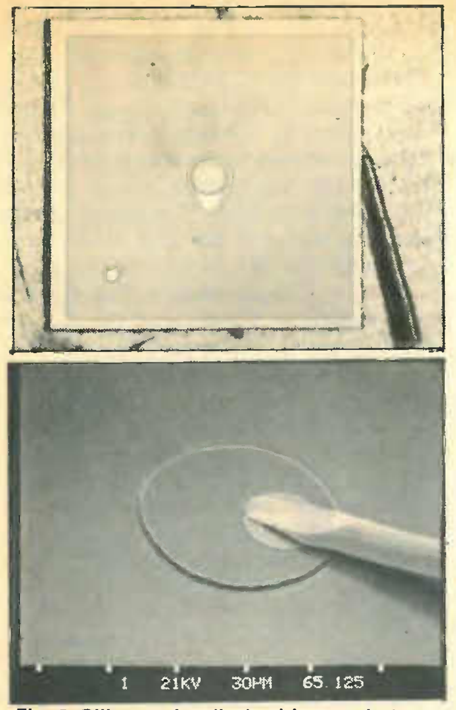

Fig. 2. Silicon p-i-n diode chip, top, is 1mm square with circle 100μm diameter and bonding pad beside it. Chip capacitance is below 0.1 pF, and reverse bias leakage current is around 50 pA at -10 V bias. Quantum efficiency at 0.85μm wavelength, corresponding to gallium arsenide injection lasers, is 0.95. Active area of InGaAs/InP photodiode isolated by mesa etching is 100μm in diameter in scanned electron micrograph (bottom). A small bonding pad is formed on the top surface as the device was intended for front illumination. Capacitance is 0.3 pF and reverse bias leakage current below 10 nA at -10V bias. Quantum efficiency is only about 0.4 because many carriers recombine in the undepleted surface layer but this can be overcome by illuminating through the substrate; anti-reflective coatings also increase efficiency.

being nearly intrinsic. The wide depletion layer reduces the junction capacitance too. The device illustrated is 100μm in diameter and has a capacitance of less than 0.1 pF.

At wavelengths beyond 1 μm, silicon becomes increasingly transparent and a different material is required for photodiodes intended for communication systems. An obvious choice is germanium which has a bandgap of 0.66 eV and so should be sensitive out to 1.8 μm or so, well beyond the optimum transmission wavelengths of 1.3 and 1.55 μm. The small bandgap of germanium is something of a disadvantage: coupled with the high density of states in the conduction band it means that the reverse bias dark current is large, which degrades the performance of an optical receiver. The other possible materials are the so-called group III-V compounds, binary compounds of elements from groups IIIb and Vb such as gallium arsenide and indium phosphide. To detect light at 1.55 μm, a material with a bandgap near 0.8 eV is needed. None of the binary III-V compounds has such a bandgap, but many of the III-V compounds form extensive solid solutions with each other, and the mixed compounds have properties intermediate between those of the binaries. So it looks as if there ought to be a wide choice of materials. In practice the choice is limited by the techniques available for preparing these materials in sufficiently pure and perfect form. The most usual materials for detectors in this range are the ternary compound (Ga,In)As and the quaternary (Ga,In)(As,P). In either material, the bandgap can be adjusted over a wide range by selecting a suitable composition. Reverse-bias dark current is smaller than in germanium by one or two orders of magnitude typically because of the much smaller density of states in the conduction band. Recently, the II-VI compounds such as (Cd,Hg)Te have also been studied for use as fast photodiodes in communication systems.

The second device illustrated has an absorbing layer of InGaAs deposited on an InP substrate, with the p-n junction formed by diffusing a dopant such as zinc into the absorbing layer. This device is designed for the wavelength range 1 to 1.6 μm, in which the InGaAs layer has a high absorption coefficient, around 10^4 cm^{-1}, so only a thin absorbing layer is needed, about 3 to 10 μm. This makes the response fast, but an important fraction of the incident radiation is absorbed in the undepleted p$^+$ region at the surface even if it is only 1 μm thick. Many of the carrier pairs formed in this region are lost by surface recombination or by recombination within this layer, so that the efficiency is reduced considerably. It is not easy to control the thickness of this layer much below 1 μm, but the problem can be surmounted by arranging for the light to be incident through the back of the device, i.e. through the InP substrate, which is transparent at wavelengths beyond 0.95 μm.

The quantum efficiency of a photodiode is the number of carrier pairs formed on average for each incident photon. It is less than unity in practical devices for three main reasons: some of the incident light is reflected; some carrier pairs are formed in undepleted material and so do not contribute to the photocurrent at high frequencies; and some carrier pairs recombine before reaching the terminals of the device. To improve the quantum efficiency, the surface of the device is often

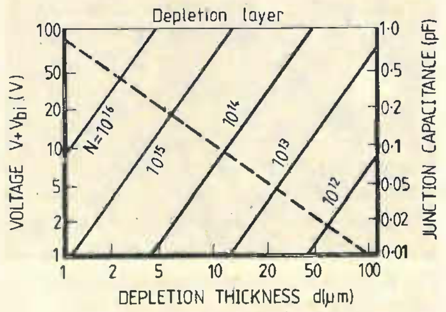

Fig. 3. Depletion voltage and junction capacitance as functions of the depletion layer thickness for a 100μm diameter diode, taking the relative dielectric constant to be 10, typical of many semiconductors.

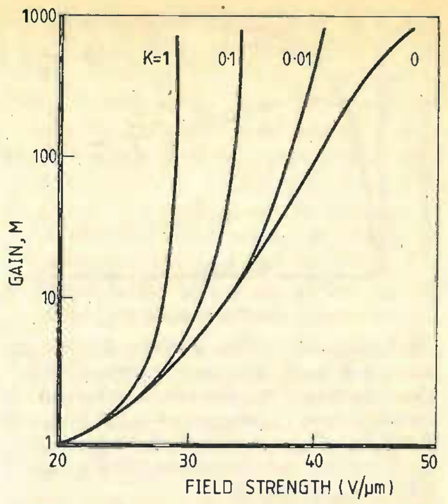

Fig. 4. Avalanche gain as a function of field strength – the breakdown characteristic. Parameter k is the ratio of ionization rates for electrons and holes.

given an anti-reflecting dielectric coating like the blooming of a camera lens; the surface reflection coefficient may be reduced from around 30% to almost zero. If the light has to pass through undepleted material, as in the lower diagram, this is kept as thin as possible or made of a semiconductor which is transparent at the wavelength of interest. Recombination of carriers within the depletion region is generally minimized by reducing deep-level impurities and crystal defects as far as possible.

The depletion layer thickness d is determined by the applied voltage V and the doping level N_b:

$$V + V_{bi} = qN_bd^2/2\epsilon\epsilon_o$$

where q is the electron charge and ϵ is the relative dieclectric constant, typically 10 to 15. Junction capacitance is

$$C_d = A\epsilon\epsilon_o/d$$

where A is the area of the junction. These relationships are plotted in Fig. 3, assuming a device diameter of 100 μm. Doping levels of 10^{12} to 10^{13} cm^{-3} are available in silicon, so that a few tens of microns can be depleted at 5 to 10 volts. In the mixed III-V compounds levels of 10^{15} cm^{-3} are the best normally available, so that 15 to 20 volts are required to deplete a few microns. Junction capitance is typically 0.1 to 0.5pF for a high-speed device so that the capacitance of a packaged device is usually dominated by the package.

The reverse-bias leakage current (dark current) of a photodiode is important because the shot noise on this current can be the dominant receiver noise in some situations. The dark current is caused by current leakage over the surface of the device as well as through the depletion region (bulk leakage). Surface leakage is minimised by careful processing and by coating the device with a passivating layer: methods vary from one material to another. Bulk leakage is due to diffusion of minority carriers from the undepleted

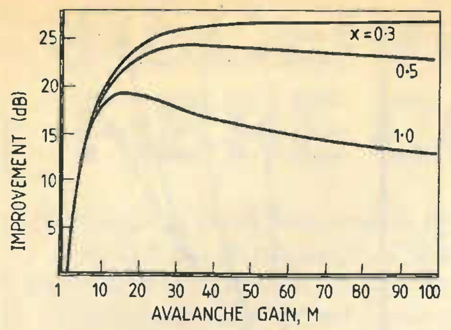

Fig. 5. Signal-to-noise ratio is improved as a result of avalanche gain. Parameter x is the exponent in the empirical expression for the excess noise factor $F = M^x$. Value of 0.3 to 0.5 relates to silicon reach-through diodes while germanium and III-V a.p.ds have a value close to 1.

regions and by generation and recombination of carrier pairs in the depletion region. The diffusion term usually dominates in materials with a large intrinsic carrier concentration, such as germanium. The generation-recombination term is the most important in silicon and in most III-V compounds of interest.

Detection in the presence of noise

The most important parameter of any receiver is its sensitivity, and there are several factors which prevent arbitrarily weak signals from being handled. The signal will have suffered various impairments during transmission, because of the dispersion and attenuation of the fibre. In addition to being distorted, the signal leaving the optical receiver has wideband random fluctuations produced by the components of the amplifier. Lastly, even with an infinite fibre bandwidth and a noiseless amplifier, the optical signal itself is statistical because of the quantum nature of light. Radio waves are also quantized, of course, but the quantum energy $h\nu$ is much less than the thermal energy kT of electrons in the amplifier components so that quantum effects do not show up at radio frequencies. At room temperature kT/h is about 6000 GHz, well above the highest frequencies used in radio transmission, and well below the frequency corresponding to a wavelength of 1 μm, which is 300 THz. Photons arrive at the detector at random instants with a Poisson probability distribution so that the variance in arrival rate is equal to the mean. If the expected number of photons in some time interval in m, then the probability that the number detected will be n is

$$p(n) = \mathrm{Pos}[n,m] = m^n e^{-m}/n!$$

Consider a binary digital system in which one needs to decide whether or not a pulse was received during each bit period. The number of detected photons n is counted for each bit period, and if that number exceeds some threshold number d a one-pulse is recorded, otherwise a zero is recorded. Errors occur if n is less than d when a one-pulse was transmitted. It is easy to see that fewest errors are made when the threshold d is set between 0 and 1 photons. The error probability is then $P_e = e^{-m}$, and one cannot have zero error probability with finite m. For $P_e = 10^{-5}$, $m = 11.5$ and for $P_e = 10^{-9}$, $m = 20.7$.

In an analogue system, we are interested in the signal-to-noise ratio (snr) at the receiver output with a post-detection bandwidth B which smooths fluctuations over an integration time $t = 1/2B$. If the mean photon arrival rate is r, then the number m which arrives, on average, during the time t is $m = r/2B$. At the output of the receiver, the signal power is proportional to m^2, while the noise power is proportional to the variance of m, which is just m. Thus signal-to-noise ratio is

$$m^2/m = r/2B$$

For example, a 50dB signal-to-noise ratio and a 1MHz bandwidth requires, average, 2×10^{11} photon/s or 40 nW at a wavelength of 1 μm.

That is the best performance one could expect, even with a perfect detector and a noiseless amplifier, limited only by the quantum fluctuations in the incoming optical signal. In real life, amplifiers are not noiseless because electrons in the conductors move with randomized velocities with energy $\sim kT$, and the amplifier has to have non-zero input conductance. Using conventional components, an amplifier with input capacitance of 10pF and a bandwidth of 10MHz would need to have an input resistance of about 10kohm or less loading the photodiode. The mean square thermal noise voltage in a bandwidth B due to a resistance R is $\langle V^2_T \rangle = 4kTRB = 8.3 \times 10^{-10}$ V^2 at room temperature for an R of 5 kohm and B 10 MHz. The signal voltage generated across R due to m photons at a wavelength of 1 μm detected in time t is $V_s = mqR/t = 1.6 \times 10^{-8}\, m$ volts. The signal-to-noise ratio is

$$(1.6 \times 10^{-8} m)^2/8.3 \times 10^{-10} = 3 \times 10^{-7} m^2$$

so that in a digital system of 22 dB ratio, m is about 20,000 photons in a bit period t (taken as $1/2B$ here). This is 1000 times or 30dB greater than the quantum noise limit, which justifies ignoring quantum noise in this calculation. As 30dB can be translated into perhaps 100 km of extra fibre at 1.55 μm – by no means a small benefit – one would like to improve this situation. There are four ways of increasing the receiver sensitivity to consider. Reducing amplifier noise is one way, obviously – discussed see later – another way is discussed in the next section, and in the last section of this article two other ways are considered: optical amplifiers and coherent detection.

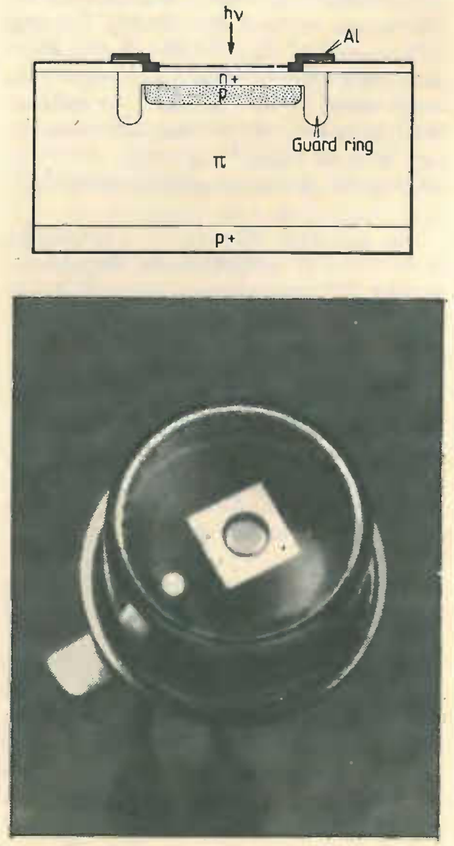

Fig. 6. Silicon reach-through avalanche photodiode is made by diffusion and implantation of dopants into a low-doped silicon substrate. Guard ring lowers electric field at the perimeter of the junction, preventing premature breakdown. Commercial silicon reach-through avalanche photodiode in a TO-18 can is the RCA 3090ZE.

Avalanche photodiodes

An electron or hole accelerated by an electric field may gain sufficient energy so that when it is scattered by the lattice a lattice atom is ionized, creating an electron-hole pair. The newly created carriers can then cause impact ionization and so lead to an avalanche process with current gain.

If only one type of carrier were capable of causing impact ionization the avalanche process would advance across the high field region, the number of carriers increasing exponentially with distance but remaining finite: avalanche breakdown would be impossible. In real materials, however, both carrier types can cause impact ionization, usually with different efficiencies, providing a regenerative or positive feedback mechanism which can lead to a (theoretically) unbounded number of carriers in the breakdown. The avalanche current gain M is plotted as a function of electric field in Fig. 4; k is the ratio of ionization rates for electron and holes. The gradient of all the curves in Fig. 4 becomes infinite for some finite field, except for $k = 0$. The implication is as follows: to get useful current gain from the diode it must be biased close to breakdown – very close if k is near to unity. But any variation in field due to the diode not being perfectly uniform or the supply voltage being imperfectly regulated causes a change in the current gain, and this change can be large if k is near unity. The current gain becomes variable and also noisy. In silicon k can be as low as 0.01, and silicon diodes can be operated at gains of a few hundred or even thousands in some cases. In germanium and many III-V compounds, k is 0.3 – 1 and it is hard to fabricate and control a device for a gain

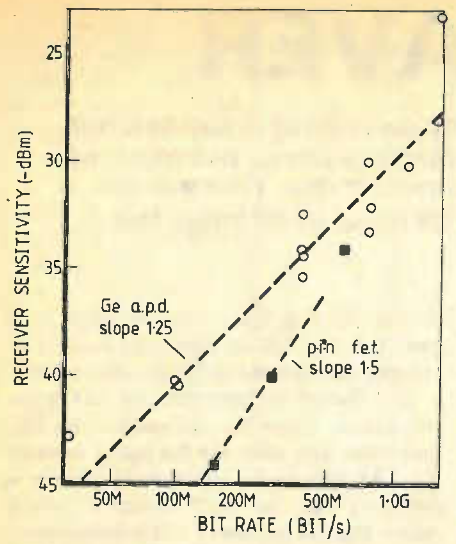

Fig. 7. Some published results on receiver sensitivity in experimental optical fibre transmission systems. Circles represent germanium diodes, and the slope of approximately 1.25 is expected for an excess noise factor exponent x close to unity. Filled squares are for p-i-n-f-e-t receivers discussed in part 2.

above 10 to 15. There are also noise problems associated with a value of k close to unity.

How is this current gain used to improve the sensitivity of an optical receiver? Current gain arising from avalanche gain increases the signal voltage across the amplifier input and so improves the signal-to-noise ratio as the amplifier noise is unaffected. However, the current gain also increases the quantum noise by the same amount as the signal, so that one cannot get beyond the quantum noise limit. In practice one cannot even get near to it because of extra noise introduced by the random impact ionization process. Consider a steady optical power P incident on the detector. The resulting multiplied photocurrent is $\langle i_p \rangle = 2P\eta q M/h\nu$. The mean square shot noise current on the photocurrent in a bandwidth B is $2q \langle i_p \rangle BM^x$, where M^x is the excess noise factor from the avalanche gain process ($0 < x < 1$). The mean square thermal noise current is $4kTB/R$. So the output power signal-to-noise ratio is

$$\frac{(2P\eta q M/h\nu)^2}{2p\eta q^2 RM^{2+x}/h\nu + 4kTB/R}$$

With $M = 1$ the thermal noise term dominates. As M is increased from unity the signal power increases as M^2, but so long as the thermal noise term dominates the total noise power is little affected and the signal-to-noise ratio increases. When M is large, thermal noise is insignificant and the signal-to-noise ratio decreases with increasing M as M^x. There is an optimum avalanche gain:

$$M^{2+x} = (4kT/R)(h\nu/xP\eta q^2)$$

so that

$$\frac{\text{Shot noise}}{\text{Thermal noise power}} = \frac{2}{x}$$

The empirical parameter x is related to k, the ratio of ionization rates for holes and electrons. Both depend on the material, and also on the electric field strength and direction. In silicon, k is about 0.02 and x is 0.3 typically. In germanium, k is between 0.7 and 1 and x is close to 1. In III-V alloys, k ranges from 0.2 to 1 and x is 0.7 to 1. The equation is plotted in Fig. 5 with different values of x. If x is small, as with a silicon diode, the optimum gain is large and the maximum in signal-to-noise ratio is broad. The diode can, in fact, be used to vary the gain of the receiver and so provide a.g.c. When x is near unity, less improvement is possible, the optimum gain is lower and the maximum much sharper. Such diodes may be difficult to control for optimum performance.

The theory of the avalanche process and the statistics of excess avalanche noise are important in the study of optical receivers, but they are beyond the scope of this article – consult the papers by McIntyre and co-workers in the bibliography for further details (part 2).

To make an avalanche photodiode in silicon with a fast response a simple p-n junction will not do because most photons will be absorbed in undepleted material where the field is negligible. It is necessary to use the "reach-through" structure shown in Fig. 6 in which the depletion region consists of a high-doped, high field-gain region followed by a lower field, low-doped absorbing region. The problem is to ensure that the absorbing region is fully depleted well before the gain region breaks down, and this demands great control over the fabrication of the device. Nevertheless, good commercial silicon reach-through diodes have been on the market for several years.

Most system work at longer wavelengths has been carried out using germanium avalanche photodiodes. Germanium seems an obvious material, as the photodiodes can be made sensitive out to 1.6μm and beyond by reducing the thickness of undepleted material near the surface. Germanium is not ideal because the ratio of ionization coefficients k is close to unity (i.e. $x = 1$) so that the excess noise factor is high. More importantly, the reverse bias leakage current density is high because the high intrinsic carrier concentration results in a large diffusion contribution to the leakage current. The unmultiplied leakage current density is typically 3×10^{-4}A cm^{-2} at room temperature, sufficient to cause a system penalty of a few decibels at a data-rate of a few hundred Mbit/s. The leakage current depends on temperature and at 50°C is about an order of magnitude greater than at 20°C, resulting in a large system penalty and reducing the optimum gain to about 3 to 5 as the dominant noise source may be multiplied bulk leakage. At room temperature, receiver sensitivities of -34 dBm at 400Mbaud and -30 dBm at 800 Mbaud have been reported using germanium photodiodes. These figures would be several dB worse at 50°C. Published receiver sensitivities at 1.3 and 1.55 μm are shown in Fig. 7 for the available range of bitrates, and it can be seen that the bit-rate dependence is approximately the 5/4 power, as one would expect from an a.p.d. with an x-factor near unity. Also shown are the results for p-i-n receivers with a 3/2 power dependence, as discussed in part 2 of this article.

In pursuit of the excellent performance achieved with silicon a.p.ds considerable effort has been expended in research on diodes made in III-V compounds. To date no system results have been reported although there is much published material on the devices themselves. As with semiconductor lasers for wavelengths beyond 1 μm. The main work has been carried out on the GaInAsP/InP system, and until recently avalanche gains in the region 10 to 20 were typical, limited probably by non-uniformity of the material of the high-field region leading too micro-plasma breakdown. More recently, a structure with the high-field region in InP has been described as shown in Fig. 8, and gains of up to several thousand reported. A different reverse-bias leakage current mechanism becomes important in the high-field region of III-V diodes: tunnelling of electrons from the valence band to the conduction band. This leakage is very sensitive to field and to band-gap. The implication is that the dark current can be reduced to an acceptable level only by keeping the high field region to low-doped, large band-gap material such as InP. The excess avalanche noise properties of the device then depend on this material. □

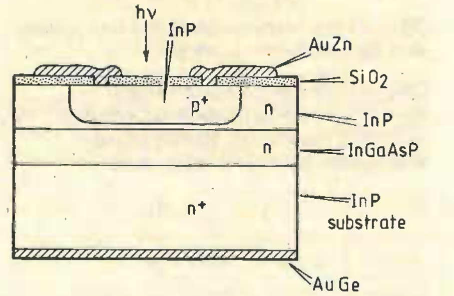

Fig. 8. Group III-V heterostructure a.p.d. has the high-field (gain) region within the large band-gap InP layer.

Correction

Phase-shifting oscillator, By Roger Roosens. A number of misprints crept into this article published in the February issue, for which we must apologise. Many of the mathematical formulae were affected and we would be happy to provide interested readers with a corrected copy if they send us a stamped-addressed envelope.

The author has asked us to point out that distortion was measured using fixed 1% resistors for the tuning elements. Such figures could not be achieved with a two-gang potentiometer.

A numerical analysis of the thermistor distortion was made with a computer and the results were compatible with calculated ones. The only significant distortion generated in the n.t.c. is third harmonic.

The measured distortion figures show that the second-harmonic distortion of the circuit increases at low frequencies. This is due to second-order effects in the i.cs due to temperature variation with the oscillator signal. This distortion sets the performance limit of the circuit at low frequencies.

HEATING-FUEL SAVER

Over the season some saving can be made in heating fuel bills by switching on later when the weather is less cold. This feature is usually incorporated in large systems but the unit described, which may be built at low cost, is intended for domestic use. There is an outdoor temperature sensor which is not essential but may be used to monitor the heating system.

by David Ryder, Ph.D.

The outdoor sensor is a thermistor, of which the resistance (R_t) must be known, or measured, at three relevant temperatures, for example 0°, 10°, and 20°C, which is connected in series with a fixed resistance R_s, across a stabilised voltage. By appropriate choice of R_s (see appendix), the relationship of the mid-point voltage (V_t to temperature can be quite well linearised, as shown in the table. The timing circuit uses a slowly-rising voltage V_p, and a comparator to close the switching relay when V_p reaches V_t. The ramp voltage V_p is generated digitally using a data-a converter in the prototype the popular Ferranti ZN425E, clocked at v.l.f. to give for example a delay of one hour per 10°C.

The power supply section shown in Fig 2 is suitable for a standard 24V d.c. octal-based relay, of which the coil resistance is typically 470 ohms. If a different voltage is used, R_d should be adjusted to give 8-12V input to the regulator.

Counting-up

In Fig. 3, the 425 internal counter is brought into use by tying pin 2 high. The internal resistance ladder is connected to the internal reference source (V_{ref}) by joining pins 15 and 16, and the analogue output V_p at pin 14 is then given by:

$$V_p = V_{ref} \times N/256$$

where N is the count reached. The counter has eight stages, and the maximum count is (1 + 2 + 4 + 8 + 16 + 32 + 64 + 128) or 255. The nominal reference is 2.56V, giving 10mV per count, but its exact value is unimportant, since the thermistor R_t is also supplied from V_{ref}, and:

$$V_t = V_{ref} \times R_s/(R_s + R_t)$$

Thus the count required to make V_p exceed V_t, and so turn on the relay via comparator IC_{2a} is given by:

N=nearest whole number above

$$\left(256\frac{V_t}{V_{ref}} = 256\frac{R_s}{R_s+R_t}\right)$$

The table shows N values for various temperatures, relating to RS code 151-237 thermistor, which is a close-tolerance device (±0.2°C). Resistance R_s should be made up to within 1% from metal-film resistors. Other thermistors can be used by measuring them and calculating the appropriate R_s (see appendix). Setting-up is easier if test-resistances are made up to substitute for the thermistor at say 0°, 10°, and 20°C, and in the prototype these were built in using a four-way switch.

Circuit operation

The 425 is clocked, pin 4, from a conventional 555 oscillator divided by a c.m.o.s. 4040B. The division ratio to 4040 pin 1 is 4096, and to pin 3, 64, the latter output being used via Tr_3 to flash an l.e.d, and via S_1 to give fast clocking of the 425 for test purposes. From the table the number of counts between 0°C and 20°C is 59, and if this is to occupy 59 minutes, one count per min, the 555 period must be 60/4096 ≈ 0.0146 sec, or 14.6 ms. Vr_1 gives a range of about 1 to 3 hours per 20°C.

The comparator $IC2_a$ has an open-collector output, which is pulled up by the 1k resistor, and the relay is switched via Tr_2. The positive feedback from the output C to the non-inverting input is needed to latch the comparator, since V_t may subsequently rise above V_p, but diode D_4 avoids loading on the input, and so on the 425

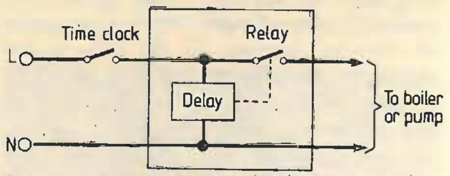

Fig. 1. *In-line connection of delay unit between time-clock and load.*

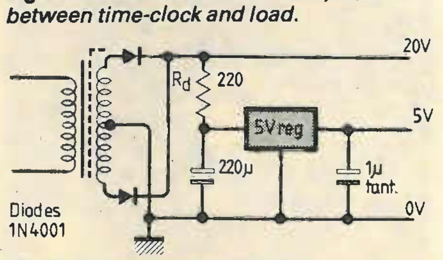

Fig. 2. *Power-supply section. The regulator may be 100 mA or 1 A type.*

Linearisation of RS code 151-237 thermistor, using calibration points 0°, 10°, and 20°C, resistor R_s 15,485 ohms. Thermistor tolerance is ignored.

°C	−5	0	5	10	15	20	25
R_t Ω	42,295	32,650,	25,377	19,900	15,701	12,490	10,000
V_t/V_{ref}	0·2680	0·3217	0·3790	0·4376	0·4965	0·5535	0·6076
Error °C	+0·4	nil	−0·1	nil	+0·1	nil	−0·3
N (counts)	69	83	98	113	128	142	156

output, during the count-up, when C is low. The 'Set' button allows the relay to be closed without waiting for the time delay.

The 'Reset' button resets the 425 counter, pin 3, resets the comparator via D_5, and resets the 4040 via the p-n-p inverter Tr_1. At switch-on, the same function is performed by the 10μF capacitor, which delays the rise of point B. The 4040 (alone) is also reset via D_6 when C eventually goes high, stopping the count at this point, and causing the l.e.d. to glow continuously.

The op.amp section of IC_2 is used to drive a milliameter from V_t to indicate outdoor temperature, and almost any f.s.d. can be used up to say 5mA. In the prototype an existing 0-100 scale was used for degrees Fahrenheit, and the biasing shown, R_b and R_f, gives a reading of approx 32 at 0°C, which can be trimmed by the mechanical zero adjustment. The resistance of R_m was made up to give a swing of 36 divisions between 0°C and 20°C (32°F and 68°F). The meter may of course be remotely mounted, perhaps alongside your barometer.

Checks

The eight counter outputs of the 425 are available at pins 5-7 and 9-13, and in that order have weights 1, 2, 4 . . . . 128. A count of 83 for example, or 64 + 16 + 2 + 1, corresponds to pins 12, 10, 6, 5 high (and the rest low), and this allows the counting to be checked using the test resistances, and the 'fast' setting of S_1. An error of one count is not important. The 555 timing can be checked by a frequency meter, or from the l.e.d, which flashes 64 times per 'normal' 425 count.

Variations

The basic circuit still has a long delay in cold weather, for example 69 counts at -5°C, and though this can be compensated by advancing the time-clock, it is more elegant to suppress it by jumping, clocking the 425 directly from the oscillator, point F, until an appropriate count is reached. Figure 4 shows two possible circuits, 4(b) being that used in the prototype. The logic shown may be realised in various ways, but diodes and transistors are cheap, and easy to lay out on Veroboard.

If it is required to use the thermometer when the time-clock is off, the delay unit must be continuously-powered, and reset may then be modified to Fig. 5, in which the time-clock signal is detected by a transistor-type optoisolator. Reverse voltage is limited by D_7. Resistor R_r should pass 5-10mA rms, and may be replaced by a capacitor, say 0.1μF, provided it is a type suitable for continuous mains working. The intermittent output allows the 1μF capacitor to provide initial reset even if the delay unit is powered up with the time-clock on.

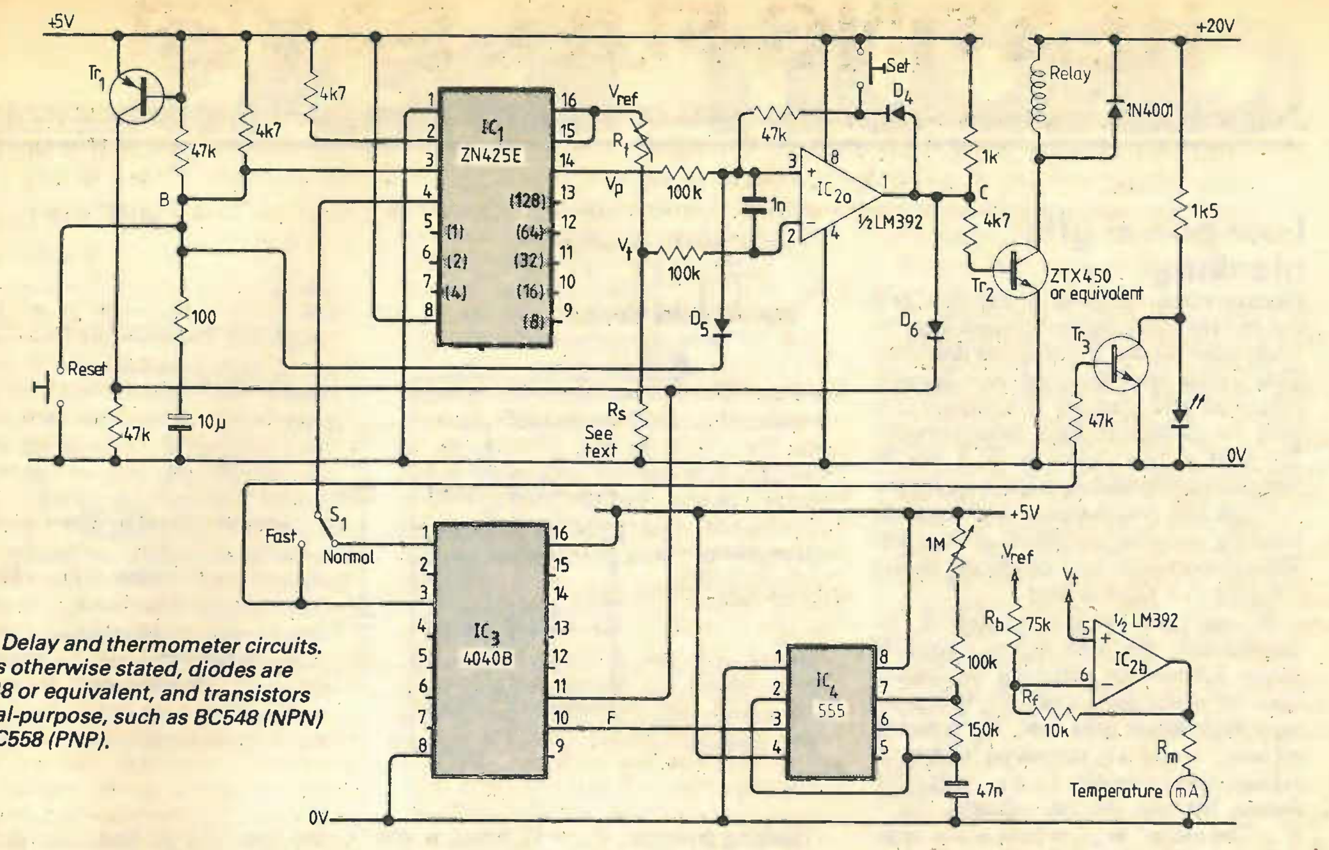

Fig. 3. *Delay and thermometer circuits. Unless otherwise stated, diodes are 1N4148 or equivalent, and transistors general-purpose, such as BC548 (NPN) and BC558 (PNP).*

Since the 425 count stops at switch-on, it stores the switch-on temperature, which may be read out later in the day by switching $IC2_b$ input to V_p (425 pin 14) rather than V_t. However it is necessary at the same time to break the normal pin 14 connection, because the feedback with C high raises V_p above its actual switch-on value.

Thermistor mounting

The RS device is a small bead, about 1.5mm dia. For the prototype, a 1.6mm hole was drilled nearly through a 12mm cube of aluminium, then enlarged part-way to a push-fit for a 4mm tube about 10cm long, which in turn fits through a 4mm hole drilled in the frame of a north-facing window. The thermistor leads were extended by 7/02 wires, and the assembly pushed down the tube, so that the thermistor bead entered fully into the 1.6mm hole. A blob of heat-conductive grease was used to improve thermal contact, and the block and tube were painted dull black. Thin twisted wire was used for connection. If a long run is needed, it would be advisable to decouple V_t to ground via 10μF to suppress any hum pick-up.

Appendix

The usual thermistor formula is $R_t = A\exp(B/T)$, where T is absolute temperature in degrees. Kelvin (C +273), and A (ohms) and B (K) are nominally constant. B is often around 3,000, and A is a small fraction of an ohm. Values can be deduced from measurement at any two temperatures, but since they are only approximately constant, calculations are best restricted to interpolation only.

