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WIRELESS WORLD MAY 1982 VOL 88 NO 1556

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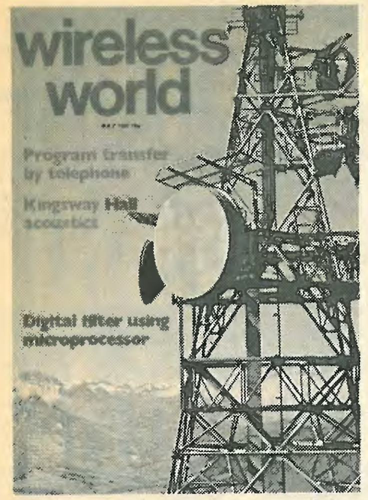

Front cover shows antennae of the Swiss PTT at Niederhorn television transmitting station. Photo: Hamer-Smith Collection

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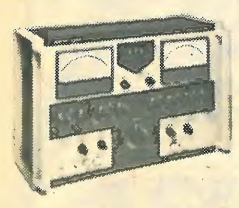

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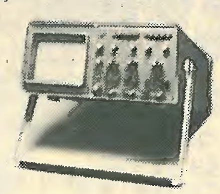

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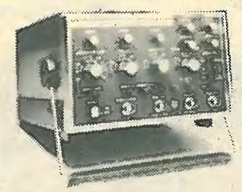

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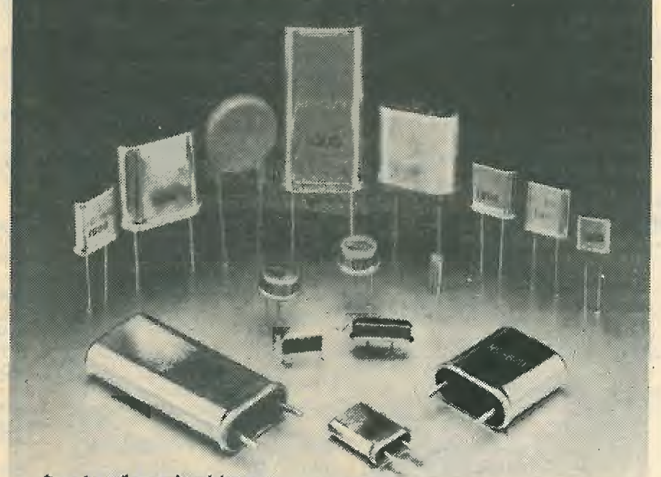

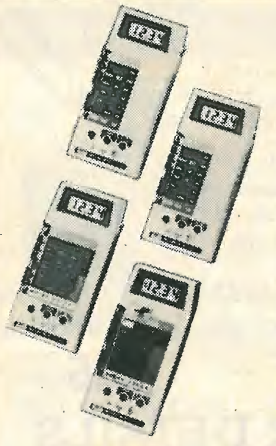

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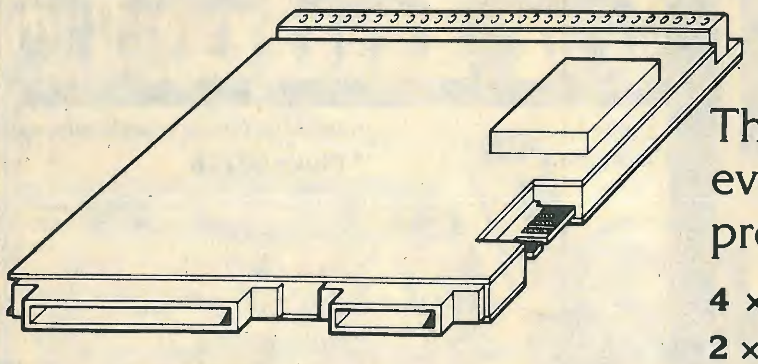

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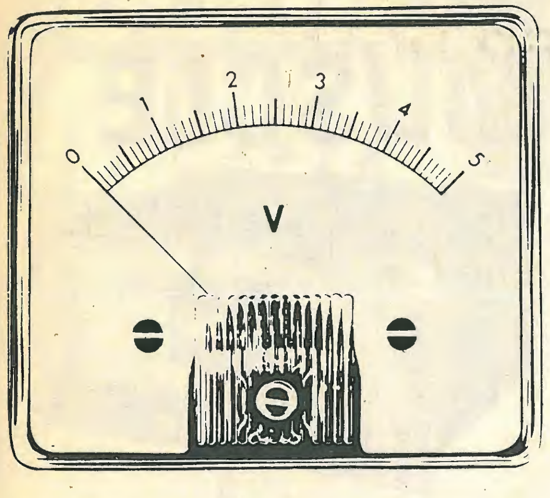

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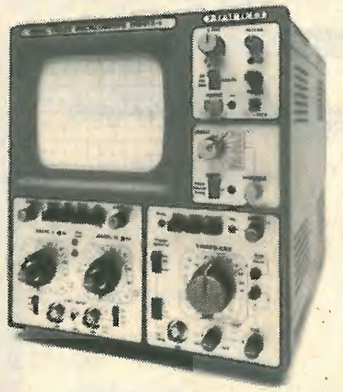

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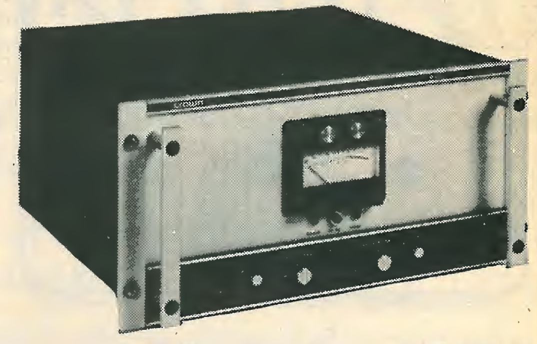

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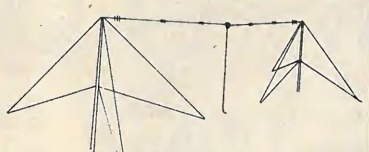

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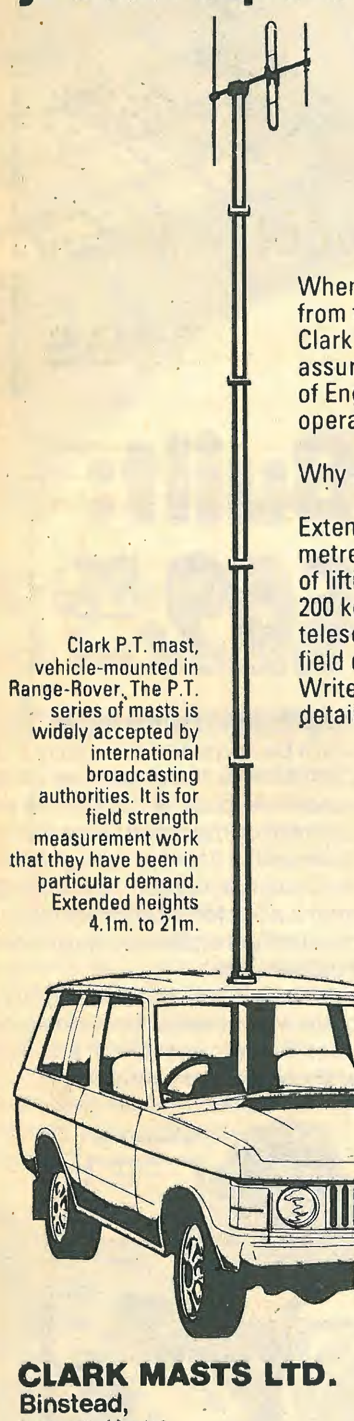

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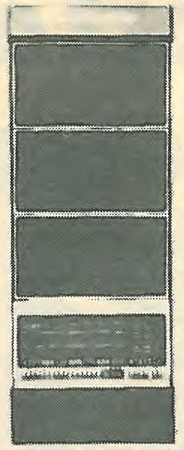

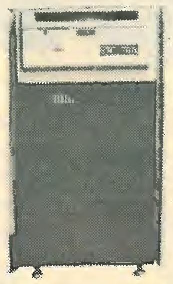

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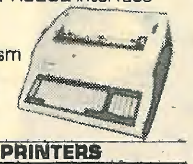

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1980 saw a genuine breakthrough – the Sinclair ZX80, world's first complete personal computer for under £100. Not surprisingly, over 50,000 were sold.

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

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

Lower price: higher capability

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

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

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

New BASIC manual

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

Kit: £49.95

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

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

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

New, improved specification

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

Built: £69.95

Kit or built – it's up to you!

You'll be surprised how easy the ZX81 kit is to build: just four chips to assemble (plus, of course the other discrete components) – a few hours' work with a fine-tipped soldering iron. And you may already have a suitable mains adaptor – 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!

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

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

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

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

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

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

How to order your ZX81

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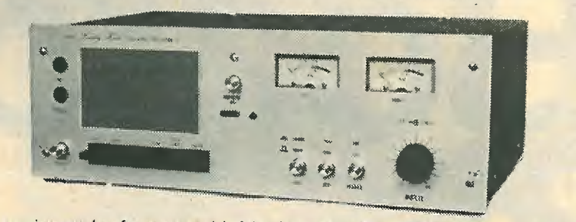

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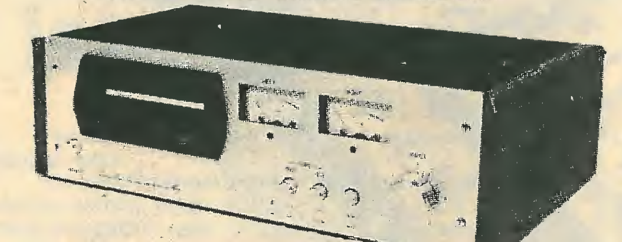
LINSLEY-HOOD CASSETTE RECORDER 1



We are the Designer Approved suppliers of kits for this excellent design. The Author's reputation tells all you need to know about the circuitry and Hart expertise and experience guarantees the engineering design of the kit. Advanced features include: High-quality separate VU meters with excellent ballistics. Controls, switches and sockets mounted on PCB to eliminate difficult wiring. Proper moulded escutcheon for cassette aperture improves appearance and removes the need for the cassette transport to be set back behind a narrow finger trapping slot. Easy to use, robust Lenco mechanism. Switched bias and equalisation for different tape formulations. All wiring is terminated with plugs and sockets for easy assembly and test. Sophisticated modular PCB system gives a spacious, easily-built and tested layout. All these features added to the high-quality metalwork make this a most satisfying kit to build. Also included at no extra cost is our latest HS 16 Sendus Alloy super head, available separately at **£8.20** but included free with the complete kit at **£75** plus VAT.
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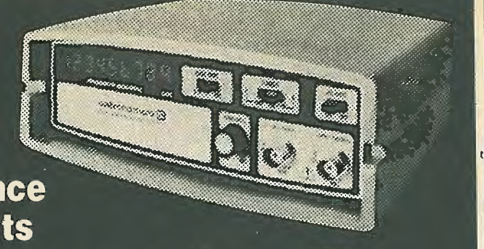

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Z80A CPU	3.99
Z80 CTC	2.99
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Z80 DART	10.00
Z80A DART	12.00
Z80 DMA	9.95
Z80A DMA	11.95
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Z80A PIO	3.75
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Z80A SIO-0	11.99
Z80 SIO-1	10.99
Z80A SIO-1	11.99
Z80 SIO-2	10.99
Z80A SIO-2	11.99
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MK 3886-4	14.47
6800 FAMILY	
6800	2.99
6802	3.99
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6809	9.99
6810	1.25
6821	1.25
6840	4.20
6850	1.50
6862	6.91
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6880	1.07
6887	0.80
68488	9.11
6875	4.18
6843	13.99
68B00	4.70
68B02	19.11
68B21	2.29
68B10	2.00
68B40	4.70
68B50	2.15
68000C4	110.00
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6502	4.25
6520	2.99
6522	4.75
6532	6.95
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8085A	5.50
8212	1.70
8216	0.99
8224	1.95
8228	3.95
8251	3.60
8253	7.95
8255	3.60
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

Device	Price
4012	0.15
4013	0.29
4014	0.58
4015	0.59
4016	0.25
4017	0.45
4018	0.58
4019	0.29
4020	0.58
4021	0.60
4022	0.62
4023	0.17
4024	0.35
4025	0.16
4026	0.99
4027	0.30
4028	0.55
4031	1.65
4033	1.60
4034	1.55
4035	0.72
4040	0.54
4041	0.69
4042	0.54
4043	0.59
4044	0.64
4045	1.65
4046	0.68
4047	0.68
4048	0.54
4049	0.26
4050	0.26
4051	0.59
4052	0.68
4053	0.59
4054	1.20
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	0.89
4518	0.40
4519	0.28
4520	0.69
4521	1.49
4522	1.20
4526	0.70
4527	0.89
4528	0.70
4532	0.85
4541	0.99
4543	0.99
4553	2.90
4555	0.39
4556	0.44
4585	0.62
74LS SERIES	
74LS00	0.10
74LS01	0.11
74LS02	0.12
74LS03	0.12
74LS04	0.12
74LS05	0.13
74LS08	0.12
74LS09	0.12
74LS10	0.12

Device	Price
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
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	0.85
74LS245	0.89
74LS247	0.63
74LS248	0.63
74LS249	0.63
74LS251	0.40
74LS253	0.39
74LS257	0.40

Device	Price
74LS258	0.39
74LS259	0.79
74LS261	1.95
74LS266	0.23
74LS273	0.75
74LS279	0.39
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	0.26
74LS390	0.54
74LS393	0.59
OIL 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	
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14 pin	0.29
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18 pin	0.33
20 pin	0.35
22 pin	0.40
24 pin	0.42
28 pin	0.54
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6 MHz	1.90
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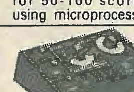

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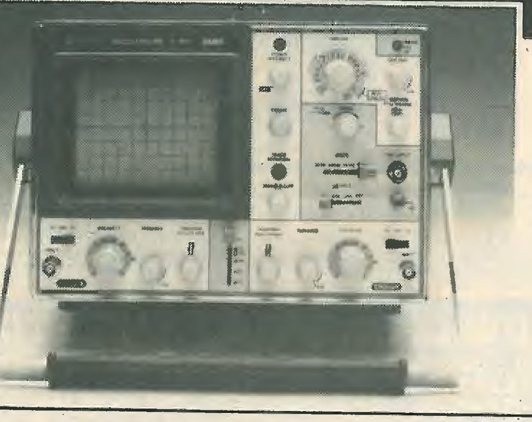

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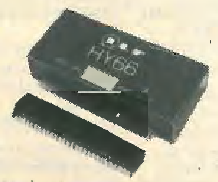

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- 7A19 500 MHz 10mV 1 Trace Plug-in
- 7A22 1 MHz 10µV Differential Plug-in
- 7A24 350 MHz 5mV 2 Trace Plug-in
- 7A26 200 MHz 5mV 2 Trace Plug-in
- 7B53A 2 Timebase Plug-in 100 MHz Trig
- 7B80 Single Timebase 400 MHz Trig
- 7B85 Timebase with delay 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.

OSCILLOSCOPES (STORAGE)

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

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

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

ADVANCE
- PG 52A 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
- 132 10 Hz-3.5 MHz 50V 50Ω RT 10ns 2 pulse 190

HEWLETT PACKARD
- 8011A 0.1 Hz-20 MHz 16V 50Ω RT 10ns inc Burst mode 475
- 8016A Digital word generator to 50 MHz 9 x 32 bit 3400

LYONS
- PG73N 20 MHz 10V 50Ω R.T. 5ns 390

RECORDERS & ACCESSORIES

BRYANS SOUTHERN
- BS314 Chart 10″ 4 Pen 16 speed 1900
- BS316 Chart 10″ 6 Pen 16 speed 2500

DCM
- 8100W Wow & Flutter Analyser 800

EM
- LVDT Linear Displacement & Transducer 50

FYLDE
- 154 Bridge supply and Amplifier 110

HEWLETT PACKARD
- 7015A XY 1 pen A4 size 700
- 7046A XY 2 pen A3 size 995

HONEYWELL
- 5600B Instrumentation tape recorder 14 ch FM/DR 9000

MICRO-MOVEMENTS
- M10-120/A Compact UV 10 ch 7 speed recorder (inc. galvos) 1900

PHILIPS
- PM8041 XY 1 pen A4 size 750
- PM8251 Chart 10″ 1 pen 12 speed 375

SE LABS
- 994 6 ch galvo preamp + DC bridge supply 450
- 3006 UV chart 6″ 6 ch 370
- 6008 UV chart 8″ 25 ch 16 speed 950
- 6150/51 UV recorder 12 ch-inc 6 ch amps 1000

SMITHS
- RE541 Chart 8″ 1 pen 8 speed 250
- RE501/4701 Cht 4″ + XY 1ch 10 spd AC Batt 200

SOLARTRON
- 3240 Modular Data Logger system P.O.A.

RANK
- 1740 Wow & Flutter meter 85
- *Note: UV recorders are priced less galvos*

SIGNAL ANALYSIS EQUIPMENT

AIRMEC
- 210 AM/FM Mod Meter 2.25 MHz-300 MHz 235
- 248A Wave Analyser 5-300 MHz 200
- 853 Wave Analyser 30 KHz-30 MHz 200

MARCONI
- TF791D FM Mod meter 170
- TF2304 Mod meter AM/FM 475
- TF2330 Wave Analyser 20 Hz-50 KHz 475
- TF2330A Wave Analyser 20 Hz-76 KHz 900
- TF2331A Distortion meter 770

RADFORD
- DM52 Distortion meter 20 Hz-20 KHz 200

SOUND TECHNOLOGY
- 1700A Distortion Meter 10 Hz-100 KHz inc. oscillator 800

WAYNE KERR
- A321 Wave Analyser 20 Hz-20 KHz 180
- *Note: see also "Spectrum Analysers"*

SIGNAL/FUNCTION/ + SWEEP GENERATORS

GENERAL RADIO
- 1362 Generator 220-920 MHz 375

GOULD
- J3B Generator 10 Hz-10 MHz O/P level meter & Attn. 350
- J4 Generator as J3 but no output level meter 220
- SG21 Generator — Square Wave only 0.3-100 MHz 80

HEWLETT PACKARD
- 204C Oscillator 5 Hz-1.2 MHz 210
- 204D Oscillator 5 Hz-1.2 MHz inc. 80dB attenuator 250
- 608E Generator 10-480 MHz AM/Pulse 400
- 8601A Gen/Sweeper 0.1-110 MHz Attn. AM/FM 1950
- 8614A Generator 800-2400 MHz AM/FM/Pulse 2800
- 8660C/86632A/86603A Synthesised Signal Generator 1-2600 MHz AM/FM digital readout, push button controls, BCD programmable 15000
- 8640B Generator 500 KHz-512 MHz AM/FM Phase Lock 4500
- 618B Generator 3.8-7.5 GHz 975
- 612 Generator 450-1230 MHz 750
- 614 Generator 0.8-2.1 GHz 825

IEC
- F51A Function 1 mHz-10 MHz Sin/Sq/Tri/Pulse/Ramp 375

LEVELL
- TG150DM Generator 1.5 Hz-150 KHz battery operated 60

MARCONI
- TF144H/4S Generator 10 KHz-72 MHz AM 550
- TF801D Generator 10 MHz-470 MHz AM 180
- TF955/2 Generator 0.2-220 MHz AM/FM 670
- TF1066B/1 Generator 10-470 MHz AM/FM 690
- TF2000 Generator 20 Hz-20 KHz-111 dB attenuator 750
- TF2002/3MI Generator 10 KHz-72 MHz AM only 550
- TF2011/S Generator 96-140 MHz FM only 550
- TF2012 Generator 400-520 MHz FM 550
- TF2015 Generator 10-520 MHz AM/FM 1150
- TF2015/1 Generator as 2015 with narrow FM deviation 1350
- TF2015/2171 Generator system with phase lock synchroniser 1900
- TF2015-1/2171 Generator system with phase lock synchroniser 1950
- TF2171 Synchroniser for 2015 1050

PHILIPS
- PM5108L Function 0.1 Hz-1 MHz Sin/Sq/Tri O/P meter — 50 and 600Ω 425
- PM5127 Function 0.1 Hz-1 MHz Sin/Sq/Tri/Rmp 450
- PM5129 Function 1 mHz-1 MHz Sin/Sq/Tri/Ramp/Pulse + Sweep + Burst 645

TEKTRONIX
- FG503 Function 1 Hz-3 MHz Sin/Sq/Tri — P/in for TM500 series 250

TELONIC
- 2003 Sweeper system 0.1-130 MHz with Attn. 750

TEXSCAN
- 9900 Sweeper 10-300 MHz 6/in CRT disp 525
- VS60 Sweeper 5-1000 MHz 890

WAVETEK
- 143 Function 0.0001 Hz-20 MHz Sin/Sq/Tri/Pulse 695

SPECTRUM ANALYSERS

HEWLETT PACKARD
- 141T/8552B/8553B 1 KHz-110 MHz system 7100
- 141T/8552B/8554B 100 KHz-1250 MHz system 9050
- 141T/8552B/8555A 10 MHz-18 GHz system 10700
- 3580A 5 Hz-50 KHz with digi store disp 2950
- 8445A Pre-selector 0.01-18 GHz 2400
- 8558B 0.1-1500 MHz Plug-in for 180 series 4450

MARCONI
- TF2370 30 Hz-110 MHz Digi-store display built-in counter and tracking gen 7500

TEKTRONIX
- 7L13 1 KHz-1800 MHz Plug-in for 7000 series M/Frame 7700
- 7L18 1.5-18 GHz Plug-in for 7000 series. High resolution. Digital storage display. Built-in pre-selector 10100
- 7603/7L13 System with display 0.1-1800 MHz 8900
- 7613/7L13 System with storage/var. persist. display 9900
- 7603/7L18 System with display 1.5-18 GHz (60 GHz with external mixers) 11100

VOLT/MULTI-METER (ANALOGUE)

BOONTON
- 92C AC/RF 10 KHz-1.2 GHZ ½ mV-3V 250

HEWLETT PACKARD
- 400E 10 Hz-10 MHz 1mV-300V DC O/P 285
- 400H 10 Hz-4 MHz 1mV-300V 75
- 411A 0.5-500 MHz 10mV-10V DC O/P 175
- 427 AC/DC/V/Ω 195
- 3400 TRMS 10 Hz-10 MHz 1mV-300V DC-O/P 390

LEVELL
- TM11 Analogue Multimeter AC/DC/V/1/Ω 115

M.L. ENGINEERING
- NAMV — DC sensitive µ Volt/nAmp meter centre zero 45

MARCONI
- TF2600 10 Hz-10 MHz 1mV-300V AC + DC O/P 230
- TF2603 50 KHz-1.5 GHz 300µV-3V 300
- TF2604 20 Hz-1.5 GHz 300mV-300V 425

PHILIPS
- PM2404 Analogue Multimeter AC/DC/V/I/Ω 100

RACAL-DANA
- 9301 RMS 10 KHz-1.5 GHz 100µV-300V 550

VIBRON/E.I.L.
- 33B-2 1mV-1V Electrometer 200

VOLT/MULTI-METER (DIGITAL)

BOONTON
- 92AD 1999FSD 10 KHz-1.2 GHz 10µV res 525

FARNELL
- DM131D 1999 F.S.D. AC/DC/V/I/Ω & Temperature. Mains/battery — Temp probe included 135

FLUKE
- 8010A 2000 FSD TRMS AC/DC/VIΩ 140
- 8010A01 As 8010A + re-charging batteries 159
- 8020A 2000 FSD Handheld AC/DC/VIΩ + cond. 89
- 8022A 2000 FSD Handheld AC/DC/VIΩ 65
- 8030A-1 2000 FSD AC/DC/VIΩ Batt + AC 165
- 8050A 20000 FSD AC/DC/VIΩ dB TRMS 215
- 8050A-01 As 8050A + re-chg batteries 245
- 8200A 16000 F.S.D. DC only fast reading system Voltmeter 850
- 8300A 120000 F.S.D. DC only fast reading system Voltmeter 1100
- 8800A 200000 FSD AC/DC/VΩ 550

GOULD
- DMM7 1999 FSD AC/DC/V/I/Ω 80

HEWLETT PACKARD
- 3490A 100000FSD AC/DC/V/Ω 550

SOLARTRON
- A200 19999FSD DC only 1µV-1 KV 65
- A203 19999FSD AC/DC/V/Ω 160
- A205 19999FSD TRMS AC/DC/V/Ω 175

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TEKTRONIX
- 547/1A4 50 MHz Dual Trace Dual Timebase 4 channel oscilloscope 150

TEKTRONIX
- 575 Transistor Curve Tracer 200

TAYLOR
- 62A AM/FM Signal Generator 4-120 MHz 85

Full details and specification of equipment listed, available. Because of long copy dates this list is not comprehensive — ring for inventory update or tell us your SPECIFIC NEEDS. Hours Monday to Friday 9.30 am -5.00 pm (lunch, 1-2 pm). **Prices exclude delivery and VAT.** We take Access or Visa.

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	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
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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
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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

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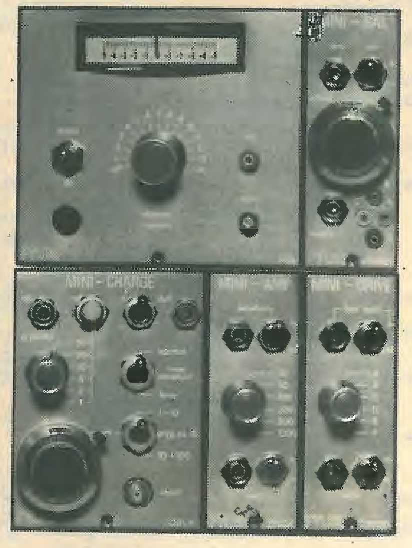

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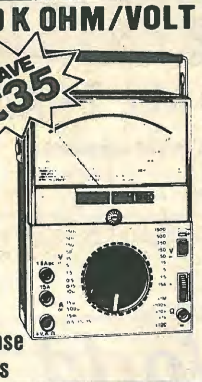

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2033A Sabtronics version of above £39.95
HC703 0.1% version of above £54.00
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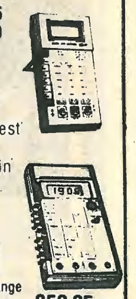
189m 3½ digit LCD 30 range Rotary switch plus Hfe Tester 10A AC/DC £69.95



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Price correct at time of preparation E&OE.
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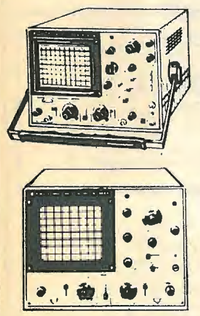
TRIO OSCILLOSCOPES



Range of mains operated Scopes with 5" displays, triggered sweep (UK c/p **£3.50**)

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CS1577A 35 MHZ; 2mV; 0.1 micro sec. £523.25
CS1820 20 MHZ; 2-5mV 1 micro delay sweep £483.00
CS1830 Mk II 300 MHZ, 2mV, 0.2 micro sec (fitted delay line) £626.75
CS1575 5 MHZ, 1mV, 0.5 micro sec. Multi display Audio scope. £312.80

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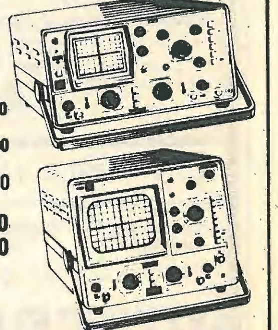
3034 Battery-mains dual trace 15 MHZ, trig to 20 MHZ built in Nicads, 5mV, 0.5 micro secs. £356.50
(Eliminator charger optional **£28.75**)
Also Available 3033, single trace 3034 £322.00
3337, dual MHZ, 130mm £454.00



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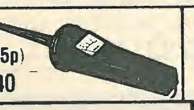

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K2103 1000A, 750V, AC 9 ranges £95.00
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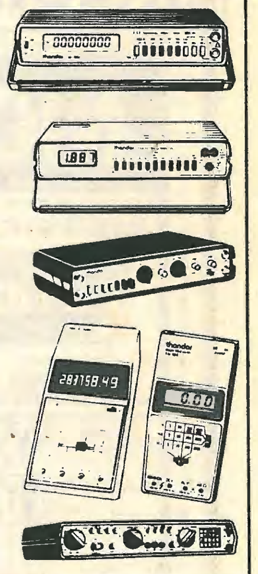

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TF200 Bench LCD. 200 MHZ. 10-30mV (600 MHZ with (TP600)) £166.75
TP600 600MHZ ÷ 10 Prescaler 10 mV £43.13
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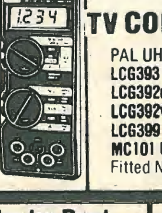

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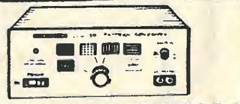

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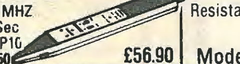

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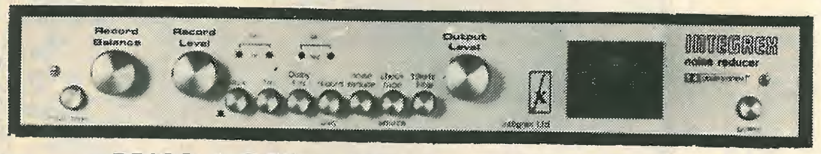

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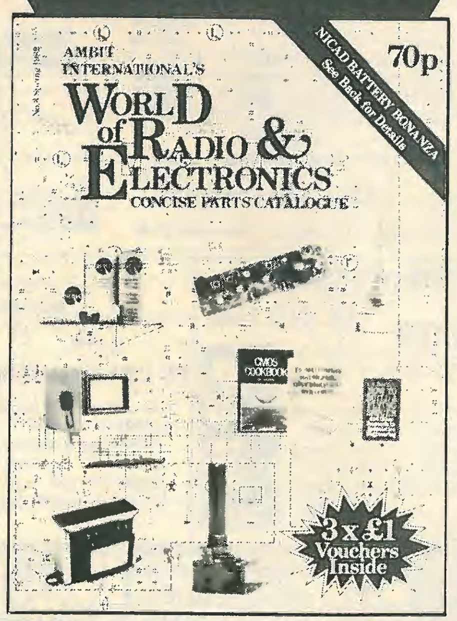

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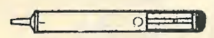

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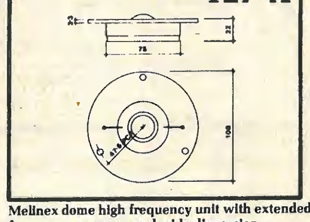

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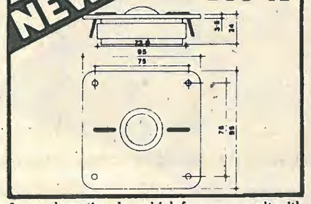

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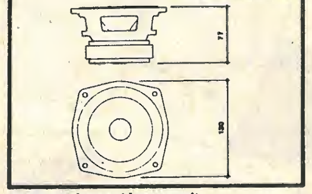

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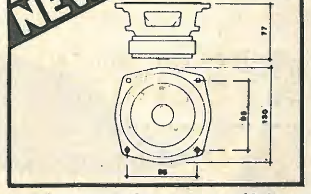

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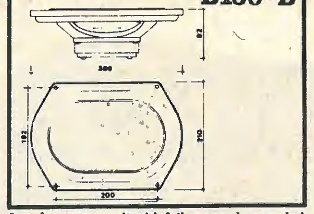

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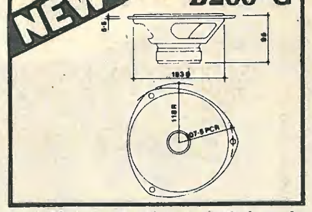

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Arms and the man

A great many words have been written in the last year or two on the amorality and expediency of engineering. On the one hand, some engineers have come to believe that the responsibility for rendering the bellicose ambitions of political leaders capable of realisation lies squarely with the designers and makers of lethal hardware – engineers themselves. If it were not for the complaisance of engineers, they say, the means to wage war in the modern manner would not exist.

Those who do not embrace this belief (or who choose to disregard its implications) point out that if "defence systems" – a weasel expression, referring to all military equipment, including that which by no stretch of the imagination can be seen in a posture of defence – were not available, then one "side" would subdue the other and impose its own ideology on the defeated. The solution to this problem, the holders of this view assert, is for each camp to arm itself to the teeth at an ever-increasing rate, threaten to irradiate the planet if provoked, but only to do so if the other side does it first. The unspeakable, impenetrable folly of such an attitude is almost too obvious to warrant argument: its holders would scarcely deny that that this method of preserving life and liberty is hardly compatible with the pursuit of happiness.

It is perfectly true, as apologists for the arms race often point out, that some of the effects of the insane compulsion to accumulate weapons are not at all as unsavoury as their raison d'être. "Spin-off" has provided most of the advances in, for example, electronics in the last few decades. Innovation and development are accelerating at such a rate that it is barely possible to see five years into the future, assuming there is one. But to what effect? After the expenditure of so much effort over so many years, with neither East or West yet persuaded that that an unstable equilibrium is a poor way to avoid catastrophic failure, are we being asked to believe that the possession of home computers, video games and digital wristwatches makes the whole thing worth while?

Some of the greatest scientists and engineers in the world, in both East and West, have laboured their entire working lives to produce hellish machinery, the whole point of which is that it shall never be used. Hospitals, schools, universities are closed or run down so that more weapons can be bought or made and the only benefits in our own field that we have to show for all this misdirection of effort and resources are a few gadgets. Admittedly, communications have improved immeasurably in response to the stimulus of military requirement, but a good deal of the improvement is taken up by the provision of entertainment.

It is a specious argument, which takes no account of the time scale involved: even in the absence of military urgency, the "improvements" and engineering advances would most probably occur in their own good time, and who is to say that that sooner is better than later when the pace of progress outstrips our understanding of it?

Much that has been written on this theme has not dwelt on the inconveniently large question of waste. Materials, the efforts of gifted men and women, irreplaceable earth resources, time and the wealth of nations are all squandered to produce equipment which, if employed in the manner for which it was designed, would have failed in its purpose. And this while millions of people in all continents are deprived of the simplest staples of life. The contrast between profligacy in the highly developed and privation in the primitive is too stark for us to contemplate the continuation of useless armed posturing into the indefinite future: for that is the outlook – either a sudden and complete end to humanity or an interminable attitude of menace between East and West. *Scientific American* has pointed out that there are now more than three TNT – equivalent tons of nuclear explosive for every single person on earth.

It has been said before on this page, and it will bear repeating, that engineers in all the developed countries have made the confrontation possible. It is therefore engineers who are in the best position to bring it to an end, by simply refusing to work on armaments. Call it rebellion or simply common sense, but since politicians the world over seem bent on killing us all, it is the only way to avoid collective suicide.

ORCHESTRAL SOUND, HALLS AND TIMBRE

or—'why does it sound so beautiful?'

This article examines aspects of the appreciation of orchestral sound, with particular reference to the transfer characteristics of the outer ear and its influence on timbre in various directions and on our sense of orientation. New subjective criteria are proposed. The Kingsway Hall is used as a model in the discussion

by Denis Vaughan*

Horseshoe balcony in the Kingsway Hall is only 17m wide, giving early reflections back at the orchestra.

For several decades the most sought-after venue for recording orchestral music in England has been the Kingsway Hall in London: legend has it that Sir Thomas Beecham was the first to identify this hall as particularly suited for the purpose. Are there some identifiable reasons for its superior warmth and clarity? Could they be applied elsewhere.

My interest in acoustics was stimulated by a request from the Australian Broadcasting Commission. The quest to find a common denominator for warm, rich string tone in a hall and in a recording has led me to study many halls, and to analyse musical qualities and our hearing capacities. These analyses have brought several surprises. First of all come our hearing capacities.

Timbre

Our localization of sound is based on three main complementary systems: only two of these have been used so far in stereo recording techniques. The first is based on the exact timing of impulses to each ear. A difference of 0.63 milliseconds we interpret as a change of angle of 90° in the direction of the earlier impulse. So we can, miraculously, recognise a timing difference is small as 0.007ms, the time necessary to move the sound source one degree to the side. The second is based on loudness and intensity: a softer sound will seem farther away. We apply this in localization: just a small change in volume on one channel will shift a stereo picture to the left or right and a general rise in level brings an instrument nearer to us. But the third system, timbre, has yet to be explored.

We hear a different timbre from every angle. Move a small clock around close to your ear, and you will notice that you can always tell where it is, and that the sound is never identical. If the clock is near your ear but always equidistant from it, this test excludes the possibility of the impulse or intensity methods contributing to the effect: we recognize each and every direction partly by its own particular timbre. If you change the timbre, the apparent direction changes. The filtering effect of our external ear, illustrated by Fig. 1 and Fig. 2, causes us to hear a very odd balance in sound reaching us face-on. The left-hand column of Fig. 3 shows that, with 400Hz as 0dB, there is a strong peak at 3kHz of 12dB and a deep trough at 10kHz of −10.5dB. So we hear certain upper-high frequencies (except 14 and 15kHz) frontally very much weaker than those at 3kHz.

timbre n. Characteristic quality of sounds produced by a particular voice or instrument, depending on the number and character of the overtones.

*Musical Director, State Opera of South Australia

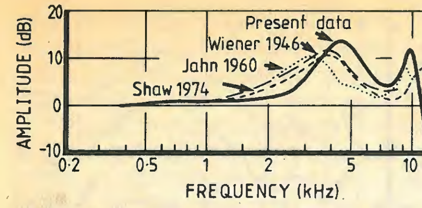


Fig. 1. *Filtering effect of the ear canal, showing peaks near 5 and 10kHz, common to all that we hear. All frequencies above 11kHz are much weaker.*

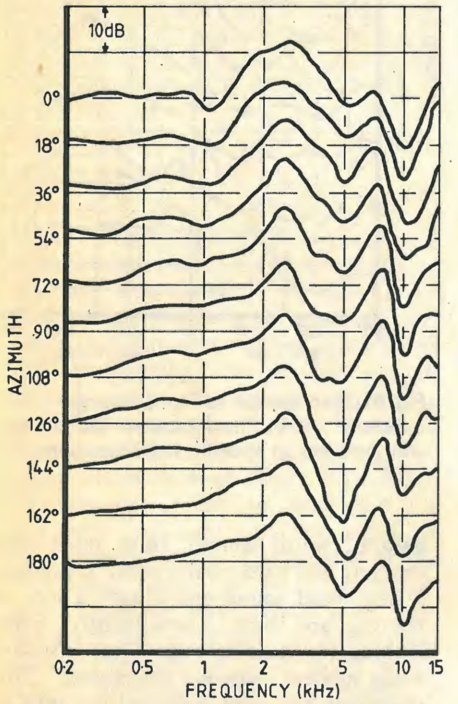


Fig. 2. *Filtering effect of the outer ear on sounds arriving in the horizontal plane. 0° corresponds to a point straight in front.*

Horizontally to the side at 90° the balance is more even. The upper frequencies become as much as 15dB stronger than the frontal spectrum and the various peaks at lower pitches are smoother, thus reducing the range between the extremes to only 15dB as opposed to the 22.5dB range of the frontal spectrum. But the sensitivity which we have at 90° for 12 and 13kHz starts to disappear already at 54° and 144°. Figures 4 and 5 summarize the table of Fig. 1 graphically.

You may have noticed another aural characteristic. We tend to identify bass notes as coming from below our ears; also, the higher we sit in a hall, the warmer it sounds. I believe that we react similarly to loudspeaker placing. Surprisingly, above our heads we can hear a strong peak at 8 and 9kHz, as shown by Fig. 6. In fact we can only hear 8kHz as coming from that direction, no matter where the sound source. But further up the spectrum, above 10.5kHz, we hear very little from over our heads. Therefore in a low room or a hall, where the predominant early reflections come from the ceiling, we can perceive very little refinement, delicacy or texture in the sound. Figure 7 is the graphical representation of Fig. 6.

Musical qualities

It is no easy task to prepare a preferential list of musical qualities in sound. Celibidache and other conductors, and several recording engineers and producers have approved the following list, which should only be regarded as tentative, and wide open to improvements:

richness — powerful multiple reflections;

density — many reflections across the hall within one second from a single impulse;

warmth — a strong bass-heavy frequency response curve, with a plateau in the tenor octave (125-250Hz) tapering off smoothly towards the top;

clarity — medium high frequencies arriving from all directions shortly after the original sound;

intimacy — an adequate supply of frequencies between 11 and 15kHz arriving early at the ear between 54° and 144° horizontally, and below 60° vertically;

weight — low frequencies arriving shortly after the original sound;

singing tone — a growth in the reverberation reaching a peak about 100 milliseconds after the original sound, then dying away smoothly over about 1.8 secs.

One reason why richness — and not a long reverberation — tops the list is because a variety of reflections coming from many angles close upon each other gives our ears a full frequency coverage. With our aural limitations of timbre in any one direction, the deficiencies can be made good only by receiving sound from all sides. In Avery Fisher Hall in New York, you can hear that in some upper/front balcony seats, where richness is present, any lack of the other qualities is much less noticeable.

Impulses

Another reason for our appreciation of richness is our astonishing capacity for quickly perceiving separate impulses in sound. Tests have shown that all listeners prefer to hear orchestral sound impulses which do not arrive simultaneously in both ears — hence the preference for stereo over mono. This scattering of the impulses is called 'binaural dissimilarity'. In a concert hall, it is the extent of the initial time-delay gap between the original sound and the first reflection — often about 40ms in a medium-sized hall — which gives much of the character to the acoustic. (Intimacy has been associated with this gap, but my list suggests other requisites.) Our ears appreciate these reflections most when they arrive close to horizontally from the side. My timbre lists show that the timbre of a hall is influenced for us first by the angle at which we hear the strongest first reflection, and then by the shape and materials of the hall, or room, and the reverberant spaces beneath it.

When we receive a lot of early reflections, one shortly after another, these impulses come in an arpeggiated form — in slow motion rather like the thrumming of a chord on a harp. This sequence of impulses we perceived as being much richer than an instantaneous reflection. A digital delay unit demonstrates this quickly, by making two or three string instruments sound like a rich chorus. Halls are preferred where the sequence of impulses, whether first or later reflections, dies away evenly. It is called a 'smooth decay curve'.

Home simulation

These two keys to richness, namely timbre and impulses, are demonstrable in the home with a system which I hope will be developed in the phonographic industry, as soon as the field of the external ear is completely measured. The system would need at least ten loudspeakers: one large one on the floor to represent the orchestra, and the smaller ones set around the room above and below the ear level, with the apposite timbre applied to each speaker

FRONTAL SPECTRUM	FREQUENCY	0°	18°	36°	54°	72°	90°	108°	126°	144°	162°	180°	OPPOSITE FIELD Sound coming from left to right ear: Low	Angle	Peak	Angle
−0.5dB	200Hz	0dB	1·5	2·5	2	1	2	1	0·5	0·5	0·5	0	−3	−108	+2	−36
+0.5	500	0	1	2·5	4	4	5·5	4·5	4	3·5	2	−0·5	−2·5	−140/60	0	−90
+1	700	0	1	2·5	3·5	4·5	5	5	4·5	3·5	1	−0·5	−4	−140/−45	−2	−90
−2	1kHz	0	2·5	4	4·5	6·5	7·5	7	6·5	5·5	5	4	−6	−30	+1·5	−90
+10	2	0	2	2	1·5	1·5	0·5	0	−1·5	−2	−2	−3·5	−12	−110/−75	−7	−90
+12	3	0	1	2	3	2	−1	−2	−2·5	−2·5	−3	−3·5	−15	−110	−8	−90
+5	4	0	3	4	3·5	1·5	−2	−5·5	−8·5	−8	−6·5	−5·5	−15	−120/−75	−9	−90
−1·5	5	0	3·5	4	5	4·5	3·5	0·5	−5·5	−9	−8	−7	−13·5	−120/−75	−12	−90
−0·5	6	0	4	6·5	7	7·5	7	5·5	2·5	−3	−4·5	−5	−13	−110/−60	−12	−85
+1·5	7	0	4·5	8·5	10	11	10	8·5	6·5	2·5	−1	−2·5	−13	−110/−50	−10	−90
−2	8	0	4·5	8	11	14	15	14·5	12	7·5	3·5	2·5	−10	−120/−75	−5	−90
−8	9	0	3·5	5·5	7	8·5	11·5	11	8	4·5	1	−0·5	−7·5	−130/−50	−5	−90
−10·5	10	0	3	5·5	7	7	6·5	7	6·5	4·5	2·5	−2·5	−6	135/−90/−50	−3	−110/−75
−10	11	0	3	3·5	6	7·5	7	7·5	7	6·5	2	−2				
−7	12	0	5	1·5	3·5	7	8·5	8	6·5	3·5	1·5	−2·5	−7·5	−130/−90	−3	−75
−2	13	0	4	0	1·5	5	5·5	6	5	1	0	−4·5				
+2	14	0	6·5	2	2	2·5	2	1·5	−0·5	−2·5	−4	−7	−11	−120/−50	−3	−75
+3·5	15	0	5·5	2·5	3	1·5	0·5	−1	−2	−3·5	−5	−7·5				

Strong h.f. sensitivity   Negative quantities

Fig. 3. *Lateral differences in timbre for one ear, compared to sound reaching us from straight ahead at eye level (from Mehrgardt and Mellert).*

according to its direction (to help to lock the stereo image) and with increasing time-delays on each speaker, equivalent to those we hear in a fine hall like Kingsway. A six-track tape or cassette could probably supply sufficient source material. All initial tests I have made in this direction improve the timbre and richness far beyond the one-plane, identical-timing and timbre of the quadrophonic system. Without dropping hints, we might call the new system 'decaphonic'. It develops the Bose system of reflections from all sides, which works best for me in rooms with little or no damping. Both point to the increased physical satisfaction when our orientation filtering system is being fully utilized in the appreciation of musical sound. The main problem lies in fixing the delicate balance between focused image and general immersion in the sound.

I have always found a stereo image to improve greatly when the frontal speakers stand at least three feet in front of a wall, as the timing of the frontal wall reflection seems to give full depth to the image. Thus, under ideal circumstances, an orchestra seems to be the same distance behind the speakers as the orchestra was behind the microphones in the studio – hence the need for simple microphone techniques. To obtain this effect in a room, I have often needed to set the speakers parallel and not angled towards me. In general, and sometimes despite manufacturers' advice, the adage of the RCA engineer Albert Pulley seems to work well in practice – that is, to set the speakers at a quarter of the width in from the sides and a quarter of the length of the room from the end. (Domestic bliss can be preserved with this obstructive placing if the speakers are disguised as occasional tables.)

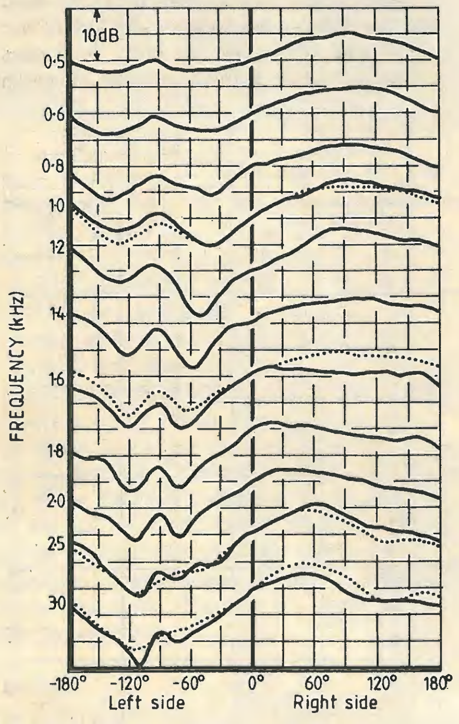


Fig. 4. *Graphical summary of lateral differences in sound pressure for the right ear. Negative angles refer to sound coming from the left side of the head. Range is from 500Hz to 3kHz.*

Long reverberation

Until such a time as a 'decaphonic' system is common currency, it is fairly obvious why very reverberant halls will be favoured for recording. Present systems use mainly microphones which pick up frontally frequencies that we can never hear there (with our 3kHz peak, 10kHz trough, and general cut-off in the ear canal above 11kHz). Also the loudspeakers are usually placed at angles where we cannot perceive several other frequencies very well, showing a 20dB range between the 3kHz and 11kHz readings. The simplest way of covering up these two aural mismatches is to add reverberation to diffuse and thus beautify the sound.

This has the unfortunate effect of robbing the interpreter of a number of breathtaking dramatic effects, because he can never achieve a quick silence, until the common 2.5s of reverberation has died away. That would never have done for Verdi, Toscanini or Callas.

Instead we should seek out a true and satisfying way to give us global (360°) reflections in the reproduction, and thus a natural, full-frequency spectrum, concentrating on our most sensitive area, between 40° and 140° laterally. Even most headphones are unnatural (save those with multi-speakers) in that they eliminate the whole of our own aural frequency filter system. The great advances in 'Kopfbezogene stereophonie' (binaural recording) fall back at this point.

Architectural prerequisites

The quest for the physical conditions necessary to produce warm, rich string tone in a concert hall was sparked off by the decision of my home town, Melbourne, Australia, to spend 33.5 million dollars (A) to build a 35 metre square, virtually all-concrete hall for that purpose. Of the many indications given to me, two of the most revealing were from Villem Jordan and Derek Sugden. Jordan could not obtain 'lateral efficiency' in a hall wider than 27 metres, and observed that all the famous halls had smaller widths. Sugden stated:

"A hall must have 'presence' so that you not only preserve clarity in a reverberant field but the music will have 'weight'. A powerful sound in the first 100 milliseconds in necessary. This can be achieved preferably with a width of about 18 metres, and if this is not possible then deep balconies must be used, or the technique of putting the audience in terraces and providing large surfaces for lateral reflections. There must be rapidly following early reflections to really achieve intimacy or presence."

A third useful piece of wisdom came from Decca's former chief engineer, Kenneth Wilkinson:

"I have recorded in many halls thoughout Europe and America and have found that halls built of mainly brick, wood and soft plaster, which are usually older halls, always produce a good, natural, warm sound. Halls built with concrete and hard plaster seem to produce a thin, hard sound and always a lack of warmth and bass. Consequently, when looking for halls to record in, I always avoid modern concrete structures." This statement has been endorsed by most of the other large record companies.

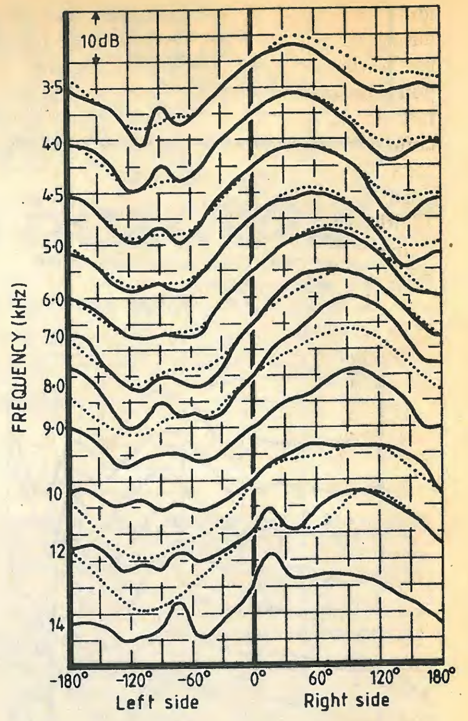


Fig. 5. *Continuation of Fig. 4 in range 3.5kHz to 14kHz. Small peak at −90° on left side persists up to 9kHz, then moves to −75°.*

First reflections

In all the famous orchestral halls, the first lateral reflections come from the side balcony faces. Their timing is exactly controlled by the width (1 foot ≈ 1s). So a central seat in the Leipzig Gewandhaus, with only 12.5m between the balcony faces, had an initial time delay gap of around 41ms. Vienna Musikvereinsaal with 15m had 49ms, Boston Symphony Hall (17/19.3m) 56/63ms, and the Amsterdam Concertgebouw (19.3m) 63ms. Those figures give a very good idea of the relative clarity and definition, intimacy and density of sound in each of the above halls. As upper-high frequencies fall off audibly through atmospheric absorption after about 15 metres, Leipzig and Vienna must have the best quality.

Looking at the Kingsway Hall, it is easy to see where it satisfies the main requirements. Its full width is at the upper limit, 27 metres, with inner walls set on pillars at 19 metres width. But the width between the horseshoe balcony faces, with a very useful curved reflecting surface beneath them, is only 17 metres at its widest point. The balcony surrounds the orchestra at a height of 3.5 metres. To be honest, I think that such a horseshoe would bring any large symphony orchestra good acoustical luck. It gives all the players reflections back early enough, and at the right angle, to allow them to obtain good ensemble. The unbroken surface allows early bass reflections to come back to the microphones (not too strong, mind you) because the long bass waves are reflected intact, and from a shape consonant to their own. It might be worth copying this reflecting shape in Abbey Road, Maida Vale, Henry Wood, Walthamstow, Brent and Watford, to name but a few London recording halls. The shape is reminiscent of those marvellous small Italian theatres.

In recent years, the Kingsway lease has been shared by EMI and Decca, also sub-letting it to RCA and other companies. Virtually all the seats have been removed downstairs and many upstairs covered with cloth. At the moment its reverberation time with an orchestra present is about 2.5 seconds.

Hall background noise

Poor Wagner cannot have guessed that in 'Tristan and Isolde', by giving his shepherd on the rocks a woodwind solo which lasted more than four minutes, he was condemning one of his greatest interpreters – Furtwangler – to recording a duet for English Horn and Piccadilly Line Train. Unfortunately, collaboration between EMI and London Underground is not yet such that the engineer's 'red light area' can extent to such nether regions. The rumble of the tube trains would not be so noticeable, were Kingsway not such a good hall. Moreover the cavernous storerooms and airducts beneath the main floor, which undoubtedly contributes to the warmth of the sound there, develop the tube rumble with equal generosity – a sound which is cruelly revealed by digital recording techniques. The hall is very much alive at all frequencies, even when no-one is in it. The presence of 80 musicians is something which you not only feel there, but which gives the indispensable and audible human element to the music, with myriad small high-frequency extra-musical sounds. The ease of tone and spaciousness achieved in Beecham's 'Scheherezade' and Furtwangler's 'Tristan' have to my ears yet to be bettered on disc. Both recordings managed to reproduce the 'hush' which was present during the sessions, and which is an integral part of the greatness of the musical interpretations. A bald silence behind the music is the antithesis of this spell-binding, breathless hush, and unfortunately I fear that Dolby techniques so far, in their valiant battle to eliminate tape hiss and mechanical noise, have also eliminated some of this integral part of the music. Digital recording is proving to be one of the better ways, which do not reduce the human element in a performance, and the comment of the acoustic on this human element.

'Singing' decay curve

It would be fascinating to know just why the string sound at the beginning of the third movement of the Beecham 'Scheherezade' is so natural. To write this article, I went down on my hands and knees, and with the generous help of the Kingsway caretaker, measured the various distances, counter-checking them against the few remaining plans of the hall. So please do not expect total accuracy.

FRONTAL SPECTRUM	FREQUENCY	0°	9°	27°	45°	63°	85° (Overhead)	99°	117°	135°	153°	171°	180° (behind)
−0.5dB	200Hz	0	−0·5	−0·5	1·5	1·5	−1·5	−1	0	1	−1	0	0
+0.5	500	0	0·5	2	1·5	−0·5	−1·5	−0·5	0	1	1·5	0	−0·5
+1	700	0	0	−1	−4	−4·5	−5	−3	−2·5	−2	1	0	−0·5
−2	1kHz	0	0·5	1	1·5	2	0·5	0	0·5	1·5	3·5	4	4
+10	2	0	−2	−4	−5	−5·5	−6·5	−7	−5·5	−4·5	−4	−4·5	−3·5
+12	3	0	−0·5	−2	−3	−4	−4·5	−5·5	−6	−5·5	−5	−3·5	−3·5
+5	4	0	−0·5	−1	−2	−2·5	−4	−5·5	−6·5	−7	−7	−6	−5·5
−1·5	5	0	−0·5	−1	−0·5	−2	−4·5	−5·5	−6·5	−7	−7	−7	−7
−0·5	6	0	1	3	2·5	2	−0·5	−2	−2·5	−3·5	−4	−4·5	−5
+1·5	7	0	1·5	5	7	6·5	4	2	2·5	2	0·5	−2	−2·5
−2	8	0	2	8	12	12·5	12	10	9	10	7	4	2·5
−8	9	0	1·5	7	10	12·5	13·5	12	11·5	11	7	1·5	−0·5
−10·5	10	0	1	5	5·5	8	8·5	7·5	7	3·5	0·5	−1·5	−2·5
−10	11	0	0·5	1	−1	2	4·5	0·5	−1	−1·5	−4·5	−2	−2
−7	12	0	0·5	2	−1	−2·5	0	−3	−5·5	−2·5	−3	−2·5	−2·5
−2	13	0	1	2	−3·5	−7·5	−4	−7·5	−10	−6	−8	−7	−4·5
+2	14	0	0·5	1	−3	−7	−2	−8	−10	−8	−7·5	−7	−7
+3·5	15	0	0	0	−3·5	−8	−0·5	−8·5	−11·5	−8	−7	−7·5	−7·5

Positive quantities   Outlined area = stronger sensitivity at 7 to 10kHz

Fig. 6. *Vertical differences in timbre (equal for both ears) compared to sound reaching us from straight ahead at eye level. From Mehrgardt and Mellert.*

All the great halls have a certain 'singing' tone, characterized by a crescendo in the decay curve. Just as we can all sing better in the bathroom, because the acoustic supports us, so the 'singing' curve gives a lift to the performers, and allows the music to take wing, without need for forcing. (I think that adding a short peak of this nature to a dry recording would give more musical results than the general confusion caused by the usual long reverberation.) No one has the formula for its production in a hall. Guildford thinks that it needs a large area of parallel surfaces above the highest seat, as in Vienna, Boston, Amsterdam, etc. Joan Sutherland (and I) think that it needs also a set of hard surfaces around the hall at the level of the performers. Schultz that it needs a filigree of smaller surfaces for the very first reflections. It is probably a combination of all three.

For the Beecham sessions, with the orchestra facing the organ, the microphones were about 2 metres in front of the stage. For an instrument just under the microphone this gives the following sequence of delays in the reflections from various parts of the hall after the original sounds:

Stage front, 14ms; upper stage front, 30ms; side balconies, 48ms; back balcony, 54ms (first frontal reflection); ceiling, 57ms (larger); diagonal walls beside organ, 73ms; side walls down stairs, 81ms (larger); arches between side pillars and inner walls, 93ms (et seq.); ceiling curves, 100ms (larger); backwall downstairs, 105ms (larger); curves organ ceiling, 111ms; side wall upstairs, 133ms (larger); back wall upstairs, 147ms (larger).

