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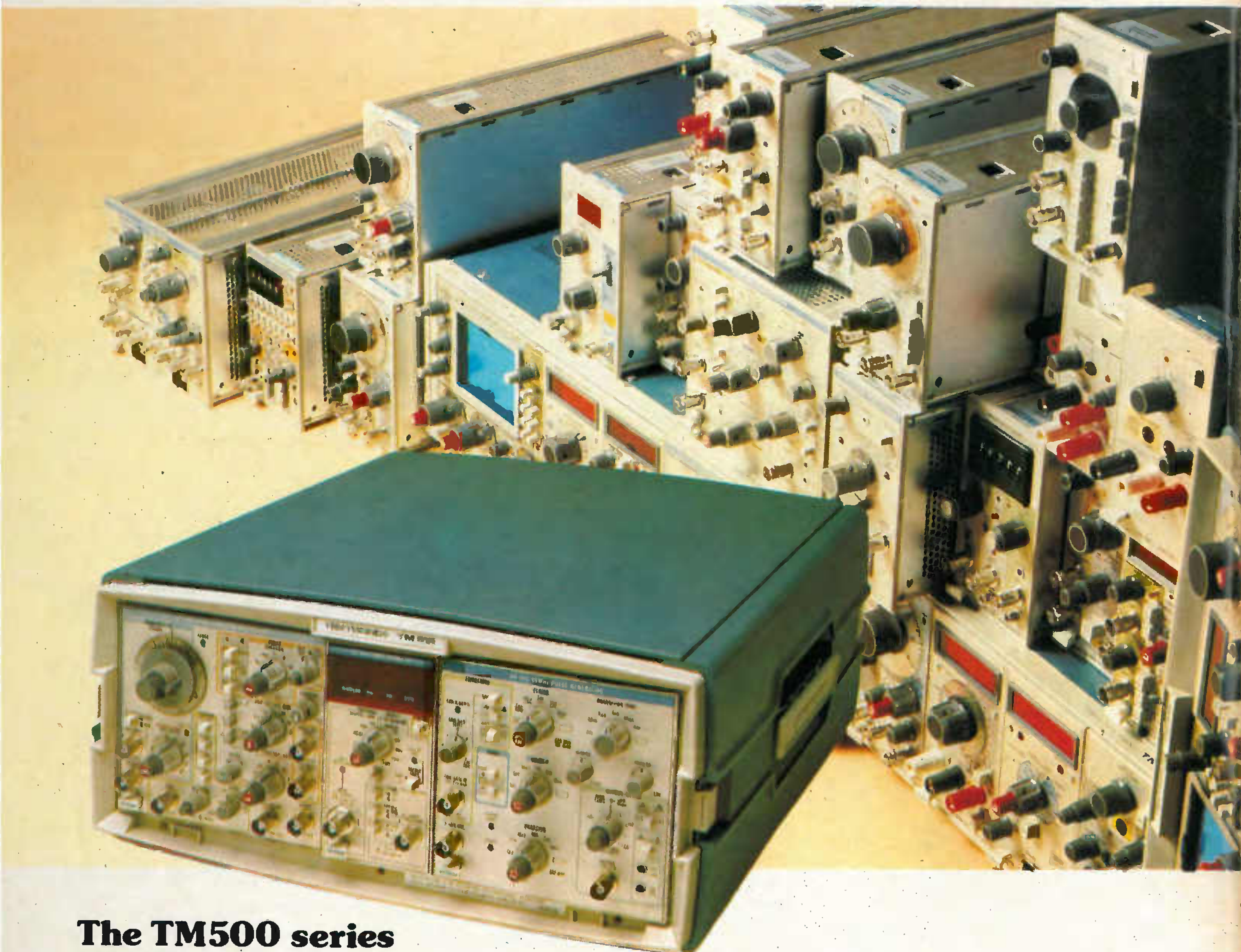

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Please send me full information on the TM500.

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Position ....

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Address ....

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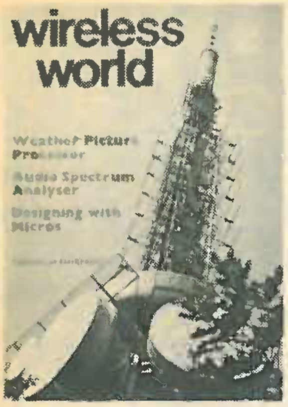
Telephone TM27

WW—001 FOR FURTHER DETAILS



Front cover shows aerials of Bantiger television station operated by Swiss PTT. Photo: the Hamer-Smith Swiss collection.

IN OUR NEXT ISSUE

***Wideband audio amplifier* design by Yuri Miloslavskij aims at good transient response using class A circuitry and no overall feedback.**

Constructional design for *multisection tone equalizer* is made inexpensive by use of quad op-amps and preset controls.

***Also* articles on community broadcasting, an unusual technique for metal detecting and analogue computing methods. For details of these see panel on page 85.**

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ELECTRONICS / TELEVISION / RADIO / AUDIO

MAY 1980 Vol 86 No 1533

DON'T GAMBLE WITH PERFORMANCE BUY LEVELL VOLTMETERS

A.C. MICROVOLTMETERS

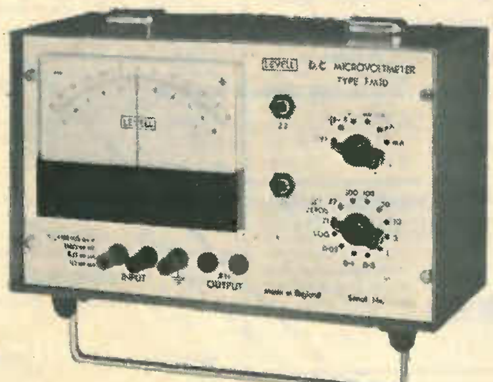
VOLTAGE & dB RANGES	15µV, 50µV, 150µV . . . 500V fsd. Acc. ± 1% ± 1% fsd ± 1µV at 1kHz. − 100, −90 . . . ± 50dB. Scale −20dB/+6dB ref. 1mW/600Ω.
RESPONSE	± 3dB from 1 Hz to 3MHz, ± 0.3dB from 4 Hz to 1MHz above 500µV. TM3B filter switch: LF cut 10Hz, HF cut 100KHz, 10KHz or 350Hz.
INPUT IMPEDANCE	Above 50mV: 10MΩ <20pF. On 50µV to 50mV: >5MΩ <50pf.
AMPLIFIER OUTPUT	150mV at fsd.

type TM3A £130 **type TM3B £145**

BROADBAND VOLTMETERS

H.F. VOLTAGE & dB RANGES	1mV, 3mV, 10mV . . . 3V fsd. Acc. ± 4% ± 1% fsd at 30MHz. −50, −40 . . . +20dB. Scale −10dB/+3dB ref. 1mW/50Ω.
H.F. RESPONSE	± 3dB from 300kHz to 400MHz. ± 0.7dB from 1MHz to 50MHz.
L.F. RANGES	As TM3.
AMPLIFIER OUTPUT	Square wave at 20Hz on H.F. with amplitude proportional to square of input As TM3 on L.F.

type TM6A £199 **type TM6B £215**



D.C. MICROVOLTMETERS

VOLTAGE RANGES	30µV, 100µV, 300µV . . . 300V. Acc. ± 1% ± 2% fsd ± 1µV. CZ scale.
CURRENT RANGES	30pA, 100pA, 300pA . . . 300mA. Acc. ± 2% ± 2% fsd ± 2pA. CZ scale.
LOG: RANGE	± 5µV at ± 10% fsd, ± 5mV at ± 50% fsd, ± 500m V at fsd.
RECORDER OUTPUT	± 1V at fsd into > 1kΩ.

type TM10 £106

These instruments incorporate many useful features, including long battery life. All A type models have 83mm scale meters and case sizes of 185 x 110 x 130mm. B types have 127mm mirror scale meters and case sizes of 260 x 125 x 180mm. Fully detailed specification sheets are available on request for our complete range of portable instruments. Prices are ex-works, carriage, packing and VAT extra. Optional extras are leather cases and power units.

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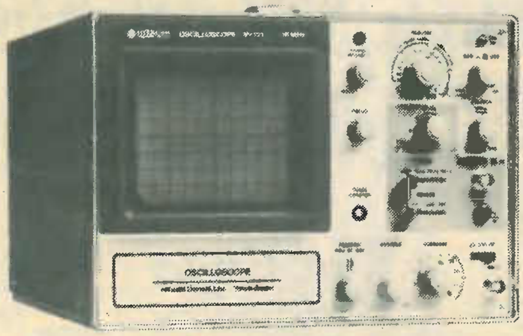
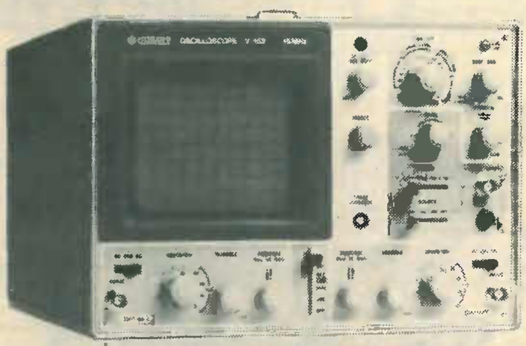
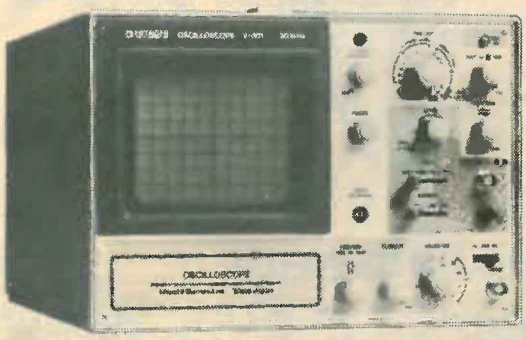


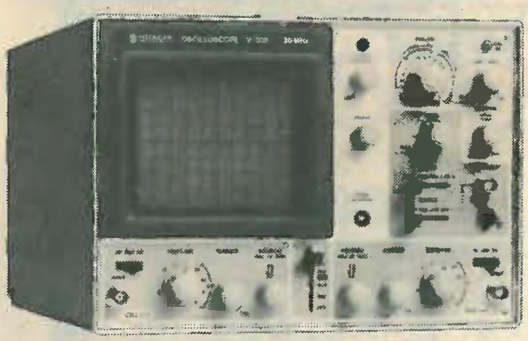
V-151 15mhz single trace



V-152 15mhz dual trace



V-301 30mhz single trace



V-302 30mhz dual trace

The Hitachi-Denshi Oscilloscopes have been researched and produced by Hitachi Electronics specialists and has resulted in a range of modern Oscilloscopes which feature wider band width, a compact design and light weight.

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- X-Y operation, which is very convenient for measuring phase difference of two wave forms.
- TV sync separator circuit facilitates rapid video signal measurements.
- Extra high sensitivity: vertical sensitivity of 1 mV div now available.
- Built in signal delay line for leading edge observation of quick rising wave forms.
- Sweep time magnifier effective for precise measurement: Sweep time magnifying ten times with one touch operation.

In addition these Oscilloscopes will ensure that very feeble analogue signals can also be measured and any of the line voltages 100, 120, 220 and 240 can be selected by tap changing.

Hitachi-Denshi have a very informative illustrated brochure available on this new range, fill in the coupon and a copy will be mailed to you by return.

Please send me further details on the Hitachi-Denshi Range of Oscilloscopes

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Company

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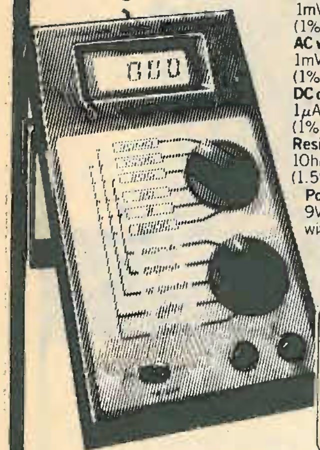


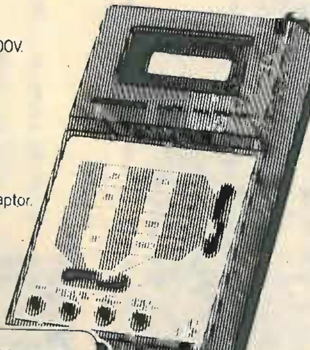
Scales:
DC volts: 1mV to 1000V (1% ± 1 digit accuracte).
AC volts: 1mV to 500V (1% ± 2 digits accurate).
DC current: 1µA to 200mA (1% ± 1 digit accurate).
Resistance: 1Ohm to 20 MOhms (1.5% ± 1 digit accurate).
Power source: 9V battery or AC with optional adaptor.
Size: 155 x 75 x 30 mm.
22–198

PRICE **53·19**

LOW–COST LCD MULTIMETER

A portable, compact sized multimeter with a full 3½ digit LCD display. Auto polarity operation, low battery indicator. 10 MOhm Input impedance.

Scales:
DC volts: 2 20 200 1000V.
AC volts: 200 500V.
DC current: 2 20 200MA.
Resistance: 2 20 200 2000 KOHM.
Power source: 9V battery or AC adaptor.
Size: 37 x 85 x 130 mm.
22–197



PRICE **39·93**

COMPONENTS AND PARTS

CAT. No.	DESCRIPTION	PRICE
276–032	LED	4 for 69p
276–033	LED	2 for 48p
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277–1003	12V DC Automotive Digital Clock Module	£17.52
276–9110	6 pin edge connector for 277 1003	40p
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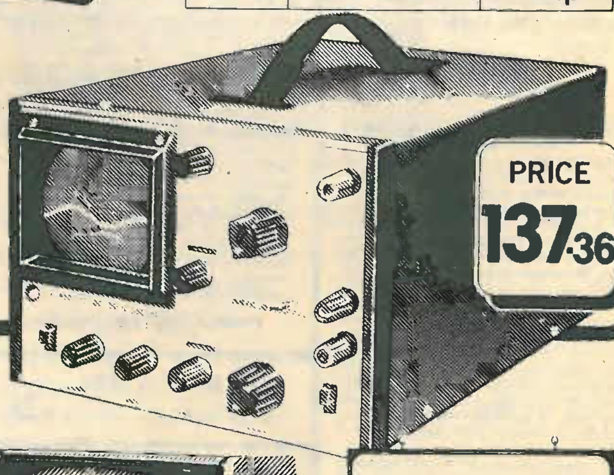
276–1364	TO 3 Heat Sink	81p

AC/DC 8 MHz OSCILLOSCOPE

A new approved 8MHz version of last years' winner! The advance design features of this oscilloscope make it an absolute essential for industrial uses on production lines, in laboratories and schools. Ideal for radio and TV servicing, audio testing, etc.

Specifications:
Horizontal axis: Deflection sensitivity better than 250mV/DIV. **Vertical axis:** Deflection sensitivity better than 10mV/DIV (1DIV 6mm). Bandwidth: 0.8MHz. **Input impedance:** 1MOhm parallel capacitance 35pF. **Time base: Sweep range:** 10Hz 100kHz (4 ranges). Synhronization: Internal ( ) **Size:** 200 x 155 x 300 mm. Supply: 220/240 /50Hz. **22–9501.**



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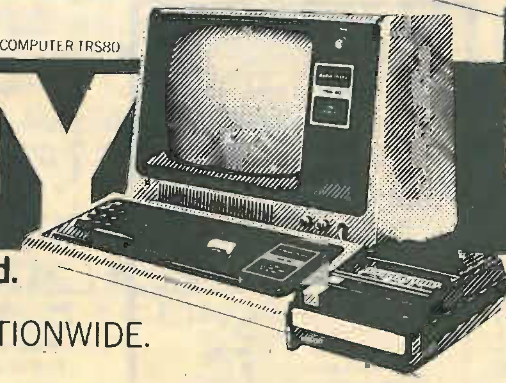

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Remember, its many important features include full four digits, so on mains voltage readings, for example, you might get *240.3* instead of the *240*, which a 3½ digit meter would read.

Some other **PM 2517** plus points:

- LED or LCD display
- True RMS readings of AC voltage and current
- Autoranging with manual override
- Optional accessories include temperature and data hold probes

Reader inquiry number 220

The PM 3207 - Super Scope - is a tough, general purpose oscilloscope which offers at a low price the quality and technology you expect from Philips Test and Measuring Instruments.

- 15 MHz dual trace
- Auto triggering from either channel with adjustable level between peaks and TV triggering
- 5 mV sensitivity, Y and X (via A input)
- B invert facility

Reader inquiry number 221

Both these instruments are available off the shelf from the **Philips Electronic Instruments Department** (see address below) or from the following distributors. **British Tungsram,** West Road, Tottenham, London N17 0RN. Tel: 01-808-4884. **Philips Service Centres** (25 throughout the country). Tel: 01-686-0505 for the address of your nearest branch. **Wessex Electronics Ltd,** 114-116 North Street, Downend, Bristol BS16 5SE. Tel: (0272) 571404.

PATTERN FOR THE FUTURE

The **PM 5519** colour TV pattern generator is already a widely used instrument. As a major manufacturer of Video cassette recorders, and colour television receivers - and the company which has developed the world's most advanced video disc system - Philips have carefully selected the best patterns for aligning and testing these products. With over 20 colour and b/w test patterns to choose from it is the most versatile pattern generator on the market.

- **PM 5519 I** for British system - versions available for other TV systems
- RF signals available in bands I, III, IV and V
- Variable Video Output (with 1 volt fixed position)
- External video and sound modulation facility
- Composite sync output for triggering - includes the line frame and blanking pulses to the local TV standard

Reader inquiry number 222

Some other Philips audio and video service instruments:

PM 5326 RF SIGNAL GENERATOR

- 100 kHz-125 MHz in 9 overlapping ranges
- Built-in 5 digit counter
- 50mV RF output at 75Ω can be attenuated to over 100dB
- Electronically stabilised output level
- Wobbulator facility

Reader inquiry number 223

PM 6307 WOW AND FLUTTER METER

- X-tal controlled oscillator
- High accuracy and frequency stability
- 3150 Hz or 3000 Hz switchable
- Separate 'Drift' and 'Flutter' indication

Reader inquiry number 224

All Philips audio and video service instruments are also available from Philips Service Centres (for details see end of PM 3207 section).

Input advertisements are designed to meet the needs of our professional customers. They are a shop window for Philips Test and Measuring Instruments - and we will be changing the display frequently because we have a lot of products to show you.

Where you require full information about a product, tick the coupon and attach it to your name and address, or letterhead - or, of course, use the journal's reader inquiry service. You will receive in return a detailed information pack reflecting your specific requirements.

	Inquiry no.	
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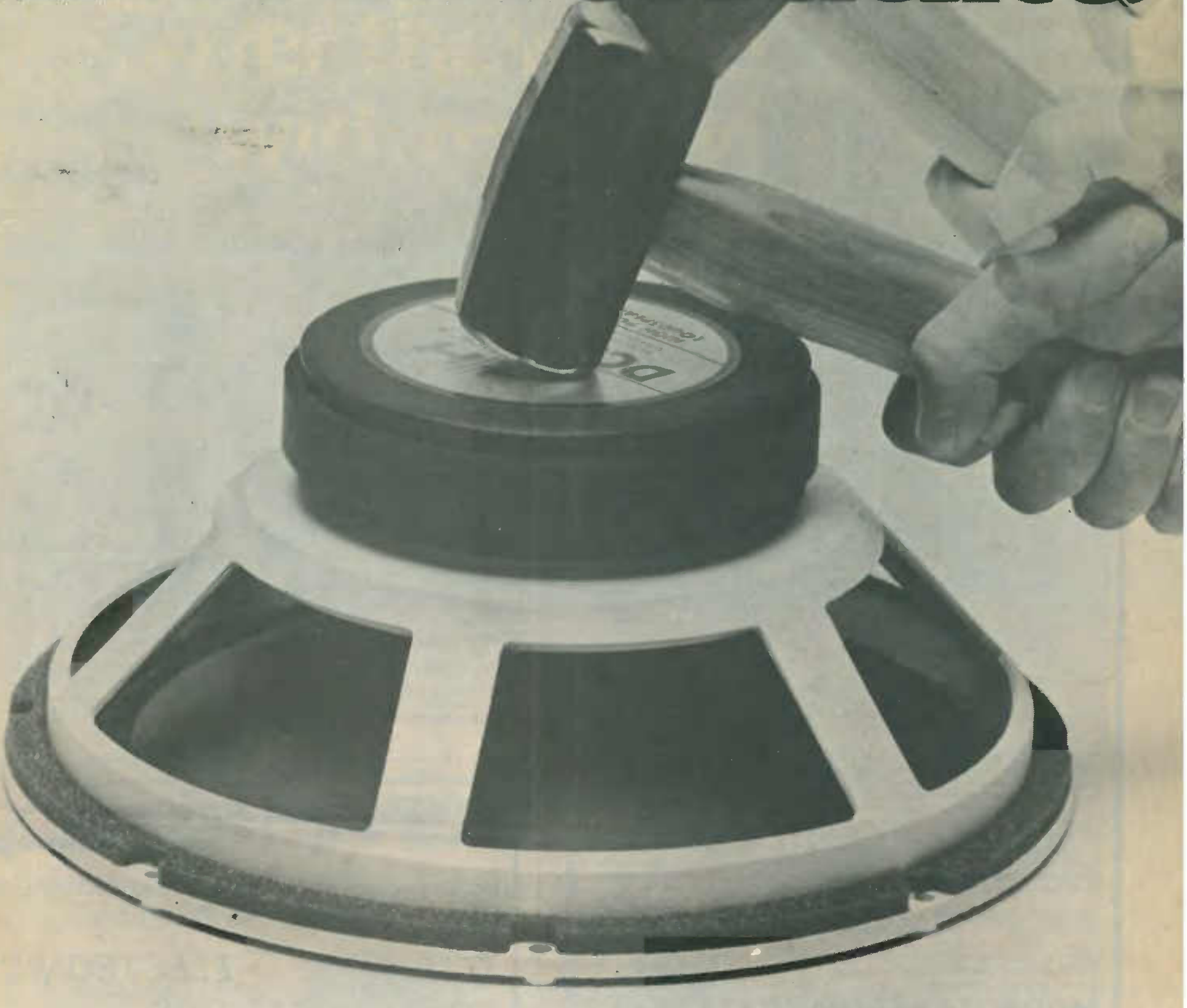

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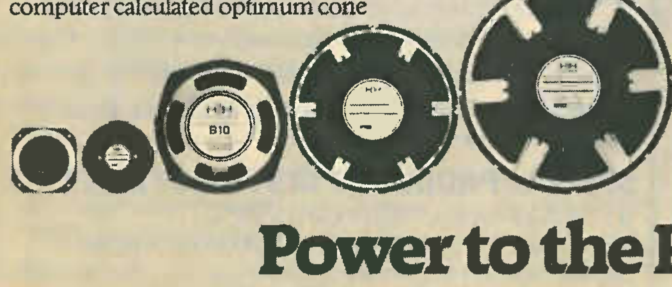

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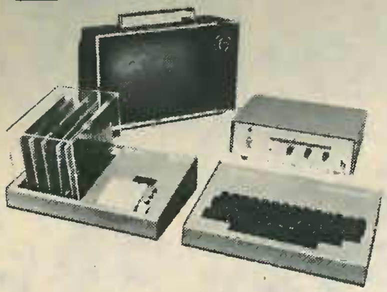

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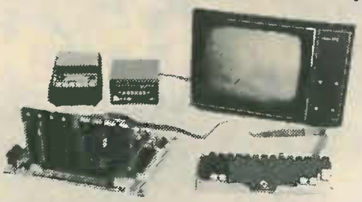

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MC 1 — PRE-AMP-AMPLIFIER. Suitable for nearly all moving-coil cartridges. Send for details.

X02: X03 — ACTIVE CROSSOVERS. X02 — two way, X03 — three way. Slope 24dB/octave. Crossover points set to order within 10%.

REG 1 — POWER SUPPLY. The regulator module, REG 1 provides 15-0-15v to power the CPR 1 and MC 1. It can be used with any of our power amp supplies or our small transformer TR 6. The power amp kit will accommodate it.

**** NEW ISSUE 5 ****

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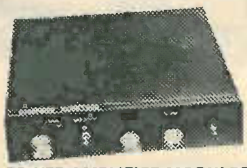
PRE-AMP KIT
This includes all metalwork, pots, knobs, etc., to make a complete pre-amp with the CPR 1 (S) module if required.



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These are available in two versions — one uses standard components, and the other (the S). uses MO resistors where necessary and tantalum capacitors

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MC1	**£26.00**
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REGI **£9.30** TR6 **£2.50**

BRIDGE DRIVER, BD1
Obtain up to 350W using, 2x170W amps and this module
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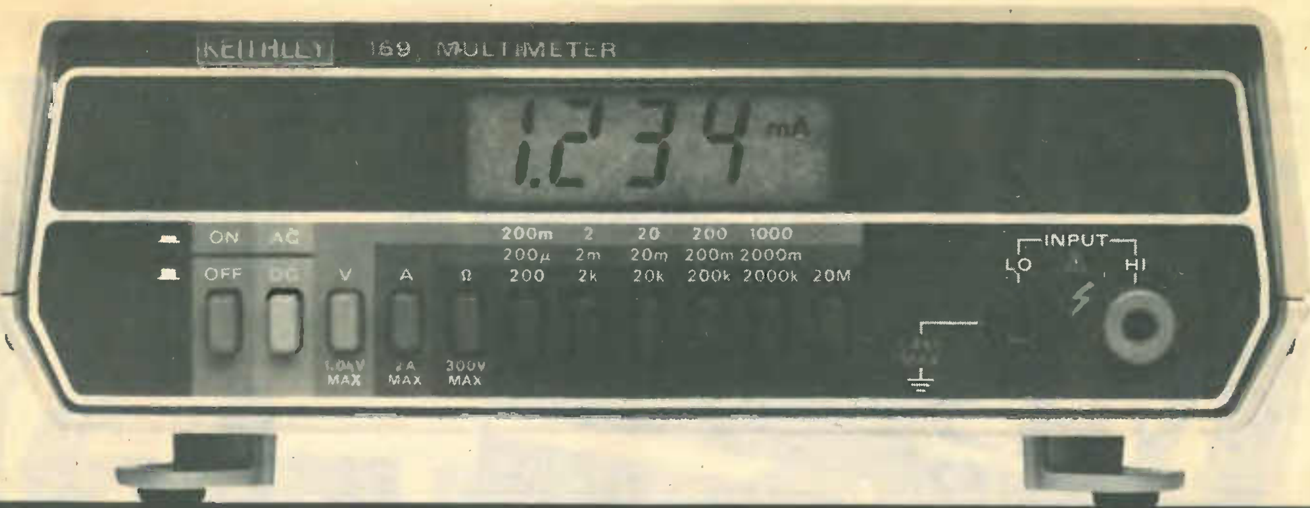

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got it right, t from the start.

Believe it or not, 2 out of every 3 home video recorders sold or rented in this country in 1979 were VHS models. VHS was also the most successful home video system worldwide.

That represents a pretty overwhelming vote of confidence. How did we manage it?

At the outset we were determined to produce a home video system that was nothing short of outstanding. That's why VHS offers standards of reproduction, reliability and compatibility that are quite simply second to none.

And of course, if you build a better system in the first place there's less need to change it later on.

So while we have continually improved the quality of our recorders – there are now triple standard VHS machines which accept PAL, SECAM and NTSC – we have never changed the design of the VHS cassette. And it will not change in the future either. Which is more than can be said for some of our competitors.

By maintaining the same cassette, VHS has become the most compatible system available. So your customers will find it much easier to swap tapes with friends and enjoy the greatest range of pre-recorded material too.

VHS is the No. 1 system in the UK, Europe, the US and Japan.

Make sure you've got it.

Right?

The world's No.1 system.

VHS

on, Hitachi, JVC, Panasonic.

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In future, recording the present will be a thing of the past.

What's past is past. And said to be best forgotten.

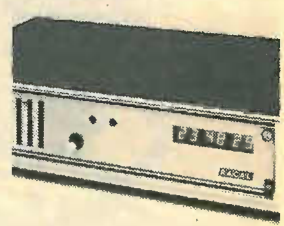
But it's fundamental to the very existence of communications recording to be able to replay a selected portion of tape to find out what was said by who, to whom ... and when. And 'when' can be vital.

Equally vital, particularly in emergencies when every second counts, is the ability to obtain such replay access rapidly, precisely, automatically. With absolute certainty—and without time-consuming multiple knob-twiddling aided by guesswork.

Racal Recorders has recognized this need and produced TIMESEARCH—designed specifically for its ICR range of multi-channel communications recorders—and providing just these facilities.

TIMESEARCH can generate a coded time reference signal of crystal accuracy and index it onto the tape. It can read and display that signal. It can search a tape at high speed for a pre-selected time signal and automatically initiate replay at that time.

In communications recording, the future becomes the present; the present becomes the past. And when you need to recall the past with precision, you need TIMESEARCH.



And for providing precise time signals every 10 seconds for recording onto magnetic tape: the International Timing Unit.

Racal Recorders always on the right track

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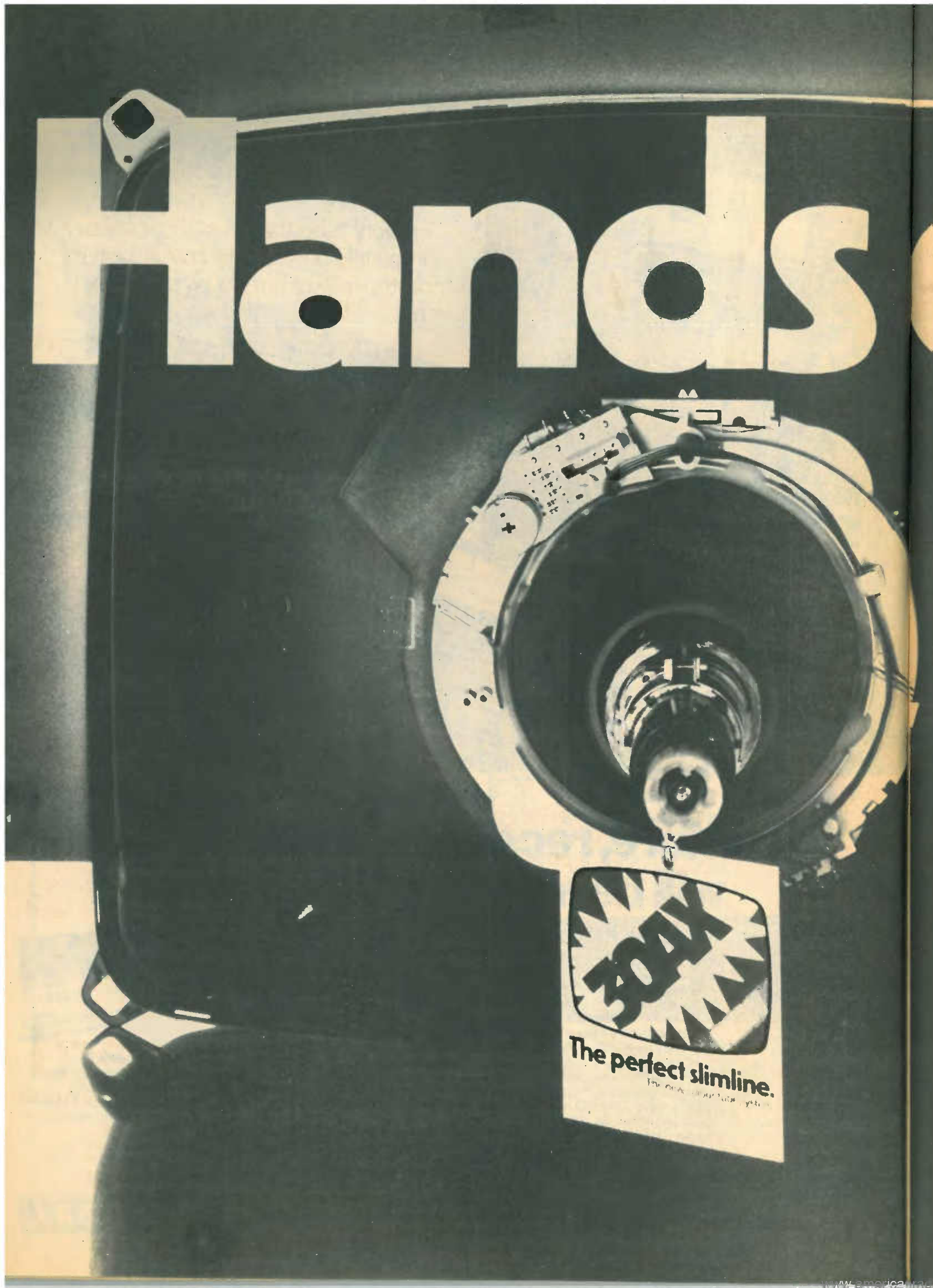
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For more information just write your name and address on this page and send it to Dept. MCG, Mullard Ltd., Mullard House, Torrington Place, London WC1E 7HD.

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But the distortion contribution from a QUAD 405 amplifier in normal use (say 85dBa) moves the eardrum <u>less</u> than this amount.

Perhaps sitting in a very quiet room at –100°C and without the music we might nearly hear them ....but "'tis bitter cold."

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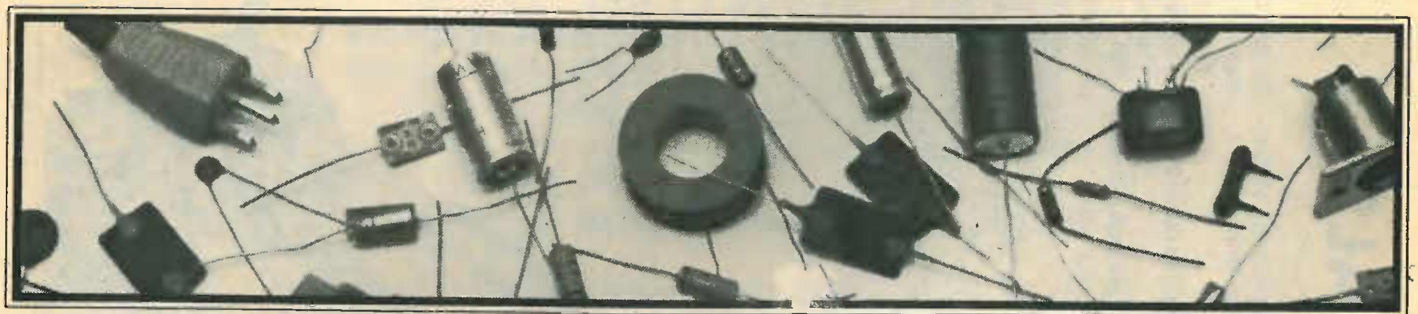

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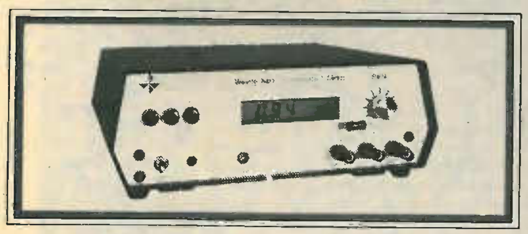

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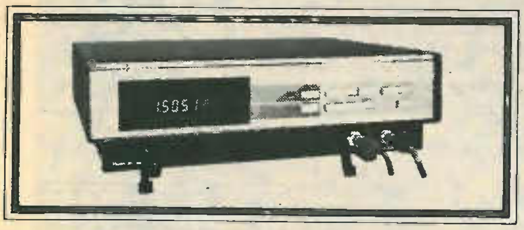

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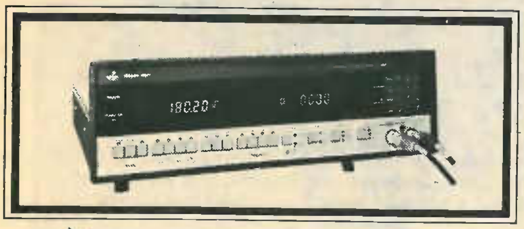

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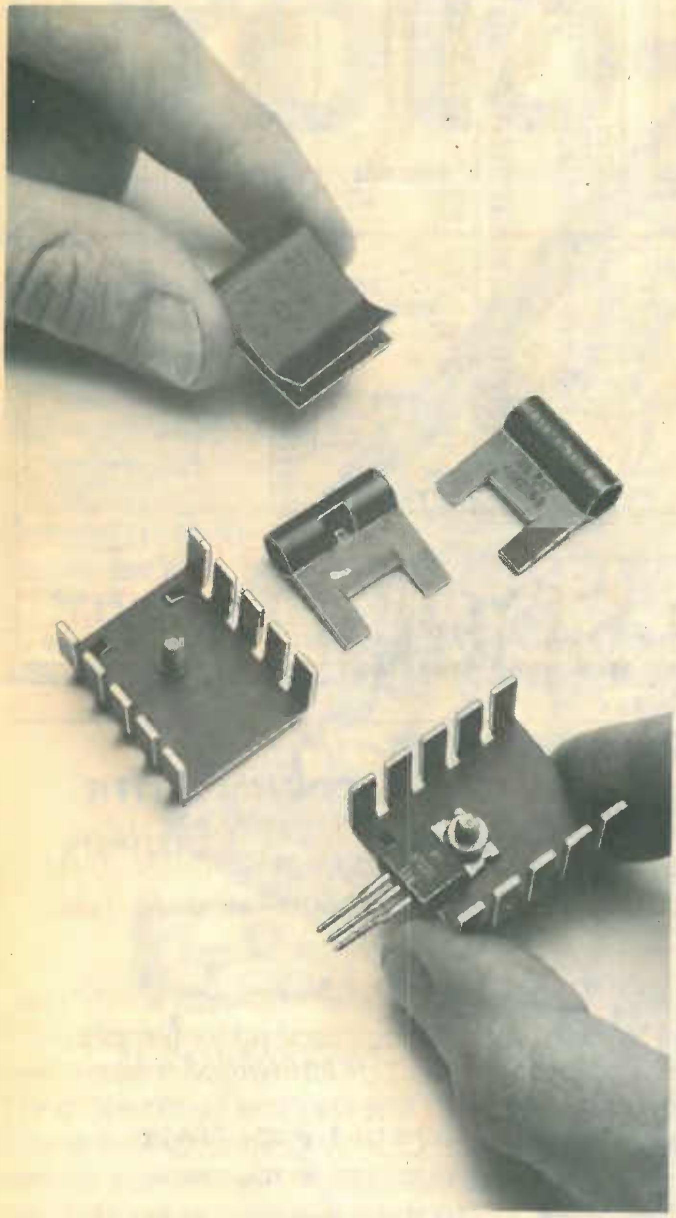

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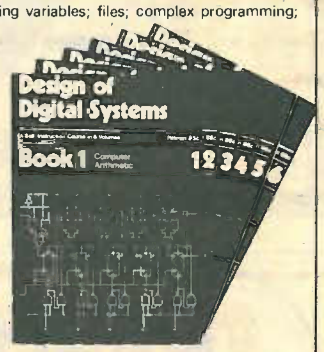

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HEWLETT PACKARD
427A. AC/DC/Ω multimeter 275
3406A. 10 kHz-1.2 GHz 345
LINSTEAD
M2B. DC/AC 10 Hz-500 kHz 25
MARCONI
TF2603. AC voltmeter to 1 5 GHz 300
PHILIPS
PM2454B 1mV-300V. 10 Hz-12 MHz Z in 19MΩ. DC O P. 300

Voltmeters-Digital
FARNELL
DM131B. 1999 FSD AC/DC/Ω/ Current Temperature 85
FLUKE
8000A 1999 FSD AC/DC/OHMS/Current 115
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SOLARTRON
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LM1420.2BA. 2300 FSD AC True RMS/DC 110
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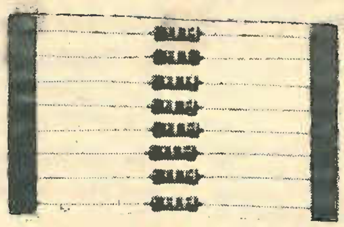

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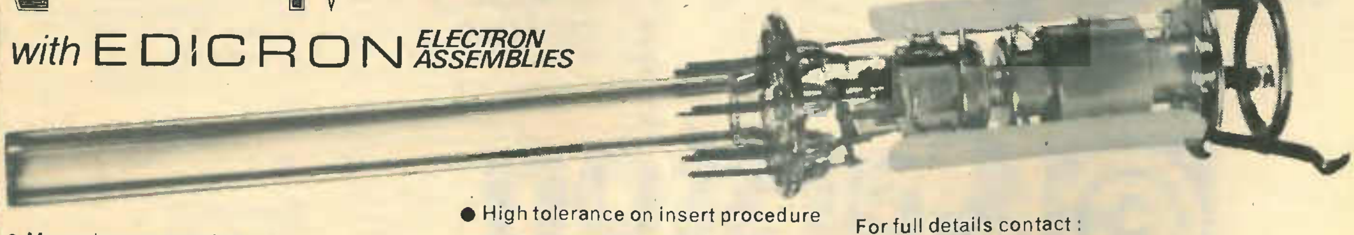

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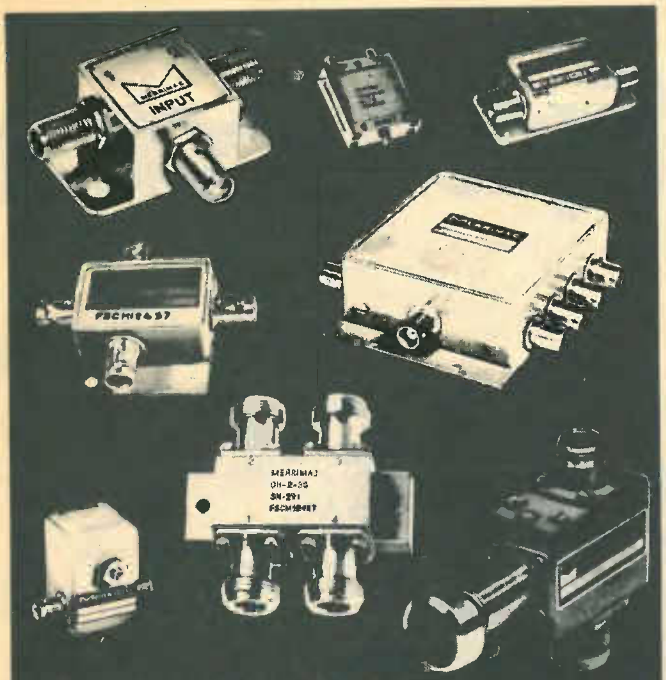

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Britain's first compl

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Also available ready assembled for £99.95

The Sinclair ZX80.

Until now, building your own computer could easily cost around £300 – and still leave you with only a bare board for your trouble.

The Sinclair ZX80 changes all that. For just £79.95 you get *everything* you need to build a personal computer at home...PCB, with IC sockets for all ICs; case; leads for direct connection to your own cassette recorder and black and white or colour television; everything!

And yet the ZX80 really is a complete, powerful, full-facility computer, matching or surpassing other personal computers on the market at several times the price. The ZX80 is programmed in BASIC, and you could use it to do quite literally anything from playing chess to running a power station.

The ZX80 is pleasantly straightforward to assemble, using a fine-tipped soldering iron. Once assembled, it immediately proves what a good job you've done. Connect it to your TV set...link it to an appropriate power source*... and you're ready to go.

Your ZX80 kit contains...

- Printed circuit board, with IC sockets for all ICs.
- Complete components set, including all ICs – all manufactured by selected world-leading suppliers.
- New rugged Sinclair keyboard, touch-sensitive, wipe-clean.
- Ready-moulded case.
- Leads and plugs for connection to domestic TV and cassette recorder. Programs can be SAVEd and LOADed on to any portable cassette recorder.
- FREE course in BASIC programming and user manual.

Optional extras

- Mains adaptor of 600 mA at 9 V DC nominal unregulated (available separately – see coupon).
- Additional memory expansion boards allowing up to 16K bytes RAM. Extra RAM chips also available – see coupon.

*Use a 600 mA at 9 V DC nominal unregulated mains adaptor. Available from Sinclair if desired (see coupon).

Two unique and valuable components of the Sinclair ZX80.

The Sinclair ZX80 is not just another personal computer. Quite apart from its exceptionally low price, the ZX80 has two uniquely advanced components: the Sinclair BASIC interpreter; and the Sinclair teach-yourself BASIC manual.

The unique Sinclair BASIC interpreter... offers remarkable programming advantages:

- **Unique 'one-touch' key word entry: the ZX80 eliminates a great deal of tiresome typing. Key words (RUN, PRINT, LIST, etc.) have their own single-key entry.**
- Unique syntax check. Only lines with correct syntax are accepted into programs. A cursor identifies errors immediately. This prevents entry of long and complicated programs with faults only discovered when you try to run them.
- Excellent string-handling capability – takes up to 26 string variables of any length. All strings can undergo all relational tests (e.g. comparison). The ZX80 also has string input – to request a line of text when necessary. Strings do *not* need to be dimensioned.
- Up to 26 single dimension arrays.
- FOR/NEXT loops nested up 26.
- Variable names of any length.
- BASIC language also handles full Boolean arithmetic, conditional expressions, etc.
- Exceptionally powerful edit facilities, allows modification of existing program lines.
- Randomise function, useful for games and secret codes, as well as more serious applications.
- Timer under program control.
- PEEK and POKE enable entry of machine code instructions. USR causes jump to a user's machine language sub-routine.
- High-resolution graphics with 22 standard graphic symbols.
- All characters printable in reverse under program control.
- Lines of unlimited length.

...and the Sinclair teach-yourself BASIC manual.

If the features of the Sinclair interpreter listed alongside mean little to you – don't worry. They're all explained in the specially-written 128-page book *free* with every kit! The book makes learning easy, exciting and enjoyable, and represents a complete course in BASIC programming – from first principles to complex programs. (Available separately – purchase price refunded if you buy a ZX80 later.)

A hardware manual is also included with every kit or built machine.

Z80A microprocessor – new, faster version of the famous Z-80 microprocessor chip, widely recognised as the best ever made.

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RAM chips.

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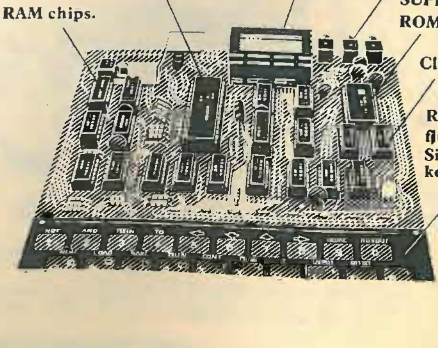

ete computer kit.

Fewer chips, compact design, volume production – more power per pound!

The ZX80 owes its remarkable low price to its remarkable design: the whole system is packed on to fewer, newer, more powerful and advanced LSI chips. A single SUPER ROM, for instance, contains the BASIC interpreter, the character set, operating system, and monitor. And the ZX80's 1K byte RAM is roughly equivalent to 4K bytes in a conventional computer – typically storing 100 lines of BASIC. Key words occupy only a single byte.

The display shows 32 characters by 24 lines.

And Benchmark tests show that the ZX80 is faster than all other personal computers.

No other personal computer offers this unique combination of high capability and low price.

The Sinclair ZX80. Kit: £79.95. Assembled: £99.95. Complete!

The ZX80 kit costs a mere £79.95. Can't wait to have a ZX80 up and running? No problem! It's also available, ready assembled, for only £99.95.

Demand for the ZX80 is very high: use the coupon to order today for the earliest possible delivery. All orders will be despatched in strict rotation. We'll acknowledge each order by return, and tell you exactly when your ZX80 will be delivered. If you choose not to wait, you can cancel your order immediately, and your money will be refunded at once. Again, of course, you have a refund option for 14 days after your computer is despatched. We want you to be satisfied beyond all doubt – and we have no doubt that you will be.

sinclair ZX80

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	Ready-assembled Sinclair ZX80 Personal Computer s. Price includes ZX80 BASIC manual, excludes mains adaptor.	99.95	
	Mains Adaptor s 600 mA at 9 V DC nominal unregulated.	8.95	
	Memory Expansion Board s each one takes up to 3K bytes.	12.00	
	RAM Memory chips – standard 1K bytes capacity.	16.00	
	Sinclair ZX80 Manual s manual free with every ZX80 kit or ready-made computer.	5.00	
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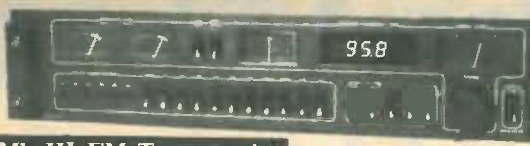
Complete Audio/Tuner Kits



Mk III FM Tuner series

Carriage for Mk III tuner £3 inc

The Mark III series FM tuner has been updated, and now includes a centre zero tuning meter as standard. The instruction manual has been meticulously revised, enabling easy assembly by constructors of various levels of experience - a preview copy may be purchased for £1.00.

Mark III A series 'Reference series' tuner modules ....£171.35 inc.
Mark III B series 'Hyperfi' modules, with switched IF BW, pilot cancel decoder ....£198.95 inc.

A matching synthesiser unit will be made available later this year, and can be retrofitted to either version. All versions include digital frequency readout/clock, VU deviation meters, 6 preset stations, 10 turn pot manual tuning, toroidal PSU, output level adjustment, 110/240v AC input. Full alignment service available.

Power Amplifier

Style and performance - with a real 'belt and braces' PSU design.