The method of calculating R_s does not however depend on A and B, but merely makes three calibration points lie on a straight line. The arithmetic is simplest if the calibration temperatures are equally spaced, $T_3 - T_2 = T_2 - T_1$. Suppose the value of R_t at T_1 is R_1, at T_2 $a.R_1$, and at T_3 $b.R_1$. Then R_s is given by:

$$R_s = R_1 \times \frac{a - 2b + a \cdot b}{1 - 2a + b}$$

As the table shows, the linearity between calibration points is good, and it is acceptable over a larger range. It may be noted that, from Thévenin's theorem, the same value of R_s applies in a circuit using a constant current through R_s and R_t in parallel. Maximum thermistor power occurs when R_t = R_s, and for Fig. 3 is 1.28^2/15,485, about 0.1 mW, which for the device used, in free air, would produce about 0.1°C self-heating. When using lower-resistance thermistors, the possibility of self-heating error should be borne in mind. □

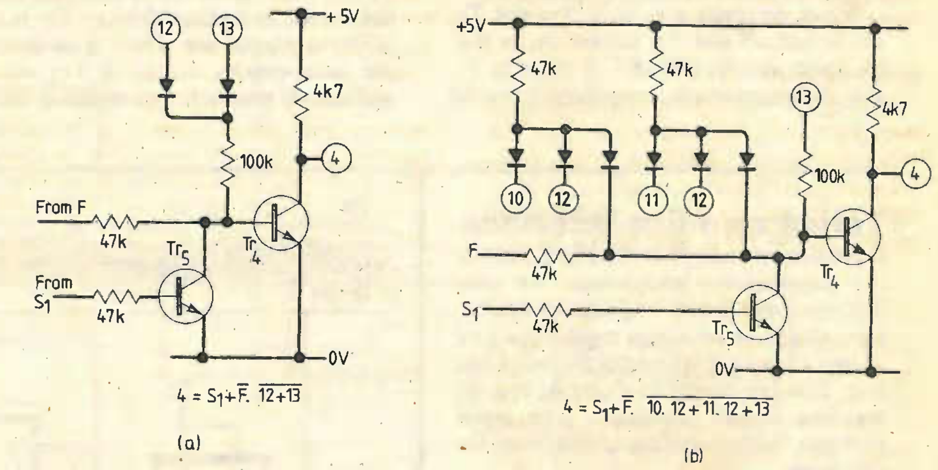

Fig. 4. *Count-jumping; 4(a), jump to 64; 4(b), jump to 80. Numbers in circles are 425 pins, and the circuits replace the direct connection of S_1 to pin 4.*

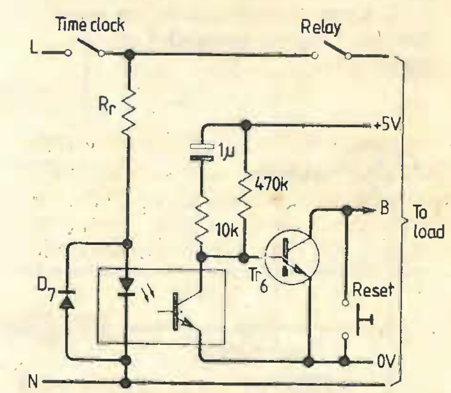

Fig. 5. *Opto-isolator reset, for use when delay unit is independently powered. With this circuit omit components 100R, 10μF from Fig. 3.*

CIRCUIT IDEAS

Low-power grid blanking

Electron-beam blanking at the first grid can involve much higher voltages than cathode blanking but is sometimes desirable. This circuit was designed for digitally-controlled grid blanking of a camera tube used for quantitive light measurements. The grid voltage (equal to V_-) can be accurately controlled during the active picture line and transitions to and from the blanking potential are short, at 40ns and 300ns respectively, with no ringing when a Schottky t.t.l. input is used.

Because grid-leakage current is extremely low, the high voltages required can be achieved by switching the connections of a charged capacitor. When the input-logic signal goes low, Tr_2 is turned off and Tr_1 and Tr_3 turned on so that the voltage over capacitor C, V_C, is the difference between the rail voltages, $V_+ - V_-$. The output to g1 is held at the negative rail, which controls the beam current.

When the input goes high, Tr_1 and Tr_3 are turned off and Tr_2 turned on, so that the more positive side of C is taken to V_- and the negative side consequently to the blanking potential, $V_- - V_C$ which is also $2V_- - V_+$. The droop in blanking potential caused by leakage through Tr_3 is negligible in normal use. There is no droop in the beam-control voltage as Tr_3 remains sufficiently conductive throughout the active line. The g1 lead must be kept well away from the target connection to avoid interference.

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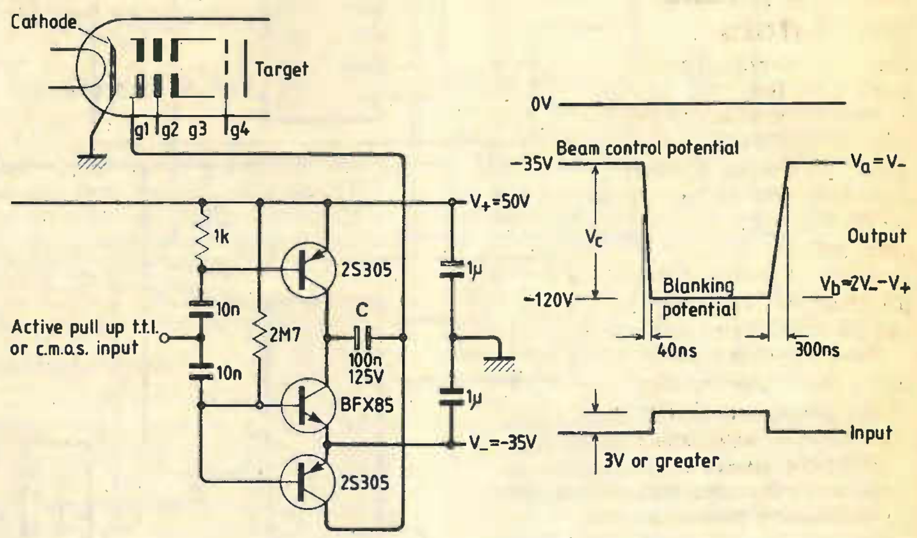
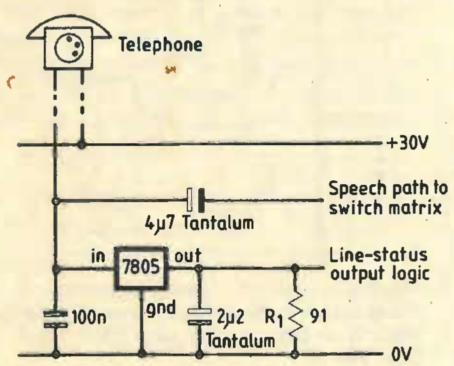


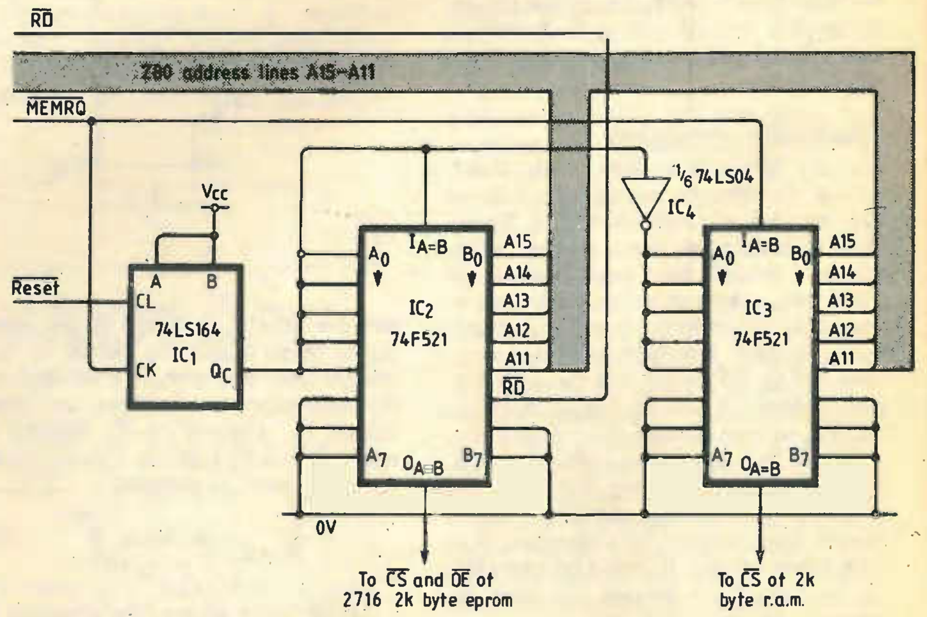
Telephone-line interface

Conventional telephone-interface circuits use relays and/or transformers for loop detection and speech coupling. In this circuit, a 5V positive-voltage regulator is used to feed a constant current to the telephone line. The line current is set by R_1 and the regulator output provides a logic signal that will 'follow' dialling pulses from the telephone.

As this circuit provides unbalanced transmission to the telephone, it is only suitable for internal (intercom type) exchanges. A ring circuit could be provided by a third wire to the telephone. Acknowledgement to the Director of Research* for permission to publish this information.

F. T. Lyne
*British Telecom Research Labs
Ipswich





Z80 memory mapping

R.a.m. area for interrupt restart vectors and e.p.r.o.m. write protection are provided by this automatic memory map and switch for a Z80 microprocessor system. On power-up, or after a reset, a 2K-byte e.p.r.o.m. (2716) occupies addresses 0000 to 07FF and a 2K-byte r.a.m. is address mapped to F800-FFFF. After a reset, the Z80 will perform an op-code fetch from location 0000. The e.p.r.o.m. will be selected after $\overline{MREQ}$ is activated. The instruction at locations 0000 to 0002 is JP F803 and the circuit will automatically switch r.a.m. and e.p.r.o.m. locations after the third memory access. The next op-code fetch will occur at location F803, causing execution to continue from the next contiguous location in e.p.r.o.m. Locations 0000 to 07FF are now occupied by the 2K r.a.m. so it is possible to initialize and modify the interrupt restart vectors, hence providing a greater degree of flexibility.

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Testing p.r.b.s. generators

Readers experimenting with p.r.b.s generators may find this circuit useful for evaluating possible feedback configurations. Driven by an external clock at any speed up to a few hundred kHz, it gates clock-pulses to an external counter for exactly the duration of one complete sequence, maximal or otherwise, so that the final counts shows the number of steps in the sequence. The generator is preset so that the count begins almost immediately.

The shift-register shown has n effective stages and is negative-edge triggered (e.g. 4006's); for a positive-edge triggered shift-register the inverted clock-signal is used.

When the system is at rest, both flip-flops are in the reset state and no clock-pulses appear at the output. Point A is low, so the auxiliary counter is held at zero and the input to the shift-register is held high. After a maximum of n clock-cycles all the stages of the shift-register will be in the high state, and the system ready to start.

The start button sets the start flip-flop on the next negative-going transition of the incoming clock-signal; contact-bounce has no effect. Point A goes high. This allows the generator to run normally, with its output (from stage n of the shift-register) controlling the auxiliary counter. When the generator output is high, the counter advances one count on each positive-going transition of the incoming clock-signal; when the generator output is low the counter is held at zero.

Once per complete sequence the generator output remains high for n consecutive clock-cycles; the counter then reaches the count of n causing point B to go high until the counter is reset (nominally a half clock-cycle later).

Because all stages of the shift-register were initially preset to the high state, the first signal at B occurs during the n'th clock-cycle from the start. This signal sets the gate flip-flop. This in turn allows clock-pulses to appear at the output, and also resets the start flip-flop while maintaining point A high so that the system continues to run. These conditions continue until the next signal appears at B exactly one sequence later, and resets the gate flip-flop; then the clock-pulses cease to appear at the output, point A goes low, the generator ceases to run, and, after a maximum of n clock-cycles, the system is back in the ready state.

Pressing the reset button will return the system to the ready state at any time.

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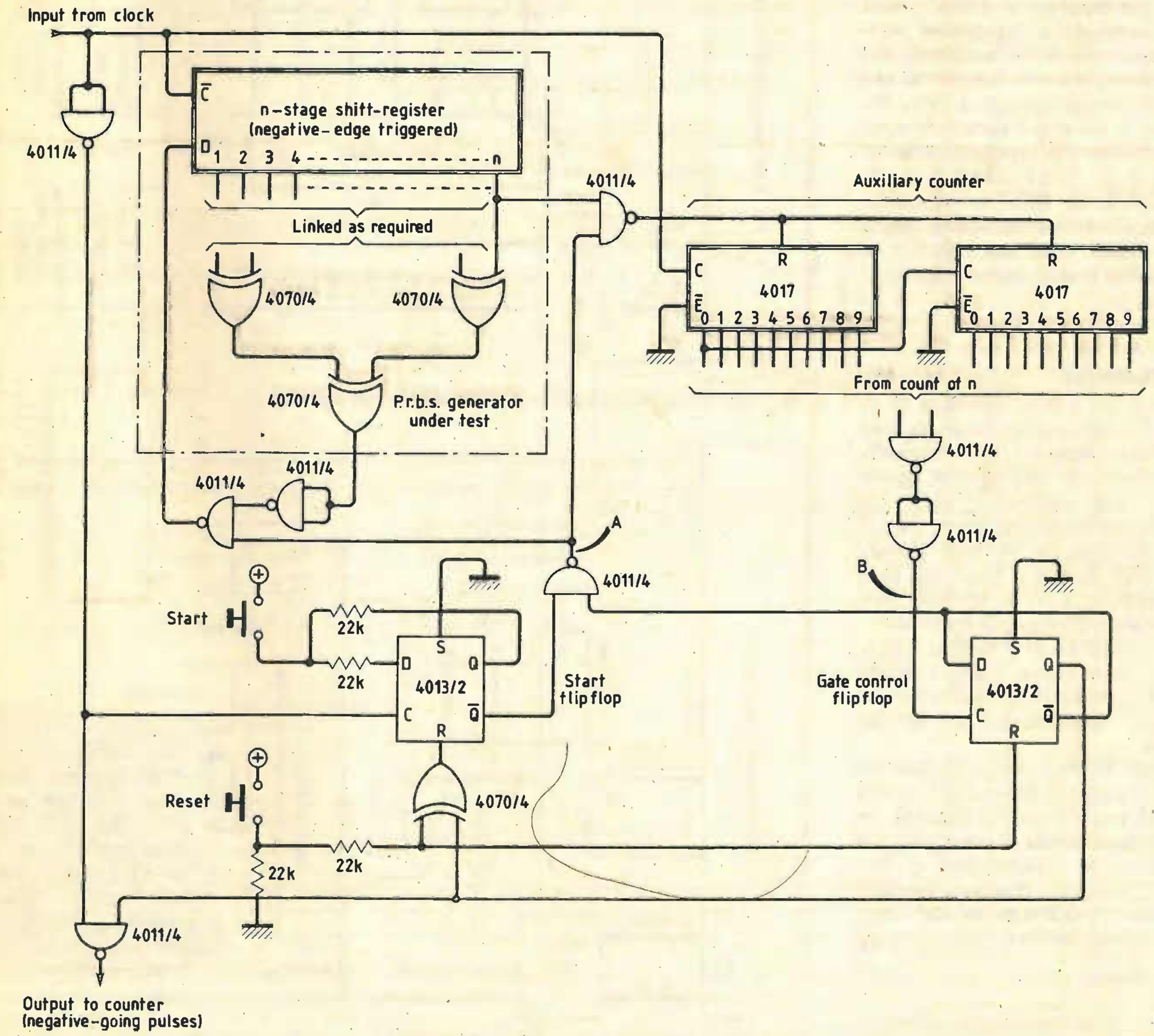
Shropshire



DESIGNING WITH MICROPROCESSORS 13

Clear-cut step-by-step procedures for the design and implementation of d.m.a. interfaces are described. Specifically, it is proved that in the case of action/status peripherals the interface reduces to two wires.

by D. Zissos* assisted by Glen Stone*

The block diagram of a d.m.a. system is shown in Fig. 1. The function and operation of the address decoder, the d.m.a. controller and the cycle-steal logic has been explained in the previous article (February, 1982). Briefly what happens is this. The programmer sends to the d.m.a. controller (by means of i/o instructions) three items of information specifying (i) the starting memory address, (ii) the size of the block, and (iii) the direction of transfer, followed by the 'go' command. On receipt of the 'go' command, the d.m.a. controller activates the peripheral interface by pulling enable signal E in Fig. 1 high (E := 1). When activated, the interface monitors the status signals of the peripheral, and requests a cycle steal when the peripheral is ready. When the microprocessor responds, the interface and the d.m.a. controller generate the appropriate command signals needed by the peripheral and the memory chip for the transfer of one item of information (usually a byte) between them. At the end of each cycle steal, the memory address is incremented/decremented, and the word count is decremented ($n := n-1$). This process continues until the word count reduces to zero ($n = 0$), at which time the interface is disabled and the end-of-transfer signal, ϵ, is generated.

D.m.a. interfaces

The function of d.m.a. interfaces is to request the microprocessor to go on hold when the main memory is to be accessed, and to generate the appropriate signals needed by the peripheral when the memory becomes accessible. In the case of cycle-steal systems, as we have already seen, the hold request is generated each time the memory is to be accessed, and removed after a memory cycle is granted.

The block diagram of a suitable d.m.a. interface, assuming logic signals throughout, is shown in the shaded section of Fig. 2. It operates in the following manner.

When logic block 1 recognizes that the peripheral is ready to be accessed, it sets flip-flop 3 by pulsing its clock terminal. Its output is Anded with the enable signal E to produce the cycle request signal c. (Assume $\bar{\epsilon}$=1). When the requested memory cycle is granted, line h is pulled high and a pulse is generated on line k. Signal h being high, and E = 1, activates logic block 2, which responds by generating the appropriate command signals needed by the peripheral for accepting or receiving an item of information. Similarly, pulse k activates the d.m.a. controller, which initiates either a memory read or a memory write cycle. At the end of the memory cycle the microprocessor resumes normal activity, until the peripheral becomes ready, which causes logic block 1 to pulse the clock terminal of FF3. This pulls the cycle-steal line c high and sometime later a link between memory and logic block 1 is established for a memory cycle. The process repeats itself until the last item has been transferred between the peripheral and memory. At this time the d.m.a. controller generates end-of-transfer signal, ϵ, to inform the system that the requested block transfer has been completed. The system responds by turning signal E off; this disables the interface.

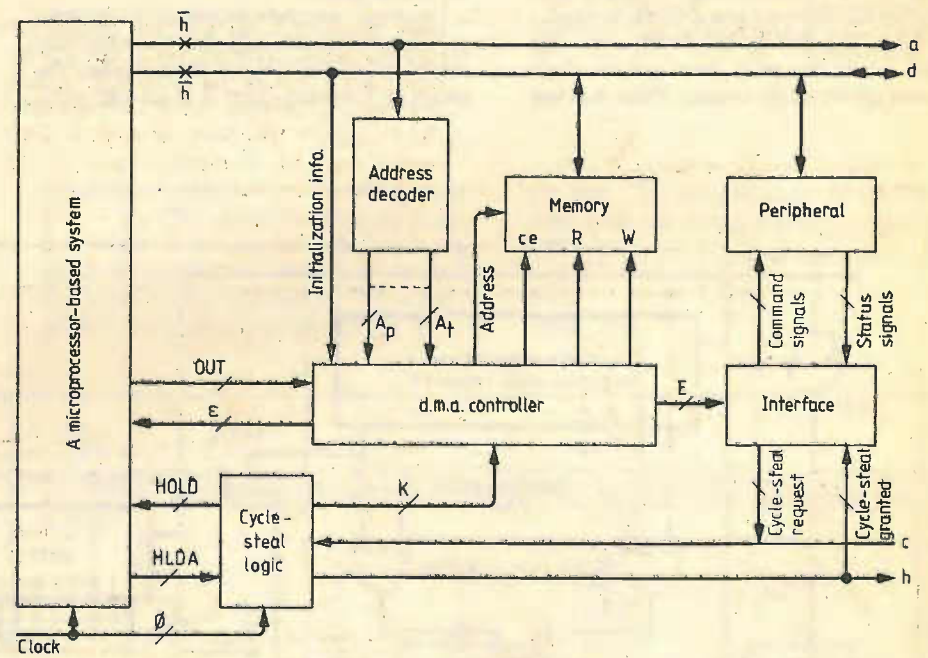


Fig. 1. Block diagram of a d.m.a. system using cycle stealing.

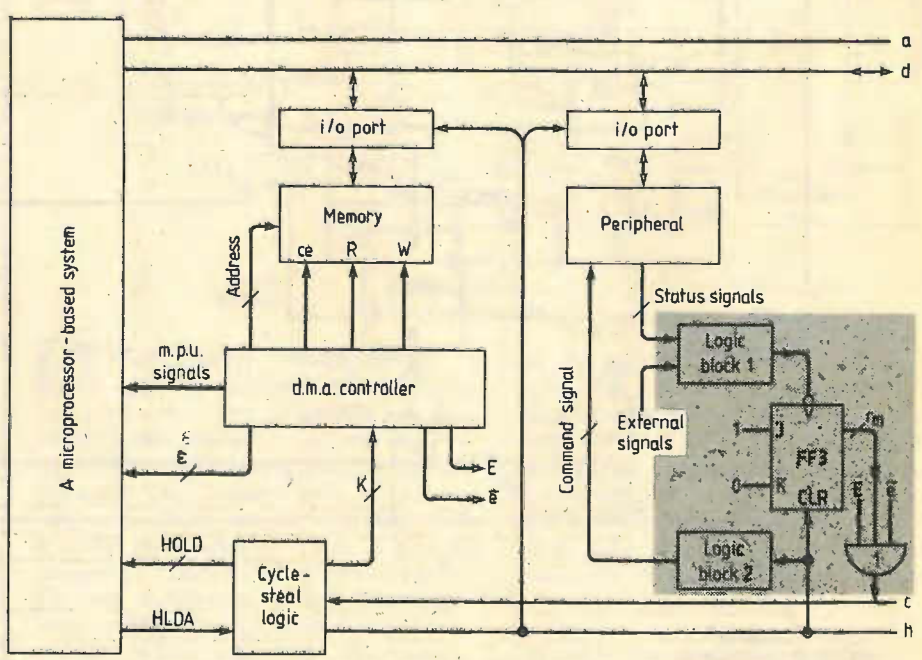


Fig. 2. Block diagram of peripheral interfaces in d.m.a. systems (shaded section).

* Department of Computer Science, University of Calgary, Canada

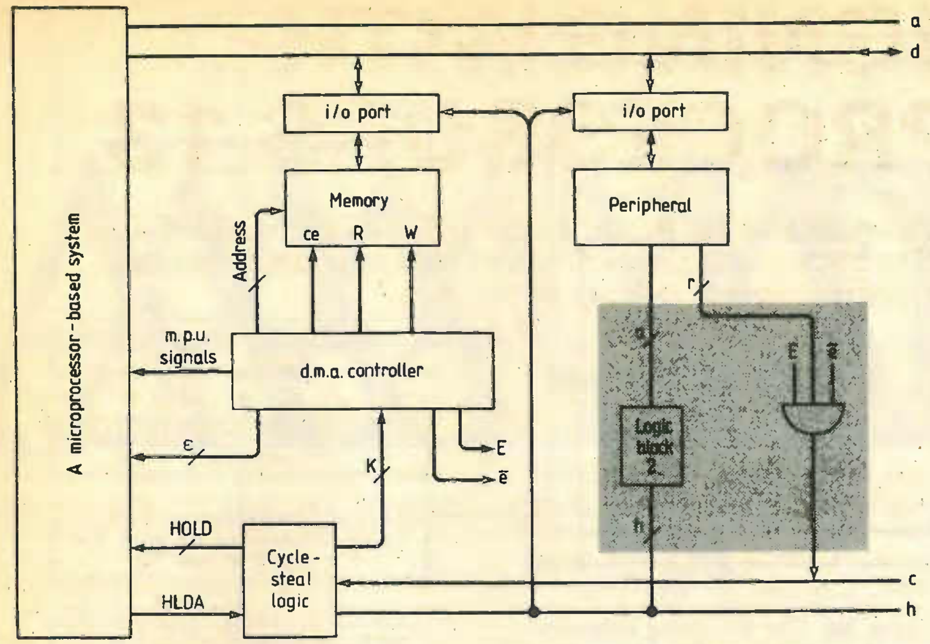


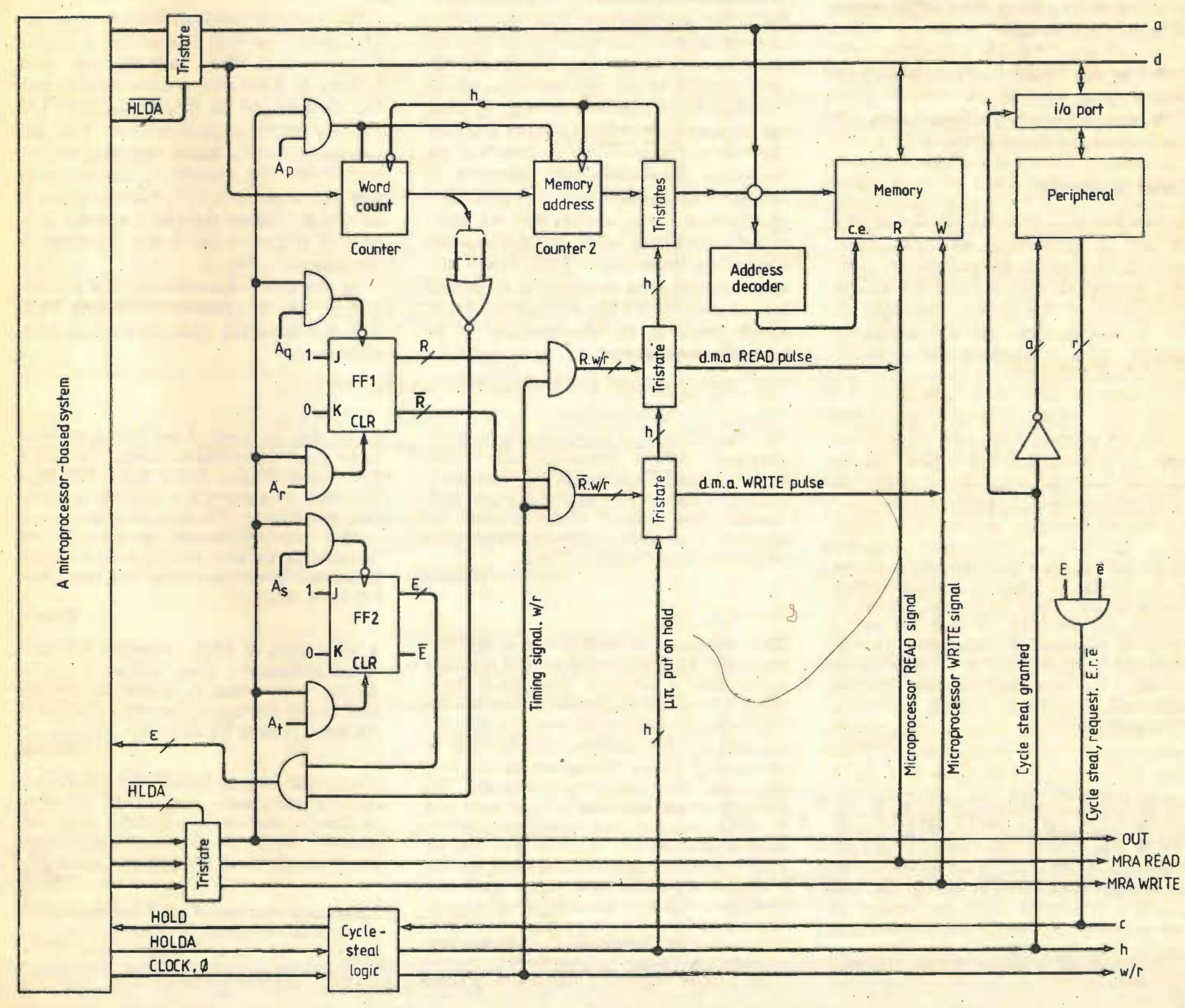
Fig. 3. D.m.a. interface for action/status peripherals.

To prevent the word count from wrapping round, that is changing from all 0s to all 1s, after the last piece of information in our block has been transferred in or out of the main memory, it is necessary to disable the interface before the peripheral becomes ready. Because software responses invariably involve a time lag, depending on system activity at the time and on the level of priority assigned to the ϵ flag, it cannot be used for this purpose. The most straightforward method in such a case is to use signal e in Fig. 3 of the previous article to disable the interface. Signal e, the reader will recall, changes to 1 at the end of the block transfer, that is when the word count becomes zero. Otherwise, the design and implementation of peripheral interfaces in d.m.a. systems, as indeed in all digital systems, is uncomplicated and is carried out using well-defined step-by-step procedures.

The two-wire interface

In the case of action/status devices and no external signals, signal r_n is generated directly by the peripheral, thus eliminating the need for logic block 1 and FF3 in Fig. 2. This reduces the peripheral interface to logic block 2, as shown in Fig. 3.

Fig. 5. Circuit implementation of d.m.a. systems.



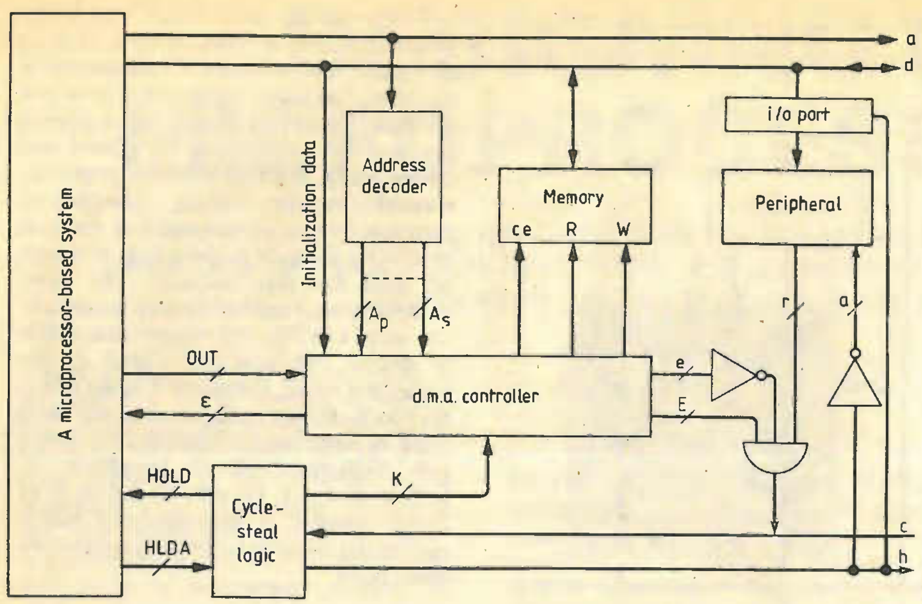


Fig. 4. The two-wire interface.

Now, to avoid possible problems resulting from peripherals being activated while data transfers take place, a peripheral will be activated when a cycle steal is terminated; that is, when the value of h changes from 1 to 0. Since action/status peripherals are activated by pulling their action terminal high, it follows that

$$a = \bar{h}$$

That is, logic block 2 reduces to a single inverter, as shown in Fig. 4.

The detailed circuit implementation of a d.m.a. system is shown in Fig. 5.

D.m.a. software

Because in d.m.a. systems transfers of data between a peripheral and the main memory take place autonomously, software is needed only to send initializing information to the d.m.a. controller in Fig. 1, and to clear the end-of-transfer signal, ε , if it is implemented as an interrupt flag. The initializing information, as we have already explained, consists of the following items

- the starting address,
- the block length,
- the direction of transfer, and
- the 'go' command.

It is transferred into the d.m.a. controller in the following manner. The programmer loads the accumulator with the initial memory address and executes an Out instruction with address A_p. This pulses the load terminal of the two counters, which transfers the accumulator contents (the initial memory address) into counter 1. At the same time, because the two counters are connected in cascade, the contents of counter 1 are pushed into counter 2. The programmer then transfers into the accumulator the block length and executes the same Out instruction. This causes the memory address in counter 1 to be pushed into counter 2, and the value of the block length (held in the accumulator) to be loaded into counter 1.

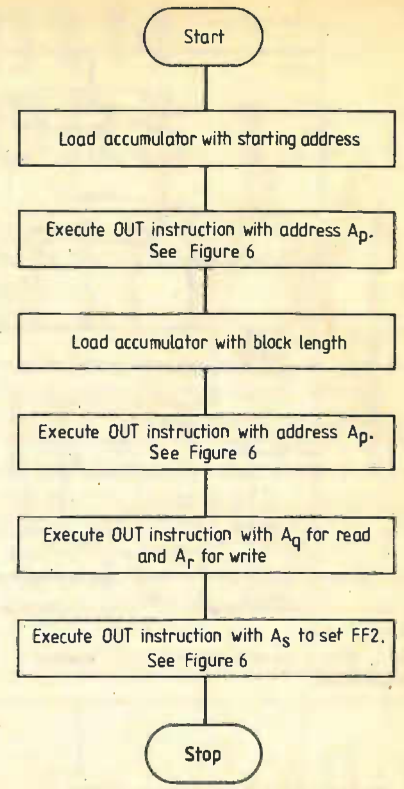


Fig. 6. D.m.a. software.

Next the programmer executes another Out instruction with A_q if the block of data is to be read from memory, and with address A_r if the data is to be written into the memory. In the first instance FF1 is set, and in the second is reset. The 'go' command consists also of executing an Out instruction with address A_s. Execution of this instruction sets FF2, turning signal E on which initiates the block transfer. For ease of reference the d.m.a. software is flowcharted in Fig. 6.