Some of these figures should be higher, where the reflection can only come back to the microphone with the help of a secondary surface, such as side wall upstairs/lower ceiling. As the microphone is not very sensitive on top (and fickle memory suggests that the stereo microphones were hung upside down for 'Scheherezade'), this means that the effectively larger reflections start about 18ms after the original sound. Boston's singing tone is based on a growth up to a peak in the decay curve, the peak reaching from 100 to 150ms. Amsterdam puts it even later. By Sugden's standards of 'presence' and 'weight' Kingsway has quite a lot of powerful reflections to offer within the first 105ms, because the larger reflections continue to return up to 14ms, the substantial and lengthy support of the musicians is assured, before the riotous ping-pong of the subsequent reverberation

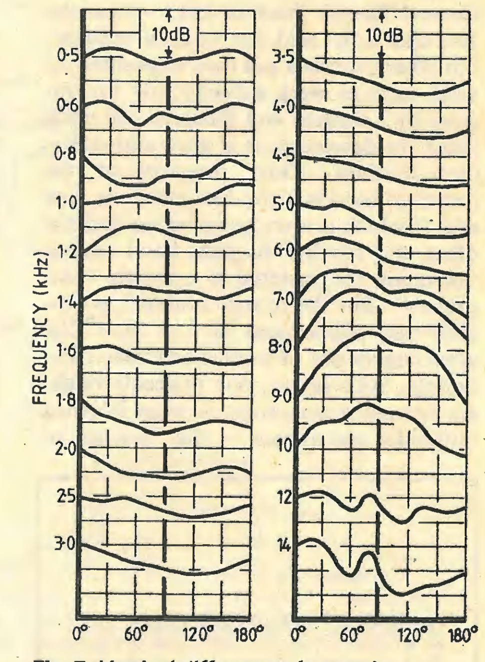


Fig. 7. *Vertical differences in sought pressure perceived equally by both ears. 90° is overhead, 180° behind.*

in every direction sets in. All later refections are naturally weaker.

Curves

Robert Lloyd, the bass, has observed that wherever there are a lot of curved surfaces, the acoustic tends to be very good. When the curves are concave, they may match the shape in which the sound waves first reach them, and thus reflect them well. When the curves are convex, they distribute the sound waves evenly over wide areas. Kingsway is rich in both types of curve. Nearly all the stage-end surfaces are curved one way or the other, with many interim small reflections, such as curves over doors, etc. I hope sincerely that this article may stimulate others to copy them, above all because of the full-frequency-range efficiency of the initial long horseshoe curve of the balcony face and its undercurve. For a full symphony orchestra it comes at an ideal moment to break up the sound, and is as worthy of respect as the exact measurements of the orchestral shell in the Boston Symphony Hall. If you wish to copy a Stradivarious, all details are relevant!

Reversal

It would be interesting to know whether sharp-eared listeners with refined equipment can detect the differences in recordings made in Kingsway the other way round, with the orchestra's back to the organ. Many recent opera recordings use this setup, which puts the singers in a better relationship to the orchestra, and allows them to move as though on a stage. It also allows the full depth of the voices to develop, in the essential 8-10 metre distance to the main orchestral microphones.

But this way round, the reflection pattern for the orchestra is changed. The low front of the stage and the small upper stage must substitute for the 3.5m high curve of the long back balcony face. The frontal, early deep-bass reflection at microphone height at 54ms has been replaced by a very early one at about 8-10ms. The difference ought to be noticeable to keen listeners as this new reflection is behind the microphones.

Awareness

Perhaps the foregoing analyses of several aspects of hearing will help listeners towards a greater appreciation of colour and texture in sound. The measurements of timbre are far from complete, and more details are due to be published next year, covering the whole of the upper right hemisphere of our field of hearing.

When stereophony was introduced, analyses of aural localization mentioned the three systems available to our body – giving the greatest importance to the timing of impulses, much less to intensity, and virtually dismissing timbre differences as inessential. It remains to be seen whether in fact timbre is not the Cinderella of the trio, ready to blossom into the most beautiful attribute when it is identified, recognized and espoused for its true worth. □

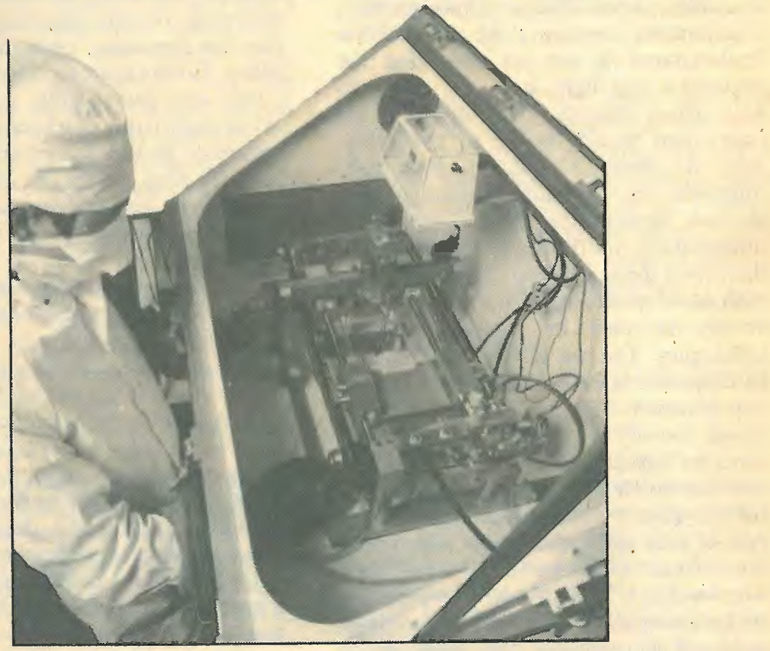
Further reading

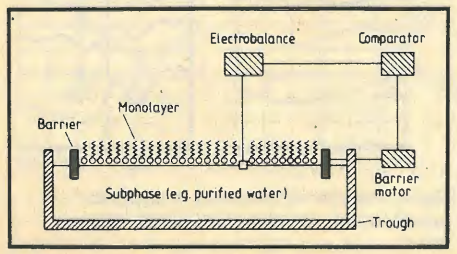
Analyses of musical qualities and hearing: *J. Sound and Vibration*, 1980, vol. 69 pp 110-138. *Musical Times*, Jan./Feb./-Mar. 1981. *Studio Sound*, J y 1981, pp 62-66.

Timbre lists; *Musical Times*, Jan./Feb./Mar. 1981.

Langmuir thin-film trough for molecular electronics

Collaboration between scientific instrument makers Joyce Loebl and a number of research establishments, especially Durham University, RSRE Malvern and ICI, has resulted in what is believed to be the world's first commercial ultra-thin film "growing" equipment. The films in question are monomolecular layers of a class of materials floated on a liquid surface, usually water transferable to a solid surface by passing it through the liquid. The material originally used by the pioneer of this technique – Irving Langmuir of General Electric back in 1917 – was the soap-like fatty acid salt sodium stearate, but other materials and their deposition on solid surfaces were subsequently investigated by Langmuir and Blodgett, one result being the development of glass anti-reflection coatings. Chief property of the materials used is a rod-like molecule, one end of which is attracted to water and the other end repelled so they stand end-on (assuming the material is correctly compressed). But the trough is aimed at possible new applications of L-B films that arise largely out of microelectronics technology. Such layers, one molecule thick, are becoming important in what is called molecular electronics – the "science of clever chemistry and electronics". Applications include insulating layers as thin as 10^{-9} metre in gallium arsenide devices and as a resist in electron-beam lithography. Organic layers may have application for gas detection, while biological molecules such as antibodies and enzymes may make field-effect devices feasible for *in vivo* monitoring. In integrated optics they offer a route to the precise building of multilayer films to one tenth of an Angstrom unit, perhaps with the molecular addition of metallic atoms to tailor response to radiation.





"Molecular Lego", as it has been dubbed, also has potential application to energy conversion devices, photosynthesis, magneto-optics, three-dimentional memory devices, and to display devices, where high electric fields may allow a high-speed alternative to current technology.

Molecules are compressed in the Langmuir trough with a constant-perimeter variable-area boundary which encloses the monolayer and prevents film contamination. A sensitive microbalance with sensor in the liquid surface monitors differential surface tension, and links through a control system to the barrier drive. A motor-driven micrometer screw automatically drives a substrate in and out of the liquid. Constant surface pressure is provided by a differential feedback system to maintain film integrity. A pre-determined number of monolayers can be programmed by a control unit using a range of dipping speeds, and a two-pen recorder charts surface pressure and area during deposition.

The trough is made by Joyce-Loebl, a subsidiary of Vickers Instruments, of Team Valley, Gateshead.

Enter WW 500 on reply card for further details.

NETWORKING SMALL COMPUTERS

Simply transferring a program or data from one computer to another by telephone is not too great a problem, but if a number of remote computers are to work together regularly in a network, relatively complex software is required to organize received information efficiently. This article describes such software designed for Pet microcomputers and outlines networking generally.

by Philip G. Barker*

As personal computers become more popluar, the need for simple methods of exchanging programs and data between them increases. Eventually, it may be possible to exchange this information through some form of readily accessible global communications network, but at present, we have to make the best possible use of the facilities available. Some of the more important information dissemination techniques currently being explored are:

– teletext broadcasts
– viewdata systems, such as Prestel
– and distributed computer networks.

Each of these approaches has its advantages and disadvantages. In the UK, experiments have been carried out using Ceefax and Oracle as a means of distributing software[1] but these methods can only be used to access information from a central point. With Prestel, two-way information exchange is possible, but there are two categories of 'user' – the ordinary customer, who can only receive and examine pages of stored material, and information providers. The major drawback of this method is that not all users can be information providers†. The Council for Education Technology is currently investigating this type of information dissemination in conjunction with a number of schools and colleges[2].

A truly distributed computing network[3,4] is the third approach to program and data distribution. Such a system has the advantage of allowing totally unrestricted bi-directional data exchange between any two parties. In this article I describe using the public switched network (p.s.n.) as a means of distributing programs and data between owners of personal computers.

Source program transmission

The distributed computing system's architecture significantly influences the type of data it can accommodate. Broadly speaking, these systems fall into one of two categories – one in which intermediate data storage is available, and one in which data transfer is direct.

In Fig. 1(a), the microcomputer owner at site X is able to dial the telephone number of the owner at site Y and then transmit information to him/her. In the context of data exchange, transmission takes place as if the two microcomputers were linked together directly[5]. No intermediate data storage is available so error detection and correction procedures have to be incorporated in the software used for receiving the data. Messages passing over the communication network are susceptible to corruption by noise or crosstalk and as a result, if the receiver fails to respond to the transmitter, data transfer is inhibited.

In Fig. 1(b), the microcomputer owner at point X can store material in a mainframe at site V or W for later retrieval. Provided that the computers at points Y and Z can meet all the necessary access control requirements, they too can gain access to the data. With this kind of network, information can be shared easily and distribution to other geographical locations is simplified.

Details of using a microcomputer as an interactive terminal, in conjunction with the public switched telephone network[6,7], and of using a microcomputer as an intelligent terminal[8] have been presented. In reference 8, algorithms for information-file transfer between a mainframe and microcomputer are discussed in detail. These files may contain machine-code programs, high-level (source-language) programs or data. Using the software described, communicating programs between one microcomputer and another (via a mainframe) is reasonably straightforward but a decision has to be made regarding whether the programs are

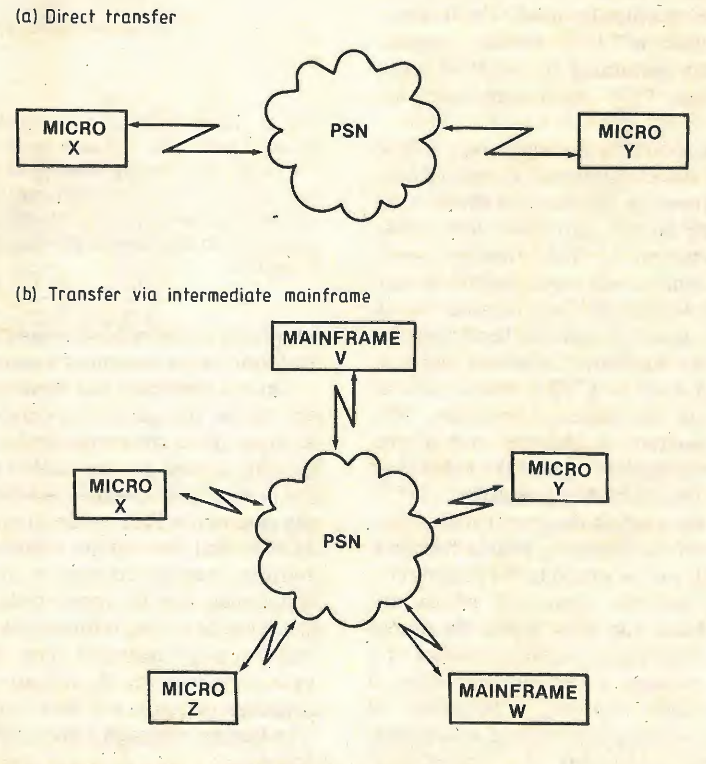


Fig. 1. In (a), the public switched network is used to link two computers together directly. Messages passing over the network are susceptible to corruption by noise or crosstalk – if the receiver fails to respond to the transmitter, data transfer is inhibited. Data from any of the three microcomputers shown in (b) may be stored in a mainframe computer and retrieved later. Using this type of network, certain codes can be imposed to restrict access of information from the mainframes to those microcomputer owners with knowledge of the code.

† British Telecom say that potentially all users can be information providers so presumably Dr Barker refers to cost limitations. – Ed.

* Dr Barker is a Principal Lecturer at the Department of Computer Science, Teesside Polytechnic.

to be transmitted in machine-code or source-language form.

Factors influencing the ease with which programs may be communicated are

– the level of language used
– the availability of internationally accepted language standards and the ability of programmers to keep within limitations imposed by these standards
– compatibility of the computers used.

These factors alone are probably sufficient to justify transmitting program files in source language form rather than as machine-code memory images. In this context we have been examining the problems associated with transmitting both Pascal and Basic programs over the p.s.n. between microcomputers and mainframes. Some interesting results have been obtained – a few of which are described here.

Files transmitted between the two computers consist of a contiguous set of characters. Certain special characters interspersed in the sequence, for example end-of-line $0D*, impose a simple record structure on these files. That the files may not be physically stored in this way in either the source or destination computer is of little consequence as far as this article is concerned.

Loading Basic from secondary storage

Once a Basic program has been transmitted from a remote computer and stored locally on a secondary storage medium such as a tape or disc drive, it is a simple matter to load the program into memory for subsequent execution. How the program is loaded will depend on the type of microcomputer used. To illustrate the purpose of this article, specific descriptions pertaining to the 3000 series Commodore PET microcomputer are included.

The function of a loading program is to recognize Basic statements contained in a secondary storage file, convert them to the appropriate format, and store them at the correct location in the memory space available. Functional requirements of such a program for the PET are summarized in Fig. 2(a), where it can be seen that the storage area for Basic programs starts at $0400 and ends at $7FFF where 32K of memory is available. Obviously, the loading program at the top end of the memory will slightly reduce the amount of space available for other programs.

One of the loading program's main tasks is to convert the incoming source code to a code which can be stored in the computer's memory, the two forms of which are represented in Fig. 2(b). When the source code is stored, each statement consists of a two-byte pointer, a two-byte encoding of the statement number, a sequence of bytes representing the original source line and a byte containing the 'end-of-line' marker. Further details on how Basic

*The 'dollar sign' indicates that the number immediately following it is in hexadecimal form. This is not the standard method of indicating hexadecimal numbers, but is familiar to most users of the microcomputer concerned. – Ed.

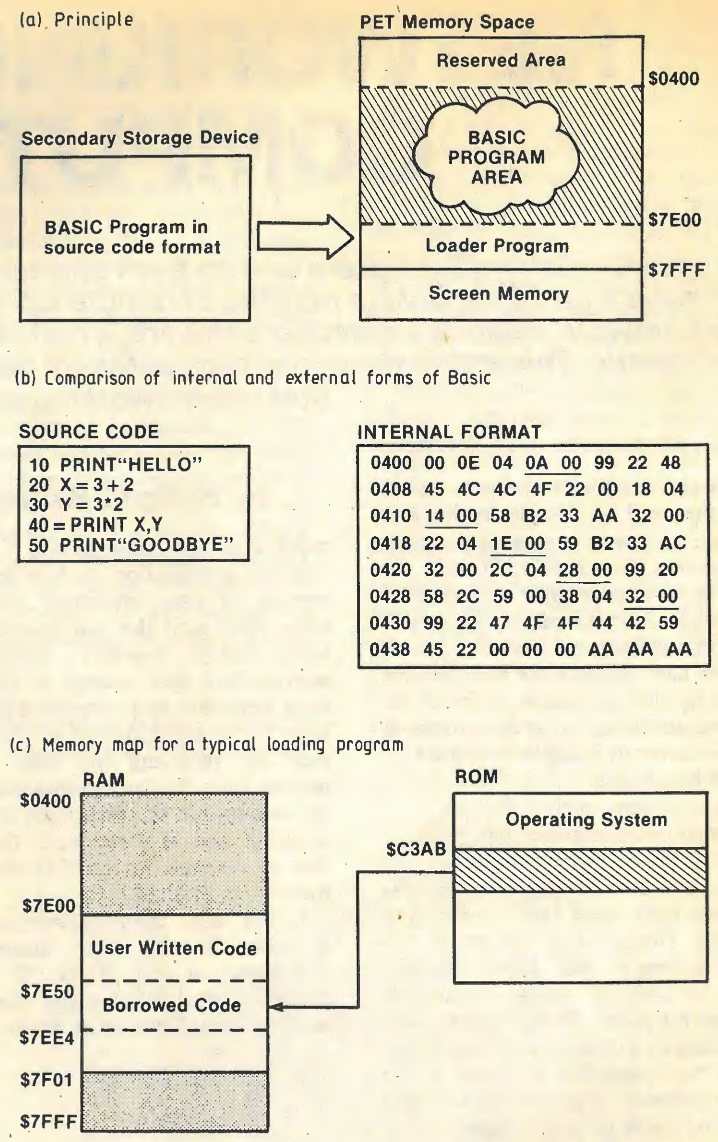


Fig. 2. The function of a source-language loading program. These diagrams, although specifically relating to the PET, are typical of most microcomputers. Underlined sections in (b) indicate the positions in memory of the Basic statement numbers.

programs are stored in memory can usually be found in the computer's manuals[9].

Once a statement has been converted, it has to be placed in the correct memory location. Both conversion and insertion are usually carried out by routines built into the computer's operating system, which in the case of the PET are locations $C34B to $C43F, and there is no reason why these routines may not be used in the programs concerned. But for most readers, copying the relevent r.o.m. information into r.a.m. will be more practical than altering the system's r.o.m. A simple assembly language program will serve this purpose. The loading program's basic structure is as follows;

Step 0: borrow code from the operating system
Step 1: initialize Basic (usually using NEW)
Step 2: read input file (get next source character)
Step 3: if 'end-of-line', go to step 6
Step 4: if 'end-of-file', go to step 8
Step 5: store source character in Basic buffer then go to step 2
Step 6: prepare for operating-system entry routines
Step 7: convert source statement held in buffer, enter into Basic memory area, then go to step 2
Step 8: pass control back to Basic command mode with a 'READY' message.

As was suggested earlier, step 7 will probably be carried out by a 'borrowed code', and the remaining steps will be implemented by the operator, see Fig. 2(c). An assembly-language program for the above algorithm – for Basic source files on cassette – is shown in Fig. 3, and a complementary flow diagram is shown in Fig. 4. When invoked, the initialization code copies $94 bytes, starting from $C34B, in the slot reserved for it through manipulation of the assembler location counter. When this is completed, the loading operation starts. The program uses a subroutine called TPREAD to transfer a block of data from cassette into the relevant buffer area. In turn, this routine makes use of the operating utility code commencing at $F855. Characters are then

Fig. 3. Basic source-code loading program written in assembly language for cassette-based systems.

```
0000                        ;
0000                        ;TAPE LOADER PROGRAM
0000                        ;*******************
0000                        ;
0000                        TAPERD=$F855            ;TAPE READ ROUTINE
0000                        DEVICE=$D4              ;INPUT DEVICE NUMBER
0000                        BASBUF=$0200            ;BASIC BUFFER
0000                        BUFFER=$027A            ;TAPE BUFFER
0000                        NEWSYS=$C55D            ;PERFORM "NEW"
0000                        CHRGET=$0070            ;LINE FETCH ROUTINE
0000                        OSCODE=$C3AB            ;START OF CODE TO BE COPIED
0000                        BASIC=$C389             ;BACK TO BASIC
0000                               *=$7E00
7E00  A0 00        START    LDY #$0
7E02  B9 AB C3     COPY     LDA OSCODE,Y            ;COPY OS CODE
7E05  99 50 7E              STA INSERT,Y            ;INTO THIS PROGRAM
7E08  C8                    INY
7E09  CC FE 7E              CPY NUM                 ;ALL DONE?
7E0C  D0 F4                 BNE COPY                ;NO - GET SOME MORE
7E0E  20 5D C5     STEP1    JSR NEWSYS              ;INITIALISE SYSTEM
7E11  20 F0 7E              JSR TPREAD              ;READ A TAPE BLOCK
7E14  20 F0 7E              JSR TPREAD              ;READ A TAPE BLOCK
7E17  A2 00                 LDX #$0                 ;INITIALISE X-REGISTER
7E19  A0 01                 LDY #$1                 ;INITIALISE Y-REGISTER
7E1B  B9 7A 02     STEP2    LDA BUFFER,Y            ;GET A CHARACTER FROM TAPE BUFFER
7E1E  C9 0D                 CMP #$0D                ;IS IT END OF LINE?
7E20                        ;
7E20  F0 1B        STEP3    BEQ STEP6               ;YES
7E22  C9 00                 CMP #$00                ;IS IT END OF FILE?
7E24  D0 03        STEP4    BNE STEP5               ;NO
7E26  4C EC 7E              JMP STEP8               ;YES
7E29  9D 00 02     STEP5    STA BASBUF,X            ;STORE IN BASIC BUFFER
7E2C  E8                    INX                     ;INCREMENT X-REGISTER
7E2D  C8           LY       INY                     ;INCREMENT Y-REGISTER
7E2E  C0 C0                 CPY #$C0                ;END OF DATA BLOCK?
7E30  F0 03                 BEQ GBLOCK              ;YES - GO GET ANOTHER
7E32  4C 1B 7E              JMP STEP2               ;NO - GO GET NEXT CHARACTER
7E35  20 F0 7E     GBLOCK   JSR TPREAD              ;GET ANOTHER BLOCK
7E38  A0 01                 LDY #$1                 ;INITIALISE COUNT
7E3A  4C 1B 7E              JMP STEP2               ;RETURN TO MAIN LOOP
7E3D  A9 00        STEP6    LDA #$00                ;PUT EOL INTO BASIC
7E3F  9D 00 02              STA BASBUF,X            ;BUFFER AREA
7E42  A2 FF                 LDX #$FF                ;SET UP POINTERS TO THE
7E44  86 77                 STX $77                 ;ADDRESS OF BASIC
7E46  A2 01                 LDX #$01                ;SOURCE TO BE PROCESSED
7E48  86 78                 STX $78
7E4A  8C 00 7F              STY YIND                ;SAVE CONTENTS OF Y-REGISTER
7E4D  20 70 00     STEP7    JSR CHRGET              ;INVOKE CHRGET ROUTINE
7E50               INSERT=*                         ;TOKENISE STATEMENT
7E50                               *=*+$94          ;AND INSERT RESULT INTO
7EE4                                                ;BASIC PROGRAM AREA
7EE4                                                ;GET READY TO GO BACK AND
7EE4                                                ;PROCESS NEXT STATEMENT
7EE4  AC 00 7F              LDY YIND                ;RESTORE Y-REGISTER
7EE7  A2 00                 LDX #$0                 ;INITIALISE X-REGISTER
7EE9  4C 2D 7E              JMP LY                  ;GO BACK TO MAIN LOOP
7EEC  EA           STEP8    NOP                     ;END OF FILE
7EED  4C 89 C3              JMP BASIC               ;RETURN TO BASIC
7EF0                                                ;
7EF0                                                ;ROUTINE TO READ A TAPE BLOCK
7EF0                                                ;
7EF0  A0 01        TPREAD   LDY #$1                 ;LOAD INPUT DEV
7EF2  84 D4                 STY DEVICE              ;PASS TO OPSYS
7EF4  8E FF 7E              STX XIND                ;SAVE X-REGISTER
7EF7  20 55 F8              JSR TAPERD              ;READ A TAPE BLOCK
7EFA  AE FF 7E              LDX XIND                ;RESTORE X-REGISTER
7EFD  60                    RTS                     ;RETURN TO CALLER
7EFE                                                ;
7EFE                                                ;DATA STORAGE AREAS
7EFE                                                ;
7EFE  94           NUM      .BYTE $94               ;NUMBER OF BYTES TO COPY
7EFF  00           XIND     .BYTE 0                 ;PLACE FOR X-REGISTER
7F00  00           YIND     .BYTE 0                 ;PLACE FOR Y-REGISTER
7F01                        .END
```

Fig. 5. This assembly language program, a modified version of the program shown in Fig. 3, is for loading source-code programs in a disc-based system.

```
0000    ;
0000    ;DISK SUPPORT ROUTINES FOR LOADER PROGRAM
0000    ;****************************************
0000    ;
0000    ;
0000    ;RESERVED LOCATIONS
0000    ;
0000    LONAM=$DA            ;ADDRESS OF FILE NAME-LOW
0000    HINAM=$DB            ;ADDRESS OF FILE NAME-HIGH
0000    LD=$D2               ;LOGICAL DEVICE NUMBER
0000    PA=$D4               ;PRIMARY ADDRESS
0000    SA=$D3               ;SECONDARY ADDRESS
0000    FILEN=$D1            ;LENGTH OF FILE NAME
0000    ST=$96               ;STATUS CODE
0000    BUFFER=$027A         ;TAPE BUFFER
0000    ;
0000    ;SYSTEM SUBROUTINE ADDRESSES
0000    ;
0000    PRINT=$CA1C          ;PRINT A STRING
0000    READY=$C38B          ;READY
0000    INPUT=$C46F          ;INPUT FROM KEYBOARD
0000    FOPEN=$F524          ;OPEN FILE
0000    CHKIN=$F770          ;SET INPUT DEVICE
0000    INBYTE=$F18C         ;INPUT SOURCE BYTE
0000    FCLOSE=$F2AE         ;CLOSE FILE
0000    CLRCHN=$FFCC         ;CLOSE I/O CHANNELS
0000    ;
```

continued

Fig. 5: continued

```
0000                      ;DEFINED SUBROUTINES
0000                      ;********************
0000                      ;
0000                              *=$7000
7000                      ;
7000                      ;DISK OPEN ROUTINE
7000                      ;
7000  A9 01     DKOPEN    LDA #$01            ;OPEN ERROR AND DISK
7002  85 D1               STA FILEN           ;COMMAND CHANNEL
7004  A9 00               LDA #$00            ;LOW BYTE OF FILE NAME ADDRESS
7006  85 DA               STA LONAM           ;STORE IN POINTER LOW
7008  A9 02               LDA #$02            ;HIGH BYTE OF FILE NAME ADDRESS
700A  85 DB               STA HINAM           ;STORE IN POINTER LOW
700C  A9 49               LDA #'I             ;INITIALISE DISK COMMAND
700E  8D 00 02            STA $0200           ;STORE IN FILE NAME
7011  A9 0F               LDA #$0F            ;LOGICAL FILE 15
7013  85 D2               STA LD              ;STORE IN LOGICAL DEVICE BYTE
7015  A9 08               LDA #$08            ;DISK IS DEVICE 8
7017  85 D4               STA PA              ;PUT IN PRIMARY ADDRESS
7019  A9 0F               LDA #$0F            ;LOAD SECONDARY ADDRESS OF 15
701B  85 D3               STA SA              ;STORE IT
701D  20 24 F5            JSR FOPEN           ;INITIALISE DISKS - OPEN 15,8,15,"I"
7020  A9 71               LDA #<PROMPT        ;LOAD ADDRESS
7022  A0 70               LDY #>PROMPT        ;OF PROMPT MESSAGE
7024  20 1C CA            JSR PRINT           ;GO PRINT IT
7027  20 6F C4            JSR INPUT           ;GET FILE NAME FROM USER
702A  A9 02               LDA #$02            ;SET LOGICAL FILE NUMBER 2
702C  85 D2               STA LD              ;STORE IN LOGICAL DEVICE BYTE
702E  A9 08               LDA #$08            ;SELECT DEVICE 8 FOR DISK
7030  85 D4               STA PA              ;PUT IN PRIMARY ADDRESS BYTE
7032  A9 02               LDA #$02            ;LOAD SECONDARY ADDRESS OF 2
7034  85 D3               STA SA              ;STORE IN SECONDARY ADDRESS BYTE
7036  A2 00               LDX #$00            ;SET INDEX TO ZERO
7038                                          ;
7038  BD 00 02  LOOP1     LDA $0200,X         ;GET CHARACTER FROM INPUT BUFFER
703B  F0 04               BEQ NEXT            ;IF ZERO THEN END OF FILE NAME
703D  E8                  INX                 ;INCREMENT X-REGISTER
703E  4C 38 70            JMP LOOP1           ;EXAMINE NEXT CHARACTER
7041  86 D1     NEXT      STX FILEN           ;SET FILE NAME LENGTH
7043  20 24 F5            JSR FOPEN           ;OPEN FILE:  OPEN 2,8,2,"???????"
7046  A2 0F               LDX #$0F            ;TEST FOR ERRORS
7048  20 70 F7            JSR CHKIN           ;SET INPUT FILE TO 15
704B  20 8C F1            JSR INBYTE          ;GET A BYTE FROM DISK ERROR CHANNEL
704E  C9 30               CMP #$30            ;IS IT ASCII ZERO?
7050  F0 17               BEQ OPENOK          ;YES - FILE OPENED OK
7052  A9 7F               LDA #<MESS1         ;GIVE DIAGNOSTIC
7054  A0 70               LDY #>MESS1         ;MESSAGE TO USER
7056  20 1C CA            JSR PRINT
7059  A9 02               LDA #$02            ;CLOSE CHANNEL 2
705B  20 AE F2            JSR FCLOSE
705E  A9 0F               LDA #$0F            ;CLOSE CHANNEL 15
7060  20 AE F2            JSR FCLOSE
7063  20 CC FF            JSR CLRCHN          ;SET DEFAULT I/O DEVICES
7066  4C 8B C3            JMP READY           ;GO BACK TO BASIC
7069  A9 91     OPENOK    LDA #<MESS2         ;TELL USER THAT THE
706B  A0 70               LDY #>MESS2         ;FILE OPENED OK
706D  20 1C CA            JSR PRINT
7070  60                  RTS
7071  0D        PROMPT    .BYTE $0D,$0A,'FILE NAME? ',$0
7072  0A
7073  46 49
707E  00
707F  0D        MESS1     .BYTE $0D,$0A,'FILE OPEN ERROR',$0
7080  0A
7081  46 49
7090  00
7091  0D        MESS2     .BYTE $0D,$0A,'FILE OPENED OK',$0
7092  0A
7093  46 49
70A1  00
70A2                      ;
70A2                      ;DISK READ ROUTINE
70A2                      ;  - EMULATES A FAST CASSETTE
70A2                      ;
70A2  8D FD 70  DKREAD    STA ACCUM           ;SAVE ACCUMULATOR
70A5  8E FE 70            STX XREG            ;SAVE X-REGISTER
70A8  8C FF 70            STY YREG            ;SAVE Y-REGISTER
70AB  A2 02               LDX #$2             ;SET NUMBER OF FILES OPEN
70AD  86 AE               STX 174             ;IN LOCATION 174
70AF  A2 02               LDX #$02            ;SELECT LOGICAL CHANNEL 2
70B1  20 70 F7            JSR CHKIN           ;SET INPUT DEVICE
70B4  A2 01               LDX #$01            ;LOAD POINTER
70B6  AD FC 70            LDA EOF             ;HAS EOF BEEN PREVIOUSLY DETECTED?
70B9  D0 22               BNE CLOSE           ;YES - GO CLOSE FILES
70BB  20 8C F1  LOOP2     JSR INBYTE          ;GET A BYTE FROM DISK FILE
70BE  A4 96               LDY ST              ;END OF FILE?
70C0  D0 0B               BNE END             ;YES - GO CLOSE THEM BOTH
70C2  9D 7A 02            STA BUFFER,X        ;NO - SO SAVE CHARACTER IN BUFFER
70C5  E8                  INX                 ;INCREMENT POINTER
70C6  E0 C0               CPX #$C0            ;BUFFER FULL YET?
70C8  F0 28               BEQ FULL            ;YES - GO BACK TO CALLER
70CA  4C BB 70            JMP LOOP2           ;NO - SO GET ANOTHER BYTE
70CD  A9 0D     END       LDA #$0D            ;PASS EOL OVER TO BASIC BUFFER
70CF  9D 7A 02            STA BUFFER,X
70D2  E8                  INX
70D3  E0 C0               CPX #$C0            ;BUFFER FULL?
70D5  D0 06               BNE CLOSE           ;NO - SO OK, ALL IS WELL
70D7  8C FC 70            STY EOF             ;YES - SO NO ROOM FOR EOF MARKER
70DA  4C F2 70            JMP FULL            ;REMEMBER EOF HAS COME
70DD  A9 00     CLOSE     LDA #$00            ;LOAD EOF MARKER
70DF  9D 7A 02            STA BUFFER,X        ;PASS IT OVER TO BUFFER
70E2  A9 02               LDA #$02            ;LOAD LOGICAL FILE 2
70E4  20 AE F2            JSR FCLOSE          ;GO CLOSE FILE 2
70E7  20 CC FF            JSR CLRCHN          ;SET DEFAULT I/O DEVICES
70EA  A9 0F               LDA #$0F            ;LOAD LOGICAL FILE 15
70EC  20 AE F2            JSR FCLOSE          ;GO CLOSE FILE 15 - COMMAND CHANNEL
70EF  20 CC FF            JSR CLRCHN
70F2  AE FE 70  FULL      LDX XREG            ;RESTORE X-REGISTER
70F5  AC FF 70            LDY YREG            ;RESTORE Y-REGISTER
70F8  AD FD 70            LDA ACCUM           ;RESTORE ACCUMULATOR
70FB  60                  RTS                 ;GO BACK TO CALLER
70FC  00        EOF       .BYTE $0            ;PLACE FOR EOF STATUS
70FD  00        ACCUM     .BYTE $0            ;
70FE  00        XREG      .BYTE $0            ;SAVE AREA FOR REGISTERS
70FF  00        YREG      .BYTE $0
7100                      .END
```

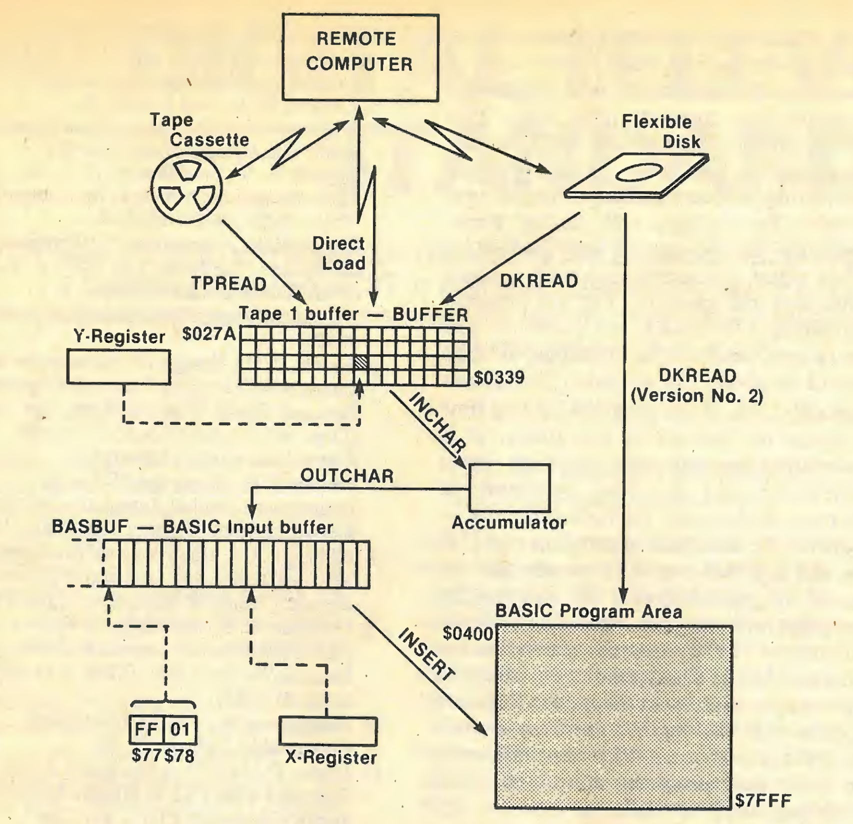



Fig. 4. Data flow diagram for the source code loading program shown in Fig. 3.

copied one at a time from the tape buffer, $027A, across to the Basic input buffer, $0200 – $0250, using the Y and X registers respectively as pointers in the indexed load and store operations. Each time an end-of-the-line character, $0D, is encountered in the input data-stream (INCHAR) an end-of-statement marker, $00, is sent to the output stream (OUTCHAR) for placement in the Basic buffer. Subsequently, at step 6, the pointers at $77 and $78 are set to point to the memory area containing the new statement. A subroutine call to the operating system utility CHRGET is then made. This is essentially a line-fetch routine that sets up the next Basic statement for processing. More details on how the routine operates are given elsewhere[10,11,12]. Once the CHRGET routine has been primed, the code for converting/inserting the new line into the BASIC program area can commence. Further source statements are then processed one at a time until an end-of-file code, $00 for tape files, detected on INCHAR terminates the loading process and passes control back to Basic direct-command mode with the prompt "READY".

A major disadvantage of the loader shown in Fig. 3 is its lack of identity checking. Inherent in the program is the assumption that the tape will be positioned at the point from which loading is to commence; the first block (program identity) is then skipped over. If necessary, it would be a simple matter to replace the first reference to TPREAD (line 21) by a call to asubroutine that allows the operator to interact. This subroutine could be used to ask the operator for the name of the file to be loaded and then automatically position the tape ready for loading. A routine of this type is essential in a loading program designed for handling source programs from discs.

To enable the loading program shown in Fig. 3 to handle disc files, two additional subroutines are needed: one to open the disk file, DKOPEN, and another to read and close it, DKREAD. Implementations of each of these are presented in Fig. 5. DKOPEN fulfils the requirements outlined above, that is, it prompts the operator for the name of the file to be loaded, checks its validity and then returns an appropriate message. The DKREAD routine emulates the action of the tape cassette thereby minimizing the number of changes necessary to the code listed in Fig. 3. Indeed, only three changes are required; the reference to TPREAD in line 21 must be changed to DKOPEN and that to TPREAD (line 65) must be altered to DKREAD. Finally, the device number in line 62 must be changed from 1 to 8.

As a means of checking that tape cassette emulation was a reasonable approach to use, a second version of the disc loading program was written using a different approach. This involved reading the whole of the disc file into memory, storing it, and then processing it as an internal file. Other than the slight modifications needed for the revised input method, no major changes to the logic of the program shown in Fig. 3 were required and no detectable difference in performance between the two disk-loading programs was observed. Furthermore, as can be seen from the following table their load size differed by only five bytes.

	Main code	DKOPEN	DKREAD	Total store
Tape loader	257	–	–	257
Disc loader 1	257	152	95	504
Disc loader 2	242	152	115	509

The loading programs can be located in e.p.r.o.m. or in any part of the memory space available for program loading. When siting these programs, two important factors must be considered;

- that the programs do not over-write themselves while running (this is usually caused by locating them too near the low end of memory), and,
- that they do not interfere with any of the operating system support software that may be partly in r.a.m. (for example, DOS support uses r.a.m. above $7EAB in 3040 disc-based 32 PET systems).

Each of these restraints can be avoided by using an appropriately structured e.p.r.o.m. However, if the loading programs are to be stored in r.a.m. their security and effectiveness depends on finding a suitable memory space into which they may be loaded and run. Unfortunately, disc loader 2 is too large to fit into the tape cassette buffer areas, $027A through $03F9, but its main body and the smaller of the two input routines (DKREAD) easily slot into this area; DKREAD could now reside at the high end of r.a.m. above about $7E10, the exact location depending what other software is present in this area. Because the version of the loading program for handling tape-based source files is too large to be stored in cassette buffer 2, as with the DKOPEN routine, it would also need to be positioned somewhere above memory address $7E10. Similar arguments apply in the case of disk loader 1. Whatever parts of high r.a.m. are used, the limit of Basic memory would need to be lowered by suitably adjusting the pointers held in zero page locations $34 and $35.

Each of the software systems described above successfully loads Basic programs from tape/disc files into memory ready for execution. These files will usually have been created by program transfer from another remote computer through the public switched network or a private communication system. Alternatively, they may have been prepared by an editing system or as a result of LISTing to either tape or disc. Because these files are in conventional ASCII form rather than in internal machine-code form they are more easily exchanged between different types of personal computer.

Comparing load times

Given that there are now several ways of loading Basic programs into memory some consideration of loading times would be appropriate. There are two important comparisons to make:

- the relative speed of loading source programs compared with memory image programs, and
- the relative speed of tape loads compared with those from disc.

To carry out the above comparisons a simple program generator was constructed. This consisted of a series of Basic statements which when executed produced (as output) another Basic program. This could be written as an ASCII file to tape and/or disk. Furthermore, once processed by either of the loaders described above, this program could also be saved in the conventional manner using a SAVE command. The program consisted of 1000 statements whose average length was about 22 characters. Its load size was 19K bytes. Measures of the time required to load this program under different conditions are

- time to load source program from tape, 1037 s
- time to load source program from disk, 260 s
- tape load time for SAVEd program, 357 s
- disk load time for SAVEd program, 10s.

There are two observations immediately apparent. Firstly, loading source programs is much slower than loading memory images; secondly, loading from disc is very much faster than loading from tape. These relationships could have been predicted intuitively and so the only value of the above figures lies in the quantitive comparisons they permit. From the values shown it can be seen that disc loading is about 35 times faster than tape loading where memory images are concerned but only about four times faster in the case of source-code loading. In the latter case, it took only 11 seconds to read the source program into memory from disc. This would suggest that about 96% of the program loading time is devoted to converting source statements into a form suitable for storage, and storing them. Similarly, in the case of tape loading, it takes about six seconds to read a block from tape into memory. The test program contained 131 blocks, i.e., 192 × 131 characters, and so its input/output time would be about 786 seconds. This means that only 24% of the program loading time is spent on conversion operations. It is interesting to note that the time spent converting and inserting programs in memory is the same for both programs – 249s for the disc loading program and 251s for the tape version. This means that the modifications converting the tape loading program into its disc equivalent do not influence the program's performance characteristics. These results illustrate the advantages of memory-image loading over source-code loading, but most readers will probably prefer to sacrifice some efficiency to make their programs more compatible with computers of a different type. □

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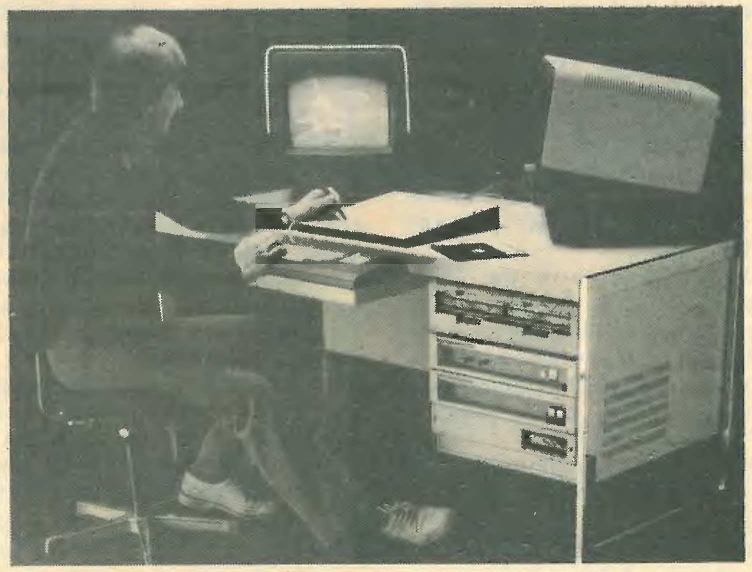
Teledon videotex in UK

The first private viewdata system based on Teledon technology has been introduced by Poulter Computervision, a new company in the Poulter advertising and marketing group. Developed by the Canadian Department of Communications, Teledon is an easy-to-use system to enable text and high-quality animated images to be transmitted to tv sets. It was chosen for audiovisual communication by Poulter largely because of its impressive graphic capability.

The company have moved fast since they discovered it late last year. In fact Graham Poulter told WW he didn't even know of it until 14 weeks prior, when Peter Ashley (now a director) told him of it after seeing it on an Australian NEB trip. They now have sole UK rights to Teledon, negotiated with the CDC licensee Norpak.

Two equipments are available, the simplest being a decoder with 64K of usable r.a.m. (there is further memory for screen mapping and holding software) controlled by a 6809 microprocessor and fed from a cassette player. Up to 200 frames or "slides" can be displayed in any order, each one appearing either instantly or progressively. With a modem attached, 10 pages of information can be recorded in 60 seconds – ten times faster than other viewdata systems of the alpha-mosaic kind. The other terminal is an information provider's graphic creation unit with digitizing tablet, colour monitors, two floppy disc drives and PDP11/03 computer. With about ten minutes' learning time, it is claimed, images can be created by retrieving an image from a library to edit, by sketching or tracing drawings on the tablet, or by using high-level commands defined as geometric elements. Animations of any length are possible and the combinations of colours with grey shades are unlimited. A page of text takes about 5 minutes to assemble while a chart might take 10 to 15 minutes.

Secret of Teledon is the picture description instruction coding that describes image content by co-ordinates – two for lines and rectangles, three for arcs, more for polygons, hence the name alpha-geometric. Images can also be described by scanning point-to-point, and they are reconstructed to whatever resolution the receiving equipment allows. Among claims made for it are future equipment compatibility as well as future information compatibility, easy conversion to alpha-mosaic or d.r.c.s. and it is said to handle more CCITT videotex-attributes than any other scheme. Teledon is in regular use in Canada, on trial in the USA, and European rights have been bought by Siemens. □



DIGITAL TELEVISION STANDARDS

Towards a worldwide compatibility for broadcasting studio equipment at recent meetings of the CCIR in Geneva, decisions were taken which will have an important bearing on the introduction of digital systems into television studios throughout the world.

by A. Howard Jones
BBC Research Department

Discussions on digital video coding have been going on for many years; in Europe they have taken place mainly in the EBU. In fact, the CCIR was largely responding to a submission from the EBU reached after extensive consultations among its members and with industry, other broadcasting unions and the American SMPTE.

It had long been accepted that to obtain the maximum benefit from digital technology one should handle the three components of the video signal (e.g. luminance and colour-difference signals) separately throughout the digital studio rather than combined into the composite PAL, SECAM or NTSC composite form as in most of the analogue studio operations of today. The use of component coding will also ensure commonality of equipment design throughout the 625-line world and to a valuable degree with the 525-line world – assuming agreement on the basic parameters defining the video signal.

There may be a case for establishing in due course a compatible family of coding standards to suit different quality requirements, e.g. of ENG at one extreme and high-definition television at the other. But the most urgent requirement was to specify the standard that will be used within all of the main studio equipment and at the inputs to the recording and transmission equipment used for international programme exchange.

It was agreed at Geneva that the main studio standard would use sampling rates of 13.5 MHz for luminance and 6.75 MHz for each of the two colour-difference signals. This corresponds to 864 and 432 samples per line respectively in 625-line countries and 858 and 429 samples per line respectively in 525-line countries.

8-bit linear p.c.m. coding will be used and it was agreed by most delegations that the coding ranges should be set as indicated in Fig. 1.

There is a good chance that these figures will have been formally written into the Recommendation by the time of the Plenary Assembly next year, together with a statement to the effect that in both 625- and 525-line areas the circuits which process only the active part of the television line should accommodate 720 luminance and 360 colour difference samples per line.

At a sampling frequency of 13.5 MHz, 720 samples occupy somewhat more than either of the nominal active line periods. The intention is that the latter will be defined by a blanking operation to be carried out when the signal eventually emerges into the analogue composite world. Meanwhile, an appropriate positioning of the 720 samples (Fig. 2 shows the EBU proposal for 625-line signals and digital and nominal analogue timing for reference) will ensure that the system will accept the whole of an analogue active line at its input regardless of the actual timing within permitted tolerances.

The adoption of this specification will ensure maximum compatibility of equipment throughout the world and will lay the foundation upon which further specifications, covering studio interfaces, digital video tape formats, and the multiplex structure to be used on international digital links, can be built. □

The author is chairman of EBU Specialist Group V1-VID in which much of the discussion on standardization has taken place.

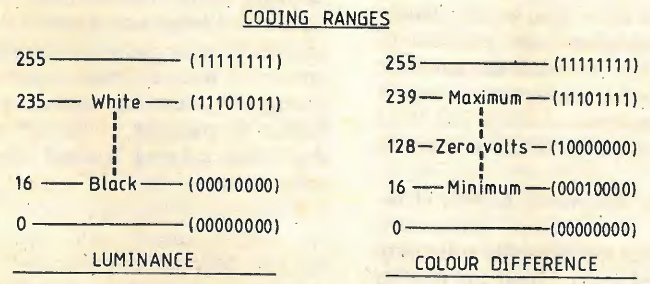


Fig. 1. *Coding ranges for the 8-bit linear p.c.m. system*

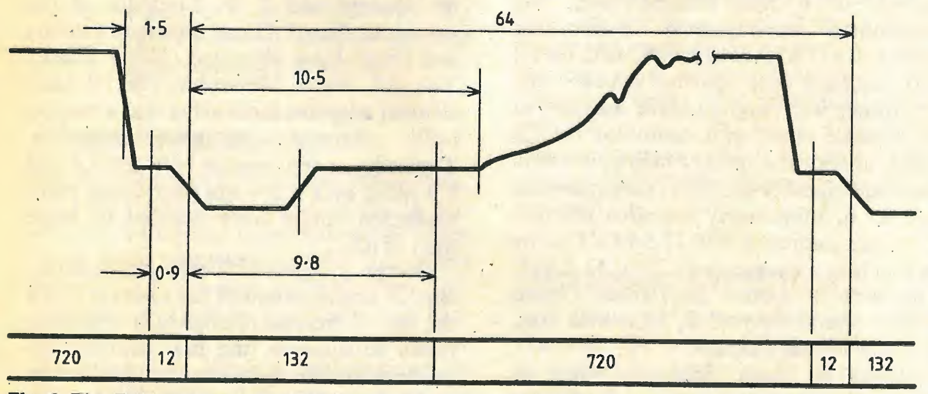


Fig. 2. *The EBU proposal for 625-line signal and nominal analogue timing for reference with 864 luminance samples for each line.*

Corrections

Remote control for a hi-fi system. Unmarked components in Steve Kirby's article in the March issue, page 54, are p-n-p transistor in Fig. 1 and 3.9kΩ for its base-emitter resistor. Transmitter diodes are high-power types – RS Components 308-512 or equivalent. Labels "standby" and "normalise" should be transposed on the keyboard. Notes on setting up the link, a simplified tone control summing circuit, and p.r.o.m. listing will be published next month In the mean time they can be obtained by sending a stamped, addressed envelope to Steve Kirby at the Department of Electronics, University of York, Heslington, York YO1 5DD.

Heating-fuel saver. The introductory paragraph states that the outdoor temperature sensor is not essential but in fact, the scheme would not work without it. The non-essential part is the meter to indicate the reading of the sensor. If this is not required, the milliameter and IC_{2b} can be omitted. In the first paragraph of the main text a d-to-a converter has been misprinted as a 'data-a converter'.

Digital, multi-track tape recorder. Contrary to the impression by the April part of this article, it was not the final section. A further part on the playback facility will be published in the next issue.

BBC micro. See News of the month.

COMMUNICATIONS

Tracking vehicles

Disclosure of hitherto secret Home Office guidelines on the police use of "bugging" and other electronic equipment has drawn attention to a form of surveillance that has largely passed unnoticed: the "tracking" of suspect vehicles by the attachment of a miniature transmitter which can then be located using sophisticated fixed or mobile Doppler-type v.h.f. and u.h.f. direction-finding equipment that overcomes many of the usual problems of accurate d/f in built-up areas. Equipment of this type is made in several countries, and indeed two years ago Rohde & Schwarz specifically described their PA002 and PA005 systems as suitable for "specialized applications in the field of personal protection or even in trailing 'prepared' vehicles". From fixed bases such equipment can locate an urban transmission to within about 100 metres. At least one American firm makes mobile equipment that would have little difficulty in following a vehicle at a discreet distance.

Direction-finding, the first application of a radio navigational aid early this century is once again in vogue. Marine v.h.f. d/f systems in the English Channel supplied by Racal have proved their use in sea rescues. American portable (man-pack) d/f equipment is currently being promoted for military detection and tracking of armoured vehicles.

Broadcast relays

For several years, some of the European external broadcasting services have been using satellite circuits to carry programmes to their overseas relays. But most of these have made use of Intelsat earth stations built primarily for telecommunications services.

However, Marconi Communication Systems have recently announced a £500,000-plus order from the Foreign and Commonwealth Office for a 10-metre, receive-only, Standard B earth station to be located on Masirah Island, off the east coast of Oman, to be completed this year. This station is expressly to receive the BBC Overseas Service programmes for retransmission on the high-power FCO transmitters forming the Middle East Relay Station, including two 750 kW m.f. transmitters.

The users of extremely high-power h.f. over-the-horizon radar and broadcasting stations may have noticed with some concern a report of recent joint-work of the Max-Planck-Institut für Aeronomie and the University of Leicester (*Nature*, 25 February 1982). This shows that the ionosphere has non-linear characteristics such that above a certain optimum power, signals received at remote sites decrease with additional power. The optimum power is usually not much more than about 6.5 MW e.r.p. – a power less than that currently used by some broadcast and radar stations.

Mobile radio and s.s.b.

The outlook for the use of v.h.f. single-sideband with 5 kHz channelling in the private-mobile radio or in the Radiophone services cannot be regarded as bright – and seems to depend on whether the fast-acting, companding-type a.g.c. system being developed by Dr McGeehan at Bath University proves suitable for incorporating into s.s.b. mobile phones.

The intensive work in the UK over the past few years on the Wolfson project for mobile s.s.b. has failed to produce the clear-cut results needed to convince users. Completely independent user-trials by British Telecom Research and by the Home Office, and related trials by manufacturers, all seem to have shown that on frequencies of the order of 160 MHz, s.s.b. equipment (without companding) does not provide fully equivalent performance to that of 12.5 kHz channelling f.m. systems and is significantly degraded in comparison with 25 kHz channelling f.m. The British Telecom results suggest that s.s.b. also requires a much higher co-channel interference protection ratio (about 20 dB) which would mean that there could be much less re-use of channels, substantially reducing the theoretical spectrum-saving advantages of s.s.b. The earlier Home Office trials highlighted the problem of Doppler frequency shift and the need for an extremely good a.g.c. system if speech quality is to be maintained above 200 MHz with vehicles travelling at more than 30 km/h.

The BT trials (*Electronics Letters*, October 29, 1981) used s.s.b. equipment specially designed to assess the suitability of the mode as a replacement for f.m. in the Radiophone service, with tests carried out under carefully controlled conditions. Speech of a well defined level was transmitted simultaneously over three radio links (12.5, 25 kHz f.m. and s.s.b.) and recorded in a moving vehicle. The recordings were later carefully assessed in an acoustic room with simulated vehicle noise, under conditions of fading, interference and signal level. The conclusion was that s.s.b. subjectively degraded the performance compared with 12.5 kHz f.m. by as much as a change from 25 to 12.5 kHz f.m. With co-channel interference, "mean scores" were: s.s.b. 1.8, 12.5 kHz f.m. 2.1, and 25 kHz f.m. 2.4.

Unless the Bath University work on a.g.c. reverses the situation, early widespread adoption of s.s.b. seems unlikely.

Marine communications

The official opening of the Marecs-A maritime satellite communications system on March 1 provided a notable technical hiccup. The planned inaugural call by Kenneth Baker, Minister for Information Technology, had to be called off at the last moment due to the aftermath of "intense solar activity".

While we all know how easy it is for press and public demonstrations to go adrift, this incident must have been particularly galling for those promoting a sophisticated system that seeks to highlight and then supersede the radio propagation vagaries of traditional marine radio!

Shipping companies have seldom proved eager to introduce new communications or navigational systems unless the costs can be off-set by lower marine insurance rates – so that 24-hour reliability must be counted a vital consideration.

There can be little doubt that marine satellite systems offer many advantages for deep-sea vessels, and will eventually supersede long-distance h.f., just as marine v.h.f. has gradually won through for short-range operations. But I wonder if I am alone in recalling the high communications efficiency of the old pre-war passenger ships using "long waves" above 2000 metres?

When static was not too bad, the highly professional radio officers and coast stations could handle traffic in a manner seldom heard on the other marine frequencies. Today, with few large passenger-carrying ships, marine traffic tends to be lighter and largely confined to the running of the ships or personal messages of the crew. As with all radio communications "progress" seems to be a matter of ever-higher frequencies – though marine radars have long paved the way to microwaves.

Topics in the air

M. Hansen and J. P. Loughlin of the American Naval Ocean Systems Center, San Diego have described (*IEEE Trans.*, Vol. AP, No 6, November 1981) a four-element adaptive aerial array that automatically minimizes multipath reception. Typically, at frequencies between 3.4 and 9.3 MHz over a 234 km over-ocean path, unwanted modes were reduced by more than 15 dB.

George J. Flynn of Washington University, St Louis, Missouri has forecast that if the rate of increase of objects in orbit continues to increase, the first collision between satellites can be expected in the next 10-15 years. He warns: "A reversal of this trend is required to prevent a serious hazard to orbiting satellites in the twenty-first century". Although the number of objects in near-Earth orbit decreased between 1978-1980, they have since increased rapidly to an all-time high of 4,740 objects, in October 1981. 137 new objects were associated with the US Landsat 3 satellite, launched in 1978, and 118 with Cosmos 1275, launched in June 1981.

AMATEUR RADIO

Licence snafu

Following meetings between the R.S.G.B. and the Home Office, the Home Office confirmed officially that the new amateur-radio licence schedule, as published in *The London Gazette* on February 12, contained errors and a revised schedule would be published with a minimum of delay. The Home Office also issued a statement that they had had "no intention of changing the basis of amateur radio operation in the U.K.".

In other words, the sensation caused by the February 12 schedule was ascribed to yet another "snafu" on the part of the licensing authorities – although to the credit of the officials concerned they reacted promptly and fairly when the consequences of the error-prone schedule were brought to their notice by the R.S.G.B. and by many horrified amateurs!