After a couple of preview comments, it seems that many of you are waiting to hear about the matching HMOSFET power amplifier for the Mk III tuner. Well, it's out at last - complete with twin toroidal PSUs for comfortable 80W RMS per channel, over 100W peak, but limited by thermal shutdown of the HMOS. 10W-100W log LED output peak indicator, DC offset protection and switch-on pause relay. AC or DC input coupling, direct or relay protected output terminals. The works.
Only one version of this item: Complete kit ....£178.25 inc. Carr. £5.

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More features and facilities, thanks to DC switching and control design

Previewing the most comprehensive audio preamplifier yet...... DC switching of 7 inputs, plus two tape in/outs. 2 low pass, 2 high pass active filters, genuine volume related loudness, 1dB channel matching, with DC volume, balance, bass and treble controls. Suitable for bus/remote control, tape dubbing, switched monitor etc. 80dB S/N+, THD -75dB or better. Pluggable PU equalization boards, tone control override. Price for complete unit about £149 ex VAT.

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91072- All switching of bands by a single pin to gnd. Varicap tuned, with LO output for synth. MW/LW version or MW/LW plus 1 or 2 SW bands
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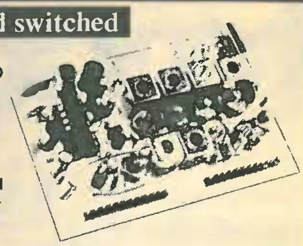

VHF Tunerheads

Europes largest stock range for broadcast and communications. Probably also the world's – details in the catalogues and PL. Specials are also supplied in the region 30-220MHz.

Pilot Cancel PLL Stereo decoders

Again, Europe's widest range of stereo decoders including pilot cancel PLL types. The pic shows the 944378 - pilot cancel including post decoder 26/38kHz filtering and muting preamp output

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Switched bandwidth FM IF strips

Broadcast FM IF strips for all occasions, including the new 911225 - with diode switched narrow filter option, ultra linear phase ceramic filters, 84dB S/N, and 0.04% THD (40kHz deviation). Plus usual things like AGC, AFC, dev. mute, level meter drive. £23.95 (supplied in screen can with 0.1 edge connection system) Also the 7230 hyperfi series - as the 911225, but with slope controlled AFC that operates in conjunction with signal level - and an extra IF amp stage for DXing.

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HA1137W	1.95	TDA1072	3.09	MC1330P	1.38
HA11225	2.47	TBA651	2.53	MC1350P	1.38
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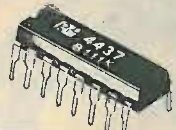
KB4420	1.95	TDA1220	1.61	KB4413	2.24
TBA120S	1.15	TDA1083	2.24	KB4417	2.53
KB4406	0.80	TDA1062	2.24	MC3357P	3.16



SL1610	1.84	SL1626	2.80
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SL1613	2.17	SL1641	2.17
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SL1625	2.50	MC1496	1.44

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PA101B Kit for 100W MOSFET PA less Heatsink £16.10. (£23 inc heatsink/bkt)

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Radio Control ICs

We have various RC ICs, including NE544 NE5044, and two new ones from OKI

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KB4446 - 4/5 ch. dig. prop FM RX IC. Suits KB4445 or RCME syst. £2.65.
KB4445/6 pair: £4.75. New 8 page data sheet 35p + SAE. More RC ICs in list

CMOS, LPSNTTL, TTL, MPU Listings in the new pricelist.

Most CMOS is available in low volume - also LPSN. Standard linears and TTL OK.

Things like ICM7216B, ICL8038, 8080A, 6800P, 2708, NE555,NE556, etc

Coming Soon..........

Contain yourselves, RF fans ! Not yet ready for a full launch until autumn, but previewed here:-

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A modular VLF to UHF SSB TX/RX system at last. With the correct first mixer, the basic PCB covers 10kHz to 1000MHz - using LO fed from ext. source (Our 2 IC Mullard synth for instance) and RF PA for TX OP. 0.2uV basic sensitivity in HF, Typ cost for HF synth SSB RX will be less than £200. Add an RF PA for full TRX for another £50. See one in our foyer, and marvel.

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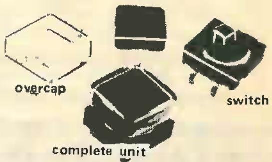
From the world's most widely used switch manufacturers - ALPS - come the biggest and best range of keyswitches, and data entry keyboard switches. The SCM81101 is shown here, with the KT5 2-part cap (with clear top, to enable easy fitting of your chosen legend. Other types are available with built in LED, 90° mounting etc.
SCM81101 : 17p, KT5 : 16p - or 29p/pair



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LCD DVM

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CM172: 13mm, 12hr, alarms,timer etc £14.32 each
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THE FOR-1004 A NEW WIDEBAND GRAPHICAL RECORDER

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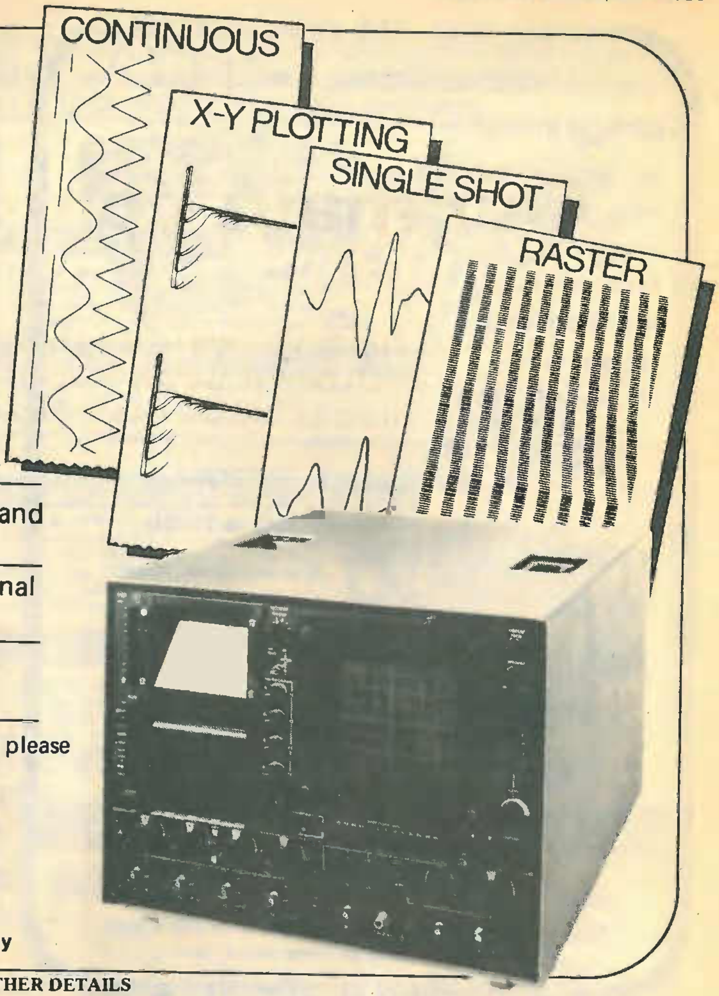

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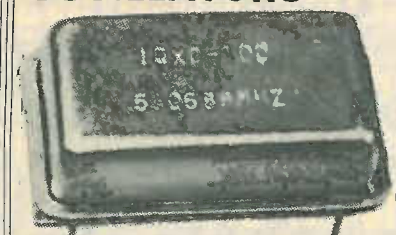

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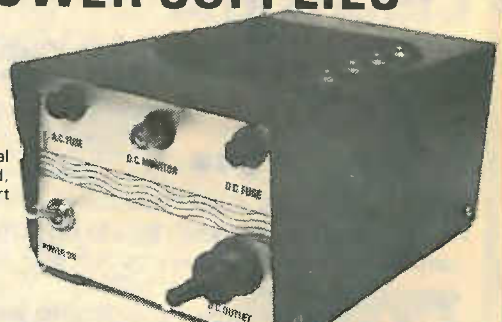

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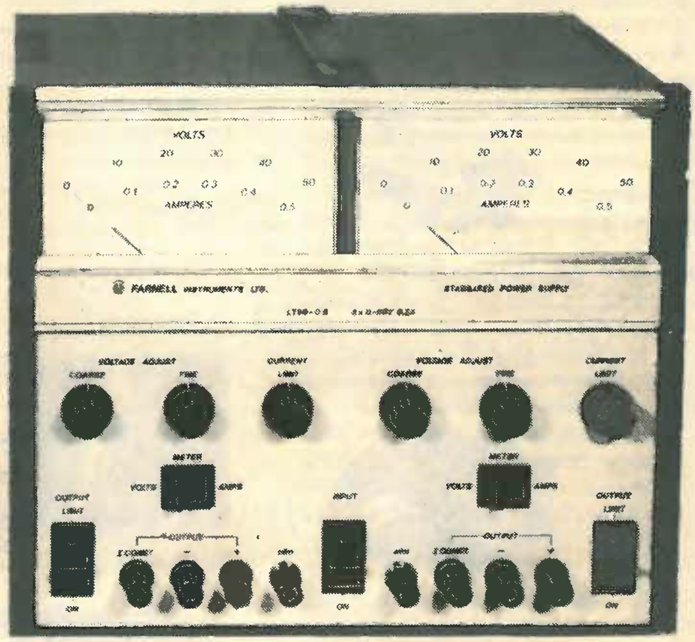

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wireless world

Current affairs

If the recent correspondence on displacement current has done nothing else it has drawn our attention to the pitfall that awaits us if we take a mental model as the whole truth about a phenomenon. Under examination is a model in the form of a set of equations and the extent to which it represents a reality. We see immediately that equations are like architects' drawings —precise, quantitative, stating relationships between quantitites but stopping somewhere short of a convincing description of an actual building. Like all mental models they lack body. The pitfall that awaits us is what A. N. Whitehead called "the fallacy of misplaced concreteness" — the mistake of attributing reality to what is no more than a construct of the mind. Because there is a word (or symbols) for it, and a corresponding mental picture, we assume it exists as a concrete entity.

As for displacement current, our readers may be forgiven if they feel confused by the various statements made about it by contributors. One author says the fact that the solution of Maxwell's equations is a propagating wave is a result that "is only obtained through the existence of displacement current" and issues the rallying cry "no radio waves without displacement current." A correspondent then asks (presumably thinking of propagation in outer space) "what is displaced in a vacuum?" to which there is no direct answer. And later another correspondent remarks "presumably no one is insisting that everyone must believe that there is any physical reality in a current which is said to flow in empty space when there is nothing to carry it . . . "

The puzzling question is: how are we justified in describing as an electric current something which has no physical reality as a motion of charge? Perhaps the answer is because displacement current exists in one respect anyway as a rational construct of the mind. We can consider this in the light of Kant's "mind contribution" to science — the notion that the mind supplies *a priori* concepts, independent of all experience (e.g. the truths of formal logic), to which we make our empirical observations conform. (See Kant's *Critique of Pure Reason.*)

When we consider any current intuitively, as a movement of charge in a conductor, its concreteness seems beyond question, especially when we are able to feel the heat or see the light or sparks it produces. But as soon as we try to define it quantitatively, in the way we do as a rate of flow of charge, Q/t, we move into an abstract world; for a rate is not an empirical fact but an *a priori* concept, independent of all experience, belonging to the realm of logic and mathematics. Current may flow but current strength doesn't: it *exists*, as a correspondent has pointed out. It is a pure concept, isolated from those realities of practical circuits in which, for example, you also need electrical potential and energy to push round the needle of your ammeter. Similar considerations apply to the rate of change of electric displacement, dD/dt. When a current is shown in the mathematical form of a term in an equation we are not seeing a full representation of a real current but merely a symbol or symbols for one of the properties of a current, its strength, defined as a rate.

Writers often refer to the "necessity" for displacement current in Maxwell's equations, as if this necessity were in itself a compelling proof of concrete existence. But, of course, necessity is not an empirical fact. As Hume showed in his famous analysis of cause and effect, "necessity is something that exists in the mind, not in objects . . . " (e.g. logical necessity).

To confuse *a priori* concepts such as necessity and rate with physical realities is to be caught in the fallacy of misplaced concreteness.

Designing with microprocessors

1 — Basic components of the microprocessor chip

by **D. Zissos and Laurelle Valen** Department of Computer Science, University of Calgary, Canada

This series of articles responds to the need "to demonstrate the respectability of the microprocessor as a down-to-earth, extremely useful, but entirely non-occult electronic component" (our March editorial) and is intended for electronics engineers who want to learn how this component can be used in the design of systems. The authors therefore use formal, step-by-step procedures in their explanations of how the device operates. This first article deals with the basic components of eight- and sixteen-bit microprocessor chips and the second will continue with their internal operation from the designer's point of view.

The starting point in the design of microprocessor-based systems, and indeed of all programmable systems, is a working knowledge of hardware, software and of their interaction. This view, although not generally accepted, is becoming more widespread. The roots of this attitude can be traced back to the early 1960s, when computers were becoming widely used. Because of the lack, at that time, of formalized hardware design procedures, much of the research effort was directed towards the development of machine-independent languages. This resulted in thick layers of software administered by bureaucrats being erected around the machines. In the 1970s formal methods for the design and implementation of hardware were developed[1], but largely were, and still are, being ignored by main-frame users. The evolution of m.s.i. and l.s.i. (medium and large scale integration) chips in general, and of microprocessors specifically, has made such an attitude progressively more difficult to sustain and justify, as the software/hardware barriers erected in the 1960s are not easily tolerated today. We shall therefore start the series by finding out how microprocessor chips work.

The newcomer to this area will be relieved to learn that basically there is no difference between various microprocessor chips, in spite of attempts to classify them into various categories, or, for example, into three generations. Their difference (as with cars) is one of refinement rather than substance. The reader should be aware that, in general, superior performance calls for expertise, and that one may experience fewer problems with a less sophisticated microprocessor chip than with the 'latest' and 'fastest.' As we shall see later, fast system response (if desired) with present-day knowledge, becomes a management rather than a technical problem.

The microprocessor chip

From the user's point of view, the microprocessor chip is a device which accepts **control data** and **problem data** and produces processed data, as shown in Fig. 1. The control data is commonly referred to as **op codes**, and the problem data as **operands***.

From the designer's point of view, the

*Operand is defined as the entity on which operations are performed.

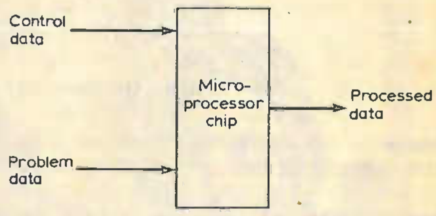


Fig. 1. The microprocessor from the user's point of view.

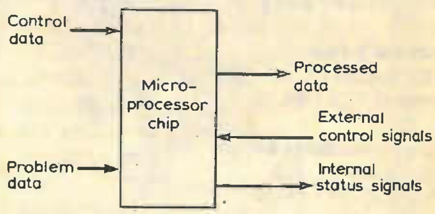


Fig. 2. The microprocessor from the designer's point of view.

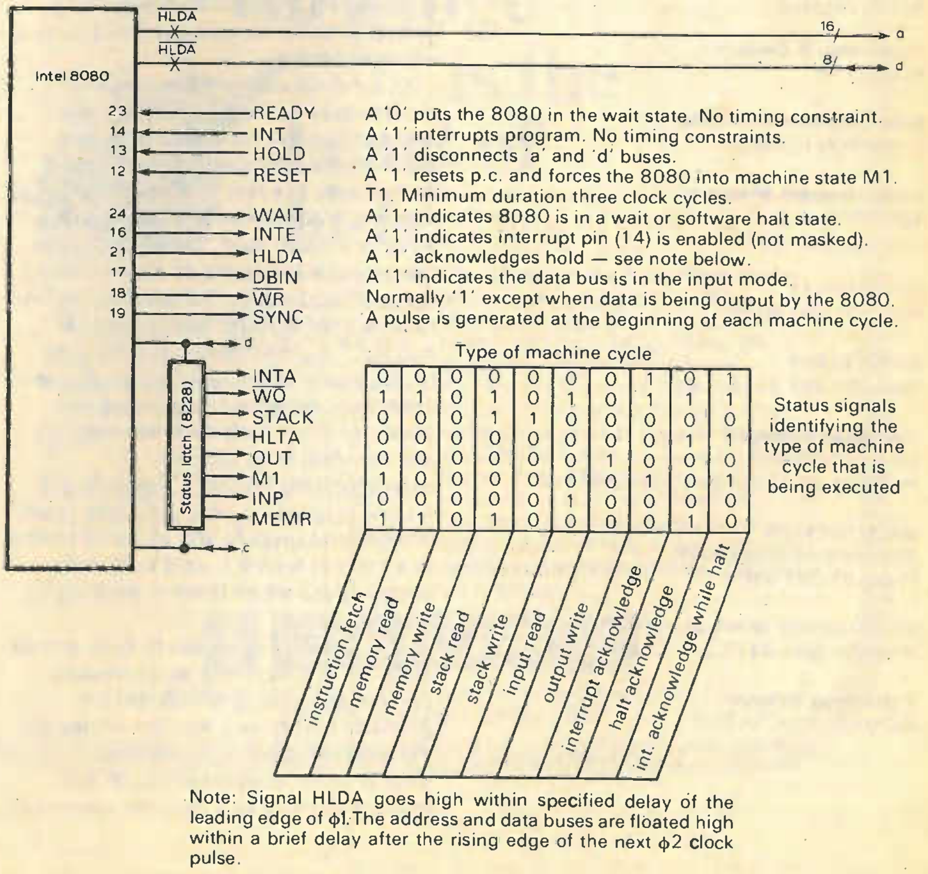


Fig. 3. Status and control signals of the Intel 8080 microprocessor chip.

microprocessor, in addition to performing arithmetic and logic operations on given data, can respond to external signals, the **control signals** in Fig. 2. Such signals are used to interrupt the execution of a program, to initiate a direct memory access cycle, and so on. In common with all digital circuits, microprocessor chips generate **status signals,** indicating their internal state. The wires carrying the control and status signals of a microprocessor chip are collectively referred to as **the control bus,** denoted by letter *c*. Similarly, the set of wires carrying the data in and out of a microprocessor chip is referred to as **the data bus** and is denoted by *d*. The **address bus** is the set of wires that carries address signals and is commonly denoted by *a*. Note that in the case of 16-bit machines, as we shall see later, the same set of wires carries the data and address signals on a time-sharing basis.

The status and control signals of the Intel 8080, Motorola 6800 and the Intel 8085 [2,3,4] are shown in Figures 3, 4 and 5, respectively.

In Fig. 6 we show the basic configuration for single-processor systems. The functions of the interface blocks are to monitor the status of signals of the microprocessor chip and of the corresponding peripheral, and to generate the correct sequence of command (control) signals that will allow them to communicate with each other.

The basic components of a typical microprocessor chip from the designer's point of view are

The accumulator(s) (acc.)
Addressing registers (r)
The arithmetic and logic unit (a.l.u.)
Condition flags
The instruction register (i.r.)
The program counter (p.c.)
The timing and control unit [5,6]

Their basic functions are as follows.

Accumulator (acc.). This is a register which is used to hold incoming and outgoing data, as well as the outcome of specified arithmetic and logic operations. Some microprocessor chips have more than one accumulator; for example, the Motorola 6800 has two accumulators, A and B.

Addressing registers (r). Any internal register that can be connected to the address bus will be referred to as an addressing register. Examples of addressing registers are: register r in Fig. 7, program counters (p.cs), stack pointers (s.ps), index registers (ixs) and so on.

Arithmetic and logic unit (a.l.u.). This is a logic circuit which performs various arithmetic and logic operations.

Condition flags. These are one-bit flip-flops whose set/reset states are determined by the result of the execution of certain instructions. They typically indicate if the outcome of an a.l.u. operation is negative, zero, or

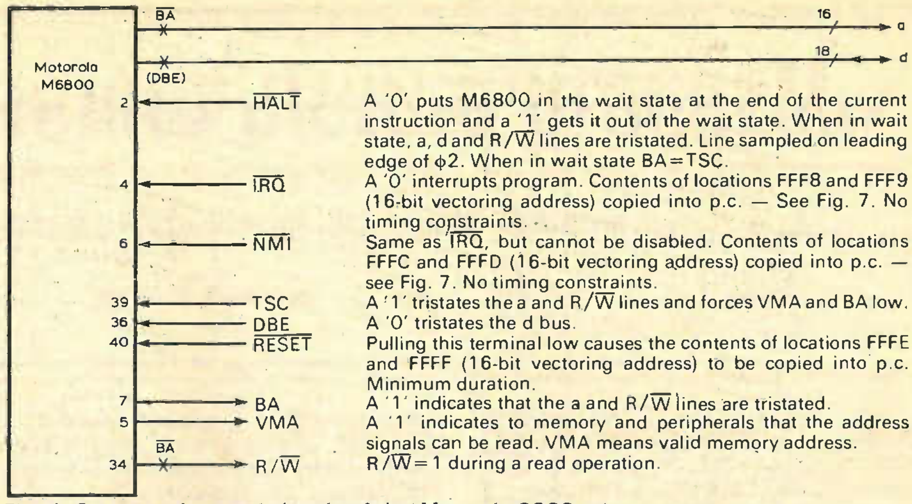
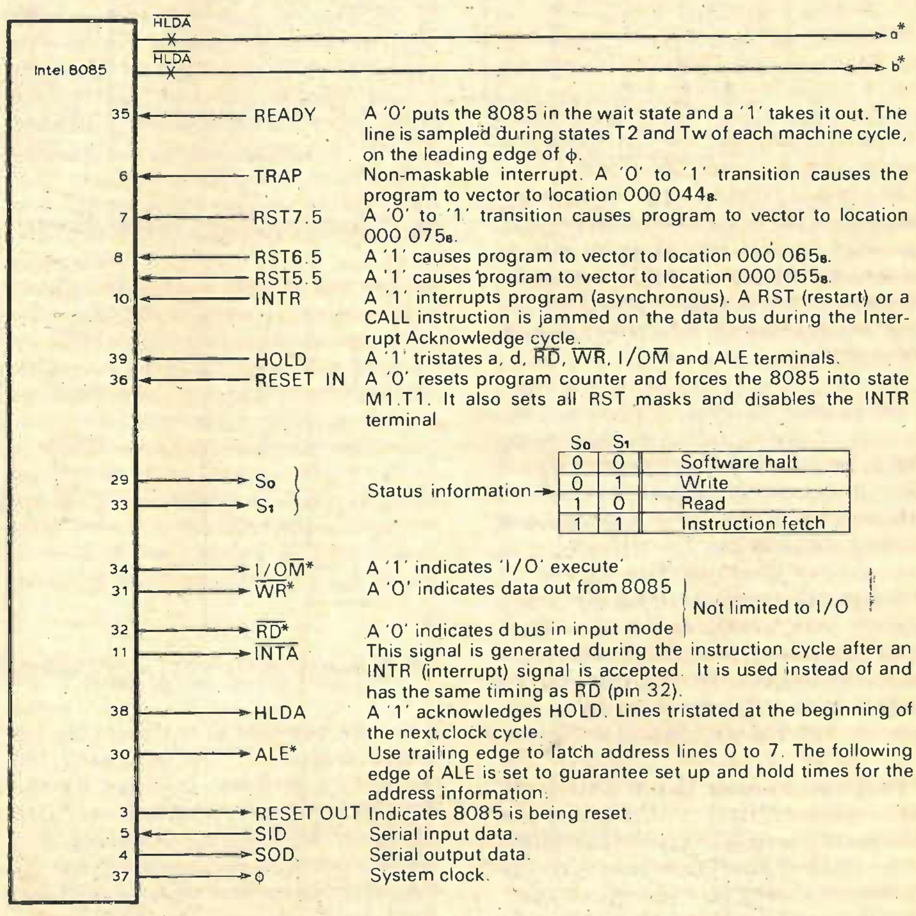


Fig. 4. Status and control signals of the Motorola 6800 microprocessor chip.



*Tristated during 'software halt'

Fig. 5. Status and control signals of the Intel 8085 microprocessor chip.

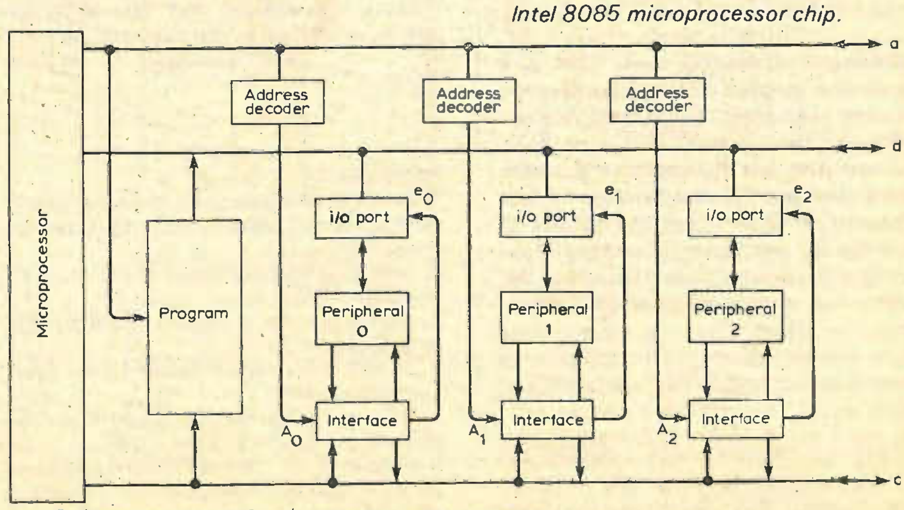


Fig. 6. Basic configuration for single-processor systems.

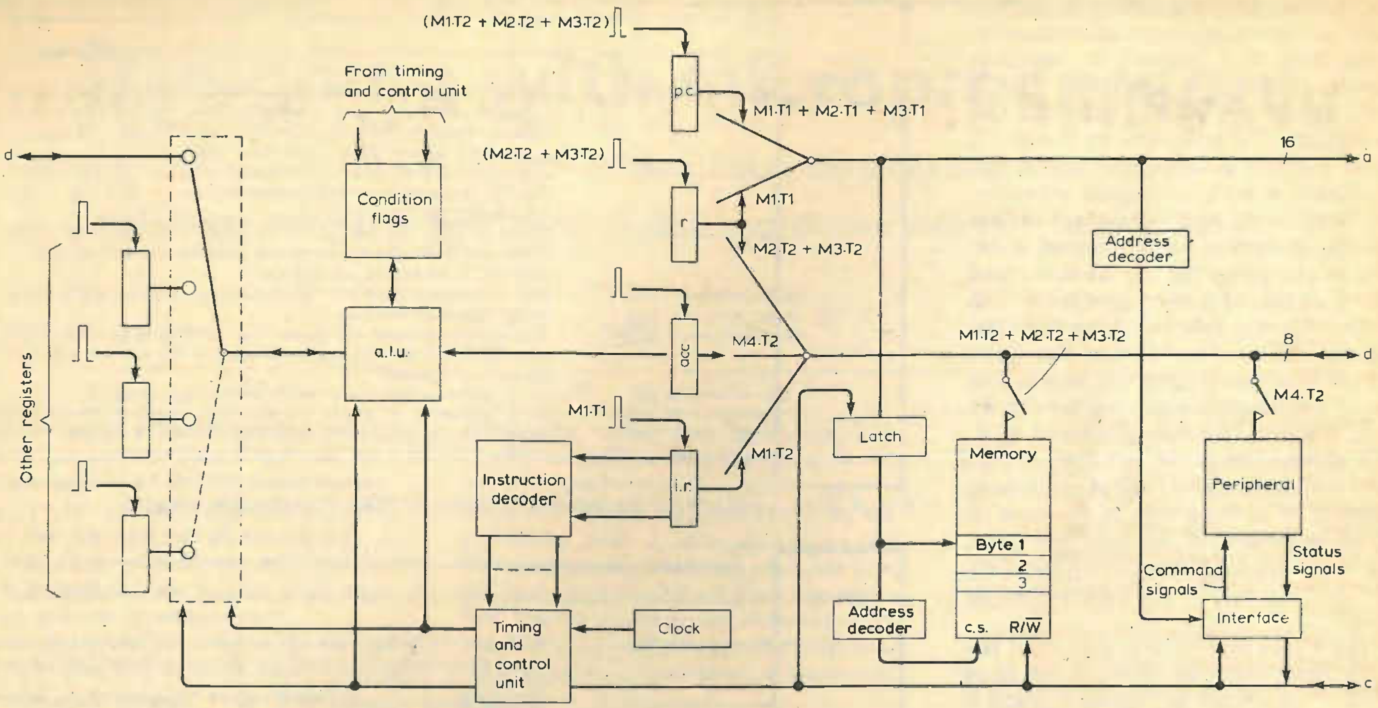


Fig. 7. Components and internal organization of an eight-bit microprocessor chip.

whether there is a carry after an 'add' operation and so on. They are mainly used to modify the sequence of program execution. Sometimes the condition flags are collectively referred to as **condition codes** or **status word.**

Instruction decoder. This is a combinational circuit used to decode the op code, held in the instruction register (i.r.), into a set of signals that can be interpreted directly by the timing and control unit. See Fig. 7.

Instruction register (i.r.). This is a register which receives the op code of each instruction in turn and holds it during execution. In our case the op code is loaded into the instruction register (i.r.) during state M1.T2 in Fig. 8.

Program counter (p.c.). This is an addressing register which holds the address of the next byte in the program to be fetched from memory, with the exception of such instructions as jump, branch and so on. It is connected to the address bus, *a*, during state T1 in a fetch cycle. See Fig. 7.

Timing and control unit. This is a sequential circuit which samples the decoded output of the instruction decoder and the external control signals, and specifies the appropriate machine cycles that are needed for the correct execution of the current instruction. It does so by generating control and timing signals which are routed to the appropriate components of the microprocessor chip. The machine cycles required to execute a three-byte (input/output) instruction are shown in Fig. 8.

Microprocessor chips contain no special circuits that do not exist in conventional digital computers. This raises the question of the necessity for special treatment. The answer is the connection problem imposed by the relatively small number of pins (typically 40) that are attached to a microprocessor chip containing the equivalent of several thousands of discrete logic components. This access problem is solved in practice by time-sharing the address and data pins, as will be described in the next article.

To be continued

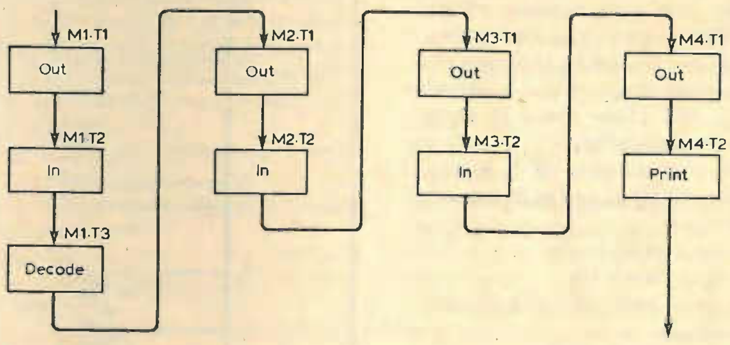


Fig. 8. Internal operation of a microprocessor chip.

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Scientific computer club

Following the publication of a two-microprocessor scientific computer design (April to September 1979 and January to February 1980) we have received a large number of requests for more information and details of clubs linked to this design. We are therefore pleased to note the formation of a computer users' club for the Adams machine, which we hope will stimulate interest in this design and encourage correspondence between readers.

To start the ball rolling a monthly newsletter, starting in May, will be circulated by Phillip Probetts to members for an annual subscription of £5.00 including postage. John Adams, the designer, will contribute a series of articles describing the computer in greater depth, and he will also help to answer members' queries. The early issues will contain short editorials and include programming information and examples, while later issues will reflect members' interests by publishing their programmes, letters and comments.

Feedback is important, so send subscriptions, suggestions, contributions and queries to Phillip Probetts, 50 Cromwell Road, Wimbledon, London, SW19, 8LZ, England.

Weather satellite picture processor

Visible and infra-red pictures from the TIROS-N series

by G. R. Kennedy

This signal processor produces real-time visible and infra-red weather pictures side-by-side and correctly exposed. Up to four satellites may be preset on the unit, which has been designed for high quality pictures from the 137MHz transmissions. For a description of a facsimile machine suitable for use with this processor, and for background information on weather satellite reception, readers should refer to previous articles by the author, listed in the references.

A prototype of the latest American polar orbiting weather satellites, TIROS-N (TIROS X1, 1978-96A), was launched on October 13, 1978. One of the main differences between the TIROS-N series and the ITOS (NOAA) predecessors is the improved picture definition. This is due to improved scanning radiometers and a faster scanning rate, 120 r.p.m. compared with 48 r.p.m. for the NOAA-1 to 5 series. Two channels of picture information are sent on the v.h.f. transmission and in normal use one channel is infra-red while the other is in the visible spectrum. The choice is made at ground control and later satellites will be capable of sending, on v.h.f., two of five available spectral range pictures from the S-band repertoire. Images received on one of the two frequencies used for the TIROS-N series, 137.50 and 137.62MHz, have a ground definition of 4km and have image-distortion correction so that the received pictures are flat, and do not suffer from "bottle distortion" as with earlier satellites. The receive antenna needs to be right-hand circularly polarized and the receiver must cope with a peak 2.4kHz deviation of ±17kHz. The TIROS-N series v.h.f. video format is shown in Fig. 1 and a block diagram of the signal processor is shown in Fig. 2.

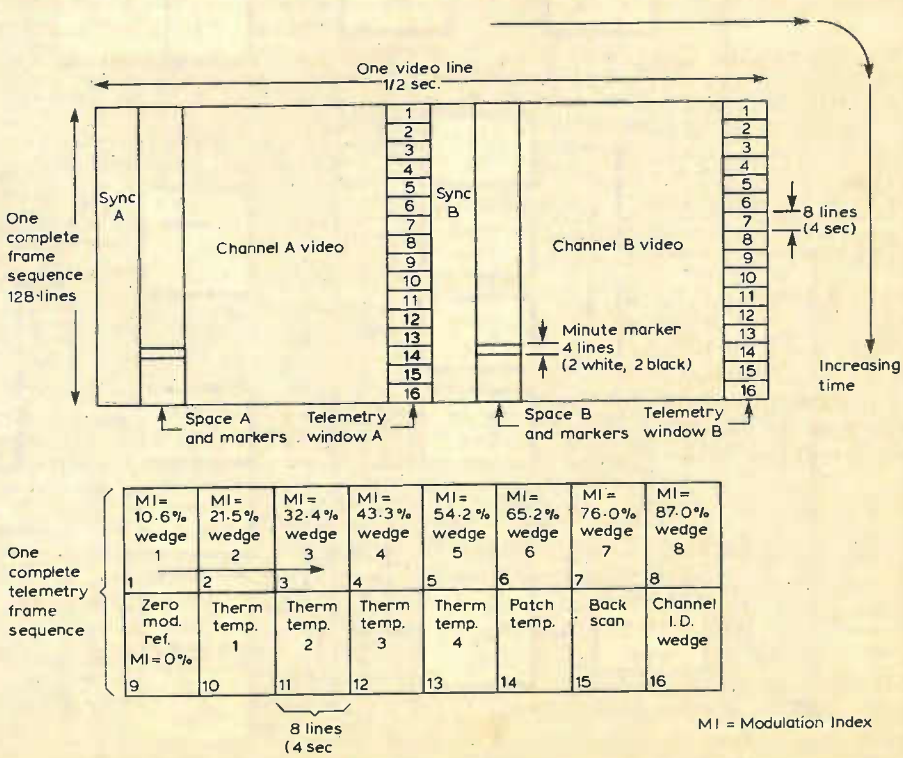
The clock channel produces various timing signals, locked to the satellite subcarrier signal, for use within the processor and externally for fax machine or oscilloscope synchronization. A phase-lock-loop is used, preceded by two limiter stages to render the clock circuits immune to signal amplitude variations. The p.l.l. output is buffered by a Schmitt trigger and divided to produce the timing and synchronizing signals.

A linear channel handles the video signal without stretching or cramping. It normally amplifies the visible-spectrum satellite channel which has a high dynamic range and is fairly constant in mean level throughout the year all within a reasonable range of geographical latitude. The linear channel comprises four parallel linear amplifiers, one selected at a time, and is used as a reference against which the third channel is adjusted. After inversion, the amplified signal is applied to an analogue switch common to both video channels.

A log.-channel is used to process the infra-red video signals. However, there are several problems in producing good pictures, such as the small f.m. subcarrier deviation for a large dynamic picture-content change. This is due to temperature variations, for example, the coldest cloud tops can be at −60°C and the warmest land at about 40°C[3]. If a coastline is to be depicted, which aids location of the weather system and is generally more interesting, only small differences of a few degrees can be expected. Because these changes are in the warm part of the infra-red range, advantage can be taken of the logarithmic amplifying process where the gain is maximum at low (i.e. warm) signal levels and reduces with an increase in amplitude. Therefore, the coastline can be enhanced and the cold cloud systems, with their large temperature variations, can be shown quite clearly. Two problems with this technique are the level at which log. amplification starts, and the changes in mean temperature with season and latitude. In this design a variable control with a dial is used which allows resetting for different orbits. The approximate mean picture level for the i.r. channel is roughly matched to that of the sunny portion of the visible channel. The sunny part of the visible channel is used because it is normal to see the daylight terminator on a polar orbiter, especially in winter. Also, interest is heightened by producing the i.r. and visible pictures side-by-side and observing, from the i.r. scene, the weather in the darkened visible section.

After the input level potentiometer, a switch allows either direct log. amplification of the signal, or expansion

Fig. 1. Video format for the TIROS-N series.



before amplification. For TIROS X1, expansion is not essential, but the facility is available for other or later satellites. The logging stage is followed by four separately switched amplifiers in parallel as in the visible channel. The output of the selected amplifier is fed to the common analogue-switch and, because the log. amplifier inverts the signal, both scenes have the same sense.

The analogue-switch multiplexes a number of analogue signals together in a serial mode. With timing from the clock channel, the switch adds the linear and log. signals in time sequence and produces a picture scan-line of each, correctly processed and in sync. with the transmitted satellite signal. This is followed by a linear output amplifier which produces a signal suitable for a fax machine or an oscilloscope.

Circuit description

The clock channel is shown in Fig. 3. The 2.4kHz demodulated subcarrier signal from the receiver output, which is amplitude modulated with the picture information, is amplified by IC_1. Signals are a.c. coupled in and out of the amplifier so that the mean 2.4kHz signal is amplified. This stage is not necessary for printing TIROS-X1 transmissions, but it is required with some Russian Meteor signals which may be required to produce weather pictures. Some of these signals, which also use the 2.4kHz subcarrier, have almost 100% amplitude modulation. The amplifier stage at the beginning of the clock chain ensures that the final pictures stay in lock by providing, under all usable signal levels, sufficient 2.4kHz to lock the following p.l.l. The input amplifier is followed by two limiter stages around Tr_1 and Tr_2, which comprise ladder-feedback tuned amplifiers with a.c. coupled back-to-back diodes at their inputs. Only the forward voltage drop of the diodes is amplified and the working point is around the zero-crossing of the subcarrier signal. In this way, amplitude modulation is ignored and the 2.4kHz is selectively amplified. The output of the second limiter feeds the p.l.l. whose v.c.o. frequency is set to 2.4kHz by R_{18}, R_{131} and C_{18}. The loop bandwidth can be selected by S_2, and the values of C_{21} and C_{22} give a good compromise for weak and strong signals. For a strong signal, a wide bandwidth gives solid lock and sharp pictures. A narrow bandwidth may be necessary in the presence of noise, but if noise impulses exceed the tracking range of the loop, a cumulative phase error can occur along the picture line to give locked and noisy pictures with vertical ripples at the right-hand side, for a left to right picture. The loop can be unlocked by S_1, which is best effected using a toggle switch biassed to the locked-loop condition. The rate of locking is set by R_{132} and by this means, the edge of the picture and the order of the i.r. and visible channels across the final image can be set. Automatic phasing can be added by replacing S_1 with a pair of transistors fed by two frequency-selective amplifiers tuned to 1040Hz and 832Hz. Seven cycles of either frequency preceed each of the channels. Normally for TIROS-X1, the i.r. channel is preceded by the higher frequency with a 50% duty cycle, and the visible by the lower frequency with a 60% duty cycle.

The 2.4kHz output of the p.l.l. is a.c. coupled to Schmitt trigger IC_{13} which squares the signal at t.t.l. level. This is buffered by Tr_3, Tr_4 and Tr_5 to an external socket for fax and oscilloscope use, and also fed to a series of dividers. IC_4 divides by 12 to give 200Hz, part of IC_5 divides by 5 to give 40Hz and IC_6 divides by 10 to give 4Hz with an equal mark-to-space ratio.

The 4Hz is distributed to Schmitt trigger IC_3 which buffers the signal to an external socket, to part of IC_5 which divides by 2 and provides a t.t.l. 2Hz sync. signal at an output socket, and also to flip-flop IC_7 where it is again divided by two with an equal mark-to-space ratio to provide a TIROS strobe signal. The division state can be inverted by reset-switch S_8 which sets the flip-flop preset to low. The strobe signal is used for printing just the i.r. or visible satellite channel. When using a facsimile recorder, printing only one image gives a print twice the size. The drum speed is 240 instead of 120 r.p.m. for the pair, and the strobe pulse, which is high for exactly half of the satellite video

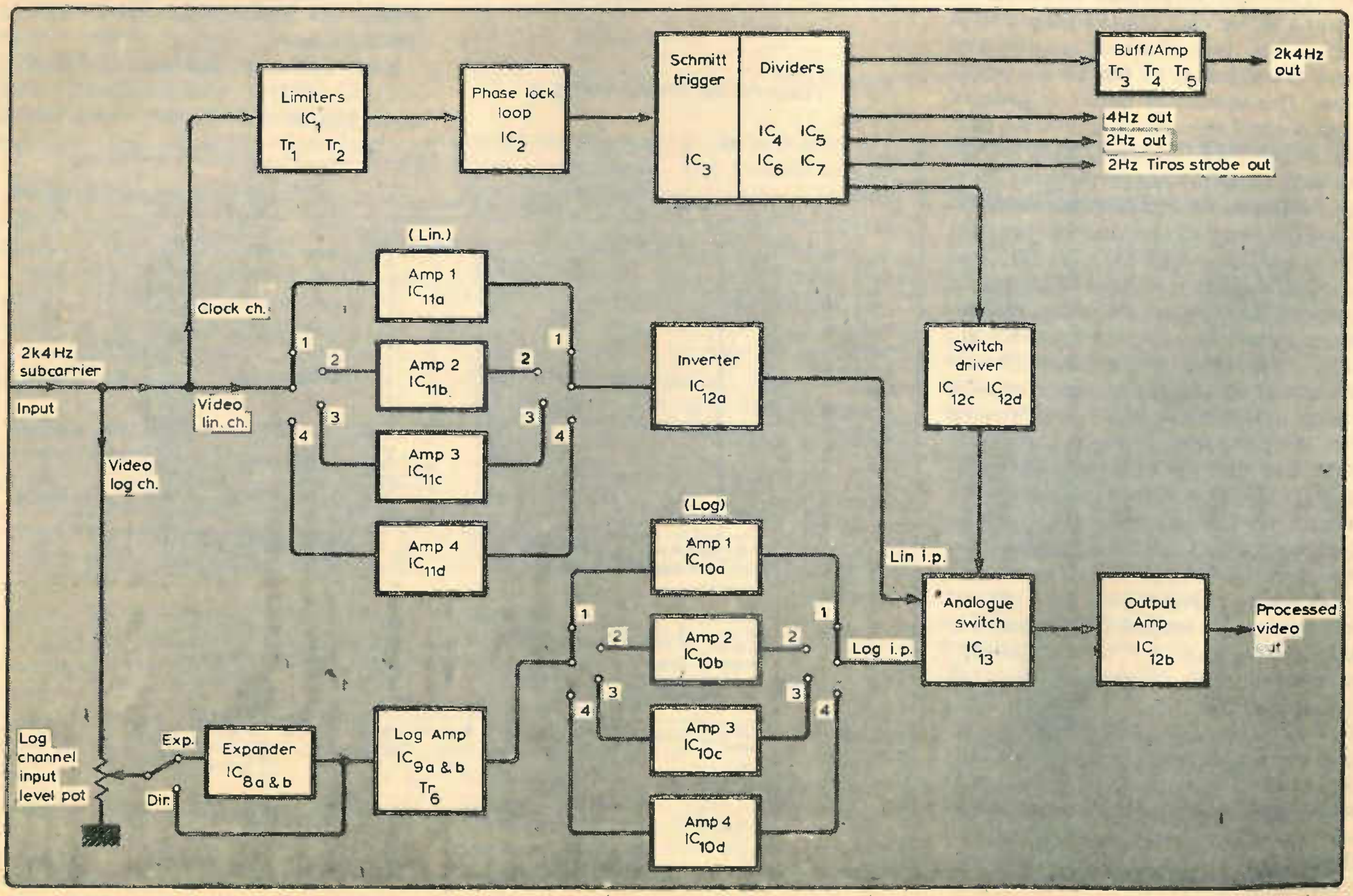


Fig. 2. Block diagram of the facsimile-machine driver.

line, keys the fax light-souce off for the unwanted half line. By switching S_8, the channel being printed can be changed. This is a useful feature in winter when the southerly portion of a northern hemisphere pass can be printed in visible, and the northern portion, which may be in darkness, printed in i.r. without losing picture lock. The strobe pulse is taken from the flip-flop Q output, and the $\overline{Q}$ output passes via S_3 to a pair of op-amps in IC_{12}. These amplifiers control the analogue switch, and drive l.e.d. indicators which show log. or lin. status. With S_3 in the TIROS position, IC_{12} is driven at 2Hz and, because no feedback resistor is used, the output latches from −12 to +12V at 2Hz. Op-amp IC_{12c} operates in the same way but at 180° out of phase, and this pair of outputs switch the lin. and log. channels on and off once per video line. With S_3 in the normal position, S_7 (log./lin.) sets the Q and $\overline{Q}$ lines of the analogue switch by selecting +12 or −12V.

The linear channel and analogue switch are shown in Fig. 4. The 2.4kHz video signal is taken via S_6 to one op-amp in IC_{11}. Each amplifier has a gain control and a level setting potentiometer which can be adjusted for a given satellite without affecting the other amplifiers. If four satellites are not required, optimisation for a particular satellite can be tried without losing the previous settings. The output of the selected amplifier goes to IC_{12a}, a unity gain inverter, which feeds part of analogue switch IC_{13}. The circuit has been designed so that only positive going signals are accepted. Both video channels pass through an inverted L arrangement of two analogue switches where the series arm has a 47kΩ resistor in series and a further 56kΩ resistor to the next stage. At the junction of these resistors the shunt switch connects directly to ground. By keeping the output impedance high, turning on the shunt switch effectively stops any signal leakage. The on resistance varies with load conditions and supply rails, in this circuit it is around 600Ω. Again, raising the path impedance makes the switch resistance insignificant compared with the two resistors. also, when the shunt switch is on, its resistance is minute compared with the series-switch off resistance and board leakage, so the overall signal leakage is very low. The output of IC_{12d} controls the series switch, and IC_{12c} controls the shunt switch. The output of each part of the dual switch circuit is summed by IC_{12b} whose gain is selected by R_{73}. A typical value for this resistor is 680kΩ which gives a gain of 12 and is suitable for the facsimile machine published from Dec. 1976 to July 1977.