In our case acknowledging the end-of-transfer flag (ε) consists of resetting FF2, that is of executing an out instruction with address A_r. □

LITERATURE RECEIVED

SE labs have issued a new shortform catalogue on the company's range of **instrumentation tape recorders.** There are a large number of recorders for laboratory or field use with a variety of numbers of track and recording speeds up to the SE9000, a 42 track digital recorder. Data Recording Division, SE Labs (EMI) Ltd, Spur Road, Feltham, Middlesex TW14 0TD.
WW401

The Micro Focus Newsletter has been produced to keep readers up to date with the latest COBOL computer language products and developments. COBOL is in increasing use in microcomputers and Micro Focus have announced a COBOL II which may be used on both mainframes and micros. The Newsletter is available free from Micro Focus, 58 Acacia Road, London NW8.
WW402

The 1981/82 Colorado Video short form catalog describes a series of specialised **video instruments** designed for slow scan tv telecommunications, computer/video input and output, measurement and analysis. The UK agents are Anaspec Ltd, Pearl House, Bartholomew Street, Newbury, Berks RG14 5LL.
WW403

RS Catalogue. The latest edition of the catalogue from **RS Components** Ltd has 344 pages and includes a newsheet called Rapid Scan, which is running a competition to find out who is RS's longest standing customer. Anyone who can find an old catalogue, delivery note or invoice from RS (or Radiospares as they were then) could win a magnum of champagne. The catalogue lists as additions to its contents over 75 items including data transmission cables, splashproof connectors, a bubble etch tank for p.c.b.s, a front panel with keyboard and the p.c.bs for a programmable timer, many new displays, a wide selection of tools and accessories and additions to the engineers bookshelf. Details from RS Components Ltd, PO Box 427, 13-17 Epworth Street, London EC2P 2HA.
WW404

Racks. The full range of Series 80 **instrument racks** from Imhof-Bedco Standard Products Ltd, Ashley Works, Ashley Road, Uxbridge, Middlesex, is detailed in a catalogue available from the company. The range includes the new S80/600 racks which meet the latest IEC297 specification. Detailed with the racks is a range of standard accessories such as tops, doors, mobile bases, etc.
WW405

A wide range of TMK **testmeters** including digital multimeters, clamp ammeters and industrial themometers, is detailed in literature from Harris Electronics (London), 138 Gray's Inn Road, London WC1X 8AX.
WW406

The French company Radiall offer a short catalogue of **microwave components,** including transitions, couplers, attenuators, relays and isolators. Write to Microwave Components, Lts, Invincible Road, Farnborough, Hants.
WW407

A forty-page catalogue of panel **meters,** multimeters and test equipment is available from Bach-Simpson, who are at Trenant Estate, Wadebridge, Cornwall PL27 6HD.
WW408

ELECTRONIC ORGAN WITH PIPE ORGAN SOUND

Observation of the waveforms emitted from a pipe organ show that many of them are triangular or closely related in shape. This design uses triangle-wave generators in a simplified organ system to reproduce them, and offers more accurate sound than those organs using sine, pulse, saw-tooth or square wave generators.

by J. H. Asbery,
Ph.D., M.I.E.R.E.

The signals from the waveform generators can be fed by way of an appropriate stop, directly to the output amplifier without any filter. This simplifies the design and the use of high-level signals reduces noise problems.

If a triangle wave is rectified, an open diapason sound is produced. Full-wave rectification produces a triangle wave of twice the frequency which can be used as a 'four-foot flute' stop.

To reduce the cost and complexity of the organ, a multiphonic system [1] has been used which required only six generators, however many alternatives are possible.

An on/off detector to drive the attack/delay modulators has been developed which provides an improved performance.

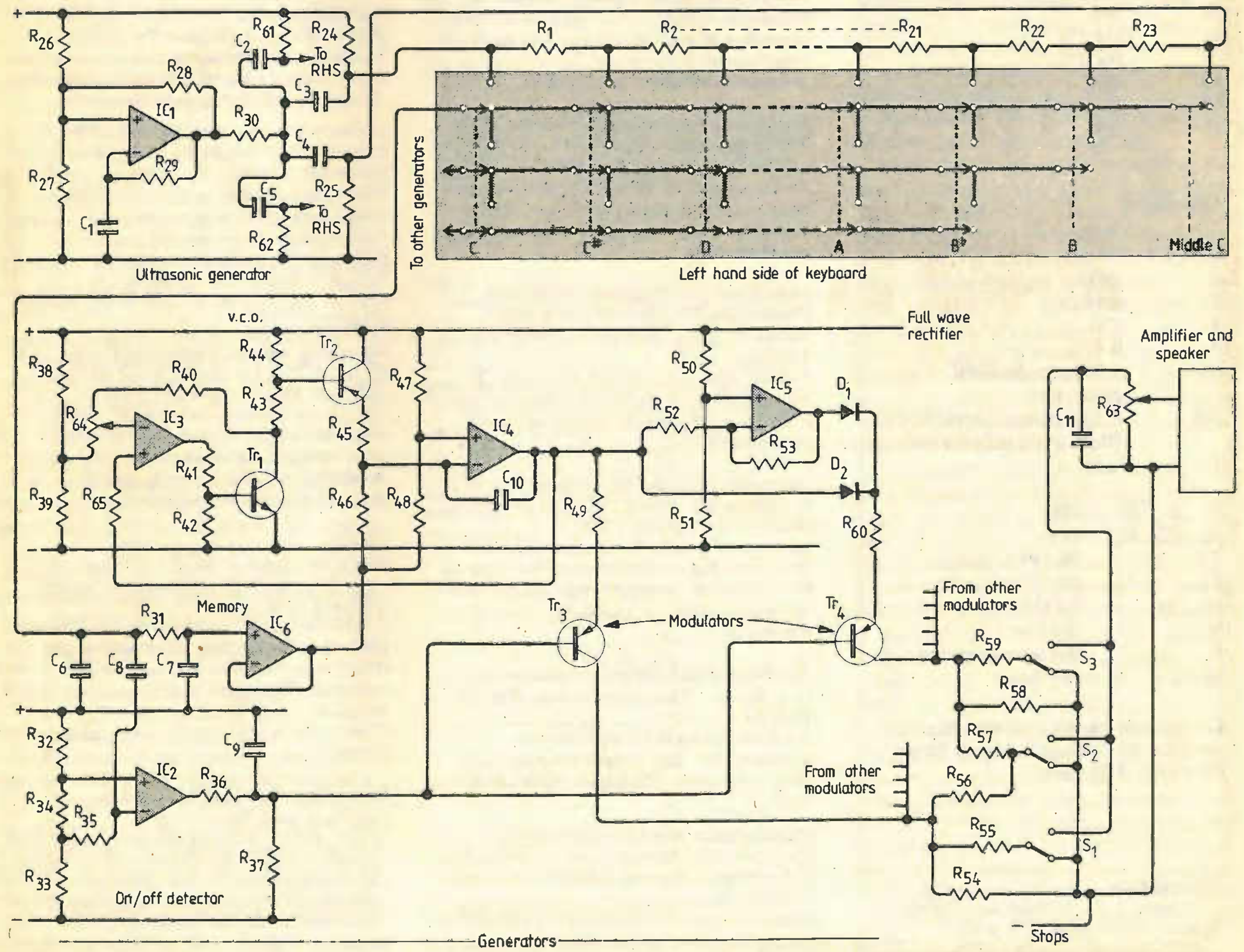
The detector can also be used with other synthesizer circuits to eliminate one pole of the switching system. An ultrasonic signal is superimposed on the d.c. voltage of the resistor chain of the keyboard. When a key is pressed, this signal appears at the input of IC_2 which switches on the modulators at a steady rate and switches them off at a steady rate when the key is released. Collector resistors R_{54} and R_{58} of Tr_3 and Tr_4 can be common to all generators and should be positioned close to the amplifier to avoid pick-up from the common earth wiring.

To produce an 'eight-foot diapason' signal it is not necessary to rectify the original triangle wave. By resistively mixing the original wave with one at half the amplitude of the full-wave rectified signal, the required tone is formed (at R_{56}, R_{57}).

Switching transistor Tr_2 is used in the reverse mode to reduce the voltage drop and improve the v.c.o. linearity.

The capacitor across the volume control (R_{63}) compensates for a loss of sensitivity at low frequencies.

The complete organ is powered by a single +15V supply. The choice of a power amplifier has been left to the constructor.



Complete circuit showing one generator.

Components

Resistors

1 to 23 a set of music scale resistors from 10Ω upwards

24	165 1%
25	162 1%
26, 27, 28	33k
29, 30, 31	10k
32, 33	33k
34	68
35, 36	100k
37	220k
38	20k 5%
39, 40	20k 5%
41	10k
42	1k
43	1.2k 5%
44	470
45	11.5k
46	23k 1%
47	20k 5%
48	20k 5%
49	47k
50	15k
51	15k
52	15k
53	15k
54	10k
55, 56	100k
57	220k
58	10k
59	100k
60	33k
61	165 1%
62	162 1%
63	10k
64	3k preset (tuning)
65	10k

Capacitors

1	2.2n
2, 3, 4, 5	0.1µ
6	220µ
7	0.18µ
8	15n
9	0.47µ
10R	0.025µ (right-hand generators)
10L	0.1µ (left-hand generators) (Both 2½% polystyrene)
11	0.1µ

IC_1, IC_2, IC_3	709
IC_4, IC_5, IC_6	741
Tr_1	BC149 or similar
Tr_2, Tr_3, Tr_4	BC307 or similar
D_1, D_2	1N4148
S_1	(8ft flute)
S_2	(8ft open diapason)
S_3	(4ft flute)

Component kits are available from the author at 87 Oakington Manor Drive, Wembley, Middlesex.

Reference

1. Asbery, J. H. Multiphonic Organ, *Wireless World*, June 1973, p.303.

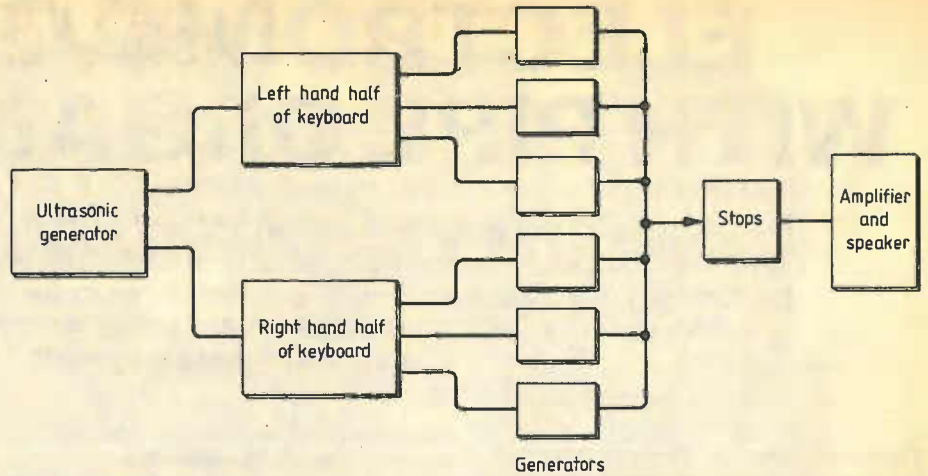


Fig. 1. *Multiphonic organ system based on six triangle-wave generators.*

BOOKS

COMPUTING

Practical Trouble-shooting Techniques for Microprocessor Systems, by J. W. Coffron. 246 pages, hardback. Prentice-Hall, £13.95.
Fault-finding techniques for the hardware of 8-bit systems using 8080, 8085, Z80 and 6800 microprocessors. Final chapter devoted to TRS-80 microcomputer.

The S-100 and other Micro Buses, by E. C. Poe and J. C. Goodwin, 206 pages, paperback. Prentice-Hall, £6.95.
The S-100 and 20 other buses, as applied to most of the popular microcomputers. Includes a description of methods of converting signals on other buses to S-100 signals. Provides pin designations of various bus systems.

Microprocessor and Microcomputer Technology, by Noel M. Morris. 255 pages, hardback/paperbakck. Macmillan £15.00/£5.95.
An introduction to the use of logic devices and microcomputers, starting from very simple description and progressing to programming and application.

Learn Computer Programming with the Commodore VIC, by L. R. Carter and E. Huzan. 100 pages, paperback. Hodder and Stoughton, £1.95.
A short course in the use of Basic on the VIC microcomputer. A number of applications and programs are given, and there are problems (with answers).

Microelectronics and Microcomputers, by L. R. Carter and E. Huzan. 232 pages, paperback. Hodder and Stoughton, £1.95.
Rather more general than the previous book, this is intended as an introduction to computing for the business or scientific user, and for those working on industrial control and measurement.

The 68000: Principles and Programming, by L. J. Scanlon. 238 pages, paperback. Prentice Hall, £10.45.
A full description of the 68000 16-bit microprocessor, its capabilities and operation. Many programs are used as illustration in the text.

Microprocessors and Microcomputers, Hardware and Software, by R. J. Tocci and L. P. Laskowski, 404 pages, hardback. Prentice-Hall, £15.70.
Micros introduced in a practical manner. First section is on basics of logic and number systems; second section deals with computer architecture; last part is on programming in machine code and assembly language.

PROPAGATION

Adaptive Array Principles, by J. E. Hudson. 253 pages, hardback. Peter Peregrinus, £13.00.
The design of adaptive aerial arrays, which automatically present nulls in their polar diagrams to sources of noise. Such aerials are used in radar, sonar, communications and radio monitoring.

Wave Propagation Theory, by J. R. Wait. 348 pages, paperback. Pergamon Press, £22.50.
Primarily on electromagnetic wave propagation in, on or about the earth, but methods described can also be applied to acoustic waveguides.

Aperture Antennas and Diffraction Theory, by E. V. Jull. 173 pages, hardback. Peter Peregrinus, £27.00.
The analysis of radiating apertures, using two complementary techniques. One is the Fourier relation between aperture field and far-field pattern, giving results for the forward radiation. Second method is based on diffraction at the aperture edge, and can be used for rear and side radiation.

Microstrip Antenna Theory and Design, by J. R. James, P. S. Hall and C. Wood. 290 pages, hardback. Peter Peregrinus, £31.00.
Design and fabrication of flat plate, 'printed' microwave aerials, with a resumé of recent advances and a chapter on trends and possible developments in the future. An appendix compares microstrip materials.

VIDEO

Video Handbook, by R. V. Van Wezel, edited by G. J. King. 403 pages, hardback. Newnes Technical Books, £19.90.
Television, video recording on tape and disc, audio and tv production, measurements and descriptions of some typical commercial equipment. Written for the video amateur and technician, using a practical approach. Includes information on building a monochrome tv camera.

Home Video Yearbook 1982. 323 pages, paperback. Link House, £7.50.
In three parts. Firstly, hardware concerned with television reception and video recording, prices and suppliers; secondly short descriptions of commercially available video tapes; thirdly, lists of addresses of manufacturers and tape suppliers.

DISC DRIVES

Read/write head assemblies involve aerodynamic, mechanical and electro-mechanical techniques and are the most critical aspect of disc-drive design. But an equally important aspect of the system is how serial data is stored and recalled on a magnetic medium moving at high speed using a single low-mass head. These subjects form this chapter.

by J. R. Watkinson

As previously stated, hard discs have a thin coating of magnetizable material and rotate at high speeds. Readers familiar with other magnetic recording systems will realize that ideally, the read/write head will be forced against, or at least touch, the recording medium. But because of the speed at which the disc rotates and the fragility of the medium, a gap is essential. Therefore, the head is designed to float, or 'fly', on the layer of air rotating with the disc. Consequently, the head is of low mass, so the gap between head and disc can be kept constant over the whole surface of the disc and a small degree of warping can be compensated for. Figure 1 outlines the read/write head's structure.

The magnetic head is carried by the slipper and consists of a permeable core with a coil wound round it. A paramagnetic barrier on the head core forces the flux out of the head onto the medium. Reluctance of the magnetic circuit depends mainly on the air gap between the head and the disc so the write flux is a function of the flying height. The air gap limits the recording wavelength to about ten times that of the flying height.

Slippers. Current 'state-of-the-art' slippers fly at less than 20 micro-inches (0.5 micron) above the disc. It is obvious that the lower the flying height, the more efficient reading and writing becomes, but what isn't perhaps so obvious is that the major design problem is making the slipper fly low enough. Lift rises rapidly as the separation reduces so to get the head closer to the disc, some of the lift has to be dumped. Early slippers had two small bleed holes, as shown in Fig. 2(a) to dump lift. These slippers had a flying height of around 100 micro-inches. Figure 2(b) shows a second generation slipper, with a large longitudinal bleed groove, designed for flying heights of about 50 micro-inches. The third example, Fig. 2(c), is designed for use below 20 micro-inches and has substantial bleed grooves and vestigial working surfaces. Although the surface of this slipper appears flat to the naked eye, it is actually formed to a high degree of accuracy in a compound curve.

Suspension. The slipper is mounted at the end of a rigid cantilever sprung toward the medium. The force with which the head is pushed toward the disc by the spring is equal to the lift at the flying height for which the head is designed. Because of the spring, the head may rise and fall over small warps in the disc; it would be virtually impossible to manufacture discs flat enough to allow this feature to be dispensed with. As the slipper negotiates a warp it will pitch and roll, in addition to rising and falling, but it must be prevented from yawing. Downthrust is applied to the slipper at its aerodynamic centre by a spherical thrust button and the required degrees of freedom are provided by a flexural gimbal.

The mass of the head/cantilever and the spring compliance have a natural resonance which must be set away from expected warp frequencies. Some cantilevers are fitted with synthetic-rubber dampers to control unwanted resonances.

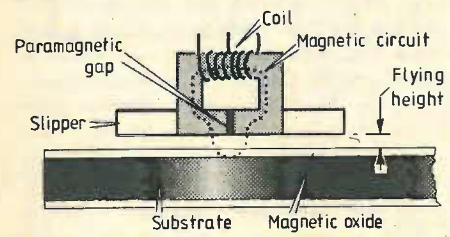


Fig. 1. *An outline of the read/write head in relation to the disc. The slipper carries the head and is aerodynamically designed so that it flies on the air rotating with the disc.*

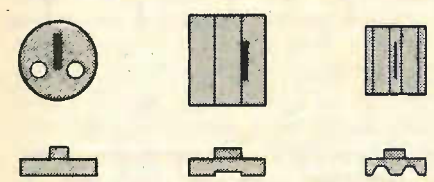


Fig. 2. *Three generations of slipper design. The first generation, shown at (a), had two bleed holes to reduce lift and flew at around 100 micro-inches above the disc. A subsequent design, (b), had a longitudinal bleed groove and flew at around 50 micro-inches. This was superseded by the current head, (c), with substantial bleed grooves for flying heights of less than 20 micro-inches. The head shown in (c) has a compound curve on its working surface which aids aerodynamics but is invisible to the naked eye.*

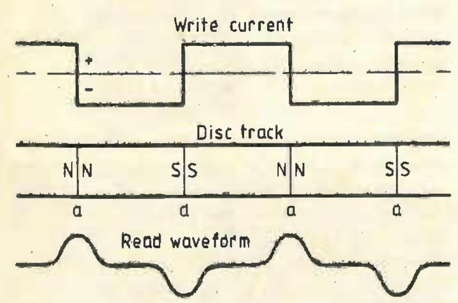


Fig. 3. *In digital recording the polarity of the medium, either N-S or S-N, is controlled by the direction of the write current. Flux reversal, at points marked a, are referred to as transitions and determine the read waveform.*

Other essentials of the cantilever are the head separating ramp, which lifts the head clear of the disc as the positioner retracts, and some receptacle for an adjusting tool to align all of the heads to the same distance from the spindle at a given cylinder.

Handling and setting head assemblies requires care and skill; in some cases skin acid from a fingerprint is sufficient to etch the slipper surface and destroy its aerodynamic contour.

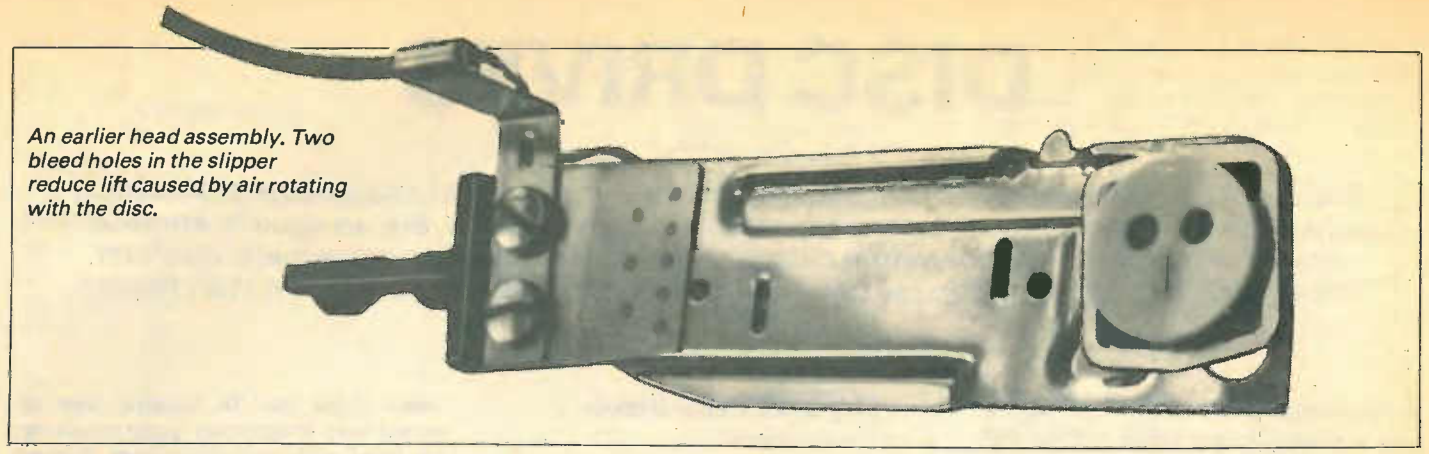
Encoding techniques

With the exception of some non-interchangeable disc drives, only one head is active at any one time. A production tolerance exists between the actual lateral position of the head gap and the ideal, and this dimension may be several wavelengths at the densities used. As a result it is not generally possible to use parallel encoding in disc drives. This constraint largely defines the encoding techniques used.

As in all modern digital recording, the medium has only two states of magnetization, N-S and S-N. Devices have been made using the unmagnetized state, but these must be considered obsolete. The write process consists of supplying sufficient current to almost saturate the medium first in one direction, then the other. No erase process is necessary, as writing to saturation will erase a previous recording. Some heads do, however, have erase poles, the use of which will be detailed.

The output voltage from a read head is proportional to the rate of change of flux, hence an output pulse will only be obtained at the point where the write current changes direction, i.e. at a transition. Figure 3 shows that the pulses alternate in polarity. The pulse amplitude is a function of the cylinder address, as the relative speed of the outer cylinders is higher.

Data to be written enters the write circuitry as serial binary with a separate clock. Encoding consists of merging these two signals into one channel in such a way that they can be subsequently separated. Perhaps the simplest form of encoding is to reverse the write current every time the data is a binary one. It can be seen from Fig. 4(a) that this approach is of no use in a single channel, as when successive zeros occur, it is not possible to reconstitute the clock.



An earlier head assembly. Two bleed holes in the slipper reduce lift caused by air rotating with the disc.

Figure 4 also introduces the concept of the 'bit cell', i.e. the time taken to record one bit. In a simple encoding system, there must be at least one transition per bit cell to carry the clock. Figure 4(b) shows a popular encoding technique, where each bit cell begins with a clock transition, and may or may not contain a further transition, depending on whether the data bit is a one or a zero. As the presence of the second transition doubles the recording frequency, the technique is known variously as f.m. or double-frequency recording. Data separation can be very simple, provided the signal-to-noise ratio is adequately high. The signal-to-noise ratio is determined not only by intrinsic medium noise and the electromagnetic environment, but also by the accuracy of the positioner. Consider the example in Fig. 5(a). Originally, data is written along path A, but positioner inaccuracy means that new data is being written along path B. Subsequently a read may take place along path C, where it will be seen that the read signal is degraded by the previous recording. The solution to this problem is to incorporate two erase gaps in the head, which erase a small area either side of the new data *after* writing. In Fig. 5(b) it can be seen that this process protects the data with a margin of undirectionally magnetized oxide. The process is called 'tunnel erase' or 'side trim', and is generally employed on drives with relatively simple positioners. Such devices usually have low recording densities and accordingly a generous flying height, giving them the advantage that they can be used reliably in environments that would normally be considered unsuitable.

F.m. is easy to decode, but it is also fairly extravagant with transitions. Any encoding method in which the number of transitions per data bit can be reduced has to be an improvement, because for a given flying height, and hence a given minimum wavelength, a greater data density is possible.

In the next generation of read electronics, it is possible to relax constraints on the clock information through phase-locked-loop techniques. With this approach, it is acceptable for a bit cell to contain either clock information or data but both are not necessary. The read clock comes from a p.l.o. which continues in the absence of a transition at clock time, and which corrects its own frequency by continuously comparing its own phase with that of data or clock transitions. In Fig. 4(c) it can be seen that the write current is reversed at the bit-cell centre for a one, and that the problem of successive zeros is handled by reversing the write current at the bit-cell boundary. It is interesting to compare the number of transitions required with the example of Fig. 4(b). On reading the data, the p.l.o. can be used to open a 'time window' at the centre of the bit cell, so that only transitions corresponding to a binary one can pass through. Obviously, the system only works if the p.l.l. is synchronized, so a series of zeros, or preamble, is used before each block to allow the loop to lock. A unique synchronizing pattern delineates where actual data begins. This phase-locked data-recovery technique is used with modified-frequency modulation encoding (or Miller encoding) and allows the arrival time of read pulses to be predicted, and therefore noise pulses to be rejected. This means that a smaller s-to-n ratio can be tolerated than with f.m. encoding, allowing tunnel erase to be dispensed with. In any case, drives employing the m.f.m. technique are likely to have more accurate positioners.

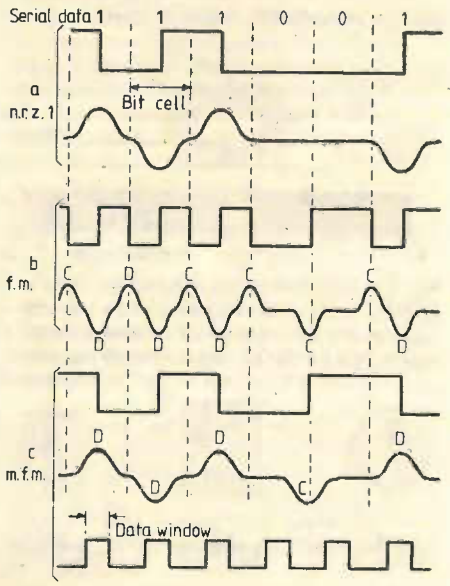


Fig. 4. Three data-recording methods compared. At (a), n.r.z.1 (modified non-return-to-zero) information is of little use on single-track recording apparatus as clock information cannot be carried. In 'f.m.' recording, (b), a clock transition is always present at the bit-cell boundary. The presence of a data '1' causes an extra transition at the bit-cell centre. In m.f.m. recording, shown at (c), a data '1' causes a transition at the bit-cell centre but the only other transitions are at the bit-cell boundaries between successive zeros. Both types of transition are used to synchronize a p.l.l. which opens a 'data window' at the bit-cell centre through which only data '1' pulses are read.

Where f.m. requires signal-to-noise ratio, m.f.m. requires minimum phase errors, if the phase-locked data recovery is not to be upset. In Fig. 6, a head is depicted reading closely packed transitions. Owing to the airgap between the head and the medium, pulses generated tend to run into one another such that the waveform peak positions do not correspond to the actual position of the transitions. The phenomenon is referred to as peak-shift distortion, and is overcome by introducing opposing timing changes during the write process. This technique, precompensation, artificially advances transitions subject to delay on reading, and delays advanced transitions by taking a running sample of (usually) four data bits, and decoding the patterns to generate different clock times in a tapped delay line. M.f.m. requires a running sample, so the two processes are sometimes combined in one circuit.

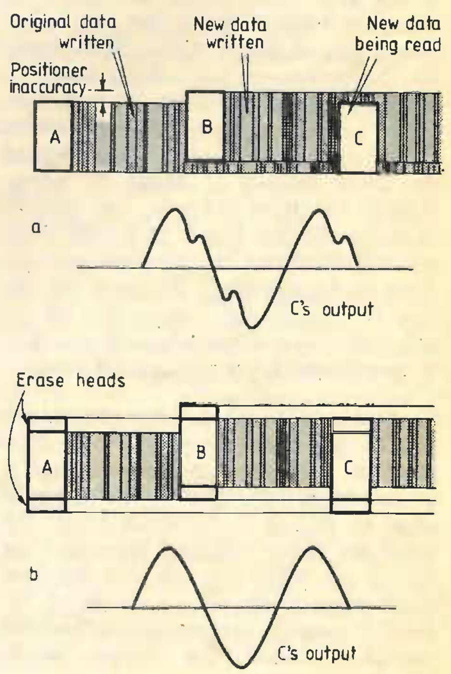


Fig. 5. In (a), track B has been written over track A, but through wide tolerances on the positioner repeatability, some of the original data remains at the edge of path B. If the new data is read while the head travels the same path it did when the original data was written, remaining original data will be read together with the new data, hence the signal-to-noise ratio will be degraded. At (b), the problem is solved by including two erase heads, one at either side of the write head, so that wherever data is written, any original data at either side of the track will be erased.

Recently, a different approach to high density recording has been developed. Central to this approach is that transitions are not permitted at successive active edges of the write clock. Figure 7(a) shows that the four combinations of any two data bits may be expressed as three-bit codes which do not contain successive 'ones'. There are, however, four combinations of adjacent pairs of bits to violate the rule, Fig. 7(b). In these cases, the six bits are substituted by alternative bit patterns which must follow certain conditions; firstly, that the substitution contains no adjacent ones, secondly that the substitution ends in a zero so that no subsequent data can violate the rule, and thirdly the position of the ones is chosen to generate transitions at sequential integer multiples of the write-clock period. Fig. 7(c) shows that the highest recorded density results from a data stream of 0011's, and that this requires only six transitions for eight data bits. At maximum density, m.f.m. requires one transition per bit, so the relative efficiency is 8/6 or 33% greater. Fig. 7(c) also shows that much of the time the recorded density is below the maximum, and that seven even steps exist in the periods between any two transitions. This evenness allows effective phase-locked noise rejection to be employed, as the arrival time of readback pulses can be accurately predicted. In addition, precompensation is only required when changing to and from the highest density, as at all lower densities the transitions are far enough apart to make peak-shift distortion insignificant. This recording technique is known as 2/3 (pronounced "two three") for obvious reasons. It is difficult to imagine a method which would achieve a significant improvement in efficiency over it. Encoding is performed by a p.r.o.m. which takes in a running sample of data in the same way as m.f.m. Similarly, reading requires phase-locked circuitry, with a further p.r.o.m. containing the reverse truth table to the encoding p.r.o.m.

Circuits

The same head is used for both reading and writing, and as stated, usually only one head is active at one time. The circuits involved in reading, writing and head selection come together at the read/write matrix where the flexible head cables plug in. It can be seen from Fig. 8 that the centre-tapped heads are isolated by connecting the centre tap to a negative voltage, which reverse-biases the matrix diodes. The centre tap of the selected head is made positive. When reading, a small current flows through both halves of the head coil, as the diodes are forward biased. Opposing currents in the head cancel, but read signals resulting from flux transitions on the disc can pass through the forward-biased diodes to become differential waveforms on the matrix bus. During a write, the current from the write generator passes alternately through the two halves of the head coil. Further isolation is necessary to prevent write-current voltages destroying the read amplifier inputs.

Write-current programming. The flying height changes as a function of relative velocity which is governed by the track radius. It is possible to program the write current from the current cylinder-address register such that the write flux remains essentially constant, despite changes in flying height. The number of write-current steps is usually between two and eight across the working surface of the disc, although some drives dispense with write current programming altogether. In Fig. 9, the write current is generated by holding the base of a transistor at a temperature-compensated reference voltage, and by selecting different emitter resistors with transistor switches. As the current source is usually at about −40V, the switches are fed from the drive logic through level shifters. The write current is directed through the head by a pair of transistors in series with the current generator, which are driven in a complementary fashion by a bistable. The purpose of write

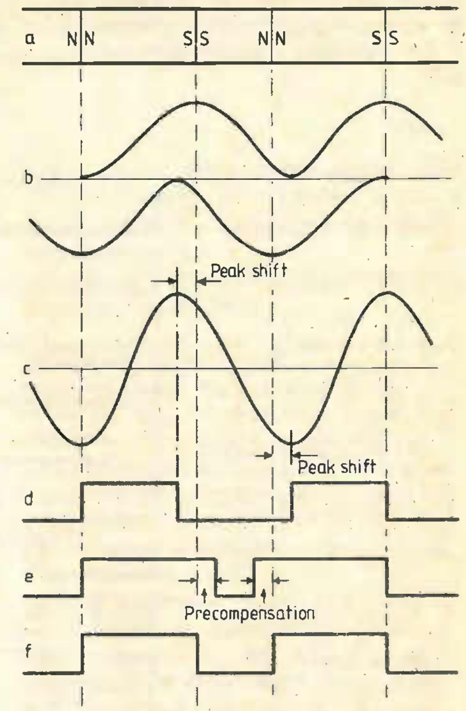


Fig. 6. Timing diagram showing peak distortion and precompensation. (a) shows the flux pattern of an ideal m.f.m. data track, and (b) shows individual read pulses from each transition, which are spread out because the head is not in contact with the medium. Peaks of the closely packed transitions are moved apart as shown in the summation of the waveforms of (b) at (c). Phase errors in the binary signal from the peak detector are shown at (d). To compensate for these errors, the write waveform is as shown in (e) and the adjusted peak detector output is shown in (f).

A modern head assembly. This type of head is designed to fly at around 50 micro-inches above the disc.

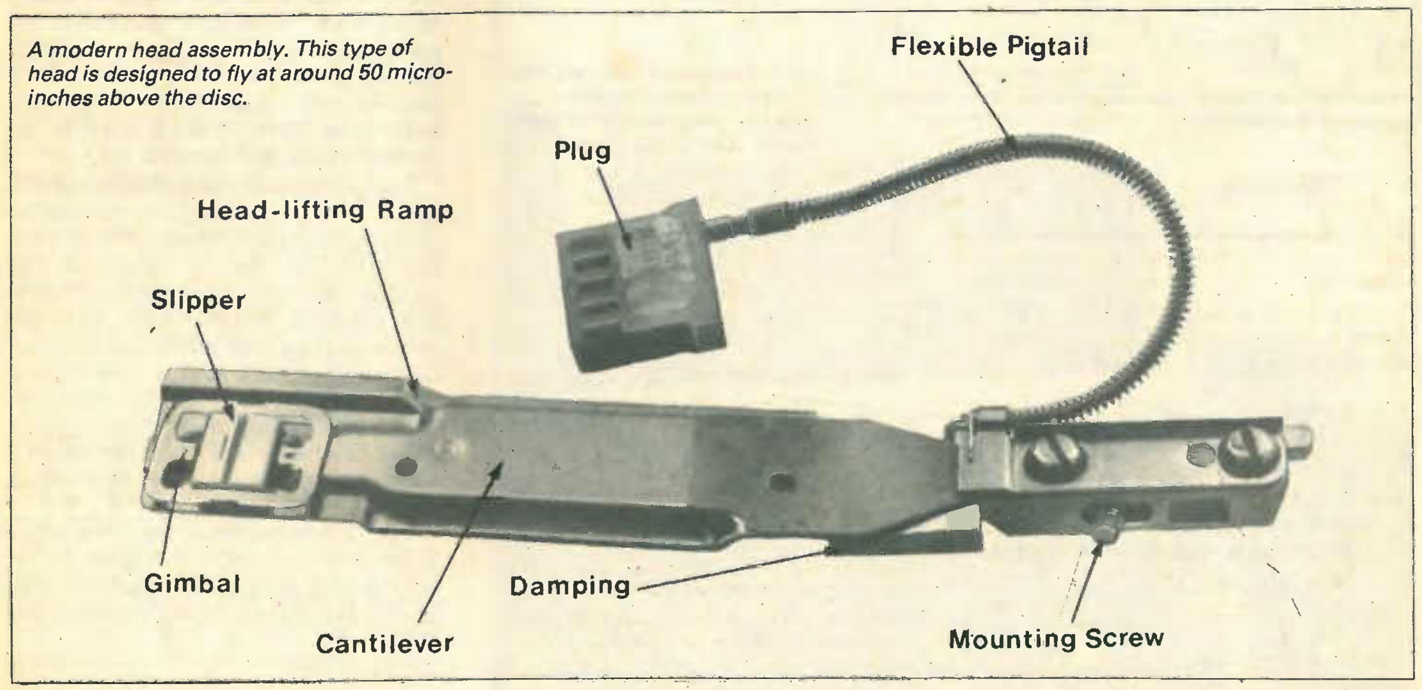


Fig. 7 (a). Two bits can be expressed as three code bits without successive transitions. In (b), adjacent pairs can break the encoding rule and in these cases, substitutions are made. Write current waveforms for seven different data streams using 2/3 encoding are shown at (c). The time steps between transitions are uniform, allowing phase-locked data recovery in the presençe of noise. A maximum of six transitions are required for eight data bits; when compared with m.f.m. encoding, this gives a saving of 33%.