Perhaps a light-hearted side of the incident was that, by omitting a key line, the Gazette unwittingly deleted all regulatory differences between Class A and Class B licences. Any Class B amateur could have legally operated on h.f. etc., until an amending notice was hastily published on February 26. The Home Office has accepted that the introduction of new power restrictions and mode restrictions on 3.5 MHz and 432 MHz, etc., were errors and may revert to traditional power regulations above 1 GHz at least while the question of "equivalent isotropic radiated power" is reconsidered further.

The world scene

No firm announcement about the release, on a non-interference basis, of the 18 and 24 MHz bands had been made at the times these notes were written. All three new bands, 10.1, 18 and 24 MHz, were released to amateurs in South Africa on January 18.

American c.b. licences are reported to have fallen from 16 million to about 10 million during the past two years. There are just over 400,000 amateur licences in the USA. A recent survey indicates that only about one-in-eight instances of radio-frequency interference (r.f.i.) problems from all types of transmitters (but basically due to inadequate electromagnetic compatibility in consumer electronic appliances etc) are reported officially to FCC – a ratio that is believed to be roughly comparable with similar interference problems in the UK.

A 16-year-old instructor for the December 1981 Radio Amateur's Examination – John Morris, GU6BGI, of the Guernsey Amateur Radio Society – coached six candidates. Five passed both sections while the sixth passed one section. One who passed, Tim Hodkinson, will have to wait for his licence until his 14th birthday next June, when he is likely to become (at least for a time) the UK's youngest licensed amateur.

Here and there

Fifty-years ago, during 1932, the international Madrid conference resulted in the first clear recognition of amateur radio by defining in the international radio regulations what amateurs could and could not do. The Madrid conference was one of the last of the international conferences in which no major changes were made to the frequencies allocated to radio amateurs – although it was already clear that pressure on their frequencies from rival users was more intense in Europe than in North America and only with difficulty was the "1.7 MHz" band retained in Europe. At that time the major ITU conferences were held every four years.

Detailed observations on and conclusions about the remarkable 5000-mile 145 MHz Euro-Asia to Africa paths by transequatorial ionospheric reflection during Solar Cycle 21 have been reported by Ray Cracknell, Z22JV in Zimbabwe, Fred Anderson, ZS6PW in Pretoria, and Costas Fimerelis, SV1DH in Athens (*QST*, December 1981). They show that high-density, ionized zones exist 10 to 15 degrees north and south of the magnetic dip equator capable at times of providing circuits between stations up to 5000 miles apart at frequencies up to 432 MHz. They believe that amateurs in suitable locations "have a unique opportunity to engage in pioneer research".

Amateur satellites

Ivan James, G5IJ has described, in *Oscar News* No 36, a novel form of 145 MHz crossed-delta loop aerial suitable for uplinks to amateur satellites in low orbits. The aerial is based on the principles of the broadband, apex-fed, polygonal loop as described by T. Sukiji and Tou (*IEEE Trans* AP-28, No 4, July 1980). The system provides some horizontal gain, requires no impedance transformer and can readily be made from soft 8mm diameter copper tubing. It has been tested on Oscar 9.

The six Russian amateur satellites, RS3 to RS8, launched last December have all been transmitting telemetry data but RS3 and RS4 are not expected to be fully activated until later in the year. The satellites are in a nearly circular orbit about 1700 km above Earth (periods of about 118.5 to about 119.8 minutes). As with other satellites in relatively low orbits it is proving difficult to provide accurate predictions for more than a few days at a time. The Russian transponders have uplink frequencies in the band 145.86 to 146 MHz and down links 29.36 to 29.5 MHz.

In brief

The 10.1 MHz band has still not been released to American amateurs and there is opposition from other users . . . A "diamond jubilee hamfest" to mark the setting up of the original "Lincoln & District Amateur Wireless & Scientific Society" in February 1921 is being organized by Lincoln Short Wave Club (G5FZ, G6COL) at the Lincolnshire Showground, 4-5 miles north of Lincoln on the A15, on Sunday May 9. The Club is aiming at a 5000 attendance, with trade and "bring and buy" stands plus family attractions . . . Derby Dale & District Amateur Radio Society has its 2nd mobile rally at Shelley High School, June 20 . . . The Worcester Club has its annual radio rally on July 11 at the High School, Ombersley Road, Droitwich . . . The RSGB has forecast 80 trade stands at the 1982 National Amateur Radio Exhibition at the New Alexandra Pavilion, Alexandra Park, north London from April 15-17 . . . Mobile rallies at Harrogate and Barry (May 23), Hull and Plymouth (May 30), Elvaston Castle, MHS Mercury (June 13) . . . With the legalization of c.b. radio it would seem that some of the former users of 27 MHz have moved elsewhere. Recent reports indicate that an illegal group of so-called "International Breakers" have been active on about 6.6 MHz, a frequency that was a "pirate-haunt" several years ago . . . . The Marconi Group recently noted the 60th anniversary of the 2MT Writtle broadcasts in 1922 paying tribute to the efforts of the amateurs, grouped in wireless clubs, recognizing that it was their petitioning of the Post Master General that helped set off regular broadcasting in the UK.

PAT HAWKER, G3VA

MICRO CONTROLLED LIGHTING SYSTEM

Hardware for the input side of the lighting system – the control desk. Modular construction is suggested to allow for variations in total system size

John D. H. White and Nigel M. Allinson

The input portion of the lighting system – the control desk – transforms the positions of the numerous faders into data in the processor memory. To maintain processing speed and hence the interactive nature of the system input and output operations are designed so that no processor WAIT states are required. This is readily achievable in the output to the dimmers by ensuring that the access time to each dimmer is less than 410 ns (the maximum data bus access time permitted by the processor) and the use of a mapped-memory input technique was chosen. However, the analogue-to-digital conversion of the fader positions is inherently slow, and so some method of increasing their apparent conversion speed is required. Three possible methods can be considered.

- Allocate a slow a-d converter to each fader which continuously tracks the analogue level of the fader and then the processor addresses each converter in turn to obtain data. The large number of faders in a lighting desk means that this would probably be a very expensive solution.
- Use an a-d converter which is fast enough to perform a conversion in the maximum access time of 410 ns. The practical conversion time must be much shorter than this to allow for the multiplexing of the faders and the sampling of the analogue levels. The cost of high-speed converters and multiplexers means this solution is also expensive.
- Rather than set the conversion speed by the processor requirements, set the speed by the desk operator's requirements. For instance, the maximum useable "response time" of the system should be about 20 ms. Hence use a converter which is fast enough to perform all the conversions required in this maximum response time. The faders can then be scanned by an analogue multiplexer, converted to digital code and stored in a block of memory locations. The processor is then able to access this block of memory. The major difficulty with this method is the unambiguous access to a block of memory by both the processor and the converter.

The final method was chosen for use in the control desk because of its lower cost. The fader units in this prototype system were designed on a modular basis. Each multiplexer connects one of 16 faders to a common analogue bus and the faders addressed via a 4-to-16 line decoder by a 4-bit digital address bus. One a-d converter was allocated to each of these 16 fader modules; however, the converter and sample-and-hold circuit used have a total conversion time of 26 µs at a 500 kHz clock frequency so one converter can access over 600 faders within a response time of 20 ms.

The authors are at Keele University.

The input circuits can be split into three parts – an analogue multiplexer which connects the faders to the a-d converter, the converter itself and associated sample-and-hold and timing circuits, and the shared memory with access control logic.

Analogue multiplexer module

The fader connected to the common analogue bus is determined by a four-bit code, and address decoding is performed by a 4-to-16 line demultiplexer (74154), Fig. 11. Analogue switch control inputs are buffered by level-shifting inverters. Fader potentiometers are connected to a bipolar reference bus derived from the a-d converter internal reference voltage, Fig. 12.

As the lighting system scales the channel presets by a master preset control, as mentioned in the first article, this requires the multiplication of stored data. For any reasonable interaction time between fader position and light output, software multiplication by the processor is out of the question. As described in the final article, fader levels are stored in log form; multiplication and division become simple addition and subtraction, and an anti-log look-up table r.o.m. is used to provide the correct code for each output dimmer. Unusually, log-law potentiometers are used for the faders.

The potentiometers can be considered as a voltage source with an internal impedance which varies with slider position. The highest internal impedance is (*track resistance*)/4, that is 25 kΩ in this case. As the output capacitance of each c.m.o.s. switch is about 5 pF, the worst-case switching time constant for 16 switches on a common analogue bus is 2 µs. With a sample time for the a-d conversion of 6 µs, this gives a significant sampling error. The solution is to introduce a capacitor C_s to the input side of each switch. The percentage error in the final output voltage is $100\% \times C_o/(C_s + C_o)$ so for $C_o = 100$ nF the error is only 0.08%. The switching time constant is now about 25 ns; τ is switch *on-resistance* × C_o. However, there is now a significant time constant associated with the potentiometer resistance and C_s, but the worse-case value is 2.5 ms which does not effect operation of the control desk.

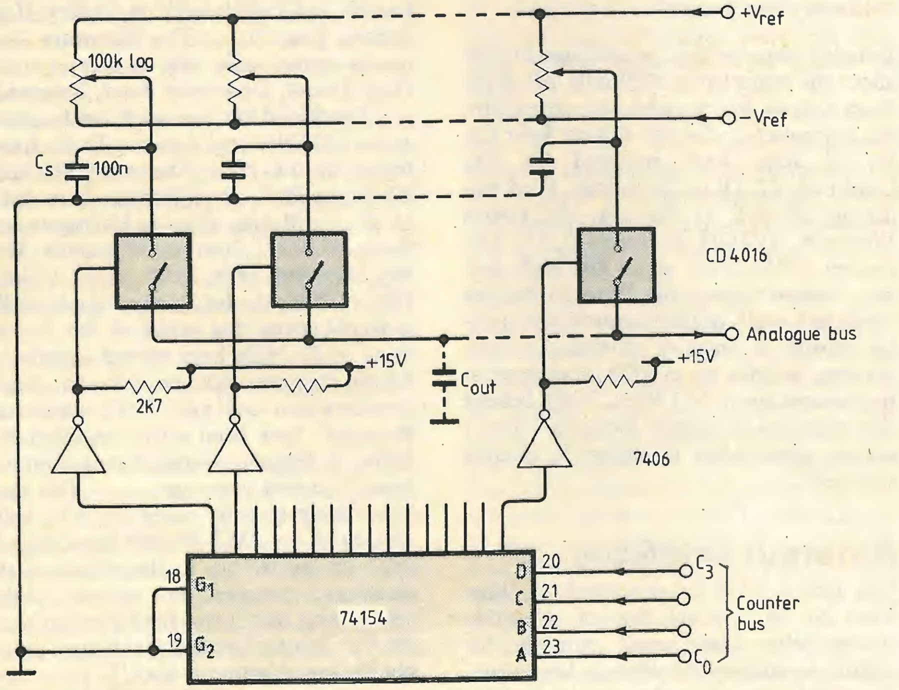


Fig. 11. Address decoding is performed by a 4-bit code.

AD conversion and timing module

The ZN427E 8-bit converter of Fig. 12 is clocked at 500 kHz, derived from the terminated processor system's 1 MHz clock (generated from the 3 MHz microprocessor clock in the Quarndon development system). The various control signals and associated sample-and-hold, are generated by a 2-bit twisted ring counter, comprised of two D-type flip-flops (7474). This type of counter was chosen for its simplicity and that all states can be detected by two-input NAND gates. The first state of the sequence enables the sample-and-hold circuit, the second state is used as a write request for the memory access logic, and the final state is used to clock a third D-type flip-flop. The output of this flip-flop is used as the start conversion pulse of the a-d converter. The end of conversion signal (EOC) goes low, and is used to hold the counter in its reset state. The positive-going edge of EOC clocks a 4-bit counter (74161A) used to address the shared block of memory and the analogue multiplexer. The data outputs are always enabled, by holding OE (pin 2) low. The LF398 sample-and-hold circuit has more than adequate specifications for 8-bit accuracy at 6 µs sample time.

The 2.55 V a-d converter reference voltage is used to bias the fader potentiometers. To reduce processing time, fader codes (positions) are first checked to determine if they are zero (i.e. channel not in use); only if they are non-zero will further processing be performed. Contact and end-resistance in the potentiometers gives a small d.c. offset, even when the channel is not being used. Hence a bipolar voltage reference is supplied to the faders to give a small "deadband", for which the output code is zero. These references are obtained by buffering and inverting the converter reference voltage by a 747 dual op-amp.

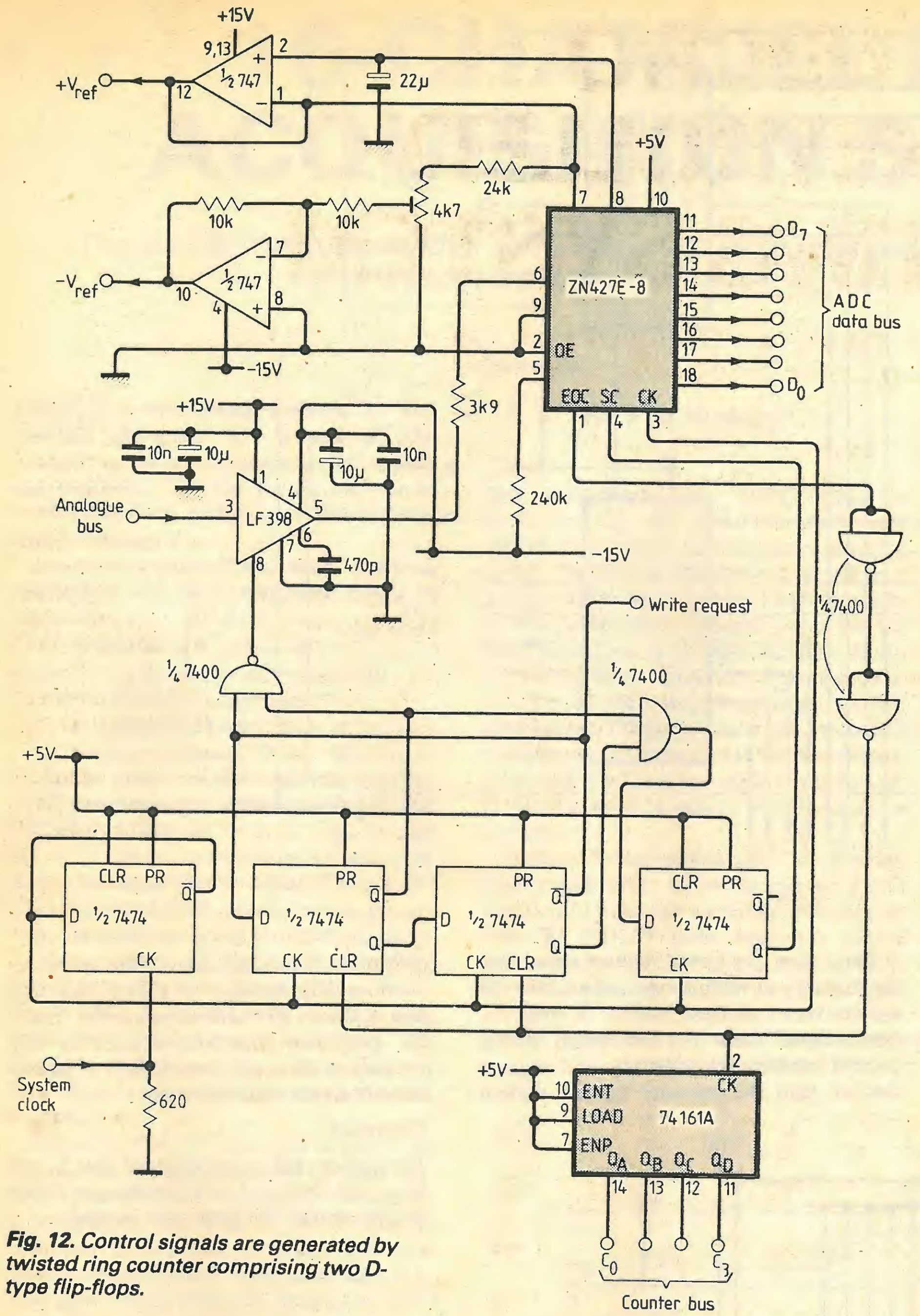


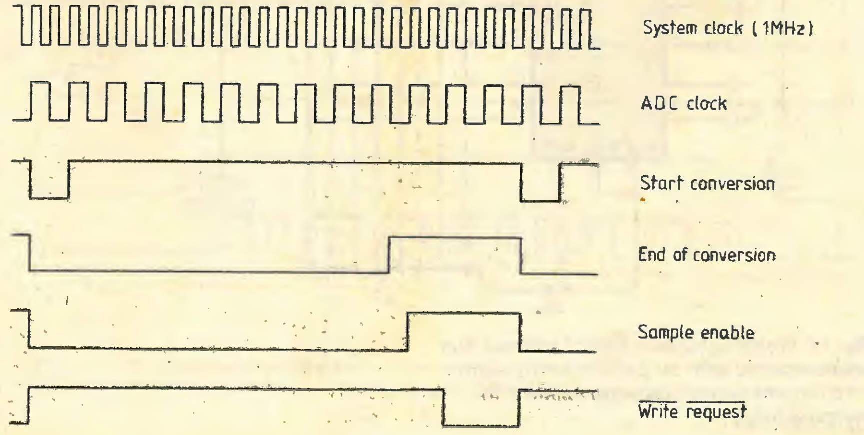
Fig. 12. Control signals are generated by twisted ring counter comprising two D-type flip-flops.

Shared memory and access control

The memory can be accessed by either the microprocessor or the a-d converter, and hence the data and address buses must be multiplexed between the microprocessor and converter. It differs from conventional direct memory access techniques in that the shared memory and processor have separate buses and operate independently, Fig. 13.

The shared memory consists of two AM27S07 (16-word × 4-bit Schottky r.a.m.), and as these devices have separate data inputs and outputs and the a-d converter only writes to this memory while the processor-only reads from it, no data bus multiplexing is required. Data outputs are tri-state which allows direct connection to the processor data bus. Address bus multiplexing is performed by two 74125 tri-state buffers; the appropriate one is enabled for read or write operations. For large systems standard 250 ns memory chips may be used instead of the AM27S07's, but they will require additional data bus multiplexing.

The eight high-order bits of the processor address bus are compared with a bit pattern set by eight wire links to determine the page location in the memory map of the input data addresses, Fig. 14. This is achieved in the same manner as the output addressing decoding described in Part 1. When the processor needs to read from the shared memory, a read request signal is generated before the system enable signal E goes low, achieved by AND-ing the address decoder output, M/IO and W/R signals. The output is latched by the 8085



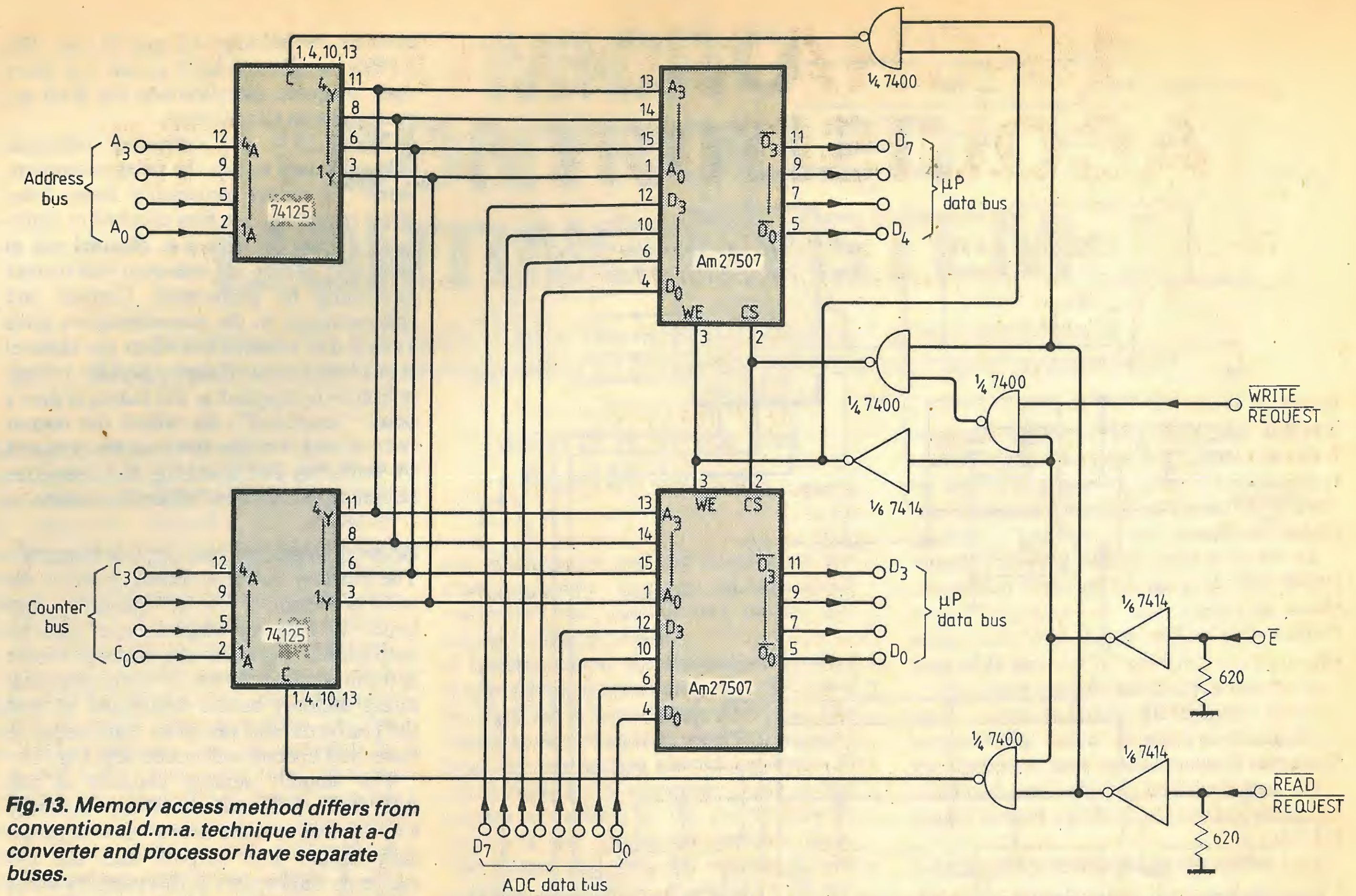


Fig. 13. Memory access method differs from conventional d.m.a. technique in that a-d converter and processor have separate buses.

address latch enable signal $\overline{ALE}$ to ensure that the read request signal is low before E goes low. Timing diagram: Fig. 15. The read request signal enables the appropriate address buffer and sets the memory to read mode.

The absence of a read request signal sets the memory to write mode and enables the a-d converter address buffer. A write request signal from the converter timing control enables the memory and data is clocked into the memory by the system enable, E. The duration of the write request is long enough to ensure that any data is always stored in the memory. Since the processor controls access to the memory at all times, no conflict of simultaneous access requests occur.

Continued

The authors ask us to point out that E_1 and E_2 in Fig. 9 should be inverted, for which the two spare 7400 gates may be used.

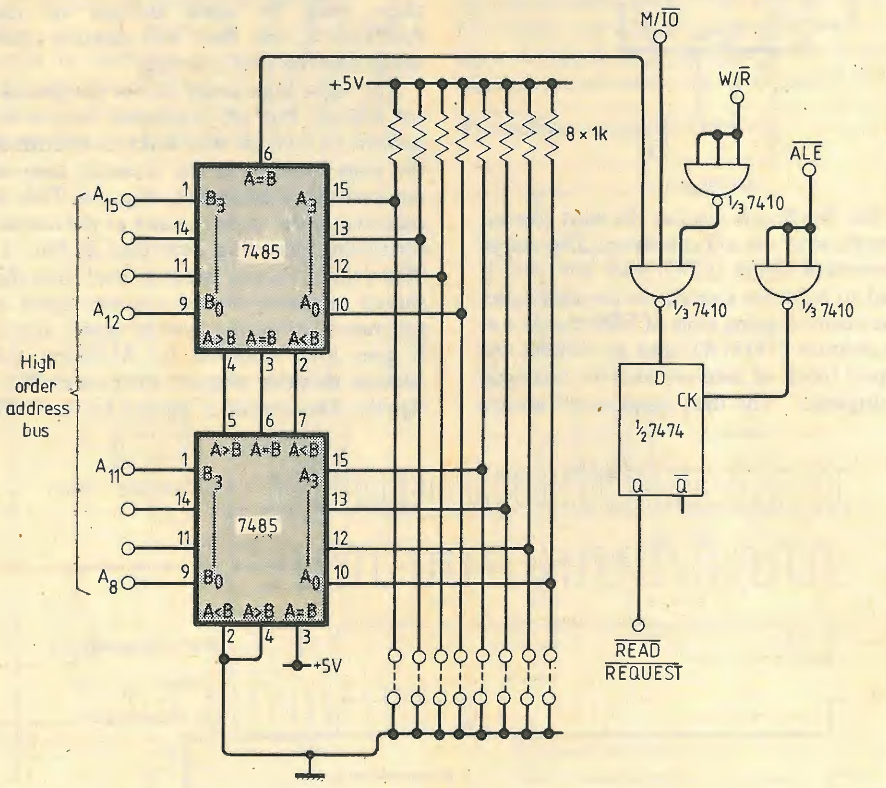


Fig. 14. Eight high-order bits of address bus are compared with bit pattern set by eight wire links to determine page location in memory map.

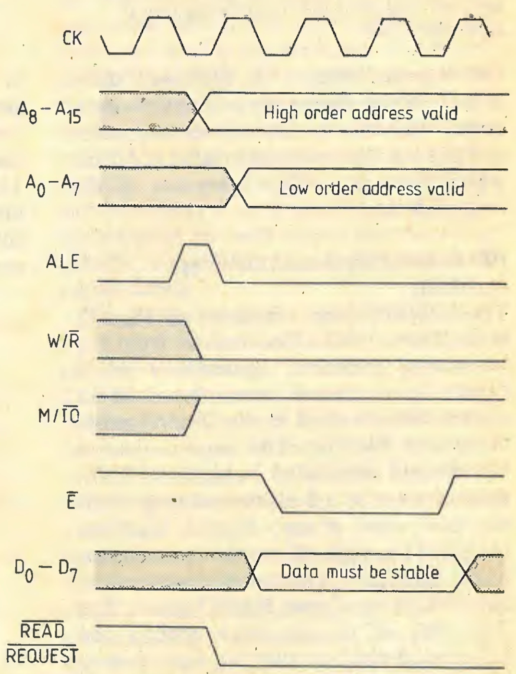


Fig. 15. READ REQUEST enables the appropriate address buffer and sets memory to read mode.

16-CHANNEL DATA ACQUISITION SYSTEM

The article concludes with a continuation of the circuit description, its operation and a sample program for scanning through sixteen channels.

by Pat Hickey*

Figure 8 is the timing diagram for the listening sequence. On power-up, the Reset line is brought low for approximately 150 ms via R_3 and C_2 to reset the address latch IC_7 and the address-enable flip-flop IC_5.

To select a channel and start an a-to-d conversion, the Basic statement below is executed:

PRINT # DN, "*n"

where DN is the device number (0-30)
* is the ASCII character "*"
n is the ASCII equivalent of the required channel "0" to "F".

When the system receives a device number (DN) corresponding to that selected on the address switches ($S_5 - S_1$ in Fig. 7), the 96LS488 will initiate a timing sequence, as shown in Fig. 8 (not to scale). The r.o.m. (IC_6) decodes ASCII information to binary data, its contents being outlined in Table 1. Four outputs of the r.o.m. give the binary data obtained by converting ASCII "0" – "F" to binary 0000 – 1111 and additional outputs are used to detect a "*" character and a carriage return (CR) – data outputs 06 and 05 are used for this purpose.

When the first "*" character is sent (2 in Fig. 8) the * line goes low (3) and the RXST and RXRDY are pulsed (4) and (5) in accordance with Fig. 5. As the data is removed (6), * detect goes high and sets the address enable FF – Q* goes high (8). The next data byte is presented (9), representing one of 16 address channels, and as RXST goes high (10), CLK goes high (11) and latches the address latch (12). RXST and CLK than go low (13) and (14), and data is removed (15).

A Carriage Return is now presented at the data bus (16) and the CR detect (or GO signal) goes low (17), and starts conversion in the AD7555 (to be discussed later). This signal also resets the address enable F-F (18), while RXST pulses (19) and (20), CRD is removed (21) and GO is returned high.

The result of all this activity is that one of 16 channels is enabled in the AD7506 (16 channel multiplexer) and a conversion cycle of the appropriate channel is started.

Talking sequence (conversion cycle)

The AD7555 is a 4½/5½-digit a-to-d conversion subsystem. A free-running clock (DMC) strobes out the b.c.d. data from the AD7555 in a 4-bit-wide bus. In this application, the DMC signal is controlled by the 96LS488 handshake signals to transmit the information to the GPIB. Each b.c.d. data byte is signalled by a digit line which goes low when that byte is being outputted, D0 going low for the most significant digit (sign and first digit), D1 for the next significant digit, etc., and D5 for the least-significant digit. In this application, D5 going low is used to send a carriage return code on the IEEE-488 bus. Although this loses one digit of resolution, it considerably eases the interface circuitry.

Figure 9 highlights the conversion timing sequence. Upon receipt of a GO signal (2) (from the listening sequence in Fig. 8) HOLD goes high (3) which instructs the AD7555 to start conversion: the free-running DMC clock is also enabled (4). Upon comparator crossing at the end of phase 0, (the beginning of the quad-slope a-to-d conversion procedure) SCC goes low (5), enabling the 1.024MHz clock to pin 12.

At the end of the conversion, SCC returns high (6) and on the next DMC rising edge (7), DAV goes high and remains high for two DMC pulses (9): during this period, the internal buffers are updated with the latest data. After this, DAV returns low (10) and brings HOLD Low (11). This is known as the master reset and disables the free-flowing DMC clock. From this point control of DMC is taken over by the TXST handshake during read-back.

At this stage, the data presented by the AD7555 is the most significant digit; TXRDY is high, indicating that data is ready; and SRQ has been brought low (12) telling the controller that a conversion has been completed and the new data is ready.

Fig. 8. Timing diagram for the listening sequence.

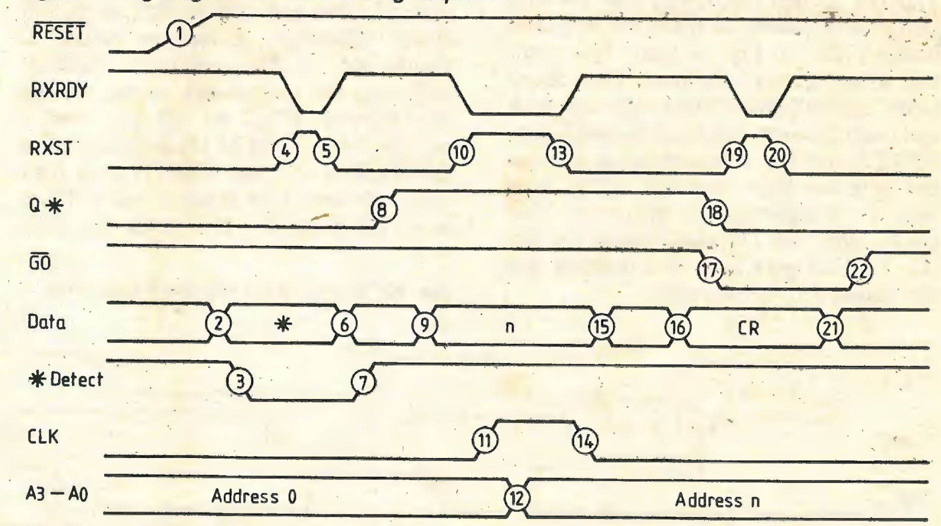
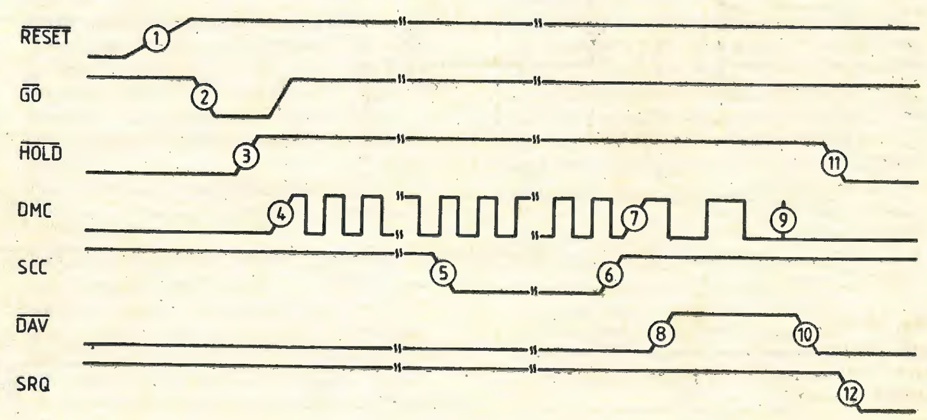


Fig. 9. Conversion cycle timing sequence.



* Analog Devices, Limerick, Ireland

PARTS LIST

Integrated circuits		
1, 2	MC3441	
3	96LS488	
4	74C08	
5, 10	74C74	
6	6331	
7	74C175	
8	74C04	
9	AD7555	
11, 23, 24	74C157	
12	74C30	
13	74C02	
14	AD7506	
15	74C901	
16	7493	
17	LM399	
18	AD517	
19, 21	AD301	
20	AD542	
22	74C10	
25	74C14	
Diodes		
1-4	led	4
5	1N914	1
6	4.7V	1
1, 2, 5, 22	470 (5%)	4
3	39k (5%)	1
4	150 (5%)	1
6-20	10k (5%)	15
21	1k (5%)	1
23	10M (1%)	1
24	5.1k (1%)	1
25	6.8k (1%)	1
26, 29, 30	10k (1%)	3
27	1M (1%)	1
28	20k (1%)	1
Potentiometers		
Rp1	500 multiturn	1
Rp2	200 multiturn	1
Capacitors		
1, 4, 6, 11	0.01µ	4
2	0.47µ	1
3	150p	1
5	10µ	1
7	0.2µ (polystyrene)	1
8, 10	33p	2
9	0.1µ	1
Miscellaneous		
X_1	4.096MHz	1
S_1-S_5, S_6-S_9	d.i.l. switch	2

Readback cycle

Data is transferred to the controller via the input instruction INPUT # DN, R$, where DN is the device number, and R$ is an ASCII string. When this statement is executed, the 96LS488 checks that TXRDY is high (indicating that the first character is ready). It takes the byte and brings TXST in Fig. 10 high (1) to show that it has received the data. This clocks DMC high (2), which brings D0 back high and loads the next data byte (4), and brings TXRDY low (5), acknowledging that the last byte has been received. TXST goes low (6), completing the sequence. This clocks DMC low (7) which brings D1 low (8). TXRDY goes high (9) indicating that the second data byte is ready.

The sequence is repeated for D1, D2, D3 and D4 (10)-(23). TXRDY goes low (23), acknowledging that D4 has been received, and TXST goes low (24) to complete the handshake. This clocks DMC low (25) and brings D5 low (26). The output from the AD7555 is D5 at this stage (the last and unused digit of the 5½ digits). However, a carriage return is transmitted to the controller instead, indicating the end of the string, via the data selector (IC_{11}). As D5 goes low, a carriage return (ASCII 13) is presented to the 96LS988 (27) and TXRDY goes high (28), indicating that it has a byte (CR) to send. D5 going low also resets the SRQ

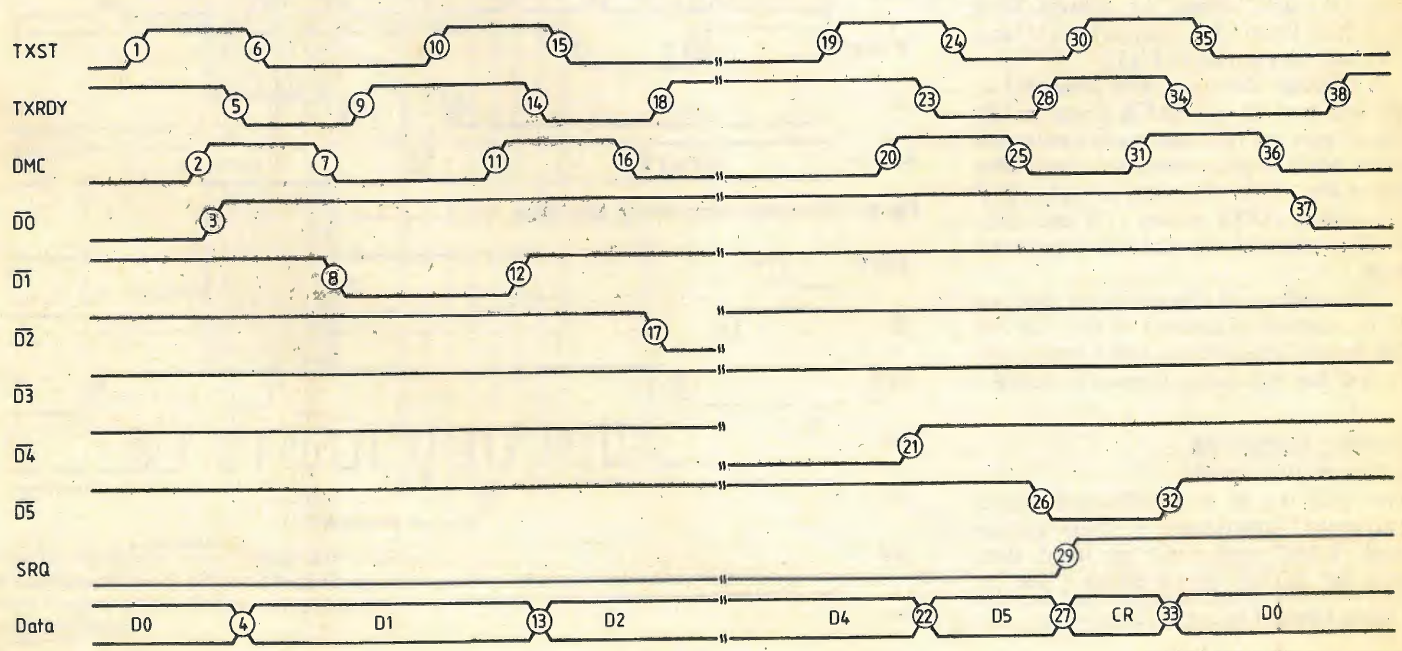


Fig. 10. Timing of the readback sequence.

flag (29). The CR is loaded during the rising edge of TXST (30) and the usual handshake follows.

The data string received by the controller is a 5 character string encoding a 4½ digit word. The first character is an encoded version of the sign and most significant digit as outlined in the table.

The program shows a simple method of converting the input string R$ to a number R. A positive or negative over-range (caused by a voltage greater than ±1.999 volts) is transmitted as "0<<<<" and "2<<<<" respectively.

INPUT # 27, R$
IF R$ = "0<<<<" THEN PRINT "+VE OVERRANGE" : END
IF R$ = "2<<<<" THEN PRINT "–VE OVERRANGE" : END
X$ = LEFT $ (R$, 1)
IF X$ = "0" THEN X$ = "+1."
IF X$ = "2" THEN X$ = "–1."
IF X$ = "<" THEN X$ = "+0."
IF X$ = "7" THEN X$ = "–0".
R$ = X$ + RIGHT $ (R$, 4)
R = VAL (R$)
PRINT "READING = ";R; "VOLTS"
END.

Service request and status byte

Bit 6 of the status byte, shown in Fig. 11, contains the service request bit (needed in the case of a serial poll), high when a service is requested. The rest of the status byte contains information as to why a service was requested. (In this case there is only one reason, an end of conversion caused by Bit 4 high.) The four l.s.bs contain the address of the last selected channel. The status byte is read during a serial poll and handshaking is performed by STRDY and STST similar to Fig. 5.

System performance

As discussed, the a-to-d converter is operated as a 5½-digit system, but only 4½ digits are used. The a-to-d conversion time varies from 1.3 seconds for full-scale negative input, to 1.7 seconds for full-scale

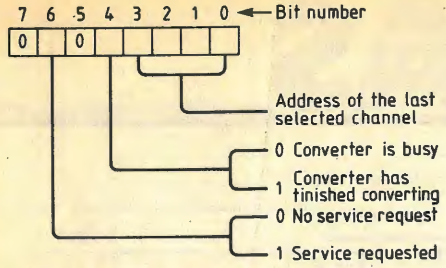


Fig. 11. Service request and data byte.

positive input. The conversion time can be reduced by a factor of ten by operating the a-to-d converter in the 4½ digit mode. Some minor changes in circuit values and pin-straps are necessary.
- Change R_{27} to 360kΩ and C_7 to 0.22µF.
- Disconnect wire from pin 22 of IC_9 to pin 1 (IC_{11}) and pins 2, 5, (IC_{24}).
- Connect wire from pin 23 (IC_9) to pin 1 (IC_{11}) and pins, 2, 5, (IC_{24}).
- Disconnect pin 8 (IC_9) from +5V and connect to GND.

In the 4½ digit a-to-d conversion mode only 3½ digits of information are transmitted on the bus.

The a-to-d converter handles input signals in the range ±1.9999 volts. Resolution is 100µV and accuracy of the prototype wire-wrap system was ±200µV. The converter exhibits no flicker or offset. Accuracy would be improved by using a printed-circuit board and by paying more attention to leakage paths through i.c. sockets, etc: it is also recommended that

Sign and most significant digit	Output of AD7555	Input to controller	ASCII equivalent
+1	0000	00110000	0
−1	0010	00110010	2
+0	1100	00111100	<
−0	0111	00110111	7

the operational amplifiers and reference (IC_{17}-IC_{21}) be kept as close to the AD7555 as possible, and as far as possible from the digital circuitry. The AD7555 data sheet gives information on appropriate p.c.b. layout. Calibration procedure:
- Adjust RP1 until pin 1 (IC_9) is at +4.096V.
- Adjust RP2 until pin 2 (IC_{20}) is at +2.0480V.

Correction. Four errors occurred in Fig. 7 of the April part of the article: diode D_4 should go to +5V, instead of ground; IC_{11} is a 74C157; IC2 on pin 42 of IC_3 should be C_3. It is not clear on the drawing that R_{15}-R_{20} go to +5V. □

Two programs, for Commodore Pet and Fluke 1720A, to scan 16 channels.

```
10 REM***PROGRAM FOR SCANNING THROUGH 16 CHANNELS***
20 REM***USING'FLUKE 1720A CONTROLLER'***
30 REM***PAT HICKEY***
40 REM***19 OCT 1981***
50 REM
100 TERM CHR$(13%)                    !TERMINATION CHARACTER IS CR
110 FORX%=0% TO 15%                   !SCAN 16 CHANNELS
120 C%=X%
130 IFC%>9%THENC%=C%+7%               !CHANNEL NUMBER IN HEX
140 C$="*"+CHR$(C%+48)                !"0" TO "F"
150 PRINT@16%,C$                      !SELECT CHANNEL
160 WAIT FOR SRQ
170 INPUT@16,R$                       !READ REPLY
180 REM***PROCESS REPLY***
190 X$=LEFT$(R$,1%)
200 Y$=RIGHT$(R$,4%)
210 R$="OVERRANGE"
220 IFY$="<<<<"THEN280                !OVERRANGE
230 IFX$="0"THEN X$="+1."
240 IFX$="2"THEN X$="-1."
250 IFX$="<"THEN X$="+0."
260 IFX$="7"THEN X$="-0."
270 R$=X$+Y$+" VOLTS"
280 CH%=SPL(16%) AND 15%              !DEVICE 16 STATUS BYTE
290 PRINT"CHANNEL";CH%;":- ";R$
300 NEXTX%
310 PRINT
320 GOTO110
READY.
```

```
10 REM***PROGRAM FOR SCANNING THROUGH 16 CHANNELS.***
20 REM***USING 'COMMODORE PET'***
30 REM***PAT HICKEY***
40 REM***19 OCT 1981***
50 REM
100 REM***MAINLINE PROGRAM***
110 OPEN16,16
120 PRINT"J"
130 FORX=0TO15
140 C=X:IFC>9THENC=C+7
150 C$="*"+CHR$(C+48)
160 PRINT#16,C$
170 GOSUB1000
180 GOSUB2000
190 PRINT"CHANNEL";CH;":-    ";R$;" VOLTS"
200 NEXTX
210 PRINT:PRINT
220 GOTO130
1000 REM***LOOP FOR SERVICE REQUEST***
1010 I=PEEK(59426)
1020 I=PEEK(59427)
1030 L=I AND 128
1040 IFL<>128THEN1020
1050 REM***READ STATUS BYTE***
1060 AD=103:REM**AD=SERIAL POLL ENABLE(SPE)
1070 GOSUB1200
1080 GET#16,S$:REM**S$=STATUS BYTE
1090 AD=102:REM**AD=SERIAL POLL DISABLE(SPD)
1100 GOSUB1200
1110 CH=ASC(S$)AND15
1120 RETURN
1200 REM***SEND ADDRESS/COMMAND TO GPIB BUS***
1210 POKE59456,0 :REM**ATN LOW
1220 POKE59426,AD:REM**SEND COMMAND
1230 POKE59427,52:REM**DAV LOW
1240 POKE59427,60:REM**DAV HIGH
1250 POKE59456,4 :REM**ATN HIGH
1260 RETURN
2000 REM***READ DATA FROM BUS***
2010 INPUT#16,R$
2020 X$=LEFT$(R$,1)
2030 Y$=RIGHT$(R$,4)
2040 IFX$="0"THENX$="+1."
2050 IFX$="2"THENX$="-1."
2060 IFX$="<"THENX$="+0."
2070 IFX$="7"THENX$="-0."
2080 R$=X$+Y$
2090 IFY$="<<<<"THENR$="OVERRANGE"
2100 RETURN
READY.
```

BOOKS

Elements of Microprogramming, by D. K. Banerji and J. Raymond. 434 pages, hardback. Prentice-Hall, £18.70.
The advantages of microprogramming over hard-wired control logic systems are described from a historical viewpoint prior to a thorough treatment of the theory, practice and application. A microinstruction is at a lower level than a machine-code instruction; an Add, for example, requires four microinstructions. Microprogrammed control possesses the advantages of flexibility and economy and the possibility of changing the instruction set or architecture of a computer by altering the microprogram.

Digital Control Using Microprocessors, by P. Katz. 293 pages, hardback. Prentice-Hall, £16.95.
Differences in emphasis between digital processing of signals and the digital control of processes are stressed in this book, which is at a suitable level for final-year degree students and engineers who are already familiar with analogue control. Sample 8085 programs are included.

Computers and the Radio Amateur, by P. Anderson. 208 pages, hardback. Prentice-Hall, £14.20.
A thorough and well presented introduction to computers in amateur radio. Presents a very readable explanation of Basic and assembly-level programming, and goes on to describe interfacing to amateur equipment and to detail electronic keying and Morse reading.

World's Radio Broadcasting Stations, by C. J. Both. 214 pages, paperback. Newnes Technical Books, £5.50.
European f.m. radio and television transmitters are included in this comprehensive listing of stations. The book, first published in Holland, presents the relevant information to enable a listener to identify or locate stations in the long, medium and short wavebands, giving frequency and wavelength, power, co-ordinates of the transmitters and their place names. In the case of television and f.m. radio, there are columns to indicate channel number, aerial polarization and whether the station transmits in stereo. A number of appendices list the addresses of broadcasting stations and DX clubs and there is a five-language glossary, a frequency/wavelength conversion table and a table giving the characteristics of tv transmitters.

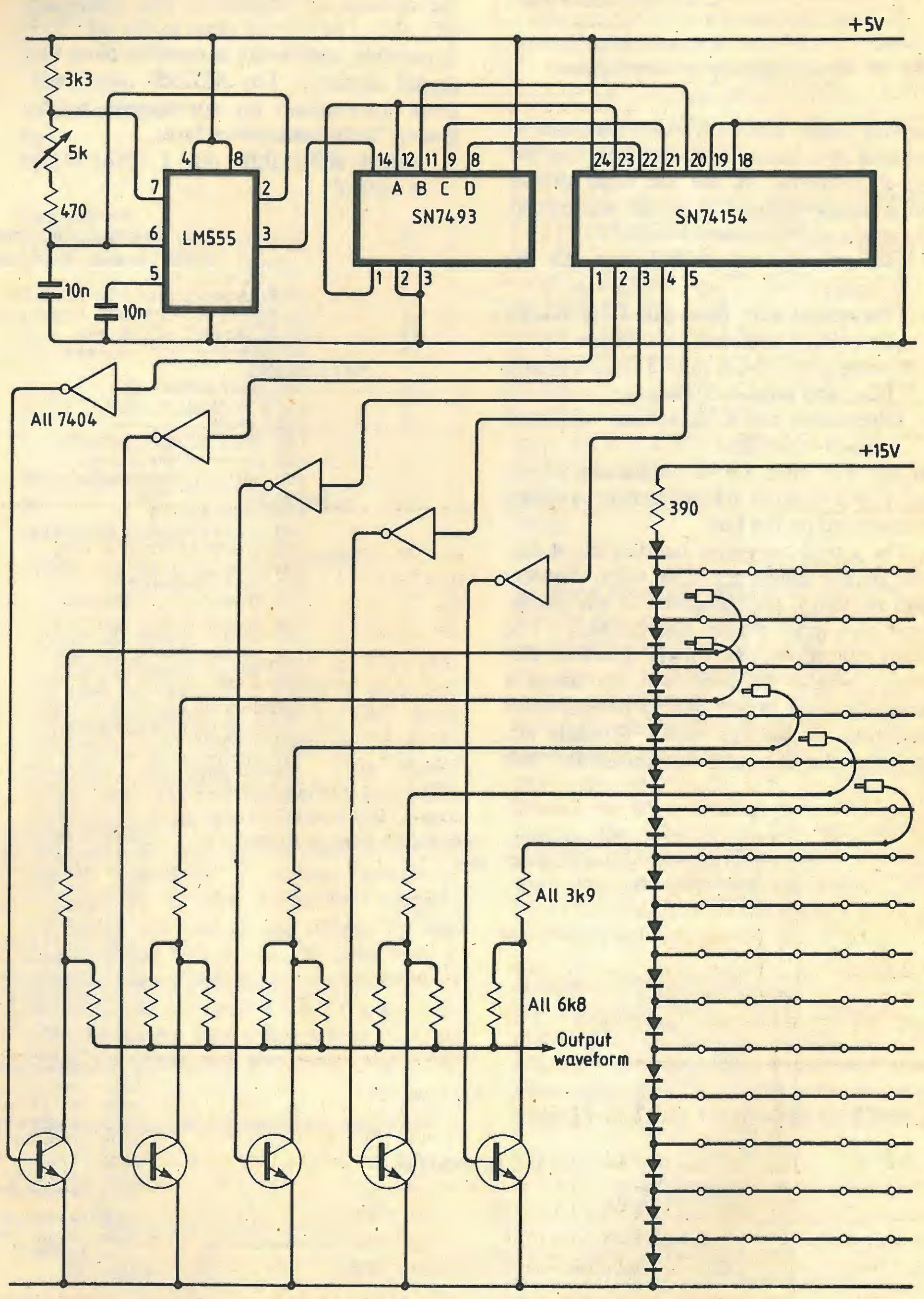
CIRCUIT IDEAS

Waveform synthesizer

Here, an X/Y matrix is used to plot a given waveform. The waveform to be synthesized is divided into a number of time domains and the voltage at the end of each domain is set on a diode-chain potentiometer. If the length of the time domain is less than half the period of the maximum frequency present in the waveform and the number of discrete levels is large, accurate reproduction of the original can be achieved. This circuit lends itself to computer control and expansion.

By varying the 555-clock frequency, the output waveform frequency may be adjusted proportionally. A 7493 counter converts the clock signal into 4-bit binary to drive a 4-to-16-line decoder, which in turn drives 16 output transistors through t.t.l. buffers. Each transistor output is fed to a common point through a resistor. For certain waveforms, an integrating capacitor may be connected accross the output to filter out steps and switching pulses.

P. D. Somerville
Crawley
Sussex



NiCd battery protection

Essentially a fold-back current limiter with a low-voltage detection capability, this circuit draws less than 300 μA and drops less than 0.35V on full transmit load.

The low loss on load, important in many battery applications, is due to the use of germanium as the control element. Only one control transistor is shown in the simplified diagram although two in parallel are used. The germanium control transistor Tr_1 is held on by a silicon transistor, Tr_2, whose base current flows through zener D_1 and R_1. With a 12V battery D_1 is 9.1V. In the event of an overload or short circuit the p.d. across Tr_1 rises and on reaching 0.6V is detected by silicon transistor Tr_3 with emitter-base connected across the emitter-collector of the germanium control transistor. Tr_3 turns on, raising the junction of D_1 and R_1 to battery voltage. This action turns off $Tr_{1,2}$ and they remain off while any load is connected.

A similar action occurs if the voltage on or off load falls below 1V/cell, i.e. below 10V. In this case the battery voltage fails to support a current through Tr_2 (requiring 0.6V) and D_1 (requiring 9.1V) and Tr_1 starts to turn off, initiating the same fold-back action. C_1 is included to damp the fold-back loop. A low-value resistor R_2 is used to control thermal run-away of Tr_1.

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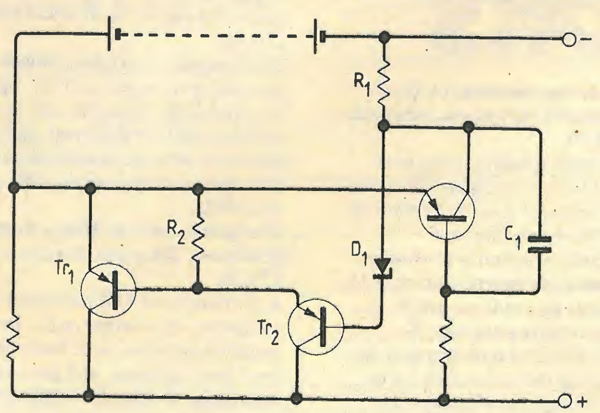
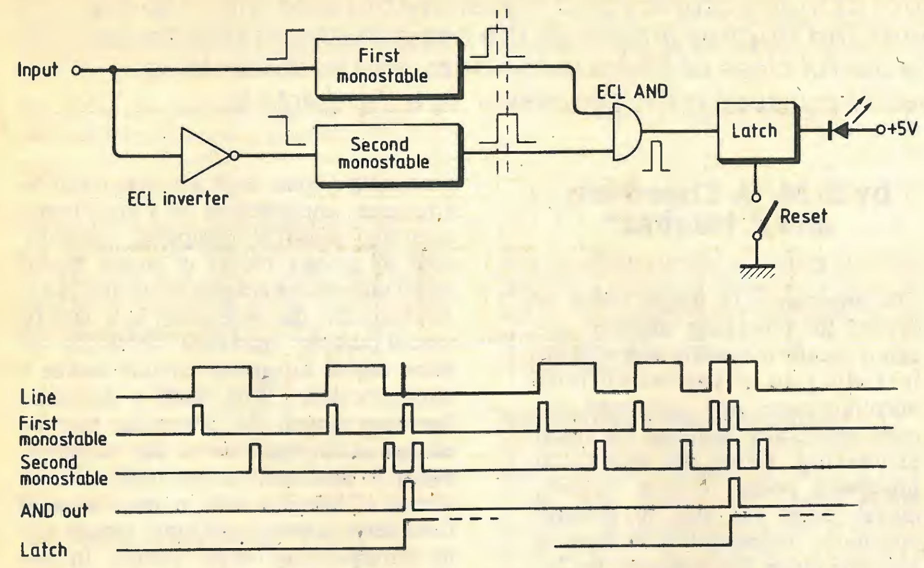
Zimbabwe





Glitch detector

Using two fast monostable multivibrators, such as e.c.l. MC10198's, it is possible to detect extremely short glitches. These devices provide a very short pulse, but although the pulse is short, it is at least twice as long as anticipated glitches. As the timing diagram shows, normal pulses are rejected using an AND gate.

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Italy

Wideband f.m. demodulator

Operation of the demodulator relies on the linear relationship between power consumption (I_{DD} where V_{DD} is fixed) and operating frequency of c.m.o.s. logic circuits. A 4013B D-type flop-flop is used because the internal clock elements have a high clock rate capability which extends beyond the normal range of usage. Measurements indicate that the demodulator will work satisfactorily from d.c. up to and beyond 20MHz.

The flip-flop is clocked by logic level transitions and the resultant current flow converted to an output voltage by the current mirror and output components. The current mirror ensures a minimal interaction between supply voltage and current in the flip-flop – a higher performance mirror could be constructed using spare devices in the 3046 array if required.

The resistor is chosen to suit the maximum input frequency (the output can swing the full supply voltage, limited only be quiescent device consumption and V_{ce} saturation) and the capacitor provides low-pass filtering to remove input frequency noise. Values shown have been used in a 10.7 MHz f.m demodulator prior to "birdy" filtering and stereo decoding.

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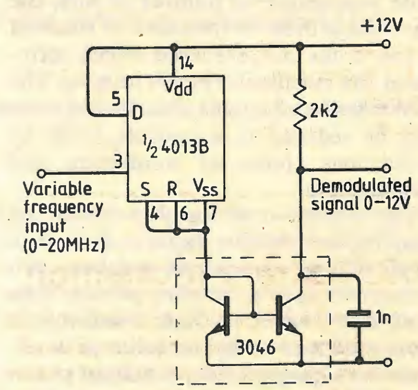
Nuneaton



Constant-current supply

This circuit is extremely simple, uses no special components, yet has a very wide range of output currents, 2μA to 100 mA in six ranges. The only limitation to output is component ratings. It also has a performance that is comparable to more expensive equipment.

Tr_1, Tr_2 and IC_1 comprise a constant-voltage supply that can be varied from 0 to 100 V by varying $V_{ref.1}$. When testing this section, no change in the output voltage could be detected on both analogue and 3½-digit voltmeters with change of supply voltage from 150 V to 250 V and with sudden application of a 100 mA load.

Tr_3 and IC_2 comprise the constant-current section, R_c is the current sensing resistor. By choosing the appropriate value of R_c or switching different values, the required current range is obtained.

The voltage drop across R_c which equals $V_{ref.2}$ was chosen to be about 0.7V so that the error in voltage measurement will not exceed this value plus the drop in the ammeter circuit, a total of less than 1V. A multi-turn potentiometer to obtain $V_{ref.2}$ enabled accurate current adjustment.