The logarithmic channel is shown in Fig. 5. The input video signal is passed through a potentiometer to set the amplitude and the scaled signal then passes to an expander[4] with resistors altered to suit standard values. With S_4 in position 1, the expander is bypassed

Components list

Resistors ¼W

31	47
30, 33	100
19, 20	180 ½W
34, 88, 89	220
15, 16	330
23, 24, 32	470
12, 18, 22, 27, 45, 112	1k
7, 26, 107	1k5
21, 35, 113	2k2
36, 93, 94	2k7
67, 69, 108	3k3
25, 28, 37, 38, 39, 40, 55, 57, 59, 61, 95, 124, 126, 128, 130	4k7
96	6k8
41, 44, 97	8k2
1, 2, 4, 5, 8, 9, 13, 14, 62, 63, 65, 74, 92, 98, 104, 106, 110	10k
99	12k
10, 29, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 100, 111, 115, 116, 117, 118, 119, 120, 121, 122, 123, 125, 127, 129	15k
42, 43, 86, 87, 90, 91, 101, 109	22k
84, 85, 102	27k
82, 83, 103	33k
17, 66, 68, 81	47k
70, 71, 80	56k
79	68k
77, 78	82k
3, 72, 114	100k
6	390k
11	470k
73	680k

Capacitors 20%

1, 3, 8, 9, 14	47n
2	50n
4, 10	470p
5, 6, 7, 11, 12, 13	1n8
16	1n
17, 18, 27, 30, 33	22n
19, 20	25μ, 10V
21, 35	100n
22, 34	2.2μ, Mylar
23	47p
24	220μ, 6.3V
25	15n
26, 32	100μ, 16V
28	47μ, 6.3V
29	33n
31	2200μ, 6.3V
36	10n
37	680p
38	330p

Semiconductors

IC_1	741
IC_2	565
IC_3	7413
IC_4	7492
$IC_{5,6}$	7490
IC_7	7474
$IC_{8,9}$	747
$IC_{10,11,12}$	348
IC_{13}	4016
IC_{14}	LM309K
$Tr_{1,2,3,4,5}$	2N3704
Tr_6	2N2223A
$D_{1,2,3,4}$	OA47
$D_{5,6}$	5.6V 400mW Zener
$D_{8,9}$	red l.e.d.
$D_{7,10,11,12,13}$	1N914

Variable resistors (see text)

R_{131}	5k
R_{133}	10k, 10 turn
$R_{134,135}$	1k
R_{136}	500, 10 turn
$R_{137,139,141,143,145,147,149,151}$	10k
$R_{138,140,142,144,146,148,150,152}$	100k
R_{132}	1M

and a resistor is placed in the op-amp feedback paths to prevent spurious oscillation. The video signal is then a.c. coupled to a rectifier. The logarithmic amplifier[5], which comprises IC_{9ab} and Tr_6, generates a logarithmic output voltage from a linear input current. Transistor Tr_{6a} is the non-linear feedback element for IC_{19a} whose output current is fed around R_{111} and Tr_6 to the summing input. Therefore, the loop current is directly proportional to the input voltage at R_{110}. IC_{9b} and Tr_{6b} form a constant current circuit where the current through R_{114} is equalled by the feedback current through the collector of Tr_{6b}. Therefore, the emitter-base voltage of Tr_{6b} is constant and, with the base of Tr_{6a} grounded, the base of Tr_{6b} must rise or fall by a voltage logarithmically related to the input voltage at R_{110}. Due to the temperature dependence of the circuit[5], R_{112} should be 1kΩ and have a positive temperature coefficient of +0.3%/degC. For normal room conditions a standard high stability resistor is adequate. Resistor R_{136} sets the offset voltage for IC_{9a} and provides some control over the lower threshold at which logging starts. Diode D_{12} prevents damage to the dual transistor if the +12V rail momentarily goes negative at switch-on. Capacitors C_{37} and C_{38} prevent the op-amps from oscillating, and C_{36} decouples the supply.

The logarithmically amplified and inverted signal is switched by S_5 to one of the linear amplifiers in IC_{10}, and the selected signal is fed directly to IC_{13} which switches in the same way as the linear channel.

Construction

The linear and log. channels should be separated to avoid crosstalk and to enable adjustments to be made without confusion. The gain controls, which are seldom altered after their initial adjustment, can be ordinary carbon presets mounted on the circuit board. The level controls, which are often adjusted, should be 10 or 15 turn

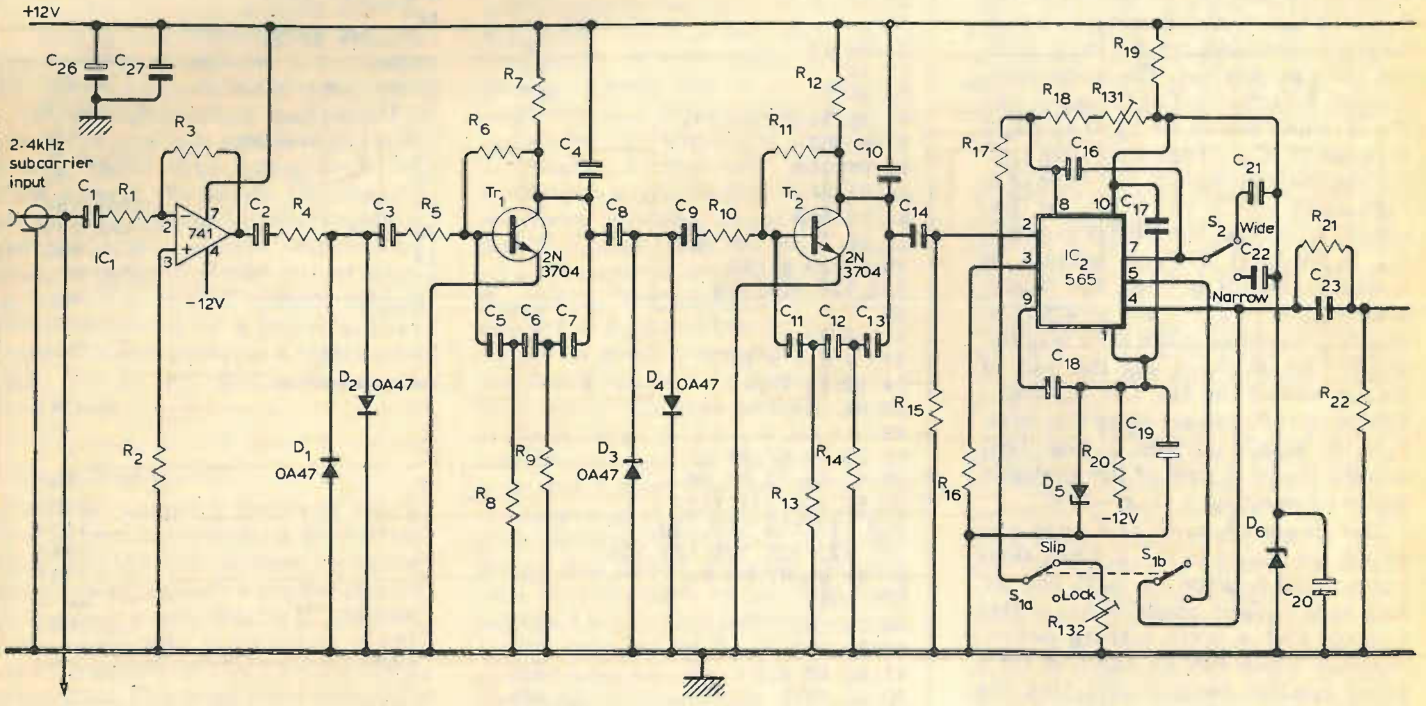
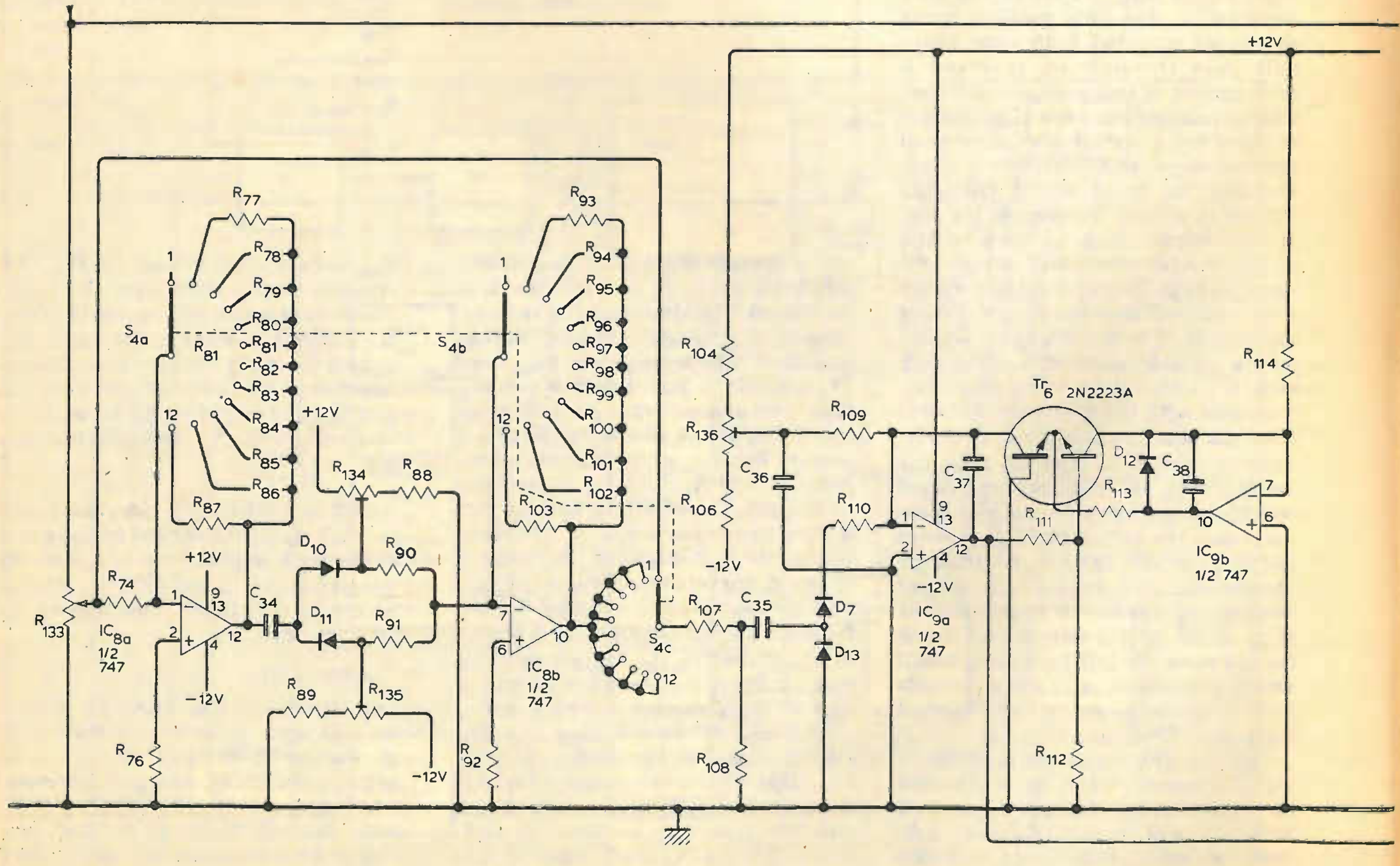


Fig. 3. (top) Clock channel.

Fig. 5. (bottom left) Logarithmic channel.



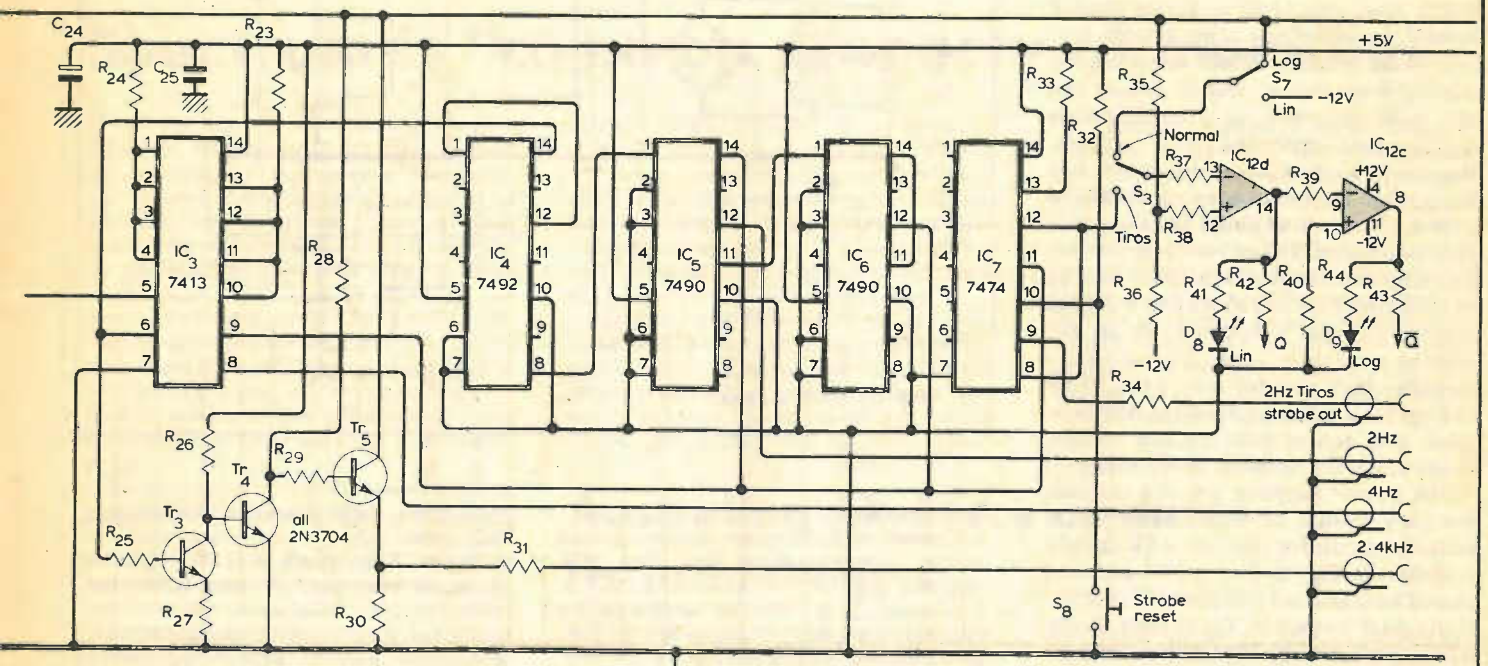
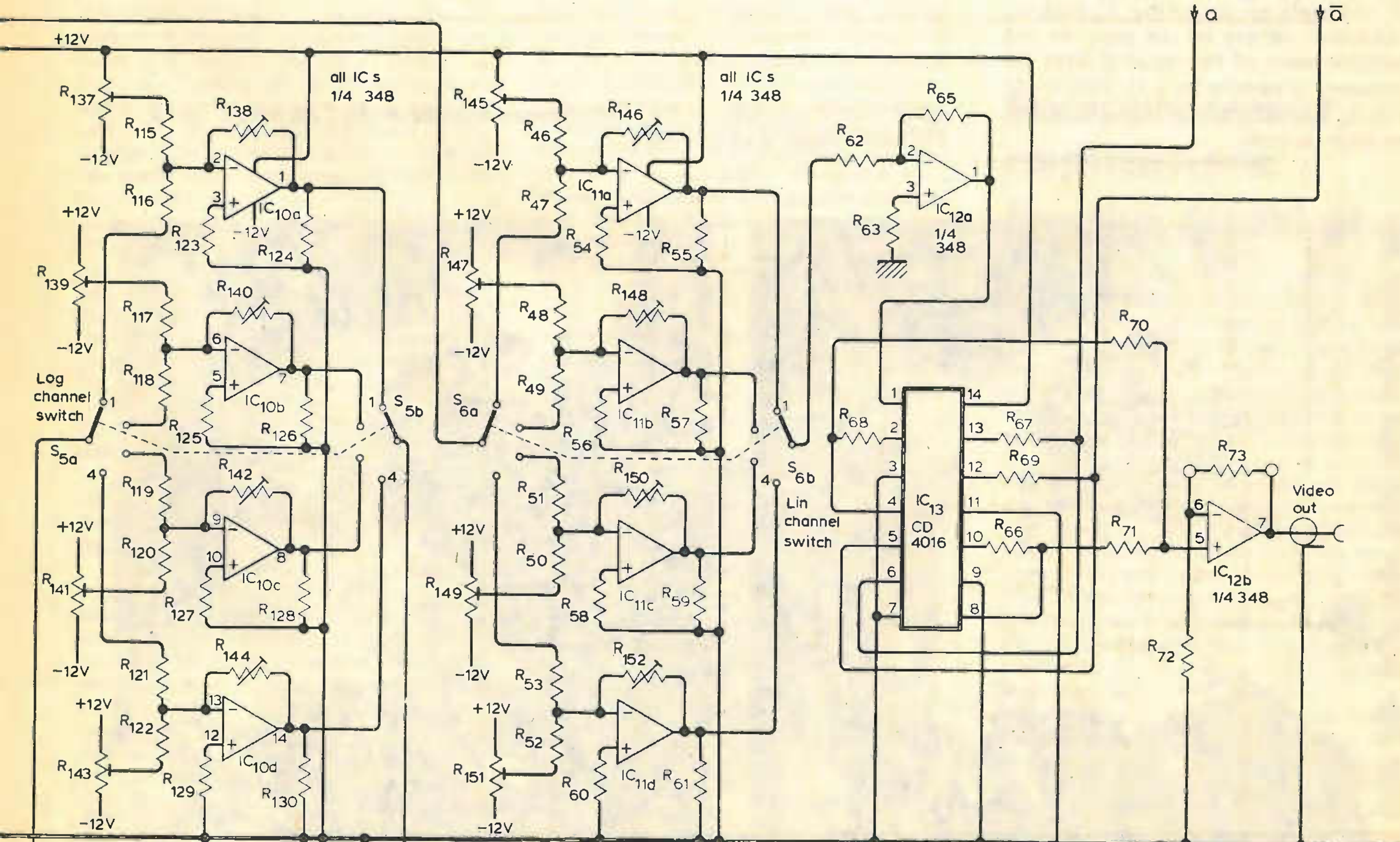


Fig. 4. (bottom right) Linear channel.



cermet types and have screwdriver access through the instrument case. If the processor is to be used with a drum fax in a darkroom, it is worth building the instrument either inside the fax machine, or in a shallow case underneath. Also, any l.e.ds or lamps should be red if bromide type paper is used. It is helpful to use large white lettering for dim-light operation, and to mount the slip/lock switch S_1 at a comfortable position away from the other controls. R_{132} can be a screwdriver slot preset, but R_{133} must be noise-free, smooth to operate, well positioned for easy adjustment and fitted with a turns-counting dial if high quality prints are to be obtained. For darkroom use, a digital mechanical dial is better than an engraved analogue type. The output-amplifier gain resistor may need to be changed if a different readout device is used, and solder pins on the circuit board make the removal of R_{73} easier.

The power supplies are not critical, but they should be well smoothed. A suitable circuit for the ½A +5V supply is shown in Fig. 6. The ±12V supplies should be stabilized and rated at 100mA. If the dual transistor Tr_6 cannot easily be obtained, two 2N3704 devices can be epoxy cemented together.

To ensure that the circuits, particularly the log. amplifier, are temperature stable, the unit can be permanently on.

After satellite acquisition, slip S_1 to establish the picture edge position on the fax or oscilloscope, and select either the side-by-side order of the visible and i.r. channels or, by using S_3 and S_7, select one picture or the pair. At the extreme ends of the pass it may be necessary to narrow the p.l.l. bandwidth with S_2, but normally this can be left in the wide position.

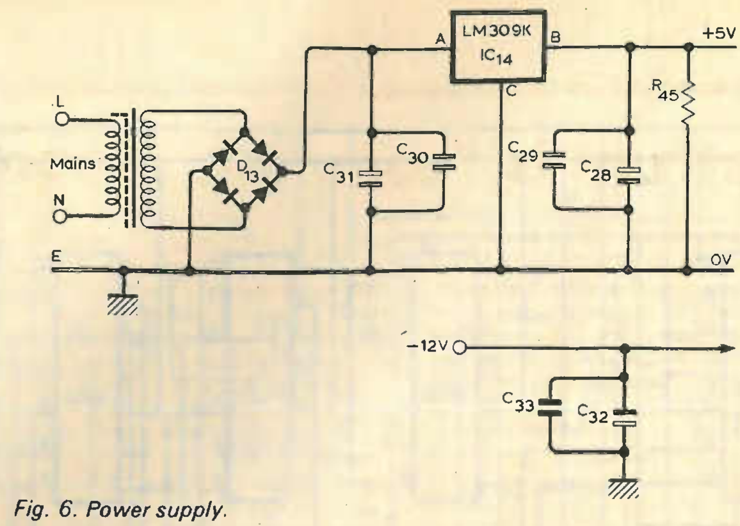


Fig. 6. Power supply.

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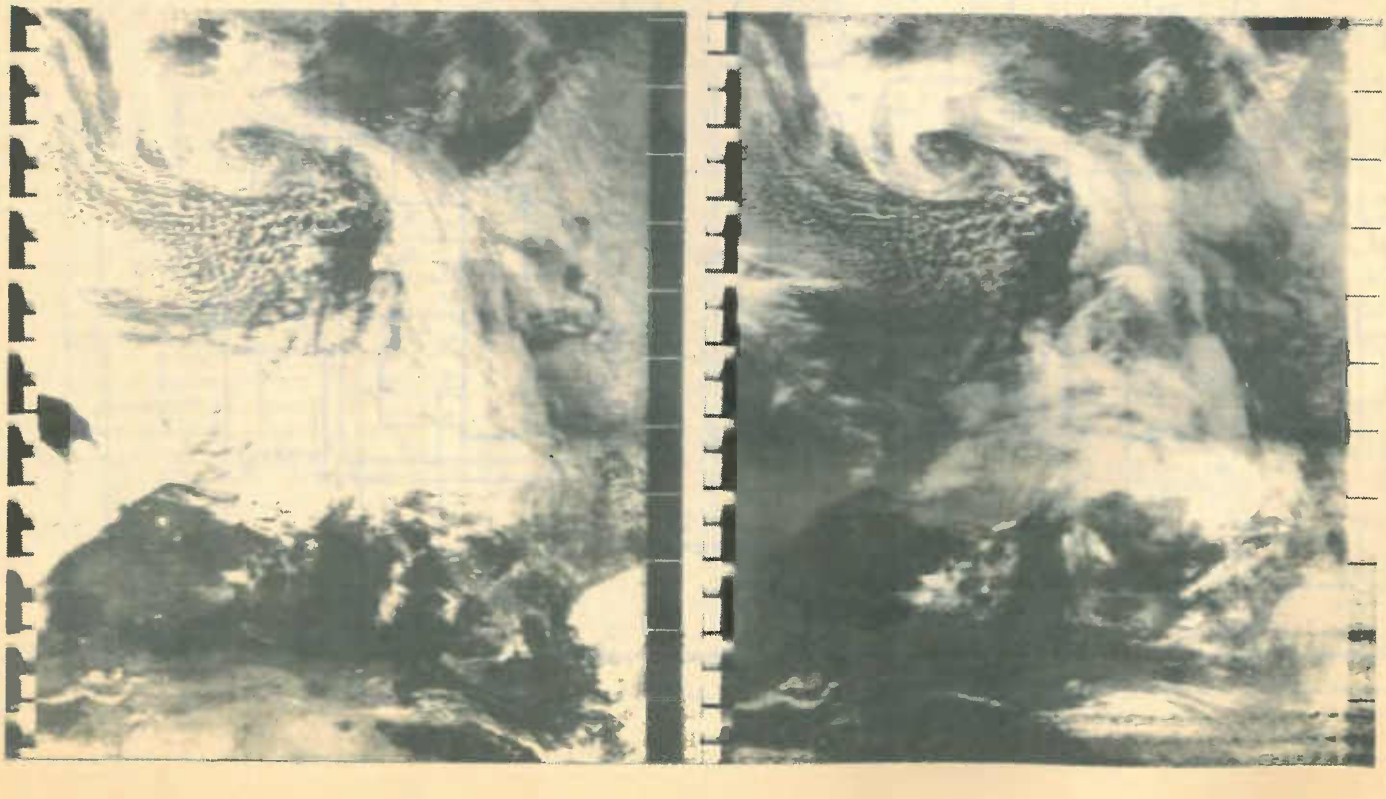
2. Kennedy, G. R. "Weather satelite picture facsimile machine," *Wireless World*, Dec. 1976, Jan., Feb., March and July 1977.
3. Anderson, R. K. et al "Application of meteorological satellite data in analysis and forecasting," ESSA Technical Report NESC 51, March 1974, National Oceanic and Atmospheric Administration, Washington, D.C. 20233, USA.
4. Baylis, P. E., Brush, R. J. H. "Contrast expansion processor," *Wireless World*, Dec. 1973.
5. Dobkin, R. C. "Logarithmic Converters," application note 30, Linear Applications volume 1, third edition, 1973, National Semiconductor Corporation, Santa Clara, California 95051, USA.

Fig. 7. Satellite pictures of the Mediterranean received on the 11th March, 1979. The visible image is on the left.



NEWS OF THE MONTH

Spectrum is "common property of mankind"

The electromagnetic spectrum and the geostationary orbit for satellites, both of which are natural resources, should be more equitably shared as the common property of mankind. This is one of the conclusions of the final report of the International Commission for the Study of Communication Problems which was recently presented to the director-general of UNESCO. The 16-member commission has welcomed the decisions taken at WARC 79 to convene a series of conferences over the next few years on specific aspects of the utilization of these resources (February issue p. 46, March issue p. 72).

The report deals comprehensively with the right to receive, seek and impart information as a fundamental human right, and its main message is the need for a greater democratization of communications (as discussed in our December 1979 leader). It takes the view that fundamental communication problems transcend mere media questions and recommends that communication "be no longer regarded merely as an incidental service and its development left to chance". In setting up new systems "preference should be given to non-commercial forms of mass communication" and, while obviously the media need their revenues, "ways and means should be considered to reduce the negative effects that the influence of market and commercial considerations have in the organization and content of national and international communication flows". The report points out that "the freedom of the citizen to have access to communication, both as recipient and contributor, is not the same as the freedom of an investor to derive profit from the media while remaining indifferent to quality and content."

On broadcasting, the "development of comprehensive national radio networks, capable of reaching remote areas, should take priority over the development of television..." and "national capacity for producing broadcast material is necessary to obviate dependence on external sources..." For communities in developing countries "local radio, low-cost, small-format television and radio systems and other appropriate technologies would facilitate production of programmes relevant to community development efforts, stimulate participation and provide opportunity for diversified expression".

Tariffs for telecommunications, the report says, "are one of the main obstacles to a free and balanced flow of information. This situation must be corrected, especially in the case of developing countries, through a variety of national and international initiatives. Governments should in particular examine the policies and practices of their post and telegraph authorities. Profits or revenues should not be the primary aim of such agencies. They are instruments for policy-making and planned development in the field of information and culture... International action is also necessary to alter telecommunication tariffs that militate heavily against small and peripheral users... UNESCO might, in co-operation with ITU, also sponsor an overall study of international telecommunication services by means of satellite transmission in collaboration with Intelsat, Intersputnik and user country representatives to make proposals for international and regional co-ordination of geostationary satellite development."

The new technologies coming into communication have both great potential and great danger, says the report. Countries should evaluate their social implications and should promote "participation and discussion of social priorities in the acquisition or extension" of these new technologies. Decisions on "the orientation given to research and development should come under closer public scrutiny". Concentration of communications technology in a few developed countries and multi-national corporations "has led to virtual monoply situations in this field. To counteract these tendencies national and international measures are required, among them reform of existing patent laws and conventions, appropriate legislation and international agreements."

Australian Air Force up-dates its technology

William Scholes, a contact in Sydney, reports that the first trials of laser-guided bombs (LGBs) in Australia, using a Mirage fighter of the RAAF, were held recently at the Woomera Rocket range in South Australia.

The trials, conducted by Texas Instruments (USA) in collaboration with the Defence Science Research Centre and the Aircraft Research and Development Unit, are a direct result of Prime Minister Fraser's response to the American call for "increased surveillance of the Indian Ocean area by America's allies," although why better killing devices are needed to improve surveillance has not been explained. LGBs use semi-active homing devices in that they contain passive detectors which collect and process laser energy which has been reflected or scattered from a target, previously illuminated by a separate laser source. The angular displacement between the bomb's central axis and the direction of the laser radiation is measured by the LGB's guidance system and correction signals are sent by means of a servo system during flight, causing deflection of the bomb's strap-on wings. The flight path is corrected accordingly and the bomb steered towards its target.

During the Vietnam conflict, both the USAF and US Navy employed LGBs as well as electro-optical guided bombs. These bombs used a similar form of visual target identification but were equipped with a different guidance system which offered greater flexibility than the LGB method.

Engineers checking operation of the LGB guidance head using a flight line test kit.

Microprocessor applications for the disabled

The Bias '80 exhibition, to be held in conjunction with Microelletronica in Milan from June 4th to 8th 1980, includes a competition for projects aimed at helping handicapped persons. Total prize money is $7000 in addition to prizes in the form of systems, instruments and other items of electronic equipment. Engineers and designers interested in competing should bear in mind that the projects should be useful as aids to disabled persons such as those who are blind, deaf mutes and persons with difficulties in communication, expression and/or movement. Consideration will also be given to other unconventional applications of microprocessors not strictly tied to the subject of the competition provided they are of real interest in the bioengineering or medical electronics field.

Special prizes will be presented in this section. Projects should be presented with block diagrams and circuits, hardware complement, software, cost, weight and dimensions. Presentation of a prototype is desirable but not essential. Entries should reach the competition secretariat no later than May 20th 1980. Phone or write to Studio Barbieri, Viale Premuda 2, 20129 Milano, Italy, tel. 796 096 421 635

"Challenge of the Chip" exhibition

There can't be many western industrialized persons to whom the "chip" is a total mystery, but the few to whom it is would do themselves a favour if they were to go along to the Science Musuem's "Challenge of the Chip" exhibition, which opened in late February and continues until sometime in December 1980.

In spite of a variety of adjectives used to describe the exhibition, and a spate of journal reports which did little more than précis the official booklet, it is one of the most effective displays the museum has staged; as a history of the development of modern microelectronics it is highly successful, dodging about from basic materials and fabrication methods to applications in a surprisingly unstrictured fashion. Some of the conceptual illustrations are particularly sharp, such as, in an early exhibit, where the seemingly paradoxical nature of semiconducting materials is outlined, i.e. that heating causes an improvement in conduction in semiconductors, the diametrically opposite effect to that observed in a conventional conductor.

The major area of concentration is of course that of computing in its many forms, from sophisticated medical equipment and military radar applications to the multitude of toys and games based on the chip.

All the exhibits do not flash lights or count or converse with human beings, although those that do have been the best occupied. The Dept. of Industry's exhibit, a small hall set aside for posters of MAP — initials not explained — was totally empty for over 20 minutes while hordes of children gleefully punched buttons and re-programmed things alongside.

Kiddies, it seems, are one of the major hazards of the exhibition business if the opinions of one or two of the "keepers" are anything to go by. "Too many of the little demons all at once, that's the worst of the school holidays," said one of them. Visiting the exhibition during term time might be the quieter answer therefore, although this presumes that coach-loads will not occasionally arrive, press-ganged into the trip by avid science teachers.

It's all great fun though, and very informative, leading right through from the development of the first point-contact transistor to the "latest" on the information retrieval systems.

Some elements were a little silly (but forgivable) such as that showing applications of the chip for "sensing" processes in rather trivial areas on the family car—oil and petrol level sensing, o.k., but sidelight checking by photoelectric means? More sensors needed to check the checking l.e.d. which in turn checks on the state of another checking device, always assuming that your l.e.ds are reliable and you don't come to the conclusion that a length of optical fibre, carried from sidelights etc. to the dashboard is all that's needed for instant feedback to the human optical system.

The relatively "perfect" actions of microcomputers were thrown into sharp relief by the apparent incapacity of the technicians who must surely have set the exhibits up to ensure good results from the video monitors dotted around the showcases. In one batch of six, two were suffering from ballooning (presumably low e.h.t.) and two from line pulling at the top of the screen.

At £1.65, the official booklet is good value, being crammed with excellent illustrations and only really falling short in the rather wooden style in which it is written and the single hole in its claim, common to the handbook and the exhibition, to show how "microelectronics will affect your future." There is no direct information or comment on either the more intense social changes or possible shifts in employment in the future as a result of "chip activity".

However, if one of its more staggering "facts" is any sort of indicator, that the pocket calculator gives us as much computing power as would have cost £50,000 only twenty years ago, then maybe the author's sharp intake of breath at this self-revelation prevented further literary effort on the subject.

Microprocessor competition

To be fair, he couldn't really have known about, for example, the results of the recent British Microprocessor Competition, which was organized by the National Research Development Council (NRDC) in collaboration with the National Computing Centre (NCC). The first prize in category 1 (working models) of £10,000 was won by Sinar Agritec Ltd, of Egham, Surrey, for their design for a portable grain moisture meter (see photo). This is adaptable for other commodities such as rice or seeds and features calibration data for several varieties of crop, located in a single e.p.r.o.m., using a computer language called FORTH.

Operation is by means of only two push-buttons and an l.c.d. unit, and the complete program routine can be stepped through by an untrained operator. The judges considered this design to be of value for agricultural purposes for both developing and advanced economies.

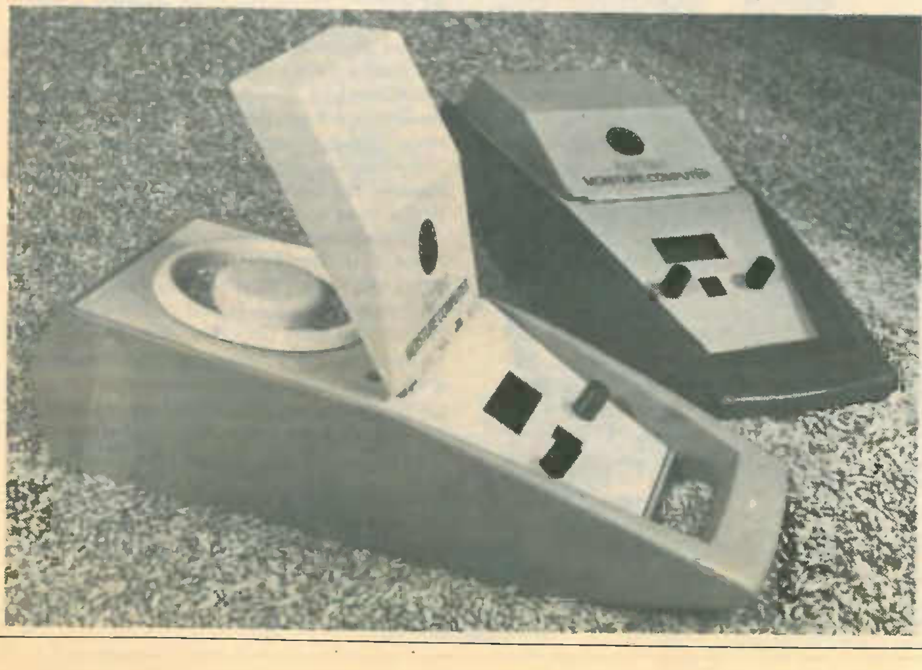
The second prize of £5,000 was won by a team from the University of Manchester Institute of Science and Technology (UMIST) Department of Mechanical Engineering. The interactive programming system for lathes permits the operator to "converse" with the machine and the judges felt that the market potential for small machine shops is substantial, if the right company can be found to complete development of the design.

The Truestock stock control system won for Grundy Terminals of Teddington, Middlesex, the third prize of £2,000. Once again, this offers sophisticated techniques for use by untrained operators enabling, for example, a component or sub-assembly to be instantly identified by pointing to it on an overlay drawing with a light pen.

In the second category (ideas on paper), MDB Electronics of Deptford, London, won the first prize of £2,000 for their design for a portable electrocardiograph machine. This offers battery operation and facilities for on-the-spot print-out and analysis of heart activity. Once developed, there could be a significant market for this type of instrument in surgeries, ambulances and first aid posts.

Second prize of £1,000 in this category was won by a private individual, Mr. C. Goss of St. Margaret's, Twickenham, for his electronic aid for the speech-impaired. This is based on comparatively cheap speech synthesis chips with limited, but nevertheless useful, vocabularies. A hand-held device is used to enter abbreviated words into a microprocessor, which employs "ingenious" algorithms to produce complete sentences. The judges foresaw the development of a device which is unobtrusive and portable, at a price which people with speech handicaps will be able to afford.

A special prize of £500 was awarded to the Royal Grammar School, Newcastle-upon-Tyne, for its microprocessor-controlled theatre lighting system.



The moisture meter designed by Sinar Agritec which won first prize in the British Microprocessor Competition. Using an RCA 1802 m.p.u., it provides calibration programs for 30 types of cereal or 64 commodities in all, and has built-in electronic weight balance and automatic temperature correction. The commodity being tested acts as a dielectric in a capacitance method of moisture measurement. The makers founded their company in 1978 on the principle that microprocessors should be applied not only to fast-profit consumer products but also to ultra-practical devices to help increase the quality and consistency of food produce. (Sinar is an Indonesian word meaning radiant light.)

Richard Kirby at conference on spectrum conservation

The keynote address at a conference organized by the IEE on the subject of "Radio Spectrum Conservation Techniques", to be held at the IEE headquarters from 7 to 9 July 1980, will be given by Richard Kirby, Director of the International Radio Consultative Committee (CCIR), to which body the ITU looks for technical guidance on radio.

His main subject will be the role of technology in coping with the more intensive frequency sharing arrangements resulting from WARC 79. General IEE interest in the subject dates from 1976, when the Electronics Divisional Board set up a special committee to investigate the many aspects of radio spectrum conservation. The idea for this year's conference arose from the committee's discussions.

Response to the call for papers has been good and topics for discussion include alternatives to the use of radio, modulation techniques for reducing the bandwidth of transmitted signals, methods of processing of information, aerial designs to limit wasteful radiation, techniques for reducing interference, computer-aided techniques for spectrum planning and management and methods of confirming the radio energy level required for a particular region or application.

For further information contact the IEE, Savoy Place, London WC2R 0BL.

Andrew Corbyn, designer of the pulse induction metal detector described in our March and April issues, explains a point about the prototype to Marie Tracey, chairman of Pulse Induction Ltd of Yateley, Surrey, which has an interest in the patent application. Andrew, 35, is a chartered engineer with degrees in mining engineering and geophysics from Imperial College. Apart from his research in rock mechanics, potential field theory and statistical evaluation of mineral deposits, he has worked as a teacher, mining engineer, computer programmer and plumber. He has designed large metal detectors for searching for gold in Western Australia. Marie, together with her husband, electronics engineer Lee Tracy, formed Pulse Induction Ltd in 1972. She has done business in metal detecting with military forces in various parts of the world and her visits to remote spots have included travel on a camel across deserts in Libya and Egypt. She is an expert shot with "cowboy" type hand guns, with which she has given demonstrations, and has also worked as an artist's model. Her company is now part of the Kay Organisation, which includes Lansing Bagnall fork lift trucks.

GLC document, largely favourable to c.b., seeks public response

A consultative document, recently issued by the GLC, outlines the main details of the citizens' band debate and urges a strong public response to support the council's "belief in the freedom of individuals to take advantage of modern technology in their work and recreation, subject only to this freedom not interfering in an unacceptable way with the freedom and rights of others."

The document points out the potential social and commercial benefits of c.b. by reference to the USA, where it is possible to use the facility to book hotel rooms, order meals in advance, give warning of traffic jams or accidents or to provide back-up facilities for the emergency services. It emphasises the advantages for those who are disabled and refers to cases such as the elderly, who may be vulnerable to sudden illness or physical assaults while in their homes, or the invaluable nature of c.b. to a disabled driver whose car may have broken down and who may be incapable of walking to a telephone.

Possible disadvantages of c.b. are also considered in the document, such as its use by the criminal fraternity in co-ordinating criminal enterprise (which could well be outweighed by virtue of the fact that anyone tuned to the transmission frequency would be warned of the plan) or obscene language broadcasts. Furthermore, the point is made that illegal c.b. activity is fairly widespread and criminal acts may be planned whether or not the service is legalized. The "pro-c.b." lobby argues that criminal activities would be rendered more difficult by official policing of the system, especially if legislation on c.b. sets included a compulsory identification code signal. Balancing this would be the problem that manpower would be required to regulate the service, which does not fit with current "trimming down" of public service departments through cuts in government funds. A decision on the issue was postponed by the government after an official statement on 6 December 1979 that the really strong argument was one based upon personal freedom, although the major problem was that of the selection of a suitable frequency band. Another important feature of the frequencies which could be used for c.b. is their relationship with sets already manufactured in the USA and Japan and, according to this document, stockpiled in this country ready for sale if c.b. is legalized. Most of these sets (about 100,000) are for operation in the 27 MHz band, and there is common ground between the advocates of c.b. and the government that this frequency band is unsuitable and undesirable for the purpose.

"This band . . . directly threatens the users of hospital and other paging systems and the activities of model control enthusiasts. In addition, it is understood that harmonics of transmissions on this band can interfere with broadcasting, the emergency services, old people's alarm systems and aircraft communications. Signals at this frequency also have a longer range than required . . .

"Estimates have been made that there could be a requirement of between 6 and 8 million sets if c.b. were to be legalized in this country. A potentially large new market could thus be created for British firms, particularly if the controls imposed on band, modulation and set specification were such that all manufacturers, overseas as well as at home, were starting from a new base in the design of the product. This would include type-approved equipment having to perform accurately to the frequency chosen and the system capable of extension to accommodate (possibly) data transmission and station coding to identify the transmitter.

"The government's clear intention to allocate a frequency other than the 27MHz band would remove an advantage currently held by the USA and Japan since they permit c.b. activity in that band and their sets are produced accordingly."

Comments and views on the issue in general should be sent before June 4th 1980 to The Director-General (DG/PR), Greater London Council, The County Hall, London SE1 7PB.

Periphonic sound

First public demonstration of periphony at AES convention

Back in 1970 Michael Gerzon, a mathematical researcher at the University of Oxford, was experimenting with tetrahedral* recording. Four almost-coincident microphones were angled for spherical sound pickup, with playback over four loudspeakers in a tetrahedral array. Microphone angles were determined, matrix co-efficients calculated and the discovery made that there was redundancy in the four channels and the minimum number of non-redundant channels was three. And it worked. Not perfectly, but well enough for him to remark two years later: "Those who have had the opportunity of hearing periphony at its best can have no doubt that the height effect is important in the reproduction of sound and in the enjoyment of music . . ."

Now, a decade later, the first public demonstrations have taken place using a recently-developed periphonic decoder. Until now only ambisonic equipment for horizontal surround sound has been available but the general theory is just as applicable to the third dimension of height.

There were not many who had heard periphony then; there can't be that many more now, though the NRDC-sponsored Ambisonic partnership did a sterling job at the recent London Audio Engineering Society Convention with frequent six-at-a-time demonstrations for three and a half days. But even if one couldn't prove the pudding one wonders why it wasn't intuitively obvious to many whom one thought it should have been that as sounds in nature arrive from all directions, a system which sets out to create a good illusion of reality should take account of this fact.

*A theory of spin spherical harmonics, a three-dimensional equivalent of circular harmonics with analogy to quantum theory, showed that the early tetrahedral array was only one member of an hierarchial family, which Michael Gerzon termed periphonic.

Whilst the market place may not yet be ready for six or eight loudspeaker sound systems interest in periphony is steadily increasing. The development of the periphonic or soundfield microphone (see "British lead in surround sound microphone' *WW*, August 1978, page 75) was a necessary condition for this, and many recording engineers are now aware that together with its signal processing circuitry it offers mono, stereo and two and three-channel horizontal surround, as well as periphonic options, at the touch of a few control knobs, to say nothing of the extraordinary post-recording flexibility for effective alteration of microphone position and polar response. And this at a time when digital systems are promising the audio world access to a greater number of high quality audio channels.

Progress in periphony and in periphonic decoder design in particular became possible due to the development of a fairly comprehensive theory of the psychoacoustics of directional reproduction which helped to unravel just why periphony didn't work perfectly the first time. Equipment design is greatly simplified and subjective results readily optimized using the results of this work, some aspects of which were summarized in a lecture by Michael Gerzon at the convention.

To oversimplify this, imagine vectors drawn from the centre of a four-speaker array with directions pointing toward each speaker and whose length is proportional to the amount of sound emitted from each speaker. At low frequencies, below 700Hz, where localization depends on inter-aural phase differencies, make the length of each vector proportional to the *amplitude* of sound emitted and add their magnitudes to give a total amplitude. Also add vectorially, which gives a localization according to the Makita theory (which is that direction to which the head turns to give zero phase difference). Now when the head points in another direction the perceived direction generally differs, and to stabilize the image position requires that the magnitude of the resultant vector is the same as the total amplitude of sound from the loudspeakers. This ratio is called the vector magnitude $\mathbf{r}_v$ (r comes from real, v from velocity) and should ideally be unity in reproduced sound, as it is with a live sound source.

At high frequencies, where localization is by inter-aural intensity differences, make the length of each vector proportional to the *energy* of sound emitted, and again add the magnitudes to give a total energy. Adding vectorially gives a localization according to the energy-vector theory (which is that direction to which the head turns to give zero intensity difference). Then, it is argued, to give good image stability the vector magnitude $\mathbf{r}_E$, i.e. the ratio of resultant vector length to total energy, should be as close to unity as possible. (This ratio would be unity for a real sound source, but it has been shown that this value cannot be attained when reproducing multiple sounds.)

As well as meeting these two criteria good decoder design must get both localizations correct for all frequencies and in all directions. Though it wasn't obvious at the time the trouble with the

continued on page 75

First periphonic decoder built by the NRDC-sponsored Ambisonic partnership has controls that allow a variety of loudspeaker arrays to be used.

LETTERS TO THE EDITOR

THE INTELLIGENT PLUG

Having been involved in power line carrier design for some time I particularly enjoyed the article "The Intelligent Plug" in the December 1979 issue. The techniques described for the remote control of domestic appliances are straightforward and practical.

Some time ago I entered into a development programme for a full duplex power line carrier intercom in conjunction with Semiconductor Circuits Inc. of Haverhill, Massachusetts. This work culminated recently with the production of a number of prototype systems, working in pairs so that a person in one room could simultaneously talk and listen to another in a separate room without having to operate any controls. We even went exotic with the addition of telephone adapters to convert the intercoms into loudspeaking telephones and demonstrated operation with both impulse and touch tone dials.

From extensive tests on these units by engineers and enthusiastic marketing personnel, we have been forced to acknowledge that power lines provide less than ideal transmission and have a decidedly unpredictable nature. On this side of the Atlantic our lines are 115 volt but have similar impedance characteristics to the one shown in Fig. 2 of your article. However, these characteristics vary from circuit to circuit, house to house, office to office. The average impedance falls from approximately 20 ohms at 30 kHz to 10 ohms at 200 kHz and then rises, depending on the circuit, to 20 or 50 ohms at 400 kHz. We have stayed clear of higher frequencies (even though they are permitted by the FCC) because of the large number of powerful medium-wave radio stations around each city. Superimposed on these impedance trends are troughs down to two or three ohms and peaks of 70 to 120 ohms. Such resonances are accompanied by zeros in transmission spectra that wreaked havoc with our frequency selection plans. These transmission 'holes' are produced by reactances in appliances connected to the circuit and to resonances in local voltage dropping transformers. We found that an 'instant on' tv set completely wiped out a channel centred on 300 kHz. Incidentally, the line loss here is greater than you show, while a good circuit will have 20dB loss; a more common figure is between 30 and 40dB and in offices this rises to over 50dB. Noise is just as unpredictable, being either non-existent or spikes of a few volts. It is worse at lower frequencies and appears to fall off exponentially as frequency rises.

Commercial manufacturers of power line carrier intercoms such as Fanon avoid transmission band irregularity problems by providing alternative working frequencies; if one doesn't work well, the other one should. This is easy in a simplex system but difficult when working full duplex since shifting frequencies necessitates switching transmit-receive filters and can be very expensive. I would imagine that working simplex or half duplex with 'The Intelligent Plut' is no less hazardous since the absence of signal due to a transmission hole is not obvious to an unskilled operator.

One major problem not mentioned in the article is that once satisfactory transmission has been established throughout the required house there is also a fair size signal heading other nearby houses, an effect that is commercially exploited by intercom manufacturers; you can put one in your baby's room while you go out on the town and the other in your neighbour's house. Transmission is generally good enough for this 'baby alarm' mode of operation. When voice transmissions are carried over the power line the effect is to automatically 'bug' your house! Even worse, the installation of a number of similar systems within a neighbourhood ensures that each will interfere with the others and nobody can reliably transmit or receive anything.

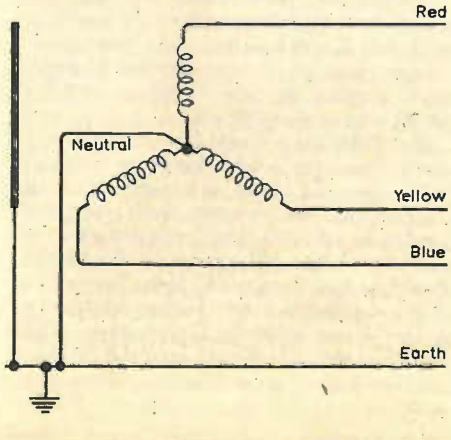
Experience with our own full duplex systems forced us to conclude that unless the power line circuits themselves are modified in some way they do not provide a sufficiently predictable link. All of the problems can be simply overcome by installing blocking filters, either in the form of adapter plugs and sockets in series with troublesome appliances or to block out-of-house transmission and reception by clipping filters around the cables entering the house.

The challenge now is to evolve acceptable line conditioning adapters and educate the general public so that this most economical signal transmission medium can come into its own for all kinds of application.

Lewis Illingworth
Beaconsfield
Quebec, Canada

As an electrical engineer employed by the supply industry, I read, with interest, the article by Messrs McArthur, Wingfield and Witten on the use of household wiring for data transmission (December 1979). However, the details of electricity distribution given in the article are not entirely correct and this may have an effect on the operation of such a data transmitting system.

In urban situations, it is true that all three phases are used for distribution, but not that every third house is connected on the same phase. It has been common for many years to loop two houses together on the same phase which could lead to severe house to house interference. More importantly, the diagram of a distribution substation is incorrect. It should show the neutral and earth solidly connected as in the accompanying diagram.



The importance of the neutral to earth connection to the Intelligent Plug cannot be under-estimated. This situation is further confused by the use of p.m.e. (protective multiple earthing — not phase multiple earthing mentioned by yourself). The introduction of p.m.e. has led to the neutral and earth being joined together at many places on the distribution system to give a number of parallel current paths, ensuring low neutral-earth impedance. The use of p.m.e. had led to the use of combined neautral-earth cables where the neutral and earth currents share the same conductor. In this case, I do not see how the Intelligent Plug, as described, could function.