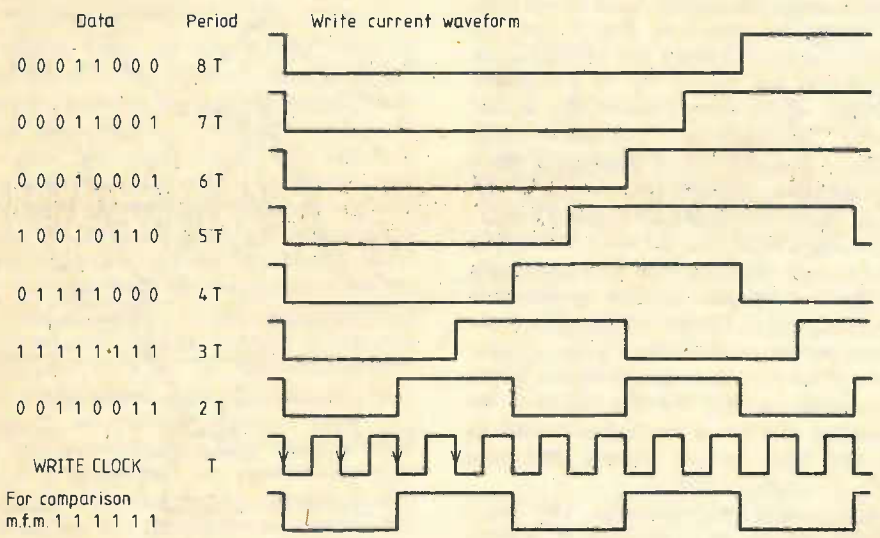
(a)

Data	Code
00	101
01	100
10	001
11	010

(b)

Data	Illegal code	Substitution
0000	101101	101000
0001	101100	100000
1000	001101	001000
1001	001100	010000

(c)



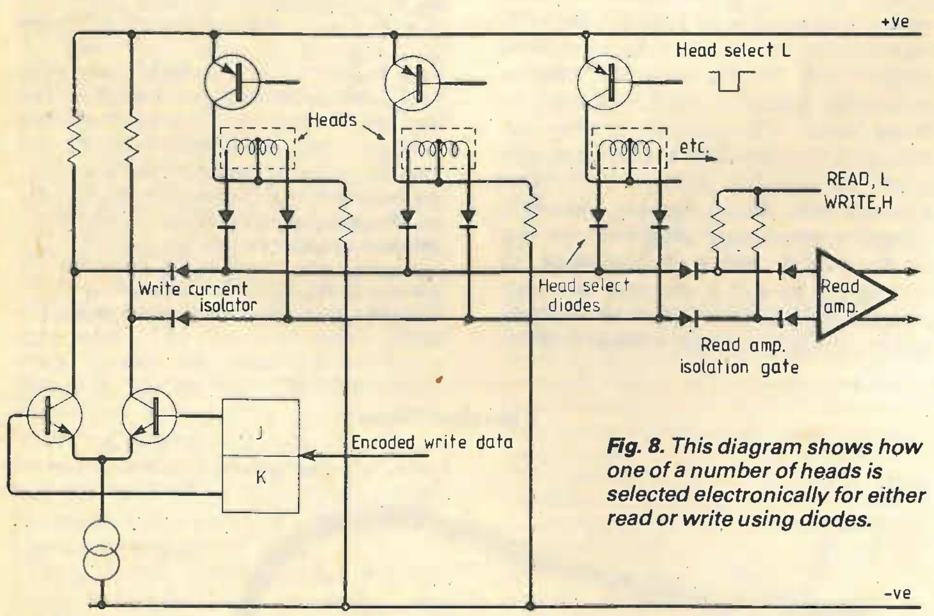


Fig. 8. This diagram shows how one of a number of heads is selected electronically for either read or write using diodes.

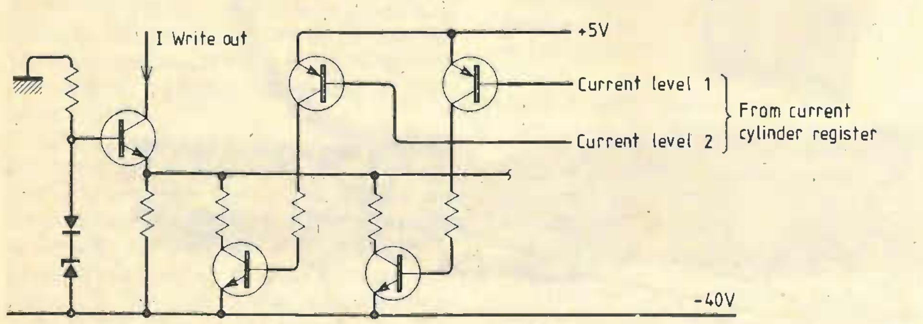


Fig. 9. A programmable write-current generator. Write current is generated by holding the base of a transistor at a temperature-compensated reference voltage, and by selecting different emitter resistors using transistor switches.

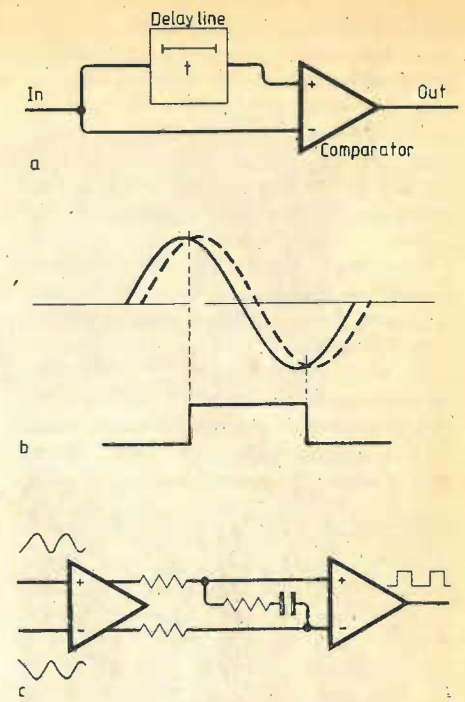


Fig. 10 (a). A simplified delay-line peak detector, and associated waveforms (b). A differential phase-lead peak detector is shown at (c).

encoding is to decide at what time to clock the bistable so that a transition is written by the current reversal.

Reading. When not actually writing, the write-current generator is turned off and the write-isolation diodes are reverse biased. The read isolation gate is enabled, allowing the differential read signal into the read linear amplifier. This amplifier raises the amplitude of the read signal to a constant level suitable for data recovery, and filters out unwanted signals. To this end the linear amplifier often contains both bandpass filters and an a.g.c. loop. In some cases, the linear amplifier's input and the a.g.c. capacitor are shorted during the address mark to stabilize the gain in the shortest possible time after entering a block. The address mark is a short section of the track preceding a data block and contains no transitions. A.g.c. squelch is released as the block is entered, and the linear-amplifier gain reduces from maximum using the fast attack slope of the forward-biased signal rectifier.

The constant-amplitude read signal now passes to the peak detector, as the position of the signal peaks corresponds to the position of the transitions on the disc. In Fig. 10(a) an analogue waveform is compared with a delayed version of itself. The comparator changes state at the signal peak. A differential version of this type of peak detector is shown in Fig. 10(c). The principle holds equally well if one signal is phase advanced, and thus the delay is sometimes substituted by the RC network shown.

The detected signal is fed to an appropriate data separator, which splits the signal into data and clock information to pass to the deserializer, which recreates data words.

To be continued □

16-CHANNEL DATA ACQUISITION SYSTEM

A 4½-digit, 16-channel data acquisition system (d.a.s.) is described which functions as a talker-listener on the IEEE-488 bus (GPIB). It uses a 4½/5½-digit a-to-d subsystem, AD7555, with ± 1.9999V full scale, as an easy interface with the Fairchild 96LS488 GPIB circuit.

by Pat Hickey

Analog Devices, Limerick, Ireland

Figure 1 shows a block diagram of the GPIB 16-channel data acquisition system. The 96LS488 connects directly to the IEEE bus and controls all the other sections. (For clarity, a number of the control signals have been omitted.) A set of eight transceivers determines the flow of information (talking or listening) and the 'listen decode' circuitry sends the appropriate address to the 16-channel multiplexer. On selection of a channel, a start conversion signal is sent to the AD7555 a-to-d converter.

When conversion is complete, a service request is transmitted to the 96LS488, which in turn interrupts the IEEE bus: the bus can then interrogate the device for status or data information. Status information includes the last channel selected and the conversion status, while data information consists of a 4½-digit b,c.d.-encoded representation of the analogue voltage.

The IEEE bus in brief

A full description and specification of the GPIB system is published in the IEEE document "IEEE Standard Interface for Programmable Instrumentation", IEE Std 488(1978), which should be referred to for a fuller explanation.

GPIB communication lines consist of eight data lines, three hand-shake lines, five control lines and eight ground lines, as shown in Fig. 2 (the IEEE connector). **Data lines** ($\overline{D1}$-$\overline{D8}$) contain the bidirectional data or information and are true low signals.

Handshakes. $\overline{NRFD}$, $\overline{DAV}$ and $\overline{NDAC}$ are the three bidirectional handshake signals. $\overline{DAV}$ (Data Valid) is pulled low by a talker when the data has been placed on the bus, which tells the listener that the data is valid. $\overline{NRFD}$ (Not ready for data) is brought high (or released) by each instrument on the bus: when all the instruments have released it, it acts as an indication to the talker that a data transfer can begin. $\overline{NDAC}$ (Not Data accepted) is controlled by the device receiving the data, a low indicating that the data has not been captured and a high that this has been done. A simplified data transfer sequence is shown in Fig. 3.

A timing sequence starts when the listener brings $\overline{NRFD}$ high (1), saying it is ready to receive the data. The talker places the data on the bus (2), allows it to settle and brings $\overline{DAV}$ low (3), telling the listener that the data is valid. The listener brings $\overline{NRFD}$ low (4), indicating that it is not ready for another data transfer until this transfer is completed. When the data has been processed, the listener brings $\overline{NDAC}$ high (5), saying that it has received the data. The listener responds by taking $\overline{DAV}$ high (6) (data is no longer valid) and removing the data from the bus (7). The listener brings $\overline{NDAC}$ low (8), acknowledging this, and $\overline{NRFD}$ high (9), indicating that it is ready for the next data byte. The timing of this sequence is not discussed here, since the 96LS488 IEEE-interface circuit takes complete control of the procedure.

Control. The five control lines are $\overline{ATN}$, $\overline{IFC}$, $\overline{REN}$, $\overline{SRQ}$, and $\overline{EOI}$. The $\overline{ATN}$ (Attention) is asserted only by the controller and, when low, indicates that information on the line is address or control information: it is high when data is being transferred. The $\overline{IFC}$ (Interface Clear) line is asserted low by the controller to reset all GPIB devices.

$\overline{REN}$ (Remote Enable) allows local (i.e. front panel) control of devices if it is allowed to become high. When low it ensures that the controller is in command. $\overline{SRQ}$ (Service Request) is forced low by a talker/listener when it wishes to indicate to the controller that it needs service. $\overline{EOI}$ (End or Identify) can be pulled low by a talker to signify the last byte in a multi-byte transfer.

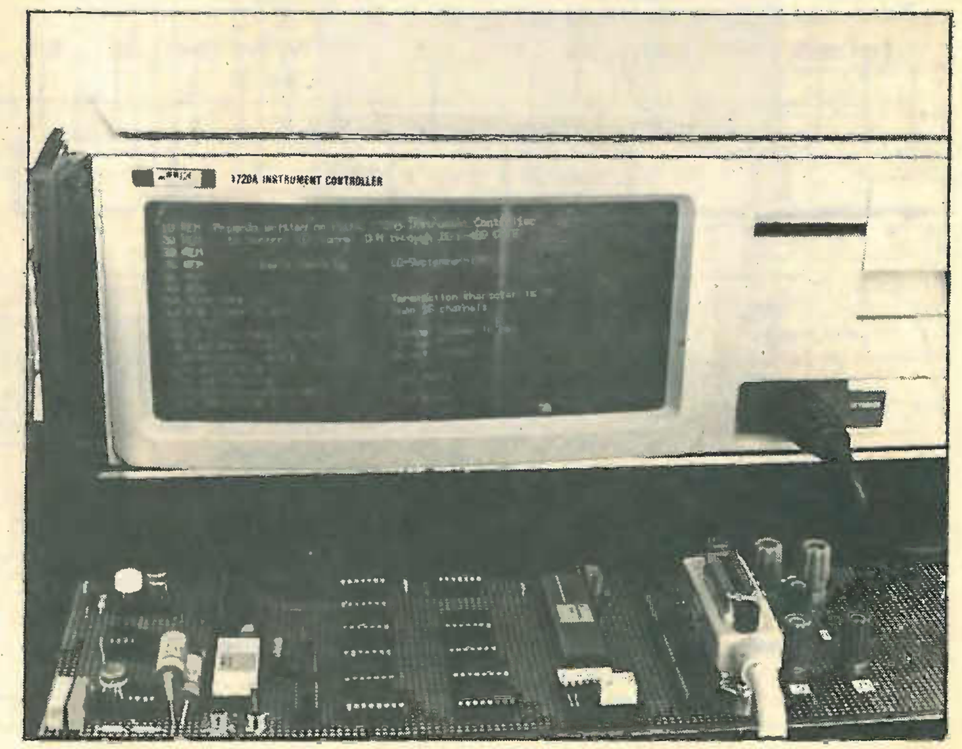
All the aforementioned signals are taken care of by the 96LS488.

96LS488 GPIB circuit

Figure 4 shows a block diagram for the 96LS488, and the following description should be referred both to that and Fig. 7 (full circuit diagram). $\overline{CP}$ is a 10MHz clock which controls all internal timing, and can be generated using a 150Ω resistor and 150pF capacitor connected to an internal Schmitt trigger.

TXST (Transmit Status) and TXRDY (Transmit Ready) signals are used in transferring data from the AD7555 a-to-d converter to the 96LS488, as shown in Fig. 5. When the d.a.s. is requested to transfer information to the IEEE bus controller, the 96LS488 checks that TXRDY is high (meaning a byte is waiting). If it is high, the 96LS488 will read the data and bring TXST high (1), indicating that it has the information. TXRDY is then brought low (2), acknowledging this fact and TXST is brought low (3) again. When the next byte is ready (4), the AD7555 brings TXRDY high (5) and the sequence is repeated.

RXST (Receive Status) and RXRDY



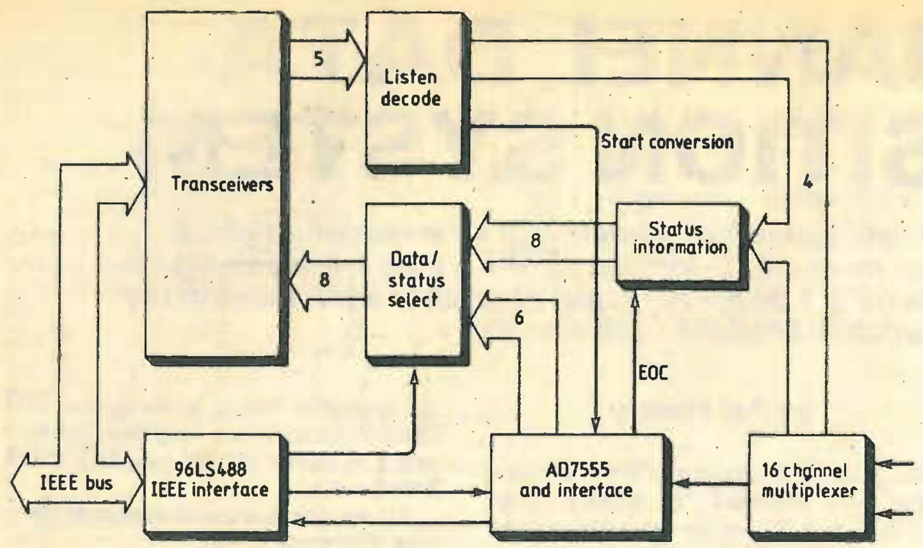


Fig. 1. Block diagram of complete system. 96LS488 interfaces and controls rest of unit.

(Receive Ready) are used as seen in Fig. 6 for transferring data from the 96LS488 to the 16-channel d.a.s. When valid data has been placed on the bus (1), RXST is taken high (2), indicating that the data is valid. When the data has been accepted, RXRDY is taken low (3), indicating that the data has been accepted, RXST is taken low (4), acknowledging this fact, and the data becomes non-valid (5). RXRDY is brought high (5), signalling that it is ready for the next byte of information. In Fig. 7, RXST is inverted and connected to RXRDY, in which case data is transferred at a data rate determined by the bus handshake.

The Drive Bus Output (DRB) signal is low when data is being transferred from the AD7555 a-to-d converter to the IEEE bus, and high when information is being sent to the data acquisition system. In Fig. 6, the signal is used to enable (or disable) a set of transceivers.

TAD (Talk-Addressed) and LAD (Listen-Addressed) are active low when the device is addressed to talk or listen.

RSV (Request Service) is brought low by the AD7555 to initiate a service request interrupt. This occurs when a conversion is completed.

D/S (Data/Status) is held low when data is being transferred to the IEEE bus, or high if status information is being transferred in a serial poll. In this application, it is used to select either data or status information via a data selector (2×74C157)

The STST (Status Status) and STRDY (Status Ready) signals operate similar to the TXST and TXRDY signals when sending status information during a serial poll. STRDY can be formed from an inversion of STST.

RTL (Return to Local Input) is tied high in this application, since the device is operating only in remote control.

CLR issues a negative pulse when the device receives a Device Clear command. This will reset all functions within the device.

TRIG (Trigger output) issues a negative pulse when the device receives a DT (Device Trigger) command. It is not used in this application. The IST (Instrument Status Input) is used in parallel poll enable.

For more information on the above signals see the Fairchild 96LS488 data sheet.

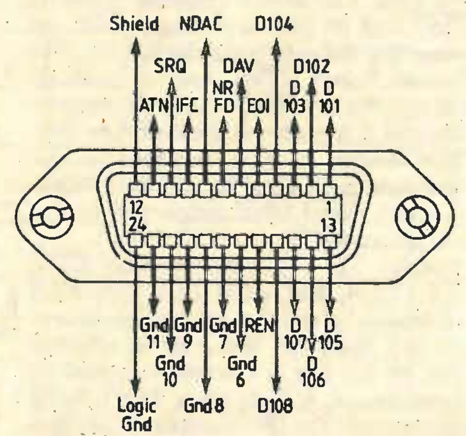


Fig. 2. GPIB communication lines shown in relevant positions on IEEE connector.

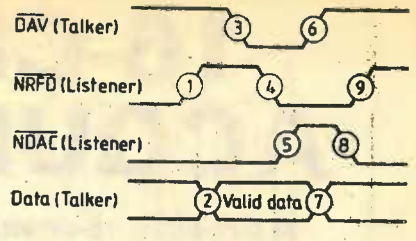


Fig. 3. Simplified data transfer sequence.

Data acquisition system

Figure 7 shows the complete circuit diagram of the data acquisition system. A brief review of each i.c. should help to understand its operation before the more complex timing of the system is discussed.

Circuits $IC_{1,2}$ are quad interface

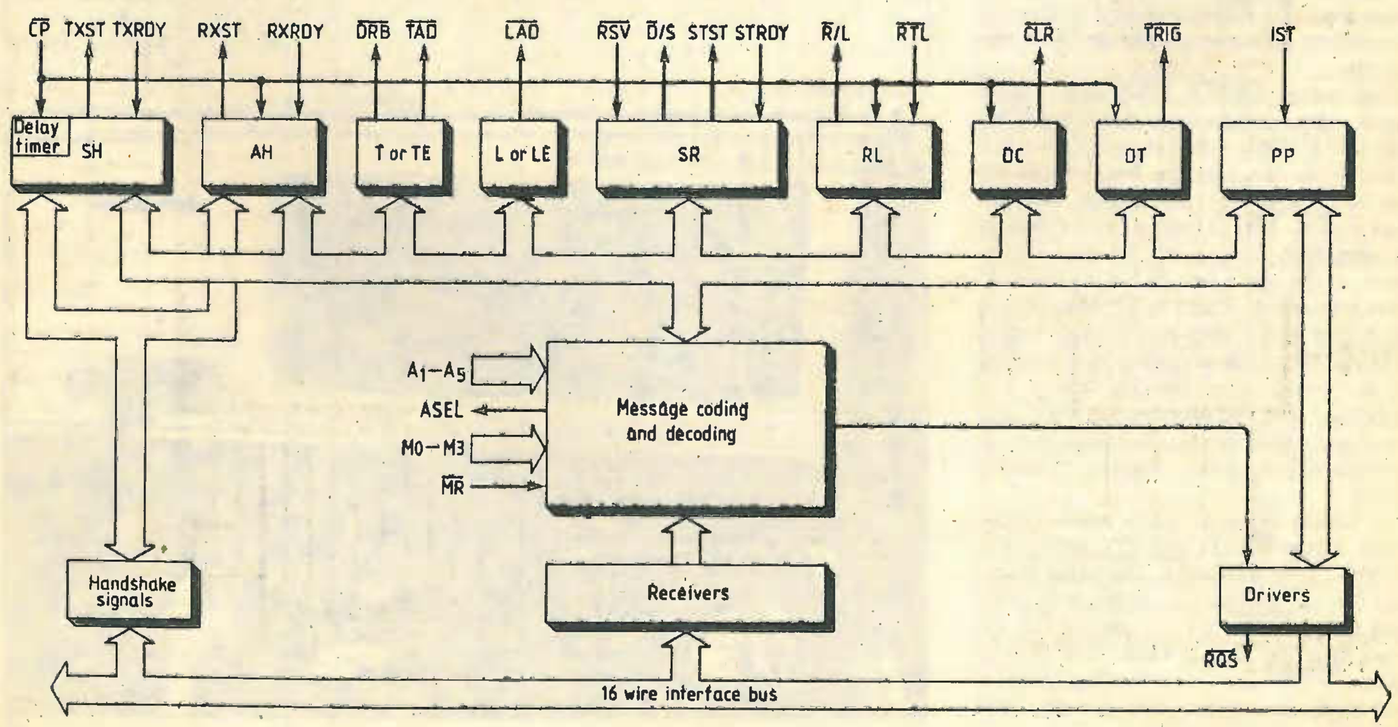


Fig. 4. Functional block diagram of 96LS488.

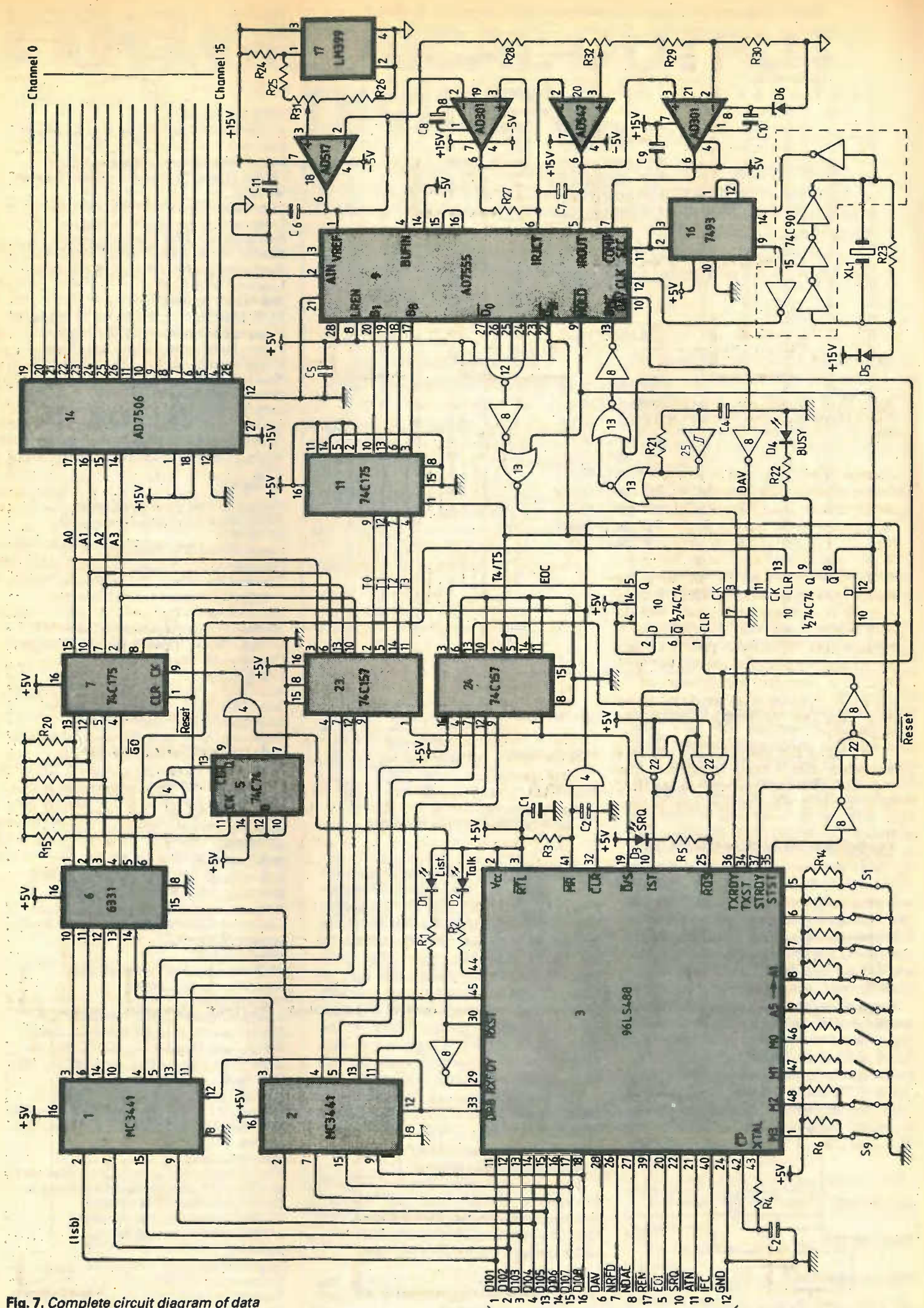


Fig. 7. Complete circuit diagram of data acquisition system.

Table 1. Contents of IC_6 r.o.m. for decoding ASCII information to binary.

R.o.m. inputs (addresses)						R.o.m. outputs (data)					
A 4	A 3	A 2	A 1	A 0		0 6	0 5	0 4	0 3	0 2	0 1
0	0	0	0	0		1	1	1	1	1	1
0	0	0	0	1	"A" (0100 0001)	1	1	1	0	1	0
0	0	0	1	0	"B" (0100 0010)	1	1	1	0	1	1
0	0	0	1	1	"C" (0100 0011)	1	1	1	1	0	0
0	0	1	0	0	"D" (0100 0100)	1	1	1	1	0	1
0	0	1	0	1	"E" (0100 0101)	1	1	1	1	1	0
0	0	1	1	0	"F" (0100 0110)	1	1	1	1	1	1
0	0	1	1	1		1	1	1	1	1	1
0	1	0	0	0		1	1	1	1	1	1
0	1	0	0	1		1	1	1	1	1	1
0	1	0	1	0	"*" (0010 1010)	0	1	1	1	1	1
0	1	0	1	1		1	1	1	1	1	1
0	1	1	0	0		1	1	1	1	1	1
0	1	1	0	1	CR (0000 1101)	1	0	1	1	1	1
0	1	1	1	0		1	1	1	1	1	1
0	1	1	1	1		1	1	1	1	1	1
1	0	0	0	0	"0" (0011 0000)	1	1	0	0	0	0
1	0	0	0	1	"1" (0011 0001)	1	1	0	0	0	1
1	0	0	1	0	"2" (0011 0010)	1	1	0	0	1	0
1	0	0	1	1	"3" (0011 0011)	1	1	0	0	1	1
1	0	1	0	0	"4" (0011 0100)	1	1	0	1	0	0
1	0	1	0	1	"5" (0011 0101)	1	1	0	1	0	1
1	0	1	1	0	"6" (0011 0110)	1	1	0	1	1	0
1	0	1	1	1	"7" (0011 0111)	1	1	0	1	1	1
1	1	0	0	0	"8" (0011 1000)	1	1	1	0	0	0
1	1	0	0	1	"9" (0011 1001)	1	1	1	0	0	1
1	1	0	1	0		1	1	1	1	1	1
1	1	0	1	1		1	1	1	1	1	1
1	1	1	0	0		1	1	1	1	1	1
1	1	1	0	1		1	1	1	1	1	1
1	1	1	1	0		1	1	1	1	1	1
1	1	1	1	1		1	1	1	1	1	1

transceivers (MC3441) and are designed to meet the IEEE standard 488- 1975. The data direction is controlled by the $\overline{DRB}$ output of the 96LS488 (IC_3): When it is low, data is transferred to the bus, and transferred from the bus when $\overline{DRB}$ is high. Switches S_1-S_5 are used to select the address of the device. As an example:- For an address of 16, S_5 is open, while S_4, S_3, S_2 and S_1 are closed. (Address is 10000 = 16). Switches S_6-S_9 are used to select the operating mode of the 96LS488 (the Fairchild data sheet gives more information on this). For a talker/listener on low speed, M0 and M1 are high, and M2 and M3 are low (ie, S_6 and S_7 are open, while S_8 and S_9 are closed).

Since all information is transmitted in parallel ASCII code, it is necessary to decode this to binary. The 6331 (IC_6) is a 32×8 bit r.o.m. which is used for this purpose, whose contents are outlined in Table 1. The address latch, IC_7 (74C175), holds the address of the selected channel, its output being connected to the input of IC_{14} (AD7506), a 16 channel multiplexer,

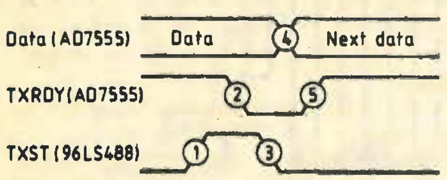


Fig. 5. *Simplified talking sequence.*

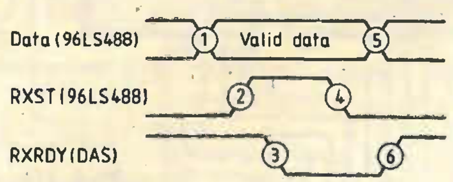


Fig. 6. *Simplified listening sequence.*

which in turn selects the appropriate analogue signal to the a-to-d converter subsystem (AD7555) IC_9. On completion of a conversion, the b.c.d. data is held in internal latches, and can be accessed by control of the DMC pin. The IEEE transmit handshake signals are used to access this information during a readback cycle. A data selector IC_{11} (756157) send 4½ digits and a carriage return to the 96LS488: When $\overline{D5}$ is high, b.c.d. data from the a-to-d converter is selected, and when $\overline{D5}$ is low a CR code is selected.

The hex. c.m.o.s.-t.t.l. inverter (IC_{15}) generates the 4.096 MHZ clock with the crystal, whilst IC_{16} (7493), a 4-bit binary counter, divides this by four, producing a 1.024 MHz clock for the AD7555.

The two multiplexer/selectors ($IC_{23,24}$) are used to transfer either data or status information to the 96LS488. When $\overline{D}$/S is low, data information is selected (T0-T5), and when high the status byte is sent.

The concluding article will continue this circuit description and include a program for scanning 16 channels. □

EVENTS

23/24/25th March
Electro-optics/Laser International '82 UK, at Metropole Convention Centre, Brighton. Details from: Cahners Exposition Group, Cavridy House, Ladymead, Guildford, Surrey GU1 1BZ.

25th March
Computational Techniques in Image Processing, at Queen Elizabeth College, London. Details from: The Meetings Officer, The Institute of Physics, 47 Belgrave Square, London, SW1X 8QX.

30th March/1st April
ETM '82 and Sensors & Systems '82 (Electronic testing and measurement) at Wythenshawe Forum, Manchester. Details from: Trident International Exhibitions Ltd, 21 Plymouth Road, Tavistock, Devon PL9 8AU.

30th March/1st April
CAD '82, (Computer-aided design conference and Exhibition) at Brighton Metropole, Sussex. Details from: IPC Exhibitions Ltd, Surrey House, 1 Throwley Way, Sutton, Surrey SM1 4QQ.

4th-7th April
National Association of Broadcasters, Exhibition, at Las Vegas, Nevada USA.

6th April
Current Research in Magnetism, at the Insitutue of Physics, London. Details from: The Meetings Officer, The Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

12th-15th April
Electrostatics Conference, at St Catherine's College, Oxford. Details from: The Meetings Organiser, Insitute of Physics.

13th-16th April
Basic Electronics for Teachers, at University of Salford. Details from: The Administrative Assistance (Short Courses) Room 110, Registrar's Department, University of Salford, Salford M5 4WT.

20th April
Satellite Development in Broadcasting: M. W. Harman, at Room SG27, University of Aston, Gosta Green, Birmingham at 6.30pm. Details from: The IETTE, 2 Savoy Hill, London WC2R OBS.

20th-22nd April
International Conference on Video and Data Recording (I.E.R.E.) University of Southampton, Southampton. Details from: Conference Registrar, IERE, 99 Gower Street, London WC1E 6AZ.