Capacitors C_1 and C_2 suppress oscillations that would otherwise occur; D_1 and D_2 protect Tr_2 and Tr_3 from possible negative voltages that may occur due to switching transients. Switching R_c during operation proved to be of no harm, but IC_2 may need some extra protection if intermittent loading with outputs greater than 30V is used frequently *(a diode between pins 3 and 7 might help. Ed).*

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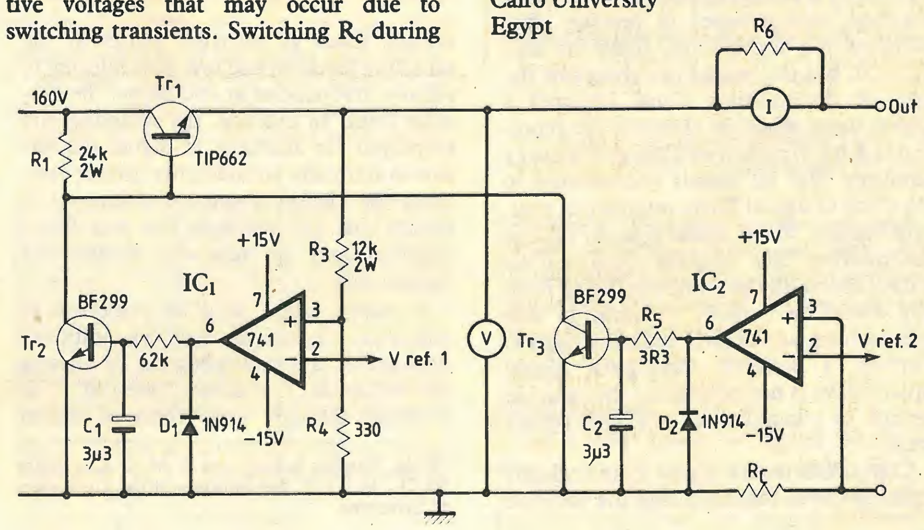

DIGITAL FILTER DESIGN

In the next few years digital filters will be increasingly used in place of their analogue counterparts, not only on account of their accuracy and versatility but also their rapidly declining cost. Authors Cheetham and Hughes introduce the basic theory in this article, give design techniques for a useful class of filters in the next, and describe their implementation by special-purpose microprocessor in a third article.

The conversion of an analogue signal into digital form requires a process of sampling at successive points in time separated by equal intervals, say T. Each sample is then converted to a binary number proportional to the sampled voltage. The sampling process requires that the analogue signal be bandlimited to below the Nyquist frequency $\frac{1}{2}f_s$, where $f_s \approx 1/T$. This may be achieved to an acceptable accuracy by low-pass filtering the analogue signal before sampling. Failure to do this will result in frequency components above the Nyquist frequency being folded back into the range below $\frac{1}{2}f_s$, causing a form of distortion known as aliasing.

Further distortion is introduced by the process of representing each sample by a finite wordlength or number of bits; the true voltage must be truncated or rounded to one of the discrete levels which correspond to a permissible binary number. The noise introduced by this quantization error may be reduced to acceptable levels by a judicious choice of wordlength and sampling rate.

The discrete-time signal produced by sampling an analogue signal is defined to be an infinite sequence of numbers each corresponding to a sampling point at time $t=nT$ for $-\infty<n<\infty$. Such a sequence is always referred to by its value at $t=nT$. Thus the sequence $\{x(n)\}$ is defined as

$$\{\ldots x(-2), x(-1), x(0), x(1), x(2), \ldots\}$$

with element $x(n)$ occuring at $t=nT$. By this definition, $\{x(n-k)\}$ denotes the sequence whose value at $t=nT$, is $x(n-k)$. Hence $k>0$, $\{x(n-k)\}$ is a delayed version of $\{x(k)\}$ where each element is shifted k places to the right and is thus delayed by k sampling intervals. It is often assumed, and arranged in practice, that elements of a discrete-time signal are zero for $n<0$, but this would not always be the case. A discrete-time signal becomes a digital signal when its elements are represented by fixed-wordlength binary numbers. Not all signals encountered in the study of digital filters originate as analogue signals. Many digital signals, such as the discrete time impulse $\{\delta(n)\}$ illustrated, are readily generated in digital form but would be unlikely to occur in that precise form as sampled analogue signals. Further, a perfectly rectangular digital square wave is not necessarily the sampled version of a bandlimited analogue square wave.

Conversion from a digital to an analogue signal involves reconstituting the sampled

by B. M. G. Cheetham and P. Hughes*

The importance of digital filters as devices for processing digitized signals is rapidly increasing now with the introduction of special-purpose microprocessors and integrated circuits specifically designed for signal processing. Using the numerical processing power of such circuits, digital filters are able to perform operations corresponding to those of analogue filters. For example, the Intel 2920 analogue signal processor with its analogue/digital converters acts as a one-chip replacement for an analogue filter.

In addition to their uses in emulating the frequency responses of established forms of analogue filters, digital filters have a wide range of other applications which take advantage of the much greater power and flexibility of numerical processing as compared with analogue methods, and the filter may not easily be described as having a particular type of frequency response. Digital filter inputs need not originate from analogue sources, and numerically generated signals are encountered in many applications. In developing the basic theory of digital filters, therefore, it is best to consider them as general devices for processing sequencies of numerical data rather than as digital realisations of analogue filters. But before doing this, this article briefly considers the sampling process often used to produce digital signals and introduces notation for representing such signals.

voltage levels as electrical pulses at the sampling instants, and low-pass filtering to remove frequencies at and above the Nyquist limit. In practice, the sampling rate employed for analogue to digital conversion is normally considerably greater than twice the highest frequency of interest to ensure that the analogue low-pass filters required may be relatively simple and inexpensive.

A digital signal may be subjected to numerical operations such as addition, subtraction and multiplication by passing the sequence of numbers (referred to as samples) through some form of digital

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processing system. Such a system could be a program implemented on a main-frame scientific research computer normally used to process blocks of stored digital signal samples for analysis some time later. Alternatively, the system may be a piece of special-purpose hardware consisting of some digital integrated circuits and/or a microprocessor. With such a dedicated hardware system the processing may be carried out in real time so that an output signal is generated as an uninterrupted stream of samples with at most a small fixed delay between each input sample and its corresponding output sample. In this case the digital system, with associated analogue to digital converters, may act as a direct replacement for an analogue system such as a filter or a modulator.

Digital processing systems can be designed to carry out a very wide range of operations on digital signals. A digital filter is a processing system which generates the output sequence $\{y(n)\}$ from an input sequence $\{x(n)\}$

$$y(n) = \sum_{i=0}^{M} a_i x(n-i) - \sum_{j=1}^{N} b_j y(n-j) \quad (1)$$

at time nT for $-\infty<n<\infty$. This is a difference equation of order M or N, whichever is the larger. When $N>0$ the filter is said to be recursive as previous output samples are used in the calculation of the present output sample. Coefficients $a_0, a_1, \ldots a_M$ and $b_1, b_2, \ldots b_N$ are fixed (time invariant) multiplication constants which characterize the effect of the filter. The design of a useful digital filter requires the selection of these constants using design techniques corresponding to those adopted for calculating component values in analogue filters, and an example for a class of digital filters is given in a subsequent article. As a simple example, consider the digital filter defined by the first-order difference equation

$$y(n) = x(n) + by(n-1) \quad (2)$$

where b is a constant. This filter is shown in diagrammatic form in Fig. 1, illustrat-

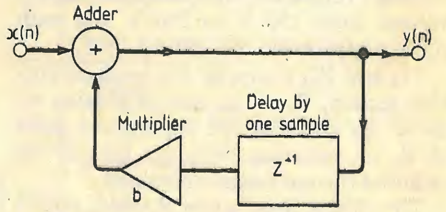


Fig. 1. First-order digital filter applies numerical operations to the sampled input signal x(n) to produce an output y(n).

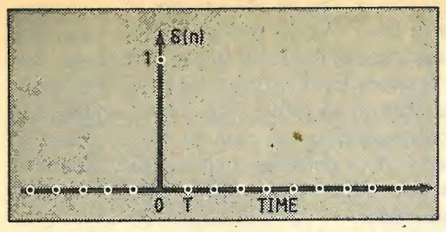


Fig. 2. The discrete-time impulse δ(n) is defined only at sampling points t=nT, $\delta(n)=\begin{cases}0, t=nT, n\neq 0.\\ 1, t=0\end{cases}$

ing the three basic operations required for any digital filter: addition, multiplication by constants and delay. Make the input sequence $\{x(n)\}$ equal to the discrete-time impulse sequence $\{\delta(n)\}$ of Fig. 2, with

$$\delta(n)=\begin{cases}1, & n=0\\ 0, & n\neq 0\end{cases}$$

The output from this simple filter may be calculated by hand. Assuming $y(-1)$ to be zero, then

$$y(0) = x(0) + by(-1) = 1$$

Following on from this

$$y(1) = x(1) + by(0) = b$$
$$y(2) = x(2) + by(1) = b^2, \text{ and so on.}$$

Hence the output will be the real exponential sequence:

$$\{y(n)\} = \{\ldots, 0, b, b^2, \ldots, b^r, \ldots\} \quad (3)$$

illustrated below in Fig. 3 for $b=0.7$. If $|b|>1$, the sequence $\{y(n\}$ would increase without limit and the digital filter would then be said to be unstable. A stable filter is one which produces a bounded output sequence, i.e. a sequence whose elements do not increase without limit as n increases or decreases (looking backwards in time) for any bounded input sequence. As the input signal in the example above is the discrete-time impulse $\{\delta(n)\}$ the output obtained is termed the impulse response of the filter. If the input had been $\{\delta(n-k)\}$, a delayed version of the discrete-time impulse, the output would have been $\{y(n-k)\}$ a similarly delayed version of $\{y(n)\}$.

Assuming the impulse response of a general filter, as given by equation 1, to be the sequence $\{h(n)\}$, consider its response to an arbitrary input sequence $\{x(n)\}$. Such a sequence may be expressed as the weighted sum of delayed unit impulses

$$\{x(n)\} = \left\{\sum_{k=-\infty}^{\infty} x(k) \, . \, \delta(n-k)\right\} \quad (4)$$

If only bounded input and output sequences are allowed, it may be shown that the digital filter defined by equation 1 is linear in the sense that if input sequences $\{x_1(n)\}$ and $\{x_2(n\}$ produce outputs $\{y_1(n)\}$ and $\{y_2(n\}$ respectively, the response to $\{\lambda x_1(n)+\mu x_2(n)\}$ will be $\{\lambda y_1(n)+\mu y_2(n)\}$ for any values of λ and μ. By extending this property to the infinite sum of scaled impulses as given by (4) one deduces that the response to $\{x(n)\}$ is

$$\{y(n)\} = \left\{\sum_{k=-\infty}^{\infty} x(k) \, . \, h(n-k)\right\}$$

The right hand side is the convolution of $\{x(n)\}$ with $\{h(n)\}$, often denoted by $\{x(n)\} * \{h(n)\}$. By a simple change of variable it may be shown that an entirely equivalent expression is

$$\{y(n)\} = \{h(n)\} \star \{x(n)\}$$
$$= \left\{\sum_{k=-\infty}^{\infty} h(k)x(n-k)\right\}$$

The impulse response of a filter therefore provides a complete characterization of its behaviour, allowing the response to any input sequence to be deduced from these two equations.

Alternative characterization

An alternative method of characterizing a digital filter is to specify its effect on sinusoidal input signals over a range of frequencies. A fundamental property of fixed linear systems in that their steady-state response to a sinusoidal input is a sinusoidal output of identical frequency but modified amplitude and phase. Define a sinusoidal sequence of radian frequency ω to be the sampled version of a sinusoidal function of time, with frequency $F=\omega/2\pi T$; for example $\{A \cos(\omega n)\}$. The response of a filter with impulse response $\{h(n)\}$ to this sequence as input may be readily calculated by first considering the theoretical response to the complex-valued exponential sequence $\{e_{j\omega n}\}$, where $j=\sqrt{-1}$. The response is an output sequence:

$$\{y(n)\} = \left\{\sum_{k=-\infty}^{\infty} h(k)e^{j\omega(n-k)}\right\}$$
$$= \{e^{j\omega n} \sum_{k=-\infty}^{\infty} h(k)e^{-j\omega k}\}$$
$$= \{e^{j\omega n} H(e^{j\omega})\}$$

$$\text{where } H(e^{j\omega}) = \sum_{k=-\infty}^{\infty} h(k)e^{-j\omega k} \quad (5)$$

The function $H(e_{j\omega})$ is defined as the frequency response of the digital filter and is a complex number for any value of ω (subject to the convergence of the series in equation 5; by the definition of stability

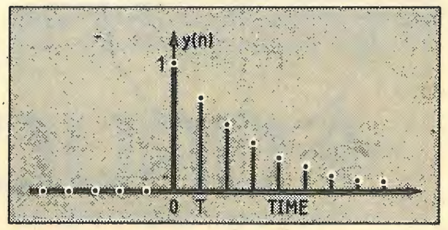


Fig. 3. Output sequence obtained by feeding δ(n) in Fig. 2 into the digital filter shown in Fig. 1 with b=0.7 is the real exponential sequence $y(n)=0.7^n$ *for n>0.*

given earlier, convergence is assured for a stable filter).

The response to $\{A \cos(\omega n)\}$ is a sequence $\{y(n)\}$ with

$$y(n) = \tfrac{1}{2}A(H(e^{j\omega})e^{j\omega n} + H(e^{-j\omega})e^{-j\omega n})$$

Denoting by $\phi(\omega)$ the argument of $H(e^{j\omega})$ and noting that since all values of $h(k)$ in equation 3 are real, $|H(e^{j\omega})| = |H(e^{-j\omega})|$ and the argument of $H(e^{-j\omega}) = -\phi(\omega)$:

$$y(n) = \tfrac{1}{2}A \mid H(e^{j\omega}) \mid \times$$
$$(e^{j(\omega n+\phi(\omega))} + e^{-j(\omega n+\phi(\omega))})$$
$$= A \mid H(e^{j\omega}) \mid \cos(\omega n+\phi(\omega))$$

Hence the modulus and argument of the complex-valued frequency response $H(e^{j\omega})$ give the gain and phase shift of the filter output relative to a sinusoidal input of radian frequency ω. Bearing in mind that

$$\int_{-\pi}^{\pi} e^{j\omega(n-k)} d\omega = \begin{cases}2\pi & \text{if } n=k\\ 0 & \text{if } n\neq k\end{cases}$$

it may be deduced from equation 3 that

$$h(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H(e^{j\omega})e^{j\omega n} d\omega \text{ for } -\infty<n<\infty \quad (6)$$

The transformation from the sequence $\{h(n)\}$ to the complex function $H(e^{j\omega})$ of ω defined by equation 5 is a Fourier transform; the reverse process given by equation 6 is an inverse Fourier transform.

As an illustration of frequency response, consider again the simple digital filter defined by equation 2. By equations 3 & 5

$$H(e^{j\omega}) = \sum_{k=0}^{\infty} b^k e^{-j\omega k}$$

which may be summed for $|b|<1$ as a geometric series, giving

$$H(e^{j\omega}) = (1-be^{-j\omega})^{-1} \quad (7)$$

Evaluating this expression for $b=0.7$ gives

$$\mid H(e^{j\omega}) \mid = (1.49-1.4\cos\omega)^{-\frac{1}{2}}$$

$$\text{and } \phi(\omega) = \tan^{-1}\left(\frac{0.7\sin\omega}{0.7\cos\omega-1}\right)$$

Frequency response graphs of gain, $|H(e^{j\omega})|$, and phase $\phi(\omega)$ over radian frequencies 0 to π, corresponding to analogue frequencies from zero to the Nyquist, are shown in Fig. 4(a) and (b).

z-transforms

Analysis and design of digital filters is greatly simplified by the use of the z-transform which is analogous to the Laplace transform for analogue filters.

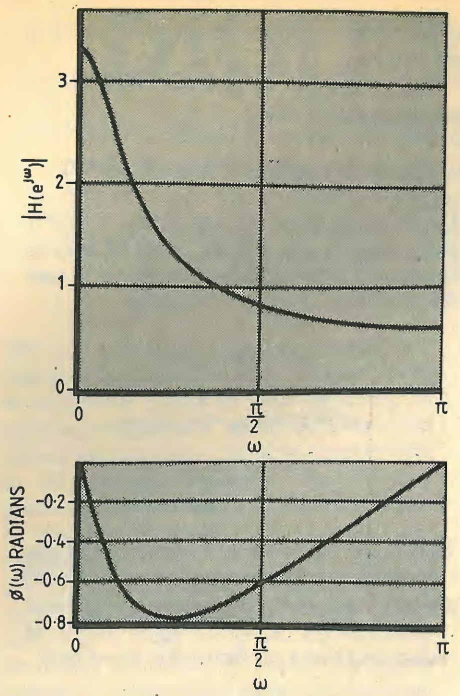


Fig. 4. Frequency response of a digital filter (in this case Fig. 1 with b=0.7) characterizes its response to sampled sinusoidal inputs of the form Acosωn. Amplitude response at top, phase response bottom.

The z-transform of the sequence $\{x(n)\}$ is defined as the infinite sum

$$X(z)=\sum_{n=-\infty}^{\infty} x(n)z^{-n}$$

for a complex variable z. Notice the similarity between this expression and equation 3; setting $z=e^{j\omega}$ gives $X(z)$ as the Fourier transform of $\{x(n)\}$. The z-transform of the impulse response $\{h(n)\}$ is $H(z)$ and hence the setting of $z=e^{j\omega}$ in this case gives the frequency response already defined as $H(e^{j\omega})$. The equation above may therefore be thought of as a generalization of the Fourier transform. Also, the z-transform of the delayed sequence $\{x(n-1)\}$ is $z^{-1}X(z)$ as each coefficient of z^{-n} is shifted along by one place. In general the z-transform of $\{x(n-k)\}$ is $z^{-k}X(z)$. Also notice that the z-transform of the impulse $\{\delta(n)\}$ is $\Delta(z)=1$.

Applying the z-transform to the output of a digital filter as defined by equation 1 gives

$$Y(z)=\sum_{i=0}^{M} a_i z^{-i}X(z) - \sum_{j=1}^{N} b_j z^{-j}Y(z)$$

which may be rearranged and expressed in the form

$$Y(z)=\left[\left(\sum_{i=0}^{M} a_i z^{-i}\right)\Big/\left(1+\sum_{j=1}^{N} b_j z^{-j}\right)\right]X(z)$$

The expression in square brackets above is equal to $H(z)$ as if the input sequence $\{x(n)\}=\{\delta(n)\}$ then $Y(z)$ becomes equal to the z-transform of the impulse response. Hence $H(z)$ may be expressed directly in terms of the multiplier coefficients, and the frequency response may be obtained directly from this expression by setting $z=e^{j\omega}$. This may be verified for the simple filter defined by equation 2 where $H(z)=1/(1-bz^{-1})$ and hence an expression for $H(e^{j\omega})$ identical to equation 7.

The transfer function of a filter, $H(z)$, has now been expressed as the ratio of two polynomial expressions in z^{-1}, the roots of which are the poles and zeros of $H(z)$. Hence

$$H(z)=a_0\prod_{i=1}^{M}(1-z_i z^{-1})\Big/\prod_{j=1}^{N}(1-p_j z^{-1}) \quad (8)$$

assuming $a_0=0$, where the poles are p_j and the zeros by z_i. Expanding by partial fractions (assuming there are no repeated roots other than at $z=0$),

$$H(z)=\sum_{i=0}^{M-N} B_i z^{-1}+\sum_{j=1}^{N} A_j/(1-p_j z^{-1})$$

which expresses $H(z)$ as the weighted sum of sequences whose z-transforms are z^{-1} and $1/(1-p_j z^{-1})$. Clearly z^{-1} corresponds to a delayed impulse $\{\delta(n-i)\}$. By referring back to the example of a first-order filter whose transfer function is $1/(1-bz^{-1})$ it may be deduced that $1/(1-p_j z^{-1})$ is the z-transform of an exponential sequence of the form

$$\{\ldots 0,\ldots 0, 1, p_j, p_j^2, \ldots p_j^r, \ldots\} \quad (9)$$

The roots of a polynomial may of course be complex numbers and therefore the sequences above may be complex. As complex roots occur in conjugate pairs, the sequence obtained for $\{h(n)\}$ is always real. A non-recursive filter, i.e. one with $N=0$, will have an impulse response with $h(n)=B_n$ for $0\leq n\leq M$ and zero otherwise. Such an impulse response is termed finite as only a finite number of elements are non-zero. The impulse response of a recursive filter ($N>0$) will include at least one sequence of the form in equation 9 and can therefore be of infinite duration. For such a filter to be stable, the above sequence 9 corresponding to each of its N poles p_i must be a decaying exponential. Hence a stable filter must have $|p_i|<1$ for all its poles.

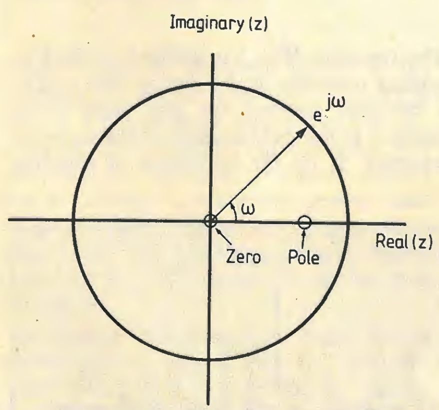


Fig. 5. Argand diagram shows pole and zero positions for H(z) obtained from Fig. 1 which determines the frequency response H(e^{jω}).

Considerable insight into the behaviour of digital fileters may be gained by plotting. Argand diagrams showing the positions of poles and zeros as values z. Such a diagram is shown in Fig. 5 for the transfer function $H(z)=1/(1-0.7z^{-1})$ which has a pole at $z=0.7$, and a zero at $z=0$. The points for which $z=e^{j\omega}$ on this plane correspond to the unit circle with centre $z=0$ and radius 1. The frequency response $H(e^{j\omega})$ is obtained by an evaluation of $H(z)$ for values of z on this unit circle, where ω is the angle subtended from the real axis to the point corresponding to $z=e^{j\omega}$. Frequencies zero and the Nyquist appear at opposite sides of the unit circle on the real axis.

A stable filter will have all its poles inside the unit circle ($|p_i|<1$). From equation 8 the value of $|H(e^{j\omega})|$ at any point on the unit circle is equal to a_0 multiplied by the product of the distances from that point to each of the zeros, divided by the product of the distances to the poles. The phase of $H(z)$ may also be readily calculated. Consequently zeros close to the unit circle correspond to frequencies for which $|H(e^{j\omega})|$ is close to zero. Poles close to the unit circle produce large values of $|H(e^{j\omega})|$, the closer the pole, the larger the modulus. Such poles can also affect $\phi(\omega)$ resulting in severe phase non-linearity.

The design of digital filters with specified frequency responses is often carried out by locating zeros and poles at appropriate points on the z-plane. Design techniques exist for both recursive and non-recursive filters: refer for details to any of the standard references, some of which are listed below. Non-recursive filters have certain advantages of guaranteed stability and easily specifiable phase characteristics, but tend to involve a large number of arithmetical operations which could make them more difficult to implement. Recursive filters are perhaps still more commonly used, and therefore the next article will introduce a design procedure for this class of filters.

continued

Further reading

Digital Signal Processing, by A. V. Oppenheim and R. W. Schafer, Prentice-Hall, 1975.
Theory and Application of Digital Signal Processing, by L. R. Rabiner and B. Gold, Prentice-Hall, 1975.
Digital and Kalman Filtering, by S. M. Bosic, Edward Arnold, London, 1979.
Introduction to Digital Filters, by T. J. Terrell, Macmillan, 1980.
Digital Signal Processing Thoery, Design and Implementation, by A. Peled and B. Liu, Wiley, 1976.

LETTERS

A CHARTER FOR ISOLATION

I wish to quote from your editorial "A Charter for Isolation" in the December issue:

"It leaves us, says Hartley, with a 'conception of the engineer as no more than a high-grade technician, a functionary not fully professional . . .' "

This conforms to a view held in this country in a previous age – 1920-50. But it surprises me that you did not correlate the holding of this view with the photo on page 37 of that issue, where "engineers practice climbing on these short poles". By our definitions, if British engineers still spend time climbing poles then we would have to say they are technicians.

The engineering profession down-graded itself for too long be accepting such jobs, even in training; besides who can afford such at present starting salaries of US $22,000 or thereabouts?

J. D. Ryder,
formerly Dean of Engineering,
Michigan State University.

THE DEATH OF ELECTRIC CURRENT

Ivor Catt's letter in the February issue only serves to illustrate the deficiences in his knowledge of mathematics and conventional EM theory and the confusion of his own theory.

Can he not see that $E/H=\sqrt{\mu/\epsilon}$ is wrong and $H=B/\mu$ is right for mathematical reasons? There is indeed a small chance that the latter does not describe correctly the true physics of magnetism but at least it is dimensionally sound.

His difficulty with step waveforms on transmission lines becomes clearer. Of course the conduction and displacement currents are both present in the line together, but only as the wave advances. The displacement current dD/dT is associated with the wave front only (D is constant elsewhere). If the wave reaches a (correct) resistive termination dD/dT ceases, the step is terminated and the resistor begins to absorb the energy in the wave. It is precisely because the displacement current flows across the transmission line that the wave is called a transverse EM wave and the displacement current is distinct from the conduction current. The energy associated with the displacement current is stored and can be recovered later (cf. radar pulse generators). It can be seen from Mr Catt's own illustration (Fig. 3, p.68 March, 1979) that the E vector (dB/dT) and the displacement current vector (dD/dT) are at right angles, therefore $E\times H$ is purely reactive. This is analogous with reactive power (VA_r), where current and voltage are 90° out of phase. The H vector associated with the conduction current is also at 90° to the E field and again no energy is dissipated; the power flow is in the direction of the conduction current. In a third case, the transmission line is resistive and there is a component of the E field along the line in a direction opposite to the current flow. Here some of the power is dissipated.

Mr Catt is further confused with regard to electric charge. The existence of electric charge is not a theory; it is a fact like the sun and coal in South Wales. Since one of the manifestations of electric charge is electric potential, any theory of electric waves that dispenses with electric charge must be rubbish. It is the objective of EM theory to explain the various manifestations of electric charge.

Mr Catt's mathematics is wrong; he does not understand the application of vectors to TEM waves and he does not distinguish fact from theory.

I'm sorry if he believes his version of Maxwell is correct; it isn't. If he was right in his belief some changes would indeed be needed and radios would not work.

Dermod O'Reilly,
Antwerp,
Belgium.

RECHARGING DRY CELLS

With reference to the letter from Mr D. F. Caudrey (Letter, August 1981) I should like to offer my findings on the subject, and also beg more information from the author.

I have been using the same four SP2 cells for about 11 weeks, five days a week, approximately 1 hour per day. At first I would recharge them (using the circuit and method due to Mr Caudrey) for an hour or two, twice a week but now I need to re-charge every day for about 2-3 hours to get an hour's use from the cells. Although I am convinced that the method is feasible in practice, I do not seem to have had the same success as Mr Caudrey, and so I would like to hear from Mr Caudrey his recommendations about charging, i.e. when and for how long.

S. P. Narey,
Idle,
Bradford.

MILLIMETRE-WAVE LENS AERIALS

I have read Dr K. L. Smith's article on millimetre wave lens aerials with interest (and some nostalgia as I was in the lens business in the early 1950s) and congratulate him on an excellent reintroduction to an almost forgotten topic.

Has it occurred to Dr Smith that his method of fabrication would be equally applicable to another of Winston Koch's inventions, the serpentine lens? This form of lens can be assembled from a set of plates which have been crimped into sinusoids. Propagation is in the TEM mode and the quasi-refraction index is simply the ratio between the widths of crimped and uncrimped sheets. Dr Smith has only to stack a set of crimped sheets and machine a profile to produce a set of path-length lenses.

The serpentine lens has two advantages over the H_{01} wave-guide lens. It is unaffected by the spacing between plates, so tolerances are easier, and by arranging for the surfaces of the sinusoidal sheets to be normal to the phase surface of the lens where they meet this surface, the lens-medium will be matched to free-space, avoiding the alternating $\lambda/4$ and $\lambda/2$ transformers which degrade the side-lobe performance of a wave-guide lens in which the refractive index has been pushed too far from unity.

The path-length lens may have disadvantages as well, but since to the best of my knowledge one has never been produced for operational use, perhaps Dr Smith will identify them by investigating the first thirteen models?

S. S. D. Jones
Malvern
Worcestershire

The author replies:

I was pleased to hear that Mr Jones enjoyed the article on mm-wave lens aerials. He has raised a very interesting point regarding the development of the serpentine plate lens aerial, which he is right in ascribing to Winston Koch. I agree on the added advantages of the corrugated conductor planes, but I did not consider employing them in the lens I made. Mr Jones raises a very interesting possibility, as I also agree with him that there would not be any fundamental problem in turning out such modified lenses by the same method I originated.

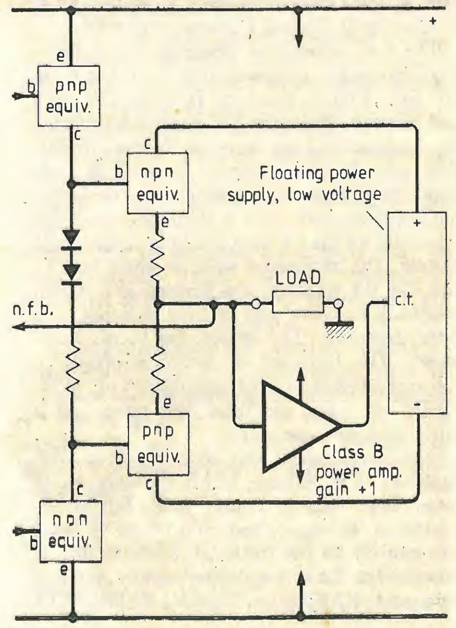
It would be most interesting to see an attempt made practically on such a design. We should thank Mr Jones for the suggestion.

LINEAR POWER AMPLIFIER

Operation of the output transistors at an approximately constant low voltage, as recommended by D. Rawson-Harris (Letter, Jan. 1982, p.40), can be used to give a class-A amplifier which retains to a considerable extent the efficiency of a class-B amplifier.

The low-voltage transistors are operated in class A from a low-voltage supply, perhaps +2, 0, -2 as suggested by Mr Rawson-Harris, and this supply is carried up and down by a slave class-B amplifier of gain +1. The class-B amplifier may produce noticeable crossover distortion; but as the effect of the distortion (or error) is only a small modulation of the almost constant c-e voltage of the class-A transistors its effect on the performance of the complete amplifier may be expected to be very small. An outline of the system is shown in the diagram.

As a piece of engineering the system cannot be rated very highly: Peter Walker's Quad amplifiers are much simpler, and their distortion is so low that they sound like a piece of wire. But the economics of producing an amplifier may be different for the amateur constructor and experimenter, and this alternative class-AB system may therefore be of interest. It has been used in some expensive Japanese amplifiers, but may be new to many *Wireless World* readers.



Mr Rawson-Harris calls his triples current amplifiers. Certainly their current gain is high; but it is poorly defined, having at least the current-gain spread of their first transistors, and they have high inlet resistance. I feel that a current amplifier should approximate to a short circuit and present a low resistance. To me the triples are enhanced transistors giving a voltage gain of many hundreds as a common-emitter amplifier, or enhanced emitter followers giving a voltage gain →1 very closely.

E. F. Good
Neasham
Darlington
Co. Durham

CLANDESTINE RADIO

Pat Hawker's review in the January and February, 1982 issues ably covers an area of interest to technical people which is noticeably omitted in the many books dealing with Resistance and Intelligence activity in World War II. Inevitably, in a collation from many sources, errors appear and among many statements of fact one finds items which are the opinions or deductions of a particular source. Some corrections which I am qualified to make, will, I hope, contribute to a valuable summary.

SOE began to design and make radio equipment before mid-1942, particularly the Type A Mk1 and the B Mk1 in 1941. The "early French Resistance suitcase set" illustrated in p.82 of the February issue was indeed the Type A MkII, which I designed in late 1941, just after the completion of the B MkI. This set was produced by Marconi, first at Writtle then at Hackbridge in quantity believed well over 1000. Many were allocated to Russia as well as to France and other areas of Occupied Europe, but details of distribution and usage are not available so far. The modular form of the A MkII, like that of the later B MkII, was to assist in assembly onto various housings, transport and concealment, as well as service by substitution.

Operational demand for a one-piece unit of the smallest size led to the re-engineering of the A MkII into the A MkIII, by Marconi production engineers. The main difference in the design was in the replacement of the TT11 Tx valve by the 7C5, which had then become available. Volume production from about the end of 1942 onwards totalled, I believe, over 4000.

The "A" series was designed for short to medium-range communication particularly to UK from France, Belgium, Holland, Denmark and Norway. While the "B" series was intended for medium to long range in Balkan, Middle East and African countries as well as from Southern France. A "C" series was considered but not developed, but a B MkIII was produced especially for the Far East and long-range jungle patrols. The transmitter was c.w. and a.m./r.t., and like the receiver, was hermetically sealed, positively buoyant, and entirely powered by a pedal-generator. The station was in two man-packs. The tendency of technical people to contract titles led to the general use of "A2", "B II" etc., but the term "B2 minor" is a misleading post-war usage.

SOE development was not centred on Gorhambury at St. Albans, which was only one of many large country houses used, but at the Frythe in Welwyn. Producton of the B MkII was entirely by the ISRB (ie. SOE) factory at Stonebridge Park, employing mainly Services personnel: RAF, Royal Signals, REME, ATS and FANY. About 7000 sets were made, with output reaching 400 per month in 1944.

I will not contest the relative merits of SIS/-SOE/Polish sets since I am as biased to one as Pat Hawker is to another, following our respective wartime employment and loyalties, but would beg to differ, since the operational requirements differed. The SOE sets were essentially para-military, with far wider application than to agent use in Northern France, and for a greater variety of operators. Too little has been said of the Polish sets and the Polish contribution, for which I have the greatest admiration. The OSS started development of suitcase sets from about mid-1942, learned rapidly, from British and their own experience, and made their contribution world-wide. Naturally, each historian tends to present the story as seen through the records and reports of his countrymen, and frequently dates are omitted, so that the order in which facts are presented implies their precedence. Reading G3VA's account of air-to-ground links (February, p.83) he quotes first MI-6 use of "early American f.m. equipment on 30MHz" then "SOE developed the 450 MHz S-Phone" and gives one date – August 1944. I have no information of the use of the American R/T sets before 1944, about the time of the "Joan-Eleanor" project, but the S-phone was working in 1941, and my colleague, Charles Bovill tested the first airborne equipment on a flight in Wellington No. L7772 on October 6th 1941. The air-set was a prototype superhet tuning through 60-70cm. It was used in Operation "Claude" on October 28th in a Whitley Mk.V. The S-Phone ground-set was developed by Capt. Bert Lane and the airset by Major Hobday, both of Royal Signals. The airset was destroyed in a crash later in 1941, but replaced by a super-regenerative air-set ten days later, by a rapid development by F/Lt Bovill. This remained standard operational equipment by 138 and 161 Squadrons until the production of the Homing Aircraft-superhet in 1943. In January 1944, a USAF Liberator was fitted with Homing S-phone gear, and in summer of that year F/Lt Bovill equipped and flew with thirty C47 aircraft of the American 60th Group Troop Carrier Sqdns, at Brindisi. These aircraft used S-phone continuously in operations until the end of the war, mainly over Albania, Yugoslavia and N. Italy. This is only a small part of the S-phone story, appropriate now in context with Pat Hawker's article.

John I. Brown, G3EUR,
S. Ockendon,
(late Major R. Signals).

THE NEW ELECTRONICS

I am afraid that my own experiences with interviewees is closely similar to that described by Mr Jaques in the January 1982 issue. I could hear an echo of my own comments and experiences as I read it through.

I like to finish an interview with a few simple technical questions, not to cause the interviewee any difficulty but to ensure that his understanding of the fundamentals of the subject is adequate. In the situation, slick, polished textbook answers are not expected but the right approach to achieving a satisfactory answer is expected. At this stage of the interview the interviewees are likely to be reasonably relaxed, and frequently have done a good job on selling themselves, so that the situation for both parties looks good.

My opening question starts with a battery feeding a capacitor through a resistor and switch in series. Assuming the capacitor is discharged at time zero, tell me how the capacitor voltage varies with time? All too frequently we do not get on to the second part (adding a series inductor) or the third part (replacing the battery with a sine-wave generator). Perhaps the interview situation is too upsetting, I try to provide not too serious help and guidance. Nevertheless one hopeful believed that the linear network with a sinusoidal input produced squarewaves.

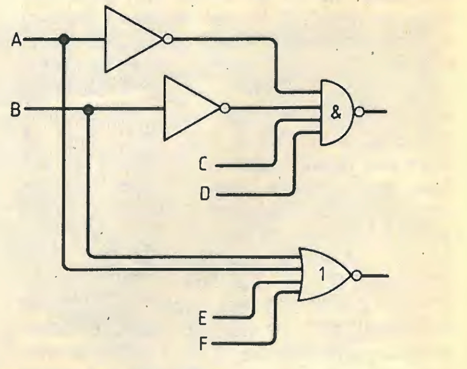
It is very difficult explaining to the MD that, in spite of the excellent paper qualifications of those already interviewed, further interviewing will be necessary.

N. A. Haran,
St. Albans,
Herts.

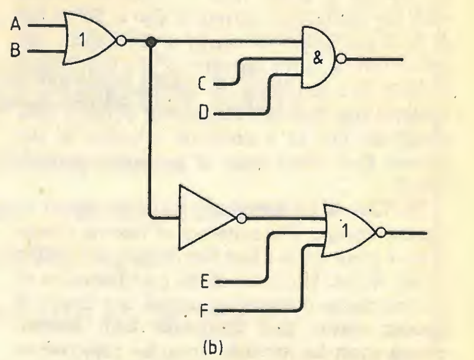
INTENTIONAL LOGIC SYMBOLS

In reply to Christopher Hudson (Letters, February 1982) the question as to whether a NAND gate is performing the function of positive NAND or negative NOR is to me as daft as asking whether a bucket is half full or half empty. The answer is both, not merely because the truth table says so but because, as an experienced logic designer I can, and do think of it as either with complete dexterity, although more frequently I think of a gate in terms of its truth table. If then I, as the designer of a circuit, cannot identify an intention, how can there be one?

Logic 1 and 0 are two states of complete equality: one is not merely the absence of the other. Some inputs, a 'clear' on a flip-flop for example, may be responsive to one state rather than the other, but this is a function of the input not of the signal feeding it. Mr Hudson does not



(a)



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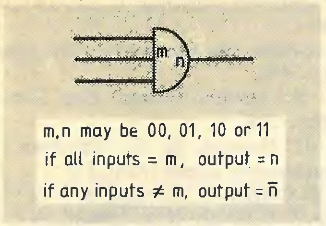

define what he means by the assertive state, I can only assume that he means the state which asserts itself, but that gets me no further. Even in the case of flip-flop 'clear' inputs, one could have an active-high and an active-low flip-flop connected to the same signal. How can the signal itself be thought of as having an assertive state? Mr Hudson illustrates the point himself in the mess he gets into over his Fig. 2. Essentially a 1 or 0 on the select are equally assertive and I maintain that, far from being unusual, it represents the general case.

In a practical design what may start out in the draft design as Fig. 1(a) may finish up as Fig. 1(b). The question is, is the two-input NOR performing the function of low-assertive NAND or high-assertive NOR? If Fig. 1(a) represents the intention then it is performing both. Should we draw it twice? Well why not, we are already being asked to show the outputs on flip-flops twice, use twice as many logic symbols as before, accept that identical devices may have different symbols, that a connection may be shown broken with a naming ceremony in between and even to accept that an inherently symmetrical device like a two gate latch should be drawn so as to make it look asymmetric, (see Cassera, November 1980) all inthe name of simplification.

The AND and OR names are a useful aid to memory as to the truth table of the gates so described. The predominance in practical logic of NANDS and NORs spoils the essential simplicity of the concept to the point where the names may be more of a hindrance. Intentional logic symbols are an attempt to restore the original simplicity. Mr Hudson's letter is in my opinion ample proof that they have failed miserably to do so.

My proposed logic symbols exploit the fact that if one is forced to live with negative and positive logic, one does not need to also live with both AND and OR because we can redefine the OR as a negative AND. As we now have only one type of function that function does not need a name, it is only necessary to define whether it is positive or negative logic, inverting or non-inverting. This is most easily achieved by putting the simplified AND truth within the symbol, thus nothing need be committed to memory: it speaks for itself.

By way of a field test I introduced my 10 year old son to my logic symbols. Within half an hour he could derive the waveforms out of any gate combination I gave him. (Previous knowledge of logic nil). With intentional logic it is necessary to define eight types of gate, with truth-table logic symbols, Fig. 2 gives a full definition. Simplicity is the name of the game.

J. E. Kennaugh,
Callington,
Cornwall.

I disagree with your correspondent, C. Hudson, over his proposal for intentional logic diagrams.

Whilst these may at first seem attractive from an academic viewpoint, in practice such circuitry can cause a good deal of confusion, particularly where multiple gate packages are in use. Consider for instance, a 7400 NAND gate split up in a circuit such that part is used as NAND, part is used as low-active OR, and the remainder as inverters. Under Mr Hudson's instructions, this results in three different drawings for the same device. A service technician trying to relate the drawing to a particular chip pack would have difficulty, without a great deal of cross-referencing. In addition, an increasing number of complex devices have inputs in which clock high and low could be equally considered to be active, since important but differing instructions are conveyed by each polarity. How would such an input be drawn?

Even if the traditional method of drawing diagrams is for some reason to be deplored, I consider that it should be retained on the basis that it is at least an established standard. To change symbols every time someone has a new idea is a recipe for annoying confusion.

To sum up, I would say that I consider Mr Hudson's proposals a change for the sake of change – rather like using Hertz for the perfectly acceptable c/s, and changing the spelling of enquiry to inquiry.

L. Hayward
Wareham
Dorset

TWINS PARADOX OF RELATIVITY

I refer to L. J. Higgins' letter (April 1981) in which I am accused of addressing myself to a "fundamental flaw" and also of imagining a "miraculous coincidence".

The first is easily disposed of, since the accusation is quite false and originates in Mr Higgins' failure to pay close attention to the text being discussed, in particular *W.W.* Oct. 1980 p.56., the first column of which cites Einstein's own activities and his words to which the second paragraph of my letter (January 1981) alluded. Thus Mr Higgins accuses Einstein, not me, of contriving a fundamental flaw.

I come now to the matter of coincidence and all that ensues.

The equation $FL/\frac{1}{2}v = mv$ shows how momentum is achieved. Unfortunately Newton did not know that material particles are held separate by interatomic forces and that, in consequence, *all* force acts at a distance, but today any competent radio engineer knows that the l.h.s. of the above equation represents the cumulative Doppler modification to an impressed force acting from a distance and having its origin fixed to some arbitarily stationary datum, motion and energy being of course related to that datum.

So we have two methods of obtaining the KE equation, the classical which is based upon an analogue with friction and this present one which depends upon Doppler. Being a physical description, the latter represents the application of negative feedback to ancient hypothesis, serving to convert that hypothesis into the form of unassailable physical description and allowing direct comparison with modern experimental results. This is an addition to the scientific method.

Even though the two methods of obtaining the KE equation differ so widely, each not mentioning what the other contains, they yield the same result which in its turn accords with experiment. The *fact* that the original derivation of the KE equation is in accord with experiment and also with the physical description is pure coincidence, nothing more.

I come next to the experimental facts which lead to the falsification of both the concept of variable time and the light postulate, thereby putting an end to the twins controversy.

When referring to J. C. Maxwell (Letters, February 1982), P. G. M. Dawe tells us that the mass increase hypothesis has been verified by experiment. He also inverts history by putting $E = MC^2$ before mass increase. In a linear particle accelerator the origin of the motive force is at rest relative to the machine and since the force acts at a distance its effect must be subject to first-order Doppler. This is a *physical fact*, which is never mentioned. If the force travelled at infinite velocity then the experiment would yield the Newtonian energy equation as its result.

However, in reality the force is known to move at the lesser velocity C and hence the declining effectiveness of the force with relative velocity is modified by a second-order term – coincidentally identical to the Lorentz transform.

Electron beam and linear particle accelerator experiments prove quite conclusively that mass is velocity-invariant. If, as Mr Dawe would have us believe, mass increase can be derived from $E = MC^2$ then either the mathematic or the derivation or the equation itself is wrong. The falsehood is proven by experiment.

Let us now contemplate the consequences of these things.

Mass increase is justified by the consideration of the elastic collision of two projectiles. Within this scenario the conclusion that mass is velocity-variant rests solely upon the stationary observer 'knowing that the clock of the moving participant of the experiment runs slower'.

If, as has earlier been shown, mass is velocity invariant then time is, inevitably, velocity-invariant as well.

In its turn the derivation showing time to be velocity variant rests entirely upon the assumption that the light postulate is true.

Because time is in fact velocity *invariant* there is no alternative but to accept that the light postulate is false.

The fact that an experimental result can appear to confirm the end product of a flight of pure fancy is indeed a miraculous coincidence. Should anyone question the fact that $E = MC^2$ is disproven, other than in the limited sense of mathematic equivalence, I would point out that the matter has never been tested directly due to insurmountable technical problems[1].

I suggest that Prof. H. Dingle's misgivings about atomic experiments were entirely justified because it has been shown that matter has never, on this planet, been converted into energy. We are left with the distinct risk that interconversion might one day accidentally occur and there exists neither mathematic nor experience to predict the outcome.

A valid alternative has been provided to replace S.R.T. and it is to be hoped that the scientists will emerge from behind their wall of icy silence and discuss the matter in terms which do not involve the double standards that thave been observed by I. Catt (Letters, February 1982).

Alex Jones,
Swanage,
Dorset.

Reference

J. Chappell. *S.S.T.* Vol. 2., No. 3, p.316-317.

AMATEUR LICENCES IN GERMANY

Just in case nobody else objects, may I correct V. A. Sancto's statement in your February issue.

Licence Class	Morse requirement	Amateur bands
B	60 letters p.m.	All amateur bands, most modes including telephony except 1815-1832 and the new 10, 18, 24 MHz bands which are telegraphy (A1A) only
A	30 letters p.m.	3520-3700 telegraphy 3600-3700 also telephony 21090-21150 telegraphy 28.0-29.7 MHz also telephony
C	none	v.h.f./u.h.f. only

H. Borsutzky,
Cologne,
W. Germany.

POWER TRANSISTOR FAILURE

I have some pulse-width-modulated switching output power amplifiers which deliver up to 18A at ± 170V into a d.c. motor and inductor of about 5 mH. The amplifiers have been unreliable over a long period, apparently random power-transistor failures occurring even after several hundred hours of operation.

The output stage uses parallel pairs of 2N6547 transistors (others have been tried), switching the load alternately between the supplies. Unmodulated switching rate is about 4 kHz, rise and fall times are typically 5μs, and the collectors are clamped at the total supply, i.e. 340V. During part of the cycle the collector-base junction is forward biased. There is active turn-off of the transistors.

Any light on the possible causes of failure will be appreciated.

I. E. Shepherd
Hydraulics Research Station
Wallingford
Oxfordshire

ORIGINS OF THE HIGH-POWER TRANSMITTER

It is now 90 years since Nicola Tesla delighted the eyes of engineers in Europe with demonstrations[1] of high-frequency discharges in gases. To obtain a voltage sufficiently high, he used what we now recognise as a loose-coupled transformer with tuned primary and self-resonant secondary, to step up the more modest levels obtainable from a high-frequency alternator and power transformer. To the more critical eye of today his circuit with its two spark gaps may seem a trifle over-complicated; but he also used a simpler arrangement with only one spark gap, powered from a low-frequency generator. Readers familiar with the circuits of early wireless transmitters, for example, that of Poldhu designed by Fleming ca 1900, would undoubtedly recognise some antecedent features. It may not be generally appreciated that Tesla himself suggested such an alternative application for his discharges: "I think that it may find practical applications in telegraphy. With such a brush it would be possible to send dispatches across the Atlantic (sic) . . ." It is clear from the contextual wording that Tesla was thinking more in terms of an ion or plasma beam than of any "etheric force"; and his later patent[2], though it includes what is recognisably an antenna, confirms this. He was probably aware of the telegraph based on atmospheric conduction proposed by Loomis and Ward[3] in the previous decade, which would certainly have benefited from a transmitter of phenomenal power. Though Tesla here seems to have had his head in the clouds, the practicality of his transformer engineering shows that his feet were certainly well grounded.

Hard on his heels we find another American (though Tesla was in fact Yugoslav), the engineer Elihu Thomson, describing [4] a similar circuit capable of providing the high potentials needed for testing electrical apparatus. This circuit appears to correspond to the simpler one of Tesla, and actually uses an air-blast at the spark-gap as suggested in Tesla's paper. As neither of these two engineers acknowledges the work of the other, we are left in some doubt as to which of them invented what. Unless earlier contenders appear, it is not unreasonable to allow them both to share the honours. Again, there is no mention of etheric telegraphy in Thomson's paper, nor in his subsequent patent [5]. And this indifference to the communication potentialities of his apparatus is the more surprising in that he had himself (it is alleged by Snyder[6]) practical experience of "Maxwell Electro-Magnetic Waves", and also had published [7] a joint account of his work with Edwin Houston on "The Alleged Etheric Force" demonstrated by Edison's experiments.

Wireless, therefore, waited for others to demonstrate viable communication, Lodge with his "syntonized" tuning and the entrepreneurial Marconi with an aerial. And only then, as wireless took off, did companies in search of higher spark power embody features of Tesla and Thomson circuits in almost every transmitter of consequence. With the subsequent demise of spark telegraphy, these features eventually vanished from wireless transmitters, though the blown spark-gap surfaced again in radar modulators in World War II [8, 9] and later still in photographic flash-gear [10]. Where then can we look today for the Tesla-Thomson "coil". Open up a "tickler" vacuum tester and you will find one; start up a xenon arc lamp and you will be using another. "Tesla Lives" is my centennial toast!

Desmond Thackeray
Music Department
University of Surrey

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HORN LOUDSPEAKER DESIGN

Bernard Jones' thoughtful letter (January, 1982) prompted me to re-examine my 1974 articles on horn loudspeaker design*, and in particular Fig. 13. The intention of this figure was to illustrate how a treble horn could be given a degree of directivity in the horizontal plane by modifying the standard circular cross section to be rectangular, with aspect ratio 2.5:1, but still ensuring that the area profile from throat to mouth followed a true exponential law (it could have been a tractrix law, but there are good reasons for avoiding tractrices at high audio frequencies).

I have re-checked my design calculations, and must agree with Mr Jones that on strictly mathematical grounds, neither vertical nor horizontal profile should fall inside the circular horn profile (in fact, the two sides of the rectangle should respectively be 1.12 and 2.8 times the radius of the circular horn). I began this particular design of horn with a circular throat to suit a circular loudspeaker, and my imperfect attempt at "fairing" from circular to rectangular cross-section has resulted in this anomaly. In practice, I can see that my artwork with damp plaster-of-Paris probably made the profile even more approximate at this point, but horns and ears are remarkably tolerant, and I doubt whether any colorations thus produced are audible, or if audible are at all obtrusive.

I can confirm Mr Jones' suspicions that treble horns give disappointing results unless mounted on baffles (hemisphere loading) to minimise diffraction effects. The sound quality from small piezo-electric tweeters (those fitted with integral plastic horns a few inches across) is very dependent on the mounting topography within a radius of up to 12 inches from the mouth.

Jack Dinsdale
Carlton
Bedfordshire

*March, May and June, 1974. Reprinted in High Fidelity Designs, volume 2.

CARTRIDGE ALIGNMENT

Good grief, Mr Frost (Letters, January), how will *Wireless World* ever graduate to promulgating the concept of pickup arm rigidity as an over-riding design concern if you want to introduce further, unnecessary bearings? It's not quite so specious an idea as the infamous thread-suspended pickup arm, but . . . As a final touch, perhaps the APT design team should develop it.

Keith Howard
Teddington
Middlesex

DIGITAL OPTICAL RECEIVERS

Dr Garrett concludes his review of receivers for optical fibre communication with the theory of digital reception and gives practical achievements with p-i-n diode/f.e.t. receivers

by Ian Garrett

In a receiver for a binary digital system, the aim is to process the signal in such a way as to be able to distinguish between two hypotheses, which we label zero and one, with the minimum possible error. In this way we seek the best estimate of the original message from the attentuated, distorted and noisy signal in the receiver. Commonly the signal is detected, amplified and filtered and then presented to a decision gate which is opened for a short interval at the centre of each bit period by a pulse from a clock circuit. This interval is called the decision time. Assume that, for a received zero bit, the receiver output voltage $v(0)$ at the decision time has a mean value m_0 and variance s_0, while for a received one, the mean is m_1 and the variance s_1, Fig. 9. Because the quantum noise is signal-dependent, s_0 and s_1 are different, in contrast to microwave transmission systems. Assume also for simplicity that $v(0)$ has a Gaussian distribution, although the multiplied quantum noise has in fact a compound Poisson distribution. The error probability is then

$$P_e = \tfrac{1}{2}\mathrm{erfc}\,(Q/\sqrt{2})$$

where $m_1 - m_0 = Q(s_1 + s_0)$. (1)

Graduating from Trinity College, Cambridge in 1965, Ian Garrett completed a PhD on radiation damage in metals in 1969. He joined the Post Office Research Department, now British Telecom Research Laboratories, as a Research Fellow working on the theory of chemical transport reactions. In 1971 he became group leader responsible for the preparation of compound semiconducting films and crystals. Since 1976 he has lead a section responsible for optical transmitters and receivers and integrated optical devices.

This says what difference there must be in optical power between the zero and one bits in terms of the noise (variances) and Q, which is related to the signal-to-noise ratio (in fact, $4Q^2$). The equation gives the value of Q needed for a given acceptable error rate. For example, $Q=6.00$ for $P_e=10^{-9}$; small changes in Q produce large changes in error rate. For design error rates of this magnitude, errors arise from the far tails of the noise distribution – six standard deviations away from the mean. That is why accurate models of noise statistics are important in optical systems. In fact the Gaussian approximation used here is successful at predicting error rate as a function of mean signal power, but is poor at giving the correct signal threshold level and the optimum avalanche gain, for this reason.

The theory of optical receivers enables calculation of m_0 and m_1, s_0 and s_1, in terms of the received optical waveform and the component values of the receiver. One can then predict the sensitivity of the receiver and model how it is affected by changes in receiver or system parameters. Details theoretical analyses are listed in the bibliography, and is only the very simplest case is considered here. If the received optical power $p(t)$ is p during a one-pulse and zero during a zero-pulse, the pulse energy for a one-pulse b_1 is pT and for a zero-pulse b_0 is zero. The photocurrent (i_p) is then $\eta qMp/h\nu$ during a one-pulse and zero during a zero pulse. This current is filtered by the receiver front-end.

A typical circuit is shown in Fig. 9 with the equivalent circuit for noise analysis. The photocurrent is then amplified and passed through an equalizing and band-limiting filter $H(f)$ resulting in an output voltage $<v_{out}>$, which corresponds to m_1 or m_0.

The noise sources which contribute to s_0 and s_1 are the amplifier thermal noise, the multiplied quantum noise and excess avalanche noise, and the shot noise on the photodiode dark current. The mean-square noise voltage at the receiver output may be expressed as:

$$<v_n^2> = (h\nu\eta)^2[M^xTI_2(<i_p^2> + I_d)/q + Z/M^2] \quad (2)$$

in which T is the bit-time, M is the current gain of the photodiode, I_2 is a dimensionless bandwidth integral of order unity, I_d is the dark current, and Z is a dimensionless parameter characterizing the amplifier noise. In fact, Z is the r.m.s. amplifier noise voltage normalized with respect to

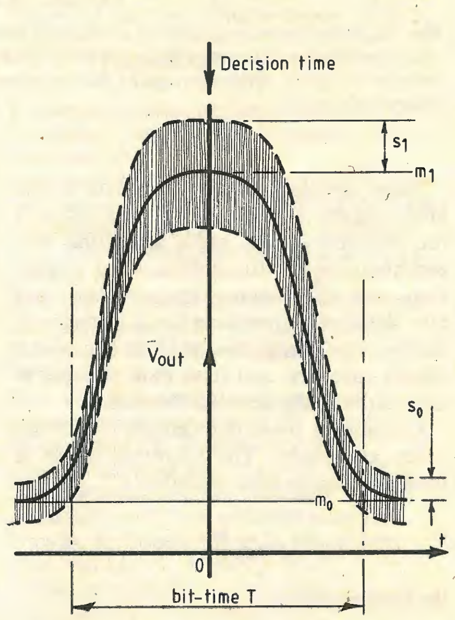

Fig. 9. In the unfiltered output pulse from an optical receiver, the shaded region indicates the variance (mean-square noise voltage), shown to depend on signal level. Mean levels m_1 and m_1 correspond to zero and one bits (spaces and marks). Pulse is slightly dispersed so that some energy is outside the bit-time T.

the receiver's response to one photoelectron. Typical values are 10^5 at a few Mbits/s to 10^7 at a few hundred Mbits/s. This equation also assumes that m_1 has been normalized to be equal to b_1, the optical energy for a one pulse.

Shortly before this article went to press, British Telecom Research Laboratories at Martlesham Heath announced the transmission in the laboratory of an optical signal capable of carrying nearly 2000 simultaneous telephone calls over 102 km of optical fibre, without the need for intermediate repeaters. Operating at 160Mbaud, this is the longest single-span fibre system yet demonstrated. Many of the critical components were made in British Telecom's laboratories at Martlesham, including the very low-loss fibre and the receiver, which is the most sensitive in the world at wavelengths between 1.3 and 1.6 μm. A InGaAs/InP p-i-n diode, of the sort described in this article, with a Plessey GAT4 m.e.s.f.e.t. were used for the critical first-stage amplifier.

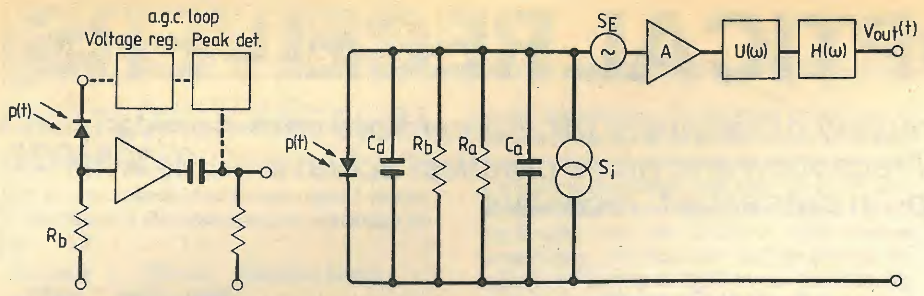

Fig. 10. In this typical circuit for an optical receiver the broken-line connections and the peak detector and voltage regulator are only necessary if an avalanche photodiode is used to control the gain. Noise model of the receiver shows principle noise sources and equalizing filters (see text).