Signalling, using the live/neutral pair, would be feasible, but because of the dangers involved and possible damage to faulty equipment, I do not recommend it. I would be interested to know what the 20 metre section of mains wire, that the authors investigated, was connected to and what effect the many junctions and branches common to household wiring have on the impedance of it at frequencies in excess of 30kHz. Before the system could be used commercially, some more detailed experiments on the characteristics of household wiring, and the effects on the distribution network that such a communication system may have, would be essential.

A. J. Skinner
Edmonton
London N9

MICROELECTRONICS AND THE THIRD WORLD

With reference to "Trickle, trickle little chip", your leader in the November 1979 issue, I would have liked to commend you for pointing out the deficiencies of the now widely discredited 'trickle-down' theory of world economic development had you not, when talking about "accelerating capital accumulation" using high technology, been advocating the very same thing, albeit in a watered down version. Unfortunately the arithmetic simply does not work. The cost of the high technology workplace, and the market for the goods produced in a world saturated by them, mean that world poverty would take hundreds of years to diminish, if ever, by these means.

In the battle against poverty, i.e. in meeting the basic needs of the poor, we must swallow some ideological pride and realize that the real 'capital' in the development equation lies in the vast waste of human potential that poverty implies. Generations of poverty bring about fatalism and stagnation, but let a poor people realise the things that can be done if they work together towards a common goal, and are free of those who are doing very nicely out of the status quo, and this vast human potential will be unlocked. Basic needs will be met in tens, not hundreds of years. The 'money' capital needed, e.g. irrigation pipes, cement, to fuel this process is surprisingly small but obviously the political problems are correspondingly large.

Once this process is under way, to consolidate the gains made microprocessor based production is highly relevant and should be used. Alternative technology, of course, is by its nature primarily for meeting local basic needs and was never really intended for developing export markets.

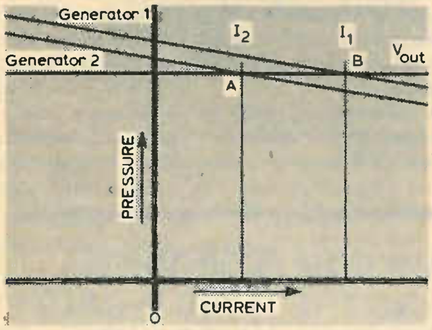
I see a two-way education process as being necessary. The Third World may not know much of the possibilities of microelectronics and people in the West may not know much of the Third World. As its role in the first part I would encourage *Wireless World*, with its world-wide readership, to give special attention to the use of microelectronics in the Third World, and for the second part I can only refer readers to magazines such as the *New Internationalist*.

N. W. P. Payne
Danbury
Connecticut
USA

PUSH-PULL AMPLIFIERS

On page 74 of your January 1980 issue is a circuit diagram for a push-pull class-A amplifier.

When two generators feed a single load the question of load sharing is liable to arise. As is well known, when the generators are in parallel it is necessary for them to have a not too low internal resistance (or regulation) to cope with inevitable differences in e.m.f., the effect of which is easily shown by a diagram,



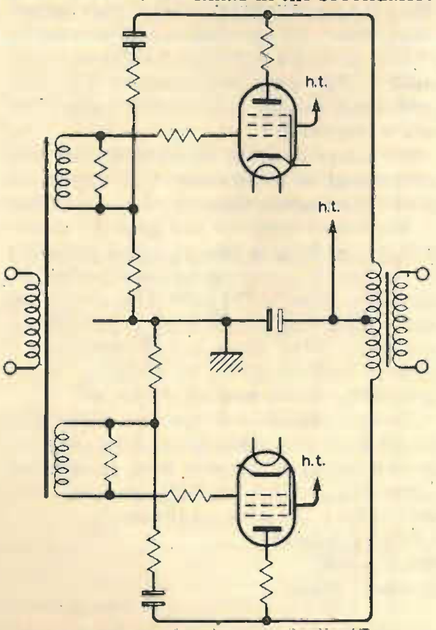
here. If the internal resistance is too low the output characteristics of the two generators are almost horizontal and the distance between points A and B can become large. Indeed it is quite possible for one of the points to be to the left of the vertical axis, which means that one generator is supplying current not only to the load but also into the other generator. Clearly there is magnification of inequalities.

In an electronic amplifier we can give to the two generators (the two halves of the output stage) any internal resistance, and the ideal arrangement for good load sharing is two generators with infinite internal resistance (i.e. current generators). There is then no magnification of inequalities in the transconductances or inputs of the two sides of the amplifier; and the combination can be given the required low output resistance in the usual way by feedback.

A good basis for such an arrangement, it seems to me, is the Peter Blomley amplifier (February, March 1971 issues). This is a class-B design; but the current-splitting stage can easily be changed to class A by putting resistance between the emitters and introducing extra bias between the bases. And, of course, other changes will be needed — to resistances and to sizes of heat sinks — to cope with the changed working conditions.

The two sides of Mr Pollock's amplifier have low output resistance, partly because of the emitter-follower connection and partly because of the overall feedback on each side (the parallel feedback chains); and that there is a serious load-sharing problem is shown by the call for resistors matched to 0.1%. An experienced engineer would, I think, have seen this unusually tight requirement as a sign that he was not on the right path.

I find it interesting to recall that one of the first published feedback-amplifier designs (the *Wireless World* p-a amplifier, if my memory serves me correctly) had similar parallel feedback paths. But in those days the moderate amount of feedback used reduced the output resistance to about only a half or a third of the load resistance. Moreover there is nothing in electrical engineering as accurate as the ratios of the e.m.fs in the secondaries



of a well-designed transformer. So there would not in this amplifier be a serious load-sharing problem. The arrangement of the output stage was, as far as I can remember, as shown above: unfortunately my pre-war *Wireless Worlds* are not to hand.

E. F. Good
Darlington
Co. Durham

TOWNSMAN AERIAL

Since the publication of my article the "Townsman 2m/70cm aerial" in the February issue, a few queries have arisen, mainly as a result of conversations over the air on the 2-metre and 70 centimetre amateur bands. Further experience with the aerial since the article was written enables me to answer most of these, although the obvious one, "Where can I obtain flat metal strip 1 cm wide?" must remain open at present.

The first question concerns a certain confusion about the tabular data. Column No. 1 is the data for the two-band 2m/70cm aerial. Columns 2, 3, 4, 5 and 6 give details of single band "simple" models for 70cm, and for indoor television reception.

In the two-band model, I can now be very precise about the positioning of the cooking-foil suppression sleeve as a result of on-air tests carried out recently since the commissioning of more 70cm repeater stations near my home. The centre of the sleeve should be 3 inches (7½cm) *below* the centre of the dipole element, and not exactly as shown in the drawing, level with it. This makes its manner of operation rather obscure, but results show that this is the best position.

Tests using a variety of different hook-up wire for the hair-pin matching loop disclose the fact (originally overlooked!) that thin wire with thin insulation bends into a tighter hair-pin than thick wire with thick insulation, and that the influence of the metal of the transformer strip is far greater with the thin wire than with the thick wire. The length shown is for thin wire with thin insulation; a possible minimum length for wire extracted from ten-amp mains flex would be in the region of 3 inches (7½cm), rather than the five inches (12.7cm) shown.

The conductor wire is taped lightly along the metal of the transformer until it flares away for 7½ inches (19cm). The shape of the flare adjusts the matching rather critically, particularly on 2m. It is helpful, to permit accurate adjustment and to maintain long-term stability, to brace this free section of the conductor wire with a strip of thin Formica and fit a grub-screw through the metal about 2cm above the last strapping, for the purpose of fine-adjusting the rate of flare. With such a screw adjustment, v.s.w.r. can be brought to unity with almost 'factory-test' rapidity.

The aerial is necessarily a compromise. It is recommended that adjustment be made to be correct on 2m, and some v.s.w.r. accepted on 70cm. This need not be worse than 1.5:1.

I used plastic tubing coloured white. I suspect that black coloured tubing may include a carbon content which would make it unsuitable for these purposes.

B. J. P. Howlett, G3JAM
Woodford Green
Essex

IS 500kHz A GOOD DISTRESS FREQUENCY?

It is quite common when using marine m.f. transmitters under certain circumstances to experience considerable loss of radiated r.f. power on medium frequency 405-525 kHz. The effect is most pronounced with very rough sea conditions in gales or storms, the radiated power dropping off on the main transmitter from its normal 7 amps r.f. down to approximately 2 amps, or under certain conditions less. In extreme cases it has been known for the radio operator to be unable to power the transmitter on m.f. due to the transmitter tripping off. H.F. is not affected to the same extent.

Similar loss of r.f. radiated power was also recently experienced when using the emergency transmitter during calm conditions but with a high temperature and high humidity present. Radiated power on m.f. dropped from its normal 4.1 amps down to 1.8 amps r.f.

In gales or storms or when humidity is high, all the aerial insulators become saturated with wet salt spray; this alone causes considerable loss of radiated power on m.f. Probably, though, a greater loss of radiated power is also caused by the fact that in such conditions the atmosphere surrounding the vessel and its antenna is saturated with salt water droplets and spray which can extend to a considerable height above sea level (well above the antenna height). This presents an extremely poor dielectric constant and means that one is attempting to operate an m.f. transmitter into a load (antenna) which is almost immersed in a saline solution existing between the aerial and sea level. It is difficult or impossible to load the transmitter into the aerial under such conditions.

This is at a time when there is always the possibility that a vessel could get into difficulties in heavy weather and it may be necessary to transmit a distress call on 500 kHz. Under these conditions it may not be possible to do so, or, if possible, it would be at much reduced power output. Should a vessel in these circumstances be any distance from another station it could result in the call going unheard on m.f. Perhaps this explains why vessels have disappeared in heavy weather without a distress call being heard.

Does not this raise the question: is 500 kHz a suitable frequency for distress traffic working under these conditions?

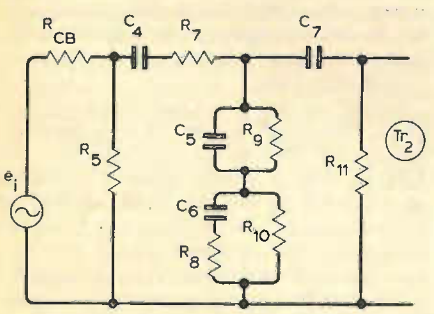
A. K. Tunnah
Ardrossan
South Australia

PRE-AMPLIFIER WITH NO T.I.D.

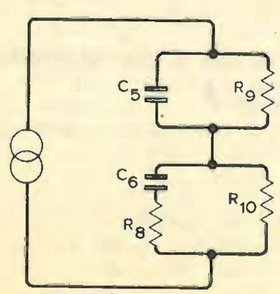
We all read very attentively the June 1979 *Journal of the Audio Engineering Society* in which Mr Lipshitz has given so many examples of the errors in commercial pre-amplifiers (even in "very expensive models") and his letter in your January 1980 issue is one more reminder. In 1978 we could not have known, unfortunately, about his article of 1979. Further, the specification of the equalization network will be considered according to the circumstances. Unfortunately, the question of the equalization network is not the main point of my article "Audio pre-amplifier with no t.i.d." in the August 1979 issue.

Firstly, the term "grossly in error" should be put in context. Let's take into account the fact that the pre-amplifier is always followed by volume and tone controls, filters, loudspeakers and a listening room. As far as is known, these units distort the signals to a greater extent (in amplitude and phase). By the way, in my August 1979 article I pointed out a discrepancy of the frequency response at the edges of the audio band, and I mentioned the possibility of modifying or completely replacing the equalization network. And for sure there is nothing in the article, using Stravinsky's words, that has "finally arrived". Taking all this into account it doesn't seem reasonable to complain of the RIAA network being "grossly in error".

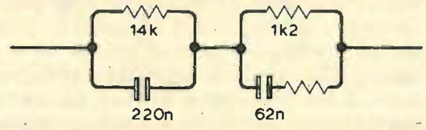
Postscript: Employing the classical equivalent network of the output circuit Tr_1 we have:



After the usual simplifications we have the equivalent network with a current generator:



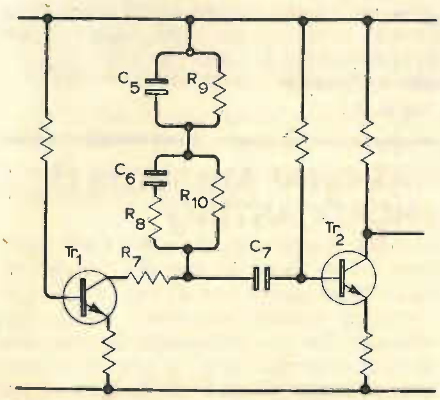
For a long time we have had the original and accurate method of calculation for such an equalization network; here, for example, is one of many possible versions:



It is clear from Lipshitz's letter and article that de-emphasis is passive, and in this case R_7, R_8, R_9, R_{10}, C_5, C_6 are the components "grossly in error". (It is just R_8, R_9, R_{10}, C_5, C_6 that are replaced in measurements by the 240-ohm resistor.)

If we take into account that R_5 of the following stage has some effect on the equalization network and there is a possible reduction of high frequencies by the input filter of the pre-amplifier (moving coil), as well as attentuation of low frequencies by all other following isolating capacitors (without putting on additional stages, etc.) we inevitably have to come to some compromise. And that has been achieved.

The circuit may also be used this way:



The resistor R_7 is used only for "equalizing" the loading of Tr_1.

Y. Miloslavskij
Institute of Constructional Physics
Moscow, USSR

"TRIVIAL" AMPLIFIER DESIGNS

I was slightly perturbed by Mr B. J. Duncan's letter in the January 1980 issue. Since he has radically altered the design of my pre-amplifier by removing the discrete semiconductors and introducing i.c. circuitry, I hardly think it is fair to carry on referring to it as my design, and do not feel impelled to take any responsibility for its performance or lack thereof.

I do agree that an unacceptable aura of mysticism still seems to surround the performance of audio equipment. A great deal of nonsense is still being talked about "musical" capacitors, metal oxide resistors, and so on, although as far as I can tell the field is still wide open for the first brave man to stand up and explain how ears can register differences that not only escape the best test gear, but are also unknown to electrical science. Presumably, given time and a complete lack of supporting evidence, such silliness will once more become unfashionable.

However, I do differ with Mr Duncan in his assessment of the worth of increasing amplifier refinement based on actual engineering principles. If someone finds a way to reduce distortion in a given case from 0.005% to 0.004%, then surely the design approach involved is worth reporting, even if the current state of art in analogue magnetic recording renders such an improvement largely academic. Also, I suggest that there is much satisfaction to be gathered in constructing a piece of equipment that will degrade the signals passing through it as little as humanly possible, even if the signals available are of variable quality.

I see no reason why amplifier designers should shut up shop just because other parts of the audio chain have a lot of catching up to do.

Douglas Self
London E17

M.F. RECEPTION

I am pleased to note that Mr Schemel's recent article on loop aerials (July 1979), and my own letter on m.f. broadcast reception (November 1978), are giving rise to some interest in this area.

I should like to take up a point in Mr Hill's letter (February 1980) concerning the use of long-wire aerials. I agree that the image rejection of domestic receivers, typically no better than 30-40dB even after careful alignment, makes the untuned connection of a long-wire aerial of doubtful value. I also agree that in the majority of cases, loop aerials represent a much more effective way of increasing signal pickup. But I ought to have made it clear that my original method of coupling the aerial to the receiver was not as Mr Hill assumed.

Where practical considerations make the erection of a long-wire aerial an attractive prospect, I found that the most satisfactory method of coupling such an aerial to a ferrite-rod receiver was to use a surplus ferrite rod aerial with a standard m.f. winding, earth one end, and connect the other to the long-wire via a 500pF variable. Mounting this assembly in a small plastic box enables the amount of coupling, and the phase of the additional signal, to be varied by physically moving the plastic enclosure with respect to the receiver. Depending on the length of the aerial used, some adjustment to the number of turns on the coupling rod may be necessary to achieve the desired tuning range.

Not only does this offer similar discrimination against second-channel interference to that obtained with a resonant loop, but the substantially omnidirectional pickup of a long-wire aerial (or even better, a loaded vertical whip) means that careful juxtaposition of receiver and coupler can produce a cardioid-type pickup pattern, which can be particularly useful at night, where absolute field strengths are quite high, and gain is not as important as directivity. During daylight hours, the omnidirectional pickup of a long-wire aerial can have advantages during a general band-scan.

I also note that Mr Hill uses a low-pass filter in the audio circuitry of his receiver. I agree that a sharp cut-off above 5kHz is extremely advantageous for reception of similarly band-limited transmissions, but surely the notch should be at 9kHz, not eight. I would also favour a faster roll-off: both the BBC and the IBA transmit a response which is substantially flat up to 5kHz, and then rolls off to −40dB at around 7.5kHz, and at least −50dB at 9kHz. A good filter for reception should be at least as steep.

I note that recent trends in consumer design do not appear to include much, if anything, in the way of audio treatment after the detector. Instead, the latest designs rely on a narrow block filter as the major part of the i.f. selectivity, relying on accurate (and usually manual) tuning to provide the necessary h.f. attenuation. The block filters popularly used have a nose bandwidth of little more than 6kHz, presumably a sacrifice willingly yielded in order to improve adjacent-channel rejection within the necessary budget. This means, however, that the recovered audio response falls sharply, and to my mind undesirably, above 3kHz or so, and that receiver tuning has to be very precise.

Given that the brief of consumer audio equipment is generally to provide the best possible reception of *local* transmissions, where even at night the wanted signal may be presumed to be at least as strong if not stronger than anything on the adjacent channels, I would suggest that a better approach would be to employ a much wider block filter, with a −3dB bandwidth of around 10kHz, and then to eliminate adjacent-channel whistles and 'monkey chatter' by means of a steep, and preferably switchable, low-pass filter with a cut-off frequency between 4.5 and 5kHz. The use of such a filter also has the advantage of eliminating high-frequency distortion products arising from the detection process.

Finally, I should like to point out that there are at least two transmitters with a ground-wave signal of usable strength in some parts of the country, which radiate a much wider audio bandwidth than the 5kHz now standard within the UK and much of Europe. They are, are the time of writing, RTE Radio 2 on 612kHz, which can be received quite well in Wales, West and North-West England, Southern Scotland and Northern Ireland, and the pirate station Radio Caroline on 963kHz, which can be heard in South-East England. It is, strictly speaking, illegal to listen to the latter, and I mention it only out of technical curiosity.

Norman McLeod
Hove
East Sussex

MILLIBEL IS RUBBISH

I have a little sympathy for Mr Duncan's *cri de coeur* (January letters) over yet another super hi-fi amplifier project (October 1979). Too often designers are carried away by maternal enthusiasm for their brainchild and the high accuracy of a modern calculator. Consistently overlooked are the realities of the situation – that the amplifier is but one element in a very long chain of accumulating imperfections and, in a domestic system particularly, the ultimate fidelity overall will be limited by the programme source.

However, my spleen feels distended by a letter in the March issue with a suggestion of such idiocy that I had to check the cover to make sure that it wasn't an issue a month early. But no, the writer was deadly serious and dangerously literate with it. Can it really be suggested that again, for one small element in the recording/reproducing chain it is *imperative* that any amplitude/frequency deviations be maintained within an accuracy of *0.05dB*? (I assume that this is the total spread). Frankly, I just do not believe it and regard the proposition as rubbish, pure and simple – and I say it as an engineer of 30 years' experience and accustomed to working to tolerances far tighter than those currently practised in the hi-fi industry.

For a start, how in heaven's name can one guarantee a consistency *considerably* better than this outside the pre-amplifier – in the programme sources, for example, which will be used for the subjective tests? Once before, when challenging a myth being propagated by hi-fi commentators of questionable ability, I offered a sum of money to any charity if the spurious arguments being put forward could be proved. My bait was never taken and it remained for others subsequently to demolish the false gods. I will make the same offer yet again, and raise the ante this time.

Prove this ludicrous proposition with an independent listening panel under a scientifically controlled set of conditions. If the panel are able to detect with statistically significant accuracy a frequency/amplitude deviation at some agreed point in the spectrum of 0.05dB on a variety of programme material, I will donate £100 to any charity named by whoever takes up my challenge. I have my charity ready if the test fails, to receive the same amount from the proposition's supporter.

Meanwhile, may I conclude by expressing my disappointment that a magazine of *Wireless World*'s stature should continue to provide a platform for cranky views. These are more proper to the hi-fi comics.

Reg Williamson
Norwich

NATIONAL MUSEUM OF BROADCASTING

As a BBC Engineer at Washford, I was interested to read about the demise of the Brookmans Park transmitters. The Washford, Somerset, regional transmitter was in fact taken out of service at the end of October, after 46 years of service. Both on grounds of electrical efficiency and maintenance effort, it had to go, but its destruction breaks another link with the early days of broadcasting.

For the present, however, the transmitter itself remains intact. Since the prime movers and rotating machinery have gone, it can never be used again, but it would provide a unique centrepiece for any museum. The main transmitter hall and office block will shortly become surplus to the BBC's requirements — what an ideal opportunity to provide a showcase for the Corporation's achievements! The IBA already have a broadcasting gallery in London (displaying BBC history!): once a central museum can be established at Washford, it would be relatively easy to mount smaller exhibitions at major BBC centres in London and elsewhere. Public interest abounds, as various "open days" over the years will verify.

The BBC are not museum curators, so it would be necessary to set up some form of trust, financially independent, but liaising closely with all departments of the Corporation to provide an interesting and financially viable museum. Historic items abound, hidden, within the BBC. Here is the opportunity to allow everyone to see them. During last summer, the Corporation were advertising two "Doctor Who" exhibitions on non-BBC sites. Surely this was not necessary.

Housed in an historic and impressive building, in a major holiday area, the possibility of free advertising on television, such an enterprise cannot fail. This is a golden opportunity, probably the final opportunity, to create a national museum of broadcasting.

J. E. Butterworth
Blue Anchor
Somerset

A POOR JOKE

In your January issue J. Greenwood lodged an objection to a marked tendency in *Wireless World* to include controversial political matters. Though I suspect I may have a little more sympathy with some of the views expressed (though not in Feb. 1980) I equally consider that *W.W.* is the wrong place to express them. One is subjected to so much political discussion in so many places, and looks to *W.W.* as a unique source of *technical* information within certain ill defined but well understood limits.

Having stood up to be counted at this end of *W.W.* I now turn to the other to express the hope that a certain five words by Mixer are no more than a slip and not signs of a trend. A second point of my agreement with Mr Greenwood is that humour *is* a fitting ingredient of *W.W.* Even though myself of Aberdonian grandparents, I was able to pass over Mixer's inevitable linkage of Scotland with northern mists and haggis with no more than a slight wince, but I did seriously deplore his gratuitous addition 'of BL cars disintegrating' as one of the noises over which a certain Klaxon horn could be heard. For one thing, it is a cheap and in this context meaningless jibe of the same order as the perennial mother-in-law jokes – hardly up to *W.W.* standard. But the serious aspect is that it is one more example of the British disease of self-denigration, which ultimately deters people from buying cars that have been made to look a joke. Does Mixer know that BL vehicles are used *exclusively* for their fleets of cars and lorries by Rolls-Royce, who testified in *The Times* that they find them very satisfactory?

In the same way we have a national problem because our children are preconditioned by silly jokers to find maths incomprehensible.

If I look like becoming political myself, it just shows what happens when such matters are brought into *W.W.!*

M. G. Scroggie
Bexhill
Sussex

Mixer replies:
Having been at the receiving end of many shafts of 'humour' concerning my own northern origins, I am familiar with the "slight wince" that Mr Scroggie feels impelled to exhibit at the mention of haggis, cabers and northern mists. I see no reason why he should be spared.

On the subject of the precarious cohesion of BL cars and Mr Scroggie's own inevitable cliché, the "British disease", the jibe was most certainly not meaningless. I am unable to comment on the use of BL vehicles by Rolls Royce, but I can say that if I had not persistently and recklessly chosen to drive a succession of unreliable BL cars myself, I would now be a good deal richer than I am.

Maxwell's equations revisited

We have received a large number of letters commenting on "Maxwell's equations revisited" by Ivor Catt in the March issue. There are too many to be published individually, so the main points will be selected and presented collectively, accompanied by a joint reply from the author.

Audio spectrum analyser

Narrow bandwidth without expensive filters

by **Peter Hiscocks,** Ryerson Polytechnical Institute, Toronto

This instrument is used with an oscilloscope to form an audio analyser at a cost more in keeping with an amateur experimenter's budget than a commercial design. The synchrodyne technique is used to avoid the need for expensive, narrow-band filters. Dynamic range is about 60dB.

The conventional mode of operation of commercial spectrum analysers entails the use of an extremely narrow-band filter, a circuit which is too complex and expensive to be attractive to the home constructor or to schools. Consequently, the design described in this article uses an unusual technique of frequency changing which neatly avoids the difficulty. This type of analyser is intended to investigate unvarying signals, which means that it is not suitable for analysing music or speech waveforms.

Figures 1 and 2 show examples of displays obtained with the instrument. The trace in Fig. 1 is the spectrum of a 1kHz square wave, while that in Fig. 2 is of a 1kHz sine wave, showing 3rd and 5th harmonics. The small responses at a lower frequency than the fundamental in each photograph are spurious products resulting from the method of analysis chosen: they do not normally cause trouble, since they are lower in frequency than the area of interest. Display axes are linear.

Since the instrument is fairly complicated to make, it cannot be recommended for a first attempt: constructors will need a digital voltmeter, a dual, regulated power supply and an audio signal generator.

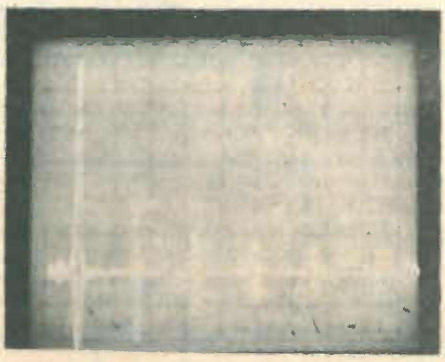



Fig. 1 and 2 show typical responses obtained with the analyser. Fig. 1 shows the spectrum of a 1kHz square wave, showing odd harmonics up to the 11th, while in Fig. 2 is the analysis of a sine wave at the same frequency, with small 3rd and 5th harmonics. Bandwidth was 200Hz.

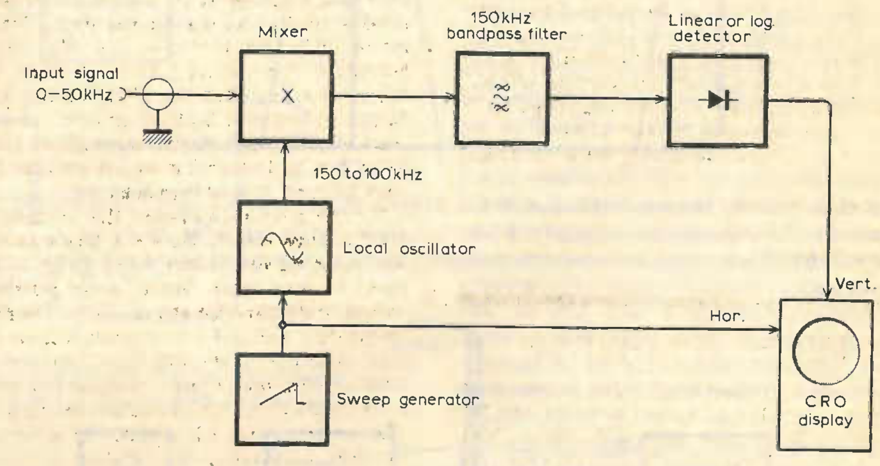


Fig. 3. Block diagram of a conventional spectrum analyser. The 150kHz bandpass filter must be very narrow: one commercial design uses five crystal resonators to achieve the required performance.

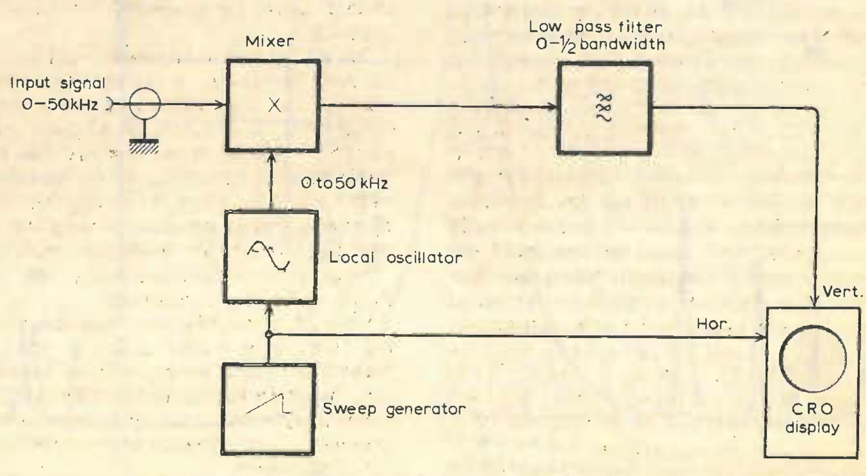


Fig. 4. Method used in this design, in which the filter takes the form of a low-pass circuit in the audio range.

Basic principle

The block diagram of a conventional spectrum analyser is shown in Fig. 3. The local oscillator might be tunable between 100 and 150 kHz, when the sum of the l.o. and input frequencies will be translated into the passband of the analysis filter. However, the construction of a filter which will separate harmonics some 60 dB apart in amplitude, a few Hertz apart at 150 kHz, poses enormous problems for the home constructor. For example, the Hewlett-Packard 3580A spectrum analyser[1] uses five crystal resonators[1], the crystals being matched for temperature drift.

Fortunately, M. G. Scroggie[2] has suggested an alternative technique based on the synchrodyne radio receiver. Figure 4 shows a block diagram of this analyser. The tunable local oscillator sweeps over the range to be analysed, and the low-pass filter passes signals that are close to a zero beat between the input signal and the analysis signal. This process may be regarded as a translation of the low-pass filter to the frequency of the local oscillator, together with a mirroring of the low-pass filter characteristics around the local oscillator frequency as shown in Fig. 5(a). The result is effectively a band-pass filter, with its centre frequency at the setting of the local oscillator and a bandwidth equal to twice the cutoff frequency of the low-pass filter. The design of the analysis filter thus becomes an exercise in low-pass filter design. In the prototype, a four pole Sallen and Key filter was used, with cutoff frequencies between 5 and 250 Hertz.

For those familiar with the techniques of correlation analysis, the analyser may be regarded as a type of cross correlator[3]. The local oscillator sine wave is cross correlated against the input signal; the low-pass filter is an averaging device which produces a signal whenever a match is found between the input sine wave and that of the local oscillator.

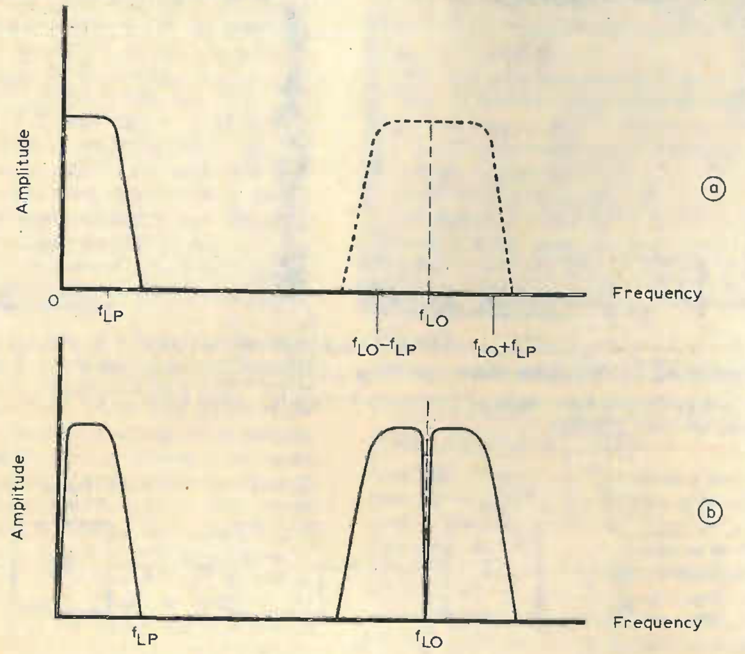


Fig. 5. Frequency response of the analyser. At (a) is shown the low-pass characteristic 'translated' in frequency to that of the local oscillator, while retaining the same bandwidth. The notches shown in the response at (b) are the result of capacitance coupling.

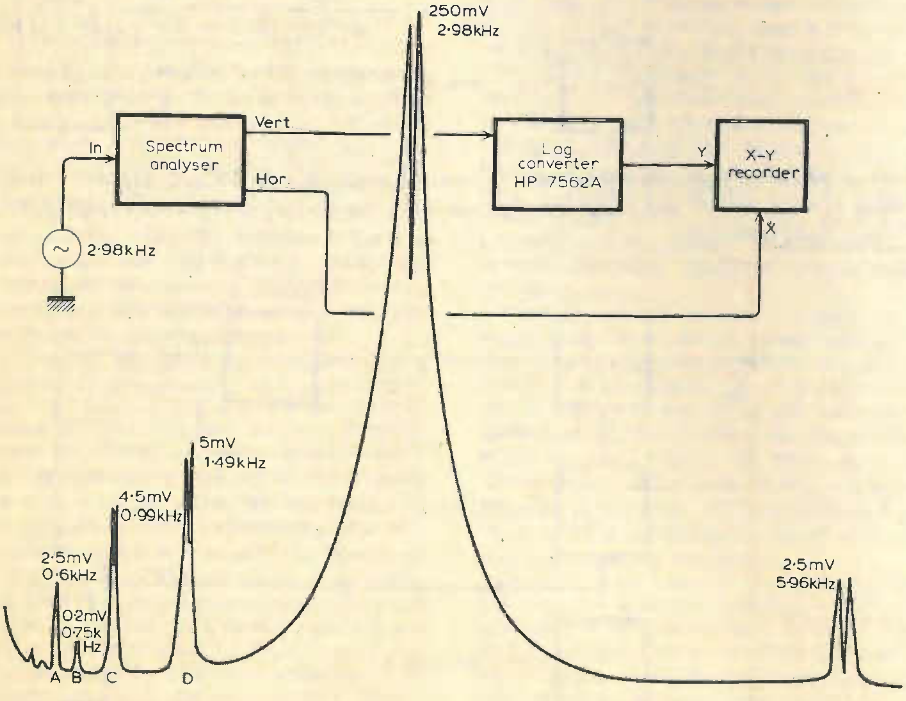


Fig. 6. A typical analysis. The fundamental is at 2.98kHz, its second harmonic being clearly shown at 5.96kHz. The spurious products are all below the frequency of the fundamental.

The local oscillator must tune over a much wider range in proportion to its centre frequency than in a conventional spectrum analyser. In this design, a sweep range between 100 Hz and 16kHz was achieved without undue difficulty. The range may be moved by switching a local oscillator capacitor.

A particular advantage of this system is its ease in identifying the frequency of any particular harmonic: the analysis frequency is equal to the local-oscillator frequency. In this design, a simple digital readout of analysis frequency is provided.

Changes in analysis bandwidth in the low-pass filter have the effect of changing the quiescent output voltage of the filter. The simplest solution to this problem is to capacitively couple the filter to the output of the mixer, even though this results in the narrow notch in the centre of the analyser's filter pass band shown in Fig. 5(b). This is a slight inconvenience in use, since the local oscillator must be slightly detuned from the harmonic frequency when reading amplitude. However, the notch does help in determining the exact frequency of a signal.

The major problem with the synchrodyne analyser is that harmonics of the local oscillator fall within the pass band of the analysis filter and show up on the display as false readings below the fundamental frequency of the input. There are two approaches to this problem. One, obviously, is to keep the distortion of the local oscillator as low as possible. The easiest approach to the design of a swept oscillator, however, is to use a function generator, and the output of a function generator must be shaped in a diode network to produce a sine wave. It is difficult to reduce the distortion of such a sine wave below one percent, particularly when this waveform is to be varied in frequency over a wide range.

The other approach is to learn to recognize and identify the spurious harmonics. An example of this is shown in Fig. 6, the analysis of a 2.98kHz sine wave from a commercial function generator. The vertical axis has been converted to a logarithmic scale by the Hewlett Packard Log Converter, thereby emphasizing low level distortion products.

The spurious distortion products due to the analyser are labelled A, B, C and D on this graph. Notice that these all fall below the fundamental of the input signal and that they are not harmonically related to the input signal.

Spurious product A is created when the fifth harmonic of the spectrum analyser local oscillator beats with the fundamental of the input signal. Products B, C and D are similarly caused by the fourth, third and second harmonics of the local oscillator.

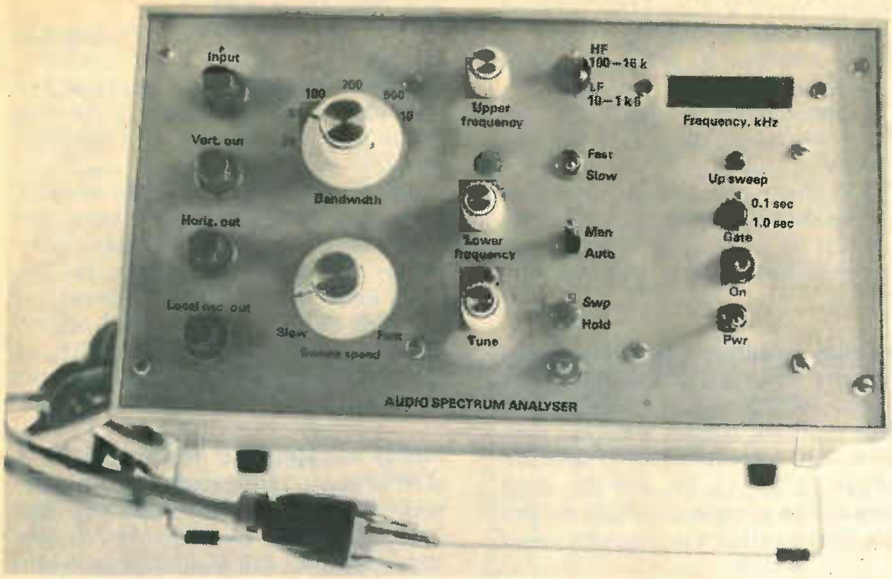


Fig. 7. Prototype analyser.

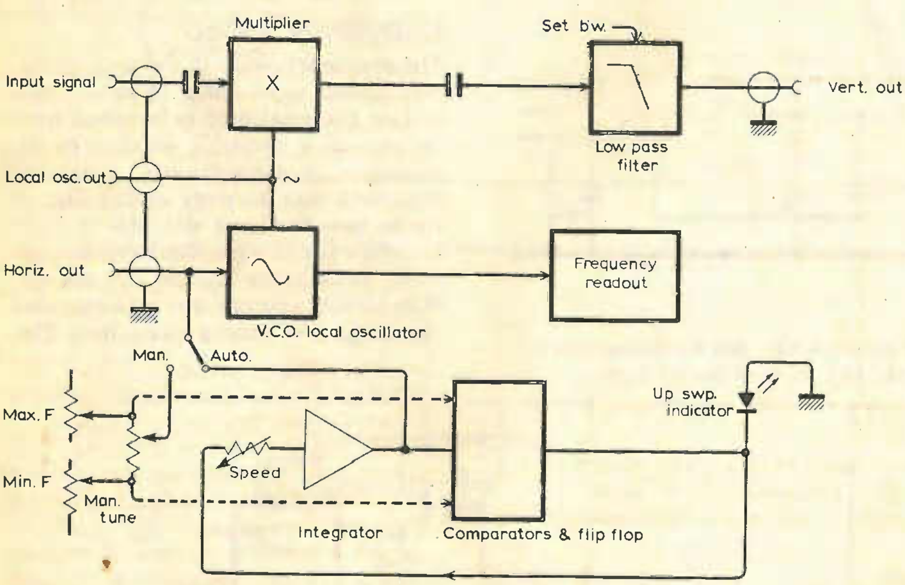


Fig. 8. Detailed block diagram of the instrument. Horizontal and vertical outputs are taken to the oscilloscope, and the local oscillator output is for use with an external counter or other test gear.

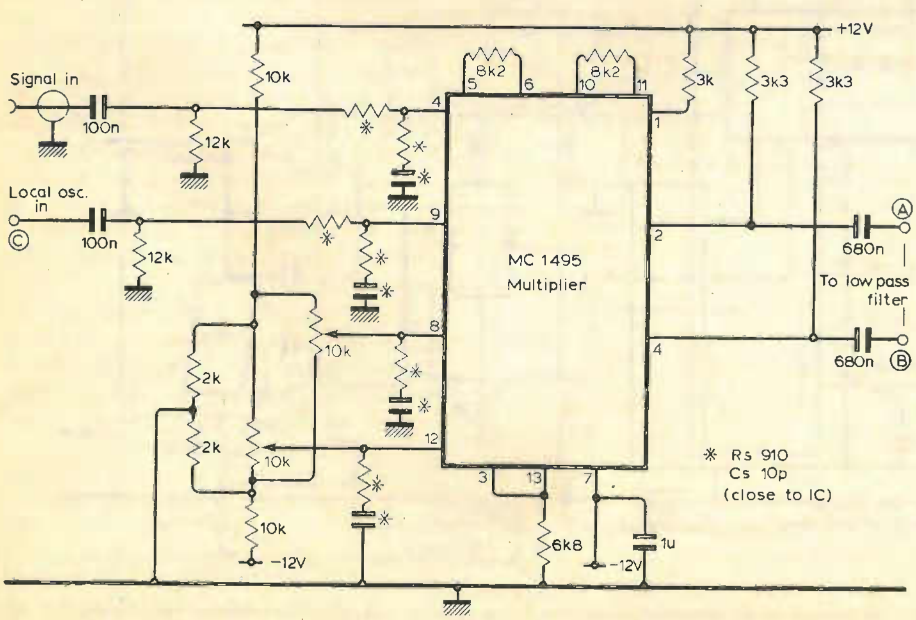


Fig. 9. Multiplier circuit.

The 5.95kHz harmonic is the second harmonic of the input signal. Spurious products do not appear below this harmonic because both it and the spurious products of the local oscillator are small in magnitude.

The spectrum analyser is shown in Fig. 7 and its detailed block diagram in Fig. 8.

Detailed circuit description

Multiplier. A Motorola MC1495 is used as the signal multiplier, shown in Fig. 9. Its maximum input signal should be limited to 8V peak to peak to limit distortion in the multiplier. The RC networks on the inputs (910Ω in series with 10pF) lower the Q of the input leads and damp out any tendency to high frequency oscillation since the MC1495 is capable of operation up to 10MHz.

The 10kΩ potentiometers are adjusted to minimize feedthrough of the v.c.o. signal when the other signal is absent.

Low-pass filters. The low-pass filter in Fig. 10 consists of a differential amplifier, followed by a four-pole, Sallen and Key, low-pass filter to achieve a slope of 24dB/octave above the cutoff frequency.

The variation of the low-pass resistors causes some d.c. shift in the voltage at the vertical output connector. This is not usually a problem, since the detector is usually a.c. coupled.

Local oscillator. The Intersil 8038 used for this purpose generates sine, square and triangle waveforms. Unfortunately, the since wave is very distorted since, although the 8038 requires a full +/— 15V, in this case it is being operated from —15V only. The distortion is reduced to an acceptable level by the germanium diode/2kΩ resistor network connected at pin 2 of the i.c. The 2kΩ resistor should be adjusted while observing the spurious harmonics on a display as in Fig. 6. The square wave output from the 8038 is used by the frequency counter display circuit.

Voltage control of frequency is accomplished by the op. amp. network[4] connected to pin 8. Since this is a *linear* v.c.o. circuit, the voltage range must be equal to the frequency range. Although 1000:1 is possible, improved stability and lower distortion are obtained by selecting the v.c.o. capacitor by the h.f./l.f. range switch. An exponential v.c.o. is described later.

A transistor network[5] connected to pin 10 of the 8038 generates a compensation current of about 1μA to improve the symmetry of the waveforms at very low frequencies. If operation at very low frequency is not a requirement, it may be omitted.

The sine wave is buffered by a 741 op. amp. and passed to the local oscillator output connector. This signal may be used in frequency-response tests of equipment. A second op. amp. increases the sine-wave amplitude by a factor of 6.7 to provide sufficient signal for the multiplier circuit.

Sweep-control. Maximum and minimum frequency are set by the two ten-turn potentiometers, F_{max} and F_{min} shown in Fig. 12. Unity-gain amplifiers A_1 and A_2 buffer these voltages, and set them up at opposite ends of the ten-turn tuning control. In 'manual' mode, operating the tuning control will vary the v.c.o. control voltage between the voltages set up on the F_{max} and F_{min} pots. (Some care must be taken in operation that the F_{max} voltage is always greater than the F_{min} voltage.)

Amplifier A_6 reverses the sense of the sweep voltage so that an increase in frequency is caused by a positive-going "Horizontal Output" voltage. The rest of the sweep-control section generates a triangular wave that sweeps between the voltages set by the F_{max} and F_{min} controls. Amplifier A_3 is the integrator for the sweep oscillator, and A_4 and A_5 act as comparators to toggle the 7400 flip-flop whenever the sweep voltage reaches V_{max} and V_{min}.

The discrete-component amplifier driven by the 7400 flip-flop amplifies the t.t.l. signal to ±12V to drive the sweep direction indicator l.e.d. and the integrator.

Frequency counter. The heart of the frequency counter in Fig. 13 is the National 74C925, which contains four decade counters, latches, a display multiplexer, and a seven-segment decoder. Transistors Tr_1 to Tr_4 are the digit drivers for the common-cathode display which, in the author's instrument, was a surplus nine-digit integrated type, only four digits being used.

The gate for the frequency counter is provided by a 555 timer, which, although possessing a time accuracy of only about 1%, is satisfactory for this circuit as a replacement for a dial indicator.

Signetics 8162 monostables provide the proper timing signals to latch and clear the counter in the manner shown in the timing diagram of Fig. 14. The 'gate time' switch sets the period of counting to 1.0 or 0.1 seconds. A second contact on this switch causes Tr_5 to select the proper decimal point for the display.

Power supply. The power supply is conventional. Integrated circuit regulators — National LM326 and Fairchild 7805 — generate the required voltages. To avoid noise and oscillation problems the sections of the spectrum analyser should be wired separately, as in Fig. 16.

Logarithmic sweep

The frequency scale in the instrument was chosen to be linear to show more clearly the relationship between harmonics of a periodic waveform. In practice, a logarithmic scale of frequency may be more useful. Fig. 17 shows how the local oscillator may be modified for a logarithmic frequency scale. Transistors Tr_1 and Tr_2 are the 8038 current sources which charge and discharge the timing capacitor. The

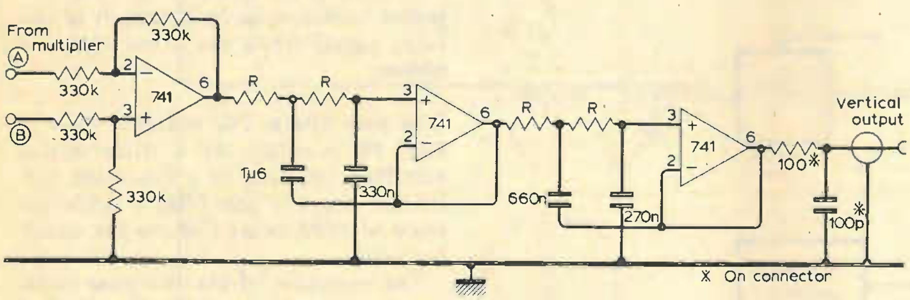


Fig. 10. Low-pass filter. The resistors shown as R are switched, and for bandwidths of 10, 20. 50, 100, 200, 500 Hz should be 72k, 36k, 15k, 7.2k, 3.6k and 1.3k.