20th-22nd April
All Electronics Show, at the Barbican Exhibition Centre, London.

20th-23rd April
Communications '82, IEE Conference and Exhibition at the National Exhibition Centre, Birmingham. Details from: IEE Conference Department, Savoy Hill, London WC2R OBL.

22nd April
Microprocessor in Building Services: M. W. Harman, at University of Strathclyde, Glasgow at 6.30pm. Details from: IEETE, 2 Savoy Hill, London WC2R OBS.

23rd-25th April
The Computer Fair, at Earls Court. (Sponsored by *Practical Computing* and *Your Computer*) Details from: Exhibition Manager, IPC Exhibitions Ltd, Surrey House, 1 Throwley Way, Sutton, Surrey.

28th April
Propulsion Research – Impact on Fuel/Emergy Conservation, at Hawthorns Hotel, Woodland Road, Bristol at 7.30pm. Details from: IEETE, 2 Savoy Hill, London WC2R OBS.

SYMMETRICAL-OUTPUT DIVIDERS

Expanding on February's article, the author first shows how further hexadecades may be added to the previously described binary-programmable counter. A basic b.c.d.-programmable counter follows and to conclude, details of how to add further decades. These circuits are designed to accept and provide equal mark-to-space ratio digital signals, and are programmable in integer steps. As frequency-dependent components are not used, the speed of each circuit is only limited by the speeds of the logic devices used.

by Gerard Girolami and Philippe Bamberger

For dividing in the range $16 \leq N \leq 256$, whether or not N is a prime number is important. If N is not prime then $N = N_1 N_2$ and the divider can be made using two programmable divide-by-1-to-16 circuits described in the previous article. These may be connected either asynchronously or synchronously, the latter method being the fastest. To divide synchronously it is necessary to enable the 74C163 inputs as shown in Fig. 9. To divide asynchronously, the output of the divide-by-N_1 circuit has to be connected to the input of the divide-by-N_2 circuit. The latter solution is not much simpler than connecting the dividers synchronously so the sacrifice in speed is usually unwarranted.

On the other hand, if N is prime, this solution no longer applies and it is necessary to design a programmable divide-by-1-to-256 counter using a slightly different approach. The procedure is identical to that used for the 1-to-16 programmable counter except that the relationships in equations (1), (2) and (3) given in the previous article must be changed to force the counter to 'oscillate' around the transition between counts 127 and 128. The new equations are:

$$L + D = 255 = 2^8 - 1 \quad (4)$$

$$D - I/2 = 127 \text{ if } I \text{ is even} \quad (5)$$

and

$$D - (I + 1)/2 = 127 \text{ if } I \text{ is odd.} \quad (6)$$

These relationships can again be implemented using two binary adders as shown in Fig. 10.

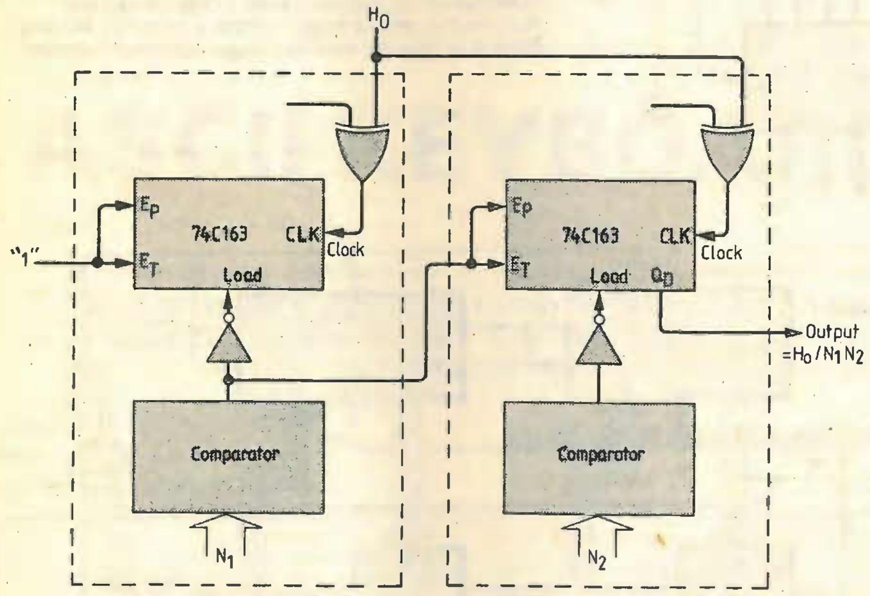


Fig. 9. Synchronous cascading of programmable divide-by-1-to-16 circuits. H_0 is the input and N_1N_2 is the divisor, N. This method only applies where N is not prime.

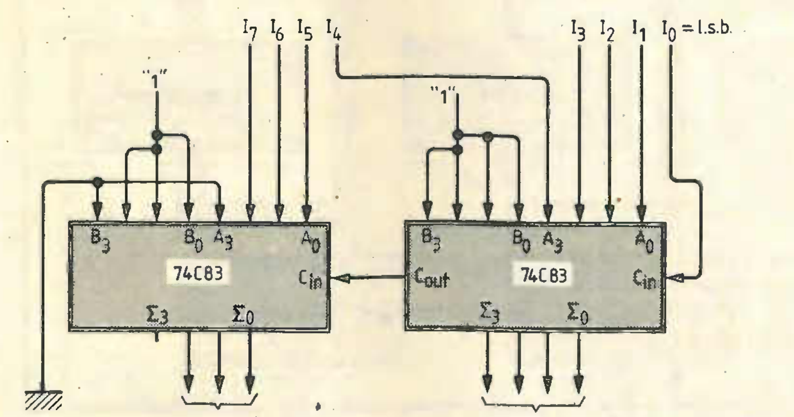


Fig 10. Connecting binary adders for a programmable 1-to-256 divider, applying equations (5) and (6). Σ_3 of the most significant decade is not used.

As shown previously, it is possible to find the logic relationships between input and load data as follows,

$$L_0 = I_0 \oplus I_1$$

$$L_1 = (I_0 + I_1) \oplus I_2$$

and so forth up to

$$L_6 = (I_0 + I_1 + I_2 + I_3 + I_4 + I_5 + I_6) \oplus I_7$$

$$L_7 = 0$$

$$D = \overline{L}$$

B.c.d. programmable counters

If division ratios from one to nine only are required, the previously described binary-programmable circuit may be used. If, however, a similar circuit is designed using a decade counter, and the maximum divisor range of one to ten is required, the counter will have to 'oscillate' at the 4-5 transition, rather than at the 7-8 transition as was the case with the binary-programmable circuit. This means that as Q_D is used as the output, the signal obtained will not be square. In fact, if the dividing ratio is from 1 to 6, there will be no output at all. It is easy to get round this problem by producing a logic 0 for states zero to four and logic 1 for the remainder, but this creates new problems;

– more circuits are required
– even with a synchronous counter, it is difficult to avoid spikes on the output, so the clock will have to latch the output signal
– the maximum operating frequency is lowered.

So, for division ratios from one to nine, it is more practical to use a binary-counter circuit. But the decade counter can be used to advantage if division ratios up to 100, or

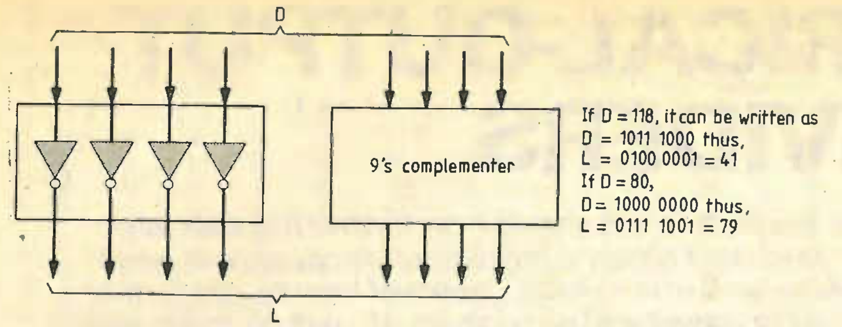


***Fig. 11.** Inverters and 9's complementers are used to apply equation (7) when cascading b.c.d.-input programmable dividers. Each additional decade will require the use of another 9's complementer.*

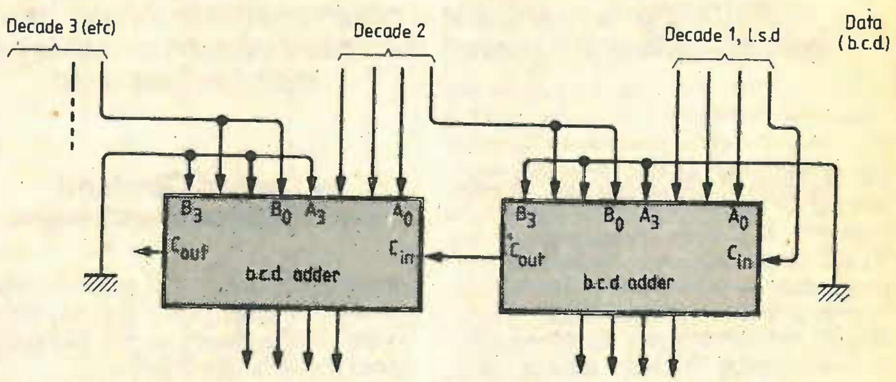


***Fig. 12.** Two b.c.d adders connected to give an output of I/2 when the divisor (I) is even, or (I + 2)/2 when the divisor is odd. The b.c.d. input value is shifted one position toward the least significant bit and a correction made through the adders when the l.s.b. of each decade is logic 1. In the original circuit, MC14560 natural b.c.d. adders were used.*

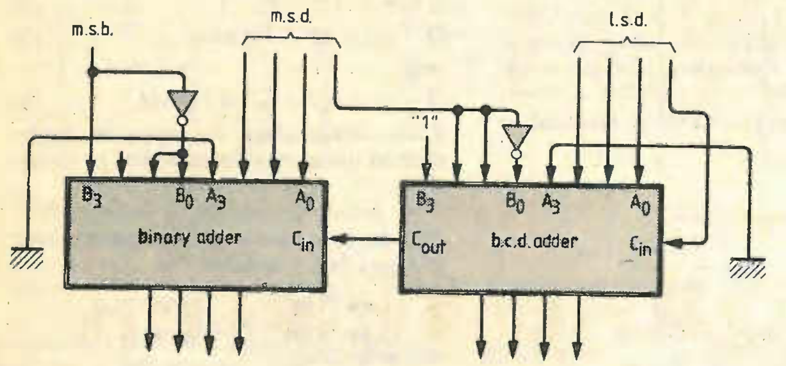


***Fig. 13.** The two adders, as shown, perform a similar function to those shown in Fig. 12, but by replacing the most significant decade i.c. by a binary type, the maximum possible division ratio is raised to 160 and the m.s.b. may be used to change the input function.*

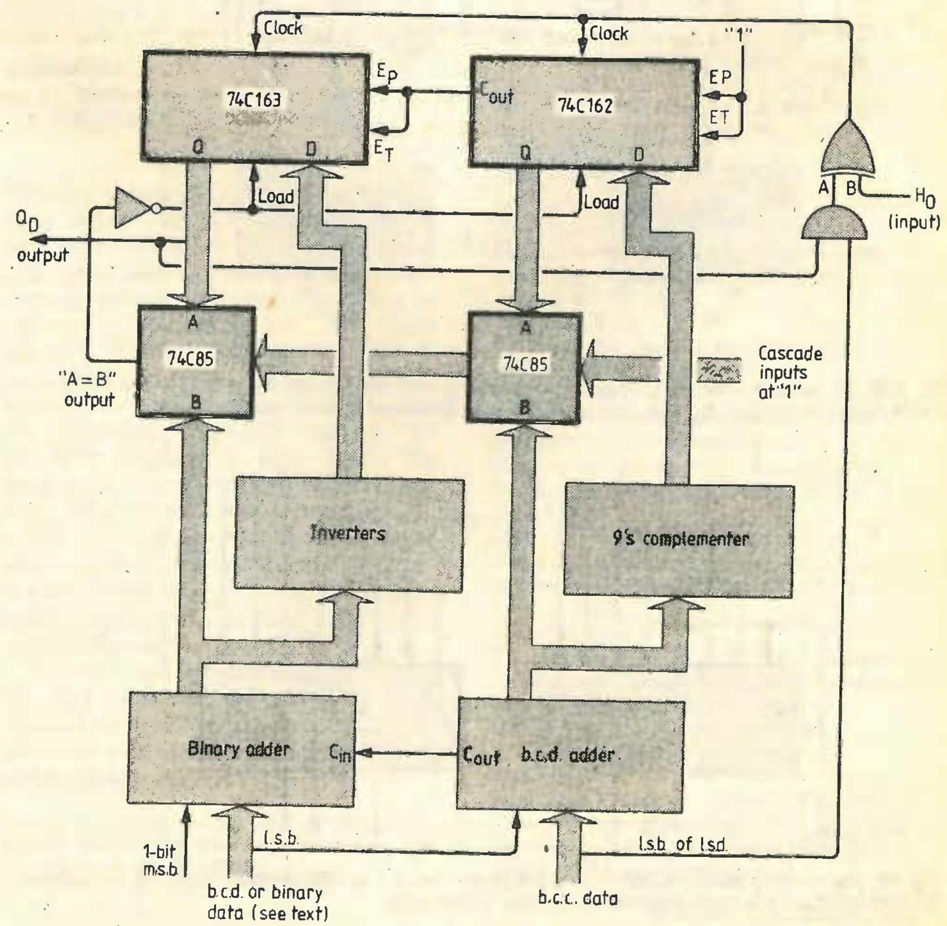


***Fig. 14.** Sections shown in Figs 11 and 13 combined with comparator and division circuits to form the b.c.d. input programmable divider for ratios 1≤I≤100. Divisors up to 160 may be used with this circuit and further decades may be added.*

even greater, are required. The following describes such dividers for ratios 1≤I≤100, and further expansion.

For ratios 1≤I≤100, two dividers are connected synchronously and are made to 'oscillate' around a given transition (at p to p+1). It should be obvious from the previous paragraph that a binary counter will still have to be used for the most-significant decade (m.s.d.).

If the output obtained is to be square, and one is to be free to choose a division ratio from 1 to 100, it is necessary to use the transition between counts 79 and 80 (or 799 and 800 if three decades are used) as the starting point.

Table 4 gives values for the following relationships;

$$L + D = 159 \quad (7)$$

$$D - I/2 = 79 \text{ if } I \text{ is even} \quad (8)$$

$$D - (I+1)/2 = 79 \text{ if } I \text{ is odd} \quad (9)$$

To apply the value 159, a 9's complementer must be used in the least-significant decade, and four inverters for the next decade, Fig. 11. In the original circuit an MC14561 9's complementer was used. To implement relationships (8) and (9), $I/2$ or $(I+1)/2$ must be in b.c.d., see Fig. 12. The b.c.d. value is shifted one position to the least significant bit, and a correction is made through the b.c.d. adders when the l.s.b. of each decade is 1.

This method works well, but it is possible to make more use of the MC14560 adders because their design is such that arithmetical operations like 14 + P (0≤P≤5), which are not supposed to be valid in b.c.d., are possible and provide the correct result. Consequently, relationships (8) and (9) can be applied using a binary adder (for the m.s.d.), and a b.c.d. adder, as shown in Fig. 13. This circuit may be expanded to suit the desired number of decades. Figure 14 shows the complete circuit, which consists of the previously mentioned sections with two comparators and the dividers added. As can be seen in Fig. 14, the b.c.d.-input divider differs from the binary-input divider mainly through the inclusion of a b.c.d. adder for processing program-input data and the 9's complementer for the counter-load data.

Two other interesting features are inherent in the circuit;

– if the data m.s.b. is held high, the maximum programmable ratio is 199, whereas the maximum-possible division ratio is 160. Consequently, if a number higher than 160 is programmed, the actual ratio will be $N - 160$. For example if N = 173, the division ratio will be 13.

– if the data m.s.b. is held low, it is possible to use the full potential of the most significant digit, i.e., the input may be programmed to give ratios from 1 to 15. This means that the total division range will be from 1 to 160, the ratio 160 occurring when the value of the two input decades is zero.

If three decades are required, the following additional components are needed;

– a decade counter between the binary and b.c.d. counter (take care with the carry and enable-output connections)

– a comparator

– a 9's complementer

– a b.c.d. adder for input data (B inputs of this adder are connected as those of the l.s.d. adder).

C.m.o.s. i.cs were originally used for the design and worked well up to 1MHz, depending on the division ratio. Changing the counters, comparators and gates to 74LS series i.cs will bring the maximum usable frequency up to around 10MHz.

Table 4: Divisor, load and detect (*I, L* and *D*) values for the b.c.d. programmable counter. This table is not given in full as it is obvious how omitted values are derived from the values given.

Divisor	Load	Detect
1	79	80
2	79	80
3	78	81
4	78	81
11	74	85
12	74	85
19	70	89
20	70	89
39	60	99
40	60	99
79	40	119
80	40	119
99	30	129
100	30	129

Bibliography

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J. L. Huertas, Square-wave frequency divider provides symmetrical output for odd divisors. *Electronic Design*, 21 September 1975, p100.

P. Bamberger, G. Girolami, Méthodes simples pour la division de fréquence symmétrique. *Electronique et applications industrielles*, No 258, 15 October 1978, pp.59-61.

A. M. Madni and R. R. Orton, Cross-coupled one shots divide by odd numbers and give a symmetrical output. *Electronic Design*, 25 October 1979, p.114.

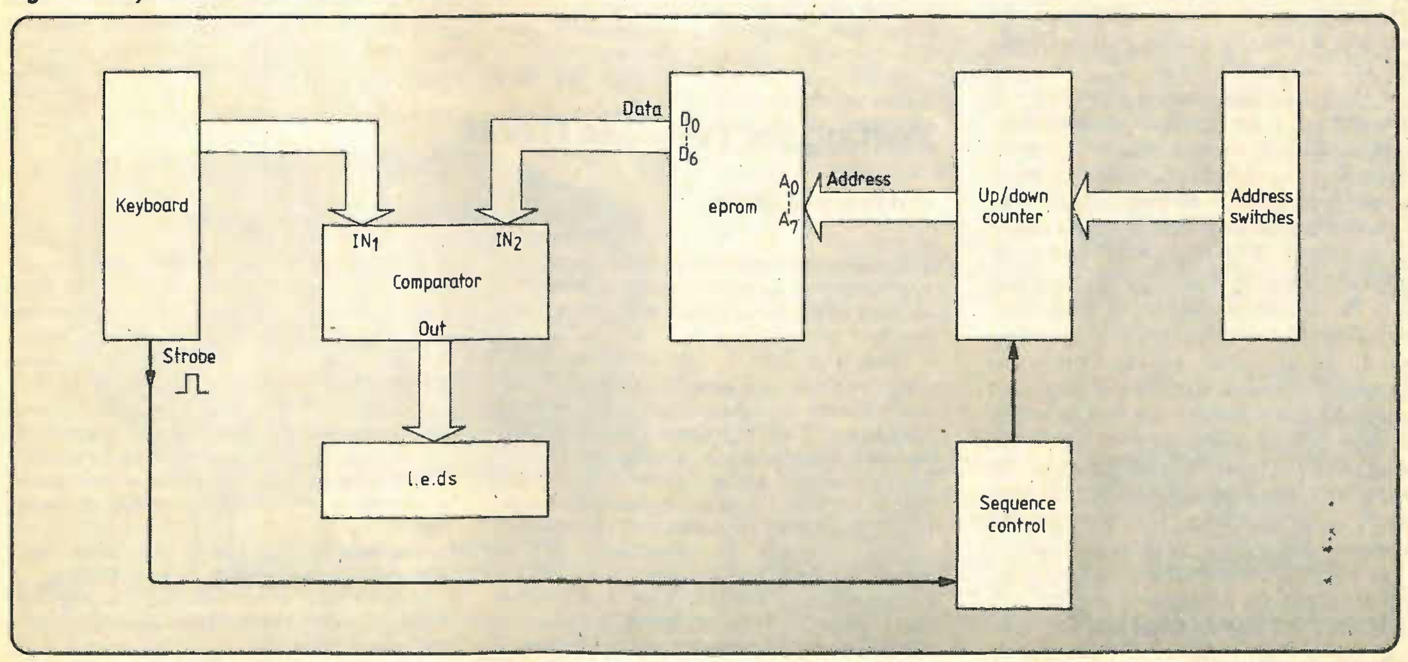
L. E. Getgen, Divide symmetrical clock pulses by odd numbers, get a symmetrical output. *Electronic Design*, 1 March 1980, p.110.

ASCII KEYBOARD TESTER

A time-saving method for detecting faulty keys or data lines. Traditionally keyboards have been tested by using a voltmeter or an oscilloscope in conjunction with a table of ASCII codes. This takes a long time and can be prone to error. The tester described here can detect faults quickly and easily.

by Waleed Habib Abdulla

***Fig. 1.** The keyboard tester in outline.*



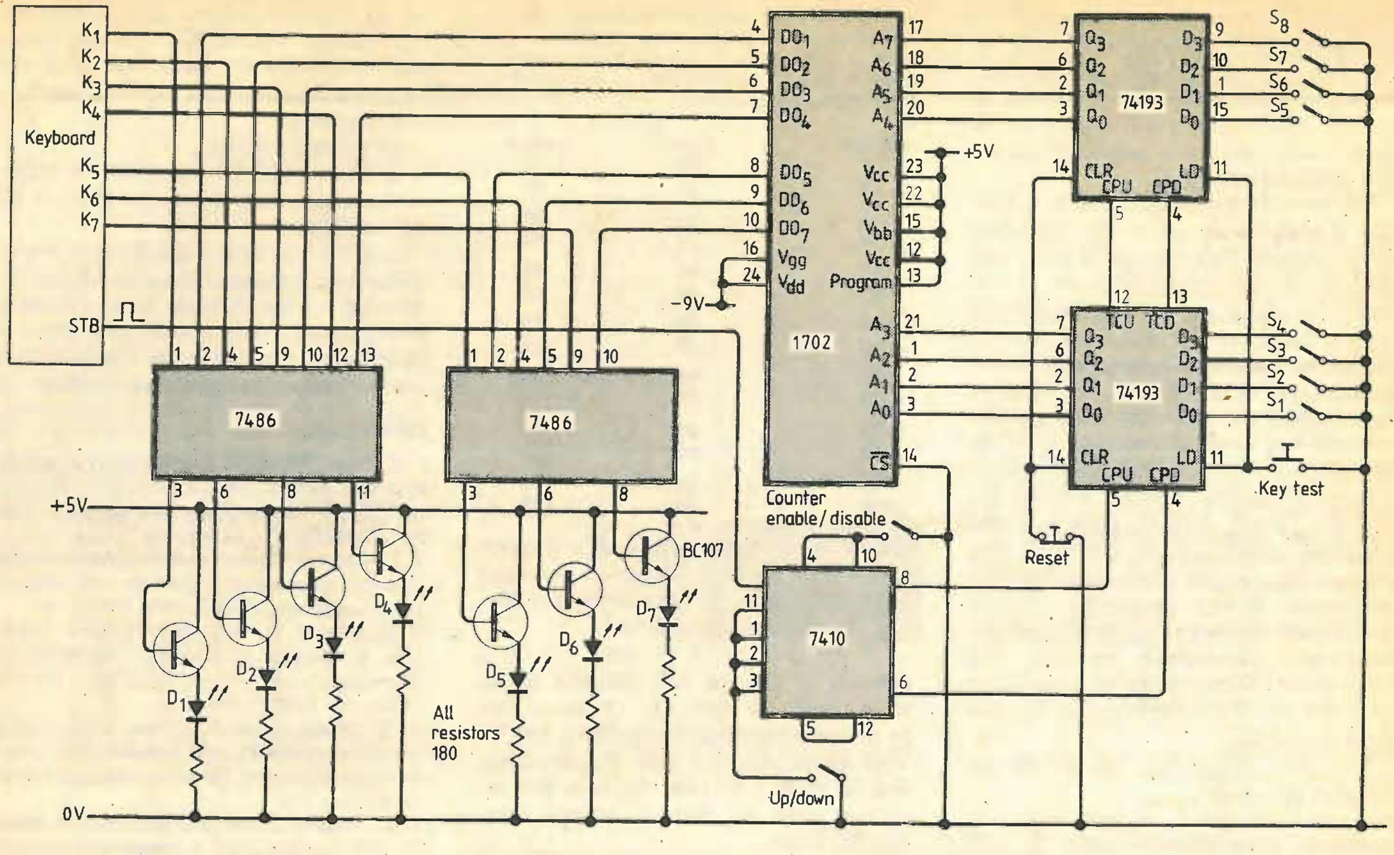


Fig. 2. The full circuit of the keyboard tester.

Figure 1 shows a block diagram of the tester. The ASCII code of each key is stored in an e.p.r.o.m. which holds an 'image' of the keyboard. When a key is pressed, the coded output may be compared with the stored code from the memory. Any mismatch will cause l.e.d. indicators to light. A counter is used to address the memory and is incremented by the keystroke strobe from the keyboard. Each time a key is pressed, the counter increments to the next address. Thus the keys must be tested in a set sequence governed by the order that they are programmed into the e.p.r.o.m. The full circuit is shown in Fig. 2. There is an up/down switch to reverse the counter, switches to set a specific address in the memory, a counter disable switch, 'reset' and 'key test' pushbuttons.

With the counter enabled and reset and switched to the 'up' mode, it is possible to press all the keys in sequence to check for errors. If no l.e.d. is lit, then the keyboard has no fault. If a l.e.d. should light then the corresponding bit can be tested inside the keyboard. It is possible to back-track and retest a key by reversing the sequence with the up/down switch. A fault may come from an individual key or from a data line. In the latter case, the same l.e.d. will remain lit when a number of keys are tested. To test a specific key the counter is disabled and the address of the key is entered on the switches. Pushing the key-test button will effect the comparison. Alternatively, one location in the memory (for example address 00) could be left vacant. Then with the counter set to that address, and disabled, the pressing of any key will cause the code coming from that key to be displayed on the l.e.ds.

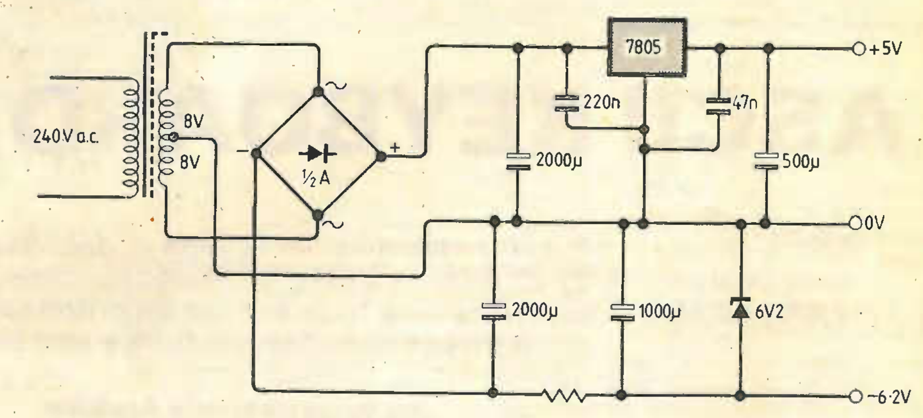


Fig. 3. A suitable power supply. The voltage needed is + 5V at 220mA. The e.p.r.o.m. requires a negative voltage between −5.5 and −9V at 20mA. Resistor value selected to suit current rating of the zener diode.

Writing for *Wireless World*

Notes for authors

Potential authors often ask us for advice on how to present their material; fearing perhaps, that anything of less than a certain grammatical standard may be rejected.

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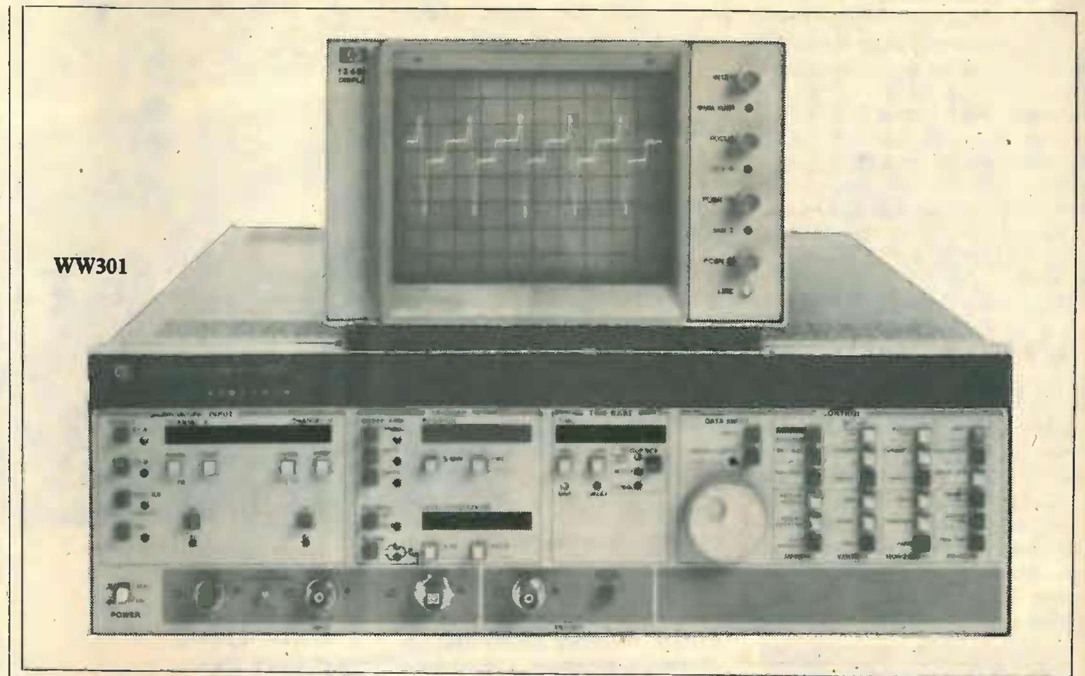
NEW PRODUCTS

WAVEFORM RECORDER



Digital waveform recorders are a new venture for Hewlett Packard but with their past experience in test and measuring instruments they have been able to jump in at the deep end. The HP5180 is a so called 'universal' waveform recorder, that is, it can be used on its own or under the control of a computer. A 10-bit a.-to-d. converter providing sampling rates up to 20MHz, and a 16K-by-10-bit memory that can be divided into a maximum of 32 segments form part of the system. Digital triggering is used so trigger times before or after the event, and trigger voltages, may be set and read accurately. One of the functions of two adjustable cursors is to pin-point a section of a waveform for vertical and/or horizontal zoom; these cursors may also be used to set trigger points. The front panel is, of course, designed ergonomically but nevertheless holds some 50 push buttons and one multi-purpose knob. With this in mind, up to four front-panel settings may be stored and recalled at will. All the front panel controls, and data i/o, are accessible through the HP-interface bus and 16-bit parallel d.m.a. (direct memory access) at transfer rates of up to 1M-word/s is possible. Hewlett-Packard Ltd, 308-314 Kings Road, Reading, Berks RG1 4ES.
WW301

ELECTROMETER

Voltage, current, resistance and charge functions are included on Keithley's model 614 electrometer. On the three measuring ranges for up to 20V direct, the 4 ½-digit meter's input impedance is $5\times10^{13}\Omega$ and 20pF; resolution on the lowest range is 10µV. The most sensitive of nine direct-current ranges has a resolution of 10fA and the maximum possible current reading is 2mA. Less than 200µV is present over the terminals on all current ranges. Resistances up to 200GΩ may be measured, also in nine ranges and resolution on the lowest range is 1Ω. Three other ranges are used for charge measurements down to around 10fC on the lowest range and up to 20nC on the highest. Outputs are provided for a chart recorder and for guarding when making voltage and current measurements. A rechargeable lead-acid battery is included. Keithley Instruments Ltd, 1 Boulton Road, Reading, Berks RG2 0NL.
WW302

TOOLS

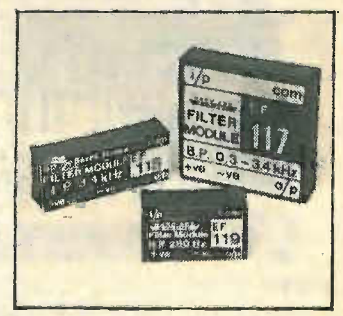
This company has a wide range of tools and has recently introduced two kits, in wallets with zips, for routine servicing. The more elaborate of these contains 25 tools, including a miniature soldering iron, de-solder braid, solder, pliers, cutters, tweezers, a knife, an i.c. extraction tool, scissors, a wire stripper and a range of screwdrivers and adjusting tools. Seven tools are contained in the smaller kit, pliers, side-cutters, tweezers and four screwdrivers. The former, the 'computer-service wallet, sells at £39.50 including v.a.t. and postage, and the latter, the 'micro wallet'; at £13.50, also inclusive. Toolmail Ltd, Parkwood Industrial Estate, Sutton Road, Maidstone, Kent ME15 9LZ.
WW303

BEAD THERMISTORS

Often, thermal and voltage/current overloads in transformers, chokes, motors, generators, etc., are sensed by means of a p.t.c. thermistor. For this application, the response speed of a protection circuit is mainly determined by the size of the thermistor and the thickness of its protective coating. Compstock have a range of general-purpose bead thermistors which all have a nominal resistance of 1kΩ at one of 13 temperatures from 80°C to 180°C, and each can be obtained as a bare pellet, resin dipped, sleeved or both resin dipped and sleeved. For all 13 reference temperatures, -5°C reduces the resistance to 550Ω and +5°C increases the resistance to 1.3kΩ. Compstock Electronics Ltd, Compstock House, London Road, Stanford-le-Hope, Essex SS17 0JU.
WW304

VOICE FILTERS

Active voice-frequency filters for use in telecommunications are available from Barr and Stroud as small p.c.b.-mounting modules. There are currently four modules, the EF117, 118, 118A and 119, all with elliptic-type transfer functions providing a minimum attenuation rate of 40dB. The 117 is a band-pass filter for the range 300Hz to 3.4kHz; attenuation variation between 350Hz and 3.0kHz is less than ±0.5dB. Both versions of the



118 are low-pass filters, the first with a cut-off frequency of 3.4kHz and the second (suffix A) with a cut-off frequency of 1.8kHz. Using the latter version, the upper part of the voice-frequency channel is left free to carry data. Lastly is the 119 high-pass filter with a cut-off frequency of 300Hz and an upper limit of 50kHz. Supply rails between ±5V and ±18V are required for these modules. Barr and Stroud, Melrose House, 4-6 Savile Row, London W1X 1AF.
WW305