More detailed treatments listed in the bibliography take into account the shape of the received pulses, pulse spreading into neighbouring bit-times because of dispersion, and other system impairments, and give detailed expressions for Z in terms of the receiver components. Here consider a simple case first and then look at some of the results of the detailed theories.

Consider a p-i-n photodiode which has unity gain only. The quantum noise is insignificant, so from equation 2:

$$s_1=s_0=\frac{h\nu}{\eta}\sqrt{Z}$$

so from equation 1:

$$m_1=b_1=2Q\frac{h\nu}{\eta\nu}\sqrt{Z}.$$

With typical component values, Z might be 10^6. So with $Q=6$, we need 12,000 photogenerated electrons per one-pulse, in agreement with the earlier rough calculation. Using discrete components, a unity-gain photodiode provides a receiver sensitivity typically 10 to 15 dB worse than an avalanche diode. However, by hybrid integrating the p-i-n diode with the first amplifier stage using a gallium arsenide m.e.s.f.e.t., the input capacitance of the receiver can be reduced so that Z falls to 10,000 or less. The receiver noise parameter Z is proportional to C^2/g_m, at high data rates where C is the total input capacitance (photodiode, gate-source and stray capacitance) and g_m is the transconductance. In state-of-the-art receivers, C is around 0.5pF and g_m is 20 ms. Such receivers have a sensitivity of −44.2dBm at 160Mbaud and −40.1dBm at 294Mbaud, at 1.3μm wavelength, and similar sensitivity at 1.55μm, better than that of a.p.d. receivers. The p-i-n/f.e.t. hybrid approach also offers the advantages of low-voltage operation, no need for feedback to control the avalanche gain, simpler device technology and probably greater reliability. Typical photodiodes, for use in p-i-n/f.e.t. receivers are shown in the first part of this article. The receiver uses a high impedance (integration) front-end amplifier for the best performance, although a trans-impedance amplifier could be used with a slight penalty. The integrating characteristic (time constant typically 1000 times the bit period) has to be equalized, which can be done simply by differentiating with a capacitor-resistor arrangement. Fig. 11 shows a typical receiver module.

Fig. 11. Hybrid p-i-n f.e.t. integrated optical receiver for high data rates, say 30Mbits/s upwards in a standard 14-pin d-i-l package is the most sensitive so far for the range 1 to 1.6 μm. Input fibre tail, visible at the top left, enters package and passes through glass block supporting the photodiode vertically so that it can be illuminated through the substrate. The thick-film circuit comprises a GaAs m.e.s.f.e.t. input stage with bipolar shunt feedback and emitter-follower stages.

Look now at how the sensitivity is reduced by the reverse bias leakage of the photodiode. Fig. 12 shows some theoretical results for the mean number of photoelectrons required per bit time n and optimum avalanche gain M as a function of the number N_d of dark current electrons per bit-time. Parameter x is the excess noise exponent of the a.p.d. and Fig. 12 is calculated assuming $Z=10^6$, typical of a receiver using discrete components at a few hundred Mbaud, and with zero optical power on zero-pulses and no pulse spreading.

It can be seen that when the dark current is negligible, we need about 300 to 1500 photons per bit-time, depending on the noise properties of the photodiode. When the dark current is large, the number of photons per bit-time which is needed is roughly proportional to the square root of the number of dark current electrons. The noise properties of the diode become far less important. This is hardly surprising as the dominant noise is then the shot noise on the dark current, and both are subject to the excess noise of the photodiode. The optimum gain decreases markedly once the dark current becomes a significant noise source.

Clearly it is important to minimize N_d and to a lesser extent to reduce x. Note that a leakage current of 160 nA gives N_d of 1000 at 1Gbaud, which is large enough to affect the optimum gain and the receiver sensitivity. At lower data rates the effect would be greater still.

Fig. 13 shows how n and M vary with extinction ratio ϵ and pulse spreading (extinction ratio is the mean power on zero-pulse divided by the mean power on one-pulse; if it is not zero the optical power on the zero level contributes to the noise s_0). The pulse spreading is represented by α, the normalized r.m.s. width of the fibre impulse response, assumed to be gaussian. The pulse originally launched into the fibre is taken to be rectangular and to occupy half the bit-time, and the dark current is assumed to be zero. Notice that the receiver sensitivity is strongly affected by pulse spreading and by non-zero extinction, and the optimum gain is reduced by zero-level noise and by fibre dispersion, the effect being greatest when x is small.

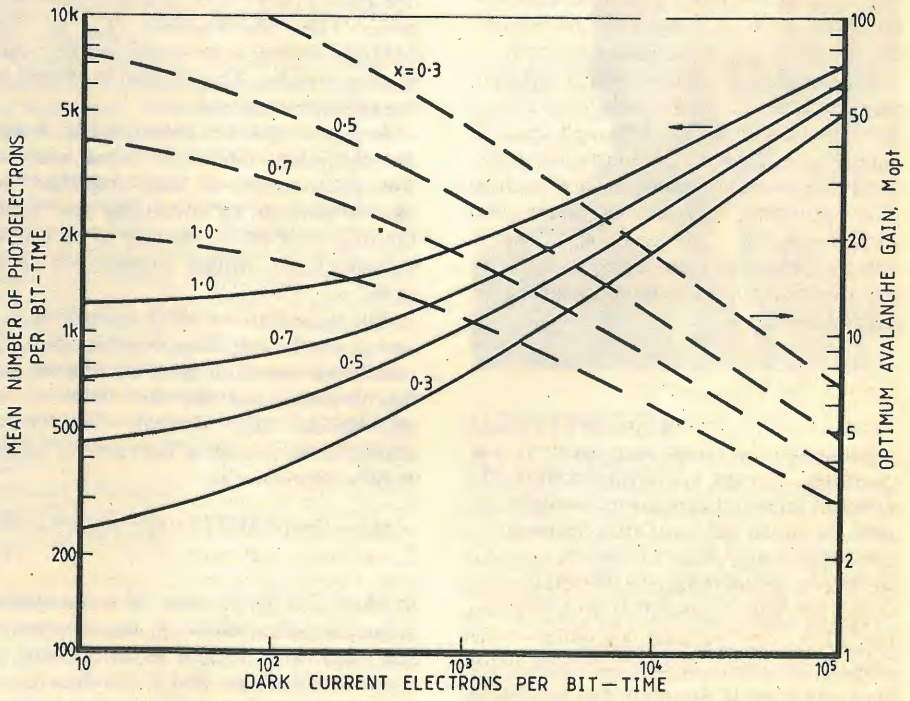

Fig. 12. Receiver sensitivity and optimum avalanche gain as functions of the number of dark current electron per bit-time (see text)

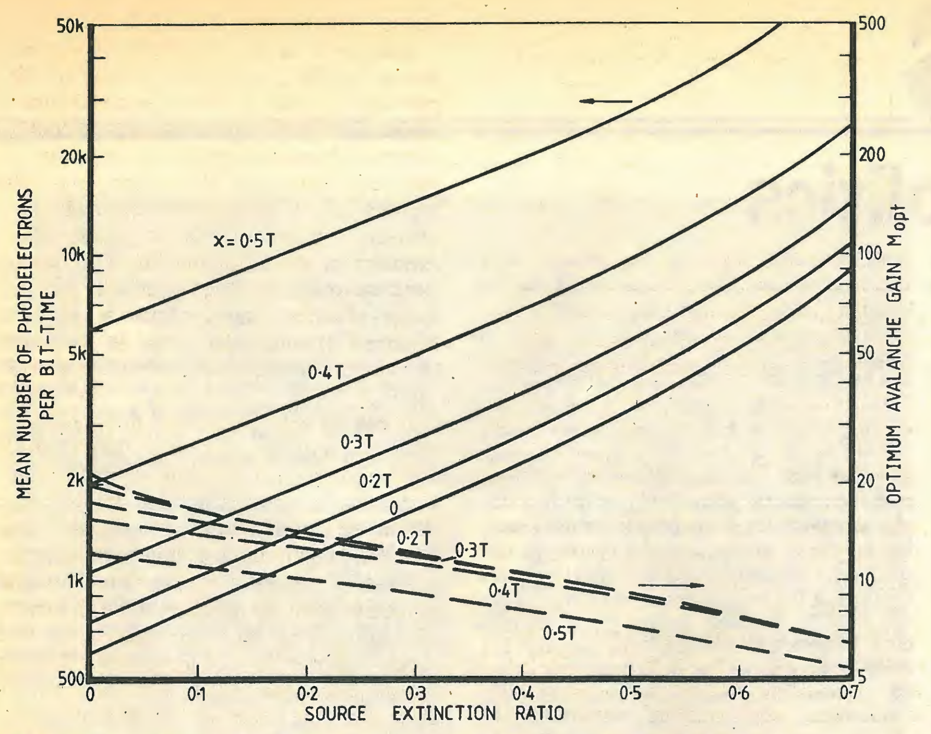

Fig. 13. Receiver sensitivity and optimum avalanche gain as functions of the source extinction ratio, assuming a value of unity for the excess noise factor exponent x. Parameter α is the r.m.s. width of the impulse response of the fibre normalized to the bit-time T, and assumed to be Gaussian for convenience in calculation, ie it is a measure of the bandwidth of the fibre.

This type of calculation, which assumes gaussian noise statistics, tends to over-estimate the optimum gain although relative magnitudes are predicted more accurately. Obviously, combinations of appreciable pulse spreading, non-zero extinction and considerable dark current (N_d=100000) reduces the receiver sensitivity very much, and also reduce the optimum avalanche gain to near unity.

Future developments

There are some obvious approaches to improving the sensitivity of present optical receivers. The p-i-n f.e.t., currently the most suitable for the important wavelength range 1 to 1.6 μm, can be improved by reducing c^2/g_m; that is by developing small-area photodiodes (30 μm diameter), very short f.e.t. gates (0.3 μm), and by increasing the transconductance. The mixed compound InGaAs may be a better f.e.t. material than GaAs in the future because of its high carrier mobility, particularly if it can be cooled, and it would also permit monolithic integration of the f.e.t., the photodiode, and eventually other receiver components. Between 5 and 8 dB could be gained here. Avalanche photodiodes could offer some improvement, at least over present day p-i-n f.e.ts, if a low-noise material could be found. Recent work on (CdHg)Te looks promising, although it is at a very early stage of development yet.

A third possibility is to amplify the optical signal before detection, using a Fabry-Perot or a travelling-wave amplifier. These devices would be similar in structure to injection lasers; their biggest problems are noise due to spontaneous emission which can be reduced only with a very narrow-band optical filter, and gain saturation in the case of the Fabry-Perot amplifier. An optical amplifier is an almost essential component for optical integration of any useful complexity, so there is considerable incentive to overcome these problems.

Finally, one may consider coherent optical transmission systems with heterodyne detection. The outstanding problems here are: divising an optical source and local oscillator with sufficiently narrow line-width; tracking the local oscillator; obtaining spatial coherence of the signal and local oscillator when they are mixed on the photodiode; and controlling the polarization of the receiver optical signal. The pay-off for overcoming this daunting list of problems is not only increased receiver sensitivity (10 to 15 dB possibly), but the familiar advantages of using the frequency and phase information on the carrier which is present optical communication systems is lost. □

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In brief . . .

Technician engineers change their image. The term 'technician engineer' was coined to cater for the non-chartered electrical and electronics engineer. But the IEETE feel the name has become confused with the general description 'technician' and that this may be a stumbling block to the understanding of the role played by their corporate members. So they will call themselves the Institution of Electrical and Electronics Incorporated Engineers, as a reflection of a professional body incorporated other than by charter, and which requires a specific level of achievement and qualification for its membership. Corporate members are now entitled to call themselves Incorporated Engineers (Electrical and Electronics) and to use the letters FIElecIE or MIElecIE.

NEWS

Cables and politics

A broadband cable system connected to all houses in urban areas and covering about half the population is the recommendation of the Government's IT Advisory Panel. Although all the services to be provided are not specified, it is suggested that the system should include tv channels, f.m. radio channels, and the panel also recommends that the system should have a two-way link which would allow any information service to be interactive, to include such facilities as links with a bank account or electronic shopping. There could also be monitoring of premises against burglary or fire and the emergency services could be summoned automatically if needed.

The scheme involves an entirely new network as the existing telephone network does not offer sufficient bandwidth. It could link in with those British Telecom networks which are of sufficient bandwidth and thus be provided with packet switching. Each home would be fed through a cable, probably coaxial, with channel selection provided at the distribution point which would have the full bandwidth service and would be able to serve up to 100 houses.

In arguing for urgency, the panel say that existing cable distribution networks are ceasing to have much value when the country is well provided with broadcasting transmitters. The panel believes that cable would be the best way of distributing the direct broadcasts from satellites; the PAL system comes out of patent restrictions at the end of 1983 and could lead to a flooding in the large-screen tv market of cheap sets from the Far East, leading to the downfall of our domestic tv manufacturing industry. If a decision were taken for an early launch of the cable system, the telecommunications industries involved would get a boost and a world lead with the possibility of high exports.

One of the pre-requisites for such a system is that current restrictions should be withdrawn and that potential information providers or broadcasters be allowed to transmit whatever they like, within the bounds of decency or sedition. There should be a self-regulating body similar to those in advertising and in newspapers.

But as the panel believes that the system should be self-financing, requiring no public funds at all, it sees a further need for urgency. The system should be at an advanced stage of planning before the next General Election before a possible change of Government could lead to a change in policy, so that potential investors, especially programme providers, can be assured of a return on their investment.

Satellite tv gets go-ahead

On the fourth of March, the Home Secretary, William Whitelaw, announced in the House of Commons that the country should make an early start with direct broadcasting by satellite (DBS), with the aim of having a service in operation by 1886. Because of the importance of making this early start, the Government had concluded that the best course would be to start with two channels initially, though this could be increased later to the maximum of five channels permitted by international allocation. The services would be transmitted at powers sufficent for individual reception and for community reception with cable distribution.

The system is to be financed privately, and there were indications that there were interested participants in the aerospace and electronics industries who were ready to pay a part.

As far as the programmes were concerned it had been decided to award both DBS channels to the BBC as they had already formulated proposals for the programming of such channels. One channel would be a subscription service including a substantial element of feature films and major sporting, cultural and other events not presently available for transmission through the usual channels. The other would be a service which would draw on the best tv programmes from around the world, and would probably be financed by a supplementary licence fee.

The Home Secretary said that although the IBA and commercial television companies had also shown some interest in providing DBS services, "their plans were less well advanced. Additionally, more time would be needed to devise the right framework, which would be likely to involve legislation".

But the IBA say that their proposals for satellite broadcasting are as well prepared as any from the BBC. Following the Government study document on DBS last year, the IBA has argued for the use of satellites to improve picture quality and for the need to have uniform standards throughout Europe, because of the overlap of satellite footprints. IBA engineers have developed the multiplexed analogue component technique for satellite broadcasting which overcomes the problems of incompatibility between the different colour systems in Europe, providing a single 625-line system with clearer pictures than are presently available on television receivers, and with multi-channel sound. Only one design for an adaptor unit would be required throughout Europe. They also argued that they had more commercial experience which would be useful for organising a subscription service.

Following immediately on the Home Secretary's announcement, British Aerospace, Marconi and British Telecom made a joint announcement that they would take equal shares in a new company, United Satellites, to provide Britain's first national broadcasting and telecommunications satellite system. The three companies had already investigated potential markets, and the technical and operational means needed both in the long and short term. The system would probably have the capacity for two tv channels and three or four communications channels. There could be sufficent bandwidth to transmit high-definition tv and digital sound channels and the possibility of transmitting a Prestel-type service this way could also be possible. Discussions with broadcasting and telecommunications organisations will define the facilities to be provided. The satellites will be leased to the users.

The satellite, to be known as Halley 1, as the 1986 launch will coincide with the appearance of Halley's Comet, is likely to be of a similar type to the European Communications Satellite (ECS) and it is planned to have two satellites in orbit, with the second as a standby and a third on the ground ready for launching.

United Satellites hope to sell their satellites around the world and believe there is a potential market for up to 100 of them.

● The IBA is participating in the experimental European service, organized within the EBU. The five-week tv experiment, to start at the end of this month, includes four sound channels, each with a different language and the IBA's teletext system for sub-titling. The closed-circuit service is to be transmitted using a mobile dish antenna via the ESA orbital test satellite.

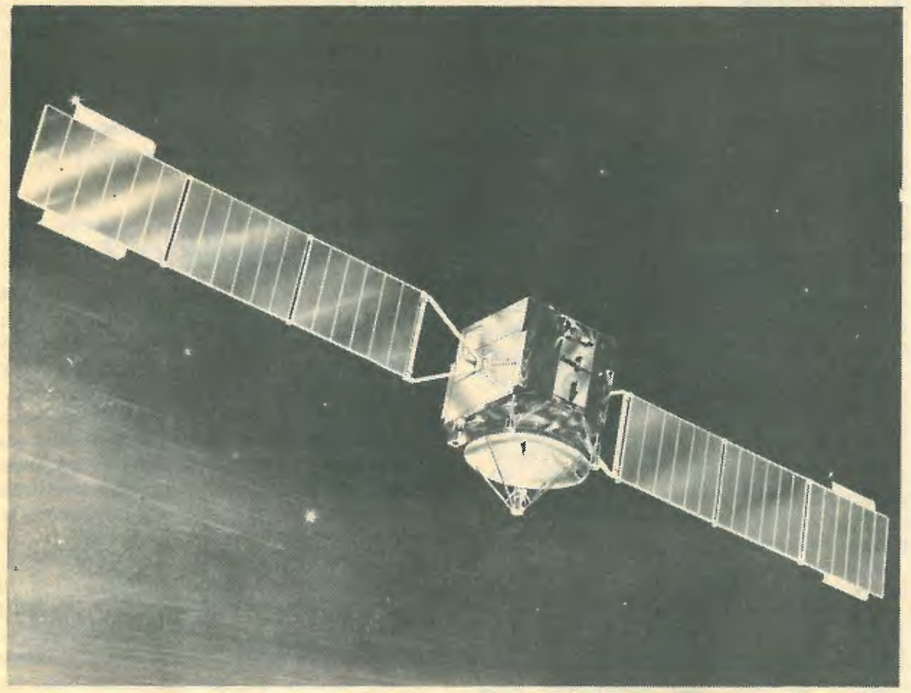
A Pan-European service is due to be launched in 1986 and the IBA has suggested that the all-British satellite should carry that service.

Maritime satellite gets sunstroke

What was to have been a blaze of publicity when the Minister for Information Technology, Mr Kenneth Baker, was to have made the first shore-to-ship telephone call by way of the new Marecs-A maritime satellite, turned into a bit of a damp squib when it was announced that the satellite had certain anomalies which needed to be sorted out before it became fully operational.

The anomalies had been caused by an overactive sun which had produced an unusually high number of sunspots. Sunspots emit high-energy particles which when they encounter a satellite can electrostatically charge the outer thermal blanket of the spacecraft. As different surfaces are charged at different levels, this can give rise to arcing and if any electromagnetic disturbance penetrates the screening this can cause spurious pulses in the electronics. The first occasion on which this happened in Marecs-A, it caused the orientation system to think that it had lost contact with the earth. It automatically went into a 'search' mode when it rotated slowly to find the earth again. This manoeuvre took eight hours before contact was re-established and this caused a whole series of checks to be carried out to assure the ground controllers and users that all was well. It was not possible to complete these checks before the official inauguration of the service. Since then, there have been further small 'glitches' caused by sunspot activity.

A major event during the initialisation of the satellite was the failure of two modules in the battery discharge regulator. Standby modules were switched in, but there is no further replacements for these components. A spokesman from British Aerospace told us that although it was worrying to lose the redundancy factor so early into the mission they were confident that this would have no effect on the planned life of the satellite of seven years and more. They were investigating the cause of the failure, and of the anomalous behaviour of the vehicle in order to build additional safeguards into Marecs-B which is to occupy a geosynchronous orbit over the Pacific Ocean.



Marecs – A maritime communications satellite suffering from anomalies caused by an overactive sun.

The two Marecs spacecraft in conjunction with an Intelsat V over the Indian Ocean offer a ship-to-shore telecommunications system which covers all the oceans. Marecs-A is the first European Space Agency's communications satellite to enter commercial service. It is also the first to be dedicated to merchant shipping, and the first to be leased by ESA to an international organisation, Inmarsat.

Marecs offers some 40 telephone circuits, four times the capacity of the Marisat satellite it replaces. It is also 11 degrees further west than Marisat and so can cover the western part of the Gulf of Mexico and some of the eastern Pacific. In addition to telephone contact the satellite can be used to receive and transmit telex, facsimile and digital data links. There is also a special emergency signal link.

In order for the satellite to operate efficiently, as much attention needs to be made to the coastal receiving stations as to the on-board system. Europe's first maritime communications station has been inaugurated at Eik, southwest Norway. Eik is the fifth in the global satellite system of earth stations and another 14 are planned including one at Goonhilly, Cornwall which will be commissioned by mid 1982.

3-D spectacle

The first British broadcast of 3-D tv takes place on May 4th at 19.00h over the transmitters of TVS, the Southern region ITV company. This follows the four 3-D tv programmes transmitted over Norddeutscher Rundfunk in West Germany, the first of which was on February 28th. TVS is negotiating rights to some of the German material, and also producing some original British material. The British programme, one of the weekly series *The Real World*, deals with three-dimensional images in general, and the 3-D inserts are being used for illustrative purposes.

The system being used for these transmissions is the old and imperfect method of 'anaglyph stereo': that is, separation of the two images is achieved by colour coding, and the viewer has to wear red-and-green spectacles. This is clearly not a system with any prospect of future acceptance as a practical method for broadcast stereo. It is however at the present time the *only* method by which stereo images can be broadcast, pending future technical developments. Consent has accordingly been given by the IBA to TVS transmission as a one-off experiment.

IBA consent was required because the anaglyph system is non-compatible: 3-D can only be seen by viewers with colour receivers. Viewers with black-and-white sets will merely see a pair of overlapping images, whether or not they look through the spectacles. And viewers who don't have the anaglyph specs will also see merely a pair of flat images.

Colour scenes cannot be transmitted, since the colour-coding is already being used for 3-D separation. The left-eye image is put out on the red channel and the red tube phosphors, and the right-eye view in green plus blue.

In fact, if a colour scene is coded in this way, a certain sensation of the colours of the scene is retained even through the red/green glasses, as the brain attempts to add together the differing information received from each eye. But ambiguity and some discomfort is caused by any brightly-coloured objects; for instance a red dress will appear bright to the left eye but dark to the right eye. Without spectacles however the scene appears relatively normal in colour values. Experiments are now being made in the transfer of colour scenes, but none are expected to be included in the first British transmission.

The research behind the German programmes has been carried out in the Eindhoven laboratories of Philips Ltd. Anaglyph image separation on tv is at best imperfect, since the green phosphors on tv tubes have quite a high red content. This means that 'crosstalk' is introduced: the left eye sees some of the green image, which should be confined to the right eye. In addition, colour coding within the PAL transmission system is itself imperfect, and allows some spread of colour information to the wrong guns. Philips have developed a method of coding the master video tapes, which at present remains secret, to eliminate this overlap and ensure the best possible separation of the two images that can be obtained within the PAL system.

The greatest problem remains the provision of the red/green anaglyph spectacles. TVS has obtained half a million of these cardboard lorgnettes, and are distributing one in every copy of *TV Times* in the Southern region. Even so, it seems there will be at best one viewing device to each set, so the programme is being scripted to allow time for it to be passed from hand to hand. The programme cannot of course be networked outside the Southern region, because of the lack of sufficent spectacles. Lucky viewers outside the region who are able to pick up TVS programmes will have to make their own arrangements to get hold of a pair of anaglyph specs.

Viewers who have seen the German programmes agree that in spite of the limitations, the results are remarkably successful; the crosstalk or double-imaging only becomes worrying when the normal, rather restricted, depth range for any scene is exceeded. And the 3-D scenes, particularly in the 'live' studio sequences, are certainly good enough to serve as a glimpse into the future. The people in the studio scenes, even in black-and-white, look much more like rounded human beings than the usual 'flat' tv images.

Mercury and British Telecom

The consortium of Cable and Wireless, British Petroleum and Barclays Merchant Bank have been given a licence to operate a private telecommunications system in the UK. The system, to be known as Mercury, will have access to the public switched network when 'appropriate terms' have been established. It will also provide an earth station for business telecommunications via satellite. The licence has been granted for a period of up to 25 years with provisions for review. Patrick Jenkin, Secretary of State for Industry said that "the British Telecommunications Act 1981 and the licence have been structured in a way to enable the Government to ensure that both British Telecom and the licensee co-exist and compete to generate new services and job opportunities and to enhance customer choice within the UK while increasing the national share of the world telecommunications market".

It seems that the competition has already started with BT cutting its charges on some of the main trunk lines joining the main business and industrial centres. The principal reason for instituting Mercury was the high cost of trunk calls.

All this may be thrown into the melting pot if the telecommunications network is to be bound in with the proposed tv cable system. Iain Carson reports in *The Observer* that the Government is to introduce a new Telecommunications Bill towards the end of the year. The Bill will propose the selling of about half the shares of BT to the public and to establish a new telecommunications authority to oversee the provision of cable tv, telephone, data and electronic mail links. The so-called Busby Bonds, announced by the Chancellor in the Budget with which it was planned to inject public investment into BT, are now likely to be replaced by the much wider de-nationalisation. BT say the report is "pure speculation".

Bildschirmtext

At the heart of Prestel is the GEC 4080 computer which uses its own language, Babbage. With a five-year lead over any rivals, GEC must have felt that they had a very good chance in the world's markets and particularly in Europe. Their confidence received a severe blow, however, when the West German Bundespost placed an order worth several millions with IBM. What was even more galling was that IBM have not demonstrated any system in public.

The GEC equipment has undergone a field trial in Germany, and the Bundespost has selected a Prestel-compatible system, as recommended by the CEPT, but the selection of an IBM system means that IBM will have to write all the software by the contract deadline in 1983.

Sweden in space by 1984

Sweden's Space Corporation is likely to be given the krona it requested for this year's space research programme, more than double the 1979/80 figure. About half of this will be contributed to the European Space Agency where Sweden collaborates actively in the programmes of research. But its national programme includes its own space research where the largest project is the Viking satellite, to be launched by Ariane in 1984 for North Pole magnetosphere studies, as well as the industrial Tele-X project. Due for launch in 1986 from Guyane Space Centre, South America, Tele-X is an experimental telecommunication satellite that will have pre-operational direct broadcast application. And it will provide high-speed digital communication for inter-office links, a teletype service to mobile stations in vehicles, and propagation measurements in the 20-30GHz band for high-speed digital data communication, as well as wideband services.

Monitoring oil spillages is the chief application of the Corporation's other main programme – in remote sensing. Marine surveillance from aircraft determines oil thickness and volume, a microwave radiometer while a laser fluorosensor classifies oil type, this information being transmitted to oil combat vessels. Remote sensors also monitor ocean ice distribution and thickness, atmospheric pollution and map vegetation, deserts and lake water to study seasonal changes.

- The Corporation manages the Esrange station which receives, processes, stores and distributes images from ESA satellites in the Earthnet scheme, and regularly collects data from Landsat. The station conducts ionospheric soundings to give investigate electron density profile (see *WW* February issue, page 37).

Where is Chernobilsky?

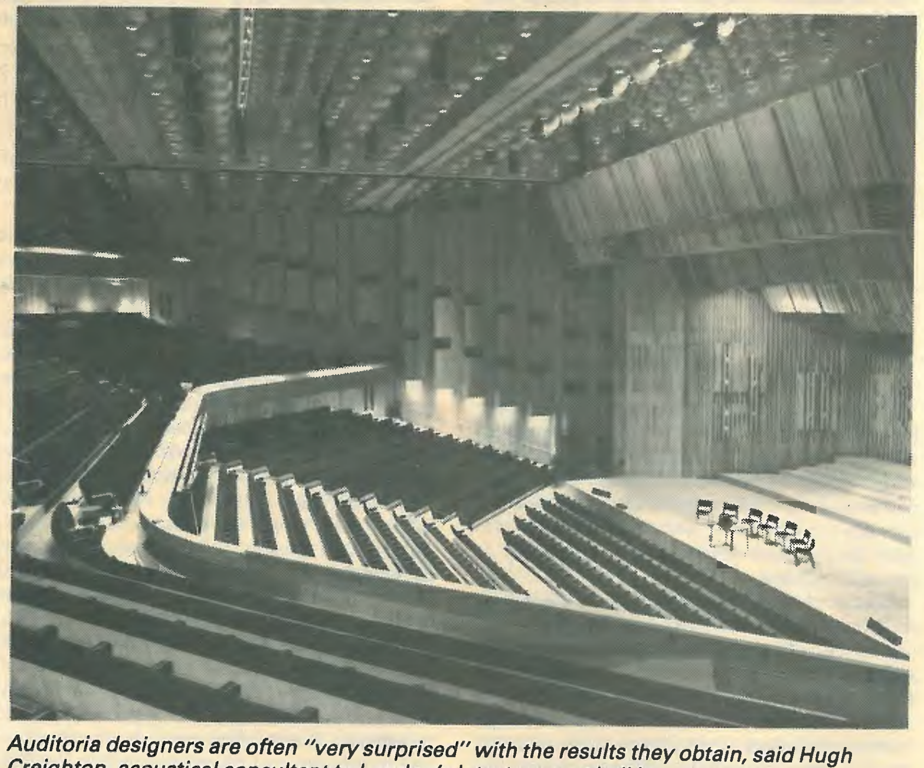
The position of the Russian electronics engineer Boris Chernobilsky who, as we reported in October 1981, page 70, was being harassed by the KGB, is giving his wife Elena great cause for alarm. After his harassment and arrest on a relatively trivial charge (hitting a policeman) Chernobilsky was sentenced to one year's imprisonment in a corrective labour camp, much against the wishes of the court, who came under a great deal of public pressure to relax the intended five-year sentence. The court sentence was that Chernobilsky be taken to the labour camp immediately, but instead was held in prison for two months, whereupon he disappeared. According to our informant, he started his journey to the camp many weeks ago, but neither his destination nor present whereabouts are known, in spite of a telegram from his wife to L. Brezhnev, and other Soviet leaders, to which she has had no reply. His wife and friends fear that the KGB are victimizing Chernobilsky because he was awarded a 'light' sentence, and that his health will be damaged by the extremely severe conditions on the journey and in the labour camp.

BBC micro

The gremlins got into the BBC micro program listings at the Paisley Microelectronics Educational Development Centre, John Gordon tells us. Routine (f) on page 82, March issue, should be

```
 500 PROCTAXCALC(450,100)
 600 PRINT tax_to_pay
 700 END
1000 DEF PROCTAXCALC(total_
     pay,tax_allowance)
1010 LOCAL pay_left,pay_
     this_rate,rate
1020 tax_to_pay=0:pay_left=
     total_pay - tax_
     allowance:rate=0.1
1030 REPEAT
1040   IF pay_left>100 THEN
       pay_this_rate=100
       ELSE pay_this_rate=
       pay_left
1050   tax_to_pay=tax_to_
       pay + rate*pay_this_
       rate
1060   rate=rate+0.1
1070   pay_left=pay_left -
       pay_this_rate
1080 UNTIL pay_left<0.1
1090 ENDPROC
```

It is useful to use lower-case characters for datanames he points out: this gets round the problem of BASIC keywords appearing at the beginning of a dataname.



Auditoria designers are often "very surprised" with the results they obtain, said Hugh Creighton, acoustical consultant to London's latest concert hall in answer to our question about reverberation time turning out lower than planned. "Hall acoustics is not a complete science" he reminded us, "but design guided by science". For although r.t. had been calculated from the hall's volume and absorbencies to be 1.8 seconds, it turned out to measure only 1.4. But the simple expedient of adding hardboard to the backs of the (fixed) seats increased the figure to 1.6 seconds, or 1.9 with an audience. And that seems to satisfy the LSO, according to a spokesman, for whom it was designed. A height restriction meant that the concrete roof beams protrude into the auditorium, their disruptive effect being reduced by the suspension of some 1,000 diffusing spheres (some also acting as lighting fittings) open at both ends to prevent undue aborption. And while siting the hell close to the foundations of the Barbican complex may reduce the vibration due to the nearby underground railway, it didn't obviate the need to re-lay the tracks and mount them on rubber.

EPROM 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 shown in this second of two 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

On entering the program one is given the system options and prompted to reply either Y (yes) or N. Next the addresses are requested in hexadecimal numbering, starting from 0000. If the e.p.r.o.m. already has data in the first 256 locations the starting address must be given as 0100, even though it is intended to reside at, say, DCBO. Options and addresses are displayed on the monitor screen. When sufficient information has been given the program repeats the e.p.r.o.m. type and prompts you to press G (go). At this point the scratchpad has been loaded with data relevant to the e.p.r.o.m. selected and whether it is in read or write mode, as defined by the options on entering the program. (A changeover d.i.l. switch is needed to select the 2708 rails; for convenience this was fitted to the plug-in card carrying the socket together with a jack for the program voltage.)

Scratchpad data is loaded by the index register as though it represented addresses; this seems to be the quickest method of loading for the 6800. Data stored in the scratchpad is given in the panel and explained as follows. The device code in ASCII enables it to be displayed on the monitor screen and serves as a check that the scratchpad has been loaded correctly. Number 04 signals the end of the ASCII data. The term "pin profiles" is one I've coined to define the logic levels on a port which are independently varied within a program. The existing address port is insufficient to drive the e.p.r.o.m., which needs 12 lines, so some are borrowed from the control port. By OR-ing the pin-profile with the other data the port will support the two functions. For example, during a read operation the address part of the port will be changing and the levels on the control will be static, during write the control part will change from pulse-off→pulse-on→pulse-off during each changed address. The loops will normally =1, except when the 2708 is being programmed which requires 200 loops. It is not permissible to apply N pulses to one location and move on. The number of loops may be varied in the range 100 to 1000, depending on the pulse width; N = 200 was chosen for convenience in generating the timing. Locations E,F contain a number which is used with the index register and decremented to zero. The time at the pulse output (port) should be measured with a universal counter or an accurate 'scope since it depends on the software route taken by the programmer, as well as the system clock frequency. Random access memory addresses determine the area of the system memory that will be written to or read from. The e.p.r.o.m. start/finish enables part-used ones to be added to. This is not to be done with 2708s as already explained. The control word is either 80 (port B is output, so write e.p.r.o.m.) or 82 (port B is input, so read e.p.r.o.m.) which shows the ease of using the 8255 in mode 0. (Other numbers in the control register will cause all kinds of trouble).

The shorthand CAD and CAP were useful since they are frequently referred to in the software. The "loops left" is loaded with the value of the loops at location A and decremented on starting at the first e.p.r.o.m address, i.e. when CAP is set to the address at 14,15. In the case of a 2708, this will now represent a value greater than 1, so the same addresses must be programmed again until 1E reaches zero. For reading an e.p.r.o.m. whether dumping the contents into r.a.m. or checking a program cycle, the loop facility is not needed as the program will exit when either CAD or CAP reach the respective addresses in 12,13 or 16,17. Thus the programmer should ensure that whichever is the smaller number of locations will cause the program to exit. The last three locations are loops-left, as explained, and the error address, to be explained later.

Port control. Since the software controls the 8255 it is essential to check that all is well before proceeding. The sequence is as follows. Select the e.p.r.o.m. type, the mode (read/write), as well as the addresses for both e.p.r.o.m. and system r.a.m. The program responds by displaying the type in four decimal figures followed by the prompt to press G. There are two chances to get this right: it's frustrating to enter the data again just because you accidentally touch the space-bar. Before the program starts the control port is checked for either 80 or 82, since other numbers will cause chaos. At this point the scratchpad has been checked twice; once visually by the user and once in software to fairly tight margins (2/256). Any error should be resolved by starting again. After a program sequence the 8255 is put into the read mode and the data is compared with the r.a.m. area specified. Any error will store the error address at the scratchpad 1F,20 locations. A message is written on the screen to invite inspection – the system 'errors' each time at the last address (which proves it's working) since to program one e.p.r.o.m. location, say 01F2, requires the user to enter ep.r.o.m start = 01F2 and, logically, e.p.r.o.m. finish 01F3.

Reading an e.p.r.o.m. This is the easiest part. Select the appropriate pin supplies

Scratchpad data defined. Location of the scratchpad is at the option of the programmer.

0, 1, 2, 3	Device code in ASCII	32 37 30 38 for 2708
4, 5	EOT code and blank	04 00
6	'read'	pin profiles e.g. as in Table 1
7	'progam'	
8	'pulse-on'	
9	–	
A	Loops = 1 except for 2708 = hex equivalent of 200	
B	– (normally blank, except during verify)	
C, D	Maximum bytes, could be used to check 'space available'	
E, F	delay = pulse time	
10, 11	r.a.m. start address	Entered by user; 'start' must be lower number than the 'finish' number
12, 13	r.a.m. finish	
14, 15	e.p.r.o.m. start	
16, 17	e.p.r.o.m. finish	
18	8255 control word	
19	–	
1A, 1B	Current address data (CAD)	
1C, 1D	Current address p.r.o.m. (CAP)	
1E	Loops left	
1F, 20	Error address – in hex (could be converted to ASCII if screen display required)	

using the small d.i.l. switch next to the socket, and enter the necessary information to fill the scratchpad. After pressing G set-up the 8255 ports by sending 82 (hex) to the control register at X503. The starting address of the e.p.r.o.m. is placed in the address ports A and C. The control pin-profile is OR-ed with the address in port C and the data read by the c.p.u. from the address of port B. This is stored in the area of r.a.m. pointed to by CAD using the indexed mode of addressing. CAD and CAP are checked to make sure they are not outside limits and only then will they be incremented until the e.p.r.o.m. data is placed in system r.a.m.

The time taken is quite short, but it is not possible to run a program from an e.p.r.o.m. in the programmer without some considerable delay and a dedicated program to do it. In my system a facility exists to move some of the system r.a.m., having set up the new start address on d.i.l. switches. Thus by moving a toggle switch the r.a.m. can be made to behave as though it was a programmed e.p.r.o.m., residing at the same address as the e.p.r.o.m will in the finished system. This may be write-protected if desired. Ensure that only one device is enabled when shifting.

Programming. This is more difficult, since the e.p.r.o.m needs to be given a program pulse for a defined time. An external voltage is required, about 27V to allow for losses, and on my system a circuit measures this voltage and turns on an l.e.d. if it is correct. Thus the light indicates that the e.p.r.o.m can be programmed. The use of a built-in program voltage is left to you; if the ports are likely to be used for general use I think it is safer to bring it in separately. Pin selection d.i.l. switch, address entry, etc is as explained for reading. After pressing G the e.p.r.o.m is placed in the write condition using the pin-profile described. A program pulse is applied by OR-ing CAP with the pulse-on pin-profile and placing it at the port. This is timed using the delay routine, after which the address is OR-ed with the write pulse-off pin-profile and stored at the port. Thus the port is in the write mode all the time, some of which is in the pulse-on mode; the e.p.r.o.m. address is only changed when the port is in plain write mode.

The choice of software timing for the pulse or the use of a monostable is left to you. If you choose monostable timing the clock frequency is not important; but a monostable is another i.c. to wire and could be susceptible to interference. Software timing has its critics too, but when other e.p.r.o.ms as well as 2708s are to be catered for it is justified in my view. Programming does take time – typically one minute for every 1024 × 8 bits. Thus for a 4K e.p.r.o.m the processor is tied-up for at least four minutes. If any interference occurs during this time it could cause trouble, so there may be some advantage to be gained by switching off any well-known generators of interference. In the home this can include anything with a thermostatic control inductive load.

Software development. Some of the development, done in hex machine code, was made easier by using the sub-routines available in the monitor, such as the "print ASCII string" sub-routine, and the "input characters from keyboard" sub-routine for setting-up the scratchpad data. If you wish to develop your own programs for any c.p.u. type, I recommend that you include a facility for additional features you may wish to try. For example, my program asks if the user wants to "read?" and if the response isn't 59 (ASCII for Y) it goes to "write?", after which it exits. There would be some advantage in writing "extra facilities; enter facility number"; you then enter different routines, to be developed later, without rewriting the remainder of the software. What you do is to reserve two memory locations at the end of the program (in the final e.p.r.o.m. for the moment a 2716) and set the index register to the address of the first, less two. Thus if the number entered is 1 the index register will be incremented by 1 × 2, so by going to this location a new starting address may be inserted. By leaving say six memory locations all FF they may be programmed later. Arrange the address routines as a subroutine so they may be used in later developments.

Infrequent users may find some advantage in making use of a 37-way D – connector and a small plug-in p.c.b. with the socket on it. This is only plugged in when an e.p.r.o.m. is to be programmed or read. The diagrams show the wiring for the d.i.l. switches connected to pins 18-21, Fig. 6 It is essential that such switches are suitable for the low-power duty that is required. Protect the wiring on this p.c.b. from handling; an unetched piece of copper laminate is ideal for the purpose as it may be connected to 0V.

Erasing e.p.r.o.ms. It is essential that e.p.r.o.ms are correctly erased before programming is started. This means exposing them to "hard" ultra-violet light for a period of between 5 and 20 minutes, depending upon the strength and closeness of a suitable source. So-called u.v. tubes with fluorescent coatings inside glass will not be satisfactory; this rules out disco black-light tubes and soft tubes used to generate artwork. The correct tubes are usually small, low-wattage with a quartz tube that permits the transmission of the mercury-vapour radiation of 254nm wavelength. Although satisfactory erasers are available commercially, you may be tempted to make your own using a replacement tube.

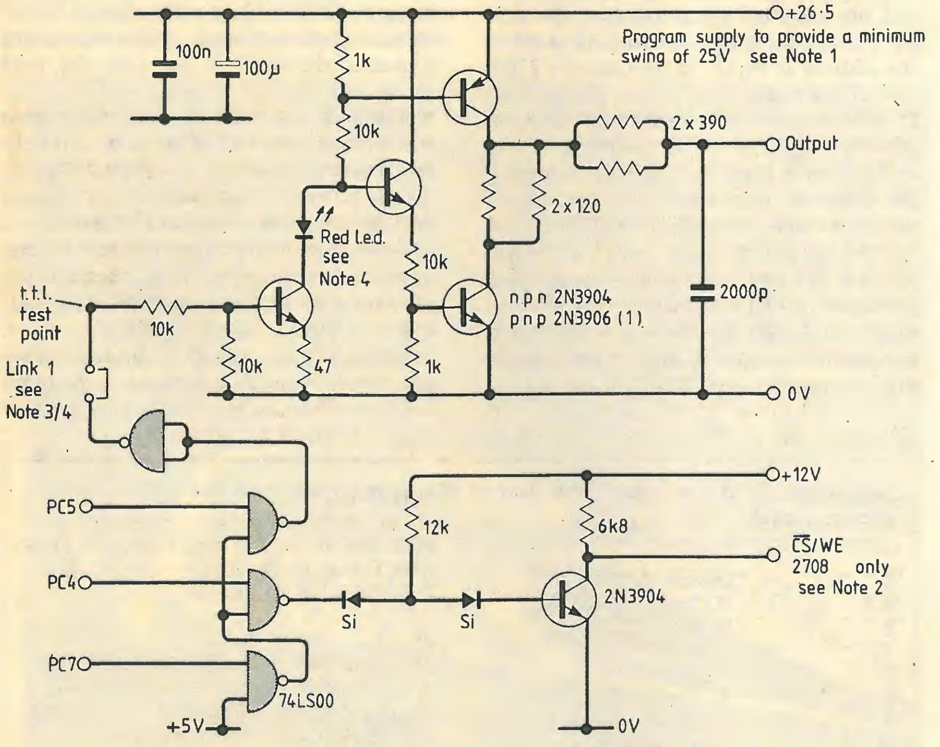
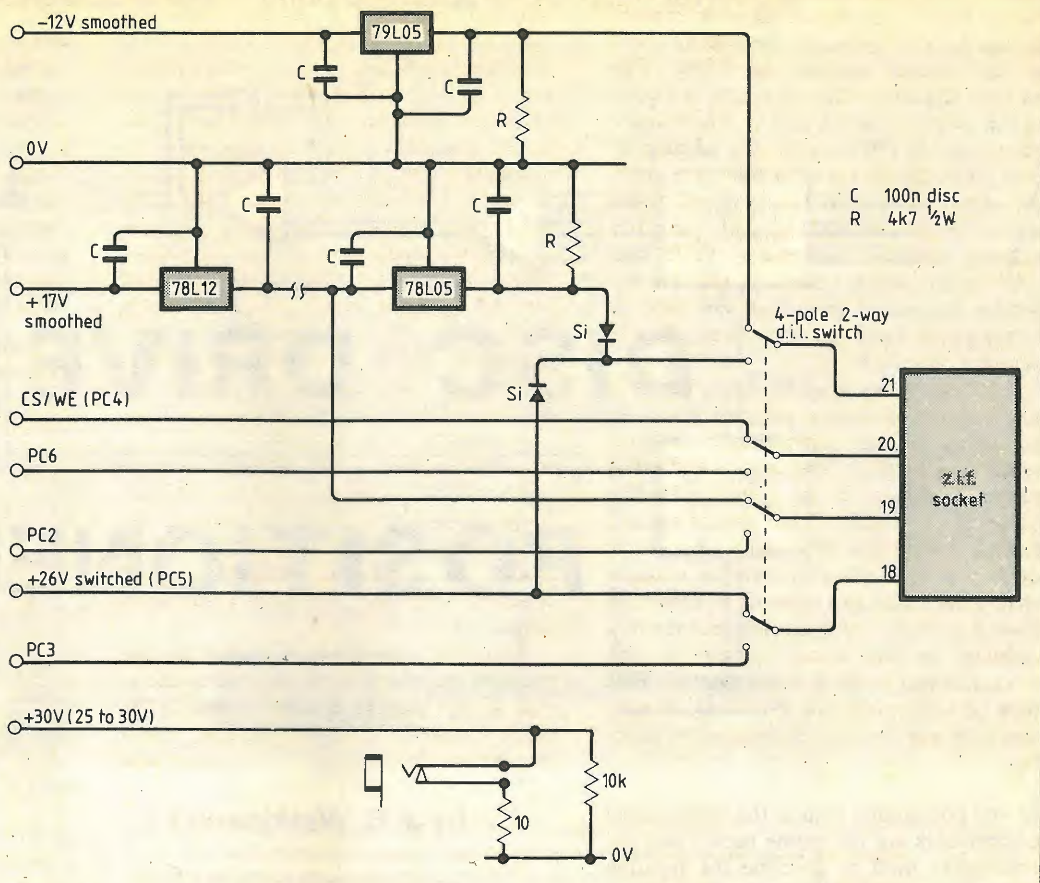


Fig. 6. In this transistor interface and reset logic PC7 is used to detect the high impedance state after reset occurs. This prevents unwelcome voltage appearing on the e.p.r.o.m. socket. Normal operation with PC7= output, logic 0 is V_p = 26V with PC5 = logic 1. Notes:

1. *Pulse output is critical and should be checked against manufacturer's data. Measurements must be from e.p.r.o.m. socket. For C_o 1800pF, T_r 1µs T_f 1.2µs. C_o 2800pF, T_r 1.5µs T_f 2µs measured on 50MHz 'scope TTL input waveform 1:3 ratio, 1 cycle 25µs.*
2. *The CS/WE pin needs to be taken low at the finish of programming before the address is changed. Since PC4 is only used with 2708 this can be done at the end of any programming sequence, as a forerunner to the verify routine.*
3. *Test point is a convenient place to drive the interface, with link 1 open.*
4. *LED is on when V_p is high. If no 'scope is available V_p should be set to 26V using a 20kΩ/V multimeter. Test point = 3.5V with link 1 open.*

Fig. 7. In the prototype programming board the 78L05, which should have been shown here with a diode in its ground lead, was mounted on the programming board together with a z.i.f. socket, d.i.l. switch and programming pulse jack socket. The diode in the regulator's ground lead raises its output to 5.7V. Current limiting at 50mA is used on the '30V' supply, which should never be less than 26V and without overshoot. The line at the junction of the two diodes is at either 5 or 25.25V, depending on the device to be programmed.



Take care in the design of a close-fitting lid or drawer to prevent the incidence of u.v. burns to eyes or skin. It is a *sine qua non* to include an interlock which breaks the tube-current in the event of the lid (or drawer) being opened during the erase period. The addition of a timer is a useful refinement as the tube has limited life. Clean the i.c's window before erasure – afterward it may be covered to guard against possible loss of data when it has been programmed. And keep the e.p.r.o.ms in conductive foam whenever possible to prevent electrostatic charge causing degradation or destruction.

Whilst this programmer satisfies the initial design requirements there is no reason why other e.p.r.o.m. types should not be catered for. Probably the easiest method of altering the pin requirements is to bring those pins which are likely to need changes to a separate header which may be used as a patch-board, in the same way that the d.i.l. switch was necessary in Fig. 6.

The 26V transistor interface, Fig. 7, is tolerant of the value of output capacitance although I recommend that the output waveform is checked. The l.e.d. is illuminated when the output is at high potential, which should be typically 26V to ensure that the miminum swing of 25V is met.

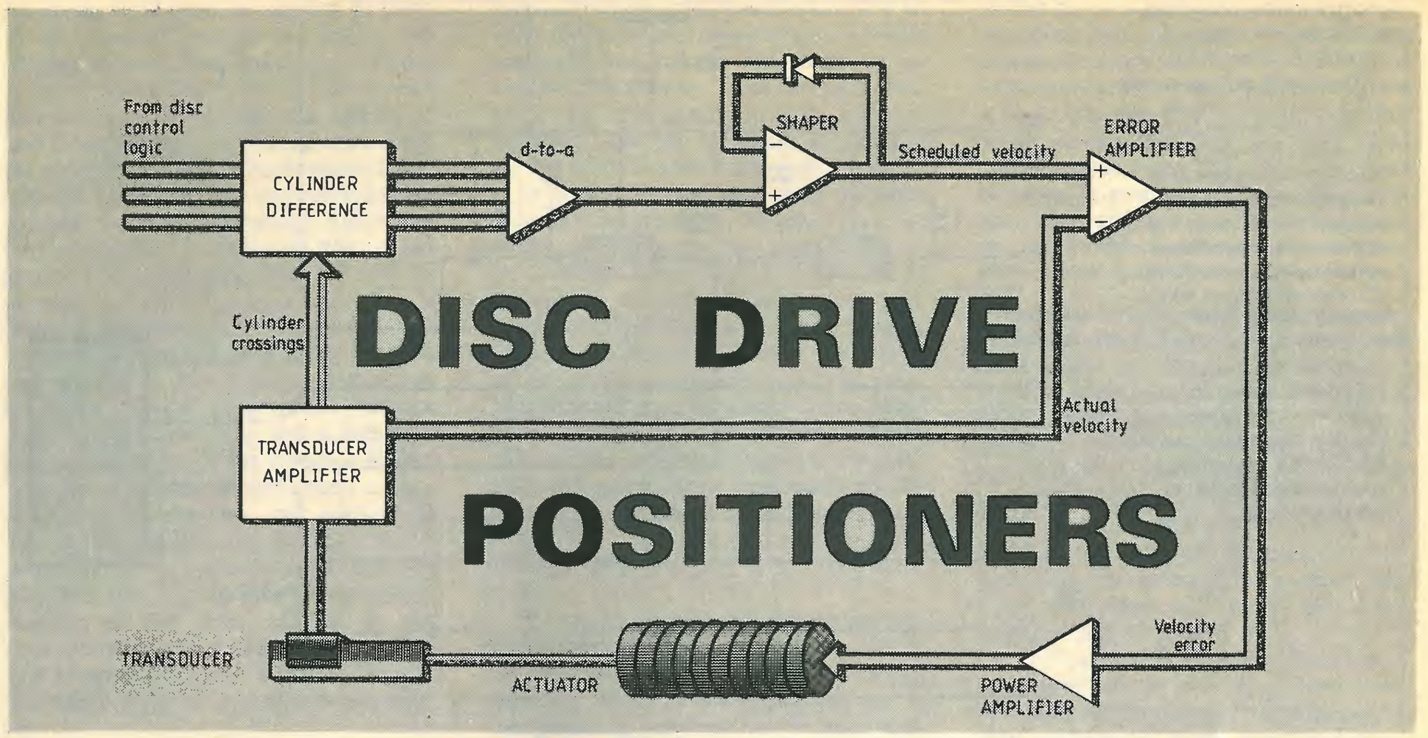
Reset logic prevents unwelcome voltage appearing on the e.p.r.o.m. when an output port is arranged so that logic 0 = 0V. If this is inverted then the problem may be resolved and the port PC-7 becomes spare and could be used to perform some other function. Personally I like to have ports at logic 0 meaning no output. □

EVENTS

April 23-25
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.
April 25
Audiojumble: sale of audio equipment at the Gandhi Hall, YMCA, 41 Fitzroy Square, London W1. Organised by Ed Lord, 67 Liverpool Road, London N1.
April 26
Amateur radio satellites; IEE lecture for younger members. IEE, Savoy Place, London WC2P 0BL.
April 27
Recent developments in the measurement of weak magnetic fields and associated applications: IEE colloquium.
April 29
Software engineering: IEE lecture.
April 29
UOSAT – a low cost spacecraft for professional and amateur scientists: IEE lecture.
April 29-30
Spectral analysis and its use in underwater acoustics: Institute of Acoustics/IEE conference. Imperial College, London SW7. Details from: Dr T. S. Durrani, Department of Electronic Science and Telecommunications, University of Strathclyde, Glasgow G1 1XW.
April 30
Up-to-date applications of dataview systems: IEE colloquium.
May 3-6
Video '82: Trade fair and Congress: International Congress Centre, Berlin. Organised by AMK Berlin, Postfach 19 17 40, Messedamm 22, D-1000 Berlin 19.
May 4
Human factors in word processing: IEE colloquium.
May 5-7
Videotext Systems '82: Conference and Exhibition. Cunard International Hotel, London. Organised by IPC Exhibitions Ltd, Surrey House, Throwley Way, Sutton, Surrey.
May 6
Digital tv effects: IEE Younger Member's lecture. Ship Hotel, Duke Street, Reading, Berks.
May 11-13
Micro City '82: Information technology exhibition. Bristol Exhibition Complex. Details from Tomorrows World Exhibitions Ltd, 9 Park Place, Bristol BS8 1JP.
May 12
Microprocessor projects for the plastics industry: Seminar at the National Computing Centre, Manchester. Organised by the British Plastics Federation, 5 Belgrave Square, London SW1X 8PH.
May 12
Electrostatics and optical effects: IOP Meeting. Institute of Physics, 47 Belgrave Square, London SW1X 8QX.
May 12
Time delay systems control: IEE colloquium.
May 12
Effects of obstacles and dielectric structures in the near-field on antenna performance: IEE colloquium.
May 12
Teletex and its protocols: IEE lecture.
May 13
Development environments for microprocessor systems: IEE colloquium.

Within 80ms a mass of ¼kg can be moved a distance of four inches and stopped to within a quarter micron of a specified point – this article shows how.

DISC DRIVE POSITIONERS



by J. R. Watkinson*

In any positioning system the most crucial components are the prime mover and the transducer used to describe the position and velocity of the element under control. Here, the main features of disc-drive positioners, including feedback loops and control circuits, are described.

With the exception of fixed head and Winchester type disc drives, the read/write heads are mounted on a rigid platform called the carriage. This carriage has one degree of freedom radial to the drive spindle and is restricted by guideways, usually in the form of rails or bars; in most cases, the carriage runs on ball bearings, one or more of which is spring loaded to take up play and ensure that the bearings roll instead of skidding. Not all carriages run on ball bearings – some run directly on the guideway – but the way in which four types of those that do are constructed is shown in Fig. 1. Rotary positioners, such as those used in Winchester disc drives, will be described in a subsequent article.

In multi-platter drives, the heads are usually mounted side-by-side between the platters to reduce the overall height of the pack and minimize the weight of the carriage. The part of the carriage to which the heads are attached is often called the T-block because more often than not it is T-shaped. For convenience, the two sides of the T-block are designated A and B, and each side will have upward and downward facing heads. So in this case there are four read/write head labels; A-up, A-down, B-up and B-down. A and B heads designed for opposite directions are similar in appearance but if they are mistakenly interchanged, slipper aerodynamics will be affected, so the head type is usually clearly marked. Slots in the T-block allow radial adjustment of the heads.

As the heads are in two rows, it is vital that the centre line along which the carriage travels is precisely on the disc radius. Figure 2 shows why. Alignment fixtures provided with the drives allow the heads to be accurately aligned and, equally important, keep the head adjustment standard between drives using interchangeable discs.

*B.Sc., M.Sc., Digital Equipment Co.

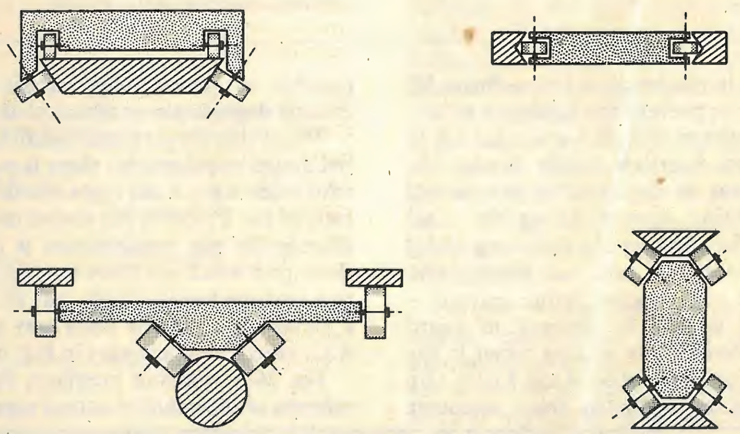


Fig. 1. Four methods used for mounting disc-drive positioner carriages. Common purpose of these is to allow only one degree of freedom, ideally along radius of the disc.

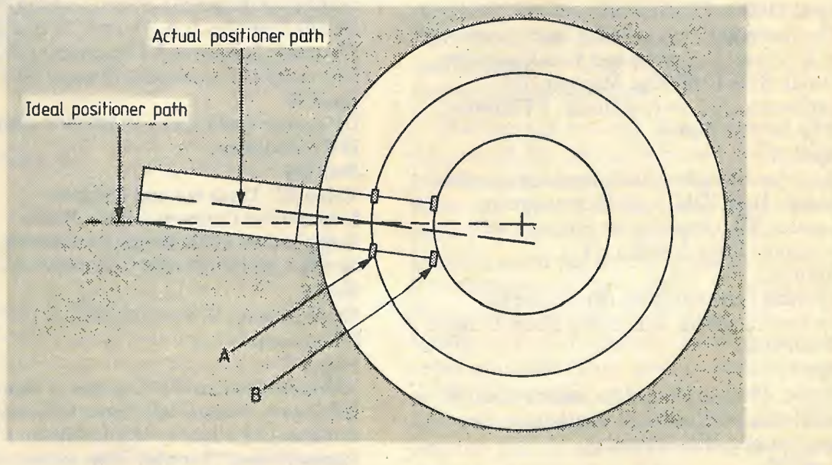


Fig. 2. Mounting read/write heads side-by-side in multi-platter drives reduces height of the disc pack and hence weight moved by the positioner, but alignment between carriage centre line and disc radius becomes more critical. Here, the heads are aligned at track A and the error caused by carriage/track-radius misalignment becomes apparent at B.