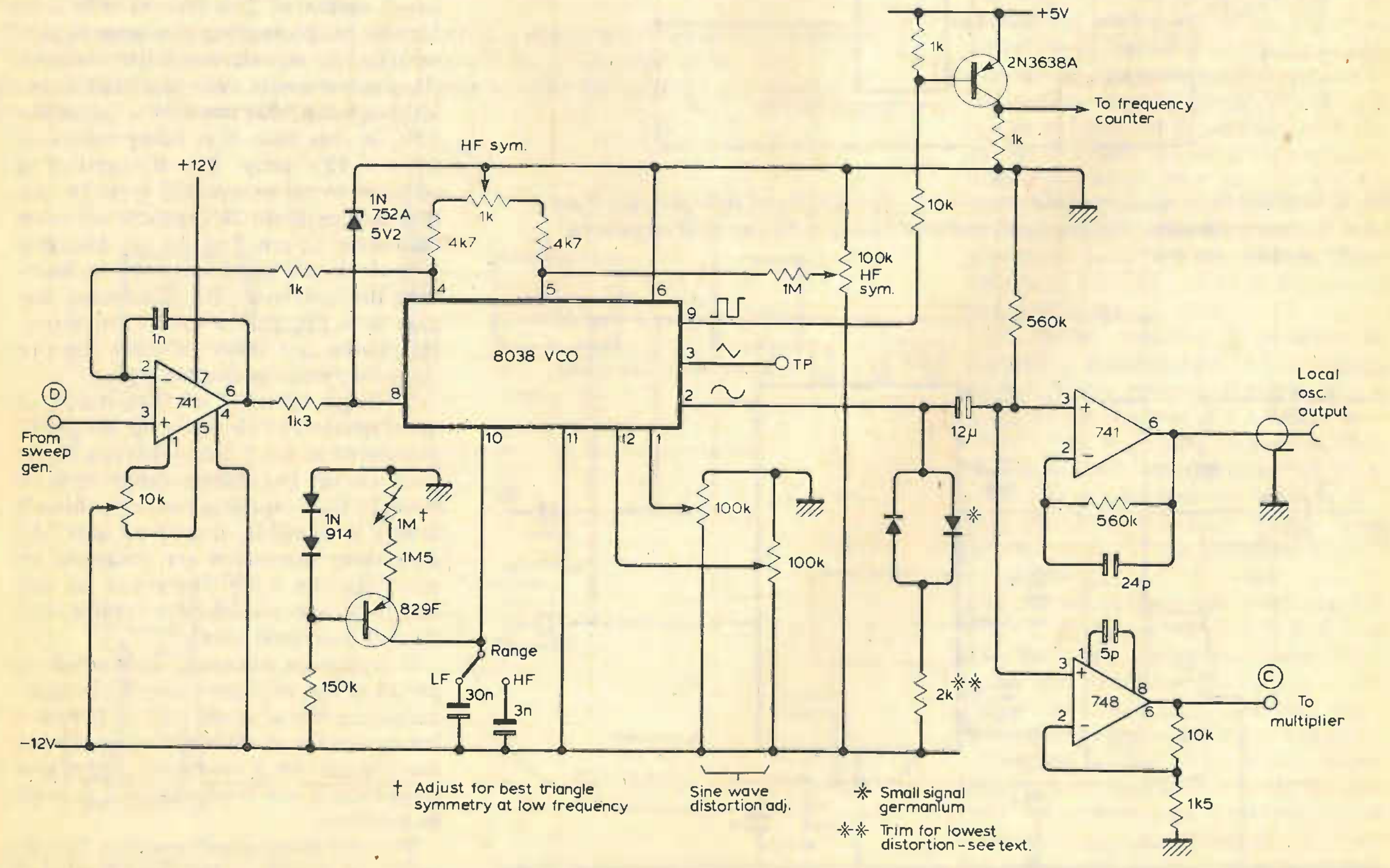


Fig. 11. Local oscillator circuit diagram.

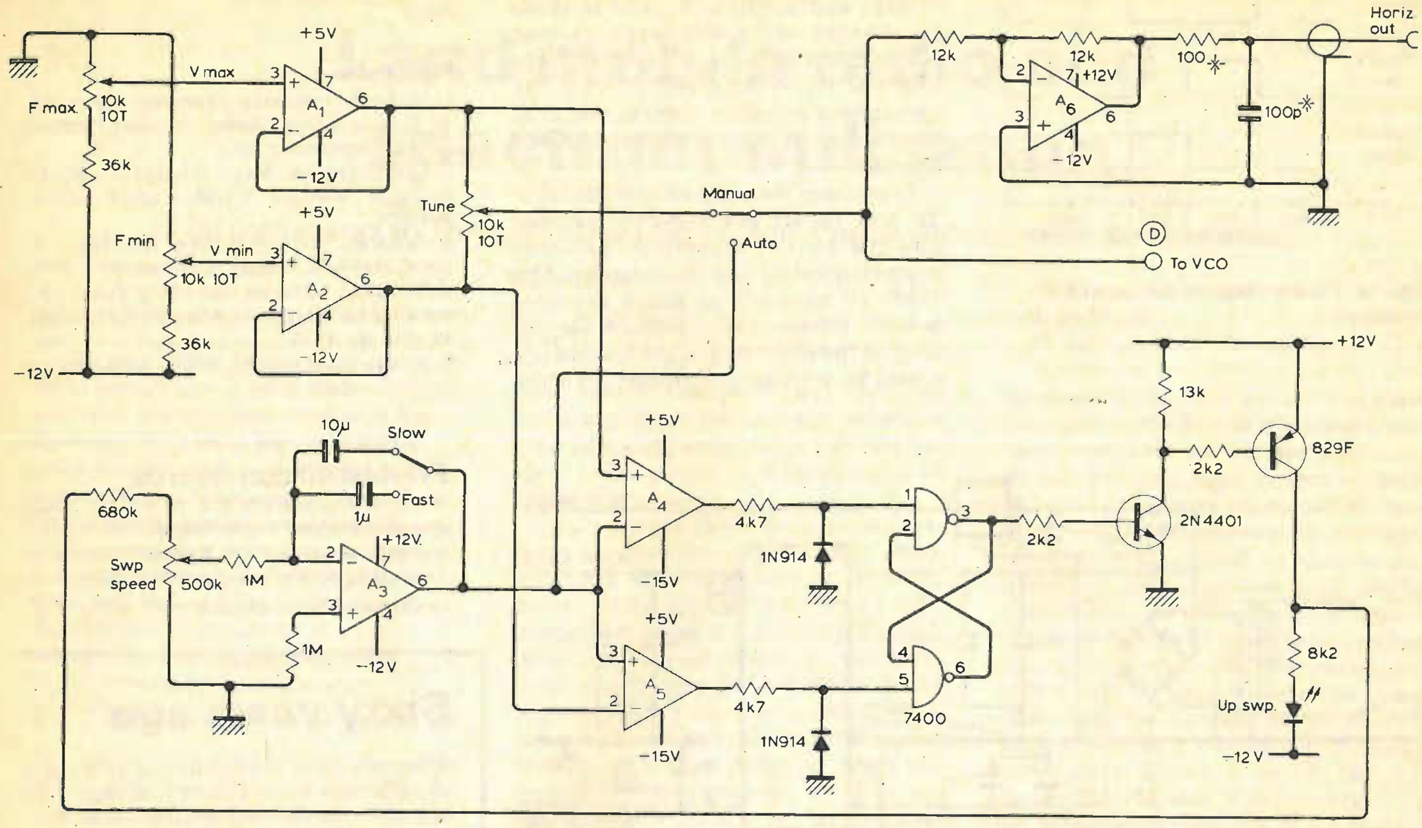


Fig. 12. Sweep control section. Components marked with asterisk are mounted on connector.

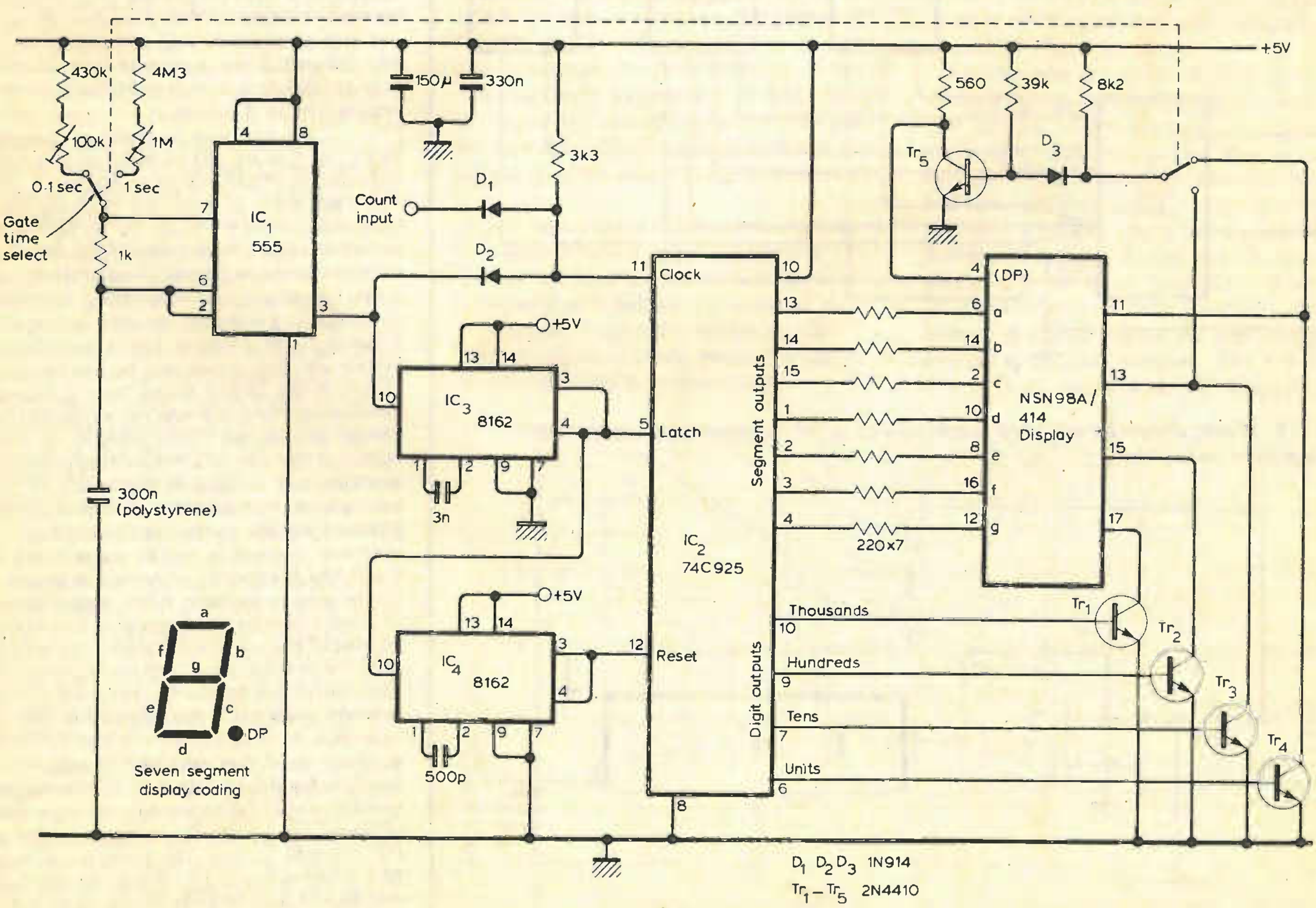


Fig. 13. Frequency counter and display. Author used a surplus National Semiconductor display module in his prototype. A multiplexed, common-cathode type is needed. An error: pins 6, 7, 9, 10 are transposed; pin 10 should be "units".

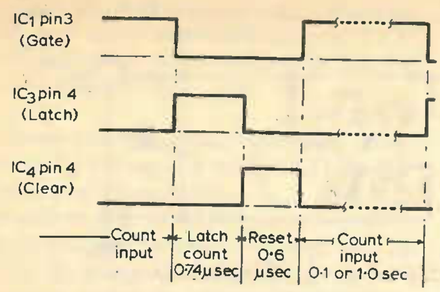


Fig. 14. Timing diagram for counter operation.

exponential relationship between base voltage and collector current in these transistors will provide the desired relationship between control voltage and oscillator frequency. The 741 operational amplifier reduces the control voltage swing at pin 8 to the desired amount.

In practice, the base-emitter diodes of Tr_1 and Tr_2 are not perfectly matched and the output waveform becomes asymmetrical at low frequencies. The 10kΩ/2Ω network at pin 4 provides suitable compensation voltage. Depending on the mismatch of the transistors, it may be necessary to ground pin 4 and connect the compensation network to pin 5.

References

1. 'A Low Frequency Spectrum Analyser', W. L. Hale & G. E. Weibel, *Hewlett Packard Journal*, September 1973.
2. 'Inexpensive Wave Analyser', M. G. Scroggie, *Wireless World*, August 1955 p. 360-365.
3. 'Separate the Signals from the Noise', T. Cate, *Electronic Design* 25, December 6, 1970.
4. 'Modified Function Generator Yields Linear VCO', A. Tagliavini, *Electronics*, October 30, 1975 pp. 96, 97.
5. Compensation of 8038, *Polyphony*, November 1977, p. 28.

Printed circuit boards

A set of single sided p.c.b.s for the audio spectrum analyzer will be available for £10.50 including v.a.t. and UK postage from M. R. Sagin at 23 Keyes Road, London N.W.2. □

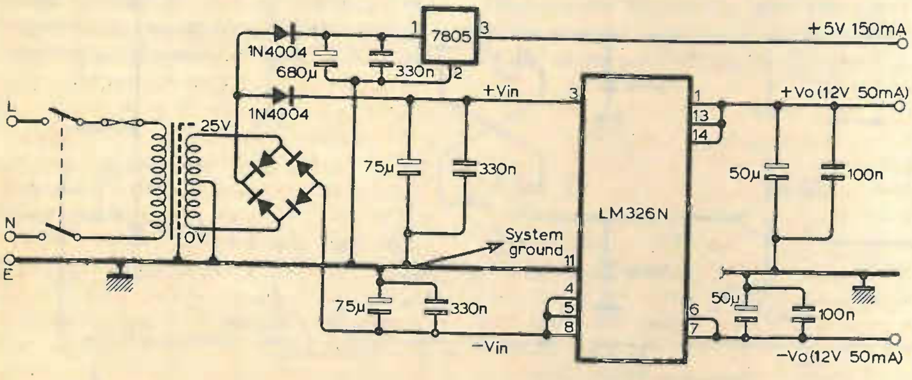


Fig. 15. Power supply circuit.

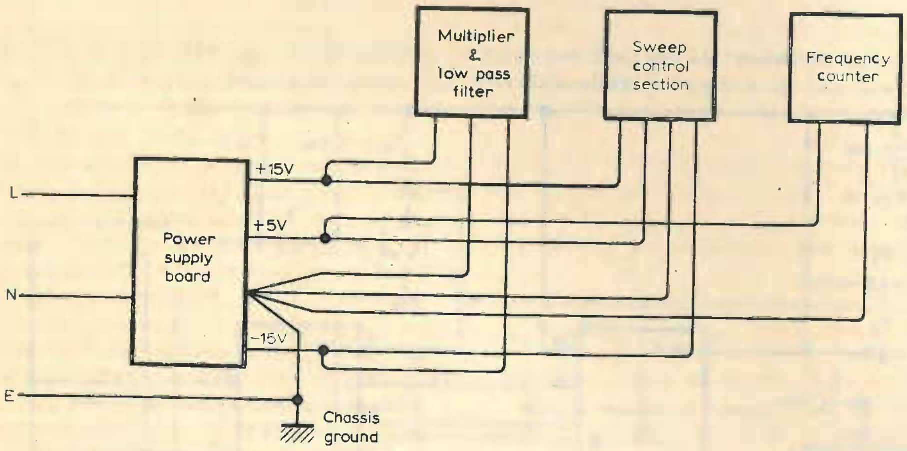


Fig. 16. Wiring should be arranged in this way to avoid common impedances and consequent instability.

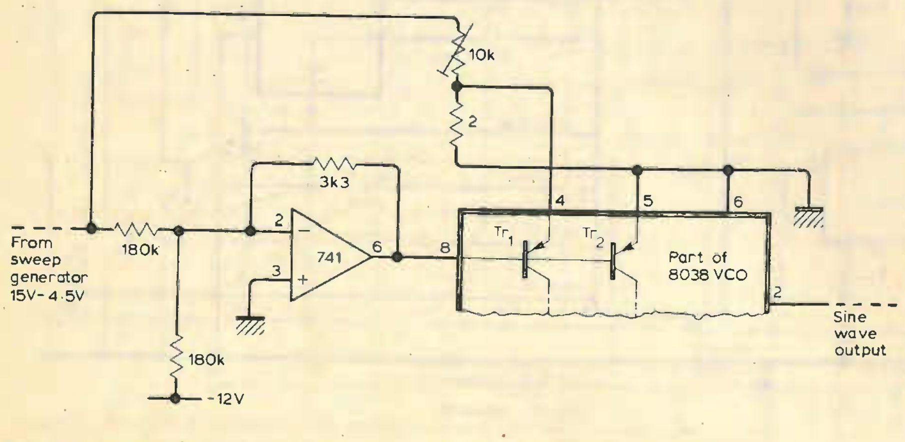


Fig. 17. Modified in this way, the local oscillator of Fig. 11 will provide a logarithmic frequency sweep.

Sixty years ago

There are several reasons for printing a monthly piece entitled 'Sixty Years Ago'. One can pick out the first mention of a well-known effect or piece of equipment; sometimes the writing itself can be funny, as in some of the replies to queries ("We advise you to take up some other pastime"); occasionally a historical event is mentioned — the outbreak of war perhaps. But the most interesting are the prophecies, most of which are wildly inaccurate. Every so often, though, one sees someone having a 'blinding flash', and just such a one appeared in the issue for May 15, 1920, in an article on research for the amateur, by W. T. Ditcham.

" . . . . . the query as to whether a simple rectifying contact can be made to generate oscillations of suitable characteristics, and there are good grounds for thinking that such is probably the case. Dr W. H. Eccles some years ago demonstrated the production of oscillations by a galena contact, though at what frequency and amplitude, or what constancy, I am not aware, and quite recently G. W. Pickard, the American experimenter, has stated that he has received signals in the United States from European continuous wave stations on an oscillating crystal heterodyne. There seem to be difficulties in the way of a practical application, probably due to lack of continuity of the oscillations, but such results having been obtained, we are encouraged to hope that a practical solution is within the bounds of possibility. If a crystal or crystal combination can be used to oscillate, it can probably also be made to amplify, and one gets a futuristic glimpse of cascade crystal amplifiers, which, if they ever materialise, will quickly relegate valve receivers to the background for all ordinary purposes. I can think of no line of research more suitable for the average amateur than this one, as the apparatus requisite for the experiments need be of the simplest, and the phenomena met with would probably fall within the comprehension of the scientific novice. The investigator who first achieves success in this particular field may feel assured of an enduring niche in the wireless Hall of Fame, and the acquirement of a fair quantity of less enduring, but nevertheless perfectly good, lucre."

Land mobile radio and spectrum utilisation

Introduction to the possible use of wideband modulation techniques

by **P. A. Matthews** B.Sc.(Eng.), Ph.D., F.I.E.E., M.I.E.E.E.
Department of Electrical and Electronic Engineering, University of Leeds

With conventional modulation methods the spectrum available for land mobile radio is insufficient to meet the demand. In this article the author first outlines the propagation problems in communicating with moving vehicles then discusses the number of users possible in a given area; and finally goes on to consider the possibility of using wideband modulation such as in the various spread spectrum techniques.

The conventional method of providing radio communication to vehicles on land is to use either a.m. or f.m. radio operating at v.h.f. or u.h.f. In general the number of channels available is insufficient to meet the demand from users or potential users of these systems.

Most signals for communicating to vehicles use a base station with antennas at a high point to cover the area to be served. The antennas on the vehicles are, however, close to the ground and it is unusual for there to be a clear line of sight between the base station and the vehicle antennas. The signal suffers from reflection at the ground, reflection from buildings, diffraction over hills and diffraction around buildings. As a vehicle drives along the road, the variation in signal strength can be divided into three parts. Firstly, as the radial distance between transmitter and receiver increases there is an increase in spatial attenuation. For this type of path, the median received power falls approximately as the fourth power of the distance between transmitter and receiver. This variation in median power level can be compared with the square law variation expected in free space.

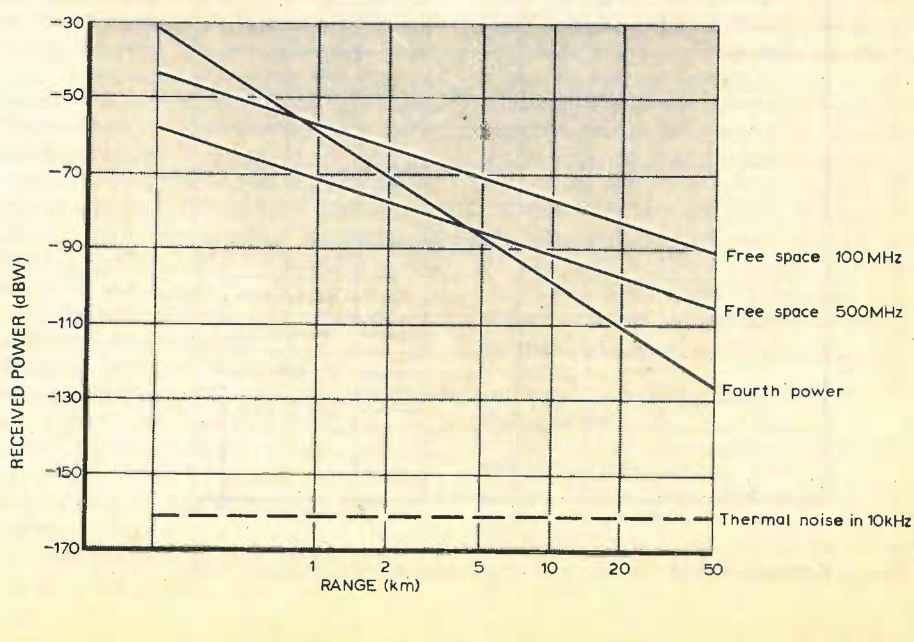
The median power level falls much more rapidly on a mobile radio path than, for example, in a line-of-sight radio relay system. The variation in power with distance is illustrated in Fig. 1. This is drawn for a transmitter power of 10W, a half wavelength dipole antenna at the transmitter, a transmitter height of 100 metres, a receiver height of 2 metres and a quarter wavelength monopole at the receiver. It is assumed that the antennas have the gains expected of ideal antennas of these lengths and that there are no circuit losses in the system. The fourth power law is independent of frequency, but the free space variation depends on frequency when the antenna gains are constant. To provide reference level the ideal noise power in a bandwidth of 10kHz is shown.

These curves show that, as the distance increases from 1km to 10km, there will be a 40dB decrease in received power. It also appears that using a 10W transmitter there is a good margin between the received power and the noise level which may be expected in the receiver. If we assume a receiver i.f. bandwidth of 10kHz and a noise figure of 6dB, then at a range of 20km the margin is 45db. However, we have not yet taken into account the fluctuations in received power due to diffraction and reflection.

Because vehicles have to follow the roads the path between transmitter and receiver will be obscured by hills and buildings. When the vehicle is in the shadow areas, a signal may be received by diffraction over the hills or around the buildings. Such diffraction effects are relatively insensitive to frequency and over any one of the bands allocated for mobile radio the attenuation of the signal due to shadowing is relatively constant for any one path. For a particular path the effect of shadowing may be calculated. However, when designing a mobile radio system we want to know the fluctuations which may occur due to shadowing as a vehicle moves from one point to another and these fluctuations are best described by a probability distribution which shows the probability of a certain shadow attenuation occurring. Measurements taken over a large number of sites[1] show that the distribution of shadow fading follows a log-normal distribution. This is shown in Fig. 2. The log-normal distribution is characterised by the standard deviation σ in dB and for different areas and frequencies the value of σ may change. However, typical values for σ seem to lie between 6 and 12 dB. Taking the curve for σ=6dB, we can see that an attenuation of more than 14dB can be expected at 1% of sites, or for a vehicle travelling along a road for 1% of the time.

Besides the attenuation due to shadowing, there is also fading caused by the phase interference of signals arriving by different paths. This occurs because signals can be reflected from buildings giving a signal at the receiving antenna which is the phasor sum of a number of signals. As the vehicle moves along the road the path lengths between transmitter and receiver for the various reflected components of the signals vary in a random manner. The vehicle has only to move a short distance in

Fig. 1. Variation in mean received power in a mobile radio system with fourth power law dependence on distance compared with square law variation in free space. Transmitter power is 10W; antenna gains 2-15dB; antenna heights, transmitter 100m, receiver 2m.



terms of the wavelength for the phasor sum to vary completely. This combination of random phasors leads to a Rayleigh distribution for the probability distribution of the amplitude of the received signal. Because the signal amplitude depends on variations in distance of a fraction of a wavelength this kind of fading is frequency sensitive and the fading pattern measured for two adjacent frequencies can be completely different. As a vehicle moves along a road this phase interference gives a rapid fading which is superimposed on the shadow fading. For the Rayleigh distribution an attenuation of 28dB can be expected for 1% of sites or 1% of the time.

Because of the combined effects of shadowing and the rapid fading due to reflection, the probability distribution for the received signal depends on the combination of the two individual distributions. The derivation of the expressions for the probability distributions has been given by French[2]. The result is shown in Fig. 2 for two different values for the standard deviation σ of the shadow fading. These curves show that at 1% of sites and with $\sigma = 6$dB, an attenuation of 24dB or more may be expected. Thus the median margin above noise of 45dB is reduced to only 21dB for 1% of sites. The actual margin required depends on the type of modulation used and the output signal/noise ratio required. For example for a s.s.b. transmission the output s.n.r. is the same as the input s.n.r. Assuming a 5kHz i.f. bandwidth, a required output s.n.r. of 10dB and a 99% probability of reception Fig. 3 shows a range of 36km. For f.m. with a 10kHz i.f. bandwidth and assuming no noise improvement the corresponding range is 25km.

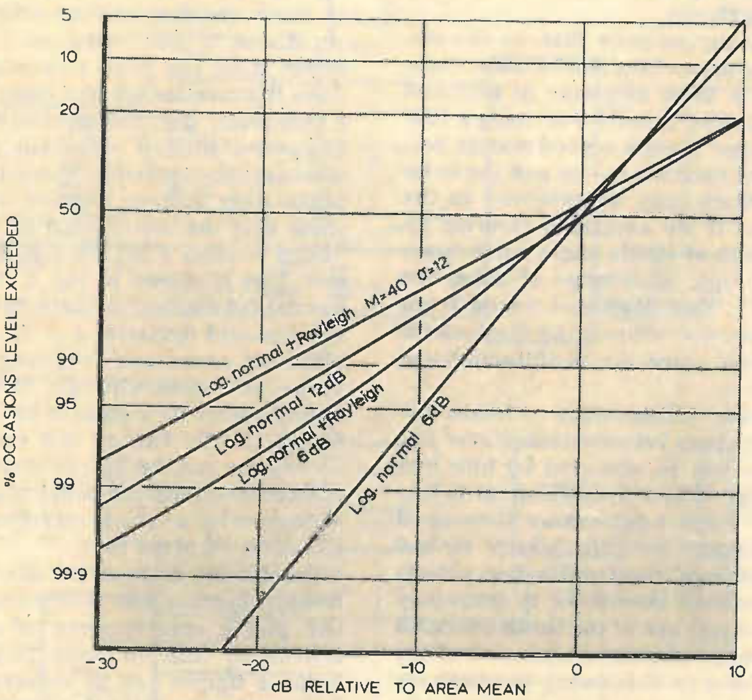


Fig. 2. Fading levels for log-normal shadow fading and long-normal plus Rayleigh fading. Area mean given by fourth power law variation.

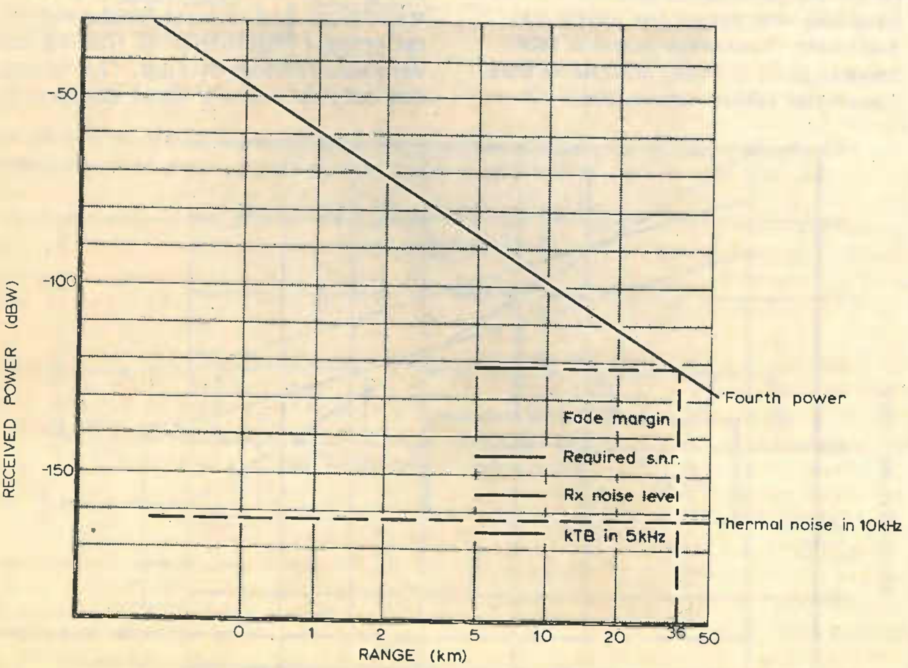


Fig. 3. Estimation of range for s.s.b. system taking into account fading.

Area cover and number of users

If an isolated area is served by one base-station the problem of fading can in principle be overcome by increasing the transmitter powers. However, there are practical limits to the power of mobile transmitters and problems caused by intermodulation of signals. In the isolated area, the number of users is limited by the number of channels available.

In practice the radio transmissions are not confined to an isolated area and interference is likely between users of the same channel in adjacent areas. To limit the effect of interference there must be sufficient distance between transmitters using the same frequency for the probability of interference to be below some low limit. If the radius served by a given transmitter is r_1, and the distance between transmitters using the same frequency is r_2, then over a large area that frequency can only be used for a fraction of the total area. The total area can be divided into cells and the total number of channels divided into groups shared between the cells. If the ratio of the distances (r_2/r_1) is called the re-use distance D then the number of groups of frequencies, C, is given by $C = D^2/3$. To find the re-use distance the probability of interference occurring must take into account the probability of fading of the wanted transmission, whilst the interfering signal may not have faded. The result is that the re-use distances may be large, and hence the number of groups large. Because the re-use distance is a ratio of distances, the number of groups is independent of the actual area, provided all the cells are within the same radio horizon distance.

Calculations of re-use distance presented in (2) show that taking into account both shadow fading and phase interference fading, the available channels may have to be divided into large numbers of groups. For example, for a probability of interference of not more than 3%, f.m. with 25kHz spacing may require 57 groups and s.s.b. 133 groups. Considering a 10MHz bandwidth, the f.m. system with a channel spacing of 5kHz would give 15 channels per group. Thus, in any one particular area the number of channels which can be used is severely limited when the problem of mutual interference is taken into account.

Because the number of groups and cells is independent of their area, the number of users in a given physical area can be increased if the area covered by each cell is limited. This implies using a large number of cells with low power transmitters in each cell. However, such a system produces problems when a call has to be made over a distance spanning several cells. Direct communication is not possible and a relay system must be set up to transfer calls from one cell to another.

Wideband modulation

So far this discussion has considered f.m. or s.s.b. transmission, and it has shown that when interference between transmissions on the same frequency is taken into account the number of users/MHz in a given area is limited to a small number. We need to consider whether other modulation techniques can accommodate more users. A class of modulation techniques which should be considered are the various spread spectrum techniques[3].

The use of wideband spread spectrum techniques has generally been ruled out for mobile radio systems because of its apparently extravagant use of the r.f. bandwidth. In a spread spectrum system the available power may be spread over a bandwidth of possibly tens of megahertz, either by modulating a conventional transmission by a noise-like wideband signal or by hopping the carrier frequency over the band. At the receiver, the original transmission is recovered by taking advantage of known properties of the wideband noise-like signal or of the hopping pattern. In both cases the s.n.r. for the wanted signal is raised relative to that of unwanted signals by the ratio: the bandwidth of the wideband signal to that of the narrow band signal. This so-called processing gain G_p improves the s.n.r. for the wanted signal, and at the same time gives the interfering signals a noise-like property. The processing gain also depends on the cross-correlation between the wanted and unwanted signals. Ideally, there should be no cross-correlation.

If a given band is to be shared by a number of users then the information from each user must be spread in a manner which is unique to that user, and in a way which produces a wideband signal which is uncorrelated with the signals from other users. The methods by which the spreading process can be carried are described by Dixon.[3] So far as a particular wanted signal is concerned, the signals from other users are noise. As the number of users increases the noise level in the band rises. If each of the transmissions produces the same power at a receiver then the s.n.r. after recovering a particular signal can be estimated. Suppose there are N transmissions, all covering the same band. Then there is 1 wanted transmission and $(N-1)$ unwanted transmissions. At the receiver antenna the s.n.r. is $1/(N-1)$, but after processing with a processing gain G_p, the s.n.r. becomes $R = G_p/(N-1)$. This gives $N = 1 + (G_p/R)$, which is plotted in Fig. 4 for various values of processing gain and output s.n.r. For example, if the required value of R = 16dB in a 5kHz bandwidth and the spread bandwidth is 10MHz, then G_p = 33dB and N = 50. It appears that 50 users could be accommodated in the 10MHz bandwidth. However, this is on the assumption that each transmission produces the same power at the receiver.

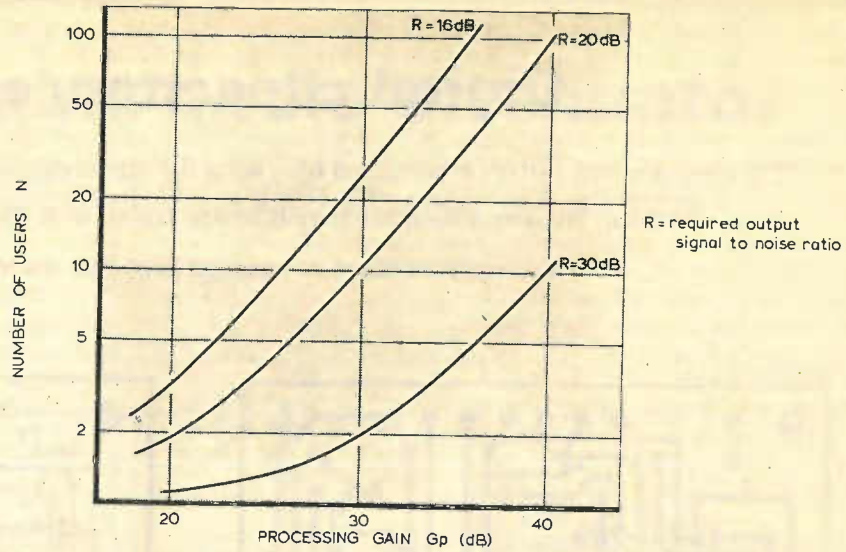


Fig. 4. Number of users in a spread spectrum system as a function of processing gain and required output signal-to-noise ratio.

Clearly this requirement for equal power levels cannot be achieved if all the transmitters on the vehicle radiate the same power because the vehicles will be at different distances from any given receiver. However, for transmission to a common base station it may be possible to control the power transmitted from the mobiles to give equal powers at the base station receiver. Because of the variability in the path loss between transmitter and receiver due to distance and shadowing, control of power must be carried out by measuring the path loss in some way. This may be possible by using the signal received at the mobile from the base station to control the level of transmission back to the base station.

With a wideband signal the effects of fading will be different from the effect on a narrow band signal. The effect of shadow fading which is relatively insensitive to frequency may be expected to be the same in both cases. The effect of phase interference fading will be different because this kind of fading depends strongly on the frequency or wavelength used. A narrow band signal suffers from deep fading because of the cancellation of the signal due to the phasor sum of the signals arriving by different paths summing to zero. On an adjacent frequency the phasor sum may reach a maximum. The effect on a wideband signal will be to distort the signal spectrum in amplitude and phase. The problem then is whether the wanted signal can be recovered from the energy in the distorted spectrum.

For transmission from mobiles to a common base station it seems that it may be possible to use wideband transmissions. Power control of the transmissions is necessary and must be based on the measured path loss. The measured path loss will compensate for the attenuation due to both distance and shadow fading provided the dynamic range of the system is great enough. The effects of phase interference fading have to be worked out in detail, but provided the signal can be recovered from the energy available it appears that wideband modulation techniques may provide at least as much system capacity as narrow band schemes.

This problem of recovery of the signal will differ depending on whether a noise-like wideband signal or a frequency hopping scheme is used. In a frequency hopping scheme the signal at any one time is a narrow band signal on a particular frequency. Even if the effect of shadow fading is removed by controlling the mean power level the particular frequency component at any one time may be reduced due to phase interference fading. This may be overcome by using several frequencies simultaneously, but this will reduce the number of users in inverse proportion to the number of frequencies used for a particular user. For noise-like signals the effect of distortion of the signal spectrum is to reduce the output s.n.r. To maintain a given output s.n.r. the number of users must be reduced. The reduction in number of users has yet to be calculated or measured.

References

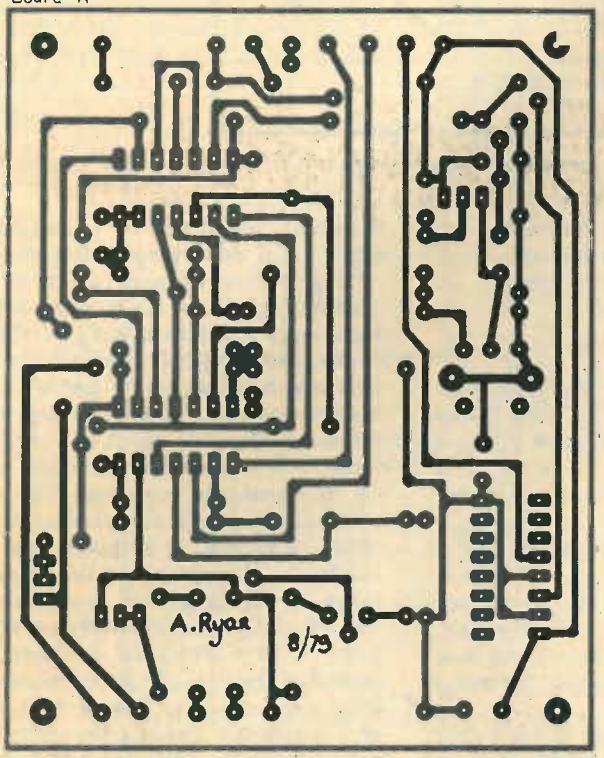
1. W. C. Jakes, Ed. Microwave Mobile Communication, Wiley, 1974, pp. 79-131.
2. R. C. French. "The effect of fading and shadowing on channel reuse in mobile radio," *IEE Trans. VT-28*, 1979, pp. 171-181.
3. R. C. Dixon. Spread Spectrum Systems, Wiley, 1976.

Digital capacitance meter

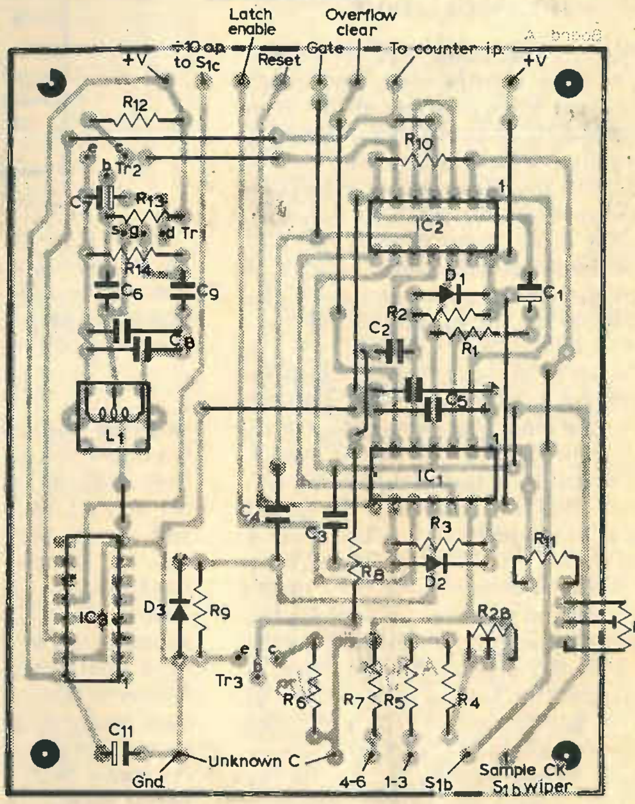
The printed-board pattern reproduced here is for the digital capacitance meter described in our April issue. There was no space to publish the layout with the article and, regrettably, we neglected to say it was held over. The drawings are full size.

Copper side

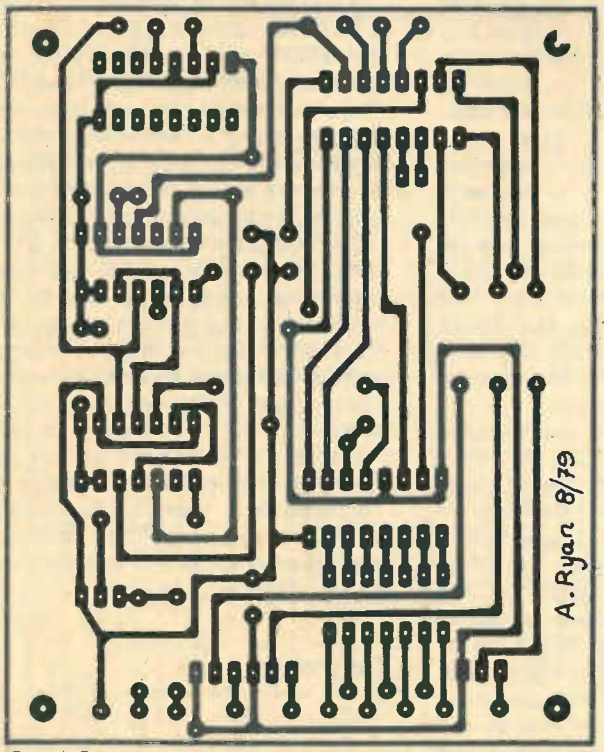
Board A

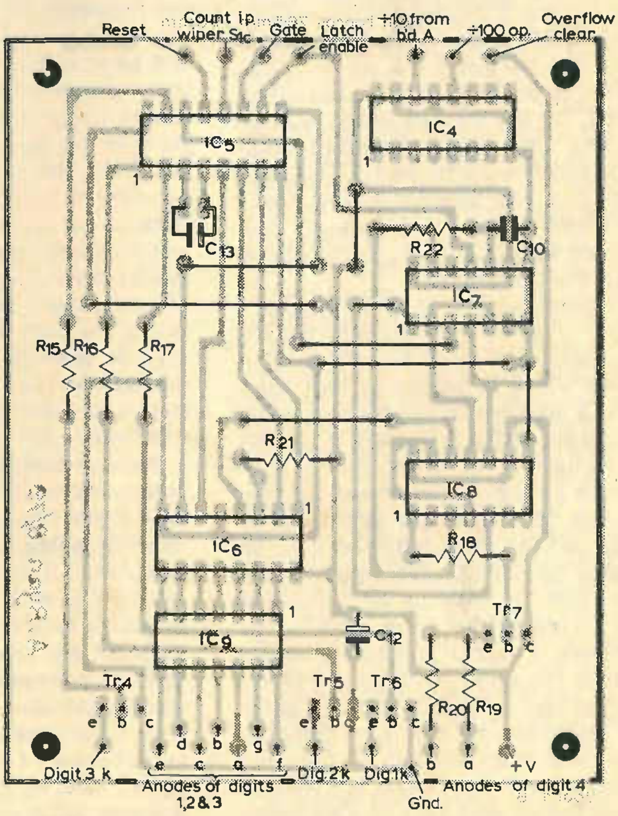


Component side



Both boards 78·5mm x 98mm





Board B

Programmable audio attenuator

Gain controlled line amplifier offers a 60 dB range in 1 dB steps

by J. M. Didden

After experimenting with various linear gain control systems, the author chose a combination of linear and logic circuits to provide a high quality audio attenuator. The final design uses a 6-bit word to program the gain, and can be used for remote control applications or, with the aid of a microprocessor, for automatic level control.

This circuit was originally designed to remotely control the volume and balance in a stereo system. Several methods were tried, such as the two-quadrant multiplier in Fig.1. However, this circuit suffered from high distortion for input levels of more than 100mV, and tracking between units was poor. Attempts to improve the performance with current-source loading did not significantly improve the performance. A f.e.t. used as a voltage controlled resistor produced similar problems, so a l.d.r. design was tried as shown in Fig.2.

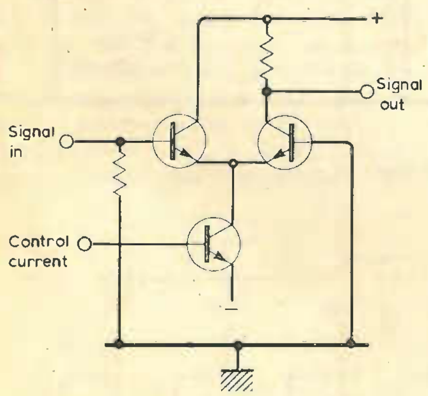


Fig. 1 Basic two-quadrant multiplier.

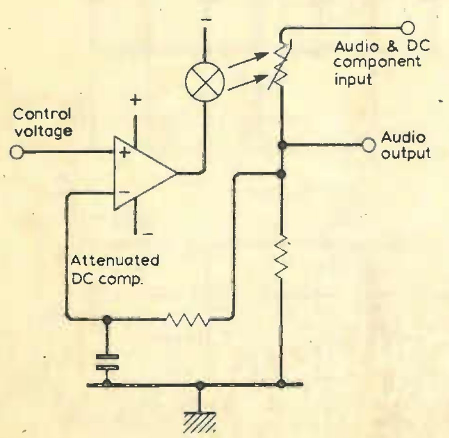


Fig. 2 Closed-loop light dependent resistor attenuator.

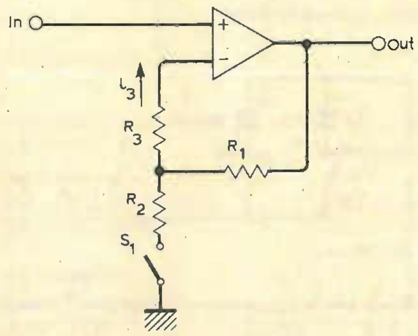


Fig. 3 Basic gain switching circuit.

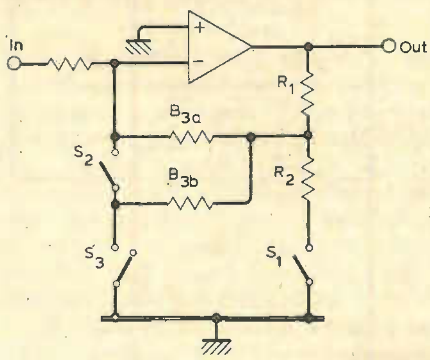


Fig. 4 Extended circuit with two independent switches.

This circuit had a good signal level capability, and tracking between units was made almost perfect by using a compound audio plus d.c. input. The attenuated d.c. was fed back to the control circuit. Unfortunately, the l.d.r. produced high noise levels at medium to high attenuation, and control-loop stability was difficult to achieve. Because these analogue approaches did not produce the performance required, I investigated gain switching with f.e.ts. Although f.e.ts are nonlinear, this is not a problem if the signal voltage across a closed switch is very small. A basic circuit is shown in Fig.3. When f.e.t. S_1 is closed, the signal across it equals the input voltage times the ratio of the f.e.t. on resistance to R_2. In practice, ratios of 1/1000 are easily obtained, so a signal level of several volts, which is not uncommon in a line amplifier, produces only a few millivolts across the switch. At these levels the f.e.t. is almost perfectly linear. Two independent gain settings can be achieved by switching R_3 and keeping I_3 constant. With S_2 closed and S_3 open in Fig.4, R_{3a} and R_{3b} are connected from R_1 to the virtual earth of the op-amp. With S_2 open and S_3 closed, R_{3b} is connected to the real earth. Therefore, by using a s.p.d.t. switch for S_2 S_3, and a s.p.s.t. for S_1, four gain settings are possible.

An extension of this circuit is shown in Fig. 5 where, with S_5 closed and S_4 open, gain is determined by the ratio of R_5 to R_1. With S_5 open and S_4 closed, the gain is determined by the ratio of R_5 to R_1 and R_3 to R_4. Combining the circuits in Fig. 4 and Fig. 5 gives eight gain settings. For all of these configurations the switches have only a small signal across their on resistance and carry very little current when opened. The values of the series resistors are high compared with the off resistance.

Selection of a suitable f.e.t. presented some problems. Switch arrays for analogue applications are available, but are generally expensive. Analogue multiplexers, such as the 4051, contain eight c.m.o.s. switches with a common input and integral one-of-eight decoder for control by a 3-bit word. However, the switching produces spikes on the audio output due to an internal capacitive coupling of the control signal to the switch terminals. This can be minimised by loading the switch, but smaller resistors must then be used which consequently produces higher distortion levels. Although "soft" switching with a RC network is one solution, see Fig. 6,

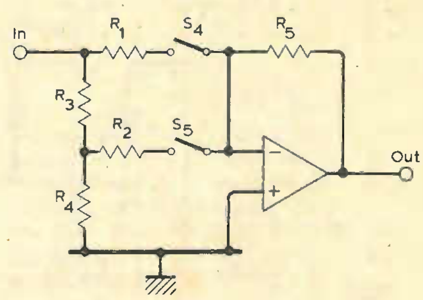


Fig. 5 Alternative two-switch circuit.

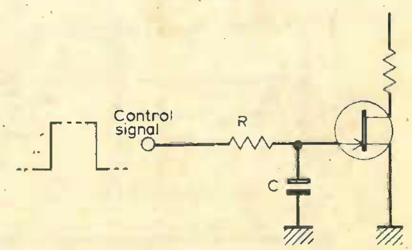


Fig. 6 Soft switching to overcome spikes.

the gate of the f.e.t. must be accessible. I finally decided to use the low cost 4007 which contains two s.p.d.t. switches and an inverter.