ANTENNAE FOR MOBILE RADIO

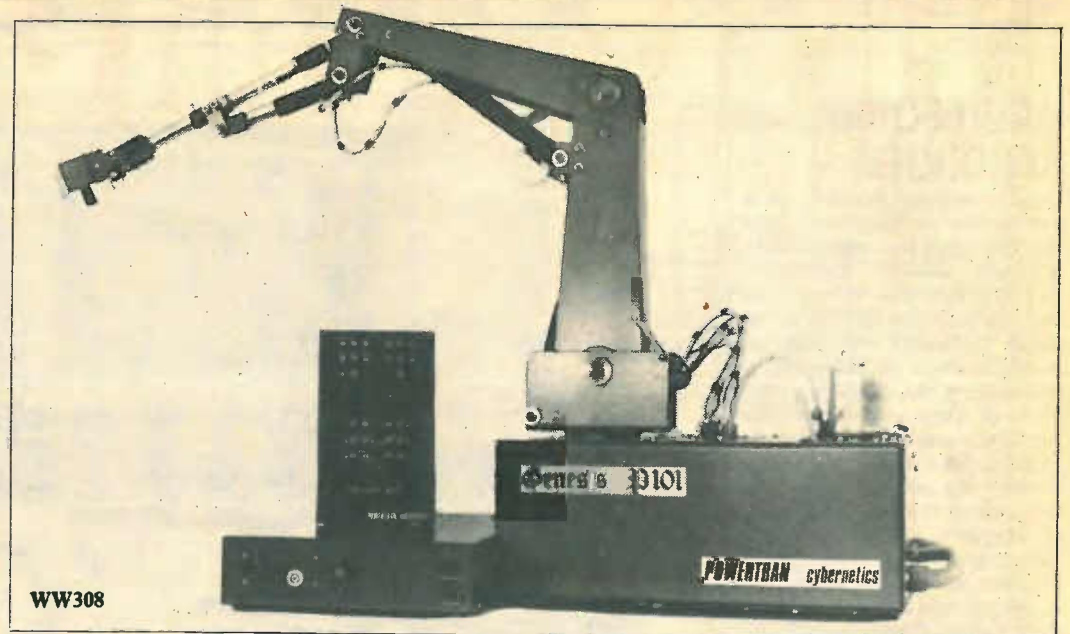
A Swedish company, Allgon Antenn AB, has produced two antennae, one for the aeronautical and land-mobile distress frequencies of 121.5 and 243MHz, and the other an omnidirectional broadband type for transmit and receive in the range 225 to 400MHz. The first, called simply type 4104 (shown in

photo) operates on both distress frequencies simultaneously and can be used in base stations, on mobile-radio units and ships, or on helicopters and aircraft travelling at less than 200mile/h. The second, type 477, is a base-station antenna covering the 225 to 400MHz frequency range without tuning. In the middle of this range, the antenna's gain is 6dB. The maximum average transmitting power is 1.5kW. Allgon Antenn AB, Box 500, S-184 00 Åkersberga, Sweden.
WW306

MODULAR ORGAN KIT

A "budget-priced" electronic organ with features only previously available on more expensive instruments is claimed for the Wersi Comet. Imported non-exclusively to the UK from Germany by Aura Sounds in kit form as well as in transportable and spinet versions, it can be bought in stages, the basic organ comprising four packs totalling £1293. Further packs include auto-accompaniment, registration memory/piano, and string/guitar facilities, bringing price to about £1900 against a factory built price of £3,600. Satellite keyboards – up to four can be connected with sections of the organ assigned to them – cost £138 in kit form. The makers claim numerous "realistic" and interesting tonal colours including synthesizer effects and guitar voices as well as the more traditional drawbar and orchestral sounds. How far the claim to realism is justified is obviously open to question, especially with auto accompaniment, but it seems much the best at simulating pipe organs. In addition to features now common to electronic organs and synthesizers that rely on voltage-controlled filters and amplifiers, this microprocessor design also has a program memory for 20 registrations; and a key memory can play background chords after notes are released. A digital transposer can pitch the organ in any key so that tuning is not required. Aura Sounds Ltd, 17 Upper Charter Avenue, Barnsley, Yorks.
WW307

WW307



WW308

GENERAL PURPOSE ROBOTS

Hydraulically driven robot arms that can be controlled either manually or by computer are manufactured by Powertran Cybernetics for industrial, educational or home use. Complete systems range in price from around £600 to £800. Each unit has its own 6802-microprocessor control and hydraulic system, and is capable of handling several pounds. One of these units, the M101, has either four or five axes of arm movement and can be fitted with wheels capable of carrying over 50kg. Communication with a computer is through an optional RS232 interface. Powertran Cybernetics, Portway Industrial Estate, Andover, Hants SP10 3NN.
WW308

CABLE SIMULATOR

Cable transmission characteristics are important in digital communciation systems, especially where p.c.m. regenerators are concerned. To reduce the amount of floor space often required for testing such designs, Wandel and Goltermann have introduced the PKN-1 for simulating cables with conductors between 0.6 and 1.4mm diameter. Cable attenuation is displayed on a digital readout and adjusted by means of two push buttons in steps of 1dB at a frequency of 1MHz. Both balanced and co-axial inputs and outputs are provided and a version of the PKN-1 with a 772kHz reference frequency can be supplied. A portable 200Hz to 620kHz level meter for measurements on voice channels in local and remote networks has also been recently introduced by the same company. This meter has an analogue dB readout, a digital frequency display and a built-in generator. Wandel & Goltermann GmbH & Co., Postbox 45, Mühleweg 5, D-7412 Eningen, F. R. Germany.
WW309

Professional readers are invited to request further details on items featured here by entering the appropriate WW reference number(s) on the mauve reply-paid card.

CW AND RTTY TERMINAL

A communication terminal for encoding/decoding Morse or Baudot is manufactured by Polemark Ltd with inbuilt display, keyboard and real-time clock. The Microdot is a portable unit, microprocessor controlled, and has a 2Kbyte r.a.m. and 4K r.o.m., part of which contains some frequently used abbreviations and test-text which may be called using single key commands. Both modulator and demodulator are incorporated for c.w., f.s.k. and a.f.s.k. (audio-frequency shift keying). On receive, speed tracking is automatic; three fixed speeds may be set when transmitting and both transmit and receive speeds are displayed on the screen. Receive and transmit may be carried out simultaneously. The terminal's input may be connected directly to the output of a receiver or tape recorder, and the output directly to a transmitter. Self test is carried out by connecting the output to the input and supply requirements are 13.8V, direct at 2.4A. A price of £395 including v.a.t. and carriage is quoted. Polemark Ltd, 148-150 High Street, Barkway, Royston, Herts SG8 8EG.
WW310

VIDEOTEX SYSTEMS '82 CONFERENCE

Cunard International Hotel Hammersmith, London W6

May 5,6,7, 1982

This important two day conference will cover in depth, both technical and marketing aspects of videotex technology.

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Speakers include: John Wakeham, MP, John Durham, Alan Haimes, David Gilbert, Ken Knight, Ted Sedman, J Döring, Murray Cook, Tony Book, Jenny Clayton, Tim Chapman, Colin Tipping, Geoff Hutt, Andrew Lighting, Anthony Harris, James Smith, John Marsh, Chris Singer, Mike Aston and Malcolm Smith.

Conference organised on behalf of AVIP The Association of Viewdata Information Providers Limited.

Run in parallel with VIDEOTEX SYSTEMS '82 EXHIBITION Cunard International Hotel May 5-7

WW

Full details from: Sue Bonnell, IPC Conferences Ltd, Surrey House, Throwley Way, Sutton, Surrey SM1 4QQ.
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SN76533N	1.30
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SN76570N	1.00
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TAA700	1.70
TBA120A	0.70
TBA120AS	0.70
TBA120B	0.70
TBA120S	0.70
TBA120SB	0.70
TBA120SQ	0.70
TBA120T	0.70
TBA120U	1.00
TBA395	1.50
TBA396	0.75
TBA440N	2.55
TBA480Q	1.25
TBA510	1.65
TBA510Q	1.65
TBA520	1.10
TBA520Q	1.10
TBA530	1.10
TBA530Q	1.10
TBA540	1.25
TBA540Q	1.35
TBA550	1.45
TBA550Q	1.45
TBA560C	1.45
TBA560CQ	1.45
TBA570	1.00
TBA641A12	2.50
TBA641B11	3.00
TBA651	1.75
TBA673	2.45
TBA700Q	1.80
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TBA720AQ	2.45
TBA750	1.85
TBA800	0.89
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TBA810S	1.35
TBA820	1.45
TBA820Q	1.45
TBA890	1.85
TBA920	1.85
TBA920Q	1.85
TBA950/2X	2.35
TBA990	1.49
TBA990Q	1.49
TBA1441	2.15
TCA270	1.10
TCA270S	1.10
TCA270SQ	1.10
TCA640	2.50
TCA650	2.50
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TCA830S	1.40
TCA940	1.65
TCEP100	1.95
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TDA1006A	2.50
TDA1010	2.15
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TDA1170S	1.95
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TDA1327Q	1.70
TDA1352B	1.45
TDA1412	0.85
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TDA2560	2.15
TDA2581	1.15
TDA2590	2.95
TDA2591	2.95
TDA2593	2.95
TDA2600	2.95
TDA2611A	1.95
TDA2640	2.50
TDA2650	2.15
TDA2653	2.15
TDA2680	2.15
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TDA3950	2.50
TDA8503	3.95
UPC1185H	3.95
UPC556C	2.95
UPC575C2	2.95
UPC1001H	2.50
UPC1025H	2.50
UPC1156H	2.95
UPC1182H	2.95
UPC1350C	2.95
UPC2002H	1.95
ZTX338	0.37
555	0.35
741	0.35

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AC126	0.22
AC127	0.20
AC128	0.20
AC128K	0.32
AC141	0.26
AC141K	0.34
AC142K	0.30
AC176	0.22
AC176K	0.31
AC187	0.25
AC187K	0.28
AC188	0.22
AC188K	0.37
AD142	0.90
AD143	0.82
AD149	0.70
AD161	0.39
AD162	0.39
AD161/2	0.80
AF124	0.34
AF125	0.32
AF126	0.32
AF127	0.32
AF139	0.42
AF150	0.42
AF239	0.42
AU106	2.00
AU107	1.75
AU110	2.00
AU113	2.50
BC107	0.10
BC107A	0.11
BC107B	0.11
BC108	0.10
BC108A	0.11
BC108B	0.12
BC109	0.10
BC109B	0.12
BC114	0.11
BC116A	0.12
BC117	0.19
BC119	0.24
BC125	0.12
BC140	0.31
BC141	0.25
BC142	0.21
BC143	0.24
BC147	0.09
BC147A	0.10
BC148B	0.09
BC149	0.09
BC157	0.10
BC158	0.09
BC159	0.09
BC160	0.28
BC161	0.28
BC170B	0.10
BC171	0.08
BC171B	0.10
BC172B	0.10
BC173B	0.10
BC174	0.09
BC182	0.09
BC182LB	0.10
BC183	0.12
BC183L	0.09
BC184LB	0.09
BC204	0.10
BC208B	0.13
BC212	0.09
BC212L	0.09
BC213	0.09
BC213L	0.09
BC237	0.09
BC238	0.09
BC251a	0.12
BC252A	0.15
BC258A	0.39
BC300	0.30
BC301	0.30
BC303	0.26
BC307	0.09
BC327	0.10
BC337	0.10
BC338	0.09
BC461	0.30
BC478	0.20
BC547	0.10
BC549A	0.08
BC550	0.07
BC557	0.07
BC557B	0.07
BC558	0.07
BD115	0.30
BD116	0.52
BD131	0.32
BD132	0.35
BD133	0.40
BD135	0.30
BD136	0.30
BD137	0.28
BD138	0.30
BD139	0.32
BD140	0.30
BD159	0.65
BD166	0.46
BD179	0.72
BD182	0.70
BD201	0.83
BD202	0.65
BD203	0.78
BD204	0.70
BD222	0.46
BD223	0.48
BD225	0.46
BD233	0.35
BD234	0.35
BD236	0.45
BD237	0.30
BD238	0.30
BD410	0.65
BD434	0.65
BD437	0.50
BD517	0.60
BD520	0.65
BDX32	1.50
BF115	0.35
BF127	0.24
BF158	0.18
BF160	0.27
BF167	0.24
BF173	0.22
BF177	0.38
BF178	0.26
BF179	0.34
BF180	0.29
BF181	0.29
BF182	0.29
BF183	0.29
BF184	0.28
BF185	0.28
BF194	0.11
BF195	0.11
BF196	0.11
BF197	0.11
BF198	0.16
BF199	0.14
BF200	0.30
BF241	0.15
BF256	0.28
BF256/LC	0.28
BF257	0.28
BF258	0.25
BF259	0.26
BF271	0.26
BF273	0.13
BF336	0.34
BF337	0.29
BF338	0.32
BF355	0.37
BF362	0.38
BF363	0.31
BF371	0.20
BF394	0.19
BF457	0.32
BF458	0.33
BF459	0.36
BF595	0.23
BF597	0.25
BFR39	0.23
BFR40	0.23
BFR41	0.28
BFR81	0.28
BFW92	0.85
BFX29	0.30
BFX84	0.26
BFX85	0.28
BFX86	0.30
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BFY50	0.21
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BU108	1.69
BU124	1.00
BU126	1.22
BU204	1.55
BU205	1.30
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BU208A	1.52
BU208/02	1.89
BU326A	1.42
BU407	1.24
BU500	1.75
MJ3000	1.98
MJE340	0.40
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MRF450A	11.50
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MRF475	2.50
R2008B	1.70
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R2322	0.58
R2323	0.66
R2540	2.48
RCA16334	0.90
RCA16335	0.80
TIP29	0.40
TIP29C	0.42
TIP30C	0.43
TIP31C	0.42
TIP32C	0.42
TIP33B	0.75
TIP41C	0.45
TIP42C	0.47
TIP47	0.65
TIP120	0.60
TIP122	0.79
TIP161	2.95
TIP2955	0.84
TIP3055	0.55
TIS91	0.20
TV106/2	1.50
2N2219	0.28
2N2905	0.40
2N3054	0.59
2N3055	0.52
2N3702	0.12
2N3703	0.12
2N3704	0.12
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2N3706	0.12
2N3708	0.12
2N3773	2.10
2N3866	0.90
2N5294	0.38
2N5296	0.48
2N5298	0.52
2N5496	0.66
2SA715	0.35
2SC495	0.80
2SC496	0.80
2SC1096	0.80
2SC1172Y	2.20
2SC1173	1.15
2SC1306	1.00
2SC1307	1.85
2SC1449	0.80
2SC1678	1.25
2SC1945	2.10
2SC1953	0.95
2SC1957	0.80
2SC1969	1.95
2SC2028	1.15
2SC2029	1.60
2SC2078	1.45
2SC2091	0.85
2SC2314	0.80
3N211	1.50

DIODES

AA119	0.08
BA102	0.17
BA115	0.13
BA145	0.17
BA148	0.17
BA154	0.06
BA155	0.13
BA156	0.15
BAX13	0.04
BAX16	0.06
BB105B	0.30
BY126	0.10
BY127	0.11
BY133	0.15
BY164	0.45
BY176	1.20
BY179	0.63
BY206	0.14
BY208-800	0.33
BY210-800	0.33
BY223	0.90
BY298-400	0.22
BY299-800	0.22
BYX10	0.20
BYX36-150R	0.20
BYX38-600R	0.60
BYX55-600	0.30
BYX71-600	0.60
OA47	0.09
OA90	0.05
OA91	0.06
OA95	0.06
OA202	0.10
IN60	0.05
IN914	0.04
IN4001	0.04
IN4002	0.04
IN4003	0.04
IN4004	0.05
IN4005	0.05
IN4006	0.05
IN4007	0.06
IN4148	0.02
IN4448	0.10
IN5401	0.12
IN5402	0.14
IN5403	0.12
IN5404	0.12
IN5405	0.13
IN5406	0.13
IN5407	0.16
IN5408	0.16
ITT44	0.04
ITT27	0.48
ITT910	0.45
ITT921	0.09
ITT923	0.15
ITT2002	0.11

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	15K-22K	0.18
11 Watt	1R-10K	0.18
	15K	0.21
17 Watt	1R-10K	0.24
	15K-22K	0.25

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B7G Skirted	0.30
B8G	0.70
B9A	0.20
B9A Skirted	0.30
B10B	0.16
B13B	0.50
8 Pin DIL	0.10
14 Pin DIL	0.12
14 Pin DIL/Q	0.30
16 Pin DIL	0.15
OCTAL	0.35
CANS	0.27

ZENER DIODES

BZX61 0.15
6V2 7V5 8V2 9V1 10V 11V 12V 13V 15V 16V 18V 20V 22V 24V 27V 30V 33V 36V 39V 47V

BZY88 0.07
2V7 3V 3V3 3V6 3V9 4V3 4V7 5V1 5V6 6V2 6V8 7V5 8V2 9V1 10V 11V 12V 13V 15V 18V 24V 27V

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VA1056S	0.23
VA1104	0.70
VA8650	0.45

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A2521	19.00
A2599	37.50
A2900	19.00
AC/HL/DD	3.00
AC/THI	2.50
AC/PEN	3.50
AC/SP3	4.50
ACP	3.00
ACVP1	3.50
ACVP2	1.50
AH201	4.00
AH221	39.00
AH238	31.50
AP4	1.50
APV4	1.50
AR8	0.70
ARP12	0.70
ARP34	2.00
ARP35	1.50
ARP37	1.00
AV3	1.50
AU13	1.50
AX224	12.00
AZ31	1.00
B2A	6.00
B36	1.85
B65	0.69
B349	0.75
B719	0.60
B729	1.20
BL63	1.20
BT5B	43.50
BT17A	95.00
BT19	32.50
BT79	12.50
CIK	14.00
C3JA	10.00
C143	18.50
C180	18.50
C1108	30.50
C1111	15.50
C1112	52.15
C1134	15.50
CBL31	2.00
CCA	2.50
CL30	1.05
CMG25	9.00
CMG29	10.85
CMV25	10.00
CV Nos prices on request	
D3a	35.00
D63	0.60
DA107	8.00
DAC32	1.20
DAF91	0.45
DAF96	0.65
DC70	1.75
DC90	1.20
DCX4-1000	35.00
DD620	1.20
DDR3	1.00
DDT	3.00
DET10	6.00
DET22	28.00
DET24	45.00
DF33	2.50
DF63	2.50
DF91	0.45
DF92	0.60
DF93	1.20
DF96	0.85
DF97	1.50
DH76	1.00
DH77	0.90
DH79	0.56
DH81	2.00
DH149	2.00
DK91	0.90
DK92	1.20
DK96	2.50
DL35	1.00
DL63	1.00
DL69	1.20
DL70	2.50
DL73	2.50
DL92	0.60
DL94	1.20
DL96	1.00
DLS10	9.00
DLS15	11.00
DLS16	10.00
DM70	1.10
DM160	2.50
DN143	1.50
DW2	1.50
DX2	12.00
DY30	1.00
DY51	1.00
DY70	5.00
DY80	1.20
DY86/87	0.56
DY802	0.60
E1C	0.80
E1F	0.50
E1T	15.00
E55L	14.00
E80CC	4.75
E80CF	10.00
E80F	9.50
E80L	9.50
E81CC	2.50
E81L	9.50
E82CC	2.50
E83CC	2.50
E83F	2.50
E86C	8.00
E88C	8.00
E88CC	2.50
E88CC-01	3.65
E90CC	1.25
E90F	9.00
E91N	2.00
E92CC	1.05
E130L	13.00
E167	4.00
E180CC	3.50
E180F	5.25
E186F	8.50
E235L	11.00
E236L	9.00
E280F	19.50
E283CC	8.25
E810F	12.50
E2134	12.00
EA50	1.00
EA76	2.00
EAA91	0.60
EAA901S	1.50
EABC80	0.56
EAC91	0.90
EAF42	1.40
EAF801	1.40
EB34	1.50
EB41	2.30
EB91	0.52
EBC21	1.50
EBC33	2.00
EBC41	0.85
EBC81	0.85
EBC89	0.65
EBC90	0.75
EBC91	0.75
EBF33	2.50
EBF85	0.95
EBF89	0.70
EBF93	0.95
EBL1	1.50
EBL21	2.00
EBL71	4.00
EC52	1.25
EC80	3.50
EC81	4.50
EC86	1.00
EC88	1.00
EC90	0.60
EC91	7.00
EC93	0.80
EC95	7.00
EC8010	6.00
ECC32	3.00
ECC33	4.00
ECC34	4.00
ECC35	4.00
ECC40	2.30
ECC80	1.50
ECC81	0.55
ECC82	0.55
ECC82 Mullard	1.10
ECC83	0.60
ECC83 Mullard	1.10
ECC84	0.60
ECC85	0.60
ECC86	1.65
ECC88	0.66
ECC88 Mullard	1.85
ECC91	0.65
ECC180	0.72
ECC189	0.78
ECC230	4.50
ECC801S	2.50
ECC803S	2.50
ECC804	0.40
ECC807	1.30
ECC808	3.15
ECC2000	12.00
ECF80	0.65
ECF82	0.60
ECF86	1.50
ECF802	1.20
ECF804	6.00
ECF806	10.25
ECF812	1.20
ECH3	2.50
ECH4	3.00
ECH35	1.50
ECH42	1.00
ECH81	0.58
ECH83	0.78
ECH84	0.93
ECL80	0.66
ECL82	0.58
ECL83	1.13
ECL84	0.74
ECL85	0.74
ECL86	0.74
ECLL800	13.50
EF22	2.50
EF37A	3.60
EF39	1.75
EF40	2.50
EF41	3.50
EF42	2.50
EF50	1.50
EF55	2.25
EF71	1.50
EF72	1.20
EF73	1.00
EF80	0.48
EF83	3.50
EF85	0.48
EF86	0.70
EF89	0.75
EF91	1.22
EF92	2.50
EF93	0.65
EF94	0.55
EF95	0.80
EF96	0.65
EF97	0.90
EF98	0.90
EF183	0.65
EF184	0.65
EF190	1.50
EF731	1.80
EF800	11.00
EF8065	9.85
EH90	0.72
EK90	0.72
EL32	0.95
EL33	4.00
EL34	1.54
EL34 Philips	2.45
EL36	1.60
EL37	5.00
EL38	4.50
EL41	2.00
EL81	2.75
EL82	0.58
EL84	0.66
EL85	3.85
EL86	0.80
EL90	0.82
EL91	6.00
EL95	0.70
EL360	9.00
EL504	1.40
EL509	3.75
EL519	4.50
EL821	10.00
EL822	10.00
ELL22	2.50
EM1	4.00
EM4	9.00
EM34	11.00
EM80	0.70
EM81	0.70
EM84	0.70
EM85	0.85
EM87	1.10
EMM803	2.50
EN10	8.00
EN32	9.00
EN91	0.95
EN92	4.00
ESU101	11.50
ESU103	12.00
ES1500	115.00
ET1	11.00
EY3	2.50
EY51	0.80
EY84	8.00
EY84W	10.00
EY86/87	0.50
EY88	0.60
EY91	1.00
EY500A	1.50
EZ35	0.60
EZ40	2.00
EZ41	1.25
EZ80	0.75
EZ81	0.58
EZ90	0.96
F6059	3.20
F6060	2.50
F6158	2.75
F6870	6.00
FW4/500	2.00
G1/371K	30.00
G55/1K	8.00
G120/1B	8.00
G150/2D	4.00
G180/2M	7.00
G400/1K	14.00
G550	11.50
GC10B	11.50
GC10D	11.50
GC10/4B	11.50
GC10/4E	11.50
GD85M/S	2.00
GD87M	1.75
GD90M	2.10
GN4	4.00
GN10	15.00
GN24	1.50
GR10G	4.00
GR10J	4.00
GS10C	12.00
GT1C	17.00
GT1C S/S	13.50
GTE175M	8.00
GTR150W	1.00
GU50	11.50
GXU1	13.50
GXU3	24.00
GXU50	12.50
GY501	1.20
GZ30	1.00
GZ32	1.00
GZ33	4.50
GZ34	2.00
GZ37	4.50
H63	1.20
HAA91	1.00
HABC80	0.90
HBC90	0.75
HBC91	0.80
HF61	2.50
HF93	0.75
HF94	0.60
HK90	1.05
HL2K	3.00
HL23DD	1.50
HL41	1.50
HL41DD	3.00
HL42DD	2.00
HL90	0.70
HL92	1.50
HL133/DD	1.50
HMO4	0.72
HP6	1.30
HR2	4.00
HVR2	1.50
HY90	1.00
KT2	3.00
KT24	3.00
KT30	1.50
KT32	1.00
KT33	1.15
KT33C	3.50
KT36	2.00
KT41	4.00
KT42	4.00
KT44	3.00
KT45	3.00
KT61	4.00
KT63	2.00
KT66 USA	6.00
KT66 GEC	9.00
KT67	2.00
KT76	2.00
KT77 Gold Lion	9.50
KT81	2.50
KT88 USA	7.00
KT88 GEC	11.50
KT88 Gold Lion	12.50
KTW61	1.50
KTW62	2.00
KTW63	1.50
KTZ41	2.00
KTZ63	1.25
KY50	0.68
KY80	0.90
L63	1.00
L77	0.60
L102/2K	8.00
L120/2K	12.00
LS731	28.00
LZ319	0.65
LZ329	0.65
LZ339	0.40
M502A	135.00
M537A	160.00
M8079	8.00
M8083	3.25
M8091	7.50
M8096	3.00
M8100	2.85
M8136	7.00
M8137	5.50
M8162	3.85
M8163	3.85
M8190	3.85
M8195	3.00
M8196	3.25
M8204	2.00
M8223	1.50
M8224	1.50
M8225	1.20
ME1400	4.00
ME1402	4.50
ME1403	10.00
ME1501	14.00
MH4	2.10
MH41	2.10
MHLD6	1.50
ML4	4.50
MS4B	5.00
MU2	11.75
MU12	1.50
MU14	1.50
N78	8.90
N118	1.00
N119	0.78
N154	0.60
N308	0.52
N329	0.60
N369	1.50
N379	0.65
N709	0.66
N727	0.82
NGT1	1.00
NR14	9.00
NR48	1.00
NR64	1.50
NR68	1.20
NR73	3.50
NR81	1.00
NR82	0.85
NU3	1.50
NU7	11.75
NU17	1.50
NU18	1.50
NU20	0.85
OA2	0.60
OA2WA	1.50
OA3	3.95
OB2	0.65
OB2WA	1.25
OC3	1.05
OD3	1.15
OE3	5.40
OG3	2.00
OM3	0.60
OM4	1.00
OM5B	3.60
OM6	1.75
OM9	4.00
OM10	1.50
ORP50	8.50
ORP93	11.50
P41	1.50
P51A	1.50
PABC80	0.50
PC84	0.60
PC86	0.80
PC88	0.80
PC92	0.85
PC97	1.10
PC800	1.10
PC900	0.95
PCC84	0.45
PCC85	0.54
PCC88	0.80
PCC89	0.80
PCC189	0.80
PCC805	0.60
PCC806	0.80
PCE82	0.80
PCF80	0.65
PCF82	0.60
PCF84	0.65
PCF86	1.20
PCF87	0.40
PCF200	1.35
PCF201	1.35
PCF800	0.40
PCF801	1.35
PCF802	0.72
PCF805	2.00
PCF806	1.00
PCF808	1.48
PCH200	1.10
PCL82	0.80
PCL83	2.00
PCL84	0.80
PCL85	0.80
PCL86	0.80
PCL200	1.80
PCL800	0.80
PCL805	0.90
PD500	3.50
PEN4DD	1.50
PEN25	1.50
PEN45	3.00
PEN46	1.50
PEN220	3.00
PENA4	4.00
PF818	0.95
PFL200	1.13
PL21	0.95
PL33	0.75
PL36	1.05
PL38	0.80
PL81	0.75
PL81A	0.75
PL82	0.80
PL83	0.52
PL84	0.65
PL88	1.00
PL95	1.00
PL302	1.00
PL345	12.50
PL500	1.12
PL504	1.20
PL508	1.75
PL509	3.15
PL519	3.35
PL801	1.50
PL802	2.95
PL820	3.00
PL806	2.75
PL6574	9.00
PMO4	0.50
PMO5	0.60
PMO7	2.00
PT4	4.00
PT15	4.50
PY31	0.80
PY32	0.80
PY33	0.80
PY81	0.70
PY82	0.55
PY83	0.70
PY88	0.74
PY500A	1.45
PY800	0.70
PY801	0.70
PZ30	0.60
Q13-110BA	47.50
QB3-300	30.50
QE03-10	3.50
QP25	1.00
QQE02-5	12.75
QQE03-12	4.50
QQE03-20	27.00
QQE06-40	19.50
QQV02-6	12.75
QQV03-10	3.75
QQV03-20A	15.50
QQV06-40A	18.00
QQZ06-40A	45.25
QS75/20	2.50
QS75/40	3.00
QS83/3	2.00
QS95/10	4.85
QS108/45	4.00
QS150/15	5.00
QS150/30	1.15
QS150/40	1.15
QS150/45	7.00
QS1200	3.95
QS1202	3.95
QS1203	4.15
QS1205	3.95
QS1206	1.05
QS1207	0.90
QS1208	0.90
QS1209	2.00
QS1210	1.50
QS1211	1.50
QS1212	3.20
QS1213	5.00
QS1215	2.10
QU37	15.00
QV03-12	3.50
QV04-7	5.00
QV05-25	1.75
QY3-125	30.50
QY4-250	52.15
QY4-400	82.00
QY5-500	99.00
QY5-3000A	379.00
R1	1.50
R2	1.50
R3	1.50
R10	4.00
R12	0.80
R16	12.00
R17	2.00
R18	8.00
R19	1.20
R20	1.20
RG1-125	3.50
RG1-240A	11.75
RG3-250A	11.75
RG3-1250	45.00
RG4-1000	10.00
RK-20A	12.00
RK22	1.00
RK33	1.00
RK34	1.00
RL16	1.50
RPL16	12.00
RPY13	2.50
RPY43	2.50
RPY82	2.50
RR3-250	37.00
RR3-1250	65.00
RS613	45.00
RS631	60.00
RS685	30.50
RS686	52.15
RS687	99.00
S6F17	35.00
S6F33	35.00
S11A	1.50
S11E/2	35.00
S104/1K	6.00
S109/1K	15.00
S130P	2.50
S130P	3.00
SC1/800	5.00
SC1/1200	5.00
SD3	1.00
SD61	1.00
SP41	4.00
SP42	2.50
SS501	79.00
ST11	1.50
STV280/40	8.00
STV280/80	30.00
T41	2.00
TB2-300	45.00
TD1-100	19.00
TD03-10F	28.00
TD3-12	4.00
TP25	1.50
TT11	1.50
TT21	19.50
TT22	14.75
TY2-125A	45.00
TY3-250	45.00
TY4-350	90.00
TY4-400	80.00
TY4-500A	80.00
TY7-6000A	315.00
TY8-600W	315.00
TYS2/250	750.00
U10	1.50
U12	1.50
U14	1.50
U15	1.50
U17	1.50
U18-20	2.00
U19	11.95
U22	1.00
U24	2.00
U25	0.68
U26	0.80
U27	1.50
U37	12.00
U41	0.70
U50	2.00
U52	1.00
U54	4.50
U82	3.00
U191	0.70
U193	0.65
U281	1.00
U282	1.00
U291	0.60
U301	0.60
U309	0.60
U801	0.80
UABC80	0.65
UAF42	1.00
UBF80	0.60
UBC81	1.00
UBF89	0.60
UBL21	1.20
UC92	0.80
UCC84	0.70
UCC85	0.60
UCH21	1.20
UCH41	1.20
UCH42	1.20
UCH81	0.65
UCL82	0.76
UCL83	1.75
UF41	1.15
UF42	1.15
UF80	0.80
UF86	1.10
UF89	1.10
UL41	1.85
UL84	0.78
UU5	2.50
UU7	8.00
UU8	8.00
UY1N	0.90
UY41	1.95
UY85	0.70
UY224	2.50
V339	3.50
V884	2.50
V914	2.00
V1103	4.50
V1135	18.50
VLS631	13.00
VP6	2.50
VP41	1.50
VP133	2.00
VR37	1.50
VR54	0.60
VR75/30	3.00
VR91	1.50
VR101	1.50
VR102	1.50
VR105/30	1.05
VR150/30	1.50
VT4C	12.50
VT25	5.00
VT75B	3.00
VT120	1.15
VT138	4.25
VT501	1.00
VU39	1.50
VX6120	5.00
VX9133	5.00
VX9181	5.00
W25	0.60
W61	1.50
W63	0.70
W77	5.00
W107	0.70
W142	1.15
W147	1.75
W727	0.65
W729	1.00
X24	1.00
X65	1.00
X66	1.00
X79	3.00
X719	0.58
XB2	1.00
XC12	1.50
XC15	1.50
XC25	0.35
XFW47	1.00
XFW50	1.00
XG5-500	19.50
XL1-5V	0.70
XR1-1600A	29.00
XR1-6400A	128.00
XSG2	1.00
Y63	2.50
YJ1060	265.00
YL1020	29.00
YL1060	15.00
YL1070	115.00
YL1071	98.50
YL1370	5.50
Z63	1.00
Z66	1.00
Z77	1.20
Z300T	5.00
Z303C	9.00
Z502C	12.00
Z504S	13.50
Z700U	1.00
Z749	0.48
Z759	16.00
Z800U	4.00
Z801U	4.00
Z803U	13.50
Z7014	9.00
ZA101	5.00
ZA1000	9.00
ZA1002	1.48
ZC1040	8.00
ZM1001	5.00
ZM1005	8.00
ZM1020	4.00
ZM1021	8.00
ZM1023	8.00
ZM1041	13.00
ZM1202	78.00
ZM1263	4.00
ZM1612	3.00
ZX1000	5.00
ZX1061	5.00
1AC6	1.20
1AH5	0.85
1AJ4	0.65
1B22	10.00
1B3GT	1.00
1B5	2.50
1C1	1.20
1C2	1.20
1C5GT	1.00
1D5	1.00
1FD1	0.90
1G3GT	1.00
1L6	1.50
1LA6	1.00
1M1	1.10
1N5GT	2.50
1S2	0.55
1T4	0.55
1U5	1.00
1X2A	1.15
1XBB	1.15
2A3	3.00
2AS15A	11.00
2B35	1.00
2B46	4.95
2C21	1.00
2C34	1.00
2C39A	19.00
2C42	4.00
2C51	0.75
2B7	1.50
2D21	0.95
2D21W	2.00
2K25	17.50
3A/147J	7.50
3A/167M	10.00
3A2	3.00
3A3A	3.00
3A4	0.80
3AT2	1.75
3AW2	3.35
3B28	12.00
3BP1	12.00
3C4	1.00
3C45	12.50
3D6	0.50
3D21A	24.00
3W4GT	2.50
4-125A	46.00
4-250A	42.00
4-400A	48.00
4CX250B E1MAC	37.50
Ex Gov't as new	12.00
4CX350A	52.00
4CM4	0.80
4DL4	0.80
4HA5	0.95
4X150A	29.50
4X500A	215.00
5A163K	10.00
5A-170K	5.25
5A189K	2.00
5AN8	1.20
5AR4	2.00
5B-254M	14.50
5B-255M	14.50
5B-257M	5.00
5C-100A	18.50
5D6	4.00
5D21	15.50
5D22	38.00
5R4GB	2.80
5R5GY	2.80
5U4G	0.85
5U4GB	1.50
5V4G	0.85
5Y3GT	0.85
5Z4GT	0.85
6/30L2	0.70
6A/203K	9.00
6A6	1.50
6A8G	1.50
6AB7	0.80
6AB8	0.86
6AC7	1.00
6AF4A	1.20
6AG7	1.20
6AH6	1.00
6AJ7	1.00
6AK5	0.80
6AK6	2.00
6AL5	0.52
6AM4	2.50
6AM5	6.00
6AM6	1.30
6AM8A	2.00
6AN5	2.00
6AN8A	2.50
6AQ5	0.82
6AR5	2.00
6AR8	2.00
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	0.80
6AV5GTA	1.50
6AU6	0.55
6AV6	0.72
6AW8A	2.50
6AZ8	1.80
6B8G	0.75
6B10	2.50
6BA6	0.50
6BA6W	3.00
6BA7	3.75
6BA8A	3.50
6BC8	1.00
6BD6	1.10
6BE6	0.72
6BF5	1.10
6BH6	1.60
6BH8	1.00
6BJ6	1.05
6BK4	2.75
6BK7A	1.50
6BM8	0.58
6BN4	1.25
6BN6	1.30
6BN7	3.50
6BN8	2.00
6BQ5	0.60
6BQ6GA	2.00
6BQ7A	0.72
6BL8	0.65
6BR5	0.70
6BR7	3.75
6BR8	1.20
6BR8A	1.20
6BS7	3.30
6BS8	1.88
6BU6	2.00
6BU8	1.15
6BW4	1.30
6BW6	4.50
6BW7	0.75
6BW8	4.00
6BX7GT	2.00
6BZ6	2.00
6BZ7	2.50
6BZ8	0.95
6C4	0.80
6C6	0.50
6C8G	1.25
6C11	2.50
6C15	2.50
6C18	2.50
6C31	1.50
6CA4	0.80
6CB5	1.50
6CB6	1.50
6CD6GA	4.00
6CF6	1.50
6CG8A	1.00
6CH6	10.00
6CL6	2.50
6CS6	0.75
6CT7	1.40
6CW4	4.00
6CX8	2.00
6CY5	1.00
6CZ5	2.00
6DC6	2.00
6DC8	0.70
6DK6	0.85
6DQ5	2.30
6DR7	2.00
6DW4	1.20
6DX8	0.74
6EA8	1.80
6EB8	1.10
6EU8	1.10
6F1	2.00
6F6G	2.00
6F8G	1.50
6F11	1.30
6F12	1.30
6F14	1.00
6F15	1.00
6F17	3.00
6F18	1.50
6F19	0.48
6F21	2.50
6F22	0.70
6F23	0.48
6F24	1.25
6F25	1.25
6F26	0.48
6F28	1.25
6F33	18.00
6F36	1.00
6FG5	1.50
6FH5	1.50
6FN5	1.50
6FL2	1.50
6GH8A	0.80
6GK5	1.00
6GK6	2.00
6H2N	0.70
6H3N	0.70
6H6	1.00
6H6GT	1.20
6HG8	1.50
6HZ6	1.00
6J5GT	0.75
6J6	0.55
6J7	1.05
6J7GT	1.25
6JB6A	3.95
6JE6	2.10
6JS6C	2.55
6K4N	1.00
6K7	1.50
6K7G	0.70
6K8GT	1.75
6KD6	3.95
6L1	2.50
6L6GC	1.25
6L6GC	1.90
6L6GT	1.20
6L7	0.55
6L15	1.50
6L17	1.50
6L18	0.80
6L19	1.00
6LD3	0.85
6LD20	0.80
6P15	0.80
6P25	4.00
6P28	2.00
6Q7	1.20
6S2	0.50
6S2A	0.50
6S7	1.10
6SC7	1.20
6SG7	1.20
6SJ7	1.20
6SK7	0.80
6SK7GT	1.20
6SL7GT	0.72
6SN7GT	0.69
6SS7	1.50
6U4GT	1.75
6U5G	2.50
6U8	0.50
6U8A	1.00
6V4	0.75
6V6GT	0.90
6W4GT	1.00
6X2	0.80
6X2N	1.00
6X4	0.96
6X5GT	0.80
6X8A	2.25
7A3	4.00
7A8	2.00
7A7	2.00
7AD7	1.75
7B6	2.00
7B7	1.40
7C5	2.50
7C6	2.00
7D6	1.40
7FC7	0.80
7GV7	2.00
7H7	1.50
7HG8	1.20
7Q7	2.00
7S7	3.00
7Y4	1.00
8C7W	3.00
8D3	1.22
8D8	2.75
8FQ7	1.40
9BW6	1.20
10C1	5.50
10C2	0.70
10C14	0.65
10D2	1.25
10F1	0.75
10F9	0.75
10FD12	0.60
10F18	0.80
10GK6	1.95
10P13	1.00
10P14	2.50
10LD11	1.00
10LD12	0.85
10Y	8.00
11E2	16.50
11E3	55.00
12A4	2.50
12AC6	0.80
12AD6	0.80
12AE6	0.85
12AG8	1.50
12AH7GT	0.85
12AH8	5.50
12AL5	1.00
12AT6	0.59
12AT7	0.55
12AT7WA	2.50
12AU6	0.60
12AU7	0.55
12AV6	0.80
12AX4GT	1.00
12AX7	0.60
12AX7WA	2.50
12AY7	4.00
12AZ7A	1.50
12B4A	1.60
12BA6	0.75
12BE6	1.05
12BH7	0.95
12BH7A	0.95
12BL6	0.70
12BY7A	3.75
12C8GT	0.70
12CX6	1.20
12E1	16.50
12E14	28.00
12GN7	3.25
12HG7A	3.25
12J5GT	0.48
12J7GT	0.70
12K5	1.00
12K7GT	0.80
12K8	1.10
12Q7GT	0.50
12S7	1.00
12SA7GT	1.00
12SJ7	0.80
12SL7	1.50
12SN7GT	1.85
12SR7	0.70
12U7	1.50
12Y4	0.50
13D3	3.20
13D7	3.20
13D8	3.20
13E1	97.50
14K7	1.20
14S7	1.00
15A6	1.00
15D2	1.00
15E	1.00
17DW4A	1.75
17JZ8	1.80
18D3	1.80
19AQ5	0.70
19G6	9.00
20A2	4.00
20D1	0.70
20D4	1.75
20F2	0.75
20K	1.00
20L1	0.95
20P1	0.55
20P3	0.80
20P4	1.05
20P5	1.15
29C1	19.50
30	2.85
30C1	0.70
30C15	0.40
30C17	0.40
30C18	2.00
30F5	0.95
30FL1	0.95
30FL2	0.95
30FL12	1.10
30FL14	1.85
30L1	0.45
30L15	0.80
30L17	0.80
30P4MR	1.00
30P12	1.00
30P16	0.80
30P18	0.80
30P19	1.00
30PL1	2.50
30PL13	0.80
30PL14	2.25
31JS6A	2.95
35L6GT	2.00
35W4	0.70
35Z3	1.85
38HE7	3.50
40KD6	3.25
50C5	0.95
50CD6G	1.15
50L6GT	2.00
52KU	0.85
57	0.85
6063	2.00
6096	2.85
75B1	1.50
75C1	1.20
80	1.40
83A1	7.00
84	0.85
85A1	5.40
85A2	2.00
89	1.20
90AV	18.00
90C1	2.10
90CG	10.85
91AG	10.00
92AG	10.00
92AV	10.00
150B2	3.00
150B3	3.90
150C4	1.50
150CV	150.00
155UG	25.00
185BT	1.50
257A	6.00
329	5.00
408A	4.00
431U	2.00
708A	5.00
715A	8.00
715C	15.50
801A	2.00
803	16.00
807	1.50
808	3.00
811A	9.00
813	18.50
833A	115.00
836	7.00
845	8.00
866A	3.00
868	5.00
885	2.00
954	0.50
955	0.90
958A	0.90
1267	7.00
1299A	0.60
1927	5.00
2050	6.00
4212E	230.00
5557	19.50
5636	3.00
5642	5.00
5651	1.75
5654	1.95
5670	3.50
5675	5.15
5683	14.00
5692	3.50
5696	2.65
5718	3.50
5725	3.50
5726	1.50
5727	2.00
5749	2.00
5750	2.00
5751	1.50
5763	3.50
5814A	2.75
5840	2.50
5842	6.50
5876	8.25
5879	3.90
5899	2.00
5915	2.00
5963	1.50
5965	2.25
5993	8.00
6005	3.50
6057	1.85
6059	3.75
6060	1.50
6064	1.85
6067	1.50
6072	4.20
6080	4.50
6080WA	8.50
6132	10.00
6146A	4.45
6146B	4.45
6201	1.50
6360	4.50
6545	8.50
6870	11.50
7025	2.50
7032	2.00
7199	3.20
7318	9.00
7360	7.50
7475	1.00
7551	4.50
7558	11.50
7586	6.00
7581A	3.00
7591A	2.35
7695	4.50
7868	3.50
8012	4.20