Motive power

There are three main methods of driving the carriage
- hydraulically
- by moving coil
- or by electric motor.

Hydraulics. The first moving-head disc drives stored data at very low density by modern standards, so if large amounts of data had to be stored, large discs had to be used. Some of these discs measured several feet in diameter. The carriage was equally large, and the only practical way of moving it was by hydraulics. Much research into hydraulic systems for applications such as power-operated gun turrets on military aircraft had already been carried out so the design of a system for driving the carriage of a disc drive was simplified.

Figure 3(a) shows the essentials of an hydraulically powered positioner, in which the pump may be driven either by the spindle motor or by a separate motor. The accumulator is required for rapid seeks, when the peak-flow requirement is greater than the pump can deliver; the analogy with a power-supply capacitor is clear. Fluid pressure is regulated by a bypass valve, the fluid equivalent of a zener diode and a series of solenoid-operated valves with calibrated orifices are used to move the carriage at different speeds. Some drives with hydraulic positioners would move from their position in the computer room, because of the reaction from fast carriage acceleration, and had to be moved back into place from time to time. Behemoth drives had two parallel spindles with opposed positioners between them to cancel out this effect, Fig. 3(b).

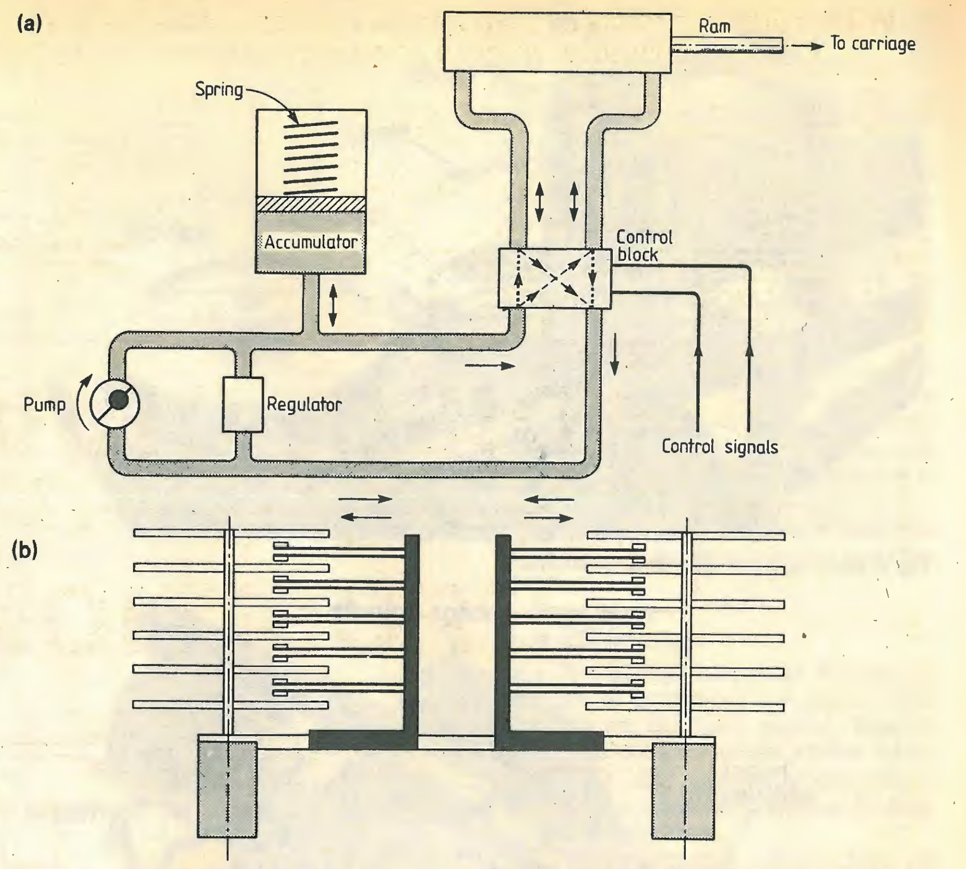


Fig. 3. Essential elements of an hydraulic positioner are shown at (a), in which the pressure from the fluid pump is regulated by a bypass valve and control signals from the drive logic operate solenoid valves in the control block. Accumulator permits high peak-flow rates without large pressure fluctuations. In (b), two opposed positioners are used to cancel out reactions caused by fast carriage acceleration.

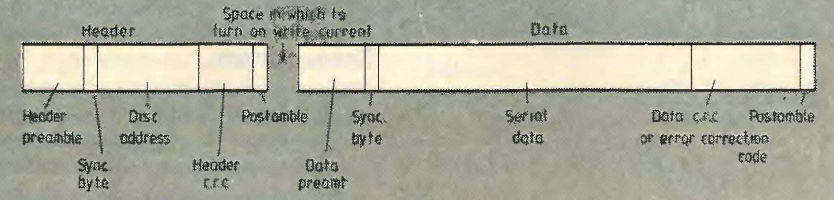
Moving coil. As head and medium design improved the storage density increased, allowing the platters to be made smaller. This made the carriage smaller and lighter so less power was required to move it. At the same time, advances in semiconductor technology brought down the price of power transistors. It thus became feasible to use a moving coil to drive the carriage, with the further weight reduction of the carriage that the principle allows being used to reduce access time.

A typical coil has a diameter of three inches and works in the radial flux from a permanent magnet weighing about 50 pounds. Smaller drives use a copper wire coil on a glass fibre former, but larger units may use self-supporting coils wound from rectangular-section aluminium strip. Aluminium has a higher strength-to-weight ratio than copper, and this consideration outweighs the disadvantage of higher resistance. The coil frequently requires forced air cooling in large units. The assembly is usually described as an e.m.a. (electromagnetic actuator), Fig. 4.

Electric motor drive. There are two main types-one is as shown in Fig. 5. In the first, the motor drives a leadscrew which moves the carriage as it turns. In some cases a stepping motor is used, where the stable positions of the rotor correspond to the positions of disc cylinders.

Disc format

The access mechanism of a disc drive works from three dimensions: cylinder, track or head, and sector. A malfunction in any of these could bring the heads to the wrong data block. In the interests of data integrity, each block of data is preceded by a header which contains the disc address of the block. Before a data transfer can take place, the disc address according to the access mechanism is compared with the disc address in the header. If the two are the same, the data transfer proceeds, if not, the transfer is aborted and a mispositioning condition exists, usually referred to as a header mismatch error. The headers are usually written once when the disc is first used, by a process known as formatting, and are then subsequently only read. Because of this, the header and the associated data require individual preambles when used with an encoding technique requiring phase-locked recovery, as the header and the data have not necessarily been written at the same time, or for that matter, on the same disc drive. Some drives, however, treat the header and the data as an entity, such that the header is rewritten every time a block is written. The diagram shows a fairly common disc-block format and lists the functions of each element.



Representative disc-data block. Header cyclic-redundancy check (c.r.c) and data-error correction words will be discussed later. The postamble is included to prevent data corruption when the write current is switched off.

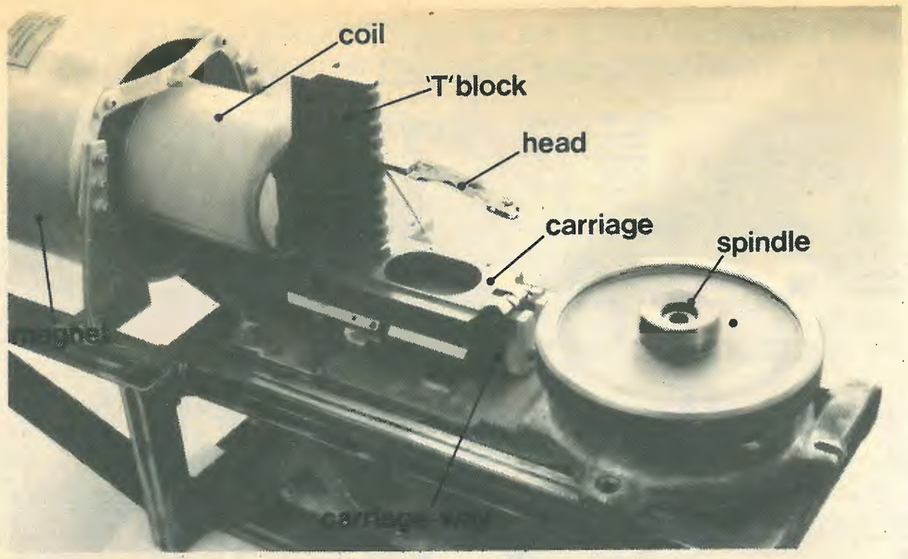


Fig. 4. Essentials of a disc-drive positioner.

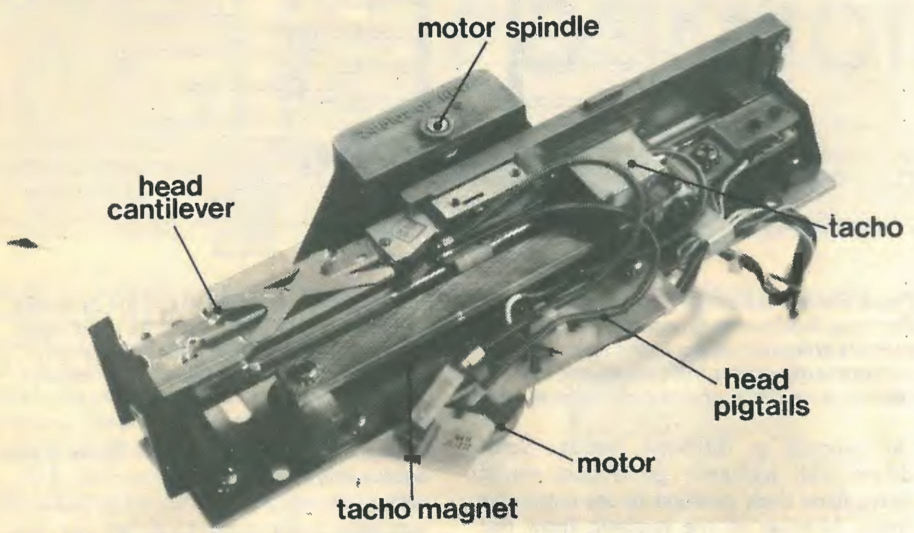


Fig. 5. One type of motor-driven positioner. This assembly illustrates how a positioner using steel wires to drive the carriage looks.

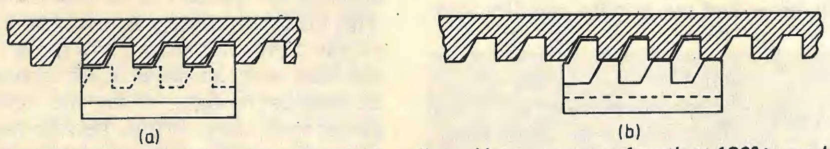


Fig. 6. Mechanical detenting. Detent pawl is split and has two sets of teeth at 180° to each other. At (a), the carriage is detented to an odd numbered cylinder and the upper pawl teeth are engaged. The lower pawl, represented by the broken line, rests against the tops of the rack teeth. In (b), the carriage is detented at an even cylinder and the lower pawl is engaged. Tooth pitch on the rack is twice the cylinder spacing.

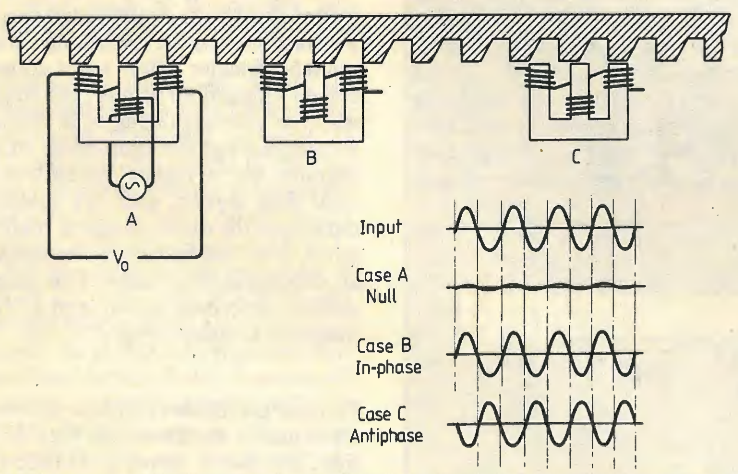


Fig. 7. Carrier-wave cylinder transducer. Oscillator feeds the transducer primary coil and the two secondaries are connected in opposite phase. Output signal phase, determined by the relative reluctance of the magnetic circuit's two limbs, is a function of the rack position. Three examples are given with associated waveforms.

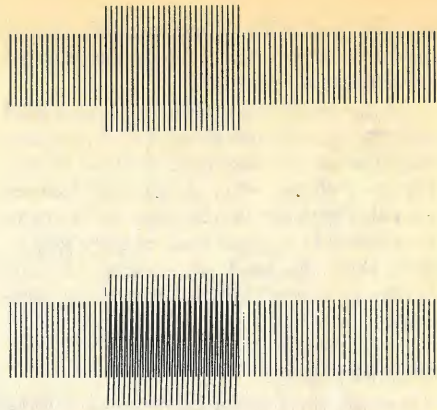


Fig. 8. Parallel bar and Moiré type gratings used to modulate a light beam produce triangle and sine-wave outputs respectively. These gratings are used to detect position and velocity.

The motor in the second type drives a drum which imparts linear motion to the carriage through flexible steel wires. These two types are normally used only in small drives.

Detenting

When the carriage is held at rest with the heads correctly aligned above the disk tracks, it is said to be detented. Early drives used mechanical detenting where pawls on a detent actuator move to engage a rack on the carriage. Figure 6 shows a two-phase detent mechanism, where the spacing between cylinders is one half the rack pitch. Mechanical detenting can be found on both hydraulic and moving coil positioners, and the pawl will be operated by a ram in the former case, or by a solenoid in the latter. The teeth on the rack are asymmetrical so that after the detent has engaged, some forward drive can be applied to take up any backlash without fear of the pawl jumping out of engagement. The detent actuator is a fine piece of precision engineering, and as such is expensive. Recent drives take advantage of the falling cost of electronic circuitry and employ electronic detenting, where the carriage is held by a feedback loop using a position transducer. Should for any reason the positioner find itself off track, the position transducer generates an error voltage which will drive the carriage until the error is cancelled. When operating in this way the carriage servo system is said to be in detent mode, track following mode, fine mode or linear mode, depending on the specific documentation consulted. During a seek, the servo system changes to velocity mode, also known as coarse mode. These are the two major operating modes of the servo.

Transducers

The purpose of a transducer will be one or more of the following

- to count the number of cylinders crossed during a seek,
- to generate a signal proportional to carriage velocity,
- or to generate a position error proportional to the distance from the centre of the desired track.

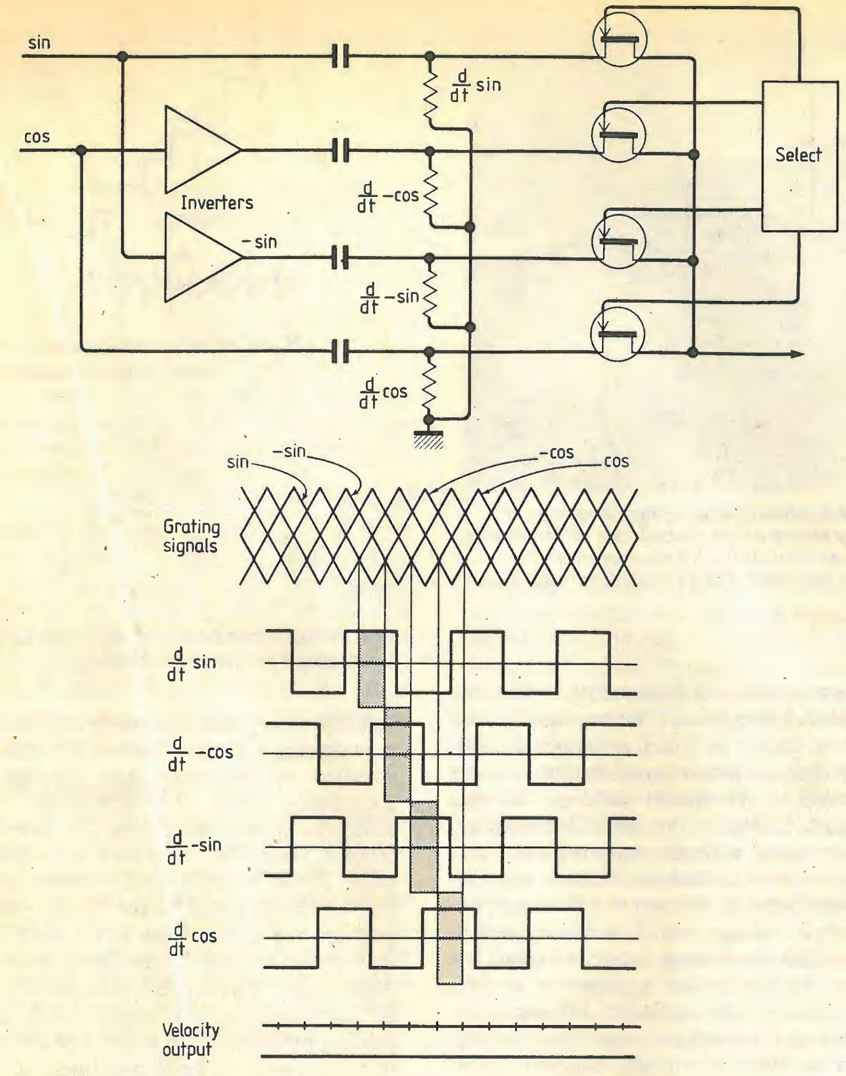


Fig. 9. Optical velocity transducer. Four quadrature signals are produced from the two-phase transducer. Each of these is differentiated, and the four derivatives are selected one at a time by analogue switches. This process results in a continuous analogue-output voltage proportional to the slope of the transducer waveform, whish is itself proportional to carriage velocity. In some drives one of the transducer signals may also be used to count cylinder crossings during a seek and to provide a position error for detenting.

Sometimes the same transducer will be used to provide all three signals. For this reason, transducers are best classified by principle of operation, rather than by function.

Magnetic transducers. There are three distinct types

- moving coil
- moving magnet
- carrier wave.

The first two types simply give an output proportional to the rate of change of flux. The only difference is whether the coil or the flux moves. Moving-magnet types often have the coil concentric with the actuator, which provides good noise shielding. Moving-coil types sometimes have a bucking coil connected in phase opposition which does not link the magnetic circuit in order to cancel out induced noise. These two types of transducer can only generate a velocity signal, but have the advantage that no precision alignment is necessary; a working clearance is all that is required.

The third type is illustrated in Fig. 7. The flux path of the transducer is completed by a rack on the carriage, often the same one as is used by the detent actuator. As the rack moves, the reluctance of the two limbs will rise and fall, and as the secondary coils are wound in opposition to each other, the output will be alternately in and out of phase with the input. A phase-sensitive rectifier gives a binary output which can be used to count cylinder crossings during a seek. As no accurate position error or velocity information can be extracted, this type of transducer is restricted to use in mechanical detent drives, in conjunction with a magnetic-velocity transducer. Adjustment of carrier-wave transducers is critical, as the signal becomes rapidly attenuated if the distance from the rack is too great, but the transducer may be damaged by the rack teeth if the clearance is too small.

Optical transducers. These devices consist of gratings, one fixed and one movable. The relative positions of the two will control the amount of light from an l.e.d. or bulb which can pass through to one or more photo-transistors.

Referring to Fig. 8, it can be seen that this class of transducer falls into two categories

- Moiré-fringe
- parallel-grating.

In a Moiré-fringe transducer the bars on the moving grating are not parallel with the bars on the fixed grating. Relative movement causes a fringe pattern which travels at a right angle to the direction of motion. This results in sinusoidal modulation of the light beam.

In the second type, all the bars are parallel so the sensor's output is a triangle wave. In both types of optical transducer, the spacing between the two gratings is critical.

Whether the waveform used for counting cylinder crossings is sinusoidal or triangular is not important, so the choice between the two transducers is governed by whether a position error or a velocity signal is required. The slope of a sine wave is steeper in the zero region than an equivalent triangle wave so it is more useful for detecting position error. Conversely the constant slope of a triangle wave is easily differentiated to produce a velocity signal. Because the differential of a triangle wave changes sign twice per cycle, a two-phase optical system is often used to give a continuous velocity-output signal. The stationary grating has two sets of bars with a 90° phase relationship and the resultant

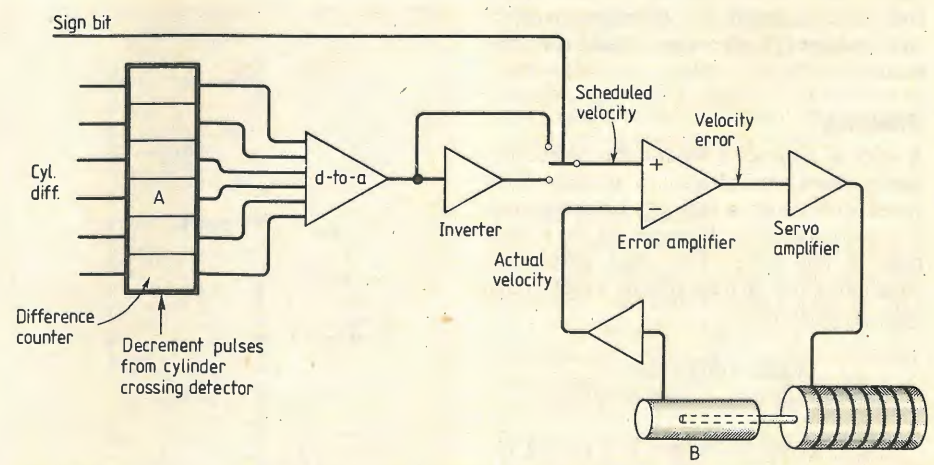


Fig. 10. Carriage velocity control by cylinder difference. Cylinder-difference value is loaded into the difference counter, A. A d.-to-a. converter generates an analogue voltage, called the scheduled velocity, from the cylinder difference. This is compared with the actual velocity from transducer B to generate a velocity error signal which drives the servo amplifier.

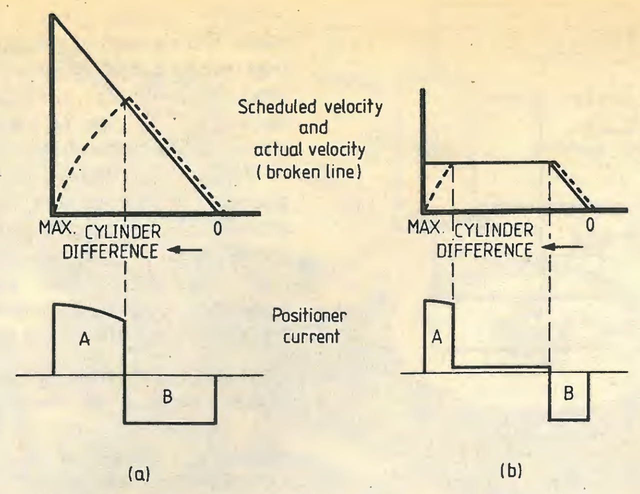


Fig. 11. In example (a), dissipation in the positioner is continuous, causing a heating problem. The effect of limiting the scheduled velocity above a certain cylinder difference is shown in (b), where heavy current only flows during acceleration and deceleration. In between, only enough current to overcome friction is required. Back to e.m.f. causes the curver acceleration slope.

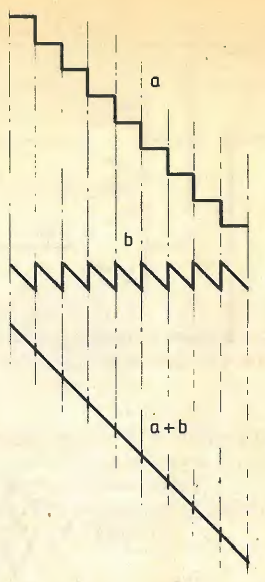


Fig. 13. Staircase from a d.-to-a. smoothed by adding a sawtooth waveform.

waveforms are referred to as sin and cos, even if they are triangle waves. The two waveforms and their complements, known as −sin and −cos, are differentiated and the four differentials selected in turn at times when there is no sign change. This process of commutation is achieved by f.e.t. analogue switches controlled by comparators looking for points where the input waveforms cross. The result is a clean output signal proportional to velocity.

Where one transducer has to generate all three of the required parameters, Moiré type gratings are preferable because of their better position-error detecting performance. A certain amount of ripple on the velocity output derived from a sinusoid has to be accepted.

Optical transducers often contain additional light paths to aid carriage-travel limit detection. The resulting signals may be used during the head-loading sequence to position the heads at cylinder zero, as the sine or triangle outputs are cyclic and do not give an absolute cylinder address. Mechanical detent drives pose the problem of finding an absolute reference to the cyclic output from the rack transducer. One solution is to drive the carriage forward slowly until it contacts the forward stop, and then to preset the cylinder count to two or three cylinders more than the maximum.

Seeking

A seek is a process where the positioner moves from one cylinder to another. The speed with which a seek can be completed is a major factor in determining the access time of the drive. The main parameter controlling the carriage during a seek is the cylinder difference:

cylinder difference =
desired address − current address.

The cylinder difference is a signed binary number representing the number of cylinders to be crossed to reach the target cylinder, direction being indicated by the sign. The cylinder difference is loaded into a counter which is decremented each time a cylinder is crossed. The counter drives a d.-to-a. converter which generates an analogue voltage proportional to the cylinder difference. As shown in Fig. 10 this voltage, known as the scheduled velocity, is compared with the output of the carriage-velocity transducer. Hence any difference between the two results in a velocity-error voltage, which is then used to reposition the carriage hence cancelling the error. As the carriage approaches the target cylinder, the cylinder difference becomes smaller with the result that the run-in to the target is critically damped (velocity α − distance) to eliminate overshoot.

Figure 11(a) shows graphs of scheduled velocity, actual velocity and actuator current with respect to cylinder difference during a seek. In the first half of the seek the actual velocity is less than the scheduled velocity causing a large velocity error. This saturates the servo amplifier, providing maximum current to the actuator which in turn accelerates the carriage to reduce the error. In the second half of the graph, the scheduled velocity falls below the actual velocity generating a negative velocity error, and the servo amplifier is now driving a reverse current through the actuator to decelerate the carriage in accordance with the scheduler. The scheduler deceleration slope can never be steeper than the saturated acceleration slope. Areas A and B on the current graph will be almost equal, as the kinetic energy put into the carriage has to be taken out. Any difference will be due to friction and other losses. The current through the coil is continuous which would result in a heating problem, so to counter this the d.-to-a. converter is made non-linear so that above a certain cylinder difference no increase in the scheduled velocity occurs. This results in the graph of Fig. 11(b). The actual-velocity graph is called a velocity profile, and consists of three regions: acceleration, where the system is saturated, a constant-velocity plateau, where only enough current is required to overcome friction, and the scheduled run-in to the desired cylinder. Dissipation is only significant in the first and last regions. The effect of carriage velocity on dissipation is as follows.

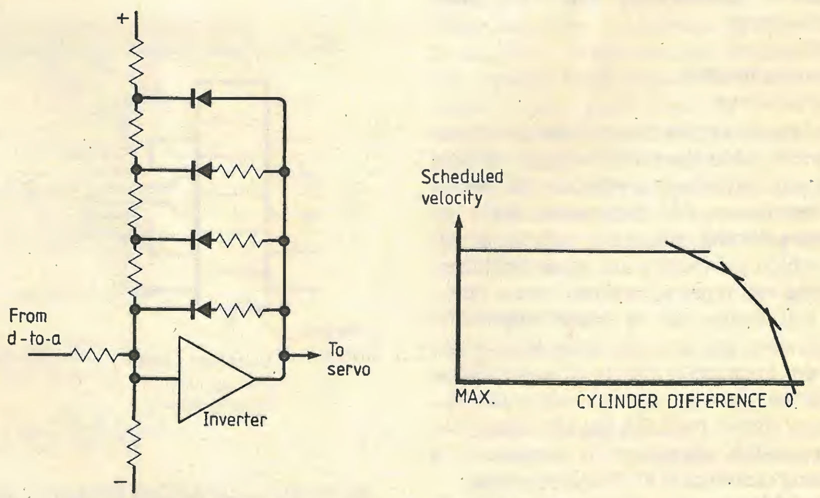


Fig. 12. Voltage-dependent feedback around the operational amplifier permits a piecewise linear approximation to a curved velocity profile. This speeds up short seeks without causing dissipation problems on long seeks.

Carriage acceleration, a, is $\propto$ actuator current, I, and

$$a=\frac{2s}{t^2}$$

where t is the seek time. Dissipation is I^2R, which is proportional to a^2R

$$a^2R=\left(\frac{2s}{t^2}\right)^2R=\frac{4s^2}{t^4}R$$

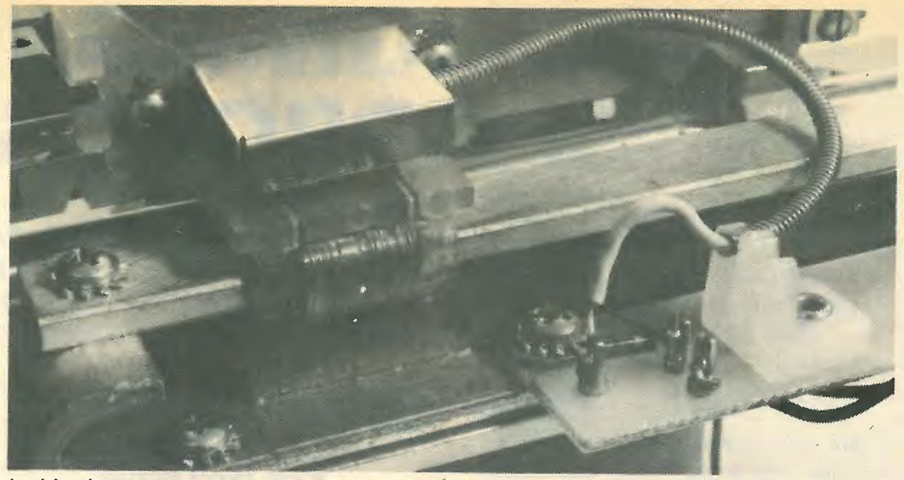
Average carriage veolocity $v\propto 1/t$, therefore, dissipation $\propto v^4$.

As a result, it is necessary to limit the maximum velocity of the positioner very accurately or severe overheating of the coil or amplifier may result.

A consequence of the critically damped run-in to the target cylinder is that short seeks are slow. Sometimes further non-linearity is introduced into the velocity scheduler to speed up short seeks. The velocity profile becomes a piecewise linear approximation to a curve by using non-linear feedback. Figure 12 shows the effect of using a shaper or profile generator, as this device is known.

Servo amplifiers

In small disk drives the amplifier is usually linear in all modes of operation, resembling nothing more than an audio output stage. As the scheduled velocity signal comes from a d.-to-a. converter, the deceleration ramp is depicted by a staircase waveform. When the staircase is compared with the actual velocity signal, the resulting velocity-error signal contains an a.c. component due to the steps. This increases e.m.a. dissipation and can cause an audible output from the coil – a problem that is sometimes solved by adding a saw-tooth waveform, at the same rate as the steps, to the shaper output. This approach is shown in Fig. 13.



In this photograph of a moving-coil transducer, the magnet under the coil can be seen clearly.

Larger units employ pulse-width modulation to reduce dissipation in the servo amplifier. The duty cycle is established typically by comparing the velocity error with a sawtooth waveform. A simplified example of this process is shown in Fig. 14. Appreciable electromagnetic radiation is caused by p.w.m. servo systems, but this is generally of no consequence as no data transfer takes place during a seek. In track following mode, p.w.m. servos revert to a linear amplifier configuration, which is why the term linear mode is often used to describe the detented state of the positioner.

The input of the servo amplifier normally has a number of analogue switches which select the appropriate signals according to the mode of the servo. As the output of the position transducer is a triangle or sine function, the sense of the position feedback loop has to be inverted on odd numbered cylinders, to allow detenting on the negative slope. In some cases a different velocity transducer is used when the heads are being retracted from the pack. Figure 15 shows a typical servo-amplifier input-selection circuit.

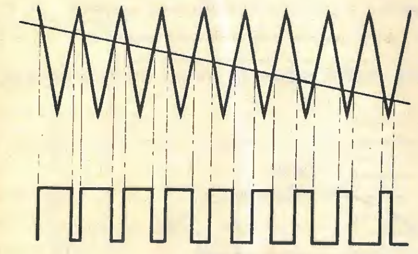


Fig. 14. Comparison of velocity error with a sawtooth waveform results in a pulse-width modulated output which can be used to reduce dissipation in the servo amplifier.

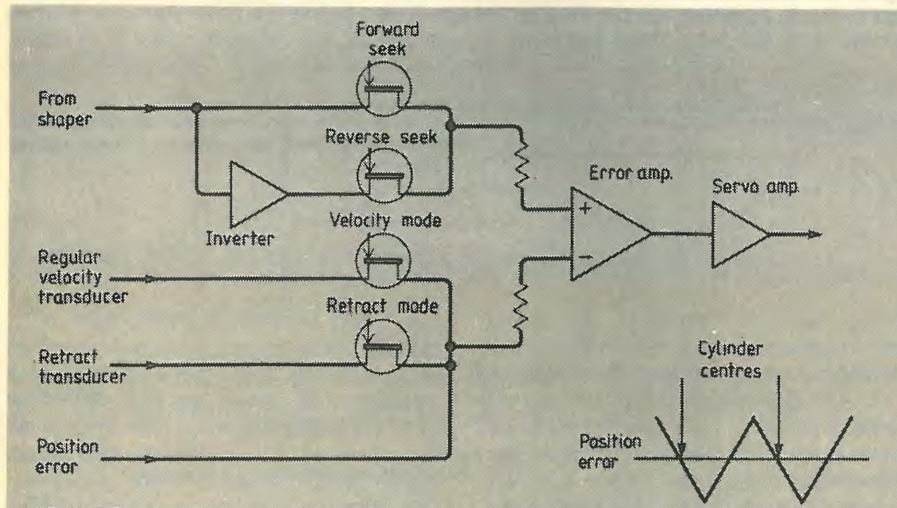


***Fig. 15.** Typical servo-amplifier input stage. In velocity mode, the shaper and velocity transducer drive the error amplifier. In track-following mode, position error is the only input.*

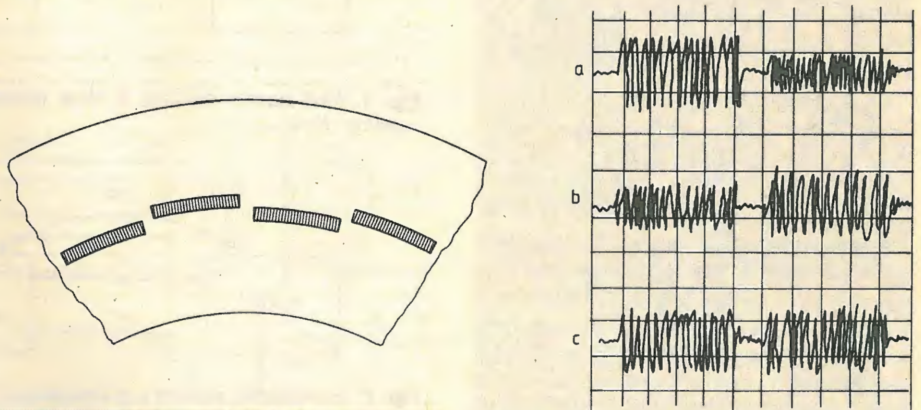


Fig. 16. Alignment disc has flux patterns displaced alternately about the centre line of the reference track. In the resulting oscillograph at (a), the head is too close to the spindle, at (b) too far from the spindle, and at (c), in the correct position.

Head alignment

On drives where interchangeable discs are used, the distance between the read/write heads and the spindle axis is critical. So to set the heads, an alignment disc (sometimes called a 'custom engineer') containing prerecorded flux patterns at a reference cylinder is used. Figure 16 shows a typical alignment-disc pattern and resulting oscilloscope waveforms for correct and incorrect head alignments. □

Disc rotation, cooling, filtration, power supplies and safety will be discussed in the next chapter.

DESIGNING WITH MICROPROCESSORS

Linking a mocroprocessor with a printer directly is wasteful: much time can be saved by sending data to a buffer for reading at a slower rate. Professor Zissos concludes his series with two articles on programmable i/o chips, this first on basic concepts, and the second on design procedure and implementation.

by D. Zissos and Jane Pleus

It is not always necessary or indeed desirable for two devices to communicate directly, particularly if one device is much faster than the other. For example, a microprocessor transmitting data directly to a slow character printer will be idling while a character is being printed. In this situation much time can be saved by the fast device transmitting each item of data to a port (in practice a data buffer) and allowing the printer to read the data from the port in its own time – see Fig 1. Such a scheme would release the microprocessor from the unproductive task of waiting and allow it to look after other tasks while the printer is printing.

Input/output ports are normally implemented with programmable chips, that is chips whose operations can be specified within limits by the user. Designing such systems involves two steps. First, the i/o chip is programmed. And second, the interface between the i/o chip and the peripheral unit is designed. Although the second stage presents no difficulty, programming the chip in practice is not always a trivial task, because of lack of a systematic method. This often prevents one from taking full advantage of the main property of such chips – that their terminal characteristics can be specified to some extent by the designer.

Clearly the source must not send data to the port until it can accept it. For this purpose the port sends a signal (hl) to the source indicating its status, namely whether it is empty or full. Signal hl must also be sent to the acceptor to prevent it from reading old data that it has already read, as shown in Fig. 2 (hl = 0 indicates that the port is empty, and hl = 1 that the port is full). Reference to Fig. 2 shows that status signal hl must be turned on by the source when it sends data to the port, and turned off by the acceptor when it reads the data; variables h2 and h3 denote these "handshake" signals.

In practice signal hl is generated by a flip-flop, the status flip-flop. A JK flip-flop implementation is shown in Fig. 3. By pulling its J terminal high and the K terminal low, a pulse on its clock terminal sets it (hl = l) and pulsing its clear terminal resets it. That is, a pulse on line h2 sets the flip-flop and a pulse on line h3 resets it. The function of the AND gate is to terminate the clear signal (CLR) immediately after the flip-flop is reset, CLR = hl.h3 = 0 when hl = 0. In practice, the port is a buffer which requires a strobe pulse with every new item of data before it accepts it: the pulse on handshake line h2 can be used directly for this.

In summary the step-by-step operation of the handshake system in Fig. 2 is as follows. The source monitors status line hl to determine whether the port is full or empty. If empty, it outputs the next item of data and pulses line h2, which strobes the data into the port and sets the status flip-flop (hl = 1) by pulsing its clock terminal. This constitutes the write operation; the read operation is initiated by the acceptor when line hl is high. When the data is read it resets the status flip-flop by pulsing its clear terminal.

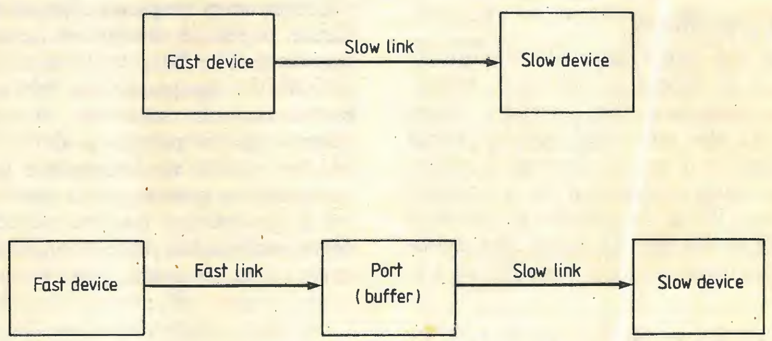


***Fig. 1.** Fast device feeding a slow device needs buffer stage to avoid microprocessor wasting time.*

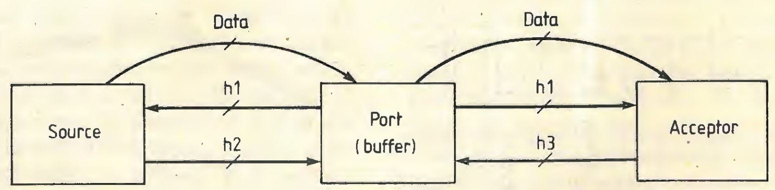


***Fig. 2.** Handshake signals are exchanged before data is transferred from source to buffer and buffer to acceptor. Source monitors status lines 1 to see if port empty: Line h2 then strokes data into port. Read operation is intended by the acceptor when h1 is high.*

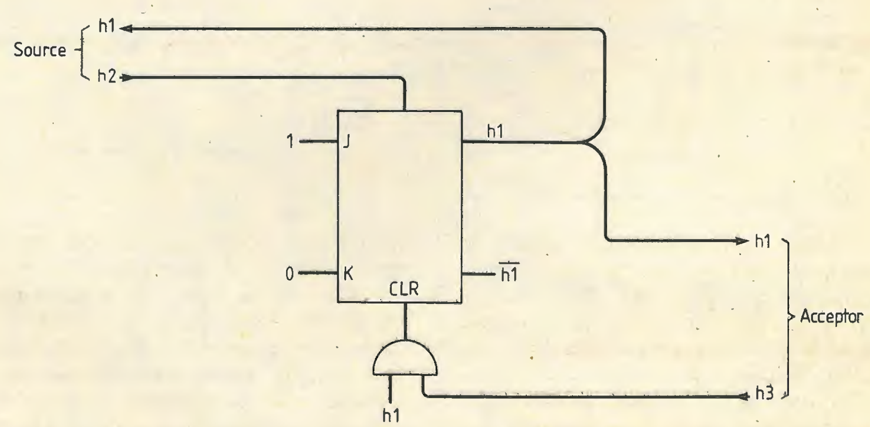


***Fig. 3.** Status flip-flop generates signal h1. With J high and K low, pulse on line h2 sets circuit and on h3 resets it.*

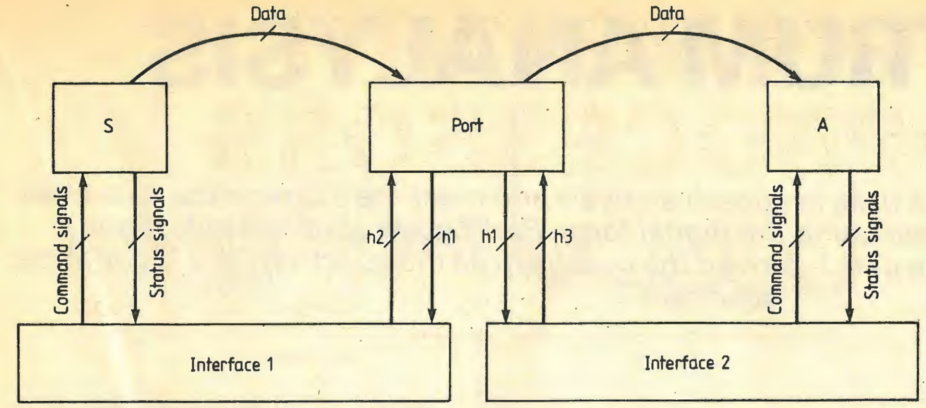


***Fig. 4.** A handshake system requires two interfaces, one to coordinate source/buffer activity and the other acceptor/buffer activity.*

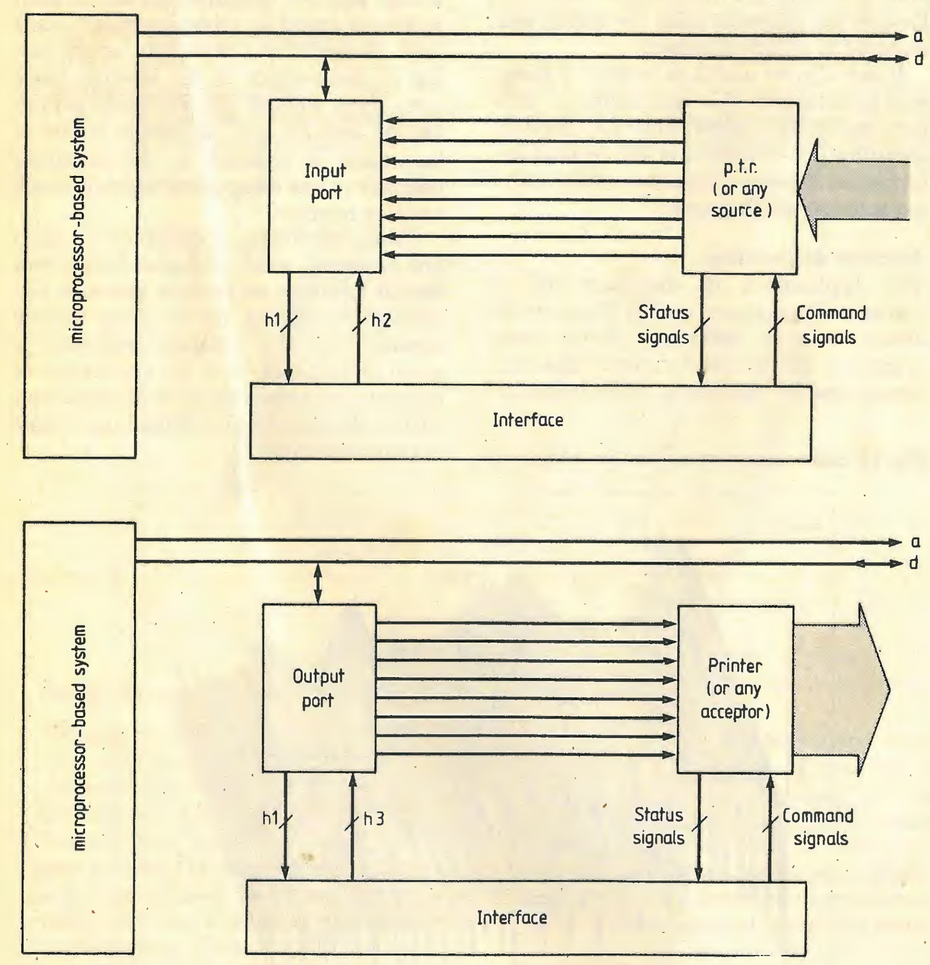


***Fig. 5.** Microprocessor-based system with input port and source (paper tape reader), top, output port and acceptor (printer), bottom.*

To implement a handshake system requires two interfaces, one to coordinate the activity of the source with the activity of the buffer, and the second to coordinate the activity of the acceptor with that of the buffer, Fig. 4.

Because most commercially-available microprocessor systems are normally provided with ports which are already interfaced to them, one need only consider interfacing peripheral devices to the ports. Therefore microprocessor-based systems with fo ports can be represented by the two block diagrams in Fig. 5. A paper tape reader and printer act as source and acceptor because their action is easy to visualize – they can clearly be replaced by any other device, equipment or process.

Next article – Design steps and implementation.

IN OUR NEXT ISSUE

80-100-watt audio amplifier

John Linsley Hood's new amplifier is described in a three-part article, beginning with an explanation of design problems in relation to the characteristics of mosfets. The design will be closely followed by a new, modular preamplifier, the pair forming possibly the best amplifying equipment yet described in these pages.

Microprocessor-controlled radio-code clock. Using the 60kHz standard-frequency time-code transmission from Rugby, this clock provides date and time information automatically, in that the display is continually corrected by the transmission. Particular attention to receiver design has greatly reduced the effects of interference, and a 6502 microprocessor is used to perform the decoding function.

Heretics guide to modern physics is a controversial review of current doctrine, set at the level of the sixth-form student or educated layman. Enormous gaps exist in our understanding of Nature and many of our fundamental theories are not very credible, says W. A. S. Murray, who in nine articles investigates electromagnetic theory, photons, duality, quantization, matter waves and haziness, and reviews the state of physics today.

Control technology and safety. Presenting information on large systems – oil rigs, nuclear power stations, aircraft – to control engineers is not a simple matter of laying out alarms and indicators on a large panel. The psychology of crisis control, the requirement for new types of equipment for data marshalling and methods of training personnel are examined by R. E. Young.

Radio in tunnels by leaky feeder. D. J. R. Martin, a specialist in underground radio communication, reviews developments in the use of leaky, or radiating, cables.

ON SALE MAY 16

CEPSTRUM ANALYSIS

This final part of the review gives uses in speech analysis and machine diagnostics, as well as calculation with an FFT analyser using the digital form. Part 2 gave application to signals containing echoes (March), while part 1 derived the cepstrum as the spectrum of a logarithmic spectrum.

by R. B. Randall and J. Hee

The applications of the cepstrum to speech analysis are mainly connected with its ability to separate source and transmission path effects, provided they have different quefrency contents. This is usually the case with speech where the source spectrum is very flat, containing a large number of harmonics of the voice pitch, but is modified by the resonance characteristics of the vocal tract, the so-called formants, which determine which vowel is being uttered. Fig. 13 shows spectra and cepstra for the vowels "oh" |0| and "ee" |i| and illustrates how the differences mainly lie in the low quefrency part of the cepstrum, which is dominated by the formant characteristic. Non-voiced sounds, such as many consonants and whispered speech, do not give peaks in the cepstrum corresponding to the voice pitch, and one of the earliest applications of the cepstrum was to separate voiced and non-voiced sounds and to measure voice pitch[10]

It is also possible by editing in the cepstrum to remove one effect completely, for example the voice, and thus simplify the tracking of the formants. Fig. 14 from ref. 11 shows a typical situation, a three-dimensional representation of the section "ea" from the word "Montreal". The picture is confused but by short-pass liftering each of the spectra to remove the voice components, as shown in Figs 15 and 16, only the formants are left and the picture becomes much clearer.

The cepstrum can be used for efficient vocoding and transmission of speech.[12] Most of the intelligence is contained in the low quefrency part of the cepstrum so only this is transmitted, along with information as to whether the speech is voiced and if so the voice pitch. At the receiver end the speech is reconstituted using the low quefrency information to generate a filter characteristic or impulse response for a source which would either be a variable frequency pulse generator for the voiced sections or a noise generator for the unvoiced sections. Despite the synthetic voice the speech was reported as sounding natural.

It can also be useful to include it along with spectral and other information in pattern recognition algorithms for speaker identification. Inclusion of the cepstral information improved the ability of the technique to exclude impostors.[13]

Machine diagnostics

The applications of the cepstrum to machine diagnosis are mainly based on its ability to detect periodicity in the spectrum, e.g. families of harmonics and uniformly spaced sidebands, while being insensitive to the transmission path of the signal from an internal source to an external measurement point.

The cepstrum technique has been proposed to aid detection of missing blades in turbines. Such blade anomalies give rise to a large number of harmonics of the shaft rotational speed in measurements[14] made both internally and externally on the casing in the vicinity of the affected blade row. Even though the harmonic pattern can be seen by eye, the whole family of harmonics is reduced in the cepstrum basically to one component which is much easier to monitor.

Similar reasoning is applicable to gearbox diagnosis; tooth anomalies have a very similar influence on gearbox vibration signals, as do blading anomalies on turbine signals.[15] A very detailed discussion is given in reference 15 of the application of cepstrum analysis to gearbox diagnosis and so here the discussion is limited to a couple of typical examples.

Fig. 14. *Scan spectrum of "ea" in "Montreal"*

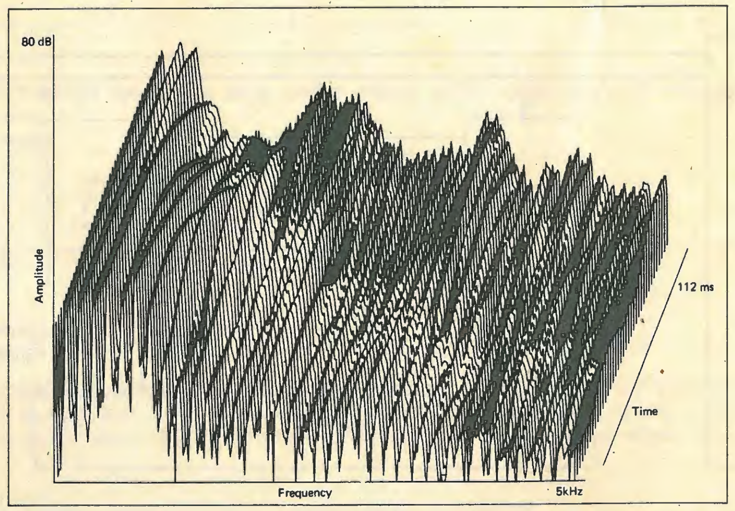
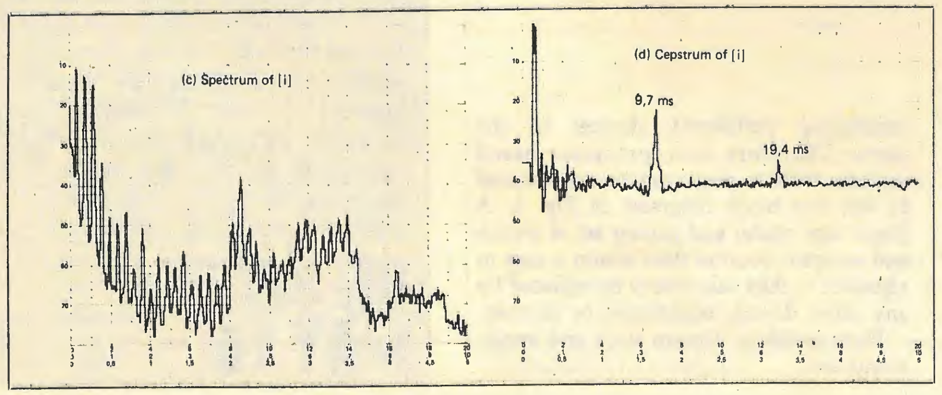


Fig. 13. *Spectra and cepstra for "ee" [I] vowel*



In gearbox vibrations deviations from exact uniformity of each toothmesh show up partly as harmonics of the shaft speed and also as sidebands around the toothmeshing harmonics caused by modulation of the toothmesh signal by the lower rotational frequencies. The sideband spacing thus contains valuable information as to the source of the modulation and can be extracted using the cepstrum. The cepstrum has the two advantages of being able to detect periodicity not immediately apparent to the eye, and of being able to measure it very accurately because it gives the average sideband spacing over the whole spectrum.

The first advantage is illustrated in Fig. 17 and was made using an FFT analyser type 2033 in conjunction with an HP9825 desk-top calculator. A 2000-line spectrum includes the first three harmonics of the toothmeshing frequency of a single reduction gearbox (a). It purposely excludes the low harmonics of the shaft speeds since these may have other causes than the toothmeshing. The spectrum was obtained by performing five 400-line zoom analyses on the same data and storing the intermediate results in the calculator memory. The 2000-line spectrum was then read digitally back into the 10K input memory of the analyser and frequency analysed once more using the scan average procedure with 75% overlapping Hanning windows to obtain the cepstrum. Fig. 17 (b) represents the average of five such cepstra. Even though it is difficult to see any periodic structure in the spectrum, it is apparent from the cepstrum that there are two families of sidebands with spacings of 85 Hz and 50 Hz respectively, the rotational speeds of the two gears. All significant components in the cepstrum stem from one or other of these two shaft speeds.

The other advantage is illustrated in Fig. 18 which shows spectra and cepstra for two truck gearboxes, in good and bad condition respectively, running on a test stand. The good gearbox shows no marked spectrum periodicity, but the spectrum of the bad one contains a large number of sidebands with a spacing of approximately 10 Hz. The cepstrum gives this spacing very accurately as 10.4 Hz and thus excludes the possibility that it was the second harmonic of the output shaft speed 5.4 Hz. It was traced to the rotational speed of second gear, even though this was idling because first gear was engaged. □

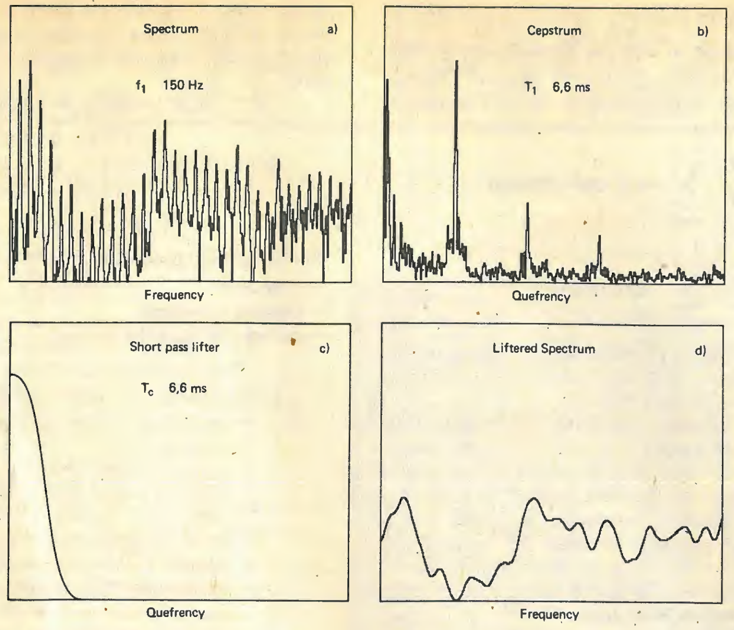


Fig. 15. *Cepstrum liftering*
a) log power spectrum of vowel
b) magnitude of cepstrum
c) short pass lifter characteristic
d) short pass liftered log power spectrum

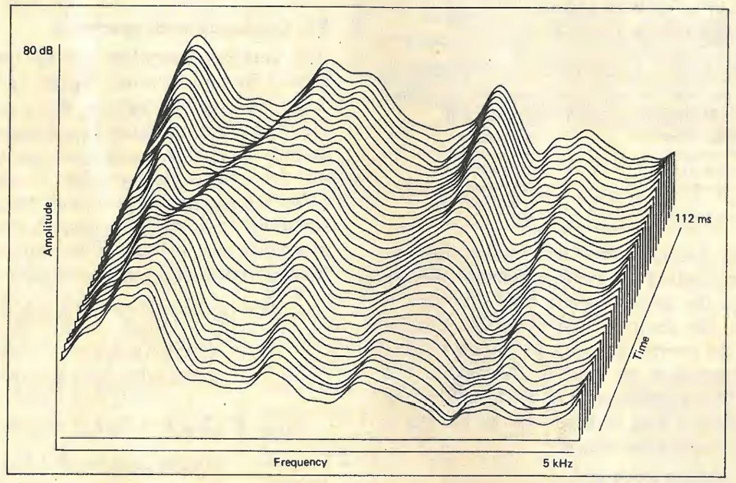


Fig. 16. *Short-pass liftered scan spectrum of "ea" in "Montreal"*

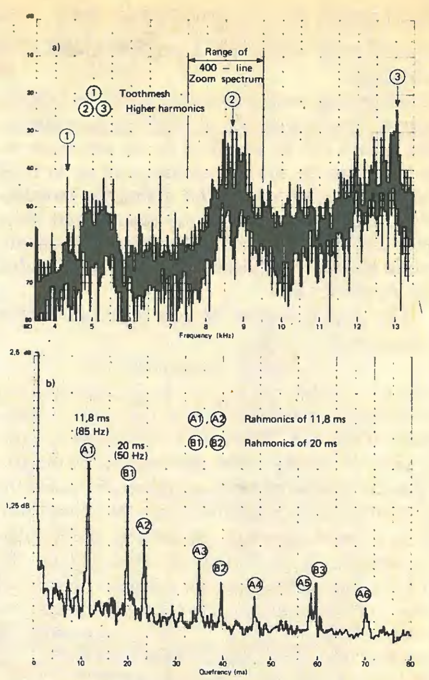


Fig. 17. *Example of a cepstrum analysis on a gearbox vibration signal*
(a) 2000-line logarithmic power spectrum
(b) Average cepstrum calculated from

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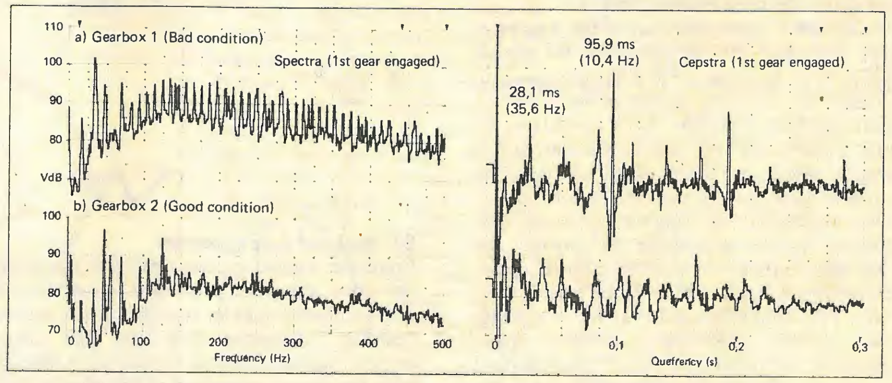


Fig. 18. *Spectra and cepstra from truck gearboxes in good and bad condition*

Appendix A

Calculation using FFT analyser and calculator.