In practice, 1dB steps in gain produce a gradual change and a range of about 60dB is sufficient for most applications. Because high value series resistors are required, high attenuation can only be achieved with the circuit in Fig. 5. However, as shown in Fig. 7, if S_{1b} is closed and S_{1a} is open, a small current flows through the internal switch capacitance. At high attenuation and high signal frequencies, this current may not be insignificant and can cause an output that rises with frequency.

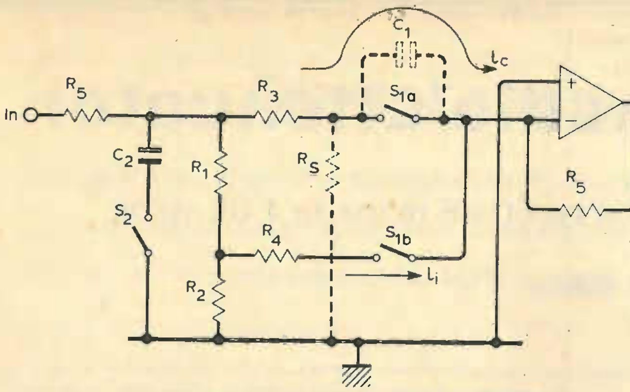


Fig. 7 Internal capacitance effect and compensation low-pass filter.

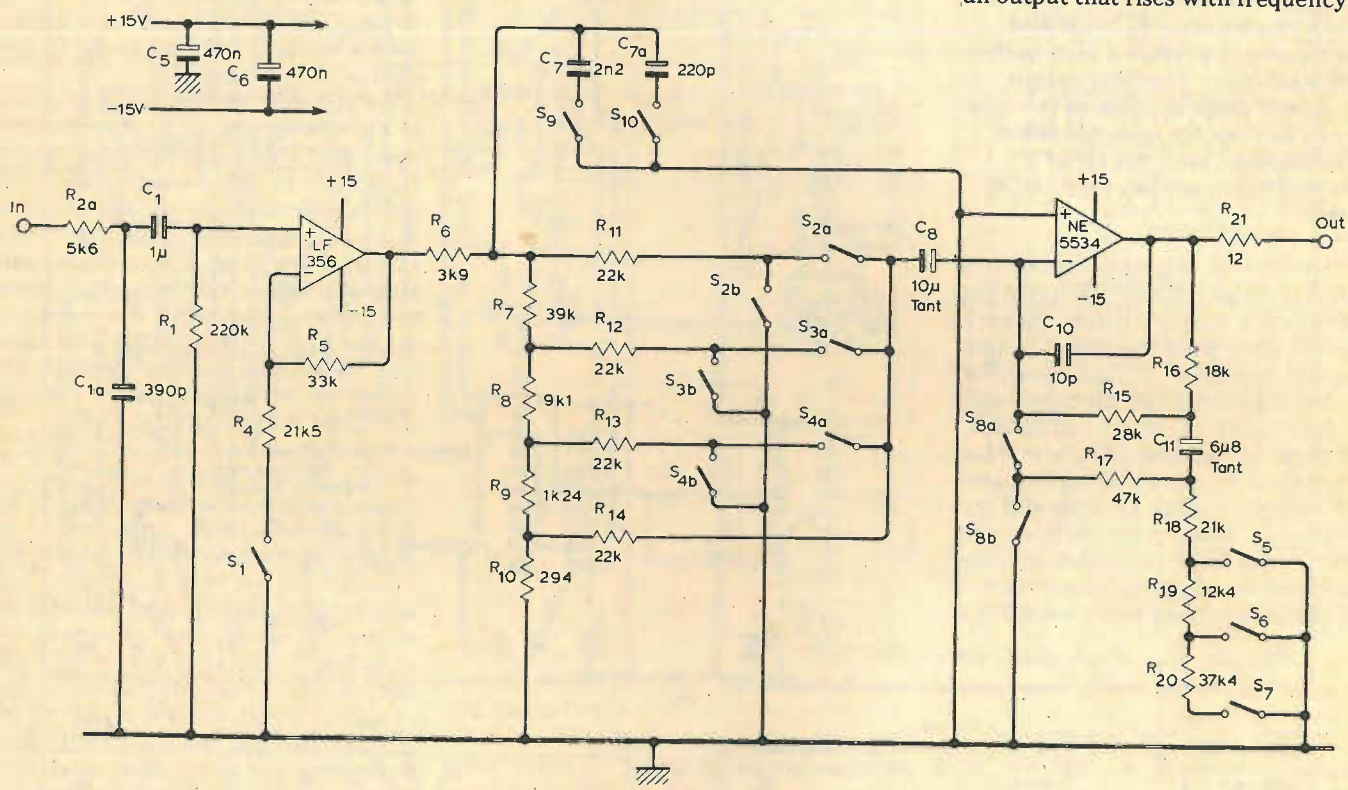


Fig. 8 Complete attenuator circuit for one channel. The switches are grouped in five i.cs as follows; S_5+S_6, S_7+S_{8ab}; $S_{2ab}+S_{3ab}$, $S_{4ab}+S_1$ and S_9+S_{10}. All resistors should be 1%.

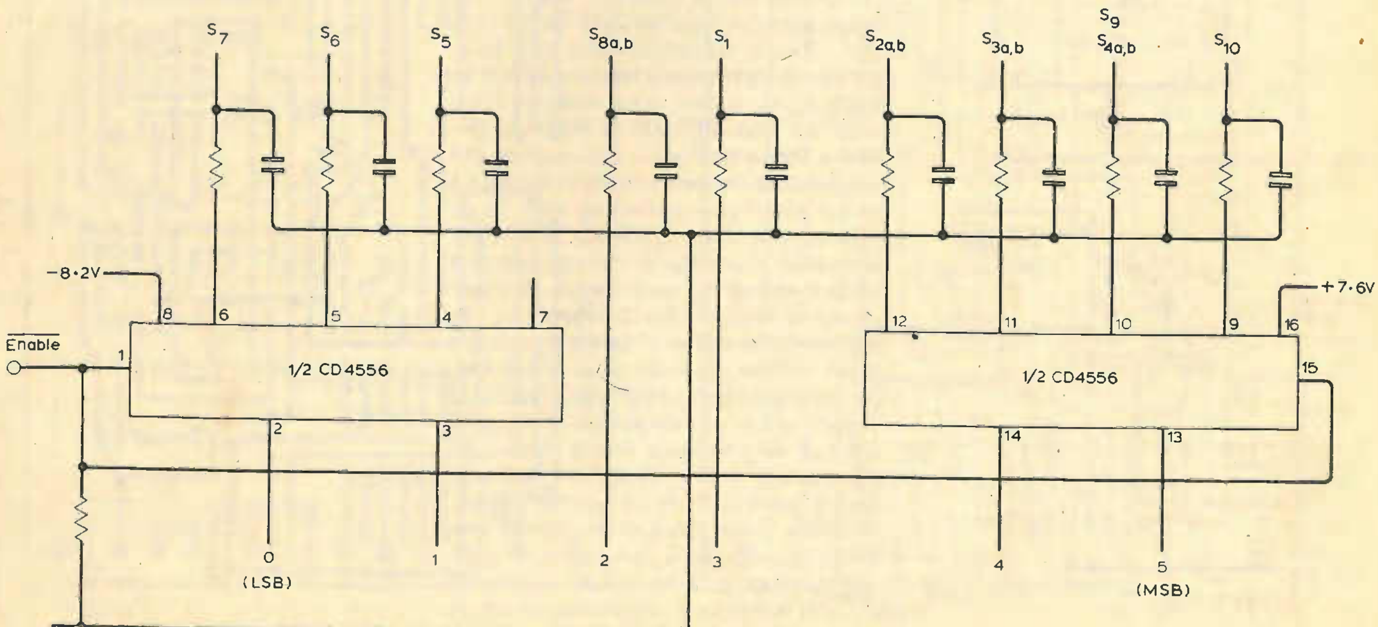


Fig. 9 Control-word decoder and soft switching for one channel. All resistors are 1MΩ and all capacitors are 1.8 nF.

This problem can be overcome by grounding the left terminal of S_1 when it is open, and this is easily achieved with the 4007 s.p.d.t. switches. Because there is an on resistance, R_s, a small signal voltage remains across the open switch. The low-pass filter R_5 C_2 compensates for this with S_2 closed when S_{1b} is closed and S_{1a} is open. The frequency response is flat within 0.3 dB up to 25 kHz and at high attenuation. Fig. 8 shows the final circuit for one channel and table 1 shows the range of attenuation levels. Ten mixed s.p.s.t. and s.p.d.t. switches are required and these can be produced with five 4007 i.cs. It is important that the signal amplitudes across S_1, S_8, S_5, S_6 and S_7 do not exceed the positive or negative supply voltages because an internal protection diode will conduct and cause distortion. As audio signals are bipolar, the supply voltage should be centered around ground because one side of the open switches is always connected to either a signal ground or virtual earth. To balance the on resistances of the p and n-channel m.o.s.f.e.ts, a positive supply of 7.6V and a negative supply of 8.2V is used. In Fig. 8, S_1 and $S_{8a,b}$ can be controlled by a single bit. Switches S_{2a} to S_{4b} and S_5 to S_7 require the four decoded values of a 2-bit control word. This is carried out by a 4556, which containes two one-of-four decoders, see Fig. 9.

Selection of the switch-network resistors is a compromise as already explained. The typical on resistance of a switch is about 300Ω and the maximum variation is about 200Ω. With a series resistor of 22kΩ 1%, this is comparable with the switch tolerance. Calculations for the resistor values are given in the appendix. Fig. 8 also shows that some switches are capacitor-coupled to the circuit by C_8 and C_{11}. These remove a small output offset-voltage change with gain which can be heard as clicks at low input signal levels.

The capacitor values have been chosen to give a low-frequency response to below 10Hz. A f.e.t. input op-amp, LF 356, is used to provide a high input impedance, wide bandwidth, high slew-rate and low distortion. A NE 5534 is used at the output because it can deliver a high output level into a 600Ω load with little distortion. With R_{21} and C_{10} to stabilize the op-amp, a 10nF load will not produce ringing or overshoot of a square-wave signal. The 5534 is also a low noise device, which is important, because most of the attenuation takes place at its input and this reduces the signal-to-noise ratio of the last stage. Performance parameters of the complete amplifier are shown in table 2. If a f.e.t. input selector switch is required, the LF 350 can be used in the inverting mode as shown in Fig. 10. The compensation capacitors, which may be necessary with other op-amps, are shown in Fig. 11.

If a visual indication of the attenuation is required, the control word can be converted to a two-digit b.c.d. output for driving a seven segment display.

To be continued

Table 1. Gain and switch settings

Attenuation steps dB	S_1	S_{2a}	S_{2b}	S_{3a}	S_{3b}	S_{4a}	S_{4b}	S_5	S_6	S_7	S_{8a}	S_{8b}
0								C	O	O		
1								O	C	O		
2								O	O	C		
3								O	O	O		
0											O	C
4											C	O
0	C											
8	O											
0		C	O	O	C	O	C					
16		O	C	C	O	O	C					
32		O	C	O	C	C	O					
48		O	C	O	C	O	C					

Table 2. Performance details of the attenuator

Max. r.m.s. output level	8.5V across 600Ω.
Max. input level	3.8V or 9V depending on S_1, provided max. output level is not exceeded.
Max. capacitive load	10 nF.
Frequency response	better than 10 Hz to 25 kHz within 1 dB.
Output noise level	at least 86 dB below 1 V r.m.s. at all gain settings (unweighted).
T.h.d. and i.m.	less than 0.03% and 0.02% respectively.
Gain	variable in 1 dB steps from 16.8 dB to —46.2 dB.

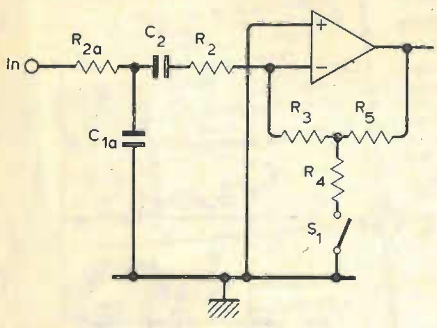


Fig. 10 Inverting input buffer.

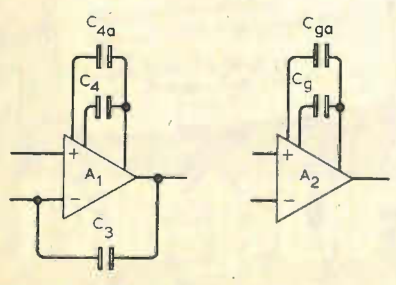


Fig. 11 Alternative compensation networks for other op-amps.

Appendix

Calculation of resistor values.

For these calculations a dB table or calculator with log. and inverse log. functions is required.

For the 1, 2 and 3 dB attenuators in Fig. 12, with S open,

$$i=\frac{U_{u1}}{R_l+R_f} \qquad (1)$$

for an output of U_{u1} volts. With S closed and an output of U_{u2} volts, the equivalent voltage source U_l is

$$U_{u2}\frac{R_x}{R_l+R_x} \qquad (2)$$

and the equivalent source resistor is

$$\frac{R_lR_x}{R_l+R_x} \qquad (3)$$

therefore,

$$i=U_{u2}\frac{R_x(R_l+R_f)}{R_lR_x+R_f(R_l+R_x)} \qquad (4)$$

Because i always equals i_s, equations (1) and (4) are equal. Substituting G for U_{u2}/U_{u1} gives

$$R_x=\frac{R_lR_f}{(G-1)R_l+R_f} \qquad (5)$$

The minimum resistor values for R_l and R_f, for a given G and R_x, are obtained if $R_l=R_f$. The minimum R_x is found for $G=3$ dB and, taking $R_x=20k\Omega$ as a design value, R_l and R_x are about 18kΩ. However, R_f is also part of the 4dB network, so this is calculated first using a R_f of 18kΩ.

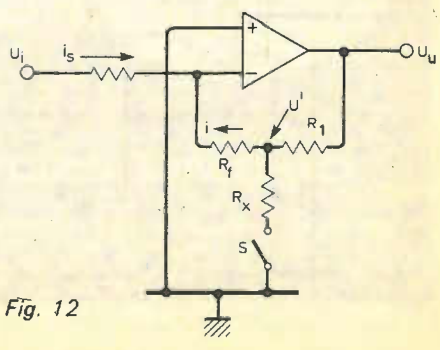


Fig. 12

The circuit is given in Fig. 13. If S_1 is closed and S_2 is open,

$$i=\frac{U_1}{R_1}+\frac{U_1}{R_2} \qquad (6)$$

With S_1 open and S_2 closed,

$$i=\frac{U_1}{R_1} \qquad (7)$$

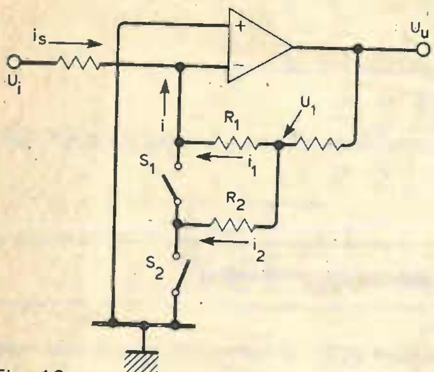


Fig. 13

As already mentioned, i_1, i_2 and U_1 are equal in both cases. In the first case, gain is the ratio of i_s to i_1+i_2, and in the second case, the ratio of i_s to i_1. The change in gain is therefore

$$G=\frac{i_1+i_2}{i_1} \qquad (8)$$

and equations (6), (7) and (8) give

$$R_1=R_2(G-1) \qquad (9)$$

and

$$R_2=\frac{R_1}{G-1} \qquad (10)$$

Substituting $R_1//R_2=18\text{k}\Omega$ in (10) gives

$$R_2=\frac{G.18\text{k}\Omega}{G-1} \qquad (11)$$

For $G=4\text{dB}$, R_2 is about 48kΩ. Using the standard value of 47kΩ and adding the nominal on resistance of the switch gives 47.3kΩ and R_1 becomes 27.6kΩ. With the nearest preferred values, R_{15} is 47kΩ and R_{17} is 28kΩ in Fig. 8.

The value of R_f in (5) now becomes 17.46 kΩ, i.e. $R_1//R_2$. The R_x values are calculated next.

For $G=1$ dB, R_x is 72.64 kΩ, which is the on resistance in Fig. 8. For $G=2$ dB, R_x is 34.23 kΩ which is $R_{18}+R_{19}+$ on resistance. For $G=3$ dB, R_x is 21.48 kΩ, i.e. $R_{18}+$ on resistance. With the nearest preferred value, R_{18} is 21 kΩ, R_{19} is 12.4 kΩ and R_{20} is 37.4 kΩ.

For the 8 dB switch refer to Fig. 14. With S open the gain is 0 dB, and with S closed the gain is R_1+R_x/R_x which gives

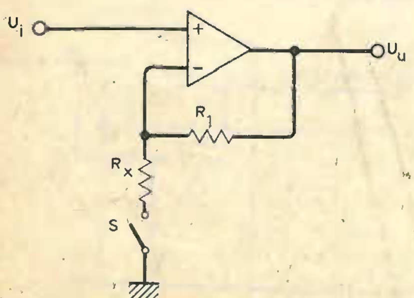


Fig. 14

$$R_x=\frac{R_1}{G-1} \qquad (12)$$

Choosing 33 kΩ for R_1 gives 21.83 kΩ for R_x. Subtracting the 300Ω on resistance gives a standard value for R_4 in Fig. 8 of 21.5 kΩ and 33 kΩ for R_5.

Calculations for the remaining switch network are more difficult because the series resistors are either connected to ground or to virtual earth, see the equivalent circuit in Fig. 15. To save a switch, R_{14} in Fig. 8 always

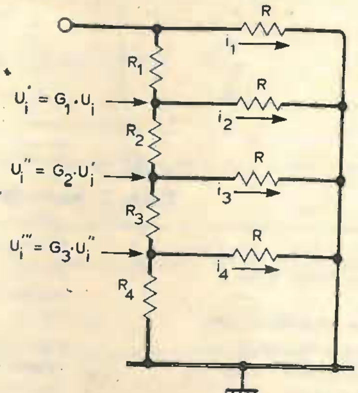


Fig. 15

delivers current to the summing node. Therefore, for the various gain settings, the following input currents flow;
No attenuation, i_1+i_4
−16 dB, i_2+i_4
−32 dB, i_3+i_4
−48 dB, i_4
For a gain step A, the current ratios are

$$A=\frac{i_2+i_y}{i_1+i_y} \qquad (13)$$

$$A=\frac{i_3+i_y}{i_2+i_y} \qquad (14)$$

$$A=\frac{i_y}{i_3+i_y} \qquad (15)$$

If all series resistors are equal, gain changes only depend on voltages G_1U_i, G_2U_i and G_3U_i. Therefore,

$$G_1=\frac{i_2}{i_1} \qquad (16)$$

$$G_2=\frac{i_3}{i_2} \qquad (17)$$

$$G_3=\frac{i_4}{i_3} \qquad (18)$$

If A is −16dB,

$$G_3=\frac{A}{1-A}(0.188-14.5\text{dB}) \qquad (19)$$

$$G_2=\frac{A}{1+A}(0.137-17.3\text{dB}) \qquad (20)$$

$$G_1=\frac{A}{1+\frac{A^2}{1+A}}(0.155-16.2\text{dB}) \qquad (21)$$

Note that A is the input-current gain step and G_n is the gain step of the voltage across the series resistor relative to G_n-1.

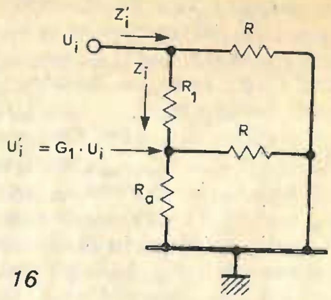


Fig. 16

In the simplified circuit of Fig. 16, because $Z_i^1=Z_i//R$,

$$Z_i=\frac{Z_i^1R}{R-Z_i^1} \qquad (22)$$

and

$$R_1=Z_i\frac{R.R_a}{R+R_a} \qquad (23)$$

also, because

$$G_1=\frac{\frac{R.R_a}{R+R_a}}{Z_i}$$

$$G_1Z_i=\frac{R.R_a}{R+R_a}$$

Therefore,

$$R_1=Z_i(1\text{-}G_1) \qquad (24)$$

and

$$R_a=\frac{R.G_1.Z_i}{R-G_1.Z_i} \qquad (25)$$

Again, using a design value of 22kΩ for the series resistors, and adding 300Ω on resistance gives 22.3 kΩ for each resistor. As R_{14} in Fig. 8 has no series switch, R in formula (30) and on will be 22 kΩ. After a little trial-and-error to find a standard value for R_1, the value of Z_i^1 was set to 15.04 kΩ, which is the constant load presented to the buffer amplifier. From (22), (23) and (24), Z_i is 41.2 kΩ and R_1 is 39 kΩ. From (25), R_a is 10.55 kΩ. By repeating this procedure Fig. 17 is achieved where

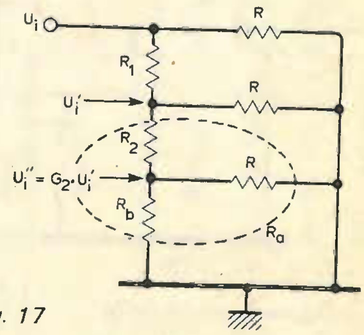


Fig. 17

$$R_2=R_a\frac{R.R_b}{R+R_b} \qquad (26)$$

$$G_2=\frac{\frac{R.R_b}{R+R_b}}{R_a} \qquad (27)$$

continued on page 74

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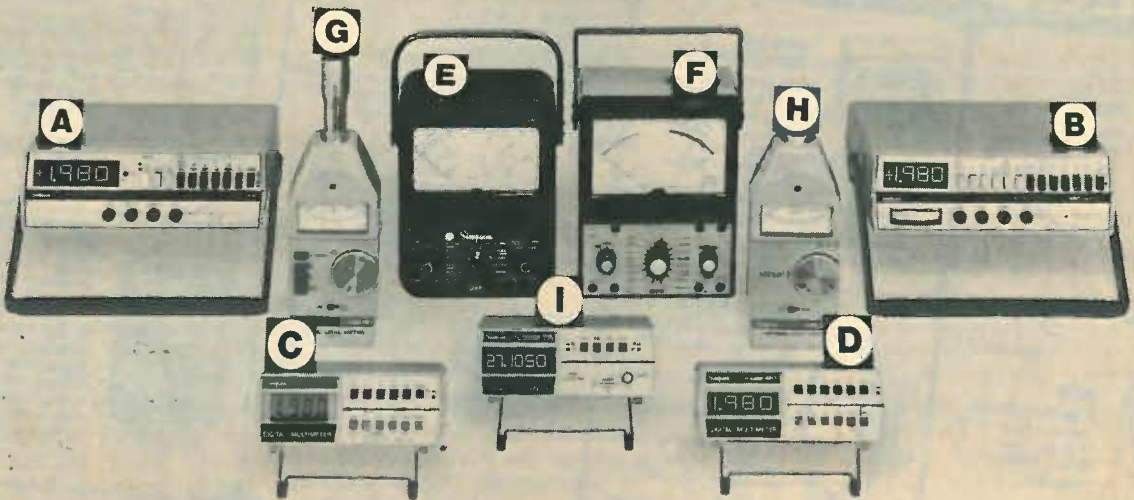

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WW—068 FOR FURTHER DETAILS

Binary codes for error protection

Detection and correction of errors in transmitted binary data

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

So far as is possible without recourse to far more mathematics than would be appropriate in *Wireless World*, Prof. Bell expounds the theory underlying the use of protection bits, which enable errors in data transmission to be detected and corrected. An example of the technique is the Hamming code used to protect the header row in teletext and viewdata transmissions

The term "error-protection" covers both "error-detection" and "error-correction". The latter is prima facie more desirable but is always more complex (much more complex for multiple errors) so that it is sometimes better in practice to use only error detection and to re-process erroneous items either by repetition or by taking them out of the system. Communication systems have to rely on repetition, but in bank clearing operations an occasional cheque on which the account number cannot be correctly read by machine can be diverted from the machine for human attention. (This is particularly relevant because error-correcting codes are less well developed in decimal than in binary notation.)

Check digits

Most of the codes in common use are binary codes, and most readers must be familiar with the use of a single (binary) check digit to detect a single error, or more exactly any odd number of errors. For example, in the ASCII code for input to a computer or for the text of teletext, each character (number, letter, punctuation mark, etc.) is represented by a particular pattern of 7 binary digits. One then adds an eighth digit which is made 1 or 0 according as the number of ones in the original 7 digits is odd or even: the total count of ones over the 8 digits is then always even, i.e. it is equal to zero modulo 2*. In order to correct an error in a binary group, one need only find *which* digit is in error and interchange 0 and 1 in that place. If we start with one information digit and add one check digit, we shall not know whether a failure of the parity check on reception is due to an error in the information digit or in the check digit, so another check digit has to be added to resolve this ambiguity. In fact a single-error-correcting code for a group n digits long requires to include enough check digits to distinguish between no error and an error in any one of n places, i.e. $n+1$ possibilities. But r binary digits can distinguish between 2^r possibilities (see "Communication Theory", *Wireless World*, April 1976) so code construction is simplified if $n=2^r-1$. The number of information digits, $n-r$, is denoted by k, the number of errors which can be corrected is t, and the complete characteristics of the error-correcting code are denoted in the form (n,k,t). The single information digit with the two check digits is then a (3,1,1) code which fits into the standard pattern of single-error-correcting codes with $r=2$, $n=2^2-1=3$, $k=n-r=1$.

Let us now try to construct the (7,4,1) code which has $r=3$. In order to show which digit places are checked by each check digit, an array is constructed with a line for each check digit containing a weight (either 0 or 1 in binary) for each of the n digits of the code. (Remember that the check digits are included in the n places.) In the following example every digit place is covered by at least one check digit, so any single error will be discovered: put another way, the no-error condition is indicated by the success of all three parity checks.

Digit no.	1	2	3	4	5	6	7
Check no. 1	0	0	0	1	1	1	1
Check no. 2	0	1	1	0	0	1	1
Check no. 3	1	0	1	0	1	0	1

Then proceeding by successive binary divisions, the first check digit indicates whether there is an error in the second half; the second check digit covers the second and fourth quarters; and the last covers the odd numbered places (odd eighths, approximately). Hamming[1] offered a special feature: if the check digits are in places 1, 2 and 4 (and successive powers of two for longer codes), the combined result of the check sums (known as the "syndrome") would represent in binary the number of the erroneous digit. For example, if check number 1 produced an even sum but numbers 2 and 3 produced odd sums, giving a syndrome 0 1 1, the error must be in digit number 3.

The addition of one overall check digit to any t-error-correcting code will allow it to *detect* $t+1$ errors. (See below for explanation in terms of "distance".) Thus the (7,4,1) code can be extended to length 8 digits, 4 information and 4 check digits, which will *correct* all single errors and *detect* all double errors. There are then 10 possibilities to consider (no error, 8 distinct single errors, or any double error) so that 4 check digits are ample: the modified code is not perfectly packed. This is the code which is used for the address elements in teletext.

It was remarked above that a single-error-*detecting* code using a simple parity check will actually detect any odd number of errors; but this is usually ignored on the ground that the occurrence of three errors is of negligible probability compared with the occurrence of one error. If errors occur at random, affecting only one digit at a time, with probability p per digit, then the probability of one error in a block of n digits is np and the probabilities of 2, 3, ... errors are $n(n-1)p^2$, $n(n-1)(n-2)p^3$ etc. One commonly takes the approximation that if the chance of one error in a block is P the probability of t errors is P^t. So if a single parity check is used for error detection when the probability of one error in a block is 10^{-3} one can ignore the detection of a triple error which occurs with probability about 10^{-9}: one is more concerned about the undetected double error which in this case would have probability about 10^{-6}.

Codes for multiple-error-correction

For codes with the capability of correcting multiple (random) errors, the method of allocating a particular task to each check digit is impracticable and one has to turn to the idea of *distance* between code members. The idea in principle is that one allocates to each *message** a cluster of *signals* surrounding the corresponding code-member

* To reduce a number modulo x, subtract from it the largest possible multiple of x leaving a difference less than x, which is defined as the original number modulo x.

* The terminology is that a *message* is a unit of information to be communicated, e.g. a number or a letter or a group of them, while a *signal* is that which is transmitted, e.g. a group of binary digits.

signal. Then as long as errors shift the signal from the code member only to another point in its cluster, the receiver can still identify the signal as originating from that code member (provided the clusters do not overlap). The distance between two binary signals (properly called Hamming distance to distinguish it from geometric distance) is defined as simply the number of digits in which they differ and the points in the cluster around the code member are known as *guard points*. A code to correct t errors must have a distance of at least $2t+1$ between any pair of code points, since each must be surrounded by a cluster of extent t, and to avoid overlapping the two clusters must be separated by a further unit of distance. If the distance is increased by one by the addition of an overall check digit, the extra set of points allocated will each be equidistant between two signal points; and this means that they can be recognized as erroneous but not corrected. The code will still be capable of *correcting* t errors and can now also *detect* $t+1$ errors. In the single-error-correcting code with $d=3$, there are n possible errors so that each cluster will contain $n+1$ points, including the code point. But the whole binary code of length n occupies a 'space' of 2^n points. Therefore the greatest number of code points which can be packed into the space (i.e. the number of members of the code) is the total number of points available, 2^n, divided by the number of points in each cluster, $n+1$. But it has been shown above that the quotient can be made equal to 2^r by choosing n equal to one less than a power of two. These Hamming single-error-correcting codes are therefore said to be perfectly packed, meaning that every point in the available space is allocated to one of the clusters of guard points.

Each code point in a code for correcting t errors will need guard points corresponding to 1, 2, ... t errors, the numbers of which are given by

$$n, \binom{n}{2}, \cdots \binom{n}{t}$$

where the binomial coefficient

$$\binom{n}{x}$$

is the number of ways of choosing x (erroneous) digits out of n and is equal to $n!/x!(n-x)!$. With the one exception of the (23,12,3) code due to Golay[2] (see Appendix), multiple-error-correcting binary codes are not perfectly packed;[3] and the packing gets worse as n increases. (One can visualise packing of shapes in three dimensions. But packing of polyhedra in n dimensions, where n may range from seven to some thousands, is to most of us just a form of expression for the mathematical constraints, or at most an allegory.) The problem then is so to distribute the code points in n-dimensional space that as many as possible may be packed in without their clusters of guard points overlapping. Unfortunately, the mathematical techniques which have been

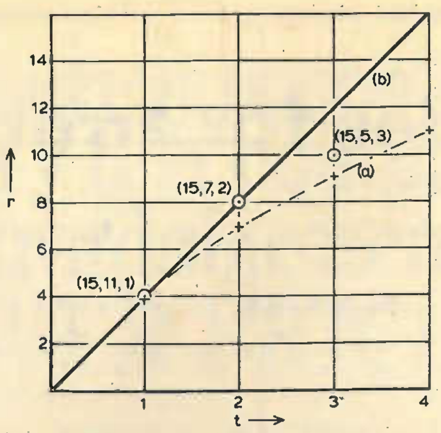

Fig. 1. Numbers of check digits for error-correcting codes of length 15. (a) Theoretical (non-integral) values. (b) The mt *rule for BCH codes. Circled points indicate the values for actual BCH codes.*

employed are above the level which readers of *Wireless World* can reasonably be expected to digest. Those who are not deterred by the use of combinatorial algebra can find the details in a specialist book[4]. A general-purpose set of codes, which can be constructed to any length $n=2^m-1$ and certain other lengths and with various error-correcting capacities is generally known as BCH (Bose-Chaudhuri Hoquenghem in full); and it has the special feature that a code of length 2^m to correct t errors can be constructed with *not more than mt* check digits. For $t=1$ the relation $r=mt$ always holds exactly and these codes are equivalent* to the Hamming codes. But for $n=15$ or greater and $t \geq 3$ for $n=15$ and roughly proportionately larger for longer codes, *fewer* check digits are required. Figure 1 for $n=15$ (a fairly small value of n makes the calculation of binomial coefficients manageable, or avoidable by the use of tabulated values) shows (a) the minimum number of check digits ideally required in order to correct 1, 2, or 3 errors (b) the straight-line relationship $r=mt$ and circled points corresponding to known BCH codes. BCH codes result from factorising suitably X^n-1, where n is the length of the code, into a product g(X).h(X); and a table of irreducible polynomials (the algebraic equivalent of prime numbers) is given in reference 4. The (composite) factors g(X) and h(X) can be used to form a generator matrix and a check matrix which are necessarily mutually orthogonal. For example, $X^{15}-1=(X^4+X+1)(X^4+X^3+X^2+X+1)(X^2+1)(X^4+X^3+1)(X+1)$. The last factor would be $(X-1)$ in ordinary algebra; but -1 does not exist separately in binary arithmetic, so $+1$ is written instead. The first three factors† multiplied together with binary arithmetic of coefficients, $1+1=0$, give the polynomial $X^{10}+X^9+X^7+X^4+X^2+1$ so that the generator matrix consists of the binary series corresponding to this plus its four shifts:

$$G = \begin{vmatrix} 1&1&0&1&0&0&1&0&1&0&1&0&0&0&0 \\ 0&1&1&0&1&0&0&1&0&1&0&1&0&0&0 \\ 0&0&1&1&0&1&0&0&1&0&1&0&1&0&0 \\ 0&0&0&1&1&0&1&0&0&1&0&1&0&1&0 \\ 0&0&0&0&1&1&0&1&0&0&1&0&1&0&1 \end{vmatrix}$$

If r is the degree of the composite factor, $k=n-r$ is the number of information digits. In this case $n=15$, $r=10$ and therefore $k=5$: it is a (15,5,3) code. For a code correcting t errors we must take t irreducible polynomials; and since each irreducible factor may in principle be of degree m when $n=2^m-1$, there may be at most mt check digits. But it may be possible to use a factor of less degree, like the third factor in this example, so that the number of check digits is less than mt. It depends how X^n-1 factorises.

It can be shown that BCH codes of length $n=2^m-1$, distance $d=[n/2]$ and $t=[n/4]$, where the square bracket mean "the nearest integer less than", are exactly related to Hadamard matrices of dimension $n+1$. Some of the Hadamard matrices can be used as the basis of the much-discussed Walsh functions. It follows from the orthogonal property of the rows of Hadamard matrices that in this particular case BCH codes are optimum in the sense of having the maximum possible number of code members for the given length and distance[5].

Implementation of BCH codes

BCH codes are *cyclic*, i.e. if one has a key pattern of digits to represent 2^0, then 2^x is represented by the same pattern shifted x places. One can represent the whole code by an array (matrix) in which each row is of length n and the number of rows is equal to the number of information digits in the code word. As a simple example, the (7,4,1) code can be represented by a generator matrix *G:*

$$G = \begin{vmatrix} 1011000 & 2^0 \\ 0101100 & 2^1 \\ 0010110 & 2^2 \\ 0001011 & 2^3 \end{vmatrix}$$

Then if the 4-digit binary number 1101 (decimal 13) is to be encoded, take the first, third and fourth rows of G, corresponding to 2^0, 2^2 and 2^3, and add them together digit by digit modulo 2 (without carries) to give 100101 as the coded version of 1101. Note that the code can be considered to be based on the polynomial $1+x^2+x^3$ and its multiples by x, x^2, x^3 and the number to be encoded is similarly represented by $1+x+x^3$; then the encoding operation is equivalent to multiplication of the polynomial equivalent of any binary message by the

* The order of the digits in a code can be changed, provided the order of columns in the check matrix is changed in the same way. Codes which result from such re-ordering are equivalent to the original code.

†The reason for these being "suitable" factors goes beyond the mathematical depth of this article.

fixed polynomial of the code. Decoding is by division of the received signal by the code polynomial: an error-free signal must divide exactly and the value of any remainder indicates the nature of the error pattern. Because a division must be started at the most-significant end of a number, the signal must be sent with high-order coefficient first: e.g., when $2^3+2^2+2^0$ is sent the train of digits moving to the right into the transmitting encoder will look like 1011. If T is the duration of a digit, the system in Fig. 2(a) will respond to a single 1 digit input by giving an output of 1 immediately, 1 after a single digit delay in the second digit place, then nothing more until 1 in the fourth place, combining to give 1011 (read from the right). Following digits, being each in turn one place later, will give outputs (counting from the same starting point) commencing with the appropriate number of noughts. Since the patterns produced by successive input digits will overlap, the various feeds to the output line must go through modulo-2 adders. A practical point is that the delays are usually obtained from shift registers, of which every stage has an equal delay of one digit period. Each stage stores one digit, and on each clock beat the content of each stage is passed to the next stage in line: the original form of (binary) shift register employed a flip-flop for each stage, but a charge-coupled device is preferable for a large number of stages. With these two modifications the circuit now looks like Fig. 2(b), where each square box represents one stage of a shift register. A blank interval – a number of noughts equal to the number of check digits in the code – must be left after each message group to allow the shift register to clear before inserting further digits.

It is a commonplace in analogue working that any operation can be inverted by placing the operator in the feedback path around an operational amplifier, e.g. the inversion from differentiation to integration. In the same way a digital operation can be inverted by substituting feedback for feed-forward; and Fig. 3 shows the dividing circuit corresponding to the multiplying circuit of Fig. 2(b). The output is zero for a number of shifts equal to the number of check digits, followed by the quotient which in the absence of transmission errors would be the original message. (Full details, including a stage-by-stage comparision with algebraic long division, are given in Peterson and Weldon[4].) If the division is not exact the remainder is left in the shift register, which should otherwise be zero at the end of the signal. It is therefore necessary to provide some means of inspecting the content of the shift register at the end of every signal block. One method would be to transfer the whole content in parallel to another register having the same number of stages and then check out serially the content of the latter. In the meantime

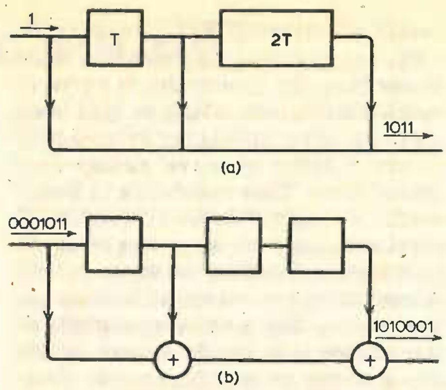

Fig. 2. (a) Encoding a single digit by means of delays T and 2T.
(b) Encoding a group of digits by means of a tapped shift register and adders.

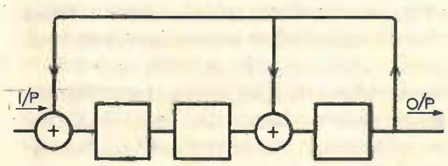

Fig. 3 Decoding by means of a shift register with feedback.

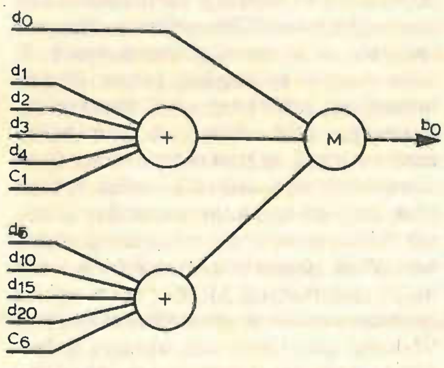

Fig. 4 Portion of majority-logic decoder, for one digit of Hsiao code.

the message would have to be held in another register, in case any corrections were required.

Decoding by majority logic

A disadvantage of the BCH codes for correcting multiple errors is that the procedure for converting from the error syndrome of the received signal to the location of the erroneous digit tends to be complicated. But there are some codes with which the step from syndrome to digit correction can be carried out by logic circuits using majority-decision gates as well as ordinary adders, but without requiring any other algebraic operation (like the solution of simultaneous equations). These methods of decoding are described by Peterson and Weldon[4] in their Chapter 10 under the title of "Majority-logic-decodable codes", including a logic diagram for decoding the Hamming (7,4,1) code. Another family of cyclic codes called Euclidean Geometry codes and Reed-Muller codes, are also suitable for this type of majority-logic decoding.

But such majority-logic decoders require the clocking of the information digits through a shift register, so that corrections can be made one by one. In communication systems the insertion of a further delay of one word time is not usually important: it does not affect the communication *rate*. But such delay is not tolerable in a computer which handles all digits in parallel, e.g. in reading information out from a random-access memory. So a different form of majority logic decoding, was proposed in the early days of semiconductor memories[6] and it relates to memories in which each digit of a word is stored in a separate l.s.i. plane. Now it is difficult to ensure perfection in every cell of a l.s.i. plane, but unlikely that faulty cells will occur in the same position in several planes of the stack. Therefore it is assumed that any given word (digit position in the planes) may have only a small number of errors. In order to avoid delay in read-out, the code is designed so that each digit in the word can be obtained immediately by majority vote of a group of digits read out from certain memory planes and the digits of these majority groups, consisting partly of information digits and partly of check digits, are interleaved and shared in such a way that the total number of memory planes need not be unduly increased. Particular examples for a 25-bit error-free output are:

(a) Single-error-correcting (best out of three voting) 35 planes;
(b) Double-error-correcting (best out of five voting) 45 planes;
(c) Triple-error-correcting (best out of seven voting) 55 planes.

Figure 4 shows how this works for the first output bit b_0 in the case of a single-error correcting code which has a total of 35 planes, 25 information digits d_0 to d_{24} plus 10 check digits C_1 to C_{10}. The elements M are the majority-logic gates, the output of which will agree with any two similar inputs (or all three if alike). It would not be true to say that the correct output is instantaneous on the computer time scale, since two successive gates are involved; but the delay in a gate is normally small compared with a digit period and certainly very small compared with the n digit periods of a serial word.

Burst errors

The codes which have been mentioned so far are concerned with random errors, and where provision must be made for several errors in a block the number of possible error patterns is large and the code correspondingly complicated: an example is the (15,5,3) BCH code, which for 0,1,2 or 3 errors in a block of 15 has 576 different error patterns and uses 10 check digits to discriminate between them. In contract, if it were known that any errors which occurred would be grouped together as a burst of 1, 2 or 3 digits the number of possible error patterns would be 15 for a single digit plus 14 for a burst of 2 and 13 for a burst of 3, making a total of 43 (including the no-error case). The first cyclic burst-error-correcting codes, due to P. Fire, needed $3b - 1$ check digits for bursts of length up to b, but later codes listed by Lucky, Salz and Weldon[7] are better. Peterson and Weldon quote on p.364 a code length 15 capable of correcting bursts up to length 3 with only 6 check digits, as against 10 or 3 random errors. In fact the rule is that a code capable of *detecting* bursts up to length b needs precisely b check digits but a code for *correcting* such bursts needs *at least* $2b$ check digits. Codes using exactly $2b$ check digits are known for lengths 7, 15, 27, 34 and 50 with corresponding values of b of 2, 3, 5, 6 and 8; and a few more check digits are required for longer codes. (But the longer codes cited by Peterson and Weldon have mostly fairly small values of b, between 3 and 7).

The mathematical techniques used in the construction of these cyclic burst-error-correcting codes are very similar to those of the BCH codes. For example the (15,9,3b) code for correcting bursts up to length 3 can be constructed from the pattern

1 1 1 1 0 0 1 0 0 0 0 0 0 0 0

which is taken to be 2^8, and its 8 right shifts which are taken to be the powers of two from 2^7 to $2^0 = 1$. Then the decimal number 409, which is $2^8 + 2^7 + 2^4 + 2^3 + 2^0$, encodes as

1 0 0 0 0 0 1 1 0 1 0 0 0 0 1

There may be a requirement to correct both random and burst errors. It is often said that random errors are typical of radio communication, as a result of thermal and shot noise in the receiver and atmospherics; but bursts are typical of land-line circuits, as a result of intermittent contacts in switching systems or interference from power lines. But clearly this is an over-simplification, particularly as land lines are using higher and higher frequencies, to say nothing of wave guides and optical fibres. Then one device to avoid special measures for the correction of burst errors as well as random errors is to scramble the order of digits before transmission and unscramble them at the receiver. The re-ordering of digits at the receiver will break up any bursts into scattered errors which can be dealt with by a code for random errors. However, the whole point of burst-error-correcting codes is that for a given number of check digits they can deal with more errors in a burst than scattered at random; so the scrambling should extend over more than one block so that, for example, a burst of 6 errors in one block length during transmission becomes 3 random errors in each of two blocks after "unscrambling" in the receiver.

Error-correcting and error-detecting codes constitute a vast subject, with special codes being developed for special purposes. This article makes no pretence of reviewing the subject: it aims merely to explain some of the underlying principles with illustrative examples. The subject is formidably mathematical, so that most users will be content to use existing codes rather than attempt to design codes for themselves; but even to list all existing codes with their properties would be a very major undertaking. Most of them can be found in books such as Peterson and Weldon[4] but there are always a few which have been developed since the publication of a book. Fortunately the basic codes such as BCH will serve for most purposes.

Appendix. The Golay code

Golay discovered a triple-error-correcting binary code of length 23, with 12 information digits, which is perfectly packed. A code of length $n = 23$ and capable of correcting up to 3 random errors will have to be able to distinguish between $1 + 23 + \binom{23}{2} + \binom{23}{3}$ error patterns. The binomial coefficients evaluate to 253 and 1771 so that the whole series sums to 2048, which is exactly 2^{11}; and so with 11 check digits (and therefore 12 information digits) the code is perfectly packed. This Golay (23,12,3) code is the only binary code capable of correcting more than one error which is perfectly packed. A cyclic code which is equivalent to the Golay code can be developed from the following sequence and its eleven shifts:—

1 0 1 0 1 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0

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Programmable audio attenuator

From this

$$R_2 = R_a(1-G_2) \qquad (28)$$

and

$$R_b = \frac{G_2R_aR}{R-G_2R_a} \qquad (29)$$

Therefore, R_2 is 9.09 kΩ (9.1 kΩ standard value) and R_b is 1.54 kΩ. The last step gives Fig. 18 where

$$R_3 = R_b - \frac{R \cdot R_y}{R+R_y} \qquad (30)$$

and

$$G_3 = \frac{\dfrac{R \cdot R_y}{R+R_y}}{R_b} \qquad (31)$$

From (30) and (31),

$$R_3 = R_b(1-G_3)$$

and

$$R_y = \frac{G_3 \cdot R_b \cdot R}{R-G_3 \cdot R_b}$$

The nearest standard value for R_3 is 1.24 kΩ and for R_4 is 294Ω. These calculations give an idea of the accuracy that can be expected. The worst case error occurs with a maximum error in the input switching network of A_2. If, for example, R_{11} and S_{2a} in Fig. 8 each have a maximum resistance error of 200Ω in the same direction, the gain error would be no more than 0.15 dB.

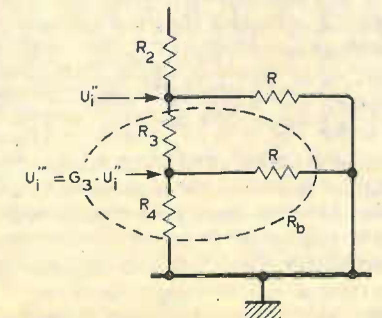


Fig. 18

Printed circuit board

A printed circuit board which accommodates one attenuator circuit and decoder will be available for £4.20 inclusive of v.a.t. and UK postage from M. R. Sagin at 23 Keyes Road, London NW2.

The author

J. M. Didden started his career in 1964 with Philips where he was involved in the design of tv receiver deflection circuits. After three years he joined the Royal Netherlands Air Force to work in air defence operations and specialise in software.

The author is currently involved with software design for NATO air defence systems. Apart from audio, his hobbies include reading science fiction.

Periphonic sound

continued from page 50

early tetrahedral array (besides its awkwardness) was that these two localizations didn't coincide; in fact energy vector localizations show that with the tetrahedral array sounds at high frequencies are pulled toward the loudspeakers.

Requirements for coincidence of localizations according to the two main theories are neatly summed up in Gerzon's diametric decoder theorem, which says that

- all loudspeakers must be the same distance from the centre
- speakers must be diametrically opposite pairs
- the sum of two signals fed to a pair must be the same for all pairs

(Incidentally, Gerzon has also shown that such layouts can be fed by $p + 1$ channels, where p is the number of speaker pairs, so four speakers need three channels, six speakers need four channels.) One of the most convenient speaker arrays that meets these requirements is a birectangular type because it also provides conventional stereo speaker placement. Speakers are at the corners of two rectangles, one horizontal, one vertical. This was the arrangement used in the recent AES demonstration which produced a very satisfying result, the loudspeakers being as acoustically unobtrusive as one would hope. The images were not so sharp as perhaps one is accustomed to with fewer loudspeakers, but nevertheless well fixed. The demonstrators remark that what is lost in image precision is gained in stability seemed borne out. Switching to the horizontal rectangle made the sound less compelling and the reversion to "full sphere" sound was distinctly more satisfying.

With the horizontal type of ambisonic decoder it is not possible to achieve a value of r_E of unity to give ideal image stability. In fact, averaged over all directions, it has been shown that the value cannot exceed 0.707. But it is possible to increase the value in some directions (e.g. 0.8 front-back) at the expense of others (0.6 left-right). Two-channel decorders are worse in this respect with a maximum average of 0.5, giving poor image stability, though it is said that judicious distribution around the circle can hide the fault to some extent. With spherical reproduction the maximum average value is 0.58; and it is argued that the decoder shelf filters must therefore be carefully optimized. But the opportunity for directional trade-offs is obviously greater, and a typical choice would be 0.69 front-back, 0.58 left-right, 0.39 up-down.