★ WE HAVE NOW MOVED TO LARGER PREMISES ★

CALLERS WELCOME

★ ENTRANCE ON A227 BY THE "LITTLE BLUE HOUSE" 50 YDS SOUTH OF MEOPHAM GREEN

CAR PARKING AVAILABLE

★ HOURS: MON.-FRI. 9.00-5.30. SATURDAY 9.30-12.00

★ 24 HOUR ANSWERPHONE SERVICE ★

ACCESS AND BARCLAYCARD ORDERS WELCOME

★ MANY OTHER ITEMS AVAILABLE ★

UK ORDERS P&P 50p PLEASE ADD V.A.T. AT 15%

EXPORT ORDERS WELCOME. CARRIAGE/POST AT COST

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FINAL RADIO AND ELECTRONICS EXHIBITION AT BELLE VUE

by the NORTHERN RADIO SOCIETIES ASSOCIATION in the

LANCASTER HALL BELLE VUE, MANCHESTER

on SUNDAY, 4th APRIL, 1982. Doors open at 11 a.m. The North's Premier Amateur Radio and Electronics Event

Features: Inter-club quiz; grand raffle; construction contest; amateur computer stands; RSCB book stall; Radio Society stands and Trophy

Home Office and Raynet stands

Belle Vue has ample car parks

FM talk-in on GB3NRS and G8NRS/A on 145MHz Chs22 R2 R6 and on 433MHz Chs SU8-RB4 RB14

ADMISSION 60p BY RAFFLE TICKET AND EXHIBITION PLAN
Enter at rear of Belle Vue, opposite main car park off Hyde Road A57

RHODE & SCHWARZ

Selective UHF V/Meter. Bands 4 & 5. USVF
Selectomat Voltmeter USWV **£450.**
UHF Sig. Gen. type SDR 0.3-1GHz
UHF Signal Generator SCH **£175.**
XUD Decade Synthesizer & Exciter.
POLYSKOPS SWOB I and II.
Modulator/Demodulator BN17950/2.

MARCONI

TF995B/2 AM/FM Signal Generator.
TF2500 Audio power meter
TF1101 RC oscillators **£65.**
6551 SAUNDERS. 1400-1700MHz. FM.
TF1066B/1. 10-470MHz. AM/FM.
TF1152A/1. Power meter. 25W. 500MHz **£50.**
TF1370A RC Oscillator **£135.**
TF791D Carrier Deviation Meter.

BECKMAN TURNS COUNTER DIALS

Miniature type (22mm diam.). Counting up to 15 turn "Helipots". Brand new with mounting instructions. Only **£2.50** each.

★ VIDEO EQUIPMENT SALE ★
CONTENTS OF COMPLETE MONOCHROME STUDIO

MARCONI Video/Audio mixing desks.
Monochrome Video cameras complete with on-board monitors.
Video monitors types CONRAC II (9" tube) PROWEST 13".
To be sold in first-class working condition.
Offers invited for complete lot.

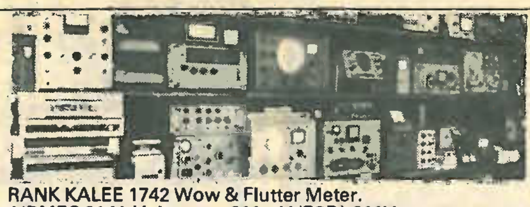
SEALED LEAD ACID BATTERIES

Gould GELYTE type PB660. 6V. 6A.H. Measures 3¾x2¾x2¾ inches. Excellent condition. **£4.50.** (75p post).

20-WAY JACK SOCKET STRIPS. 3 pole type **£2.50 each** (+ 25p p.p.). Type 316 three-pole plugs for above—**20p ea.** (p.p. free).

P. F. RALFE ELECTRONICS

10 CHAPEL STREET, LONDON, NW1
TEL: 01-723 8753



RANK KALEE 1742 Wow & Flutter Meter.
AIRMEC 314A Voltmeter. 300mV (FSD)-300V.
AIRMEC Wave Analysers types 853 & 248A.
DERRITRON 1KW Power Amplifier with control equipment for vibration testing, etc.
TELONIC type 1204 0-500MHz sweep generator **£150**
TELONIC type 121 Display scopes **£90**
TELONIC type 101 Display scopes **£75**
WAYNE KERR AF signal generator S121 model **£85**
RADIOMETER Distortion Meter BKF6 **£125.**

SPECIAL PURCHASE OF TEKTRONIX 454 PORTABLE OSCILLOSCOPES

Tektronix 454 DC-150MHz dual-beam oscilloscopes in stock now. 5mV/cm Y-amplifier (1mV cascaded). 2.4ns risetime. Calibrated sweep delay. We can offer these units in first-class operational condition complete with three months' guarantee, for a once only price of £850.
Full specification sheet upon request.

★ OSCILLOSCOPES ★
TEKTRONIX 500 SERIES SCOPES AT BARGAIN PRICES:

All in good working order. Available to callers only
TYPE 543B with 'CA' plug-in 25MHz DB .... SOLD OUT
TYPE 545B with 'CA' plug-in 25MHz DB .... SOLD OUT
TYPE 585A with '82' unit. 80MHz. Few left ~~£250~~. Reduced to **£200**

PLEASE NOTE. All the pre-owned equipment shown has been carefully tested in our workshop and reconditioned where necessary. it is sold in first-class operational condition and most items carry a three months guarantee. For our mail order customers we have a money-back scheme. Repairs and servicing to all equipment at very reasonable rates. PLEASE ADD 15% VAT TO ALL PRICES.

DC POWER SUPPLIES

★APT 10459/8, 12-14V @ 5 Amps **£25** (£2 p.p.)
★APT 10459/8, 24V @ 5 Amps **£25** (£2 p.p.)
★We can supply the above power supply at any fixed voltage between 5V and 36V at 5A **£25.**
★Mullard Dual supplies. Brand new with handbook. Pos & Neg 12V at 1A and 0.4A respectively. Dimensions 9x4x5ins. **£10** + (£1 p.p.)
★FARNELL Current limited. Dimensions 7x5x4ins. Following types available: 13-17 Volts @ 2A **£15.** 27-32 Volts @ 1A 5V **£15.** 5V @ 3A **£15.** (pp £1.50).

SPECIAL PURCHASE
LAMBDA POWER SUPPLIES

Excellent LXS Series DC power units at less than a tenth of new price. The snag? — they're all 110V AC Input. Prices as follows:
5V at 24A. LXS D5 0V R. **£25.** (List £350).
5V at 14A. LXS CC 5 0V. **£20.** (£258).
24V at 3.1A. LCS C 24. **£15.** (£223).
Carriage each £2.50 extra
Special note: The 5V power supplies may be operated (both primary from 230V) and DC output to give a maximum output voltage of 12.5DC when connected in series. Deduct 10% from price for two off or more, i.e., 12V DC at 24A for **£45** + Tax! Very cheap!

VARIABLE VOLTAGE BENCH SUPPLIES

Variable voltage DC power supplies for workshop use. Constant voltage, variable 0-30V output at 1A. Cased, free standing, volt-metered output. Short circuit proof. Size 4 × 5× 7". Only **£30**—each (pp £1.50).

COMMUNICATIONS TEST EQUIPMENT

MARCONI TF1066B/1. AM/FM Signal Generator. 10-470MHz. 0.2uV-200mV output. FM Deviations up to ±100KHz from 30Hz-15KHz **£550**
MARCONI TF995A/5 AM/FM Signal generator. Narrow deviation model 995 covering 1.5-220mHz **£450**
MARCONI TF1064B/5 FM signal generator covering in three ranges 68-108, 118-185 and 450-470MHz. Modulation FM fixed deviations of 3.5 and 10KHz. AM fixed 30% **£225**
MARCONI TF791D FM Deviation meter £185

ROTRON INSTRUMENT COOLING FANS

Supplied in excellent condition, fully tested:
115V, 4.5 × 4.5 × 1.5" **£4.50.** 230V **£5.** 115V, 3 × 3 × 1.5" **£4** + postage ea. 35p.

100V DC ELECTROLYTIC CAPACITORS

Sprague 'Powerlytic' type 36D. 10,000uF. 100V. Brand new at surplus price! Only **£4** ea. PP 50p.

GRAPHICSGRAPHICS GRAPHICS

What's going on in Computer Aided Design—and how will it develop? Ever wondered about the maths behind interactive 3-D graphics? Want to know about the graphics capabilities of the powerful Hewlett Packard HP-83?
Our April issue examines three aspects of graphics in computing. We review Grandstand, a game for gamblers with a Pet computer; show how microprocessor control has come to the farm ...
That's just a sample of Practical Computing, together with advice for users of Pet, Apple, Tandy and Sinclair ZX 80/81 computers. Buy Britain's leading personal computer magazine.

APRIL ISSUE OUT NOW. 80p AT YOUR NEWSAGENT'S—BUT HURRY.

Practical Computing

CHILTERN ELECTRONICS

B.C.M. Box 8085, LONDON, WC1N 3XX
BRAND NEW SURPLUS DISK DRIVES

Due to bulk purchase of bankrupt stock, we are able to offer these Floppy and Hard Disk drives at a fraction of their usual cost. Both are brand new in original boxes dated 1979/80. They are both manufactured by the famous Data Recording Equipment Co. who are known worldwide for their high engineering standards.

★ DRI SERIES 32 5-MEGABYTE CARTRIDGE DRIVE
Successor to the famous Series 30, these are similar in design but double the density on the same type of cartridge. It will either operate as a single 5.6 Megabyte drive or emulate two 2.5 MByte drives, and can be daisy chained on to all similar drives such as RK05, Pertec, Wangco, etc.
Manufacturer's list price is over £3,000. **Our price £420!**

Controllers available for S-100 Bus Systems for £400, complete with all documentation and software. This gives you a beautiful hard disk system for less than the cost of many floppies. Controllers also available for PDP11 and LSI-11.

★ DRI SERIES 7200 FLOPPY DISK DRIVES
These are new 8-inch double-sided single or double density units, giving up to 1.6 Megabytes unformatted capacity on a single disk. Interface is the same as Shugart, die cast alloy construction, top quality.
Our price only £250 or two for £450!

OTHER COMPUTER BARGAINS

MINIATURE 5 VOLT 20-AMP POWER MODULES
These beautiful little pocket-sized power supplies weigh less than 4lbs, and yet deliver a massive 22 amps at 4 to 6 volts with 0.1% regulation and full overvolts and overcurrent protection. Standard 230v mains input.
Usually these units cost over £250 each — manufactured by Farnell/Gould.
Our price £34.50 brand new, INCLUDING VAT AND POSTAGE

PERTEC 9-Track Magtapes. (Model 6840)
For callers only we have some of these beautiful tape drives available for only **£130 each.** Originally these cost over £2,500 each—and they are only a few years old. They are sold without guarantee and need a good clean-up, but we have spares available cheaply and they are very easy to interface to a micro.
ASCII 84 Key Professional Keyboards in case **£30**
Video Monitors, 9 inch with PSU **£27**
Video Monitors, Ball Inc. 14 inch **£40**
Video Monitors, 14 inch green screen in case **£99**
Proto cards: Over 350 TTL ICs and sockets—none are soldered, and 5V 3A Regulated PSU for £25 or £30 inc. VAT/Postage.
Please add 15% VAT and carriage to above.
We stock wide range of DEC Systems from PDP8E to PDP11/70 and have lots of one-off bargains. Why not visit our office near High Wycombe sometime.
Please telephone Nigel Dunn on 0494 714483 any time

WW—065 FOR FURTHER DETAILS

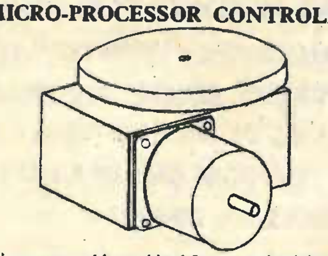
WRONG TIME?

MSF CLOCK is ALWAYS CORRECT – never gains or loses, SELF SETTING at switch-on, 8 digits show Date, Hours, Minutes and Seconds, auto GMT/BST and leap year, can expand to Years, Months, Weekdays and Milliseconds, also parallel BCD output for computer or alarm, etc., receives Rugby 60KHz atomic time signals, built-in antenna, 1000Km range, GET the RIGHT TIME £62.80.
V.L.F.? EXPLORE with a 10-150KHz Receiver, £16.50.
60KHz RUGBY RECEIVER, as in MSF Clock, serial data output for computer, etc., decoding details, £17.90.
Each fun-to-build kit (ready made to order) includes all parts, printed circuit, case, postage, etc., instructions, money back assurance so GET yours NOW.

CAMBRIDGE KITS

45 (WD) Old School Lane, Milton, Cambridge. Tel: 860150

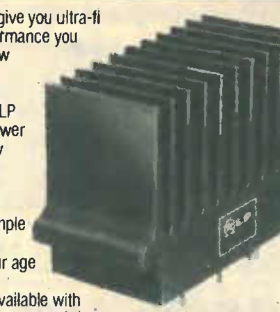
STEPPING MOTOR ROTARY TABLE
MICRO-PROCESSOR CONTROLLED



Stepping motor driven rotary table machined from cast aluminium parts, table diameter 130mm, gear ratio 120:1, motor 200 steps per revolution, 24,000 motor pulses per table revolution, max. speed in start/stop mode 10 degrees per second. Easily stackable to produce a pan and tilt mechanism, £192 each. Motor drive pcb type 440 to interface to microprocessor port, £32 each. Other machines made to order. Complete 8085 based computer systems with software available.

F.H. PRECISION ENGINEERS
24 Belvoir Avenue, Trentham, Stoke-on-Trent ST4 8SY
Tel. 0782-643278 (Ansaphone)

WHY AN ILP MOSFET POWER AMP?

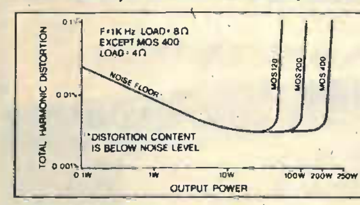


Because ILP MOSFET power amps give you ultra-fi performance without costing big money. Performance you thought you couldn't afford at a price you know you can.

All ILP modules are compatible with each other — you'll find many more in other ILP ads in this magazine. Choose ILP MOSFET power amps when you need the fastest possible slew rate, low distortion at high frequencies, better thermal stability. MOSFET power amps work with complex loads without difficulty and without crossover distortion. Connection is simple — via 5 pins. With other ILP modules you can create almost any audio system, whatever your age or experience.

ILP MOSFET power amps are now available with integral heatsink (no extra heatsink required), or ready for mounting on to your own heatsink or chassis. Full dissipation detail on data sheet, available on request. Each carries a 5 year no quibble guarantee and comes with full connection data.

Send your order FREEPOST today on the coupon at the foot of this ad.



Load impedance, all models, 4 ohm — infinity
Input impedance, all models 100K ohm
Input sensitivity, all models, 500 mV
Frequency response, all models 15Hz-50kHz-3db

MOSFET Ultra-Fi, with heatsinks

Model No.	Output power Watts rms	DISTORTION T.H.D. Typ at 1kHz	DISTORTION I.M.D. 50Hz/7kHz 4:1	Supply voltage Typ/Max	Size mm	Wt gms	Price inc. VAT	Price ex. VAT
MOS 120	60w/4-8Ω	<0.005%	<0.006%	±45±50	120×78×40	420	£29.76	£25.88
MOS 200	120w/4-8Ω	<0.005%	<0.006%	±55±60	120×78×80	850	£38.48	£33.46
MOS 400	240w/4Ω	<0.005%	<0.006%	±55±60	120×78×100	1025	£52.20	£45.39

MOSFET Ultra-Fi without heatsinks

MOS 120P	60w/4-8Ω	<0.005%	<0.006%	±45±50	120×26×40	215	£26.82	£23.32
MOS 200P	120w/4-8Ω	<0.005%	<0.006%	±55±60	120×26×80	420	£32.81	£28.53
MOS 400P	240w/4Ω	<0.005%	<0.006%	±55±60	120×26×100	525	£44.75	£38.91

Protection:
Able to cope with complex loads, without the need for very special protection circuitry (fuses will suffice).

Ultra-fi specifications:
Slew rate 20Vμs. Rise time3μs. S/N ratio 100db. Frequency response (–3dB) 15Hz-100kHz. Input sensitivity 500mVrms. Input impedance 100k. Damping factor (8Ω/100Hz)>400.

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Colour printout is quickly assimilated, makes graphics more understandable and is an ideal medium for the presentation of complex data or concepts.

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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.

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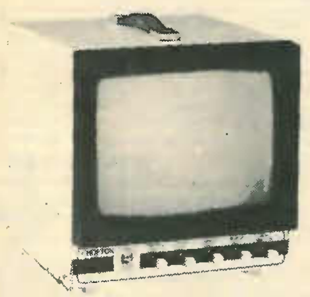

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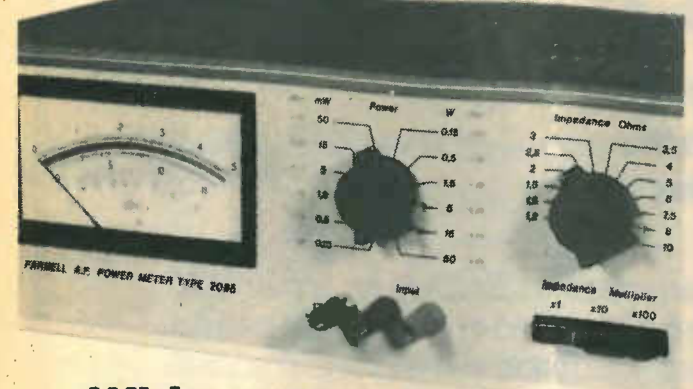
Audio power meter



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Model No.	Module	What it does	Current required	Price inc. VAT	Price ex. VAT
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AND OTHER EXCITING NEW MODULES

Model No.	Module	What it does	Current required	Price inc. VAT	Price ex. VAT
HY 13	Mono VU meter	Programmable gain/LED overload driver.	10 mA	£6.84	£5.95
HY 67*	Stereo headphone driver	Will drive stereo headphones in the 4 ohm-2K ohm range.	80 mA	£14.20	£12.35
HY 72	Voice operated stereo fader	Provides depth/delay effects.	20 mA	£15.07	£13.10
HY 73	Guitar pre-amp	Handles two guitars (bass and lead) and mic with separate volume/bass/treble and mix.	20 mA	£14.09	£12.25
HY 76	Stereo switch matrix	Provides two channels, each switching one of four signals into one.	20 mA	To be announced	
HY 77	Stereo VU meter driver	Programmable gain/LED overload driver.	20 mA	£10.64	£9.25

For easy mounting we recommend:
B 6 mounting board for modules HY6 -HY13 £0.90 inc. VAT. (0.78 ex. VAT.)
B 66 mounting board for modules HY66-HY77 £1.12 inc. VAT. (0.99 ex. VAT.)

*All modules are encapsulated and include clip-on edge connectors. All operate from ±15V minimum to ±30V maximum, needing dropper resistors for higher voltages. HY67 can be used only with the PSU 30 power supply unit. Modules HY6 to HY13 measure 45×20×40mm. HY66 to HY77 measure 90×20×40mm.

FP 480 BRIDGING UNIT FOR DOUBLING POWER

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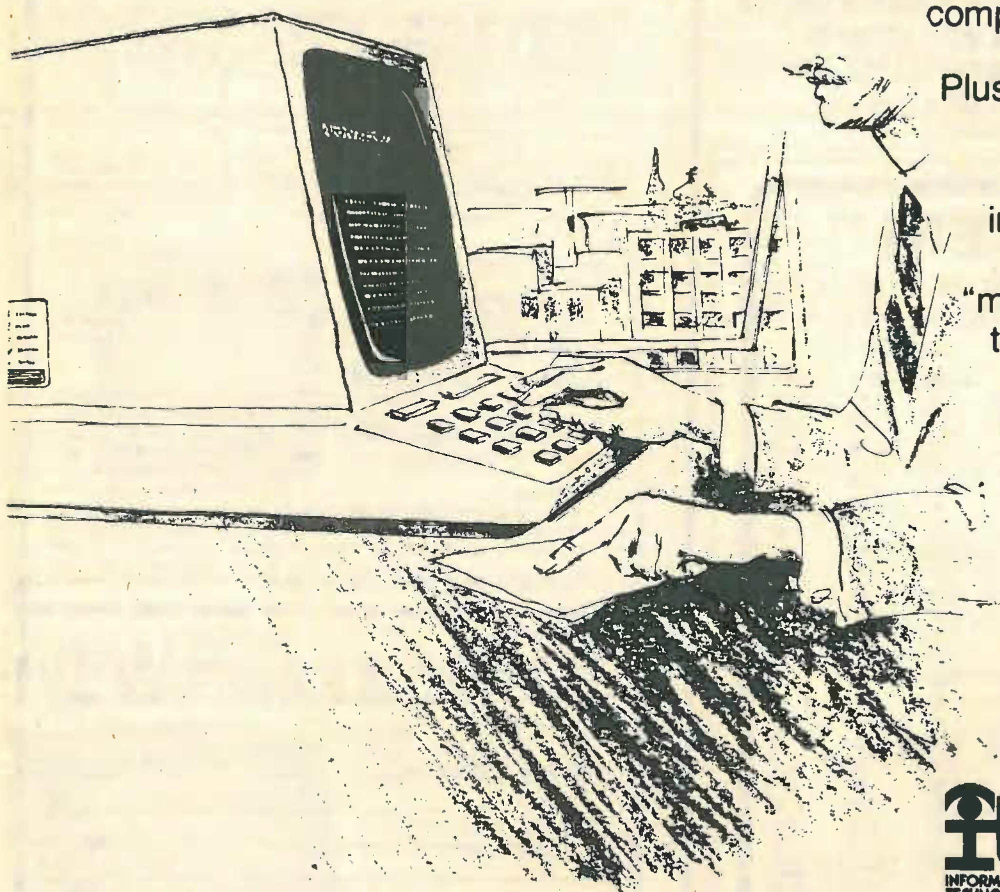

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2N3632	6.03	2N5090	8.44	BLX66	4.91	BLY83	7.45
2N3733	6.13	2N5102	9.44	BLX67	5.41	BLY84	7.25
2N3866	0.92	2N5590	7.85	BLX68	7.29	BLY85	6.02
2N3924	1.66	2N5591	10.21	BLX69X	21.15	BLY87A	6.43
2N4040	9.29	2N5641	4.68	BLX91A	8.84	BLY87C	6.43
2N4041	10.97	2N5642	8.11	BLX92A	13.06	BLY88A	8.66
2N4127	9.18	2N5643	12.44	BLX93A	19.19	BLY89C	9.10
2N4128	11.03	2N5913	2.34	BLX94A	35.79	BLY89A	12.65
2N4129	12.08	2N6080	5.94	BLX95	44.59	BLY69C	11.90
2N4427	1.15	2N6081	9.87	BLX98	84.95	BLY91A	6.95
2N4429	9.89	2N6082	10.17	BLY33	1.87	BLY91C	6.90
2N4430	11.30	2N6083	11.08	BLY34	1.07	BLY92A	9.25
2N4431	12.50	2N6084	12.27	BLY35	7.50	BLY92C	9.06
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4-125A	42.90	6155/QY3-125(AEL)	
4-250A	50.70		22.40
4-400A	58.20	6156/QY4-250	45.30
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PSU 30	±15V combinations of HY6/66 series to a maximum of 100 mA or one HY67.	£5.18	£4.50
	The following will also drive the HY6/66 series except HY67 which requires the PSU 30.		
PSU 36	1 or 2 HY 30.	£9.32	£8.10
PSU 50	1 or 2 HY 60.	£12.58	£10.94
PSU 60	1×HY 120/HY 120P/HD 120/HD 120P.	£15.00	£13.04
PSU 65	1×MOS 120/1×MOS 120P.	£15.32	£13.32
PSU 70	1 or 2 HY 120/HY 120P/HD 120/HD 120P.	£18.31	£15.92
PSU 75	1 or 2 MOS 120/MOS 120P.	£18.63	£16.20
PSU 90	1×HY 200/HY 200P/HD 200/HD 200P.	£18.63	£16.20
PSU 95	1×MOS 200/MOS 200P.	£18.77	£16.32
PSU 180	2×HY 200/HY 200P/HD 200/HD 200P or 1×HY 400/1×HY 400P/HD 400/HD 400P.	£24.54	£21.34
PSU 185	1 or 2 MOS 200/MOS 200P/1×MOS 400 1×MOS 400P.	£24.68	£21.46

All models incorporate ILP toroidal transformers except PSU 30 and PSU 36 which include our own laminated transformers.