Even though the analyser basically performs a forward transformation of 1024 real data points, the results can be modified in the calculator so as to obtain the inverse transform of up to 1024 real or complex values thus giving the possibility of calculating both power cepstra and complex cepstra. The actual algorithms used are more generally applicable and so are detailed in Appendix B.

The digital version of eqn 3 for the power cepstrum is

$$C_p(n) = F^{-1}\{\log F_{xx}(k)\}$$

where n stands for $n\ \Delta t$ (Δt is the sampling interval) and thus indicates the time. n runs from 0 to 1023. Likewise k represents the frequency $k\ \Delta f$ (Δf is the line spacing in the frequency spectrum) and in principle also runs from 0 to 1023 even though only the values from 0 to 512 are calculated. Because of the implicit periodicity of all functions calculated by the FFT process the values of k from 512 to 1024 also represent the negative frequency components (from −512 to 0) and can usually be derived from the positive frequency values.[16] As $F_{xx}(k)$ is a real even function, the inverse transformation can be replaced by a forward transformation (Appendix B1). In general only the one-sided power spectrum is given, and the simpler calculation method of Appendix B2 will be advantageous. With this method, only the one-sided spectrum is transformed, and the real part of the transform gives the desired cepstrum. Another advantage of this method is that the envelope cepstrum (amplitude cepstrum of the one-sided spectrum) of Fig. 4 may be obtained at the same time. In fact the analyser itself automatically calculates this and displays it as the instantaneous spectrum, which can be viewed on a linear amplitude scale. The envelope cepstrum is

$$C_e(n) = |\mathcal{F}^{-1}\{\log G(k)\}|$$

where $G(k)$ is the one-sided power spectrum. The formula for the complex cepstrum is

$$C_c(n) = \mathcal{F}^{-1}\{\log_e A_x(k) + j\phi_x(k)\}.$$

Because the logarithmic spectrum is a conjugate even function, the calculation method of Appendix B3 may be used. Note that the phase function $\phi_x(k)$ must be unwrapped to a continuous function of frequency in place of the principal values modulo 2 π which are calculated from the real and imaginary parts of the complex spectrum. Moreover the log amplitude must be scaled in nepers (natural log of the amplitude ratio) to correspond to the radians of the phase spectrum.

The analysers in general are a.c. coupled, so the zero frequency value in the power spectrum is not calculated. It is therefore necessary to insert a value before calculating the cepstrum. In practice best results are obtained by setting the zero frequency component equal to the value of the neighbouring line.

As the FFT algorithm used in the Analysers types 2033 and 2031 is optimized for signals with no d.c. component, it is advantageous to subtract the mean log spectrum value before calculating the cepstrum. This optimizes the signal noise conditions in the cepstrum, and is particularly valuable when editing and transformation in both directions is to be performed.

In calculation of the complex cepstrum it is advisable before attempting to unwrap the phase spectrum to remove any simple delay, which gives a linear slope to the phase spectrum. This should be done to the maximum extent possible in the time signal before transformation, and then in the phase spectrum itself by varying the linear component until the number of "jumps" over 2π is minimized.

Appendix B

Calculation of inverse Fourier transform

The forward and inverse discrete Fourier transforms, as calculated by the FFT analysers, are defined as

$$X(k) = \frac{1}{N}\sum_{n=0}^{N-1} x(n)\exp{-j2\pi kn/N}$$

$$\text{and } x(n) = \sum_{k=0}^{N-1} X(k)\exp j2\pi kn/N$$

where $X(k)$ the discrete complex spectrum $x(n)$ the sampled time function and N number of samples in the time record.

The Fourier transform implemented in the analysers types 2033 and 2031 is designed to be used forward transformation of real-valued time signals, but by using some of the properties of the Fourier transform, as listed in the tables, it can also be used for forward and inverse transformation of any complex signals. The inverse transformation of the three types of signals: real-valued, real and even, and conjugate even are described in the following. The

Algorithm	Conditions
$\mathcal{F}^{-1}\{X(k)\} = (N\mathcal{F}\{X^*(k)\})^*$	any $X(k)$
$\mathcal{F}^{-1}\{X(k)\} = N\mathcal{F}\{X^*(k)\}$	$x(n)$ real
$\mathcal{F}^{-1}\{X(k)\} = N\mathcal{F}\{X(k)\}$	$x(n)$ real, even
$\mathcal{F}^{-1}\{X(k)\} = (N\mathcal{F}\{X(k)\})^*$	$X(k)$ real

Time signal	Spectrum
real and even	real and even
real and odd	imag and odd
imag and even	imag and even
imag and odd	real and odd
real	conjugate even
conjugate even	real

results are sketched where the vertical lines indicate the result of the FFT calculation and the solid lines the desired result. Not that zero is shown in the centre of the diagram. During many of the operations, zero frequency or time will be located at the start of the record, but because of the periodicity of all functions the negative frequencies or times will be located in the second half of the record.

B1. Real-valued spectrum

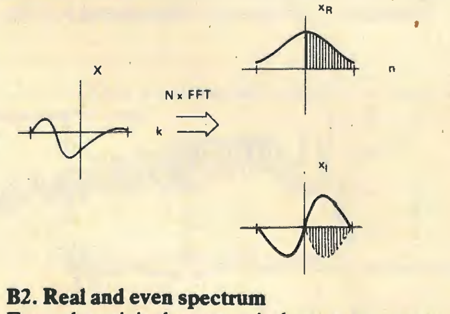
From the table it follows that

$$\mathcal{F}^{-1}\{X(k)\} = N[\mathcal{F}\{X(k)\}]^*.$$

The calculation procedure for positive time is then

- forward transform
- form complex conjugate
- multiply by N.

The result for both positive and negative time is seen in Fig. B1. For the special case of even spectra it is possible to omit the second step, but in that case the next procedure will normally be preferable anyway.



B2. Real and even spectrum

From the original symmetrical spectrum a new one-sided spectrum is formed which has the original spectrum as its even part and is zero for negative frequencies. The real part of the inverse transform of such a spectrum is identical with the inverse transform of the original spectrum. As normally only the positive frequency components of the original spectrum are given in any case, this saves forming the symmetrical spectrum for negative frequencies. It follows that

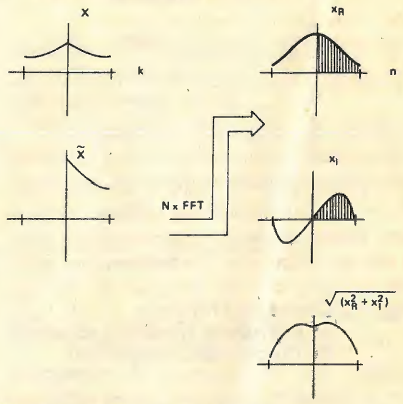
$$\mathcal{F}^{-1}\{X(k)\} = NR_e[\mathcal{F}\{\tilde{X}(k)\}]$$

$$\text{where } \tilde{X}(k) = \begin{cases} 2X(k), & 0<k<512 \\ X(k), & k=0, k=512 \\ 0, & -512<k<0 \end{cases}$$

$$\tilde{X}_e(k) = X(k).$$

The calculation procedure, Fig. B2, is thus

- form $\bar{X}(k)$
- forward transform
- extract and scale the real part.



B3. Conjugate even spectrum

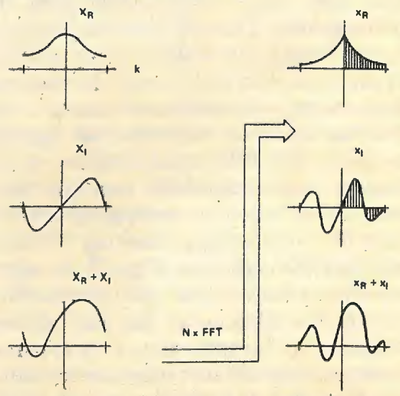
Any complex spectrum can be inverse-transformed by transforming the real and imaginary components separately by the procedure B1. However, this requires two Fourier transformations as well as some extra storage capacity for the intermediate results. In the situation where the spectrum is conjugate even, i.e. corresponding to a real time signal, the following procedure can be used. This requires only one transformation and a minimum of storage space.

$$\mathcal{F}^{-1}\{X(k)\} = \mathcal{F}^{-1}\{X_R(k) + jX_I(k)\}$$
$$= N[\mathcal{F}\{X_R(k)\} - j\mathcal{F}\{X_I(k)\}]$$
$$= N[\xi_R(n) + \xi_I(n)]$$

$$\text{Also } \mathcal{F}\{X_R(k) + X_I(k)\} = \xi_R(n) + j\xi_I(n)$$
$$\text{where } \xi_R(n) = \mathcal{F}\{X_R(k)\}$$
$$\text{and } j\xi_I(n) = \mathcal{F}\{X_I(k)\}$$

The calculation procedure, illustrated in Fig. B3, is as follows.

Add the real and imaginary parts for positive and negative frequencies. In practice this means adding the imaginary parts to the real parts (of the positive frequency spectrum) for the first half of the record and subtracting the same imaginary parts from the real parts for the second half in reverse order.



Forward transform. Add the real and imaginary parts for positive and negative time. The negative time section will be located in the second half of the record and can be removed to its correct position before the first half. Zero time will then be in the centre of the record.

NEW PRODUCTS

SPECTRUM/ NETWORK ANALYSER

Frequencies in the range 50Hz to 1.8GHz are covered by Takeda Riken's combined spectrum/network analyser, with which a dynamic range of 100dB may be displayed. The TR4172 has a built-in tracking generator, a four-channel memory, eight tunable markers and is GPIB compatible. Facilities for measuring phase and group delay, with a simultaneous display of amplitude, are included. This instrument is for use in both production and research and development applications. Chase Electronics Ltd, Church Lane, Teddington, Middx TW11 8PA.

WW301

WW301

BLUE L.E.D.

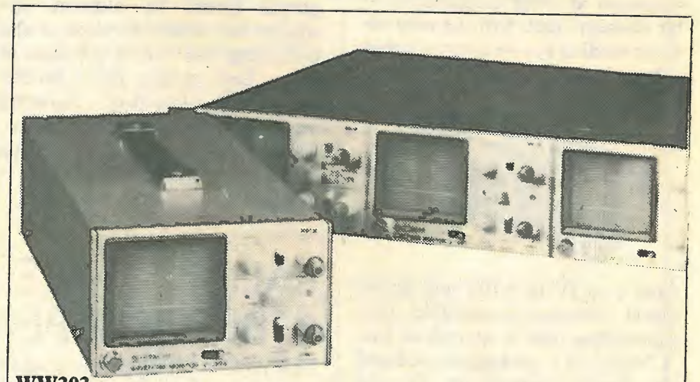
This is a 490nm gallium nitride l.e.d. intended primarily as a colour reference source in chromatography applications. Light output, in a viewing angle of 4°, is typically 2mcd at 10mA, which is also the maximum forward-current rating. Forward voltage varies between around 4.5V at 0.5mA and 7.5V at 10mA. The ESL50B2 is housed in a standard l.e.d. package. Anglia Components Ltd, Burdett Road, Wisbech, Cambs PE13 2PS.

WW302

WAVEFORM MONITOR

The V-098, designed for broadcast and professional video applications, is a waveform monitor that can be set to give a flat response, an IRE (Institute of Radio Engineers) response, or display waveforms subjected to a 4.43MHz bandpass filter. In addition, two line and field sweeps can be selected and various other adjustments made. This monitor is from Hitachi Instruments, a new division of Hitachi Denshi, and can be obtained for mounting in a 19in rack or as a portable unit running off batteries. Hitachi Denshi (UK) Ltd, 13-14 Garrick Industial Estate, Garrick Road, Hendon, London NW9

WW303



WW303

PORTABLE VIDEO RECORDER

According to Sulkin (UK) Ltd who import the Technicolor 212E, it is "the world's smallest, lightest and simplest" video cassette recorder. It uses 6.3mm tape cassettes not much larger than a standard audio cassette, for either 30 or 45 minutes of play, and weighs around 3.2kg with rechargeable batteries. Made by Funai and designed by Futec of Osaka, the mechanism is similar to the one used in the Grundig VP100 recorder and mentioned in last December's issue (New Products, page 87). But Grundig now say they will not market their recorder in the UK because of supply shortage. The 212E two-head recorder uses an Hitachi-made colour camera, though almost any other can be used via a simple adapter, with an electronic viewfinder, zoom lens, and close-up ×6 "macro" setting. A u.h.f. television tuner will be available shortly. Sulkin (UK) Ltd, 73 Grosvenor Street, London W1X 9DD.

WW304

WW304

TEACH YOURELF

An introduction to digital electronics suitable for beginners is given by a kit from Cambridge Learning covering such subjects as boolean algebra, gating, flip-flops, shift registers, ripple counters and half adders. Problems, with solutions, and an appendix covering basic principles are included in the manual. At £19.90, the kit comprises logic i.cs, a 'solderless' breadboard, l.e.ds, a handful of other components and, of course the manual – all in a pocket-sized wallet (for 14cm-wide pockets). A power supply or 4.5V battery is required. Supplementary kits delving further into digital electronics are proposed. Cambridge Learning Ltd, Rivermill Lodge, St Ives, Huntingdon, Cambs PE17 4EP.

WW305

NEW PRODUCTS

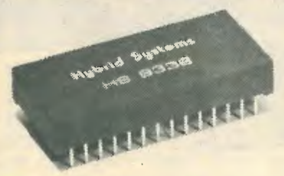
UNINTERRUPTIBLE P.S.U.

No-load to full-load voltage and frequency fluctuations of this uninterruptible power supply and regulator's output are ±1% and ±0.1% respectively. Maintenance-free batteries, normally under charge, drive the 240V/50Hz output during momentary or total mains failure and large mains fluctuations from 0 to 270V and from 40 to 70Hz have little effect on the output. The switch from mains to battery backup is not apparent at the output. Surge currents up to five times the nominal rating are provided for starting inductive motors, etc. These units can supply from 250VA to 2kVA, handle 100% overloads for 30 minutes and include comprehensive overload protection. T.h.d. is 2%. Compec Systems Ltd, Welton, Brough, N. Humberside HU15 1PT.
WW306

WW306

12-BIT D-TO-A

Linearity error of this 12-bit microprocessor compatible digital-to-analogue converter is 0.01%. The HS9338 has its input registers organized as three independent 4-bit elements each with its own register-loading enable input. Output voltage is programmable in ranges



from 0 to 5V to ±10V and an internal reference is available; output-settling time is quoted as 5μs. A 24-pin d.i.l. package is used and the device operates on 5V and ±15V supplies. Hybrid Systems UK, 12a Park Street, Camberly, Surrey.
WW307

FLUX-DENSITY METER

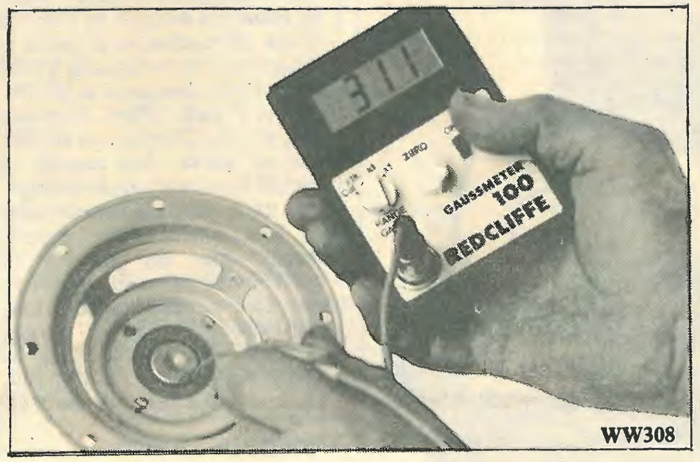
A small meter for checking magnetic fields up to 19.99 kilogauss ($1G=10^{-4}T$) in three ranges is manufactured by Redcliffe. Readings – down to 0.1G on the most sensitive range – are given on a 3 1/2-digit l.c.d. and the meter has a peak measurement function for checking and locating maximum flux areas in pulse-magnetised coils. Two probes are available, one for transverse fields and the other for axial fields, and a battery charger is supplied. Reference magnets are also available. Redcliffe Magtronics Ltd, 24 Emery Road, Brislington, Bristol BS4 5PQ.
WW308

ACRYLIC FILTERS

Expansions in Chequers' range of acrylic filters for light-emitting devices have been made. Red, green and grey filters are available in four shades, amber and blue filters in two. There are also yellow and purple filters. In addition, designers can obtain a sample wallet containing four shades or colours of filter. Each sample has a section treated with Glarecheq – a coating for reducing glare and reflection. Chequers (UK) Ltd, 1-4 Christina Street, London EC2A 4PA.
WW309

CALIBRATABLE STROBOSCOPE

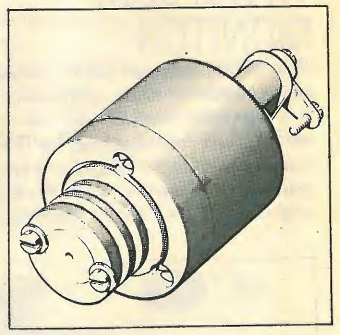
This type of instrument is used in every field of engineering and has medical applications, yet we see surprisingly few new designs. Firnor Misilon has introudced a stroboscope which it claims has, "features usually associated with units costing twice as much." Retailing at £198 excluding v.a.t., the WM10 has three ranges covering rates from 0 (off?) to 16000 flashes per minute. When used without external triggering, the flash rate can be set to within 1% at certain points on the continuously-variable scale using a mains-frequency dependent calibration method; a t.t.l. compatible output is provided. Maximum light output of the unit is 10W and mains inputs from 110V to 240V a.c. can be used. Firnor Misilon, Unit 49, The Maltings, Stanstead Abbotts, Herts.
WW310



WW308

ATOM SOURCE FOR VACUUM DEPOSITION

Researchers at UMIST's chemistry department developed a fast-atom bombardment (f.a.b.) source for mass spectrometry now available from Ion Tech Ltd. The saddle-field gas gun provides an intense neutral beam of fast atoms and does not require the use of a charge exchange cell to neutralize the gas ions produced with an electrostatic saddle field oscillator. The cold cathode ion gun also has application in thin-film vacuum deposition and



in substrate cleaning. Much better adhesion between a surface and, say, copper is obtained if it is first bombarded with the atom gun, the makers say. Known as the FAB-GG, the gun is available from Ion Tech Ltd, 2 Park Street, Teddington, Middx TW11 0LT.
WW311

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.

Item No.	
1	TEKTRONIX PORTABLE OSCILLOSCOPE type 422. Dual Trace £350
2	TEKTRONIX STORAGE MONITOR type 613 £395
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20	HEWLETT PACKARD WIDE RANGE OSCILLATOR type 200CD £35
21	HEWLETT PACKARD AUDIO OSCILLATOR type 200J £35
22	HEWLETT PACKARD PULSE GENERATOR Model 212A £25
23	HEWLETT PACKARD DC MICRO VOLT AMMETER type 425A £40
24	HEWLETT PACKARD OSCILLOSCOPE 182A with 1808A and 1825A, 75MHZ Dual Trace Delayed Sweep £950
25	HEWLETT PACKARD DIGITAL VOLTMETER type 3430A £65
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37	B & K ACCELEROMETER PREAMPLIFIER type 2622 £30
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AAY32	0.48	ASZ17	1.15	BC177	0.32	BD135	0.46	BF259	0.32	GM0378A	2.02	OC20	2.88	OC207	2.88	ZTX550	0.29	2N2147	4.60
AAZ13	0.17	ASZ20	2.64	BC178	0.16	BD136	0.46	BF336	0.38	KS100A	0.52	OC22	4.60	OCP71	2.30	1N914	0.06	2N2148	4.31
AAZ15	0.17	ASZ21	2.88	BC179	0.32	BD137	0.46	BF337	0.38	ME340	0.69	OC23	2.88	ORP12	1.15	1N916	0.10	2N2218	0.37
AAZ17	0.17	AU113	2.88	BC182	0.13	BD138	0.55	BF338	0.41	MJE370	0.84	OC24	4.60	R2008B	2.30	1N4001	0.07	2N2219	0.27
AC107	0.63	AUY10	3.45	BC183	0.13	BD139	0.55	BF521	4.60	MJE371	0.82	OC25	1.15	R2009	2.59	1N4002	0.07	2N2220	0.23
AC125	0.29	AU110	2.88	BC184	0.13	BD140	0.58	BF528	2.88	MJE520	0.54	OC26	1.15	R2010B	2.30	1N4003	0.07	2N2221	0.23
AC126	0.29	BA145	0.15	BC212	0.13	BD144	2.30	BFS61	0.23	MJE521	0.84	OC28	2.30	TIC44	0.31	1N4004	0.08	2N2222	0.23
AC127	0.29	BA148	0.17	BC213	0.13	BD181	1.38	BFS98	0.23	MJE2955	1.50	OC29	2.30	TIC226D	1.38	1N4005	0.10	2N2223	4.89
AC128	0.35	BA154	0.12	BC214	0.13	BD182	1.36	BFW10	1.12	MJE3055	1.27	OC35	1.73	TIL209	0.23	1N4006	0.13	2N2368	0.29
AC141	0.32	BA155	0.13	BC237	0.13	BD237	0.62	BFW11	1.10	MPF102	0.40	OC36	1.73	TIP29A	0.49	1N4007	0.14	2N2369A	0.29
AC141K	0.40	BA156	0.12	BC238	0.13	BD238	0.62	BFX84	0.35	MPF103	0.40	OC41	1.04	TIP30A	0.52	1N4009	0.08	2N2484	0.29
AC142	0.32	BAW62	0.06	BC301	0.38	BD410	1.05	BFX87	0.35	MPF104	0.40	OC42	1.04	TIP31A	0.38	1N4148	0.05	2N2646	0.58
AC142K	0.40	BAX13	0.07	BC303	0.39	BDX32	2.30	BFX88	0.35	MPF105	0.40	OC43	1.04	TIP32A	0.41	1N5400	0.15	2N2904	0.37
AC176	0.35	BAX16	0.07	BC307	0.13	BDY20	1.73	BFY50	0.29	MPSA06	0.30	OC44	0.98	TIP33A	0.62	1N5401	0.16	2N2905	0.37
AC187	0.32	BC107	0.18	BC308	0.13	BDY60	3.16	BFY51	0.29	MPSA56	0.32	OC45	0.75	TIP34A	0.77	1S44	0.05	2N2906	0.24
AC188	0.32	BC108	0.18	BC327	0.14	BF115	0.40	BFY52	0.29	MPSU01	0.61	OC71	0.63	TIP41A	0.51	1S920	0.09	2N2907	0.24
ACY17	1.50	BC109	0.18	BC328	0.14	BF152	0.18	BFY64	0.35	MPSU06	0.75	OC72	0.81	TIP42A	0.48	1S921	0.10	2N2924	0.30
ACY18	1.32	BC113	0.17	BC337	0.14	BF153	0.18	BFY90	1.09	MPSU56	0.79	OC74	0.75	TIP2955	0.81	2G301	1.15	2N2925	0.25
ACY19	1.27	BC114	0.17	BC338	0.14	BF154	0.20	BSX19	0.31	NE555	0.52	OC75	1.15	TIP3055	0.64	2G302	1.15	2N2926	0.17
ACY20	1.27	BC115	0.21	BCY30	1.44	BF159	0.20	BSX20	0.31	NKT404	2.30	OC76	1.15	TIS43	0.49	2G306	1.15	2N3053	0.30
ACY21	1.32	BC116	0.22	BCY31	1.73	BF160	0.20	BSX21	0.33	NKT403	2.88	OC77	1.73	ZS140	0.29	2N404	1.50	2N3054	0.63
ACY39	2.88	BC117	0.26	BCY32	1.73	BF167	0.28	BT106	1.38	NKT404	2.53	OC81	1.38	ZS170	0.24	2N696	0.37	2N3055	0.75
AD149	0.86	BC118	0.21	BCY33	1.73	BF173	0.35	BTY79/400R		OA5	1.38	OC81D	1.38	ZS171	0.26	2N697	0.37	2N3440	0.80
AD161	0.40	BC125	0.21	BCY34	1.15	BF177	0.40		2.30	OA7	0.69	OC81Z	1.38	ZS178	0.26	2N698	0.81	2N3441	0.98
AD162	0.40	BC126	0.21	BCY39	3.91	BF178	0.40	BU205	1.50	OA10	0.63	OC82	1.04	ZS271	0.26	2N705	1.44	2N3442	1.44
AF106	0.40	BC135	0.17	BCY40	3.22	BF179	0.40	BU206	1.73	OA47	0.14	OC83	0.92	ZS278	0.65	2N706	0.29	2N3614	2.53
AF114	0.86	BC136	0.22	BCY42	0.35	BF180	0.32	BU208	2.30	OA70	0.29	OC84	0.92	ZTX107	0.14	2N708	0.29	2N3702	0.13
AF115	0.86	BC137	0.22	BCY43	0.35	BF181	0.32	BY100	0.46	OA79	0.14	OC122	2.30	ZTX108	0.14	2N930	0.29	2N3703	0.13
AF116	0.86	BC147	0.14	BCY58	0.22	BF182	0.35	BY126	0.15	OA81	0.20	OC123	1.38	ZTX109	0.14	2N1131	0.35	2N3704	0.13
AF117	0.86	BC148	0.14	BCY70	0.20	BF183	0.32	BY127	0.16	OA85	0.20	OC139	4.60	ZTX300	0.15	2N1132	0.35	2N3705	0.13
AF139	0.38	BC149	0.15	BCY71	0.21	BF184	0.32	BZX61	0.20	OA90	0.09	OC140	4.60	ZTX301	0.16	2N1302	1.38	2N3706	0.13
AF186	1.15	BC157	0.15	BCY72	0.20	BF185	0.35	Series		OA91	0.09	OC141	4.93	ZTX302	0.21	2N1303	0.92	2N3707	0.13
AF239	0.45	BC158	0.15	BCZ11	2.01	BF194	0.16	BZY88	0.12	OA95	0.09	OC170	1.44	ZTX303	0.21	2N1304	1.38	2N3708	0.12
AFZ11	4.60	BC159	0.15	BD115	0.48	BF195	0.14	Series		OA200	0.17	OC171	1.44	ZTX304	0.23	2N1305	1.15	2N3709	0.13
AFZ12	4.60	BC167	0.13	BD121	1.96	BF196	0.15	CRS1/40	0.69	OA202	0.17	OC200	1.73	ZTX311	0.15	2N1306	1.73	2N3710	0.12
ASY26	1.61	BC170	0.13	BD123	3.22	BF197	0.16	CRS3/40	0.86	OA211	1.73	OC201	2.88	ZTX314	0.29	2N1307	1.27	2N3711	0.12
ASY27	1.04	BC171	0.12	BD124	2.30	BF200	0.46	CRS3/60	1.04	OAZ200	1.73	OC202	3.16	ZTX500	0.16	2N1308	2.01	2N3771	1.61
						BF224	0.29	GEX66	3.45	OAZ201	1.73	OC203	3.45	ZTX501	0.16	2N1309	1.38	2N3772	1.84
						BF244	0.32			OAZ206	1.73	OC204	3.45	ZTX502	0.21	2N1613	0.37	2N3773	2.07
														ZTX503	0.22				

2N3819 0.35; 2N3820 0.45; 2N3823 0.69; 2N3866 1.15; 2N3904 0.20; 2N3905 0.20; 2N3906 0.20; 2N4058 0.23; 2N4059 0.23; 2N4060 0.18; 2N4061 0.18; 2N4062 0.18; 2N4124 0.18; 2N4126 0.18; 2N4286 0.17; 2N4288 0.21; 2N4289 0.21; 2N5457 0.37; 2N5458 0.37; 2N5459 0.37; 2S017 11.50; 2S019 13.80; 2S026 28.75; 2S103 1.73; 2S302 2.30; 2S303 4.03; 2S322 4.03; 2S324 4.03; 2S701 2.30; 2S745A 1.09; 2S746A 1.09

VALVES

A1834 10.35; A2087 13.58; A2134 20.13; A2293 8.62; A2426 17.63; A2521 24.38; A2900 14.43; A3343 51.75; AZ31 1.26; AZ41 1.32; BK448 110.27; BK484 149.09; BS90 52.27; BS810 86.25; BT5 58.13; BT17 106.89; BT19 36.17; BT29 327.69; BT69 333.50; BT75 102.46; BT95 127.02; CBL31 2.30; CL33 2.30; CY31 1.15; C1K 21.30; C3A 11.50; C3JA 23.23; DA41 28.75; DA42 21.51; DA100 97.93; DAF91 0.46; DAF96 1.15; DET22 32.78; DET24 52.90; DF91 0.46; DF96 1.15; DK91 1.21; DK92 1.44; DK96 1.26; DL92 1.26; DL94 1.38; DL96 1.26; DLS10 9.48; DLS15 12.37; DLS16 12.37; DLS19 12.37; DM70 1.44; DM71 1.44; DM160 3.96; DY87 0.74; DY802 0.96; E55L 25.17; E80CC 11.27; E80CF 12.96; E80F 14.19; E80L 13.98; E81CC 6.62; E81L 14.06; E82CC 7.03; E83CC 7.16; E86C 13.23; E88C 7.12; E88CC 3.86; E90CC 9.94; E90F 11.39; E91H 5.34; E92CC 9.40; E99F 10.16

E130L 19.39; E180CC 11.39; E180F 7.83; E182CC 13.80; E186F 12.58; E188CC 9.40; E280F 25.88; E283CC 9.02; E288CC 18.54; EA52 28.18; EA76 2.30; EABC80 1.38; EAC91 0.92; EAF42 1.44; EAF801 2.02; EB41 2.30; EB91 1.01; EBC33 2.02; EBC41 1.44; EBC81 1.26; EBC90 0.97; EBF80 0.58; EBF83 1.44; EBF89 0.97; EBL31 2.88; EC90 1.28; EC91 9.33; EC92 1.44; EC157 349.26; ECC33 4.02; ECC35 4.02; ECC40 2.30; ECC81 1.01; ECC82 0.82; ECC83 1.01; ECC84 1.36; ECC85 1.38; ECC86 2.30; ECC88 2.07; ECC89 1.88; ECC91 10.27; ECC189 1.90; ECC807 2.02; ECC808 2.59; ECF80 1.24; ECF82 1.38; ECF86 1.73; ECH35 2.30; ECH42 1.32; ECH81 1.38; ECH83 1.44; ECH84 1.47; ECL80 1.15; ECL81 1.73; ECL82 1.15; ECL83 1.73; ECL84 1.61; ECL85 1.28; ECL86 1.38; EF37A 4.02; EF39 3.16; EF40 3.45; EF41 2.30; EF42 2.30; EF50 1.73; EF54 5.75; EF55 2.88; EF80 0.92; EF83 4.03; EF85 0.92

EF86 1.74; EF89 1.84; EF91 2.07; EF92 6.68; EF93 1.15; EF94 1.24; EF95 6.27; EF98 1.44; EF183 0.92; EF184 0.96; EF804S 12.65; EF805S 12.65; EH90 1.61; EK90 1.24; EL32 1.73; EL33 4.02; EL34TH 2.53; EL34MUI 3.16; EL36 1.84; EL41 1.44; EL42 2.02; EL81 4.03; EL83 4.03; EL84 1.15; EL86 2.88; EL90 1.10; EL91 8.21; EL95 1.51; EL156 27.60; EL360 9.77; EL500/504 2.16; EL509 3.63; EL821 11.96; EL822 12.55; EM34 5.75; EM80 1.26; EM81 1.15; EM84 1.15; EM85 1.44; EM87 1.73; EN32 13.66; EN91 2.94; EN92 5.23; EY51 2.02; EY81 1.89; EY83 2.02; EY84 10.57; EY86 0.96; EY88 2.02; EY500A 2.23; EY802 94; EZ35 97; EZ40 1.44; EZ41 1.44; EZ80 0.96; EZ81 0.96; EZ90 1.38; FW4-500 2.88; FW4-800 2.88; G1.371K 41.40; G551K 12.65; G180.2M 18.42; G240.2D 12.85; G400.1K 19.28; GN4 8.62; GN4A 8.62; GS16 10.35; GT1C 14.38; GU50 14.31; GU51 13.62

GXU1 16.10; GXU2 28.43; GXU3 30.49; GXU4 32.77; GXU50 17.25; GY501 3.16; GZ32 1.44; GZ33 4.60; GZ34 2.88; GZ37 4.60; KT61 4.02; KT66 11.50; KT88 13.80; KTW61 2.02; KTW62 2.02; KTW63 2.02; M8079 12.29; M8080 9.49; M8081 11.30; M8082 9.87; M8083 8.54; M8091 11.99; M8096 4.31; M8097 4.09; M8098 5.50; M8099 5.98; M8100 9.49; M8136 9.98; M8137 9.73; M8140 5.17; M8141 5.52; M8142 7.77; M8144 4.31; M8149 5.86; M8161 9.11; M8162 10.36; M8163 5.17; M8190 5.29; M8195 4.25; M8196 7.47; M8204 6.57; M8212 12.47; M8223 3.80; M8224 4.66; M8225 2.99; M8248 13.32; MU14 1.73; MX119 58.65; MX123 67.85; MX145 62.10; MX151 17.25; MX152 143.75; MX161 166.75; MX163 23.11; MX164 27.95; MX166 161.00; MX168 48.30; N78 20.13; OA2 2.30; OA3 5.69; OA4 4.02; OB2 1.44; OB3 2.20; OC2 3.04; OC3 2.20; OD3 2.20; OZ4 1.84; PC86 1.61; PC88 1.61; PC95 1.49

PC97 1.38; PC900 1.38; PCC84 1.15; PCC85 1.38; PCC88 1.38; PCC89 1.56; PCC189 1.61; PCC805 1.51; PCC806 2.07; PCE82 2.07; PCF80 1.15; PCF82 1.15; PCF86 1.84; PCF87 1.84; PCF200 3.74; PCF201 2.45; PCF801 1.84; PCF802 2.19; PCF805 1.84; PCF806 1.84; PCF808 1.84; PCL82 1.15; PCL83 2.30; PCL84 1.15; PCL85 1.24; PCL86 1.24; PCL805/85 1.24; PD500 4.14; PE06-40N 31.40; PFL200 2.07; PL36 1.38; PL81 1.38; PL81A 1.38; PL82 1.38; PL83 2.55; PL84 1.24; PL504/5 1.61; PL508 2.07; PL509 3.73; PL519 3.73; PL801 1.27; PL802 3.40; PY33 1.27; PY81 0.97; PY82 0.92; PY83 0.81; PY88 1.01; PY500A 2.07; PY800 0.97; PY801 0.97; QQV02-6 16.17; QQV03-20A 20.13; QQV06-40A 47.15; QQV07-50 60.66; QQZ03-20A 59.80; QQZ06-40A 63.37; QU37 14.38; QV03-12 5.62; QV04-7 2.88; QV08-100 137.08; QY3-65 57.06; QY3-125 62.40; QY4-250 77.05; QY4-400 80.44; QY5-500 168.83

QY5-3000A 356.66; QZ06-20 34.16; R10 5.75; R17 1.89; R18 4.89; R19 1.38; R20 1.66; RG3-250 35.77; RG3-250A 37.49; RG3-1250 63.94; RG4-1250 43.13; RG4-3000 90.36; RR3-250 53.54; RR3-1250 94.83; S11E12 55.20; S130 3.45; S130P 4.03; STV280-40 11.50; STV280-80 24.15; SU41 2.88; SU42 10.35; TD03-10 32.78; TD03-10E 32.78; TD03-29F 33.93; TT15 34.50; TT21 16.98; TT22 16.98; TT100 59.51; TY2-125 69.01; TW4-400 74.07; TY4-500 105.97; TY5-500 187.45; TY6-800 193.20; TY6-5000A 356.50; TY6-5000B 264.50; TY6-5000W 316.25; TY7-6000A 368.80; TY7-6000W 322.00; TZ40 28.75; U18-20 2.88; U19 15.81; U25 1.33; U26 1.66; U37 10.35; UABC80 1.44; UAF42 1.44; UB41 1.44; UBC41 1.73; UBF89 1.38; UCC84 1.26; UCC85 1.38; UCF80 1.32; UCH42 1.38; UCH81 2.67; UCL82 1.20; UCL83 1.66; UF41 1.15; UF42 1.44; UF80 1.66; UF85 1.66; UF89 1.66; UL41 2.88

UL84 1.38; UM80 1.15; UY41 1.44; UY85 1.20; VLS631 15.24; XG1-2500 58.02; XG2-6400 113.50; XG5-500 28.23; XG2-6400 155.42; XR1-1600A 58.88; XR1-3200 87.15; XR1-3200A 93.15; XR1-6400 108.30; XR1-6400A 164.23; YD1120 264.50; YD1240 366.62; Z759 19.32; ZM1000 6.03; ZM1001 6.19; ZM1020 10.83; ZM1021 10.17; ZM1022 10.60; ZM1023 8.81; ZM1040 22.26; ZM1041 19.16; ZM1042 20.44; ZM1051 100.05; 1B3GT 2.58; 1B24 11.50; 1B35A 28.75; 1B63 57.50; 1R5 1.21; 1S5 0.46; 1T4 0.46; 2AS15 11.50; 2C39A 21.85; 2C43 20.70; 2D21 2.94; 2E26 17.86; 2J42 109.25; 2J55 239.97; 2J70A 442.75; 2J70B 418.34; 2K25 40.25; 3-400Z 57.50; 3-500Z 63.25; 3A5 2.70; 3B24 9.20; 3B28 16.50; 3B29 11.50; 3B240M 17.25; 3B241M 17.25; 3C23 26.83; 3C45 28.18; 3CX100A5 23.00; 3E29 29.67; 3S4 1.26; 3V4 1.38; 465A 29.15; 4-125A 41.99; 4-250A 41.99; 4-400A 52.05

4B32 29.16; 4C35 74.75; 4CX250B 51.75; 4CX350A 80.50; 4X150A 24.41; 4X150D 28.75; 5B254M 23.12; 5B255M 23.12; 5C22 74.75; 5J180E 1380.00; 5R4GY 4.03; 5U4G 1.75; 5U4GB 2.90; 5V4G 1.75; 5Y3GT 0.98; 5Z3 1.73; 5Z4G 1.75; 5Z4GT 1.75; 6-30L2 1.79; 6AB4 1.44; 6AB7 1.73; 6AC7 1.61; 6AF4A 1.84; 6AG7 2.30; 6AH6 5.52; 6AK5 4.15; 6AK6 2.81; 6AL5 1.01; 6AM4 2.65; 6AM5 8.21; 6AM6 2.07; 6AN5 4.45; 6AN8A 3.97; 6AQ5 1.10; 6AS6 5.73; 6AS7G 9.49; 6AT6 0.98; 6AU5GT 4.97; 6AU6 1.24; 6AV5GA 4.52; 6AV6 0.98; 6AX5GT 3.57; 6B7 1.73; 6B8 2.02; 6BA6 1.15; 6BA7 5.89; 6BA8A 4.31; 6BC4 4.27; 6BE6 1.24; 6BH6 1.75; 6BJ6 1.24; 6BK4 4.84; 6BL6 97.75; 6BL7GT 4.44; 6BM6 97.75; 6BN6 1.89; 6BQ7A 4.28; 6BR7 4.60; 6BR8 2.02; 6BS7 4.60; 6BW6 4.60; 6BW7 1.75; 6BX7GT 5.70; 6BZ6 2.73; 6C4 1.01; CB6A 2.86; 6CD6GA 5.83; 6CG7 2.62; 6CH6 11.96; 6CL6 4.12

6CW4 8.83; 6D2 1.01; 6DK6 3.00; 6DQ6B 4.69; 6EA8 3.38; 6EB8 2.44; 6EW6 1.73; 6F6 2.02; 6F23 1.84; 6F28 1.33; 6F33 34.50; 6H1 14.38; 6H2N 1.21; 6H3N 1.21; 6H6 1.73; 6J4 6.10; 6J6 6.21; 6J7 2.88; 6K4N 1.44; 6K6GT 1.50; 6K7 1.73; 6K8 2.02; 6KD6 7.31; 6L6G 2.88; 6L6GA 1.73; 6L6GT 2.24; 6L6GC 2.88; 6L7 2.30; 6N2P 1.21; 6N3P 1.21; 6N7 1.73; 6P25 4.14; 6Q7 2.53; 6R7 2.07; 6SA7 1.67; 6SC7 1.73; 6SF7 1.84; 6SH7 1.73; 6SJ7 1.84; 6SK7 1.50; 6SK7GT 3.08; 6SN7GT 1.84; 6SQ7 1.50; 6SR7 1.73; 6SS7 2.07; 6U5G 2.30; 6U8 0.92; 6U8A 3.38; 6V6GT 1.84; 6X4 1.38; 6X5GT 0.97; 7B7 1.96; 7C5 3.40; 7C6 2.60; 7H7 2.30; 7R7 1.73; 7S7 2.59; 7Y4 1.84; 7Z4 2.13; 11E3 60.82; 12AT6 1.38; 12AT7 1.01; 12AU6 2.97; 12AU7 0.83; 12AV6 2.55; 12AV7 4.00; 12AX7 1.01; 12AY7 4.69; 12B4A 3.62; 12BA6 2.52

12BE6 2.79; 12BH7 1.29; 12BY7 3.11; 12E1 19.67; 12E11TT 19.26; 12E14 34.50; 13E1 123.05; 19H4 28.75; 19H5 40.25; 24B9 55.20; 30C15 1.84; 30C17 1.84; 30C18 1.84; 30F5 1.93; 30FL1/2 1.28; 30FL12 2.07; 30FL14 1.84; 30L1 1.15; 30L15 2.07; 30L17 2.07; 30P4 1.06; 30P19 1.38; 30PL1 2.88; 30PL14 1.93; 30PL15 2.07; 35W4 0.69; 50C5 0.81; 75B1 5.38; 75C1 2.70; 85A1 8.63; 85A2 2.75; 90AG 14.90; 90AV 14.90; 90C1 3.35; 90CG 16.72; 90CV 17.50; 92AG 14.90; 92AV 14.90; 95A1 7.48; 150B2 3.47; 150B3 6.39; 150C2 2.21; 150C4 2.75; 211 21.85; 723AB 40.25; 803 11.50; 805 23.00; 807 4.31; 811A 21.08; 812A 21.08; 813 91.15; 833A 153.57; 866A 17.56; 872A 24.69; 922 5.01; 931A 18.15; 1624 2.59; 1625 1.96; 2050 8.00; 4212E 304.75; 4212H 304.75; 5544 62.10; 5545 67.85; 5551A 123.51; 5552A 166.98; 5553A 259.10; 5642 6.45; 5654 3.93; 5651 4.66

5670 5.18; 5675 21.47; 5687 6.31; 5696 4.35; 5718 7.87; 5725 5.62; 5726 3.62; 5727 6.47; 5749 5.14; 5751 4.80; 5763 4.66; 5814A 4.28; 5840 5.06; 5842 13.90; 5876A 19.55; 5879 5.38; 5886 12.08; 5963 3.38; 5965 4.00; 6005 5.62; 6021 5.13; 6057 4.02; 6058 12.47; 6059 4.60; 6061 4.89; 6062 4.31; 6063 4.20; 6064 8.54; 6067 4.02; 6072 5.80; 6080 7.88; 6097AxBxC 166.75; 6146A 12.24; 6146B 9.34; 6159B 19.91; 6189 10.03; 6201 10.92; 6442 17.25; 6883B 14.64; 6973 4.38; 7025 2.73; 7551 6.45; 7586 11.66; 7587 20.11; 7609 36.57; 7868 5.04; 7895 13.25; 8005 86.40; 8068 6.33; 8122 60.11; 8136 2.48; 8417 6.76; 18042 8.63; 18045 12.06

Tested Ex-Equipment
4CX250B 5.75

BASES

B7G unskirted	0.25
B7G skirted	0.35
B9A unskirted	0.25
B9A skirted	0.35
Int Octal	0.40
Loctal	0.63
Nuvistor base	0.86
8 pin DIL	0.17
14 pin DIL	0.17
16 pin DIL	0.20
Valve screening cans all sizes	0.35

CRTs

2AP1	9.78	5ADP1	40.25	VCR138A	14.38
2BP1	10.35	5BP1	11.50	VCR139A	9.20
3BP1	11.50	5CP1	11.50	VCR517A	11.50
3DP1	5.75	5CP1A	46.00	VCR517B	11.50
3EG1	8.05	5FP15A	17.25	VCR517C	11.50
3FP7	6.90	5UP7	28.75		
3GP1	6.90	DG7-5	72.82		
3JP1	9.20	DG7-31	66.78		
3JP2	9.20	DG7-32	66.78		
3JP7	11.50	DH3-91	67.65		
3KP1	17.25	DH7-11	130.09		
3RP1	40.25	VCR97	13.80		
3WP1	23.00	VCR138	11.50		

Tube Bases
Prices on application

INTEGRATED CIRCUITS

7400	0.18	7423	0.38	7460	0.21	7495	0.84	74136	0.59	74175	1.17	TBA480Q	2.12		
7401	0.20	7425	0.35	7470	0.44	7496	0.94	74141	1.02	74176	1.33	TBA520Q	2.65		
7402	0.20	7427	0.35	7472	0.38	7497	3.62	74142	2.64	74178	1.56	TBA530	2.28		
7403	0.20	7428	0.50	7473	0.44	74100	1.77	74143	2.99	74179	1.56	TBA540Q	2.65		
7404	0.21	7430	0.20	7474	0.44	74107	0.52	74144	2.99	74180	1.38	TBA550Q	3.70		
7405	0.21	7432	0.35	7475	0.62	74109	0.84	74145	1.15	74190	2.19	TBA560CQ	3.70		
7406	0.49	7433	0.46	7476	0.48	74110	0.59	74147	2.30	74191	2.19	TBA673	2.52		
7407	0.49	7437	0.37	7480	0.64	74111	0.82	74148	2.02	74192	2.19	TBA700	1.75		
7408	0.23	7438	0.37	7482	0.86	74116	2.13	74150	2.07	74193	2.19	TBA720Q	2.65		
7409	0.23	7440	0.37	7483	1.15	74118	1.15	74151	1.08	74194	1.44	TBA750Q	2.38		
7410	0.20	7441	1.04	7484	1.21	74119	1.77	74154	2.07	74195	1.38	TBA800	1.38		
7412	0.33	7442	0.83	7486	0.45	74120	0.95	74155	1.04	74196	1.55	TBA920	3.34		
7413	0.37	7447AN	1.35	7490	0.69	74121	0.49	74156	1.04	74197	1.55	TBA920Q	3.34		
7416	0.37	7450	0.21	7491	0.94	74122	0.71	74157	0.86	74198	3.11	TBA990Q	3.34		
7417	0.37	7451	0.21	7492	0.69	74123	1.36	74159	2.53	74199	2.64	TCA270Q	3.34		
7420	0.21	7453	0.21	7493	0.69	74125	0.67	74170	2.76	76013N	2.02	TCA760A	1.59		
7422	0.23	7454	0.21	7494	0.94	74126	0.67	74172	5.06	TAA570	2.65				
						74128	0.72	74173	1.63	TAA630S	4.02				
						74132	0.83	74174	1.84	TAA700	4.50				

Terms of business: CWO. Postage and packing valves and semiconductors 58p per order. CRTs £1.73. All prices include VAT.
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In some cases prices of Mullard and USA valves will higher than those advertised. Prices correct when going to press.
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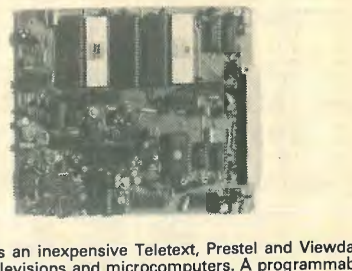
TELETEXT AND PRESTEL VIEWDATA

Universal single plug-in board

Combined TELETEXT AND PRESTEL



The Lion Viewdata plug-in board is an inexpensive Teletext, Prestel and Viewdata single board designed for use in televisions and microcomputers. A programmable interface serial and parallel accepts remote controls, keyboards and microcomputer interfaces. The board is directly exchangeable with our Teletext only board (Mullard set), and other teletext boards are simply exchangeable.

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- ★ Full editing or message keyboard option
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- ★ Microcomputer interface
- ★ Autodial local and remote programming
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- ★ Timed Teletext pages
- ★ Re-programmable interface
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- ★ Replacement of Teletext boards

LION VIEWDATA TV, 18 Harcourt Terrace, London, S.W.10 - Tel: 01-373 5218

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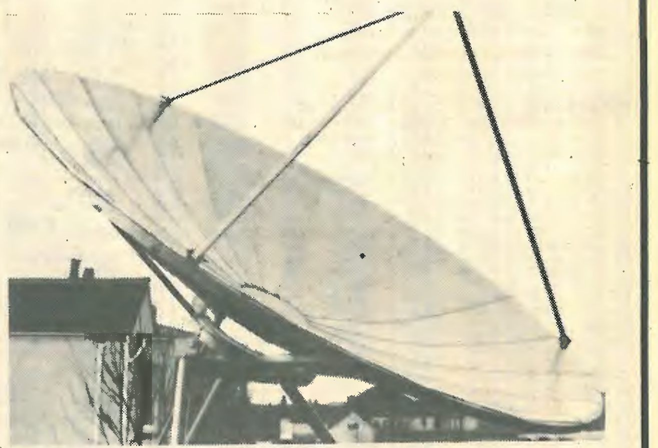

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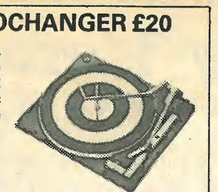

Plays 12", 10" or 7" records, Auto or Manual. A high quality unit backed by BSR reliability. Stereo Ceramic Cartridge. AC 200/250V. Size 13½×11¼in. 3 speeds. Above motor board 3¾in. Below motor board 2½in.
Post £2   Board £1 extra

HEAVY METAL PLINTHS Post £2

Cut out for most BSR or Garrard decks. Silver grey finish, black trim. Size 16x13¾in. **£4**

DECCA TEAK VENEERED PLINTH. Post £1.50 **£5**
Superior finish with space and panel for small amplifier. Board is cut for B.S.R. 18¾in.×14¼in×4in. Black/silver facia trim. Also with board cut out for Garrard only £3. **Plastic cover £6**

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13¾×12×2¼in.	£5	16⅝×13×4in.	£6
15¼×13½×4in.	£6	14½×13⅛×2¾in.	£5
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BSR SINGLE PLAYER DECKS

BSR P232 BELT DRIVE QUALITY DECK
Manual or automatic play.
Precision ultra slim arm.
Cueing device. Bargain price
With stereo ceramic cartridge
£24 Post £2

BSR P204 SINGLE PLAYERS SPECIAL OFFERS
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GARRARD 6-200 SINGLE PLAYER DECK £22 Post £2
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Stabilised output, 9 volt 400 m.a. U.K. made in plastic case with screw terminals. Safety overload cut out. Size 5 × 3¼ × 2½in. Transformer Rectifier Unit. Suitable Radios, Cassettes, models, £4.50. Post 65p.

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EMI 13½ x 8in. LOUDSPEAKERS

Model 450, 10 watts R.M.S. with moving coil tweeter and two-way crossover; 3 ohm or 8 ohm. **£9.50** post £1.50. "Final Clearance".
SUITABLE BOOKSHELF CABINET £6.50.
18 × 11 × 6in., post £1.50

RELAYS. 6V DC **95p.** 12V DC **£1.25.** 18V **£1.25.**
BLANK ALUMINIUM CHASSIS. 6×4–**£1.45;** 8×6–**£1.80;** 10×7–**£2.30;** 12×8–**£2.60;** 14×9–**£3;** 16×6–**£2.90;** 16×10–**£3.20.** All 2½in. deep. 18 swg
ANGLE ALI. 6×¾×¾in. 18 swg. **30p.**
ALUMINIUM PANELS, 18swg. 6×4–**45p;** 8×6–**75p;** 14×3–**75p;** 10×7–**95p;** 12×8–**£1.10;** 12×5–**75p;** 16×6–**£1.10;** 14×9–**£1.45;** 12×12–**£1.50;** 16×10–**£1.75.**
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RESISTORS. 10Ω to 10M. ¼W, ½W, 1W, **1p:** 2W **10p.**
HIGH STABILITY. ½w 2% 10 ohms to 1 meg. **8p.**
Ditto 5%. Preferred values, 10 ohms to 10 meg, **3p.**
WIRE-WOUND RESISTORS 5 watt, 10 watt, 15 watt **20p**
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JACK PLUGS Mono Plastic **25p;** Metal **30p.**
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2.5mm and 3.5mm **JACK SOCKETS 20p. Plugs 20p.**
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Sockets 3-pin, 5-pin **10p.** Free Sockets 3-pin, 5-pin **25p.**
Plugs 3-pin **20p;** 5-pin **25p;** Speaker plugs **20p;** Sockets **15p**
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U.H.F. COAXIAL CABLE SUPER LOW LOSS, 25p yd.
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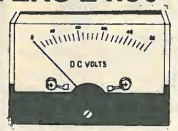
5kΩ to 2MΩ. LOG or LIN. L/S **50p.** DP **90p.** Stereo L/S **£1.10.** DP **£1.30.** Edge Pot 5K. SP **45p.**

MINI-MULTI TESTER

Deluxe pocket size precision moving coil instrument. Impedance + Capacity – 2000 o.p.v. Battery included.
11 instant ranges measure:
DC volts 10, 50, 250, 1000.
AC volts 10, 50, 250, 1000.
DC amps 0-100mA.
Continuity and resistance to 1 meg ohms in two ranges.
£6.50 Post 65p
De Luxe Range Doubler Model, 50,000 o.p.v. **£18.50.** 7 × 5 × 2in. Post £1

NEW PANEL METERS £4.50



50μa 100μa, 500μa, 1ma, 5ma, 50ma, 100ma, 500ma, 1 amp, 2 amp 25 volt, 50 volt, VU Meter. 2¼x2×1¼in. Post 65p

RCS SOUND TO LIGHT CONTROL KIT
Kit of parts to build a 3 channel sound to light unit. 1,000 watts per channel. Suitable for home or disco. Easy to build. Full instructions supplied. **£15** Post 95p
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200 Watt Rear Reflecting White Light Bulbs. Ideal for Disco Lights, Edison Screw. 6 for **£4,** or 12 for **£7.50.** Post 65p. Suitable panel mounting holders **85p.**

RCS "MINOR" 10 watt AMPLIFIER KIT £14
This kit is suitable for record players, guitars, tape playback, electronic instruments or small PA systems. Two versions available: Mono, **£14;** Stereo, **£20.** Specification 10W per channel; size 9½ × 3 × 2in. SAE details. Full instructions supplied. 240V AC. Post £1.

RCS STEREO PRE-AMP KIT. All parts to build this pre-amp. Inputs for high, medium or low imp per channel, with volume control and PC Board. Can be ganged to make multi-way stereo mixers **£2.95** Post 65p

MAINS TRANSFORMERS

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250-0-250V 70mA, 6.5V, 2A	£4.50	£2
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350-0-350V 250mA, 6.3V 6A CT	£12.00	£2
300-0-300V 120mA, 2×6.3V 2A C.T.; 5V 2A	£12.00	£2
220V 45mA, 6.3V 2A	£2.50	£1

AUTO 115V to 240V 150W **£9.** 250W **£10.** 400W **£11.** 500W **£12.** £2.

GENERAL PURPOSE LOW VOLTAGE

Tapped outputs available

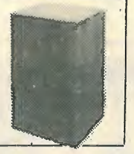
2 amp. 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 25 and 30V	£6.00	£2
1 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£6.00	£2
2 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£10.50	£2
3 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£12.50	£2
5 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£16.00	£2

5-8-10-16V. ½ amp.	£2.50	80p	12-0-12V. 2 amps	£3.50	£1
6V. ½ amp.	£2.00	£1	15-0-15V. 2 amps	£3.75	£1
6-0-6V. ½ amp.	£3.50	£1	20V 1 amp	£3.00	£1
9V. 250ma.	£1.50	80p	20-0-20V 1 amp	£3.50	£1
9V. 3 amp	£3.50	£1	20-40-60V 1 amp	£4.00	£2
9-0-9V. 50ma	£1.50	80p	25-0-25V 2 amps	£4.50	£1
10-0-10V. 2 amps	£3.00	£1	28V 1 amp Twice	£5.00	£2
10-30-40V. 2 amps	£3.50	£1	30V 1½ amp	£3.50	£1
12V. 100ma	£1.50	80p	30V 5 amp and 17-0-17 2a	£4.50	£2
12V. 750 ma	£2.00	80p			
12V 3 amps	£3.50	£1	35V 2 amps	£4.00	£1

TOROIDAL 30-0-30V 4a and 20-0-20V ½a **£10** £2

CHARGER TRANS	Post	RECTIFIERS	Post
6-12 volt 3a	£4.00+£2	6-12 volt 2a	£1.10+80p
6-12 volt 4a	£6.50+£2	6-12 volt 4a	£2.00+80p

OPUS COMPACT SPEAKERS £22 pair Post £2



TEAK VENEERED CABINET
11×8½×7in, 15 watts
50 to 14,000 cps. 4 ohm or 8 ohm
OPUS TWO 15×10½×7¾in 25 watt 2-way system **£39 pair.** Post £3.