Because of this the shelf filters of an horizontal-only decoder are different from those for a spherical or periphonic decoder. (Shelf filters allow different matrix coefficients to be used at low and high frequencies and provide a controlled transition from one to the other.) For instance the ratio of l.f. to h.f. shelf-filter gains for horizontal-type decoders is 0:1.76 (in dB) for the W signal and 0:—1.25 for the X and Y directional components, whereas for a periphonic decoder the gains are 0:3 for W, and 1.76:0 for X, Y, Z signals. Production periphonic decoders would almost certainly contain switchable shelf-filtering but the day that four channels reach the home, existing ambisonic decoders will need some alteration!

For periphony to be judged in effectiveness against horizontal systems perhaps what is needed is a statistical assessment in objective terms compared with stereo and two and three-channel horizontal surround systems. It was eight years after the introduction of the first quadraphonic surround system before preference tests were carried out (by NHK) that showed the square speaker array had a rating of + 0.9, + 0.5 and + 0.3 for non-experts, audio enthusiasts and acoustic engineers respectively, where 1.0 meant "slightly better" than two-speaker stereo. Little wonder it didn't catch on?

BBC's data company will link with Europe-wide information service

In order to exploit commercially its large store of information, which includes 24 million press cuttings from British national and provincial newspapers as well as complete collections of news bulletins broadcast on radio, tv and external services, the BBC has set up a new trading company called BBC Data.

The new company is an information provider for Prestel International and is currently discussing, with a number of other organizations, ways of making BBC information available in machine-readable form. BBC Data's manager, Richard Hewlett, says that the company will also link up with Euronet-DIANE as a "host" information provider (see our news report, Feb. 1980 issue) although the precise interface method has not yet been decided.

Mr Hewlett expects BBC Data's income to be "substantial" after about three years and the next major move will be a deal with a computer services "bureau" whose equipment will be used as a host for the electronic versions of the BBC's files. Information acquisition will then merely entail the customer contacting the bureau via computer terminals accessed by telephone.

Massive report on GaAs is dubious

A report written by Gene Hnatek, quoted as a "noted US authority on integrated circuit technology" by Infotech, and which is said to consist of 650 pages, priced at £150, has been dismissed by Dr Cyril Hilsum, a leading UK expert on gallium arsenide applications, as "melodramatic."

The report maintains that GaAs devices, due to their increased switching speed, will "rapidly replace the silicon chip," but Dr Hilsum points out that production processes cannot compete with silicon on an economic basis and GaAs will be used only where its properties make it a sensible choice. □

Exhibitions, courses and conferences

Breadboard '80 will be held at the Royal Horticultural Halls, Elverton St, Westminster, London SW1, from November 26 to 30, 1980. Opening times have been changed to read Wednesday 26, 10 a.m. to 6 p.m., Thursday 27, 10 a.m. to 8 p.m., Friday and Saturday, 10 a.m. to 6 p.m. and Sunday 30, 10 a.m. to 4 p.m.

Electronic Test and Measuring Instrumentation '80 will be held at Wythenshawe Forum, Manchester, April 22 to 24th 1980. Full details are available from Trident International Exhibitions, Ltd, 21, Plymouth Rd., Tavistock, Devon.

The S.E. Asia 3rd Biennial International Exhibition of Electrical and Electronic Engineering opens at the World Trade Centre, Singapore from 21 to 25 October 1980. Interested parties should contact Interfama Pte. Ltd, 834, 8th Floor, World Trade Centre, Maritime Square, Singapore 0409.

Cambridge Microcomputers are offering a series of one-day courses under the general title of "Practical Introduction To Microprocessors." Each course costs £50 (plus v.a.t.) for early courses (22 April, 21 May, 18 June, 30 July) with later courses (September to December 1980) costing £55 per day and a five-day course on m.p.u.-based systems costing £240 plus v.a.t., running from March to July 1980. Further details are available from Cambridge Microcomputers Ltd, Milton Rd, Cambridge CB4 4BN.

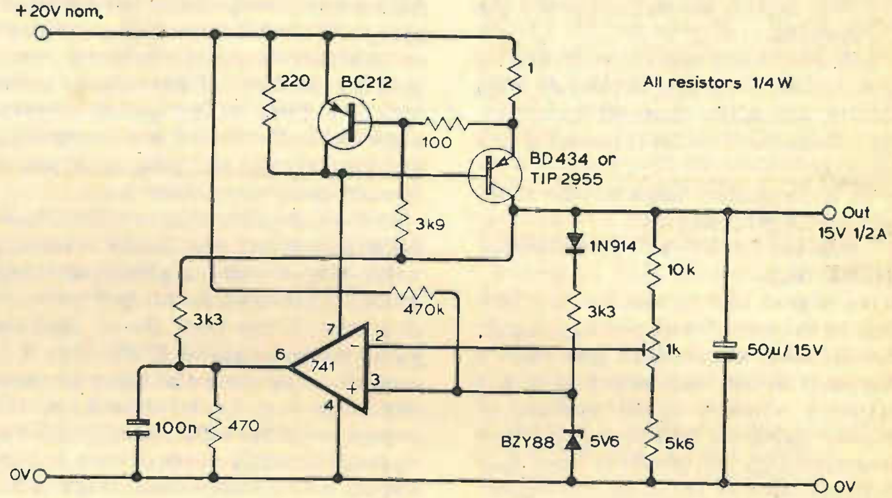
A series of lectures and seminars dealing with general microelectronics topics will be held at the South-West Herts Teachers' Centre, Tolpit's Lane, Watford. It will be run by the GEC-Marconi Group and a teachers' organization. Contact Peter Rackham, Marconi House, Chelmsford CM1 1PL.

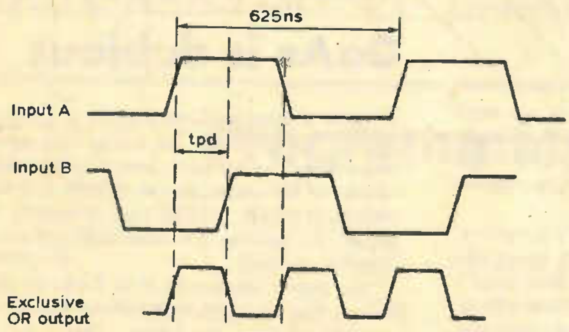
CIRCUIT IDEAS

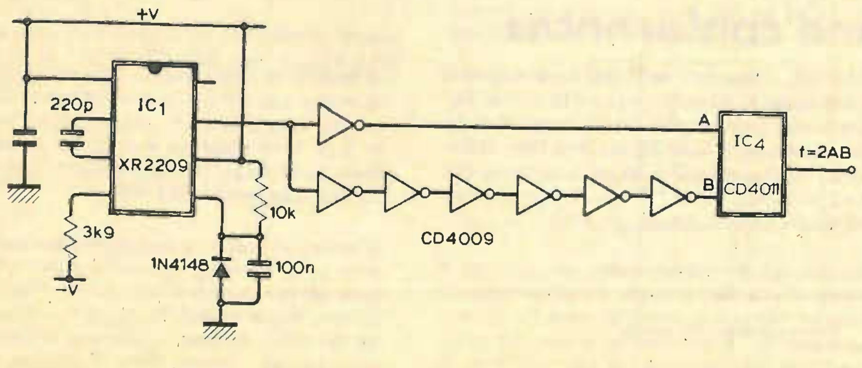
15V ½A regulator

Although cheap and general purpose components are used throughout, this circuit offers good load regulation and temperature stability. Output resistance is typically 20 μΩ at low frequencies and, unlike conventional regulators where the power transistor is connected to the op-amp output, only a few hundred milliVolts are required across the series-pass transistor to maintain regulation. The circuit can be built for negative regulation by using n-p-n transistors in the negative supply lead of the 741. Fold-back current limiting is included to limit the maximum dissipation to 4W. The 3k3 resistor allows the output stage of the 741 to turn off when no current is being drawn, and the 220 Ω resistor prevents the 741 quiescent current from turning the power transistor on. The diode and 470kΩ resistor allow start-up and the 0.1μF capacitor improves the response to sudden changes in output current.

J. W. Rowe
Brinsley
Notts.







High-frequency doubling with c.m.o.s.

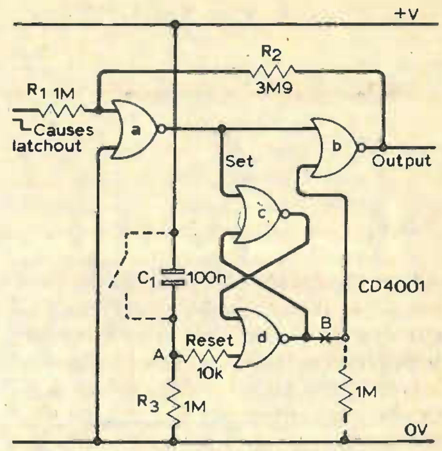
High-frequency doubling can be achieved by using the propagation delay of c.m.o.s. together with exclusive OR gating. The circuit shows an oscillator operating at 1.6 MHz, and an exclusive OR gate fed with the oscillator output and an inverted and delayed output. Propagation delay of the buffers depends on V_{DD} and the load capacitance, but for a 7.5V supply and a load capacitance of 50pF, the delay for each buffer is about 34ns. Therefore, the total delay t_{pd} for six buffers is 204ns and the difference between the two signals is 170ns, which produces a 3.2 MHz output with an almost equal mark-to-space ratio.

D. J. Greenland
Bear Hill
Cambridge

Simple manual-reset latch

One 4001 can provide a latch that will turn off but will not turn on again until manually reset. Gates a and b together with two resistors form a Schmitt trigger which provides noise immunity. A low at the input causes the output of gate a to go high and the output of gate d to go high which then inhibits the output of gate b after it has gone low. Reset is achieved by removing the power supply to discharge C_1, or replacing C_1 with a push-to-make switch for manual reset. If the capacitor is used it must be large enough to ensure that the input goes high before point A goes low. If a switch is inserted at point B and 1MΩ resistor connected to 0V, the circuit will follow the input. Resistors R_1 and R_2 can be omitted if the latch is driven by logic and noise is not a problem.

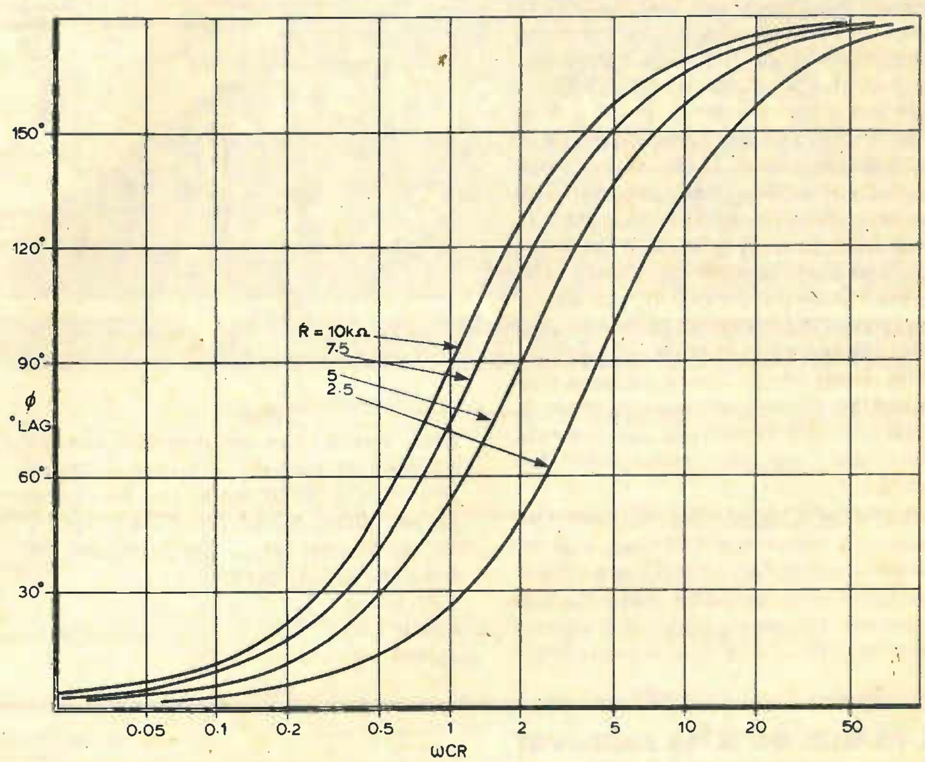
I. J. Nicolle
Guernsey
Channel Isles

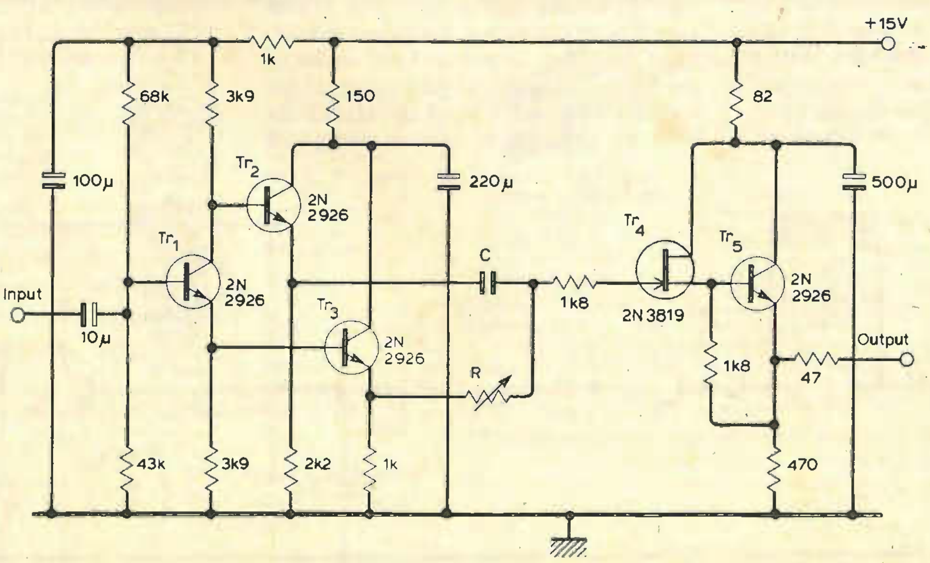


Variable phase all-pass filter

This all-pass filter offered constant amplitude, a distortion content of less than 0.1% for a 1V r.m.s. output, and a frequency range up to 100 kHz. Transistors Tr_1, Tr_2 and Tr_3 form a low output-impedance phase-splitter which drives a CR network. Transistors Tr_4 and Tr_5 form a buffer stage, and the 1k8 gate resistor prevents spurious oscillations. With a 10kΩ potentiometer and a suitable value for C, the phase of a waveform can be varied from 0 to nearly 180° or, by reversing C and R, from 180 to near 0°. The graph shows the normalized all-pass phase response with four values of R.

T. G. Izatt
Preston Polytechnic
and
E. Ball
Salford University



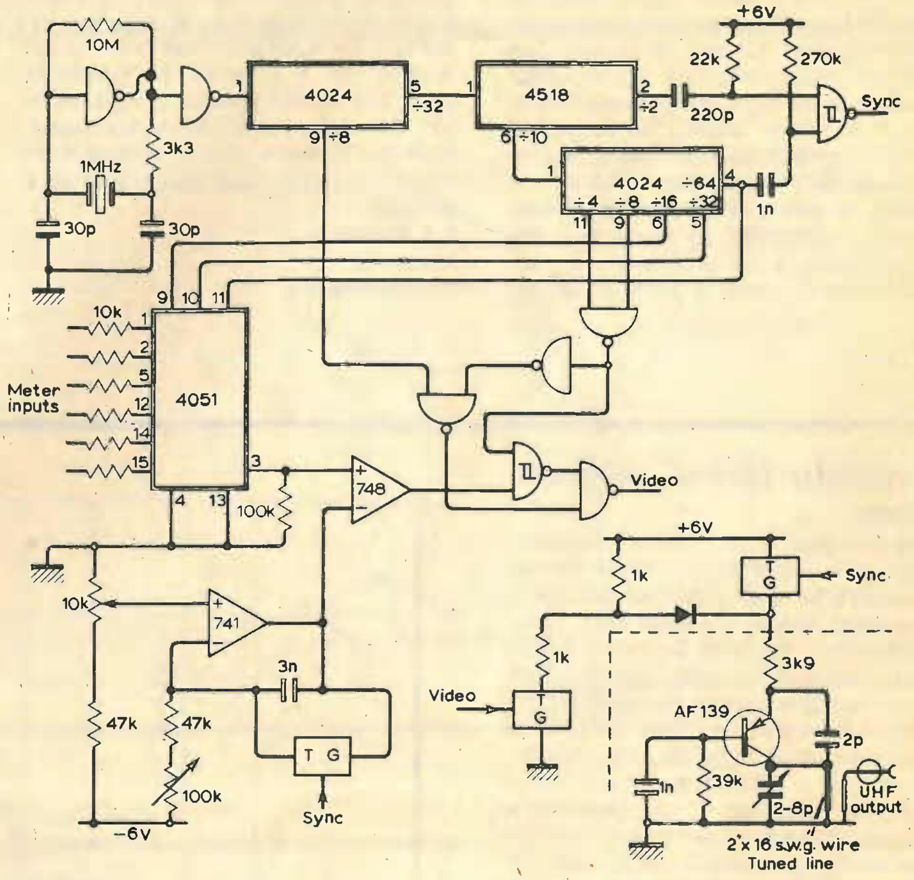


Multi-channel voltmeter with tv display

This voltmeter provides up to 25 channels and displays them as horizontal bars on a television screen. A scale is provided by an 8× line-frequency square wave, gated as a video signal between adjacent bars. The circuit comprises an integrator which ramps from 0 to 1V in 40μs and is reset to slightly below 0V at each line sync. pulse. The input signal is gated by one or more 4051 analogue multiplexers, depending on the number of channels required, and fed to a 748 comparator whose remaining input is connected to the integrator. When the integrator output equals the input signal, the video output is switched from white to black. The sync. timing chain consists of a 1MHz crystal oscillator, a 4024 and 4518 which provide a divide-by-64 for line sync. (15,625Hz) and a second 4024 provides a divide-by-320 for frame sync. (48.8 Hz).

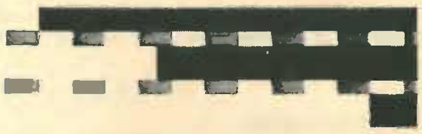
An AF139 modulator is shown, but the circuit can be modified to drive one of the commercial modulators now available. The transistor is housed in a small tin box and the 10kΩ preset is adjusted to zero the display on a convenient scale point close to the left of the screen. The 100kΩ preset is adjusted with a 1V input to set the display on the tenth scale point. These adjustments should be rechecked because there is some interaction between the controls. The display can also be adjusted for centre zero.

A similar circuit, but without the scale and input multiplexing, can be used as a wobbulator display or a simple spectrum analyzer. The drive for the v.c.os can be generated from a second integrator, reset only on the frame sync.



pulse. For 25 channels, four 4051 i.cs are enabled in turn by a 1-of-4 decoder driven by a divide-by-32 and 64 on the second 4024. All of the 4024 outputs, except frame sync., are increased in frequency four times.

J. D. Owen
Castle Lloyd
Dyfed



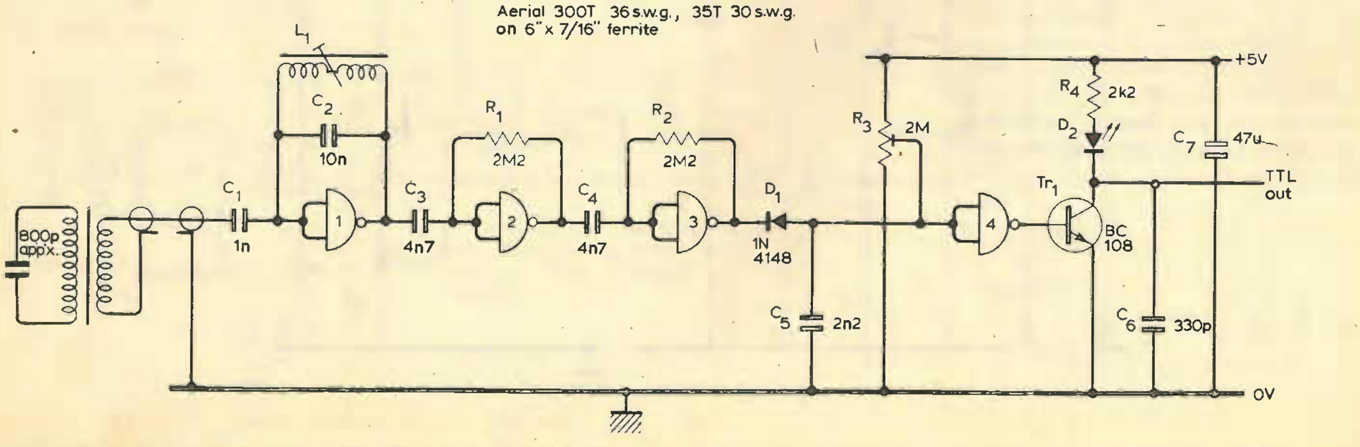
Displays from left to right show 0V, 0·35 and 1V

C.m.o.s. 60 kHz receiver

One c.m.o.s. NAND gate i.c. can be used as a low frequency receiver as shown. All of the gates are connected as inverters and the first three operate in the linear mode with 100% feed-back. Gate 4 and Tr_1 provide amplification and a t.t.l. interface. The input to gate 4 is biased so that; with no carrier, Tr_1 is turned off and the output is high. With the carrier on, negative half-cycles at the output of gate 3 partially discharge C_5 via D_1 and turn Tr_1 on via gate 4. Although the a.c. gain and d.c. input-output voltage varies with different packages, three 4011AE i.cs functioned satisfactorily with R_3 adjusted to give a carrier-off voltage of 0.3V at the base of Tr_1. With a correctly tuned aerial, the only critical components are C_1, C_2 and C_5. The value of C_2 assumes L_1 to be the input winding of a yellow-coded i.f. transformer.

G. Jackson
Greigiau
Cardiff

Aerial 300T 36 s.w.g., 35T 30 s.w.g. on 6" x 7/16" ferrite



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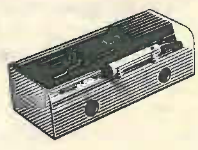
Contains both the model CX230 soldering iron and the stand ST3. Priced at **£5.70** (1.49)
It makes an excellent present for the radio amateur or hobbyist.

Model SK4 Kit

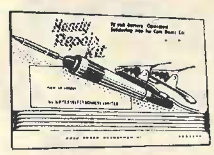
With the model X25/240 general purpose iron and the ST3 stand. this kit is a must for every toolkit in the home. Priced at **£5.70** (1.49)

Model SK1



This kit contains a 15watt miniature soldering iron, complete with 2 spare bits, a coil of solder, a heat sink and a booklet, 'How to Solder'. Priced at **£5.95** (1.53)

Model MLX 12volts



The soldering iron in this kit can be operated from any ordinary car battery. It is fitted with 15 feet flexible cable and battery clips. Packed in a strong plastic envelope it can be left in a car, a boat or a caravan ready for soldering in the field. Price **£4.55** (1.14)

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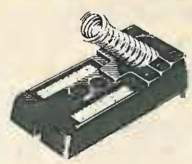

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Why does an electron have inertia?

Give me an electron and I can move the world

by T. B. Tang, M.Tech., Ph.D. Darwin College, Cambridge

Professor Jennison's article in June 1979, in dealing with the mass and inertia of the electron, mentioned Mach's suggestion that the inertia of a body originates from the influence of the distant masses of the Universe. Although the Mach Principle has no empirical support, the author here sketches an elementary scheme for the interaction it visualizes and claims that this "appears capable of explaining, in a manner, some of the known facts concerning inertial mass."

WHEN you switch on an oscilloscope to monitor a signal, you are in essence deflecting a scanning beam of electrons by an electric field proportional to the signal. The inertial mass of an electron has been established as a constant whose value is known to 6 parts in 10^6, so that the angle through which the beam will be deflected can, if you wish, be predicted for any given strength of the transverse electric field.

Many people, however, are not satisfied by merely knowing *how* things behave: they want to find out *why* as well. Why does an electron have inertia, and furthermore why is its inertial mass that particular value and not some other magnitude? Indeed, why matter in general exhibits inertia? Inertia is, of course, defined in Newton's Second Law. Therefore the question is reduced to why $F = m\,a$, where the symbols have the usual significance. Our modelling of the objective world will be more complete if this law, of which the First Law is a special case, is shown as derived and no longer remains an axiomatic postulate.

Mach principle

As mentioned in a recent *Wireless World* article[1], so far the only suggestion to explain inertia is that attributed to Ernst Mach. The idea can be traced further back, to Leibniz, but it is usually referred to as the Mach Principle, a terminology used by Einstein who strived to incorporate it in his theory of gravitation – but did not quite succeed. It is, contrary to the opinion expressed in that article, *not* entirely a qualitative hypothesis that is incapable of accounting for the precise observations of inertial mass and inertial force. In fact, it has been realised in a number of alternative theories[2-8]. True, none of them is commonly accepted. Nevertheless, many interesting deductions can be made in even a simple realisation of the Mach Principle[9]; some we are going to describe in this article. First, however, let us discuss the content and the plausibility of Mach's (or Leibniz's) proposal.

The Mach Principle embodies the conception that the inertia of an object arises wholly from its interaction with background matter. A force has to be applied to an electron to change its state of motion, because, in its own frame of reference, the applied force is needed to balance the pull by you, the Earth, the sun and planets, and the 'fixed stars': a pull which is generated whenever it accelerates relative to the surrounding matter. Were all background matter removed then for the electron, alone, no distinction could be made between uniform and accelerated motions. This seems reasonable enough unless space on its own can, metaphysically, have intrinisic inertial properties. (Strictly speaking, quantum field theory envisages that the vacuum is still filled with carriers of the fields of the lone electron. The existence here of these virtual quanta is, however, completely irrelevant because there are no other particles to absorb or emit them.)

In other words, accelerating an electron is kinematically *and dynamically* equivalent to accelerating, in the opposite direction, all other matter in the Universe. Take the particular case of rotation. In accordance with the Mach Principle, an object is dynamically non-rotating, meaning suffering from no centrifugal or Coriolis force, if and only if it is seen to be not rotating with respect to distant matter, which constitutes the bulk of the Universe and which by definition is non-rotating. The Earth is rotating, as made apparent for instance by the Foucault pendulum at the United Nations' headquarters in New York. So there must be much more matter in the sky than there is under our feet. Is then the collection of some 10^{11} suns forming the Milky Way non-rotating? Its shape is of a flattened disc, indicating the presence of centrifugal forces. There should exist, therefore, extragalactic matter. It duly turns out that the Galaxy is but a member of the 'Local Group' of about 30 galaxies, which, together with more galactic groups and chains, forms what has been recognised as the Virgo Supercluster. This local supercluster, containing 10^2 to 10^3 galaxies, is apparently again flattened. Well, from sky surveys we find at least 10^{10} other galaxies further out in the Universe!

From the measured degree of isotropy (to 3 parts in 10^4) of the 2.7K cosmic radiation, it has been calculated[10] that the distanct galaxies cannot be rotating faster than once in 10^{19} years. The placing of this lower limit on the rotational period, 10^9 times the age of the Universe, is a strong, albeit indirect, observational support for the Mach Principle.

Second Law of motion

Let us now devise a simple mathematical expression for the Machian interaction which is experienced whenever matter accelerates, and explore the consequences. Following Einstein (see for example his book *The Meaning of Relativity*) we assume that the interaction is gravitational in nature, so that its strength between one gravitational mass (m) and another (M) depends on G, the universal constant of gravitation, and will have the form

$$F = (G/c^2)mMar^{-1} \qquad (1)$$

where a is the relative acceleration and r the distance between m and M. F has to fall off as the first power of r, no faster and no slower, else strange things would happen[9]. The velocity of light c is involved in the coupling constant to give the right-hand side the dimension of a force. The form of equation (1) will be justified by its predictions.

F as specified above is Newtonian in the sense that it is instantaneous interaction. However, it was shown by Milne and McCrea, in the 1930s, that Newtonian cosmologies lead to results which are formally identical to those from general relativity models, once an interaction cut-off range is introduced. That is, the Universe is considered as a closed sphere in Euclidean space, with a finite radius, the test particle under study being put at its geometrical centre. With the use of this convention in solving first-order linear problems, the mathematically difficult (and perhaps even pathological) relativistic models can be avoided, and at the same time difficulties such as the existence of infinite gravitational potential in an unbounded universe disappear. In this way, the pull on m which is being accelerated with respect to other matter in the 'island universe' can be summed, in the simplest (scalar) manner, as

$$F_m = (G/c^2)m(-a)\int_0^{cA} 4\pi r^2 \rho r^{-1} dr = -ma(2\pi G\rho A^2) \quad (2)$$

in which ρ is the mean density of the Universe, whose 'radius' is its present age A multiplied by c. Checking with experimental and observational data we now discover the remarkable fact that, within the margin of errors, the dimensionless number

$$2\pi G\rho A^2 = 1 \quad (3)$$

Hence (2) very probably reduces to $F_m = -ma$. Since the applied force $F = -F_m$, Newton's Second Law is at once derived.

Life and gravitation

There are in cosmology a number of numerical coincidences which are empirically found to hold but none of which can be fitted into the structure of known physics. Equation (3) is one of them but, as has just been shown, turns out to be explainable by the Mach Principle. They are of imposing importance to us, speculating or otherwise (see last sentence of this paragraph). Based on some of the other cosmological coincidences, Dirac has proposed several unconventional cosmological models, in a series of papers in *Proceedings of the Royal Society* the first of which was in 1938 and the latest in 1979. However, we shall have the space to say no more about the numerical 'coincidences', except to state that the validity of many of them is a prerequisite for our ability to live in the Universe[11, 9]!

To continue with the discussion on the Machian theory, we point out that it can reproduce all the dynamic effects pertaining to co-ordinate acceleration in Newtonian mechanics. The case of linear acceleration has been dealt with in the above. In circular motion, centrifugal and Coriolis forces of the right form come out when F_m, acting on m which is 'non-rotating' by 'rotating' background matter, is summed in the same manner. This should hardly be surprising, since these forces are consequences of Newton's Second Law which can be derived via F_m.

Most interestingly, it has been claimed[12] that the force described by Newton's Law of universal gravitation is in fact but a manifestation of F_m. The elementary particles in two bodies execute implusive motions ('zitterbewegung' of electrons etc.) and are therefore continuously accelerating; the resulting Machian interaction between their constituents is, it was argued, the force traditionally called 'gravitational attraction'. My comment is that, if this bold idea is valid, then inertial and gravitational forces are completely unified, and also the problem of infinite self gravitational energy for a point-like electron is removed. The theory will achieve such economy and eliminate such a long-outstanding singularity that it should not be wrong.

Relations between inertial and gravitational masses

Equation (2) *proves* that the inertial mass of an object is proportional to is gravitational mass m. This is why two balls of different weights but released from identical heights should really take the same time to strike the ground. The proportionality has been demonstrated with increasing accuracy by Galileo (who probably had not performed the Leaning Tower experiment he said he had, but did have done some inclined plane experiments), Eotvos, Dicke, and others. It cannot be explained, however, in either classical mechanics or Einsten's theory of gravity: in the latter, indeed, it is postulated under the name 'Principle of Equivalence'.

There is another interesting deduction. When the object is alone, it has no inertial mass but, when brought back to the centre of the island universe, it acquires a mass m. At the same time, it acquires a gravitational potential energy

$$E' = -G\int_0^{cA} m(4\pi r^2\rho/r)dr = -mc^2 \quad (4)$$

where in the last step we have used (3). The process should conserve energy and, therefore, the inertial mass has to be associated with an energy $E = mc^2$, as implied by $E + E' = 0$.

The mass of an electron

As a final illustration of the fruitfulness of hypothesis (1), an estimation will be made of the rest masses of stable elementary particles. The exercise will be instructive but, unfortunately, only a phenomenological approach can be adopted and the accuracy will only be to the rough order of magnitude. Consider an electron. Since its inertial mass is not an intrinsic property but is purely determined by surrounding matter, m will be slightly different from that of another electron. However, the difference Δm is 'insignificant', because experimentally electrons are observed indistinguishable (as shown for example by chemical spectroscopy). Now, the energy associated with Δm is, as has just been deduced, Δmc^2. The longest time interval over which the electron has existed before its mass is 'measured' (before it interacts with another particle) is the age of the Universe. Hence, the difference is unobservable, as judged by Heisenberg's uncertainty principle, if

$$\Delta mc^2 A \leqslant h \quad (5)$$

where h is Planck's constant and any factors of the order unity are ignored. Secondly, the total number of electrons, or protons, in the Universe is $N = \rho(cA)^3/m$, factors such as $4\pi/3 \sim 1$ again being neglected. By a statistical rule of thumb,

$$\Delta m/m = 1/N^{1/2} \quad (6)$$

Substituting for N and eliminating Δm between (5) and (6) we obtain

$$m \leqslant [(h^2/c)\rho A]^{1/3} \quad (7)$$

which, on plugging in the numerical values, gives 10^{-27} g and is a correct order of magnitude! The degree of closeness is astonishing in view of the enormous range of magnitudes for different combinations of the factors appearing in (7). Heavier particles should be unstable, which indeed is the case. A zero rest mass (and correspondingly a vanishing Δm) is, of course, also consistent with (5) and (6); this is the case of the other two types of stable particles, namely the photon and the neutrino family.

If the Mach Principle can be generalised, it may be conceived as that all local properties are related to the global condition of the Universe and as such are ultimately changeable: that a part, however small, must not be regarded in isolation from the whole. This means that any collection of particles constitutes an open system, for which dynamic equilibrium will always be accidental rather than the normal state, just as a living organism or a biosphere is. The Principle itself is speculative, enjoying as yet no direct empirical evidence, but we have sketched here an elementary scheme for the interaction it visualises. Surprisingly, the resulting simple-minded theory appears capable of explaining, in a manner, some of the known facts concerning inertial mass. Are you sufficiently impressed to believe that you now understand more about what actually happens to the electron beam in the oscilloscope, and why one should wear a seat belt?

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WORLD OF AMATEUR RADIO

Communication receiver design

Even before the end of the 1930s, the h.f. communications receiver could provide a high standard of performance: designs such as the National HRO, Hallicrafters SX28, Hammarlund Super Pro and the RCA AR88 enabled operators to select and copy extremely weak signals close up to far stronger signals, aided by good single-crystal filters and the reasonable immunity to spurious responses of single-conversion superhets having two tuned r.f. stages. Indeed many of the subsequent developments were aimed primarily at reducing the high cost of tuning mechanisms used in such models with their four ganged tuned circuits and with providing the additional stability and lower tuning rate needed to cope with single-sideband transmissions. The gradual change from valves to transistors tended to result at first in lower standards, particularly in the reduced ability of receivers to cope with both very weak and very strong signals without driving stages into non-linearity. Questions of "shape factor" of filters and then "dynamic range" of the early stages of solid-state designs have tended to dominate the scene, and it is only in the past few years that all-solid-state designs have reached and improved on the best valve designs of the fifties and sixties.

Now, however, the steady progress is making the measurement and evaluation of receiver specifications increasingly difficult, as Wes Hayward, W7Z01 has pointed out. Such parameters as "minimum detectable signal" are easier to describe than actually to measure; "intercept point" is being interpreted in different ways, and so on; furthermore many of the improvements become important only in highly competitive conditions, making little noticeable difference during routine communication.

The limiting factors of high-performance receivers now tend to be: reciprocal mixing due to noise side-bands on the h.f. oscillators; insufficient "ultimate rejection" of filters, particularly when actually installed in receivers; non-linearity and sometimes non-reciprocal effects in "passive" components such as crystal filters and ferrite cores. For most amateurs the difference between a "good" and a "not-so-good" receiver is still likely to involve questions of "operability"; convenient controls without backlash; absence of hum; ability (missing from many current models) to be able to turn the a.g.c. off; good audio performance, etc. Perhaps what we are seeking is the good electronics of the best 1980 models combined with the excellent mechanical designs of 40 years ago. Unfortunately while electronics still get relatively cheaper, mechanical excellence grows steadily more expensive.

Winter Sporadic E

Recently it was suggested (WoAR March) that while American amateurs recognise the existence of a winter Sporadic E season, this did not appear to be the case in Europe. John Branegan, GM4IHJ of Saline, Fife, however, reports that he has observed such a season each year since 1977. He uses sensitive equipment including a tunable Eddystone 770R v.h.f. receiver, various pre-amplifiers and converters feeding a Yaesu FRG7, a multi-standard tv receiver and rotatable 3-element Yagi aerials.

He finds the winter Sporadic E season usually starts about Christmas and lasts until about the first week in February (with three of four days of such events followed by several days without any). During winter, SpE signals are heard up to about 53MHz and on about one-in-three occasions to 70MHz; very rarely to about 90MHz; no event extending to 144MHz has been observed. From contacts with VE1AVX during the 50MHz F2 layer openings, he believes that winter SpE occurs on the same days at the same local time in Eastern Canada. As an example of a typical winter SpE event he provides a clear picture of Norwegian tv (48.25MHz) taken on January 21 this year. Curiously, he does not find that the range of SpE signals changes in the manner that has been suggested as likely due to the gradual descent of metallic particles in wind-shears, but remains in the range bracket of 650 to 1250 miles throughout the events.

GM4IHJ is convinced that there are still endless possibilities for amateurs to add to our meagre understanding of Sporadic E, including the differing world patterns (SpE conditions are almost a regular daily event in tropical countries such as India).

EMC regulations increasing

German amateurs are worried at some aspects of new "electromagnetic compatibility" regulations which are due to be introduced there in July 1981 and which could present major problems to the operators of medium or high-power transmitters in residential areas. While a welcome feature of these regulations is the setting of a minimum limit to the strength of broadcast transmissions that are regarded as protected against interference, ranging from 0.1 to 0.5 mV/m for v.h.f. and television to 1mV/m for m.f. and l.f. transmissions, they also specify the standard of "immunity" to very strong local signals that receivers should be expected to withstand, implying that listeners and viewers can expect to be protected against any signals which are stronger. The limits vary from 3V/m to only 0.5V/m between 47 and 108MHz and as low as 0.2V/m on intermediate frequencies of the receiver. It has been shown that field strengths of 15V/m can be encountered at distances of about 12m from amateur transmitting aerials of stations operating at legal levels in Germany.

Regulations introduced early in 1980 in Switzerland appear similarly to set a limit of 1V/m to receiver immunity, with the possibility that the amateur station may be held to blame for interference arising from higher signal levels. The subject is also being considered with a view to EEC regulations. The German e.m.c. regulations are not concerned with electronic appliances other than radio and tv receivers and do not cover audio amplifiers, tape recorders or electronic organs.

In brief

Jeremy Royle is reported to be developing new techniques for the transmission of slow-scan tv pictures in colour . . . Amateur stations in the USSR are reported to be increasing by about 8 to 12 per cent annually and by early 1979 there were 30,034 stations of which 3629 were "club" stations, 17,234 individual h.f. stations and 9111 v.h.f. licences; nevertheless it is suggested that in some areas numbers of stations remain stagnant due to insufficient attention being given to the development of amateur radio, especially stations for collective ("club") use . . . Swiss amateur licences increased from 2341 at the end of 1978 to 2681 at the end of 1979 . . . The number of amateur licences in West Germany, where for a long time the totals were roughly comparable with the UK, now seem to have forged decisively ahead, totalling 41,500 of which 17,610 are Class C (v.h.f. only) licences. There are 1305 club stations (including 208 repeaters) and 2090 "YL" and "XYL" licensees . . . The annual Radio & Electronics Exhibition of the Northern Radio Societies Association will be held at Belle Vue, Manchester, on April 27, with numerous contests, inter-club quiz. Morse code challenge, 145.550MHz and 433.200MHz talk-in stations (GB4NRS G8NRS/A) . . . The RSGB National Amateur Radio Exhibition is at Alexandra Palace on May 9 and 10.

PAT HAWKER, G3VA

Outlook for short-wave broadcasting

Meagre increase of frequency allocations gained from WARC 79

by Jim Vastenhoud Radio Nederland

Most readers will have seen reports about the 1979 World Administrative Radio Conference (WARC 79) in this journal, and will know that short-wave radio stations all over the world attach great importance to its results. The main objective of the conference was the re-allocation of the radio spectrum (February issue pp. 46-48, March issue pp. 72-74). The allocations are to be found in Article V of the Radio Regulations, a book which contains all international agreements on the use of the radio spectrum and is the standard reference for radio users all over the world. Article V was revised previously in 1959. Since then, however, there have been significant shifts in the usage of the spectrum, partly due to technical developments, such as the opening-up of satellite communications, but also resulting from other world developments like the new frequency requirements of nations which have gained their independence since 1959. These frequency requirements of the emergent nations affect all fields of communications and especially those bands which were already heavily loaded, or even congested, in 1959.

Increased demand

The most marked increase in the demand for radio spectrum space in the past twenty years has taken place in the fields of maritime mobile communications and short-wave radio broadcasting. In Band 2, the v.h.f./f.m. band, agreement was reached at WARC 79 on an expansion in Regions 1 and 3 to 108 MHz. A planning conference, to be held in a few years' time, will decide about the channel allocations in this band for each area. Before this can take place, however, non-broadcasting services which still make use of the band will have to be relocated in other frequency ranges. Medium-wave broadcasting has also grown considerably, but a frequency plan for the medium- and long-wave bands was adopted at the ITU conference on m.f./l.f. broadcasting in 1974/75 (January 1976 issue, p. 42) and its results were accepted (with some minor changes) at WARC 79.

The frequency range between 6 and 30 MHz is suitable for world-wide communications without the use of repeaters or satellites. This fact makes this h.f. part of the spectrum important to various users — mobile communications on land, at sea or in the air, fixed communications between points on earth, radio amateurs, and broadcasting, to mention a few. In the past twenty years the occupation of various bands in this range has changed. Extensive monitoring, taking place all over the world in recent years, has shown that the number of stations in the fixed bands (which occupy about 48% of the available short-wave spectrum) has considerably decreased. It has also shown that the number of stations inside the allocated short-wave broadcasting bands has grown to intolerable levels.

The decrease of band loading in the fixed bands was due partly to the development of satellite communications, which proved to be more reliable to the fixed user and is able to handle all traffic without interference. Apart from this measured effect, however, many young nations still feel the need for frequencies in the fixed bands, to establish and maintain domestic or international radio communications (telephony, commercial traffic, data transmission).

Many short-wave broadcasting organizations, after studying the results of monitoring the fixed bands and looking at the gloomy situation inside the short-wave broadcasting bands, had the feeling that it would be reasonable to re-allocate portions of the fixed bands for broadcasting purposes. This feeling was strengthened by the knowledge that some administrations (the official postal and telecommunication authorities of the various countries) have permitted their short-wave broadcasters to move into the fixed bands. This situation, not endorsed by many countries who live by the intentions and rules of the Radio Regulations, was made possible by the use of an escape clause in these regulations which renders such a move possible if no interference is caused to other services which are allotted in the fixed bands. Since the broadcasting service usually replaced a fixed service of the same country (though at an increased bandwidth), generally no complaints from other fixed users were filed and the broadcasting service in the fixed band could thus be established.

Exclusive h.f. bands

In most countries, however, short-wave broadcasting stations have not been allowed to operate "out-of-band", because the administration is wary of causing congestion in the fixed bands with transmissions of another kind. Most administrations felt bound by the 1959 agreement, which established certain frequency bands for the exclusive use of high frequency (short-wave) broadcasting only and provides a similar arrangement for the fixed bands. Mixing the two would cause precedents which would harm international interests.

At the start of WARC 79 a number of administrations had hoped to correct this situation by extending a number of short-wave broadcasting bands into adjacent fixed bands, thereby giving all s.w. broadcasters equal opportunities to

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establish a good service while doing away with the privileged situation of those broadcasters who are already operating in the fixed bands. It was not expected that all the administrations concerned would co-operate with such a measure, but those against were considered to be in the minority.

However, things turned out differently. The non-aligned countries, which now have a voting majority in most international bodies, could only be partly convinced of the reasonableness of the international broadcasters' requirements. Moreover, they were concerned about the loss of fixed frequencies, which are so vital to them.

Meetings held in the important working group 5BB, which dealt with the frequency range between 3.9 and 27.5 MHz, were difficult and progress was slow. The proposals, which obtained a majority in the group, did account for about 780 kHz of band extension for all broadcasting bands between 9 and 22 MHz, or less than half the extension needed to operate short-wave broadcasts with a reasonable chance of satisfactory reception quality. The results, agreed on by Committee 5 and the Plenary Assembly, are given below.

Band (m)	Old frequency range (MHz)	New frequency range (MHz)
75 m	3.950-4.000*	3.950-4.000
49 m	5.950-6.200	5.950-6.200
41 m	7.100-7.300†	7.100-7.300
31 m	9.500-9.775	9.500-9.900
25 m	11.700-11.975	11.650-12.050
22 m	—	13.600-13.800
19 m	15.100-15.450	15.100-15.600
16 m	17.700-17.900	17.550-17.900
13 m	21.450-21.750	21.450-21.850
11 m	25.600-26.100	25.670-26.100

* Not allocated in Region 2. 3900-4000 kHz allotted in Region 3.
† Not allocated for broadcasting in Region 2 (the Americas).

The outcome must be considered "meagre" by many administrations and short-wave broadcasters in the western world, who have put so much work into measuring and evaluating data and calculating what they consider to be a very reasonable proposal for all concerned, based on technical data rather than on political motives. It is a disapproving result, which might also be ascribed to the failure of some delegates from less technically developed areas to fully appreciate the real value of the proposals put forward and their unjustified reserve as to the good intentions behind them.

An observer at WARC 79 must have felt that some of the voting was indeed not free from political motivation. Some countries could occasionally be seen grouping together, and the influence of certain leaders was sometimes very evident. But this is all part of the modern set-up where each country has one vote only, regardless of the size of its population.

One of the important decisions taken at the conference was to set in motion the preparation for a new technical conference. Such a conference, called a planning conference for the h.f. broadcasting bands, will be held in two sessions, probably in 1982 or 1983. The first session will establish the technical parameters to be used during the planning conference. Some of the important parameters are: maximum number of frequencies used for the same programme to the same zone; the necessary or maximum transmitter power to be allowed; and a specification for a single-sideband system suitable for future use. Also, the CCIR, which is the ITU's technical consultative committee for broadcasting, is to prepare and distribute extensive data on directional antennae, on methods of estimating field strengths and transmission losses, on calculating necessary protection ratios between co-channel and adjacent channel broadcasts, on frequency prediction methods, on solar indices, and so on.

The second session, which will be the planning conference proper, will be held 12 to 18 months after the first session. During this period all concerned will be in possession of the same data. This means that there will be no technical arguments based on data of different origins or liable to different interpretations. It also means that everyone concerned has at least the opportunity to prepare for the responsible task of participating in a world forum on h.f. broadcasting, which will determine its weal and woe for the next twenty years or so. □

News notes

The Australian government has authorized tv stations to go ahead with data broadcasting services. The announcement was made by Mr T. Staley, the minister for Post and Telecommunications, who welcomed this development as a useful addition to community services.

A multi-track digital recording of an opera, using the 3M Mincom 32-track digital mastering system, was made by Polygram during December 1979 and January 1980. The recording of Wagner's four-and-a-half-hour opera "Parsifal" was performed by the Berlin Philharmonic Orchestra and the Chorus of the Berlin Opera. Analogue tapes were also made of the sessions.

The first deep water optical-fibre telephone cable, a trial 9.5km loop, was laid by the STC division of ITT, using the Post Office cableship "Iris" in Loch Fyne, on the West coast of Scotland early in March. A regenerator housing with mechanical terminations was also laid with the cable, to be equipped later with the necessary regeneration equipment.

IN OUR NEXT ISSUE

The case for community radio

Many people are dissatisfied with the centralised nature of national broadcasting, even when it includes regional and local stations. Community feeling, discussion and culture could be encouraged by alternative radio. Norman McLeod assesses what could be done in the UK.

'Off-resonance' metal detector

This newcomer to metal detecting is basically similar to the b.f.o. type but senses the search coil's inductance change differently and uses the properties of a parallel-tuned circuit to obtain more information about the physical nature of the object.

What happened to analogue computers?

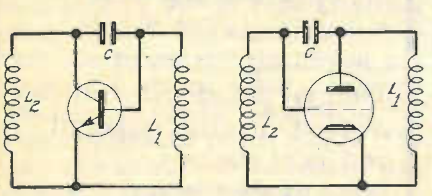
Apart from the i.c. op-amp, analogue computing techniques seem to have been swamped by the tide of digital computers and microprocessors. This article reminds us of the basic electronic analogue techniques and of how flexible they are for modelling proposed systems.