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12/24V RANGE PRI 220/240V
SEC: 0 12V 0V 12V

TYPE	AMPS 12v	AMPS 24v	PRICE £	P/P £
242	0.3	0.15	1.70	0.50
213	10.50		2.65	0.94
71	2	1	2.77	1.20
18	4	2	3.98	1.57
68	3	1.5	3.46	1.57
85	5	2.5	6.06	1.57
70	6	3	6.67	1.57
108	8	4	8.03	1.57
116	12	6	9.31	2.10
17	16	8	11.46	2.25
115	20.10		13.69	2.25
187	30.15		19.23	2.55
232	40	20	27.61	5.00
226	60	30	35.35	4.50

15/30V RANGE PRI 220/240V
SEC: 0V 12V 15V 0V 5V 9V 15V
VOLTS AVAILABLE 3 ⟹ 15 — 0 — 15

TYPE	AMPS 15v	AMPS 30v	PRICE £	P/P £
112	1	0.50	2.84	1.20
79	2	1.0	3.29	1.20
3	4	2	6.18	1.57
20	6	3	7.19	1.90
21	8	4	8.52	1.90
51	10	5	10.57	2.10
117	12	6	11.94	2.25
88	16	8	16.14	2.40
89	20	10	18.54	2.55
90	24	12	20.57	2.80
91	30	15	23.63	2.90
92	40	20	33.21	5.00

25/50V RANGE PRI 120/220/240V
SEC: 0V 20V 25V 0V 8V 15V 25V
VOLTS OUT 5 ⟹ 25 — 0 — 25

TYPE	AMPS 25v	AMPS 50v	PRICE £	P/P £
102	1	0.50	3.29	1.57
103	2	1.0	4.09	1.57
104	4	2	7.65	1.90
105	6	3	9.09	2.10
106	8	4	12.24	2.40
107	12	6	16.15	2.40
118	16	8	22.46	2.80
119	20	10	27.05	2.80
109	24	12	32.44	5.00

30/60V RANGE PRI 120/220/240V
SEC: 0V 24V 30V 0V 10V 18V 30V
VOLTS 6 ⟹ 30 — 0 — 30

TYPE	AMPS 30v	AMPS 60v	PRICE £	P/P £
124	1	0.5	3.30	1.57
126	2	1	6.36	1.57
127	4	2	7.86	1.90
125	6	3	11.78	2.10
123	8	4	14.72	2.40
40	10	5	17.10	2.40
120	12	6	19.44	2.55
121	16	8	27.70	2.90
122	20	10	32.05	4.50
189	24	12	37.02	5.50

48/96V RANGE PRI 120/220/240V
SEC: 0V 36V 48V 0V 36V 48V
VOLTS 12 ⟹ 48 — 0 — 48

TYPE	AMPS 48v	AMPS 96v	PRICE £	P/P £
430	1	0.5	4.69	1.57
431	2	1	7.84	1.57
432	4	2	12.94	2.25
433	6	3	14.62	2.40
434	8	4	20.04	2.70
435	10	5	28.75	2.90
436	12	6	36.16	4.50
437	16	8	39.47	5.50

AUTOTRANSFORMERS 240/220 – 115V
65VA — 10 KVA
0V 115V 220V 240V

TYPE	VA	PRICE £	P/P £
25	65	3.90	1.20
64	80	4.82	1.20
4	150	6.21	1.57
69	250	7.54	1.57
53	350	9.73	2.10
67	500	11.70	2.40
83	750	13.51	2.25
84	1000	18.31	2.55
95	2KVA	34.36	5.50
73	3	64.74	5.50
57	5	97.85	7.00
101	10	179.05	10.50

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240V LEAD IN:115V 2PIN SOCKET OUT

TYPE	VA	PRICE £	P/P £
56W	20	6.60	0.94
64W	80	8.43	1.57
4W	150	10.86	1.90
69W	250	13.17	2.10
67W	500	20.46	2.40
84W	1000	30.24	2.80
95W	2000	54.83	5.50
73W	3000	78.67	7.00

LINE ADJUSTMENT AUTOTRANSFORMERS
0 200 210 220 230 240 250

TYPE	VA	PRICE £	P/P £
415C	50	2.31	0.94
416C	100	3.46	0.94
417C	200	4.00	1.20
418E	350	6.26	1.57
419F	500	6.74	1.90
420E	750	8.33	2.10
421F	1000	11.64	2.25

TYPE	VA	PRICE £	P/P £
149F	60	8.40	1.90
150F	100	9.71	1.90
151F	200	13.84	2.25
152F	250	16.69	2.40
153F	350	20.77	2.80
154F	500	26.03	2.90
155F	750	36.75	5.50
156F	1000	47.42	6.50

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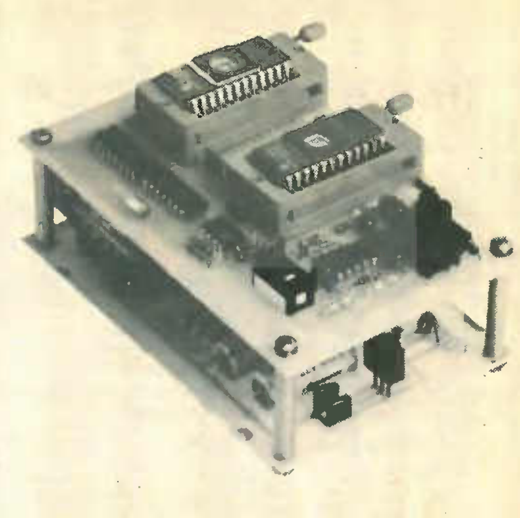

Yes, the new Delph EPROM copier will copy 2516, single rail 2716, and 2532 EPROMs. No computer required. Just insert the ROMs and press the button. Programming is finished when the LED goes out. 2K-4K select switch on board.

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- Review of the growing range of ZX81 boards and control ports
- How to adapt the ZX81 to use Atari joysticks

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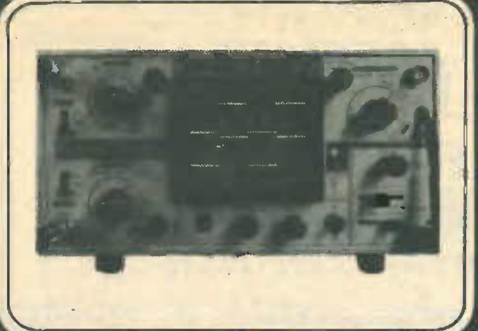

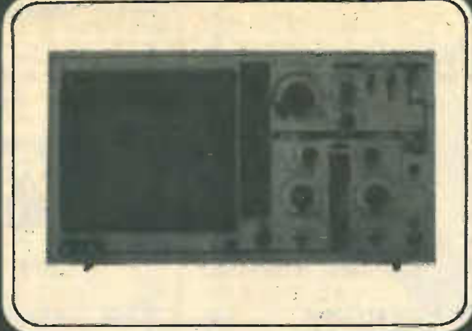

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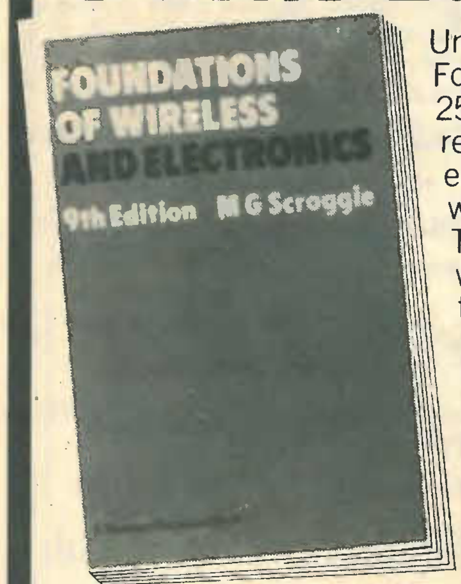

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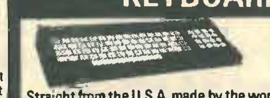

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ORDER NOW OR SEND FOR DETAILS.

COOLING FAN SPECIAL

Keep your equipment cool and reliable with our range of professional fans.
ETRI 99XU01 Miniature equipment fan 240 vac working DIM 92 x 92 x 25 mm **BRAND NEW** complete with finger guard. Makers price £16 our price £10.25
BUHLER 69.11.22 micro miniature 8-16 v DC reversible fan. Measures only 62 x 62 x 22 mm. Uses a brushless DC servo motor, almost silent running ideal portable equipment, life in excess of 10,000 hours. BRAND NEW manufacturers price **£32.00** our price **£13.95**
MUFFIN/CENTAUR cooling fans, tested ex equipment 240v **£6.50**, 115v **£5.50** + p&p £1.90
KOOL TRONICS Powerful snail type blower gives massive air movement with centrifugal rotor DIM as a cube 8" x 8" x 6" air aperture 2.5" x 2.5" with flange fixing. **BRAND NEW** 110v 50 Hz ac working ONLY **£9.95** + £1,90 p&p.

ELECTRONIC COMPONENTS & EQUIPMENT 66% DISCOUNT

Due to our massive bulk purchasing programme which enables us to bring you the best possible bargains, we have thousands of I.C.'s, Transistors, Relays, Cap's., P.C.B.'s, Sub-assemblies, Switches, etc. etc. surplus to our requirements. Because we don't have sufficient stocks of any one item to include in our ads., we are packing all these items into the "**BARGAIN PARCEL OF A LIFETIME**" Thousands of components at giveaway prices! Guaranteed to be worth at least *3 times* what you pay plus we always include something from our ads. for unbeatable value!! Sold by weight

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5v D.C. POWER SUPPLIES

Following the recent "SELL OUT" demand for our 5v 3 amp P.S.U. we have managed to secure a large quantity of ex-computer systems P.S.U.'s with the following spec.; 240 or 110v A.C. input. Outputs of 5v @ 3-4 amps, 7.2v @ 3 amps and 6.5v @ 1 amp. The 5v and 7.2v outputs are fully regulated and adjustable with variable current limiting on the 5v supply. Unit is self contained on a P.C.B. measuring only 12" x 5" x 3". The 7.2v output is ideal for feeding "on board" regulators or a further 3 amp LM323K regulator to give an effective 5v @ 7 amp supply.
Supplied complete with circuit at only **£10.95 + £1.75pp.**
Believed working but untested, unguaranteed.

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Dept. W.W., 64-66 Melfort Rd., Thornton Heath, Croydon, Surrey. Tel: 01-689 7702 or 01-689 6800

MAIL ORDER INFORMATION
Unless otherwise stated all prices inclusive of V.A.T. Cash with order. Minimum order value **£2.00** Prices and Postage quoted for UK only. Where post and packing not indicated please add **60p** per order. Bona Fida account orders minimum £20.00. Export and trade enquiries welcome. Orders despatched same day where possible. 3% surcharge on Access and Barclaycard orders.

WW – 094 FOR FURTHER DETAILS

Advertisements accepted up to 12 noon Monday, 5th April, for May issue, subject to space being availabe.

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* **There are opportunities for Managers, Project Managers, Engineers and Technicians.**
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(1471)

BBC TRANSMITTER DEPARTMENT
MOTSPUR PARK, SURREY

ENGINEER, VACUUM DEVICES

£8,950-£10,924 p.a.
(according to qualifications and experience)

We require an Electronic Engineer, with C.Eng/degree/HNC qualification, plus a minimum of three years' post-qualification experience in the design, manufacture or application of vacuum devices used in broadcast transmission.

Specific areas of involvement and responsibility include the application, acquisition, testing and distribution throughout the BBC of all types of vacuum devices and in particular the valves and klystrons, etc., used at transmitting stations, computerised stock control and in staff management.

Relocation expenses will be considered and benefits include 5 weeks' annual holiday. Men and women are equally eligible to apply.

Requests for application forms to **The Engineering Recruitment Officer, BBC, Broadcasting House, London W1A 1AA, quoting reference 82.E.1140/WW and enclosing an addressed envelope at least 9" x 4".**

BBC

(1544)

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We have vacancies in ALL AREAS of the U.K.

Ask for a Free Jobs List

Telephone: 01-637 5551 (3 lines)

(291)

Sound Attenuators Limited require an

Electronics Engineer

to work on the active control of sound in ducts. We require a graduate in electronics with at least two years' practical experience and an interest in acoustics. The project involves the implementation of basic research already undertaken at the University of Essex. The successful candidate must demonstrate self-reliance, practical ability and a keen interest in seeing the project through to a successful conclusion.

Write in the first instance, enclosing a full c.v. to:

Mr. A. T. Fry
Sound Attenuators Ltd.
Eastgates, Colchester, Essex
Tel: 0206 866911

(1566)

Systems Design Team

Satellite Communications Ground Terminals

Marconi Space and Defence Systems are Europe's acknowledged leaders in the development of advanced systems for aerospace and satellite communications.

To meet the growing interest in satellite communications we are strengthening the specialist teams working on sophisticated satellite ground terminals – offering total involvement from initial design and development through to implementation.

We need ambitious and enthusiastic men and women with several years' post-graduate experience in the design, development or operation of ground terminals or in other communications systems drawing on similar RF techniques. A knowledge of military satellite communications would be a distinct advantage.

SYSTEMS MANAGER

Aged 30+ must be able to combine high level technical expertise with the man-management skills necessary to weld a group of systems professionals into a closely knit team. At least 4 years' experience in a similar role is essential.

SENIOR SYSTEMS ENGINEERS

Applicants should be in their late 20's to early 30's and have had relevant in-depth experience.

SYSTEMS ENGINEERING

We have a number of openings for graduates in their mid-20's with an Honours degree in Engineering, Physics or Mathematics and 1-2 years' post-graduate experience.

These are key career positions carrying salaries that fully reflect their importance, as well as an attractive range of benefits, including relocation assistance where necessary.

To discuss any of these posts with one of our senior specialists or project managers, telephone Bill Seton, Ext. 18, or Liz Kahn, Ext. 22, on (01) 954 2311 or write to them at Marconi Space and Defence Systems Ltd., The Grove, Warren Lane, Stanmore, Middlesex, HA7 4LY.

Marconi
Space & Defence Systems

1546

CAMBRIDGE HEALTH DISTRICT
(TEACHING)
PHYSICS DEPT.
ADDENBROOKE'S HOSPITAL
HILLS ROAD, CAMBRIDGE

Medical Physics Technician Grade II

(£6,668-£8,316 p.a.)

An electronics technician is required to provide maintenance and support services to the CT Head Scanner at Addenbrooke's Hospital and to electro-medical equipment in the thoracic surgical unit, Papworth Hospital.
Applicants should hold an appropriate HNC or equivalent qualification and have several years' experience in the field of electronics. (Mini-computer experience advantageous).

For further details contact
Mr P. E. Ward,
Principal Physics Technician
Addenbrooke's Hospital
Hills Road, Cambridge CB2 2QQ
Tel: (0223) 245151 ext. 471

Application form and job description from the Personnel Dept. Ext. 7350.

INSTITUTE OF PSYCHIATRY

AUDIO-VISUAL TECHNICIAN

A vacancy exists for an Audio-Visual Technician at this postgraduate medical school and associated teaching hospital. Applicants should be experienced in maintenance of television equipment and preferably hold relevant technical qualifications: eg City & Guilds Course 222 or 224.

Salary according to experience and qualifications on Whitley Council Medical Laboratory Scientific Officer scale currently £4,958 p.a. to £6,993 p.a. plus London Weighting £932 p.a.

For application form with job description please write to the **Assistant Secretary, Institute of Psychiatry, De Crespigny Park, Denmark Hill, London SE5 8AF or telephone 703 5411 Ext 214 quoting reference MJC/WW.**

(1547)

LEADING LONDON ADVERTISING AGENCY
Requires

YOUNG ENGINEER

to take charge of all in-house audio and video equipment including Rank Cintel, Sony 1" and studio cameras. Applicants should send details of experience to Box 1552, c/o Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

(1552)

HIGH-LEVEL VACANCIES FOR HIGH-FLYING ENGINEERS!

GRADUATE SENIOR SYSTEMS ENGINEER to take charge of design and development of microwave frequency synthesizers, navigation transponders and other sub-systems. Must have strong technical background, have experience, and be over 30. Salary at least £10,000. Bedfordshire.
TECHNICAL SUPPORT ENGINEER. OCR systems. Large peripheral experience essential including CDC/Pertec/Data Products range. National and international travel. To £9,500. S.W. London.
SENIOR DIGITAL DESIGNER. Applied research in radar signal processing. Experience high speed real-time HW/SW. Knowledge of bitslice processors, array multipliers useful. To £11,000. South Coast.
SENIOR ENGINEER to establish feasibility of LSI or VLSI chip sets for signature verification products and carry through the design up to production, whilst also assisting in design of discrete version. Salary up to £10,000. Surrey.
Please telephone or send c.v. to:

Charles Airey Associates

13/16 Jacob's Well Mews, George Street, London W1H 5PD
Tel. 01-486 9250

"PROBABLY THE BEST KNOWN SUPPLIER OF ELECTRONIC ENGINEERS IN THE COUNTRY" Financial Times (1357)

THE THOMSON FOUNDATION TELEVISION COLLEGE
An

ENGINEERING LECTURER

and an

ASSISTANT ENGINEERING LECTURER

are required at the College to join a team of staff training engineers from developing countries, in Television and Radio. The successful candidates will have had a minimum of 5 years' or 3 years' experience respectively and broadcasting technology, and will hold an appropriate degree, HND or equivalent.

Salaries: Lecturer – £9,251 by 5 increments to £11,504;
Asst. Lecturer – £7,284 x 5 to £9,052.

The posts are pensionable, based at Glasgow where the residential training is conducted, but involve also short assignments abroad each year for in-country training.

Please write or phone for application form to **Principal, Thomson Foundation TV College, Kirkhill House, Newton Mearns, Glasgow G77 5RH (041-639 1021).**

(1545)

Electronics – up to £7,500

Have you an Electronics Qualification? Could you apply it to Scientific Instruments?

then this could be just the job you're looking for. It offers variety and real opportunity to apply both skill and design initiative to the solution of a whole range of technical problems of a one-off nature.

We are:

* a leading pharmaceutical company with world-wide interests.

You will:

* help to design, modify and where necessary repair advanced scientific instruments and computers in the Physical Chemistry Department.

Probably in your 20's, male or female, you should ideally have:

* formal training up to HNC or equivalent
* an interest in scientific measurement techniques
* sound practical experience of electronics.

We offer:

* a competitive salary dependent upon experience and ability
* day release opportunities for further study
* Flextime working
* very modern facilities in a newly opened building.

Interested? For an application form please ring our automatic telephone answering service on 01-650 6541, giving your name, address and quoting reference no. WRL/176.

Alternatively write to A. G. Murdoch, Personnel Officer, The Wellcome Research Laboratories, Langley Court, Beckenham, Kent BR3 3BS.

Wellcome

(1543)

THEATRE PROJECTS

Theatre Projects Special Projects Group is a manufacturing company specialising in audio and lighting control equipment for the broadcast, film and theatre industries. We are currently seeking the following additional staff to provide a firm foundation for expansion.

PRODUCTION MANAGER

Must be capable of planning and controlling all aspects of a mixed batch production/custom manufacturing environments often working to tight schedules. Will be required to plan and set up own manufacturing facility when we shortly move to new premises. The applicant should have 2-3 years in a related area of responsibility and be educated to HNC or degree standard. He/She will be part of the core of management of this part of the company.

PROJECT ENGINEER – BROADCAST AUDIO SYSTEMS

The candidate must have prior engineering design experience and a broad understanding of the design/manufacturing environment. He/She will be required to oversee projects from concept/quotation through to installation. Specialist skills in either circuit or mechanical design are required along with familiarity of the broadcast environment.
Both posts command a salary from £7,500, which is negotiable according to the skills and experience of the applicants.

Theatre Projects, 11 Marshalsea Road, London SE1. Tel: 01-403 3838

(1562)

REPORTER/STAFF WRITER

MIDDLE EAST ELECTRONICS

An enthusiastic journalist, ideally with technical qualifications (Degree or HND) and experience, to work on Middle East Electronics.

This magazine, which is going monthly in May, is read by senior electronic engineers in the Middle East and the Editor is looking for a responsible number two to develop the journal's potential.

Writing and subbing skills essential plus knowledge of the industry and, preferably, experience of developing countries and their technology problems. Computer science background an advantage.

Our UK office is located in Morden, Surrey, but we offer opportunities for travel. Salary £7,613 p.a. (subject to NUJ consultation).

For an application, please write to, or telephone Ray Ashmore, Editor, Middle East Electronics, Crown House, London Road, Morden, Surrey. Tel: 01-543 3051.

Salary and conditions is accordance with the IPC/NUJ agreement.

We are an equal opportunity employer.

IPC BUSINESS PRESS
THE LARGEST COMPLEX OF BUSINESS AND SPECIALIST PUBLICATIONS IN THE WORLD.

(1563)

Research & Development Engineers

YOUR OPPORTUNITY TO ADVANCE BROADCAST TELEVISION TECHNOLOGY

Tremendous growth and success has resulted in career opportunities at Sony Broadcast Ltd., a company established four years ago to specialise in the high technology field of broadcast television equipment. The Advanced Developments group is part of an international R&D team committed to pioneering new technology. Applications are invited from experienced engineers capable of contributing to one or more of the following activities:

- Digital Video Systems
- Digital Audio Systems
- Audio/Video Digital Recording
- Mathematical Modelling
- Computer Control Systems
- Microprocessor Applications
- Analogue Video Development

The successful candidates will join one of the following sections:-

Research & Development
Established as a world leader pioneering digital recording, we are currently extending our range of activities. The R/D team is responsible for studying the development and application of digital video and audio processing techniques. In addition increasing support is required from theoretical studies and computer simulation.

Special Design Projects
Increasing use is being made of computer and microprocessor based equipment for signal routing and control in studio centres. Hardware/Software engineers are required for the development of automated broadcasting and remote control systems. This can include "one off" developments designed to customer requirements.

Appointments will be made at all levels and applicants should have an honours degree or equivalent qualification. Attractive salaries are offered together with first class conditions of employment and relocation assistance will be given where appropriate.

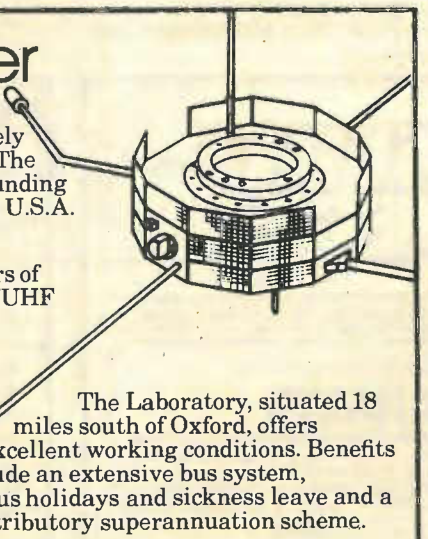
If you are interested contact:- **Mike Jones, Senior Personnel Officer**

Sony Broadcast Ltd.
City Walt House
Basing View, Basingstoke
Hampshire RG21 2LA
United Kingdom
Telephone (0256) 55 0 11

SONY® Broadcast

(1540)

An Electronics Engineer

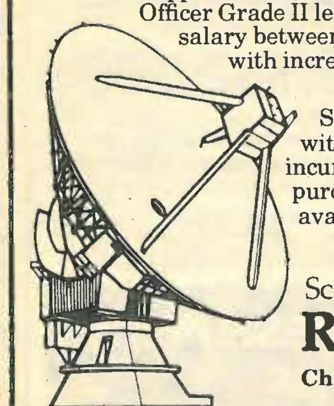


Is needed to make original contributions within a lively internationally collaborative space sciences programme. The post will be concerned initially with a magnetospheric sounding satellite and will include some travel to Germany and the U.S.A.

Applicants, holding a degree or equivalent chartered institution status, should be able to offer two or three years of proven practical design experience, preferably with VHF/UHF systems, digital and analogue circuits or micro processor application.

The appointment, at Professional and Technical Officer Grade II level, attracts a starting salary between £6,557 and £7,520, with increments to £8,697.

The Laboratory, situated 18 miles south of Oxford, offers excellent working conditions. Benefits include an extensive bus system, generous holidays and sickness leave and a non-contributory superannuation scheme.



Some assistance with the expenses incurred in house sales/purchase may be available.

Apply by phone or letter to Lorna Bird, Ext. 510, quoting VNO 17.
Closing date: 8th April 1982.

Science and Engineering Research Council
Rutherford Appleton Laboratory
Chilton, Didcot, OXON. OX11 0QX. Telephone Abingdon 21900.

(1548)

£25,000?

S/W QUALITY ENGINEERS
with PDP 11/34 and RSX experience to work on Software to 0521 standards. To £10,000 – Hants.

SERVICE ENGINEER
To carry out field maintenance on Business Computer Systems. To £10,000 + car – London.

PROJECT MANAGER
To control the development of Industrial Process Control Systems. To £11,500 – Bucks.

DEVELOPMENT ENGINEER
to work on Static Invertor Systems. To £12,000 – London S/W.

R.F. DESIGN ENGINEER
to lead the development of a new Low Power Transmitter. To £10,000 – Yorks.

DESIGN ENGINEERS
with R.F. Micro Wave, Analogue, Digital or Software experience to work on new Instrumentation Systems. To £11,000 – Herts.

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Windsor (07535) 57818/58022
24-hour service (1119)

CLIVEDEN

CHARING CROSS HOSPITAL MEDICAL SCHOOL
(University of London)

MEDICAL PHYSICS TECHNICIAN

An enthusiastic person is required in the Department of Anaesthesia in Charing Cross Hospital Medical School.

Work involves a full range of physiological measurements on patients in the operating theatres and Intensive Care Unit, and maintenance of equipment.

Assistance will also be required in the development of instrumentation for measurements and techniques in the cardiovascular, respiratory and electrophysiological fields.

The successful candidate should be qualified in at least one of these fields and show an interest and willingness to learn about the others.

An aptitude for meeting the many demands that working in a small team places on the individual will also be sought.

Salary will be within the range of £4,958-£6,993 per annum plus £859 London Weighting Allowance, according to qualifications and experience.

Applications on forms obtainable from The Secretary, Charing Cross Hospital Medical School, The Reynolds Building, St. Dunstan's Road, London W6 8RP (tel: 01-748 2040 ext 2067) within three weeks of the appearance of this advertisement.

(1533)

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FIELD SUPPORT
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VIDEO, ETC.

For free registration ring
0453 883264
01-290 0267

LOGEX
ELECTRONICS RECRUITMENT SERVICE
LOGEX HOUSE, BURLEIGH, STROUD
GLOUCESTERSHIRE GL5 2PW
TEL 0453 883264, 01-290 0267 (321)

Electronics Engineers

Glaxo have the following opportunities at their Research Central Services Unit at Greenford, which is involved in the design and maintenance of electronic equipment needed for experimental work:

ELECTRONICS DESIGN ENGINEER
£6705 pa to £9475 pa

to carry out design work on a wide range of laboratory equipment employing analogue, digital and microprocessor techniques. Candidates, aged 25+, should be qualified to degree level or equivalent with several years general design experience.

SERVICE TECHNICAL OFFICER/ENGINEER
£5874 pa to £9210 pa

to be responsible for general servicing work. Candidates, qualified to Higher National Certificate or City & Guilds Full Technical standard should have several years experience of analogue and digital equipment, preferably in a laboratory environment.

Starting salaries will be between the figures quoted which include London Allowance and will reflect qualifications and experience.

In addition the Company operates a bonus scheme and non-contributory pension scheme. Assistance with relocation expenses will be available in appropriate cases.

Please write or telephone for an application form to: Miss E. M. Butler, Personnel Department, Glaxo Group Research Limited, Greenford Road, Greenford, Middlesex UB6 0HE. Tel: 01-422 3434, ext. 2707 quoting reference number ZH/418.

Glaxo Group Research Ltd.

(1541)

GWENT HEALTH AUTHORITY

ELECTRONIC AND BIO-MEDICAL EQUIPMENT MAINTENANCE TECHNICIAN GRADE II

This is an established post offering wide scope and opportunity in the development of electronic and bio-medical services. The successful candidate will be responsible to the Area Engineer for the testing and maintenance of a variety of electronic and bio-medical equipment throughout the area, and will also be responsible for the development of policy regarding maintenance contracts.

The technician will be based at a purpose-built workshop at Allt-Yr-Yn Hospital, Newport, and will be responsible for an establishment of two junior grade technicians, but authority has been given for the further development of this service.

Applicants should be in possession of ONC/HNC (or equivalent qualifications) in Electrical/Electronic Engineering, and should have wide experience of Health Service electronic equipment and safety aspects involved. In addition to these requirements, the applicant should be capable of preparing reports and be able to develop and operate a planned preventive maintenance scheme.

Hours: Normally 38 per week.

Salary: £6,668-£8,316

Application form and job description are available from:

The Area Personnel Department
Mamhilad, Pontypool, Gwent

Closing date: 31.3.82

(1559)

TRAINEE BROADCAST ENGINEERS

ITN needs more engineers to support its expanding programme of news coverage – expansion which is expected to continue through the 80s with the development of the Channel Four news service.

We have a number of vacancies for Engineering Trainees, vacancies which could give you the opportunity to start a career in Broadcasting Television Engineering with ITV.

First, we need you to have a firm interest in pursuing a career in the technical branch of broadcasting.

Then you should have completed, or expect this year to complete, theoretical training in Electronic Engineering with a bias towards Television or Audio applications. Qualifications most suitable are T.E.C. Higher Technical Diploma, T.E.C. Higher Technical Certificate or the HND/HNC equivalent.

Initially, you would be involved in a 9-12 month familiarisation period by a rotational attachment to our four maintenance areas and the Projects Department.

After successful training you would be employed on the maintenance or operation of a wide range of broadcast equipment in our Central London Studios near Oxford Circus, from which the ITN national news programmes are networked.

Successful applicants will join ITN in early September, 1982. Starting salaries would lie within the range of £5,120 (at 18) rising to £6,472 at age 20.

If you have the qualifications and the drive to work with us in a busy, lively environment then call us on 01-637 8644 ext 275 or write to

The Manager, Technical Training
ITN House
48 Wells Street
London W1P 4DE

for an application form quoting reference 476099

(1532)

Electronics R&D

£8,589

Join us in the forefront of technology

HF-VHF-UHF and Microwave

A challenging and full career in Government Service

Candidates, normally aged under 30, should have a good honours degree or equivalent in a relevant subject, but any candidates about to graduate may be considered.

Appointments as Higher Scientific Officer (£6,530-£8,589) or Scientific Officer (£5,176-£6,964) according to qualifications and experience. Promotion prospects.

Please apply for an application form to the Recruitment Officer (Dept WW 4.82), H M Government Communications Centre, Hanslope Park, Milton Keynes MK19 7BH.

1425

Senior Engineer – Broadcast Video Equipment

A challenging role in high technology Quality Assurance

Due to significant continued expansion, an excellent opportunity has arisen at the international headquarters of Sony Broadcast, a world leader in professional broadcast television equipment. The Company has an expanding range of high technology products which includes video cameras, VTRs, editing control systems, digital time base correctors and monitors.

An experienced engineer is required to join the Quality Assurance team and assume responsibility for the throughput of cameras and other products. Activities will include close liaison with other engineering departments and will necessitate working to stringent specifications. A knowledge of current camera measurement practices would be advantageous.

Age 25+ applicants should be educated to at least HNC Electronics and have several years engineering experience. The position would suit a self starter who also has the ability to lead and motivate a small team. Prospects for career development are considerable.

We offer a first class working environment in our new prestigious engineering complex, together with an attractive salary and excellent conditions of employment, which include Company pension/life assurance schemes, private medical cover and staff restaurant.

If you are interested please write, giving details of experience and present salary, to Mike Jones, Senior Personnel Officer.

SONY Broadcast

Sony Broadcast Ltd.
City Wall House
Basing View, Basingstoke
Hampshire RG21 2LA
United Kingdom
Telephone (0256) 55 0 11

1529

Communications Proposals Engineer

to £10,500

Join the UK's leading Communications System House specialising in oil field locations.

Palmer EAE require a Proposals Engineer with a broad experience of Multi-Channel Microwave links, P.A. and entertainments systems, standby power supplies, SOLAS and telephone plant.

Applicants should be educated to HNC/DEGREE standard and be familiar with recognised international standards, i.e., C.C.I.R., C.C.I.T.T., etc. Duties will include preparing technical proposals, procurement specifications and procedures relating to installation/commissioning.

This post is based in Great Yarmouth and occasional overseas travel will be required. Excellent terms and conditions are offered including pension scheme, BUPA, relocation expenses, etc.

There are also a number of vacancies for suitably qualified COMMUNICATIONS ENGINEERS and TECHNICIANS to work both in the UK and overseas.

For further information regarding these opportunities on an application form for the post of Communication Proposals Engineer, please telephone:

Mike Futter on Great Yarmouth (0493) 58541
Palmer EAE Limited, Offshore House, Gt. Yarmouth, Norfolk

PALMER EaE

(1560)

TECHNICAL/SERVICE MANAGER

Due to the expansion of our business we are urgently seeking a person capable of setting up and running a pager service department, of maintaining transmitters and of evaluating and commissioning both paper and mobile systems. This is an exciting position in an established company and will appeal to the person who has technical experience and wishes to become involved also in the commercial side of a company with expansion plans for the future. A high salary, car and other benefits are available for the right person.

Send CV to: P. Sinnot, Managing Director
Pageboy Services (UK) Ltd., Westley House
Trinity Avenue, Bush Hill Park, Enfield
EN1 1HP. Tel. 01-367 4545

(1518)

CAPE WARWICK LTD.

require

Electronics, Control & Instrumentation Engineers

As an expanding independent testing laboratory we require suitably qualified/experienced engineers to design, arrange, manufacture, commission and maintain test equipments.

Send c.v. or telephone for application forms to:

Mrs. E. Archer
Cape Warwick Ltd.
Cape Road, Warwick
Warks CV34 5DL
Tel: Warwick (0926) 496421
(A Thomas Tillings Company)

(1535)

UNIVERSITY COLLEGE CARDIFF
FACULTY OF SCIENCE

ASSISTANT EXPERIMENTAL OFFICER

Applications are invited for the post of Assistant Experimental Officer in the faculty of science electronics workshop. Duties will include the design, development and maintenance of electronic equipment, particularly microprocessors for both research and teaching.

Applicants should have a degree in electronics or related subject or an equivalent qualification. Experience in microprocessor interfacing techniques and electronic instrument design would be an advantage.

Salary scale O.R. 18 £5,285-£8,925

Applications to the Vice Principal (Administration) and Registrar, University College Cardiff, P.O. Box 78, Cardiff, from whom further particulars may be obtained.

Closing date 2nd April. Ref. No. 2348a.

(1556)

APPOINTMENTS IN ELECTRONICS

to £15,000

MICROPROCESSORS
COMPUTERS – MEDICAL
DATA COMMS – RADIO

Design, test, field and support engineers – for immediate action on salary and career advancement, please contact

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Engineering and Technical Recruitment
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1558

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(1549)

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(T526)

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Printed in Great Britain by QB Ltd., Sheepen Place, Colchester, and Published by the Proprietors IPC ELECTRICAL-ELECTRONIC PRESS LTD., Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS, telephone 01-661 3500. *Wireless World* can be obtained abroad from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd. INDIA: A. H. Wheeler & Co, CANADA: The Wm. Dawson Subscription Service Ltd, Gordon & Gotch Ltd. SOUTH AFRICA: Central News Agency Ltd: William Dawson & Sons (S.A.) Ltd. UNITED STATES: Eastern News Distribution Inc., 14th floor, 111 Eighth Avenue, New York, N.Y. 10011.

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