LOW VOLTAGE ELECTROLYTICS 10p
1 mf, 2 mf, 4 mf, 8 mf, 10 mf, 16 mf, 25 mf, 30 mf, 50 mf, 100 mf, 250 mf. All 15 volts. 22 mf/6v/10v; 25 mf/6v/10v; 47 mf/10v; 50 mf/6v; 68 mf/6v/10v/16v/25v; 100 mf/10v; 150 mf/6v/10v; 200 mf/10v/16v; 220 mf/4v/10v/16v; 330 mf/4v/10v; 500 mf/6v; 680 mf/4v/10v/16v/25v; 1000 mf/2.5v/4v/10v; 1500 mf/6v/10v/16v; 2200 mf/6v/10v; 3300 mf/6v; 4700 mf/4v.
500mF 12V **15p;** 25V **20p;** 50V **30p.** 1200mF 76V **86p.**
1000mF 12V **20p;** 25V **35p;** 50V **50p;** 100V **70p.**
2000mF 6V **25p;** 25V **42p;** 40V **60p;** 1200mF 76V **80p.**
2200mF 63V **90p.** 2500mF 50V **70p;** 3000mF 50V **65p;**
4500mF 64V **£2.** 4700mF 63V **£1.20.** 2700mF/76V **£1.**

HIGH VOLTAGE ELECTROLYTICS

8/450V	45p	8+8/450V	75p	32+32+16/350V	90p
2/500V	45p	8+16/450V	75p	100+100/275V	65p
16/350V	45p	8+8/500V	£1	150+200/275V	70p
32/500V	75p	32+32/350V	50p	220/450V	95p
32/350V	50p	32+32/500V	£1.80	32+32+32/325V	75p
50/450V	95p	50+50/300V	50p	50+50+50/350V	95p

CAPACITORS WIRE END High Voltage
.001, .002, .003, .005, .01, .02, .03, .05 mfd. 400V **5p**
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.22MF 350V **12p.** 600V **20p.** 1000V **30p.** 1750V **50p.**
.47MF 150V **10p.** 400V **20p.** 630V **30p.** 1000V **60p.**

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Size 11×9×⅛in. Operating voltage 240V, 250W approx. Suitable for Heating Pads, Food Warmers, Convector Heaters, Propagation, etc. Must be clamped between two sheets of metal or ceramic, etc.
ONLY **60p** EACH (FOUR FOR **£2**) ALL POST PAID.

NEW baker Star sound

high power full range quality loudspeakers produced to give exceptional reproduction. Ideal for Hi-Fi, music P.A. or discotheques. These loudspeakers are recommended where high power handling is required with quality results. The high flux ceramic magnet ensures clear response.

MODEL	INCHES	OHMS	WATTS	TYPE	PRICE	POST
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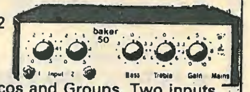
DELUXE MK II	12	8	15	HI-FI	£14	£2
SUPERB	12	8-16	30	HI-FI	£24	£2
AUDITORIUM	12	8-16	45	HI-FI	£22	£2
AUDITORIUM	15	8-16	60	HI-FI	£34	£2
GROUP 45	12	4-8-16	45	PA	£14	£2
GROUP 75	12	4-8-16	75	PA	£18	£2
GROUP 100	12	8-16	100	Guitar	£24	£2
DISCO 100	12	8-16	100	Disco	£24	£2
GROUP 100	15	8-16	100	Guitar	£32	£2
DISCO 100	15	8-16	100	Disco	£32	£2

BAKER 150 WATT MIXER/POWER AMPLIFIER £89 Post £2

SLAVE VERSION £75

For Organs, Discotheque, Vocal, Public Address. Three loudspeaker outlets for 4, 8 or 16 ohms. Four high gain inputs, each 20 mv, 50K ohm. Individual volume controls "Four channel" mixing. 150 watts into 8 ohms R.M.S. Music Power. Distortion less than 1%. Slave output 500 M.V. 25K.ohm. Frequency Response 25 Hz – 20kHz ± 3dB. Integral Hi-Fi preamp separate Bass & Treble. Compact – 16" x 8" x 5½". Lightweight – 14lb: Master volume control. Made in England. 12 months' guarantee. 200/250v A.C. mains or 120V to order. All transistor and solid state devices. 100 Volt Line £15 extra.
New Stereo Slave Model 150 + 150 watt £125. Post £4.
BAKER'S NEW PA150 MICROPHONE PA AMPLIFIER £129. PP £3
4 channel 8 inputs, dual impedance, 50K-600 ohm 4 channel mixing, volume, treble, bass. Presence controls, Master volume control, echo/send/return socket. Slave input/output sockets.

BAKER £69 Post £2 50 WATT AMPLIFIER



Ideal for PA systems, Discos and Groups. Two inputs, Mixer, Volume, Controls, Master Bass, Treble Gain.

RCS offers MOBILE PA AMPLIFIERS. Outputs 4-8-16 ohms
20-watt RMS 12v DC, AC 240v, 3 inputs. 50K **£46** PP £2.
40-watt RMS 12v DC, AC 240v, 4 inputs. 50K 100v Line **£75** PP £2
Mic 1; Mic 2; Phono; aux. outputs 4 or 8 or 16 and 100v line
60-watt RMS, Mobile 24 volt DC & 240-volt AC mains. inputs 50K. 3 mics + 1 music. Outputs 4-8-16 ohm + 100 volts line **£95** PP £2

FAMOUS LOUDSPEAKERS "SPECIAL PRICES"

MAKE	MODEL	SIZE	WATTS	OHMS	PRICE	POST
SEAS	TWEETER	4in	50	8	£9.50	£1
GOODMANS	TWEETER	3½in	25	8	£4.00	£1
AUDAX	TWEETER	4in	30	8	£6.50	£1
SEAS	MID-RANGE	4in	50	8	£7.50	£1
SEAS	MID-RANGE	5in	80	8	£12.00	£1
SEAS	MID-RANGE	4½in	100	8	£12.50	£1
GOODMANS	HIFAX	7¼in	100	4/8/16	£22	£2
AUDAX	WOOFER	8in	40	8	£14.00	£2
GOODMANS	WOOFER	8in	25	4/8	£6.50	£1
GOODMANS	HB	8in	60	8	£12.50	£1
RIGONDA	GENERAL	10in	15	8	£5	£2
AUDAX	WOOFER	10in	50	8	£16.00	£2
GOODMANS	PP12	12in	75	8/15	£24.50	£2
GOODMANS	GR12	12in	90	8/15	£27.50	£2
GOODMANS	HPD	12in	120	8/15	£29	£2
EMI	HI-FI	13x8	10	3/8	£9.50	£1

SPEAKER COVERING MATERIALS. Samples Large S.A.E.
B.A.F. LOUDSPEAKER CABINET WADDING 18in wide **35p** ft.
CROSSOVERS. TWO-WAY 3000 c/s 3 or 8 or 15 ohm **£1.90.** 3-way 950 cps/3000 cps. 20 watt rating. **£2.20.** 3 way 60 watt **£6.**
LOUDSPEAKER BARGAINS
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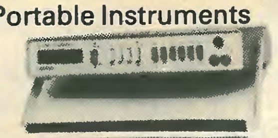

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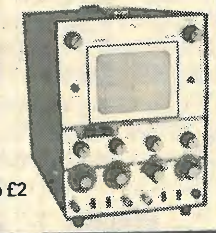

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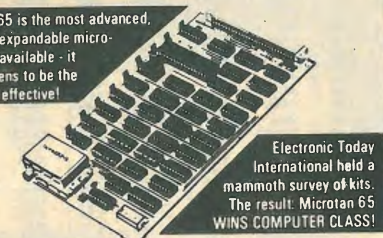

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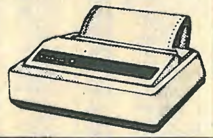

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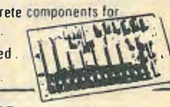

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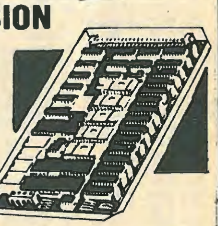

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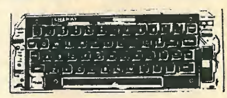

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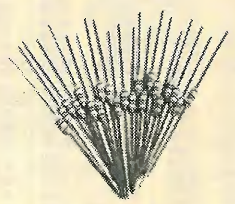

100R	1k	10k	100k
110R	1k1	11k	110k
120R	1k2	12k	120k
130R	1k3	13k	130k
150R	1k5	15k	150k
160R	1k6	16k	160k
180R	1k8	18k	180k
200R	2k	20k	200k
220R	2k2	22k	220k
240R	2k4	24k	240k
270R	2k7	27k	270k
300R	3k	30k	–
330R	3k3	33k	330k
360R	3k6	36k	–
390R	3k9	39k	–
430R	4k3	43k	–
470R	4k7	47k	470k
510R	5k1	51k	–
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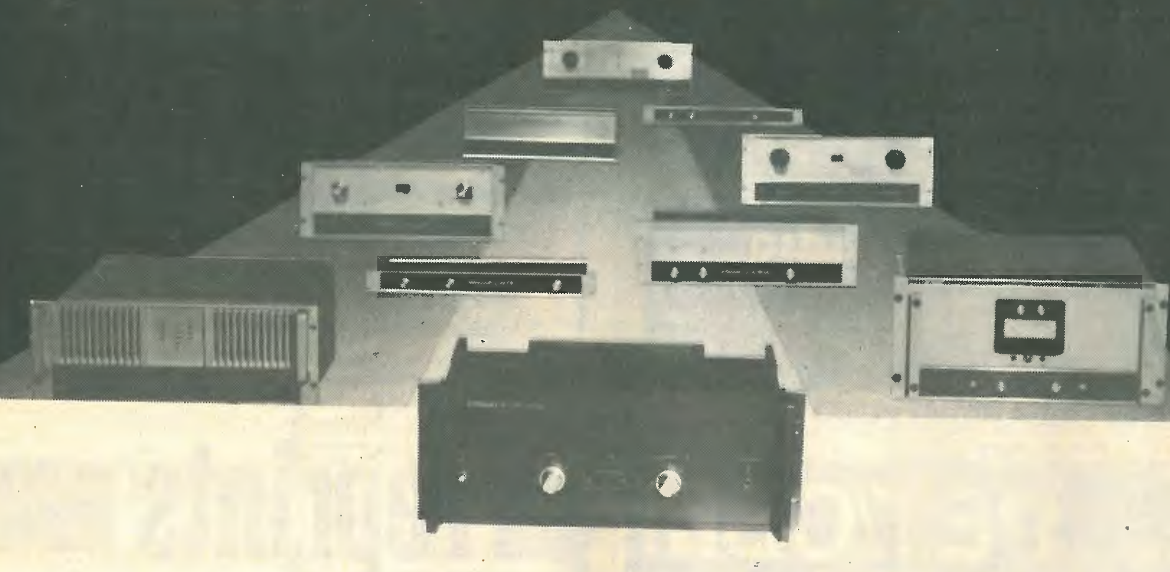

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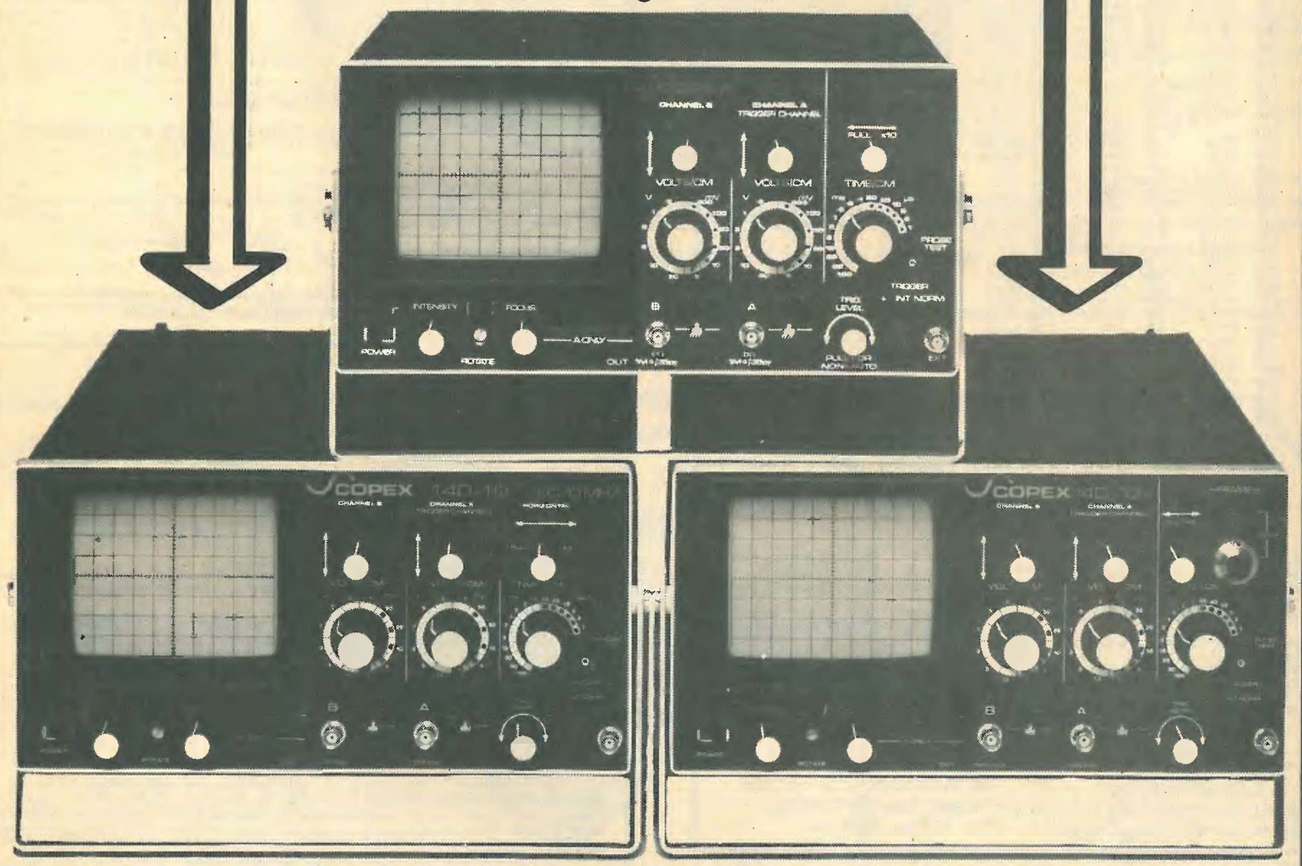

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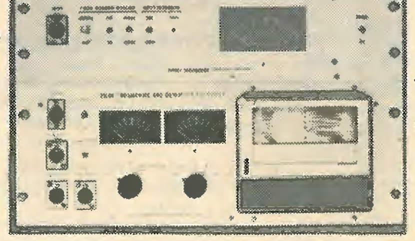

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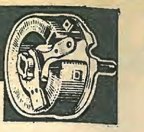

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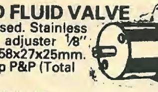

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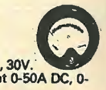

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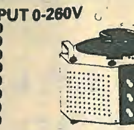

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7414	35p
7416	25p
7417	25p
7420	17p
7421	30p
7422	20p
7423	22p
7425	28p
7426	30p
7427	25p
7428	30p
7430	15p
7432	25p
7433	27p
7437	27p
7438	30p
7440	17p
7441	70p
7442A	36p
7443	90p
7445	60p
7446A	93p
7447A	45p
7448	45p
7450	17p
7451	17p
7453	17p
7454	17p
7460	17p
7470	36p
7472	30p
7473	30p
7474	20p
7475	30p
7476	30p
7480	50p
7481	100p
7482	70p
7483A	45p
7484	100p
7485	90p
7486	20p
7489	210p
7490A	25p
7491	60p
7492A	30p
7493A	30p
7494	50p
7495A	50p
7496	45p
7497	120p
74100	85p
74107	22p
74109	40p
74116	90p
74118	75p
74119	90p
74120	70p
74121	25p
74122	45p
74123	48p
74125	40p
74126	40p
74128	40p
74132	45p
74136	32p
74141	65p
74142	200p
74145	70p
74147	100p
74148	75p
74150	80p
74151A	45p
74153	45p
74154	59p
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74156	50p
74157	50p
74159	100p
74160	80p
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74162	60p
74163	60p
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74165	55p
74166	70p
74170	140p
74172	300p
74173	65p
74174	60p
74175	60p
74176	50p
74177	70p
74178	100p
74180	50p
74181	160p
74182	90p
74184A	90p
74185	120p
74186	500p
74188	325p
74190	50p
74191	50p
74192	50p
74193	50p
74194	70p
74195	60p
74196	70p
74197	80p
74198	100p
74199	100p
74221	80p
74251	70p
74273	75p
74276	140p
74278	150p
74279	80p
74283	75p
74284	200p
74285	200p
74290	100p
74293	100p
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74LS13	25p
74LS14	40p
74LS20	15p
74LS21	15p
74LS22	16p
74LS27	16p
74LS30	15p
74LS32	16p
74LS38	16p
74LS42	36p
74LS47	40p
74LS48	75p
74LS51	15p
74LS55	30p
74LS73	25p
74LS74	16p
74LS75	24p
74LS76	20p
74LS83	45p
74LS85	50p
74LS86	20p
74LS90	28p
74LS92	40p
74LS93	30p
74LS95	45p
74LS96	100p
74LS107	45p
74LS109	30p
74LS112	34p
74LS113	30p
74LS114	30p
74LS122	42p
74LS123	50p
74LS124	120p
74LS125	30p
74LS126	30p
74LS132	45p
74LS133	30p
74LS136	30p
74LS138	34p
74LS139	36p
74LS145	75p
74LS147	160p
74LS148	90p
74LS151	40p
74LS153	60p
74LS154	90p
74LS155	40p
74LS156	40p
74LS157	35p
74LS158	36p
74LS160	40p
74LS161	40p
74LS162	40p
74LS163	40p
74LS164	48p
74LS165	100p
74LS166	90p
74LS170	120p
74LS173	70p
74LS174	45p
74LS175	50p
74LS181	140p
74LS190	50p
74LS191	50p
74LS192	50p
74LS193	48p
74LS194	40p
74LS195	48p
74LS196	60p
74LS197	65p
74LS221	60p
74LS240	70p
74LS241	70p
74LS242	80p
74LS243	80p
74LS244	65p
74LS245	90p
74LS251	40p
74LS253	40p
74LS257	45p
74LS258	45p
74LS259	80p
74LS260	100p
74LS266	25p
74LS273	75p
74LS279	45p
74LS283	45p
74LS295	
74LS298	160p
74LS323	250p
74LS324	150p
74LS348	150p
74LS352	100p
74LS353	100p
74LS363	160p
74LS364	160p
74LS365	32p
74LS367	32p
74LS368	36p
74LS373	70p
74LS374	70p
74LS375	50p
74LS377	90p
74LS378	70p
74LS390	55p
74LS393	50p
74LS395	
74LS399	200p
74LS540	135p
74LS541	135p
74LS640	200p
74LS641	200p
74LS644	250p
74LS645	200p
74LS669	200p
74LS670	170p
74LS682	450p
74LS684	450p

4000 SERIES

4000	12p
4001	14p
4002	15p
4006	65p
4007	16p
4008	60p
4009	35p
4010	40p
4011	14p
4012	16p
4013	35p
4014	60p
4015	60p
4016	30p
4017	45p
4018	60p
4019	32p
4020	60p
4021	65p
4022	70p
4023	20p
4024	40p
4025	20p
4026	130p
4027	32p
4028	60p
4029	75p
4030	40p
4031	170p
4034	160p
4035	80p
4036	295p
4039	295p
4040	55p
4041	70p
4042	55p
4043	60p
4044	70p
4046	70p
4047	75p
4048	55p
4049	27p
4050	27p
4051	60p
4052	80p
4053	60p
4054	130p
4055	125p
4056	120p
4059	500p
4060	90p
4063	100p
4066	35p
4067	400p
4068	18p
4069	18p
4070	18p
4071	18p
4072	18p
4073	20p
4075	20p
4076	60p
4081	16p
4082	20p
4086	72p
4089	150p
4093	40p
4094	150p
4095	95p
4096	95p
4097	340p
4098	90p
4099	120p
40085	90p
40097	120p
40098	120p
40102	180p
40103	180p
40106	45p
40109	100p
40163	100p
40173	120p
40174	90p
40175	100p
40193	120p
40257	160p
4502	70p
4503	50p
4507	40p
4508	200p
4510	65p
4511	50p
4512	65p
4514	150p
4515	150p
4516	75p
4518	45p
4520	70p
4521	150p
4526	75p
4527	90p
4528	75p
4532	90p
4534	500p
4536	300p
4538	120p
4539	110p
4543	100p
4553	290p
4555	50p
4556	60p
4560	180p
4568	300p
4569	160p
4572	30p
4583	90p
4584	45p
4585	100p
14495	400p

74S SERIES

74S00	60p
74S04	60p
74S08	75p
74S32	90p
74S74	90p
74S85	300p
74S86	180p
74S124	300p
74S132	160p
74S133	75p
74S138	225p
74S139	225p
74S157	250p
74S163	300p
74S174	250p
74S175	320p
74S194	350p
74S241	450p

LINEAR ICs

AN103	200p	MB3712	200p
AY1-0212	600p	MC1310P	150p
AY1-1313	668p	MC1458	40p
AY1-1320	320p	MC1495L	350p
AY1-5050	140p	MC1496	70p
AY3-8910	600p	MC3340P	120p
AY3-8912	650p	MC3401	90p
AY5-1224A	240p	MC3403	120p
AY5-1315	600p	MK50398	750p
AY5-4007D	520p	ML920	800p
CA3028A	120p	MM57160	620p
CA3019	80p	MN6221A	600p
CA3046	70p	NE531	150p
CA3048	225p	NE555	20p
CA3059	300p	NE556	50p
CA3080E	72p	NE564	420p
CA3086	48p	NE565	130p
CA3089	225p	NE566	155p
CA3090AQ	375p	NE567	140p
CA3130E	90p	NE570	425p
CA3140	50p	NE571	425p
CA3160E	100p	NE5534A	150p
CA3161E	190p	PLL02A	500p
CA3162	450p	RC4136	70p
CA3189E	300p	RC4151	200p
CA3240	120p	S566B	260p
CA3280G	200p	SAD1024A	850p
DAC1408-8	200p	SFF96364	800p
HA1366	300p	SL490	350p
HA1388	270p	SN76477	500p
ICL7106	850p	SN76488	500p
ICL8038	300p	SP8515	750p
ICM7555	80p	TA7120	160p
LC7120	350p	TA7204	200p
LC7130	350p	TA7205	90p
LF347	160p	TA7222	160p
LF351	48p	TA7310	160p
LF353	100p	TAA271	275p
LF356P	95p	TBA651	200p
LF357	120p	TBA800	90p
LM10C	425p	TBA810	100p
LM301A	27p	TBA820	90p
LM310	120p	TBA950	300p
LM318	200p	TCA220	350p
LM319	225p	TCA940	200p
LM324	45p	TDA1004A	300p
LM335Z	140p	TDA1008	320p
LM339	65p	TDA1010	225p
LM348	75p	TDA1022	550p
LM358P	75p	TDA1024	120p
LM377	175p	TDA1034B	250p
LM380	75p	TDA1170	300p
LM381AN	180p	TDA2002V	325p
LM382	120p	TDA2020	320p
LM386	95p	TL071/81	45p
LM387	120p	TL072/82	75p
LM389	95p	TL074	130p
LM393	100p	TL084	110p
LM394	350p	TL094	200p
LM709	36p	TL170	50p
LM710	50p	TL430C	70p
LM711	70p	UAA170	170p
LM733	100p	UA2240	300p
LM741	18p	UDN6118	320p
LM747	70p	UDN6184	320p
LM748	35p	ULN2003	100p
LM2917	200p	UPC575	400p
LM3302	140p	UPC592H	200p
LM3900	55p	UPC1156H	300p
LM3909	95p	XR2206	300p
LM3911	130p	ZN414	90p
LM3914	210p	ZN419C	225p
LM3915	225p	ZN423E	150p
LM3916	225p	ZN424E	135p
LM13600	125p	ZN425E	350p
M51513L	300p	ZN427E	625p
M51516L	500p	ZN1034E	200p
		ZN1040E	700p

VOLTAGE REGULATORS

FIXED PLASTIC

	+ve			-ve	
1A					
5V 1A	7805	45p		7905	50p
6V	7806	50p		7906	60p
8V	7808	50p		7908	60p
12V 1A	7812	50p		7912	50p
15V 1A	7815	55p		7915	50p
18V 1A	7818	55p		7918	60p
24V 1A	7824	55p		7924	60p
5V 100mA	78L05	30p		79L05	65p
6V 100mA	78L06	30p	12V	79L12	70p
8V 100mA	78L08	30p	15V	79L15	70p
12V 100mA	78L12	30p			
15V 100mA	78L15	30p			

OTHER REGULATORS

LM309H 1A5V	100p	78HGKC	600p
LM309K 1A 5V	135p	78HO5KC	550p
LM317K	325p	78MGT2C	140p
LM317T 1A Adj	200p	78GUIC	200p
LM337T	225p	79GUIC	225p
LM323K 3A 5V	500p	79HGKC	700p
LM723 150mA Adj	37p	ICL 7660	200p
TL494	400p	TL497	300p
78S40	225p	LM305AH	250p

OPTO-ELECTRONICS

2N5777	45p	ORP60	120p
OCP71	180p	ORP61	120p
ORP12	120p	TIL78	55p
TIL32	55p		

OPTO-ISOLATORS

ILD74	130p	TIL111	90p
MCT26	100p	TIL112	90p
MCS2400	190p	TIL113	90p
ILQ74	240p	TIL116	90p

LEDS

0.125"		0.2"	
TIL209 R	11p	TIL220 R	13p
TIL211 Gr	16p	TIL222 Gr	15p
TIL212 Ye	18p	TIL228 Ye	22p
TIL216 R	18p		

DISPLAYS

3015F	200p	MAN3640	175p
DL704	140p	MAN4640	200p
DL707	140p	NSB5881	570p
DL7750	200p	TIL311	600p
DL7760	200p	TIL312/3	110p
FND357	120p	TIL321	130p
FND500	90p	TIL322	130p
FND507	90p	TIl330	140p

EXPERIMENTOR BREADBOARDS
EXP300 600p EXP350 330p

COMPUTER COMPONENTS

CPUs

1802CE	700p
2650A	£12
6502	450p
6502A	600p
6800	370p
6802	425p
6809	£10
6809E	£15
8035	750p
8039	850p
8080A	350p
8085A	550p
1NS8060	£11
TMS9980	£20
Z80	370p
Z80A	450p
Z80B	£16
8088	£18

SUPPORT DEVICES

3242	800p
3245	450p
6520	300p
6522	500p
6532	775p
6551	650p
6821	160p
6851	650p
6821	160p
6845	£10
6847	£10
6850	160p
6852	250p
6875	600p
8154	950p
8155	800p
8205	220p
8212	180p
8216	180p
8224	250p
8226	250p
8228	425p
8243	450p
8250	950p
8251	350p
8253	550p
8255	350p
8257	800p
8259	800p
8279	950p
Z80P10	300p
Z80AP10	350p
Z80CTC	300p
Z80ACTC	350p
Z80ADART	
Z80ADMA	£12
Z80S10-1	£12

CRT CONTROLLER

CRT5027	£18
CRT5037	£18
CRT6545	£12
EF9365	£60
MC6845	£10
MC6847	£10
SFF96364	£8
TMS9918	£60
TMS9927	£18

MEMORIES

2114L	400p
2101-3L	120p
2107B	500p
2111A	300p
2112-A	300p
2114-2L	95p
2147	450p
4027-3	300p
4044-45	450p
4116-15	90p
4116-20	70p
4118-3	300p
4118-4	450p
4164-2	£8
4816AP-3	£5
5101	300p
6116P-3	800p
6116LP-3	750p
6514-45	£3
6810	200p
7489	210p
74S189	225p
74S201	350p
74S289	325p

ROM/PROMs

74S188	325p
74S287	300p
74S288	225p
74S387	325p
74S471	650p
74S472	850p
74S474	650p
74S570	650p
74S571	650p
74S573	950p

EPROMs

1702A	500p
2708	300p
2716 (+5V)	300p
2564	£25
2516 (+5V)	300p
2532	550p
2732	550p
2716-300NS	500p
2732-300NS	750p

UARTS

AY-3-1015P	300p
AY-5-1013P	300p
COM8017	300p
IM6402	450p
TR1602	300p

CHARACTER GENERATORS

RO3-2513	
U.C.	750p
L.C.	700p
SN74S262AN	£10

INTERFACE ICs

AD558CJ	775p
AD561J	£14
AM25S10	350p
AM25LS2521	£2
AM26LS31	160p
AM26LS32	190p
DAC80	£20
DM8131	375p
DP8304	480p
DS8830	140p
DS8831	140p
DS8832	250p
DS8833	225p
DS8835	150p
DS8836	150p
DS8838	225p
LF13201	450p
MC1488	55p
MC1489	55p
MC3418	950p
MC3446	300p
MC3480	850p
MC3486	500p
MC3487	300p
MC4024	325p
MC4044	325p
MC14411	700p
MC14412	900p
MM58174	£12
ULN2003A	100p
ULN2004A	100p
75107	160p
75110	160p
75112	180p
75114	160p
75115	160p
75121	140p
75122	140p
75150P	140p
75154	140p
75182	230p
75324	375p
75361	150p
75363	150p
75365	150p
75451/2	72p
75491/2	70p
8T26/28	120p
8T95/96	120p
8T97/98	120p
81LS95/96	90p
81LS97/98	90p
9602	220p
9637AP	160p
ZN425E-8	350p
ZN426E-8	350p
ZN427E-8	650p
ZN428E-8	500p

TELETEXT ICs

SAA5020	£6
SAA5030	£9
SAA5041	£16
SAA5050	£9

CRYSTALS

32.768KHz	100p
100KHz	300p
200KHz	370p
Freq in MHz	
1.0	320p
1.008	350p
1.5	450p
1.8432	225p
2.00	250p
2.45760	250p
2.5	250p
3.276	150p
3.5795	100p
3.686	200p
4.00	150p
4.194	200p
4.43	150p
4.608	250p
4.915	250p
5.0	[illegible]
6.0	[illegible]
6.144	[illegible]
7.0	[illegible]
7.168	[illegible]
8.00	[illegible]
8.86	[illegible]
10.00	[illegible]
10.5	[illegible]
10.7	[illegible]
12	[illegible]
14.318	[illegible]
14.756	[illegible]
15	[illegible]
16.00	[illegible]
18.00	[illegible]
18.432	[illegible]
19.968	[illegible]
20	[illegible]
26.690	[illegible]
27.145	[illegible]
38.6667	[illegible]
48.0	[illegible]
55.5	[illegible]
116	[illegible]
145.80	[illegible]

KEYBOARD ENCODER

AY-5-2376	700p
74C922	500p

MODULATORS

6MHz UHF	375p
8MHz UHF	450p

BAUD RATE GENERATOR

COM8116	£8
MC 14411	£7

DISC CONTROL

FD1771	£20
FD1791	£30
FD1793	£32
FD1795	£35
FD1797	£37
WD1691	£15
WD2143	550p

CONNECTOR SYSTEMS JUMPER LEADS

24" Cable with Headers

	14pin	16pin	24pin	40pin
Single end	145p	165p	240p	380p
Double end	210p	230p	345p	540p

Cable with Sockets

	20pin	26pin	34pin	40pin
Single end (24")	160p	210p	270p	300p
Double end (18")	290p	385p	490p	540p

ID CONNECTORS

(Speed Bloc type)

No of ways	10	20	26	34	40
Header					
Plug	90p	165p	200p	240p	270p
Recp'cle	90p	165p	200p	240p	270p
Edge conn	200p	240p	300p	380p	550p

EUROCONNECTORS

	Plug	Skt.
DIN 41612 2x32 Way	300p	350p
Angled 2 + 32 Way	350p	400p
DIN 41617 31 Way	200p	200p
DIN41612 3x32-way	350p	420p

(for 2x32 Way please specify A + B or A + C type)

DIL HEADER PLUGS

	14pin	16pin	24pin	40pin
Solder type	50p	60p	100p	275p
IDC type	130p	140p	200p	285p

MIN D CONNECTORS

No. of ways	9	15	25	37
MALE				
Solder	90p	135p	200p	280p
Angled	160p	230p	285p	425p
FEMALE				
Solder	125p	190p	245p	375p
Angled	175p	240p	310p	500p
Hoods	100p	100p	100p	150p

Centronix type 37-way conn. £6.50
25-way D conn. jumper M: £5 F: £5.50

DIL SWITCHES

4-way	90p
6-way	120p
8-way	120p
10-way	150p

ZIF SKTS

24 pin	£6
28 pin	£7
40 pin	£10

EDGE CONNECTORS

	0.1"	0.156"
2 x 18 Way		150p
2 x 22 Way	310p	170p
2 x 23 Way	335p	
2 x 25 Way	350p	200p
1 x 43 Way	260p	–
2 x 43 Way	450p	–
1 x 17 Way	700p	–

LOW PROFILE DIL SOCKETS BY TEXAS

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

WIRE WRAP SOCKETS BY TEXAS

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

TRANSISTORS

AD161/2	45p	BFX30	27p	TIP32A	40p	2N3055	48p	2SC2078	200p
BC107/8	13p	BFX84/5	40p	TIP32C	45p	2N3442	140p	3N128	120p
BC109C	14p	BFX86/7	27p	TIP33A	70p	2N3553	240p	3N140	120p
BC117	20p	BFX88	27p	TIP33C	80p	ZN3584	250p	3N141	110p
BC147/8	9p	BFX89	150p	TIP34A	90p	2N3643/4	48p	3N201	110p
BC149	10p	BFY50	24p	TIP34C	120p	2N3702/3	12p	3N204	120p
BC157/8	10p	BFY51/2	24p	TIP35A	120p	2N3704/5	12p	40290	260p
BC159	11p	BFY90	80p	TIP35C	140p	2N3706/7	14p	40361/2	75p
BC169C	12p	BRY39	45p	TIP36A	140p	2N3708/9	12p	40408	90p
BC172	12p	BSX19/20	24p	TIP36C	180p	2N3773	300p	40409	100p
BC177/8	17p	BU104	225p	TIP41A	50p	2N3819	25p	40410	100p
BC179	18p	BU105	190p	TIP41C	55p	2N3820	40p	40411	300p
BC182/3	10p	BU108	250p	TIP42A	40p	2N3823	50p	40594	120p
BC184	11p	BU109	225p	TIP42C	65p	2N3866	90p	40595	120p
BC187	30p	BU126	150p	TIP54	160p	2N3902	700p	40673	75p
BC212/3	11p	BU180A	120p	TIP120	75p	2N3903/4	18p	40871/2	100p
BC214	12p	BU205	200p	TIP122	90p	2N3905/6	20p		
BC237	15p	BU208	200p	TIP142	130p	2N4037	65p		
BC327	16p	BU406	145p	TIP147	130p	2N4123/4	27p		
BC337	16p	BUX80	600p	TIP2955	78p	2N4125/6	27p		
BC338	16p	E310	50p	TIP4055	70p	2N4401/3	27p		
BC461	36p	MJ802	400p	VN10KM	100p	2N4427	90p		
BC477/8	30p	MJ2501	225p	VN66	80p	2N4871	60p		
BC516/7	40p	MJ2955	90p	ZTX108	12p	2N5087	27p		
BC547B	14p	MJ3001	225p	ZTX300	13p	2N5089	27p		
BC548C	12p	MJE340	60p	ZTX500	15p	2N5172	27p		
BC549C	16p	MJE2955	100p	ZTX502	18p	2N5191	90p		
BC557B	14p	MJE3055	70p	ZTX504	18p	2N5194	90p		
BC559C	16p	MPF102	40p	2N697	25p	2N5245	40p		
BCY70	18p	MPF103/4	30p	2N698	45p	2N5296	65p		
BCY71/2	22p	MPF105	30p	2N706A	30p	2N5401	50p		
BD131/2	50p	MPSA06	30p	2N708	30p	2N5457/8	32p		
BD135/6	40p	MPSA12	50p	2N918	45p	2N5459	32p		
BD139	40p	MPSA13	50p	2N930	18p	2N5460	60p		
BD140	60p	MPSA20	50p	2N1131/2	36p	2N5485	44p		
BD189	60p	MPSA42	50p	2N1613	25p	2N5875	250p		
BD232	60p	MPSA43	50p	2N1711	25p	2N6027	48p		
BD241	60p	MPSA56	32p	2N2102	70p	2N6052	300p		
BD242	60p	MPSA70	50p	2N2160	350p	2N6059	325p		
BF244B	35p	MPSA93	40p	2N2219A	25p	2N6107	65p		
BF256B	50p	MPSU06	63p	2N2222A	25p	2N6247	190p		
BF257/8	32p	MPSU07	60p	2N2369A	25p	2N6254	130p		
BF259	36p	MPSU45	90p	2N2484	25p	2N6290	65p		
BF337	30p	MPSU65	78p	2N2646	45p	2SC1172	150p		
BFR39	25p	TIP29A	35p	2N2904/5	25p	2SC1306	150p		
BFR40/1	25p	TIP29C	40p	2N2906A	25p	2SC1307	150p		
BFR79	25p	TIP30A	35p	2N2907A	25p	2SC1957	90p		
BFR80/1	25p	TIP30C	40p	2N2926	9p	2SC1969	200p		
BFX29	40p	TIP31A	40p	2N3053	30p	2SC2028	120p		
		TIP31C	45p	2N3054	65p	2SC2029	250p		

DIODES

BY127	12p
BYX36300	20p
OA47	8p
OA90/91	9p
OA95	9p
OA200	9p
OA202	10p
1N914	4p
1N916	7p
1N4148	4p
1N4001/2	5p
1N4003/4	6p
1N4005	6p
1N4006/7	7p
1N5404/5	14p
1N5404/7	19p
IS920	9p

BRIDGE RECTIFIERS

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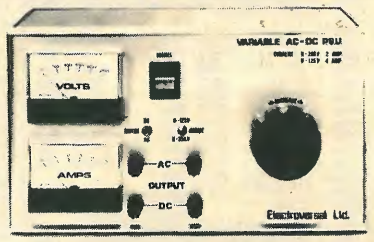

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For an application form, please write to the Recruitment Officer (Dept. WW 5), HM Government Communications Centre, Hanslope Park, Milton Keynes, MK19 7BH.

(1589)

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- ★ R.F. communications.

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(1581)

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(Ref 000010)

Responsible for the maintenance of all the ENG and OB transportable equipment including BVP330 cameras, BVU50 and 110 recorders, VPR2 and VPR20 C-format machines, TBCs and editing systems.

Radio Links Maintenance
(Ref 000011)

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(Ref 000012)

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Central Maintenance
(Ref 000013)

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Applicants should have qualifications to HNC level or equivalent and be experienced in maintaining the relevant broadcast TV equipment.

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For more information and an application form contact:
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346 Clapham Road
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(1585)

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If you are interested in this challenging position and would like more details, please write or telephone in complete confidence to:
Mr D. Abbott
Engineering Product Manager
Rediffusion Consumer Manufacturing Ltd.
Fullers Way South
Chessington
Surrey KT9 1HJ
Telephone: 01-397 5411

REDIFFUSION

(1571)

ELECTRONIC TECHNICIANS AND ENGINEERS

Marconi Communication Systems Limited are involved in the installation, commissioning, of communication equipment, worldwide. If you have formal qualifications in an electronic engineering discipline or H.M. Forces equivalent, with at least seven years experience in installation testing, commissioning and maintaining electronic equipments and hold a current U.K. driving licence, you could be one of the people we are looking for to fill one of the following vacancies:-

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WW (1593)

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Candidates should have industrial experience in the electronics/telecommunications industry and preferably should have a degree or equivalent qualifications and teaching experience.

Salary scales: L I £5,034-£8,658, L II £6,462-£10,431, starting points depending on qualifications and experience.

Further details and forms from Head of Department of Engineering, CCAT, Cambridge CB1 2AJ (Tel. Cambridge (0223) 63271 ext. 132) to whom forms should be returned by 30th April.
(1596)

THE ROYAL FREE HOSPITAL AND THE ROYAL FREE HOSPITAL SCHOOL OF MEDICINE

MEDICAL PHYSICS TECHNICIAN II (ELECTRONICS)

Salary on scale: £7600-£9248 inclusive

An experienced engineer is required by the Medical Electronics Department to assist with the development and maintenance of electronic circuits and systems.

The successful applicant will be seconded to the Royal Free Hospital School of Medicine, Hunter Street, WC1, until about the end of 1982 before moving to the interdepartmental workshop at Hampstead, London NW3.

Considerable experience in the design of electronic circuits and systems using state-of-the-art techniques is essential.

Applicants should preferably hold a Higher National Certificate in appropriate subjects or an equivalent, or higher, qualification.

Application form and job description available from the Personnel Department, Royal Free Hospital, Pond Street, Hampstead, London NW3 2QG. Tel: 01-794 0500 ext. 4286. Please quote ref. 0770.

Camden & Islington Area Health Authority (T)

(1572)

Electronic Engineers for Q.A. Department Wembley Middlesex.

Racal BCC are members of the highly successful Racal Electronics Group and are world leaders in the design and manufacture of tactical radio-communications equipment.

We require two experienced electronic engineers to fill positions at Intermediate grade within the Quality Assurance department. Preference will be given to engineers who are familiar with the requirements of Def—Stan 05-21 and who have experience in a number of Q.A. functions including defect analysis, quality costs, and the monitoring and control of Company systems.

Applicants aged 26-50 must be educated to HNC/HTC level or above in electronics. A working knowledge of communications equipment would be a distinct advantage.

We offer excellent conditions of service including a good basic salary and Group Productivity Scheme, 27 days annual holiday, a contributory pension scheme and a free life assurance.

Please apply in writing stating qualifications, experience and current salary to the:
Personnel Officer, RACAL-BCC, South Way, Exhibition Grounds, Wembley, Middlesex.

Racal-BCC

RACAL

World leaders in electronics

(1573

Radio Operator Technicians

for British Antarctic Survey

The British Antarctic Survey requires Radio Operator Technicians to man single handed wireless stations at their permanent Antarctic bases. The appointments will cover two consecutive Antarctic winters which involves an absence from the United Kingdom of about 32 months.
Applicants must be able to maintain SSB transmitting and receiving equipment as well as aerial arrays. Communication between the Antarctic Stations and the United Kingdom is by radio teleprinter through a cable and wireless station. Teleprinter, morse and voice communication is also maintained between foreign Antarctic stations, ships and aircraft.
Qualifications: MRGC or better and a capability of sending and receiving morse at a minimum of 20 wpm.
Experience in maintaining communication equipment is essential. A knowledge of teleprinters and touch typing an advantage.
Applications from amateur and armed service trained personnel will be considered provided that the necessary expertise can be demonstrated.
Applicants to work overseas should be single, aged between 22-35, physically fit and male.
Salary: From £5,410 per annum plus a pay addition and gratuity. Clothing, messing and canteen are provided free on the station and free messing aboard ship. Free accommodation whilst overseas. Low income tax.

Application forms may be obtained from: The Establishment Officer, British Antarctic Survey, High Cross, Madingly Road, Cambridge CB3 0ET.
Please quote Ref: BAS 57.
Closing date: 27 April, 1982

Natural Environment Research Council

(1595)

HAMMERSMITH AND FULHAM HEALTH AUTHORITY

CHARING CROSS HOSPITAL

MEDICAL PHYSICS TECHNICIAN GRADE 1

Salary scale: £8968-£10319 per annum inclusive

An Electronics Technician with considerable experience of maintenance of electronic and biomedical equipment is required to supervise the day-to-day work of nine technicians engaged in the repair, calibration and safety checking of a wide range of medical and laboratory equipment.

Applicants should have previous experience of personnel supervision and an extensive knowledge of the electrical safety aspects of medical equipment.

Opportunities will exist for the development of electronic instrumentation and a knowledge of microprocessors would be desirable. The successful candidate will be expected to participate in the activities of the medical electronics section of the department of medical physics.

Ideally, the successful candidate will have an HNC or HND in electronic engineering.

For an application form and job description, please contact Mrs J. Cordery, District Personnel Department, Charing Cross Hospital, Fulham Palace Road, London W6. Telephone 01-748 2040 ext. 2992.

(1609)

Technical Training Officer

Marconi Avionics are one of the world's leading companies in the research, development, design and manufacture of advanced avionics systems.

We are now seeking a Training Officer to take responsibility for identifying the changing skill needs throughout our Borehamwood location through close and continuing liaison with development, test and production management, followed by the planning and development of suitable practical courses. This will be particularly important in the areas of test equipment application and wiring and soldering skills.

Applicants should have a good training background, supported by an HNC and practical experience of electronic circuit construction, testing, and fault diagnosis of analogue/digital equipment. On a personal level, tact, diplomacy, and an ability to communicate effectively at all levels are essentials.

This is an excellent opportunity for a man or woman to make a meaningful contribution to the training needs of a world leader. Salary will be competitive and accompanied by first class benefits.

For further information, please write or telephone: Tony Elliott, Marconi Avionics Limited, Elstree Way, Borehamwood, Herts, WD6 1RX. Tel: 01-953 2030.

(1569)

MARCONI AVIONICS

A GEC-Marconi Electronics Company

Leeds Western Health Authority

THE GENERAL INFIRMARY AT LEEDS

SENIOR ELECTRONICS TECHNICIAN (Grade MPT III)

Applications are invited from persons experienced in electronic maintenance, preferably with imaging and counting equipment, to work in our well-equipped Nuclear Medicine Department. Knowledge of computer systems particularly 8080A microprocessors would be an additional (or alternative) recommendation. The work is interesting, responsible and includes design and development of specialised electronic units. A less experienced person may be considered on the MPT IV Grade.

Minimum qualifications are HNC in electronics or equivalent and NHS experience is desirable.

Salary Scale (Whitley conditions apply).

MPT III – £5536 – £7155
MPT IV – £4668 – £6137

For further information including Job Description contact: The Sector Personnel Officer, The General Infirmary at Leeds, Great George Street, LEEDS LS1 3EX. Telephone (0532) 32799 Ext 355.

Closing Date: 14th May 1982.

(1588)

Kingdom of Lesotho

Transmitter Engineer

Up to £11,500 p.a. plus benefits

A challenging post in this beautiful and mountainous kingdom in southern Africa.

Applicants must possess an engineering degree and have at least five years experience in transmitter engineering and maintenance.

Duties will include operation and maintenance of two 100kw shortwave transmitters, identifying operational needs, and staff supervision and training.

Appointment will be on contract for two years.

Salary includes a substantial tax-free allowance paid under Britain's overseas aid programme.

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★ Children's holiday visit passages and education allowances
★ Subsidised housing
★ Appointment grant and interest-free car loan

For full details and application form write quoting YC/202/WW or telephone 01-222 7730 Ext 3639.

Crown Agents

The Crown Agents for Oversea Governments & Administrations, Recruitment Division, 4 Millbank, London SW1P 3JD.

(1575)

ELECTRONIC DEVELOPMENT ENGINEER

We are seeking to expand our development team by recruiting a young Graduate with two to three years' experience of designing analogue and digital circuitry.

Our range of products includes Modulation Meters, SSB Transmitter Drive Units and Spectrum Analysers. Experience in any of these fields would be an advantage but is not strictly essential.

We are offering an excellent working environment plus a really attractive salary to the successful applicant.

Please contact H. M. Evans – M.D. by letter or phone.

SAYROSA ELECTRONICS LTD.
Anstey Mill Lane, Alton Hants GU34 2QQ
Tel: (0420) 84500

(1604)

U.S.A.

British-run company near New York seeks Electronic Engineer (B.Sc. or equivalent) for design of medical and industrial instruments. Could probably represent us later in UK. Starting salary $15,000 (£8,000). Please send résumé of training and experience to Bailey Instruments Inc., Saddle Brook, NJ 07662.

1578

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We are the newly-formed marketing arm of a manufacturing company, now established for over 50 years.

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We are offering a salary commensurate with age and experience, as well as commission, four weeks' paid holiday and a company car.

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Tel: 01-204 7246

(1605)

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The applicant should have good connections to the electronic shops and manufacturers of cabinets, to whom our products should be offered with priority.

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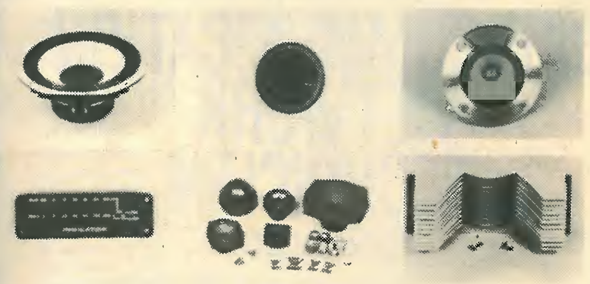
West Germany



TV-am

ENGINEERING AND OPERATIONS DEPARTMENT

TV-AM, the breakfast television contractor, requires staff to perform engineering and operational duties at all grades, both within the Breakfast Television Centre and on outside broadcast including ENG type operations. Previous experience in television broadcasting would be an advantage.

Applications in writing with curriculum vitae to:

THE PERSONNEL ADMINISTRATOR, BREAKFAST TELEVISION CENTRE, HAWLEY CRESCENT, LONDON NW1 8EF.

(1590)

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For 1. West Midlands 2. South East 3. West of England

Required by Townsend-Coates, a leading franchised distributor of electronic components.

The successful applicants will have component knowledge, be already selling to industry or have sales flair.

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Please sent C.V. to:
Managing Director
Townsend-Coates Ltd.
Lunsford Road
Leicester LE5 0HH

(1594)

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SIDE SCAN, MAGNETOMETER, SB PROFILER
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Please write, quoting WW106, to:

THE MANAGING DIRECTOR
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ADMIRALTY ROAD, GREAT YARMOUTH
OR TELEPHONE: 0493 50723, EXT. 200, MRS. GOFF

UNIVERSITY OF ESSEX

M.Sc. (European Joint Scheme)

This is a new two-year degree scheme supported by the E.E.C., which involves one year in each of the two co-operating institutions, the Universitat Fridericiana Karlsruhe in West Germany and the Ecole Superieure d'Ingenieurs en Electrotechnique et Electronique in Paris. The first year comprises specialist courses and the second year is a project year. A limited number of places are available for highly qualified students. Applicants should hold a first or second class honours degree in Electrical Engineering and have a working knowledge of French and German. The scheme is recognised by S.E.R.C. for tenure of advanced course studentships for the two-year period.

Please write to: Dr. B. G. Evans, Department of Electrical Engineering Science, University of Essex, Colchester CO4 3SQ. Phone: Colchester (0206) 862286 ext. 2269 Telex: 98440 (UNILIB G)

(1599)

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For further details and an application form please telephone Mrs. R. Sidders on 01-952 2333 or write to her at:-

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If you would like to join a young progressive team of people at our Milton Keynes office, write with your CV to:

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Zehntel Ltd
62 Tanners Drive
Blakelands
Milton Keynes
MK14 5BP

(1583)

SCOTTISH OFFICE

DIRECTORATE OF TELECOMMUNICATIONS

WIRELESS TECHNICIANS (£5,300-£7,060)

Applications are invited for at least three posts of Wireless Technician in the central services department of the Scottish Office. The posts are expected to be based in Edinburgh, East Kilbride and Montreathmont (near Forfar). Candidates must hold an ordinary national certificate in Electronic or Electrical Engineering or a City and Guilds of London Institute certificate in an appropriate subject or a qualification of a higher or equivalent standard and have three years' appropriate experience. Some assistance may be given with relocation expenses.

A valid UK driving licence and ability to drive private and commercial vehicles are essential.

Application forms and further information are obtainable from Scottish Office Personnel Division, Room 110, 16 Waterloo Place, Edinburgh EH1 3DN. Tel. 031-556 8400 ext. 4317 or 5028. (Quote Ref. PM (PTS).

Closing date for receipt of completed application forms is 14 May, 1982.

(1607)

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For United Arab Emirates
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Must be able to work independently to promote the company products. We are main distributors for Storno UK and need first-class engineer to push sales and attend customers' enquiries. Bachelors only or married no children.

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(1612)

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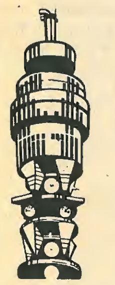

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(291)

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(321)

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We are an expanding Television Rental and Retail company with a vacancy for an additional Television Service Engineer.

Suitable applicant will preferably hold an R.T.E.B. certificate or be training towards this qualification.

The post is directly responsible to the Service Manager.

A clean driving licence is essential.

A spacious flat is available if required.

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(1434)

INNER LONDON EDUCATION AUTHORITY

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The Television Centre produces a range of educational programmes distributed in the form of videocassettes, sound cassettes and 16mm film. It has a colour studio equipped to professional broadcasting standards (Link 110 cameras, Neve sound mixer, Ampex VPR2s, etc.) a mobile unit and a battery portable camera.

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A vacancy exists for a Television Camera Operator to work principally in the studio but also to assist if required in a monochrome training studio, in location video recording, and in the mobile unit. When not required to work with cameras, the operator would be expected to be attached to other technical sections so a general interest in the technical side of television is highly desirable. Applicants should have had some formal training together with practical experience, though consideration will be given to those who lack the latter.

FILM SOUND RECORDIST (ST2)

SALARY RANGE £6,663 – £7,557 plus £1,104 London Weighting Allowance

The work is largely film recording using the Nagra, but with periods of studio duty (rigging, boom operation, tape and grams, etc), and film transfer work. Working hours are based on a 35-hour week, though overtime is often necessary, particularly where travel to locations is involved. Occasional overnight stops are required. Although applicants should have thorough knowledge of sound techniques in a film television environment, consideration will be given to those who are willing to learn, have appropriate technical qualifications, and experience elsewhere in the sound recording field.

MAINTENANCE ENGINEER (ST3)

SALARY RANGE £7,857 – £8,514 plus £1,104 London Weighting Allowance

The maintenance section has four members and is responsible for all the equipment at the studio centre, both vision and sound. Applicants must have relevant technical qualifications (a knowledge of digital techniques would be an advantage), and should have good experience in the field, though consideration would be given to experience in allied fields. Limited "on the job" training is available, and the Authority will pay for attendance at specialised manufacturers' courses, where these are considered necessary.

Further information and application forms are available from the Education Officer (EO/Estab 1B) Room 365, County Hall, London, SE1. Please enclose an SAE. Completed forms should be returned 14 days from appearance of advertisement.

(1577)

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GAUMONT KALEE Flutter Meter £45
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MARCONI TF.2600 Sens. Valve Voltmeter 10V-300V f.s.d. ± 1% £95
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ADVANCE SG65A Oscillator 10Hz-100KHz Sine/Sq. O/P, 0-6V £65
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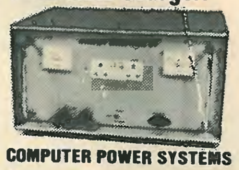

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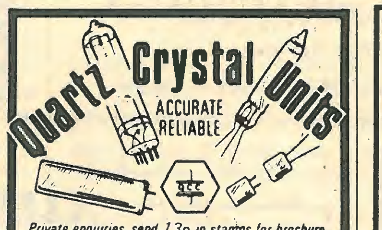

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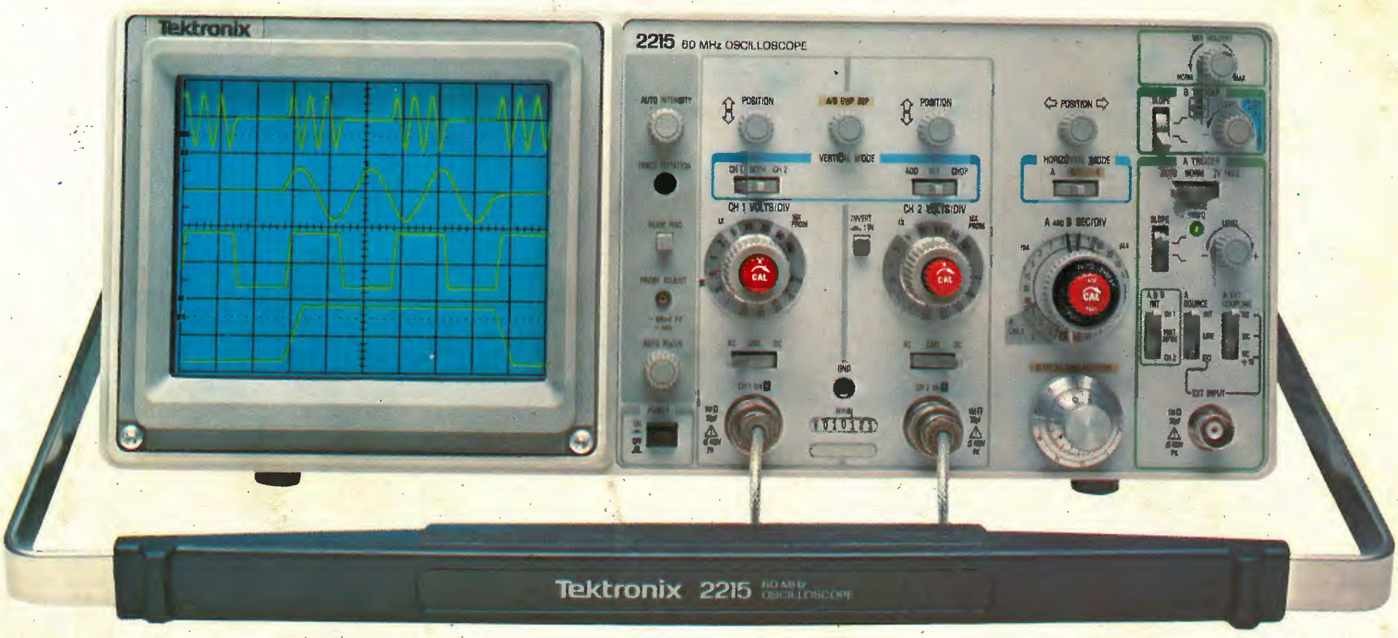

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