On sale 21 May

LC oscillators: general theory

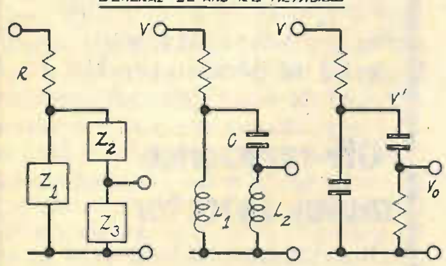
by Peter Williams, Ph.D. Paisley College of Technology

TRANSISTOR AND VALVE OSCILLATORS



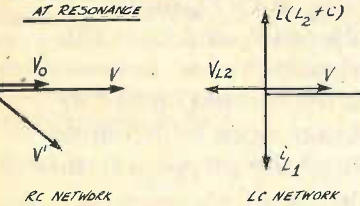
Transistor and valve oscillators can be closely related: not in the obvious way by a direct replacement, but with inputs and outputs interchanged. If a particular network requires a transistor of short-circuit current-gain h_{fe} for oscillation, and used with a valve with terminations reversed requires an open-circuit voltage gain of μ, then $\mu = h_{fe}$. Neither the input resistance of the transistor nor the output resistance of the valve appear in the frequency and gain-determining relationships. This is a surprising result and though exactly true only for a circuit composed of pure reactances it remains useful under a wide range of practical conditions. The minium number of pure reactances for oscillation with a single device is three, two of one type and the third of the opposite type. By extension, circuits may use mutual inductance and other more complex arrangements but at the frequency of oscillation the reactances are always equivalent to two inductive and one capicitive or vice versa.

GENERAL LC AND RC NETWORKS



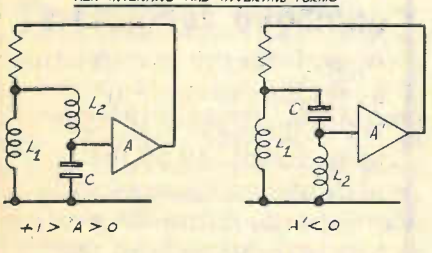
Taking the device resistance (h_{ie} for the transistor and r_a for the valve) into the external circuit the passive circuit becomes the general form shown, i.e. activated by an ideal voltage amplifier from left to right or by a current amplifier from right to left. The particular LC form corresponds to the previous valve/transistor oscillators. The configuration is identical with the RC lag-lead network, the basis with the related Wien and lead-lage networks of so many RC oscillators. In the LC form the overall phase shift is found to be 180° at the frequency for which the reactances go into series resonance and an inverting amplifier is used. The RC circuit has zero phase shift at the frequency of maximum response and needs a two-stage amplifier for the non-inverting gain. From the standpoint of frequency stability, it is the rate-of-change of phase of the passive network at the frequency of oscillation that is important. The higher this value the smaller the frequency shifts in compensating for internal amplifier phase errors or those resulting from the intermodulation via feedback distortion components.

PHASE RELATIONSHIPS AT RESONANCE



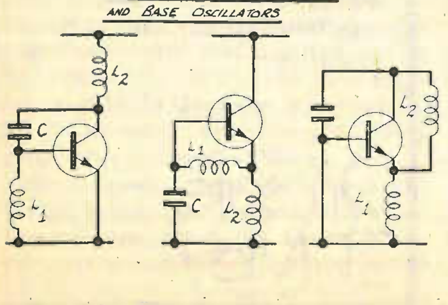
These are quide different for the two circuits; that the LC circuit has a higher $d\phi/d\omega$ at the frequency of oscillation. Considering the RC circuit first, the two sections result in successive phase lags and leads. It is simplest to visualize if the second stage impedance is much higher than the first but with equal time-constants. There is then a simple relationship for the frequency at which the first stage provides a 45° lag simultaneously with a 45° lead for the second stage, i.e. a net phase-shift of zero. Equal R and C values modify the relationship but leave the principle the same, viz a single frequency at which the phase shifts cancel. The LC circuit depends on resonance to obtain the necessary phase conditions. The currents in L_1 and L_2, C are antiphase only for those frequencies at which the reactance of C exceeds that of L_2. The net current flow can therefore become zero resulting in there being no voltage dropped across R. It is this that allows R to vanish from the frequency and gain-determining equations.

NON-INVERTING AND INVERTING FORMS



Further inspection of the phase relationships shows that the voltages across C and L_2 are anti-phase with v_c greater in magnitude than v_{L2}. Because, at resonance, v_{L2} is antiphase to the drive voltage v, it is the inductor voltage in this configuration that is normally used to close the oscillatory loop. This form is shown in the second of the two circuits with an inverting amplifier. If the locations of L_2 and C are interchanged then at the same frequency the output of the network is now in phase with the drive voltage but of greater magnitude. Hence a non-inverting voltage amplifier with voltage gain below unity is required. The new oscillator might be described as a grounded-collector (or drain or anode) oscillator but *not* a common-collector. This last terminology must be avoided as there is no external signal source and hence there cannot be a common point between input and output. The terminal that is grounded is merely a matter of convenience, perhaps of biasing of minimizing stray capacitance or of extracting the signal; the nature of the oscillator remains unchanged.

GROUNDED EMITTER, COLLECTOR, AND BASE OSCILLATORS



The three circuits shown simply represents shifts in ground points for the same basic oscillator; L_1 still appears between base and emitter, L_2 between collector and base. The supply times are assumed to have zero impedance to ground and bias networks are omitted. This latter point is of practical importance because one factor influencing the choice of configuration will be the case of biasing. Considering the common base circuit first it can be seen that a direct current path is needed for the colleltor current, but one whose impedance is very high at the frequency of oscillation. This suggests a large-value inductance (or a parallel resonant circuit!) which is not an attractive solution. This problem is not present with the other two, though each requires a bias path for base currents. If the bipolar transistors are replaced by junction fets capable of operating with $V_{GS} = 0$ then a self-biasing oscillator results in each case.

LC oscillators: general theory

THEORY

● The two forms have the passive networks similarly terminated on the assumption that only the input resistance of the transistor and the output resistance of the valve or f.e.t. need be considered, i.e. in both cases there is a conducting path across L_1 but not across L_2.

● Let $t_v = v_o/v$ for the general passive network shown. Applying Thevenin's theorem to R, Z_1

$$t_v = \frac{Z_3}{Z_3+Z_2+\frac{Z_1R}{Z_1+R}}\ \frac{Z_1}{Z_1+R}$$

$$= \frac{Z_1Z_3}{Z_1Z_3+Z_1Z_2+(Z_1+Z_2+Z_3)R}$$

For oscillation the circuit would need to be connected to an amplifier of voltage gain A_v so that

$A_v t_v = 1$ at one frequency only

$$A_v = 1+\frac{Z_2}{Z_3}+\frac{R}{Z_1Z_3}(Z_1+Z_2+Z_3)$$

By reciprocity, if the same network is interconnected with an ideal current amplifier of current gain A_i then A_i has to meet the same constraint.

For many oscillators the impedances are almost pure reactances i.e. $Z_1=jX_1$, $Z_2=jX_2$, $Z_3=jX_3$, where X_1, X_2, X_3 can have either sign subject to the constraints to be established below.

$$A_v = 1+\frac{X_2}{X_3} - j\frac{R(X_1+X_2+X_3)}{X_1X_3}$$

Equating real and imaginary parts

$$A_v = 1+\frac{X_2}{X_3}$$

$$X_1+X_2+X_3=0$$

(i) This last condition corresponds to the series resonant condition of X_1, X_2, X_3.

(ii) The constraint cannot be satisfied using three reactances of the same type as there must be at least one capacitive and one inductive for resonance.

(iii) If used with a grounded-emitter (grounded-source) stage with inverting gain then $X_2 > X_3$ and they must be of opposite types.

(iv) To simultaneously satisfy the second constraint, X_1 must be of the same type as X_3.

The above are the conditions resulting from $A_v<0$. Other conditions obtain for $1>A_v>0$ and $A_1>1$.

● A comparison of the related LC and RC forms shows the lead/lag cancellation of the former, and the availability of more than one feedback connection for the latter, since the voltages at resonance are all either in phase or in antiphase.

● Because $V_c + V_{L2} = V_{L1} = V_o$ and V_{L2} is antiphase to V_c, then V_c is in phase with V_o and exceeds it i.e. $1>A>0$.

For the second form, V_{L2} is antiphase to the output and $A'<0$.

$$\frac{X_1}{X_3}+\frac{X_2}{X_3}+1=0$$

$$\text{i.e.}\ \frac{X_1}{X_3} = -A_v$$

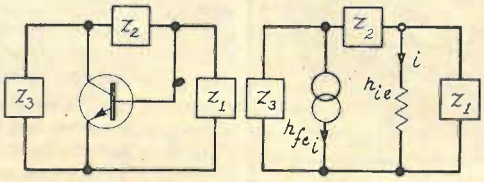
$$X_1:X_2:X_3::-A_v:A_v-1:1$$

EXAMPLE

A bipolar transistor with $h_{fe(min)}$ of 50 is used with C=500pF and is required to oscillate at 200kHz. Determine suitable values for L_1, L_2

$$Z_1=j\omega L_1\quad Z_3=j\omega L_2$$

$$Z_2=\frac{1}{j\omega C}$$



The fraction of the output current flowing in h_{ie} is

$$i = \frac{\frac{Z_1}{h_{ie}+Z_1}.Z_3}{Z_3+Z_2+\frac{h_{ie}Z_1}{h_{ie}+Z_1}}(-h_{fe}i)$$

$$\therefore -h_{fe} = \left(Z_3+Z_2+\frac{h_{ie}Z_1}{h_{ie}+Z_1}\right)\left(\frac{h_{ie}+Z_1}{Z_1Z_3}\right)$$

$$= \frac{h_{ie}}{Z_1Z_3}(Z_1+Z_2+Z_3)+1+\frac{Z_2}{Z_3}$$

$$= \frac{-h_{ie}}{\omega^2L_1L_2}\left(j\omega(L_1+L_2)+\frac{1}{j\omega_c}\right)+1-\frac{1}{\omega^2CL_2}$$

Equating real and imaginary terms

$$\omega^2 = \frac{1}{(L_1+L_2)C}$$

$$-h_{fe} = 1-\frac{1}{\omega^2CL_2}$$

$$h_{fe} = \frac{(L_1+L_2)C}{L_2C}-1=\frac{L_1C}{L_2C}=\frac{L_1}{L_2}$$

$$\therefore L_1 = 50L_2$$

$$L_1+L_2 = \frac{1}{(2\pi 200.10^3)^2 500.10^{-12}}$$

$$= \frac{1}{4\pi^2.5} \approx 5.07\text{mH}$$

$$\therefore 51L_2 = 5.07\text{mH}$$

$$L_2 \approx 99.4\pi\text{H}$$

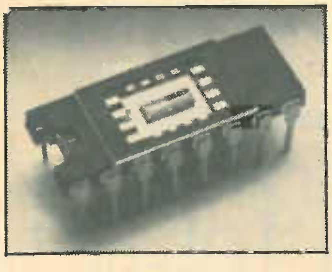
$$L_1 \approx 4.97\text{mH}$$

h_{ie} plays no part in determining the resonant frequency nor in the ratio of the components. But it does affect Q and the behaviour of the circuit for any departures from the nominal conditions.

NEW PRODUCTS

Image sensor

Drive circuits are included in the IPL 64P image sensor i.c., which forms the first item in a new family of devices from Integrated Photomatrix. It can be operated in conjunction with a t.t.l. oscillator and other features include a programmable shift reg-



ister, making operation as a 1 to 64 element array possible. The i.c. is c.m.o.s. compatible and a quartz window extends the spectral response to 250nm, making it suitable for spectrographic applications. The one-off price is £45. Integrated Photomatrix Ltd, The Grove Trading Estate, Dorchester, Dorset.

WW301

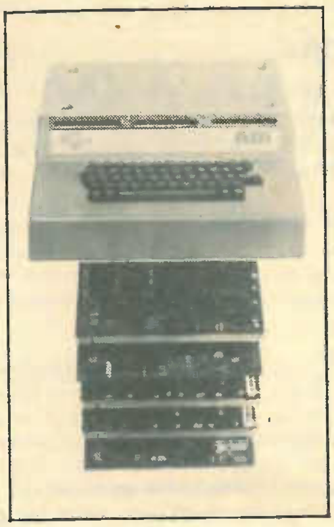
Flexible contact transducer

Designed as a self-adhesive acoustic transducer and intended for applications such as the direct amplification or recording of acoustic musical instruments, the "C-Ducer" is a flexible electret transducer in flat tape form available in several lengths to suit various instruments. According to the makers, C-Tape Developments, the device offers a very low noise level, a flat frequency response over the range 10Hz to 5MHz, and is supplied complete with a f.e.t. amplifier, which has a variable output level, permitting control of an external amplifier. Because the device detects vibrations through a solid it is relatively insentitive to airborne signals, partially relieving the typical problem of "howlround," which is induced acoustic feedback. The makers quote many other uses such as that of stress detection, burgular alarms (where "invasive" sounds can be picked off for attention), or situations where a high immunity to electromagnetic or radio frequency interference is a problem. The amplifier/polarizing supply required consists of two PP3 batteries and the amplifier unit is portable. The "professional" range has provision for mains or phantom powering and the price scale begins at £59 plus v.a.t. C-Tape Developments, 128, Grange Rd, Guildford, Surrey. GU2 6QP.

WW302

Versatile microcomputer

The System 80 computer, which is fundamentally a packaged Nascom -2, has been designed for flexibility, several new boards having been introduced. The main housing contains a racking frame which holds a mother board, a power supply, the c.p.u. board and up to four expansion boards. Provision is made for external connection to the boards and the computer has a g.r.p. cover with a keyboard cut-out. A future expansion housing will accommodate a further five boards, mounted on top of the System 80 case. A programmable character generator board uses 2k bytes of static r.a.m. and can accept the Nascom block-graphics r.o.m. The high resolution graphics operate on a cell structure consisting of 112 dots. Up to 128 cells can be produced in the 2k r.a.m. and each cell, once defined, can be displayed any-



where on the screen. A colour board offers high or low resolution for the three main television systems or an r.g.b. output. High resolution uses 6k of static r.a.m. and gives a choice of 16 colours. A dynamic r.a.m. board is available with 16, 32 or 48K bytes and has decoding, buffering and memory support. An input/output board can accommodate three MK 3881 p.i.as, a MK 3882 counter-timer and a 6402 u.a.r.t. The fifth optional board, a floppy disc controller, can handle up to four Siemens double-density, double-sided 5¼in drives using the 1791 i.c. Various link options permit single or double-sided and single or double-density disc to be used and the c.p.u. can be run at 2 or 4MHz. Nascom claim that the larger the system, the more competitive the price becomes. For example, with System 80 supported by 96K of r.a.m., a programmable character generator, a high resolution colour card, and a complete twin disc set, the cost is about £1,750. All parts can be supplied in kit form. Nascom Microcomputers Ltd, 92 Broad St, Chesham, Bucks.

WW303

Sound level exposure time meter

The Department of Employment's "Code of Practice for Reducing the Exposure of Employed Persons to Noise" defines the maximum time for which an employee may be safely exposed to high sound levels in a working day. At 90dBA an employee may work for eight hours but if the level increases to 93dBA (a barely audible increase), the energy content is doubled and the permissible working time reduced to four hours. At a typical discotheque level of 110dBA the exposure limit is less than five minutes per day. In addition to displaying the sound level, the Willie 85E has a linked scale showing the level and the maximum permissible exposure time. The microphone is mounted on a "pull-out" boom to limit case reflections and the list price of the complete unit is £130. It is also available as a full measurement kit complete with calibrator in an attache case, priced at £215. W. C. Willis and Co, Ltd, 6 Methil St, Scotstoun, Glasgow G14 0BH.

WW304

Mobile radio test set

Full system testing of mobile communication receivers and transmitters is the function of the Farnell TTS 520. The test set (lower of the two instruments shown in the photograph) is married to a signal generator and is capable of handling outputs of up to 100W via a suitable IEEE488 interface module. The TTS 520 incorporates an r.f. counter, an automatic modulation meter, a directional r.f. power meter, an a.f. voltmeter, an a.f. synthesiser, a distortion analyzer, an a.f. counter, weighing filters and an r.f. power load/attenuator. Among the measurements Farnell says the test set can handle are transmitter frequency, power output and modulation level, sensitivity,

bandwidth and distortion content. Transmitter continuous tone modulation checks can be carried out as can checks on aerial efficiency. Identical tests can be carried out on receivers by means of the SINAD or quieting method. Price of the test set is quoted as "well under £6,000 excluding v.a.t." Farnell Instruments Ltd, Sandbeck Way, Wetherby, Yorkshire LS22 4DH.
WW305

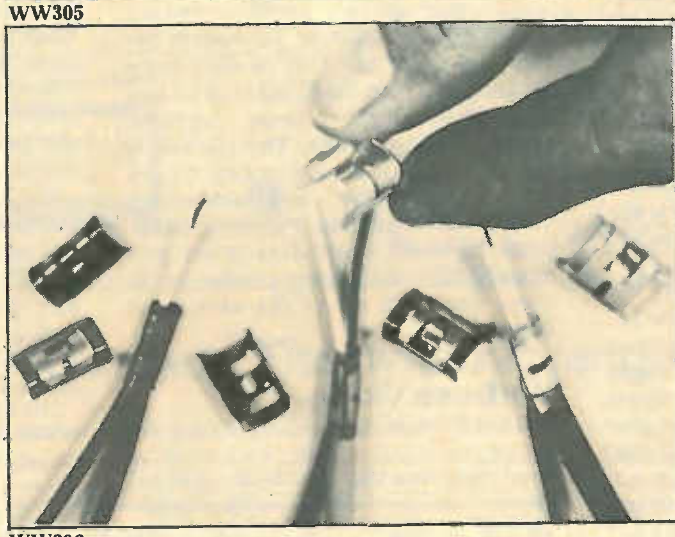
Wrap-around braid connectors

Although a specialised tool is recommended for installation by the makers, Thomas and Betts, the "Shield-Kon" range of connectors can be used to make secure outer braid or foil connections to conventional shielded or co-axial cable in a matter of seconds. Four sizes are available over the range 0.055in to 0.300in in diameter. Thomas and Betts Ltd, Sedgwick Rd, Luton, LU4 9DT.
WW306

Miniature digital panel meter

The overall measurements of the OEM-1 digital panel meter module, made by Anders Electronics Ltd are 60×38×15mm deep. In spite of being very thin, the unit features a 3½ digit liquid crystal display with ½in digits and can be powered from a single 9V d.c. supply. The current drawn is 1mA and the makers say that the single-chip dual-slope a-to-d converter provides a true differential input with auto-zero and auto-polarity operation drawing a cumulative current of 1pA. Among the unit's operational modes is the display of inputs up to ±200mV directly with an accuracy of 0.1%. Alternatively, it can be connected for differential (i.e. ratiometric) operation, permitting operations such as resistance and temperature measurement. "Quantity" price is £10 per unit, with evaluation samples


WW305


WW306

costing £21.90, plus v.a.t. Anders Electronics Ltd, 48-56 Bayham Place, London NW1 0EU.
WW307

Contemporary-type reverb plate

A "contemporary-type sound" is claimed for the Ecoplate reverberation plate, made by Programming Technologies Inc. of Linolnwood, Illinois. One of its features is a long h.f. decay time giving a "crisp sibilance that is very attractive for contemporary music". The long decay time is in contrast, to the fast h.f. decay of plates like the more natural-sounding EMT plate. A new smaller version, Ecoplate II, was shown at the February London AES convention that measures 173 × 109 × 26cm. If plates are made smaller they must also be made thinner to keep the eigentone density and hence coloration constant. But with a thinner plate, air pressure dampens the higher frequencies, resulting in a loss of high frequency decay time. To offset this, Ecoplate II has been developed to match the characteristics of the larger plates, the makers say, by the use of a "special" metal and damping plate. Reverberation time is adjustable from one to six seconds. Price is £1300 and UK sales are through Turnkey at 8 East Barnet Road, New Barnet, Herts EN4 8RW.
WW308

Power line filters

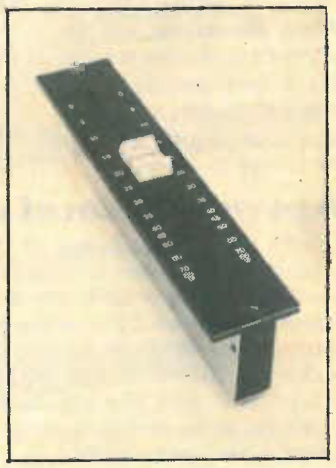
Protection against surges and transients is the main function of "Kleanpower" line filters, made by Lightning Elimination Associates. The MB series is an extension of the LEA type SE but offers the additional features of protection from noise spikes, r.f.i. and other disturbances which could cause damage or logic errors. Typical applications mentioned by the makers include computers, multiplexers, medical monitoring systems, electronic registers, word processors, communications systems on 200/240V a.c. supplies and has a maximum current rating of 13A. Lightning Elimination Associates Ltd, Vine Cottage, Moreton, Thame, Oxon.
WW309

Sealed touch keyboard

Optional X-Y or individual leadouts and a choice of 12 or 16 key formats are features of the Invader fully sealed touch keyboard. The unit, manufactured by Jack Evans Electronic Distribution has a normal operating temperature range of −29°C to +60°C and each contact will carry up to 100mA at 300V d.c. at a typical contact resistance of 1 milliohm. The makers quote the advantages of a wipe-clean flat surface and very low profile, and the keyboards are fully t.t.l. and c.m.o.s. compatible. Jack Evans Electronic Distribution Ltd, 244 Bath Rd, Hayes, Middlesex.
WW310

Conductive plastic digital fader

A new conductive plastic digital fader offers a direct grey scale 8-bit output from zero to decimal 255 within a stroke length of 102mm. The makers are Penny and Giles and the fader is interchangeable with the company's 1100 and 1500 series faders, making use of identical top plates and fascias. Applications quoted for the fader include driving digital attenuators or direct inputs to a computer. Penny and Giles Group, Mudeford, Christchurch, Dorset BH23 4AT.
WW311



Neon displays

Described as "bright neon orange seven segment displays" by the makers, Impectron, the NEO-8000 range of indicators measure 130×80×9mm, operating at a peak anode supply of 190V and peak anode current of about 5mA. Normal operating temperature range is −10°C to +60°C; the displays are designed for either p.c.b. or socket mounting and the makers expect them to be used in public information displays, vending equipment and industrial control equipment. Impectron Ltd, Foundry Lane, Horsham, W. Sussex.
WW312

SIDEBANDS

By Mixer

Extended view

We get a lot of press handouts from the BBC and IBA. Fairly often, they are about new transmitters and relay stations and, to be perfectly honest about it, we don't often spare them much more than a passing glance as they slither across our desks on their way to the news person. We think we know all about it, you see, having read so many.

So I thought, too, until I read a recent example and took note of some of the figures. Four new relay stations were to be opened, each serving as few as 500 people. One of them was to transmit to an audience of 2500, but three of the four were for 500-600. It struck me as totally admirable that small communities like this weren't being ignored, so I rang the Beeb to ask for more information. (I spoke to the BBC because it was their press release, but the IBA are just as much involved.)

It turns out that a four-channel relay station can cost about £40,000, so that the smallest groups are having about £80 per person spent on them, split between BBC and IBA. In Orkney, where the groups are smaller, the cost has been much higher — around £480 per person. In a year the two broadcasting organizations get through about £8million between them on this sort of filling-in exercise and the communities served are getting smaller as the bigger blank spots are eliminated. Coverage of the UK population is now 98.6% and it would need about another 100 relays like these to get it up to 98.7.

A bewilderment of terms

I think it's time we tidied up the verbiage a bit, because it's beginning to confuse a lot of people who aren't engineers, but who have to know something about electronics so that they can make decisions which could affect everyone. It isn't just beginning either — it's got some of them talking a whole lot of utter cobblers because they've misunderstood definitions.

A recent report for the Department of Industry set out to discover what use industry was making of, to pluck a word out of the air, microprocessors. The information was gathered by telephone, the questions being put to managing directors of companies by interviewers whose main concern in life is not electronics. So, to start with, this was not a very promising approach; not many company directors could, with any confidence, distinguish an integrated circuit from a momentarily-inactive centipede. It was, in fact, a proceeding not unlike a Xingu Indian and a native of Vladivostok discussing Test cricket.

The reason for the difficulty seems to lie in the quantity of different descriptions given to i.cs, some of which mean the same while others don't. Take just a few: integrated circuit, microelectronics, microchip, microprocessor, solid-state, 'new technology', silicon chip, silicon microcircuit, microcomputer — how on earth can we expect a non-specialist to ask or answer intelligent questions when faced with a collection of gobbledygook like that?

For example, if a non-engineer is asked how long his company has been using microchips, microelectronics, silicon microcircuits or solid-state devices, he might say they've used them for ten years, say, meaning they've had small-scale logic, linear circuits, counters and the like. The trouble is that these words are taken to be synonymous with 'microprocessor', 'new technology' and 'microcomputer' to the lay mind, which does rather tend to mean that any survey conducted on these lines will be, at the very least, suspect.

Verbose video

All that exhausting trekking across the sitting room carpet every two or three hours to push the television channel button is now, of course, very much a thing of the Spartan sixties. No one with any claim to the smallest degree of savoir vivre will countenance any more effort than a touch of the button of a remote-control unit. A quick tap on the key-pad and off goes one piece of imported, American life-style propaganda to be replaced by something more mind-stretching like "Blankety Blank". You can even wind down the sound during the commercials without tiring yourself out. What more could one ask?

A good deal, it appears, because there are plans to produce a telly-box that not only does as it is told but tells you it's done it — it talks back. Now, personally, what I like to see in pets, small children, wives and domestic appliances is blind, unquestioning obedience. I do not wish to become involved in tiresome discussion with a garrulous electrical device.

I can see myself becoming visibly annoyed if, when told to switch to "Match of the Day" the creature says "Oh! do you think that's wise? There is a Western on BBC2 which is really rather super — I firmly believe you would be much better off with that." Mind you, if you could instil some semblance of your own tastes into a store in the machine, you would be able to rely on the thing protecting you from nasty shocks. An inadvertent instruction to switch to "Top of the pops" would meet with an offended refusal to do any such thing and a suggestion that you read a good book for the next two hours because there isn't anything worth watching.

Maybe there's something in the idea after all.

Garage gurus

"It'll cost yer, squire," is a remark that garage mechanics learn before they progress to more advanced expressions such as "Mama". The pursed lip, sorrowful shake of the head and low whistle of disbelief are acquired much later in life, on the threshold of manhood and around the time when they learn how not to bat an eyelid when uttering a statement such as "That'll be a fiver, guv," after a cursory glance at the points and a quick polish of the radiator cap.

I exaggerate, of course. Garage mechanics are quite possibly totally admirable to a man, but I usually come upon them in circumstances of such dire discomfort and after such long periods of lonely vigil by the roadside that Sir Galahad himself would appear ill-natured and surly.

Having, at length, arrived on the scene, diagnosis of the trouble is usually rapid, and the fault can be put right there or at the garage, because spares are fairly easy to get hold of and reasonably quick, though expensive, to fit. (I speak as one with some experience of the above scenario.)

In short, on their own ground these chaps are pretty competent, on the whole, even though the prices they charge often do seem to have been calculated by squaring the chassis number. What bothers me is what will happen when microprocessors begin to take over.

It is also a matter for concern to Olaf Lambert, of the Automobile Association. While conceding that chips will make for quieter and more economical cars, he is worried that not many garages are going to be able to afford the test gear to diagnose faults, particularly as the connectors may well be different in different makes of car, in keeping with the VITSOL policy (Variety is the spice of life).

I do so agree. It is not easy to imagine the minor prophet at the local garage explaining the sleeping sickness afflicting one's wheels in terms of microprocessors. "It's yer chips, innit?" he will say. "What yer want is new r.o.m. — soon wear out, these foreign ones", he will remark, casually, mentioning also that he will need to pay a 'high-technology bonus' and that it will therefore cost even more than usual.

It almost makes you hope the oil runs out quickly so that we can all go back to push-bikes.

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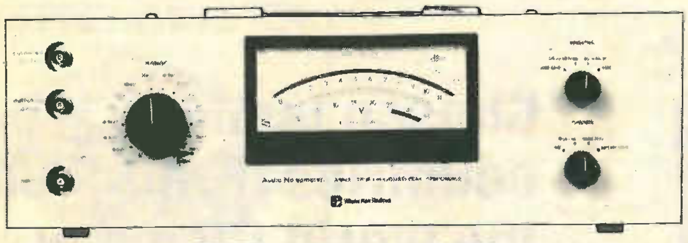

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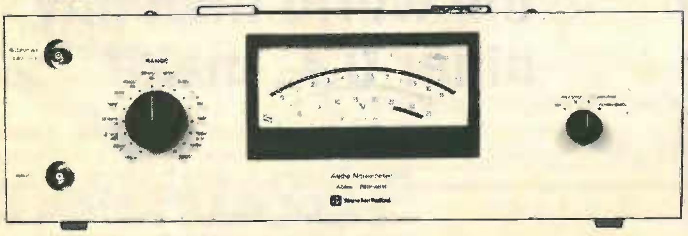

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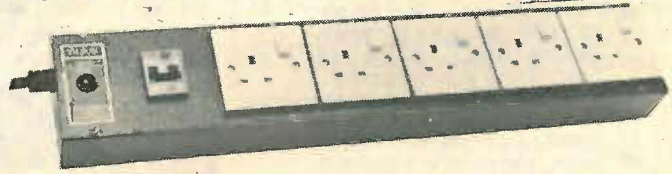

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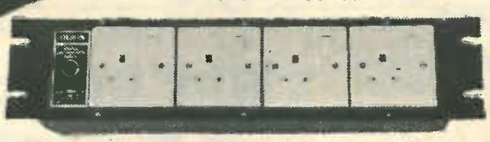

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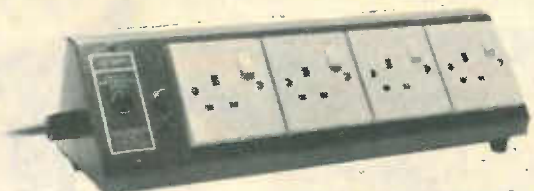

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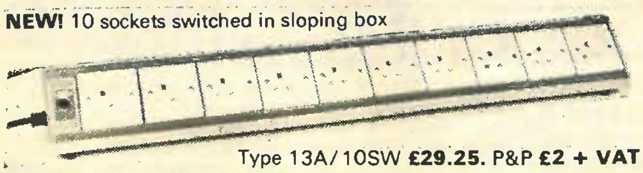

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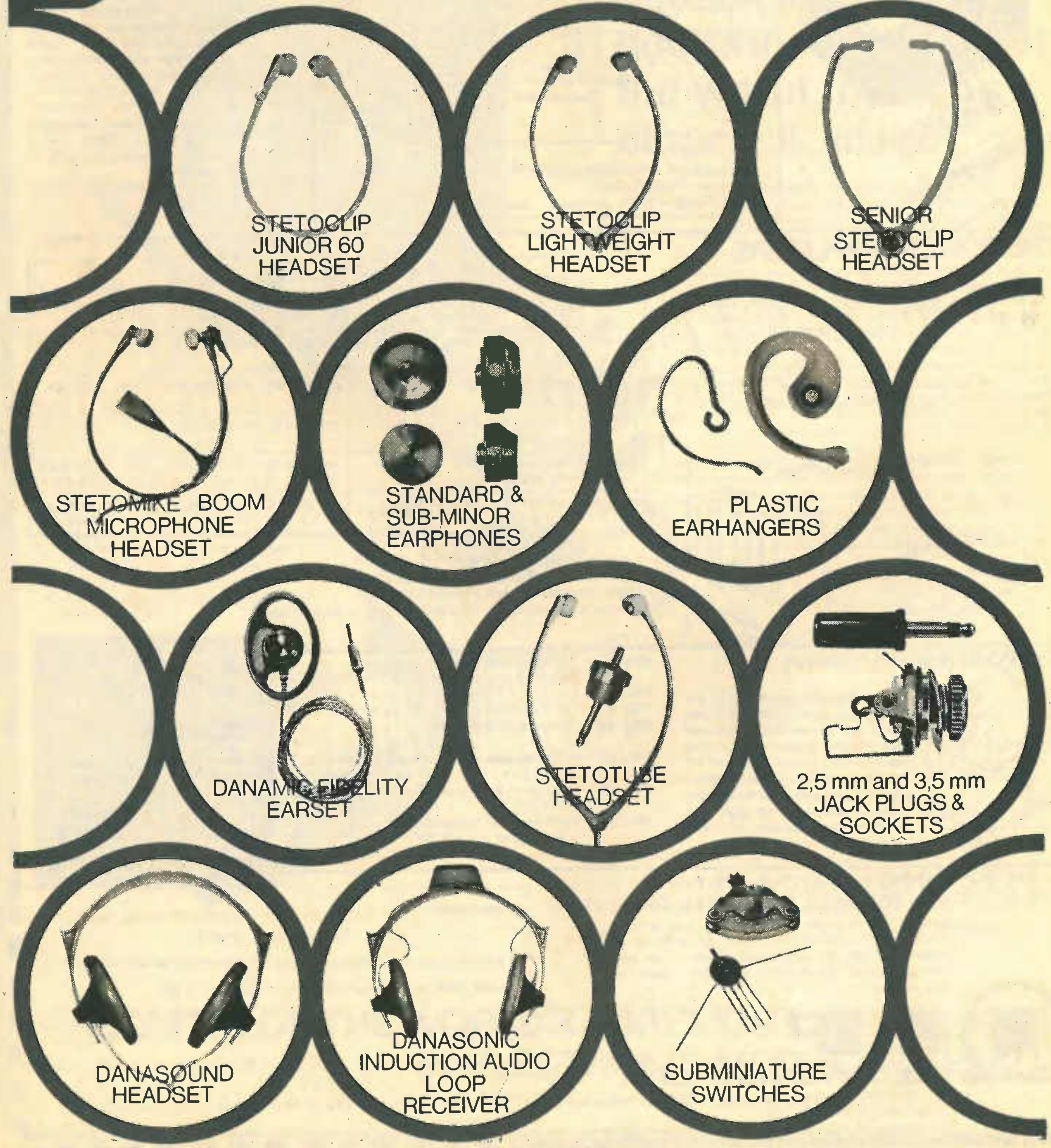

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TRIO TEST INSTRUMENTS

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NEW

THE CS1830 30 MHz + Sweep Delay

The CS1830 is a completely new 30 MHz dual trace oscilloscope employing a square format, internal graticle, PDA tube for accurate bright display. A new feature is the inclusion of calibrated sweep delay with a range of 1μS-100 mS and trace bright up to show the delay position. As you can see from close study of the photograph, the CS1830 has **all** the facilities you could require in a high performance instrument but for more detail, simply ask us for a comprehensive leaflet.

Brief specification

Rectangular PDA tube 120 × 96 mm. P31 phosphor.

Bandwidth DC—30 MHz		Overshoot less than 3%
Sensitivity	5mV/cm (30 MHz)	Sweep time 200nS/cm-0.5 S/cm
	2mV/cm (20 MHz)	Linearity better than 3%
Input R.C. 1 M /23 pF		Trig. bandwidth DC—30 MHz
Risetime 11.7 nS		Sweep delay 1μS-100 mS

CS1830 only **£455** + VAT includes 2 probes

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THE C51572 30 MHz for the VTR Lab.
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The CS1572 is a dual trace 30 MHz oscilloscope designed for the video tape recorder engineer. Video delayed sweep facilities are provided to allow magnification and analysis of any point in a single video frame together with separation of video odd and even fields. A truly unique tool for anyone concerned with video measurements as well as a top specification dual trace wide band oscilloscope for general lab use. The complete range of video facilities is too great to explain in a small advertisement so why not call us and ask for the full story on the CS1572.

Brief Specification

As for CS1830 except that the sweep delay feature is replaced by comprehensive video sweep delay facilities which allow complete analysis of video wave forms and VTR alignment.

CS1572 only **£425** + VAT, includes 2 probes

ESTABLISHED

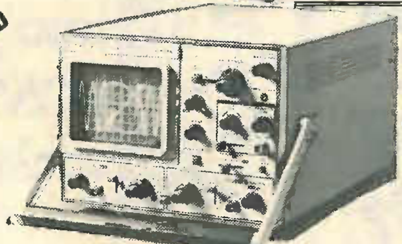
THE CS1577 30 MHz at 2mV + Signal Delay
The most popular scope in the range.

The CS1577 is, without doubt, our most popular oscilloscope and hundreds of satisfied users in all sections of the electronics industry will confirm this. The CS1577 combines a wide bandwidth DC-30 MHz performance with extremely wide trigger bandwidth (DC-40 MHz) and 2 mV sensitivity over the full bandwidth.

Fixed signal delay is provided by a helix delay line which allows viewing of the leading adges of fast pulses for accurate rise time measurement, and the 130 mm PDA tube gives a bright, stable trace even at the highest sweep speeds (20 nS/cm using × 5 expansion). Good triggering, even at low levels has always been an outstanding feature of Trio oscilloscopes and the CS1577 demonstrates this to perfection. Triggering, as in the other 30 MHz instruments can be from CH1 or CH2 **or** can be alternated with the beam switching so that input signals of differing frequency will provide stable displays. Truly an oscilloscope masterpiece. CS1577.

CS1577 only **£410** + VAT, includes 2 probes.

ESTABLISHED



THE CS1575, unique dual trace 4 function Audio Scope

The CS1575 is a unique tool for the audio engineer. It features the normal facility of dual trace display with sensitivity to 1 mV/cm but not only can it display the input signal on two channels, it can **simultaneously** display the phase angle between them and measure the phase angle referenced to a zero phase calibration display. In addition to these unique features, you also have independent triggering from each channel to give stable displays even with widely differing input frequencies.

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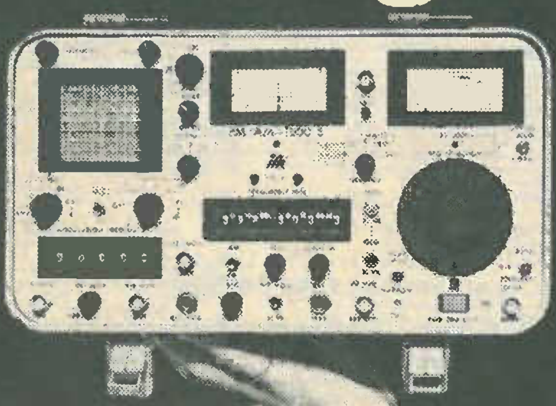

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For further information contact Mike Taylor

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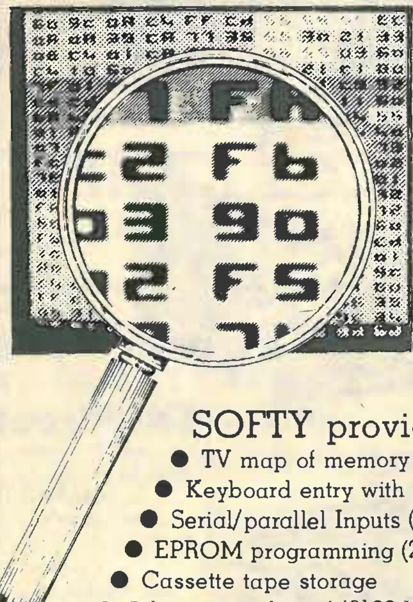

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SEMICONDUCTORS

Type	Price
AA119	0.12
AAY30	0.31
AAY32	0.48
AAZ13	0.21
AAZ15	0.39
AAZ17	0.31
AC107	0.69
AC125	0.23
AC126	0.23
AC127	0.23
AC128	0.23
AC141	0.29
AC141K	0.40
AC142	0.23
AC142K	0.35
AC176	0.23
AC187	0.23
AC188	0.23
ACY17	0.98
ACY18	0.92
ACY19	0.86
ACY20	0.80
ACY21	0.86
ACY39	1.72
AD149	0.80
AD161	0.52
AD162	0.52
AF106	0.52
AF114	0.86
AF115	0.86
AF116	0.86
AF117	0.86
AF139	0.46
AF186	1.38
AF239	0.52
AFZ11	3.16
AFZ12	3.16
ASY26	0.46
ASY27	0.46
ASZ15	1.44
ASZ16	1.44
ASZ17	1.44
ASZ20	1.72
ASZ21	2.30
AU113	1.96
AUY10	2.38
AU110	1.96
BA145	0.15
BA148	0.15
BA154	0.10
BA155	0.12
BA156	0.10
BAW62	0.06
BAX13	0.07
BAX16	0.10
BC107	0.14
BC108	0.14
BC109	0.15
BC113	0.14
BC114	0.15
BC115	0.16
BC116	0.17
BC117	0.20
BC118	0.12
BC125	0.18
BC126	0.23
BC135	0.16
BC136	0.17
BC137	0.17
BC147	0.10
BC148	0.09
BC149	0.10
BC157	0.10
BC158	0.09
BC159	0.12
BC167	0.14
BC170	0.13
BC171	0.12
BC172	0.12
BC173	0.14
BC177	0.17
BC178	0.16
BC179	0.18
BC182	0.13
BC183	0.12
BC184	0.13
BC212	0.15
BC213	0.14
BC214	0.17
BC237	0.10
BC238	0.14
BC301	0.38
BC303	0.38
BC307	0.12
BC308	0.12
BC327	0.23
BC328	0.21
BC337	0.21
BC338	0.20
BCY30	1.15
BCY31	1.15
BCY32	1.15
BCY33	1.04
BCY34	1.04
BCY39	3.45
BCY40	1.15
BCY42	0.29
BCY43	0.29
BCY58	0.18
BCY70	0.17
BCY71	0.20
BCY72	0.15
BCZ11	1.72
BD115	0.52
BD121	1.50
BD123	1.50
BD124	1.50
BD131	0.40
BD132	0.44
BD135	0.39
BD136	0.39
BD137	0.40
BD138	0.46
BD139	0.49
BD140	0.51
BD144	2.30
BD181	1.26
BD182	1.36
BD237	0.46
BD238	0.63
BDX10	1.05
BDX32	2.30
BDY20	1.44
BDY60	1.72
BF115	0.29
BF152	0.21
BF153	0.23
BF154	0.20
BF159	0.26
BF160	0.18
BF167	0.23
BF173	0.23
BF177	0.28
BF178	0.28
BF179	0.29
BF180	0.35
BF181	0.35
BF182	0.35
BF183	0.29
BF184	0.29
BF185	0.29
BF194	0.10
BF195	0.10
BF196	0.12
BF197	0.14
BF200	0.31
BF224	0.23
BF244	0.32
BF257	0.28
BF258	0.30
BF259	0.37
BF336	0.35
BF337	0.35
BF338	0.36
BFS21	4.55
BFS28	2.56
BFS61	0.23
BFS98	0.23
BFW10	0.74
BFW11	0.74
BFX84	0.25
BFX85	0.26
BFX87	0.24
BFX88	0.24
BFY50	0.30
BFY51	0.30
BFY52	0.30
BFY64	0.30
BFY90	1.44
BSX19	0.24
BSX20	0.23
BSX21	0.23
BT106	1.44
BTY79/400R	3.67
BU205	2.02
BU206	2.59
BU208	2.30
BY100	0.52
BY126	0.16
BY127	0.17
BZX61 Series	0.21
BZY88 Series	0.15
CRS1/40	0.69
CRS3/06	0.52
CRS3/40	0.86
CRS3/60	1.04
GEX66	1.73
GEX541	4.60
GJ3M	0.86
GM0378A	2.02
KS100A	0.52
MJE340	0.92
MJE370	1.35
MJE371	0.71
MJE520	0.60
MJE521	0.63
MJE2955	1.44
MJE3055	0.86
MPF102	0.35
MPF103	0.35
MPF104	0.35
MPF105	0.35
MPSA06	0.28
MPSA56	0.30
MPSU01	0.41
MPSU06	0.53
MPSU56	0.56
NE555	0.52
NKT401	2.30
NKT403	1.99
NKT404	1.99
OA5	1.09
OA7	0.63
OA10	0.74
OA47	0.16
OA70	0.35
OA79	0.35
OA81	0.35
OA85	0.35
OA90	0.09
OA91	0.09
OA95	0.09
OA200	0.10
OA202	0.10
OA211	1.15
OAZ200	1.15
OAZ201	1.15
OAZ206	1.15
OAZ207	1.15
OC16	2.30
OC20	2.88
OC22	2.88
OC23	3.16
OC24	3.45
OC25	1.04
OC26	1.04
OC28	2.30
OC29	2.30
OC35	1.73
OC36	1.73
OC41	0.92
OC42	0.86
OC43	2.59
OC44	0.69
OC45	0.63
OC71	0.63
OC72	0.63
OC73	1.15
OC74	0.74
OC75	0.74
OC76	0.63
OC77	1.38
OC81	0.74
OC81Z	1.38
OC82	0.74
OC83	0.74
OC84	0.74
OC122	1.73
OC123	2.02
OC139	2.59
OC140	3.16
OC141	3.74
OC170	1.15
OC171	1.15
OC200	1.73
OC201	2.02
OC202	2.02
OC203	2.02
OC204	2.88
OC205	2.88
OC206	2.88
OC207	2.02
OCP71	1.44
ORP12	1.15
R2008B	2.02
R2009	2.50
R2010B	2.02
T1C44	0.35
T1C226D	1.38
TIL209	0.23
TIP29A	0.47
TIP30A	0.48
TIP31A	0.51
TIP32A	0.55
TIP33A	0.79
TIP34A	0.84
TIP41A	0.72
TIP42A	0.81
TIP2955	0.77
TIP3055	0.64
TIS43	0.52
ZS140	0.29
ZS170	0.24
ZS178	0.62
ZS271	0.26
ZS278	0.65
ZTX107	0.13
ZTX108	0.12
ZTX109	0.14
ZTX300	0.14
ZTX301	0.15
ZTX302	0.17
ZTX303	0.20
ZTX304	0.22
ZTX311	0.14
ZTX314	0.23
ZTX500	0.15
ZTX501	0.16
ZTX502	0.18
ZTX503	0.20
ZTX504	0.23
ZTX531	0.23
ZTX550	0.18
1N914	0.06
1N916	0.08
1N4001	0.07
1N4002	0.07
1N4003	0.08
1N4004	0.08
1N4005	0.09
1N4006	0.09
1N4007	0.10
1N4009	0.07
1N4148	0.07
1N5400	0.15
1N5401	0.15
1S44	0.05
1S920	0.08
1S921	0.08
2G301	1.15
2G302	1.15
2G306	1.27
2N404	1.15
2N696	0.29
2N697	0.29
2N698	0.35
2N705	1.38
2N706	0.17
2N708	0.23
2N930	0.23
2N1131	0.30
2N1132	0.30
2N1302	0.40
2N1303	0.40
2N1304	0.52
2N1305	0.52
2N1306	0.58
2N1307	0.58
2N1308	0.63
2N1309	0.63
2N1613	0.29
2N1671	1.73
2N1893	0.29
2N2147	2.02
2N2148	1.89
2N2218	0.29
2N2219	0.28
2N2220	0.21
2N2221	0.21
2N2222	0.21
2N2223	3.16
2N2368	0.20
2N2369A	0.24
2N2484	0.23
2N2646	0.63
2N2904	0.29
2N2905	0.29
2N2906	0.24
2N2907	0.24
2N2924	0.24
2N2925	0.25
2N2926	0.16
2N3053	0.29
2N3054	0.58
2N3055	0.81
2N3440	0.69
2N3441	0.92
2N3442	1.26
2N3614	1.73
2N3702	0.13
2N3703	0.15
2N3704	0.15
2N3705	0.15
2N3706	0.15
2N3707	0.15
2N3708	0.12
2N3709	0.15
2N3710	0.12
2N3711	0.12
2N3771	2.02
2N3772	2.30
2N3773	3.45
2N3819	0.41
2N3820	0.52
2N3823	0.63
2N3866	0.83
2N3904	0.15
2N3905	0.15
2N3906	0.15
2N4058	0.16
2N4059	0.12
2N4060	0.14
2N4061	0.14
2N4062	0.15
2N4124	0.17
2N4126	0.17
2N4286	0.23
2N4288	0.25
2N4289	0.28
2N5457	0.40
2N5458	0.40
2N5459	0.40
2S017	7.48
2S019	7.48
2S026	13.80
2S103	1.73
2S302	0.86
2S303	0.86
2S322	0.92
2S324	1.44
2S701	1.73
2S745A	0.40
2S746A	0.40

VALVES

Type	Price
A1834	10.35
A2087	13.58
A2134	10.06
A2293	8.62
A2426	17.63
A2521	11.62
A2900	10.98
A3343	25.56
AZ31	1.26
AZ41	1.32
BK448	88.43
BK484	119.54
BS90	31.33
BS810	35.24
BT5	43.47
BZ17	79.29
BT19	27.08
BT29	242.93
BT69	247.30
BT75	102.46
BT95	95.16
CBL31	2.30
CL33	2.30
CY31	1.15
C1K	11.50
C3A	11.50
C3JA	23.23
DA41	21.50
DA42	12.30
DA100	52.90
DAF91	0.46
DAF96	1.15
DET22	24.15
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
DY86/7	0.73
DY802	0.96
E55L	25.17
E80CC	9.27
E80CF	11.96
E80F	9.75
E80L	9.51
E81CC	6.62
E81L	10.28
E82CC	7.03
E83CC	7.16
E86C	12.48
E88C	6.71
E88CC	3.86
E90CC	9.34
E90F	9.71
E91H	5.34
E92CC	8.86
E99F	9.39
E130L	19.39
E180CC	8.86
E180F	7.83
E182CC	9.34
E186F	11.62
E188CC	7.36
E280F	25.88
E283CC	9.02
E288CC	17.25
EA52	19.43
EA76	2.02
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	4.60
EC90	1.28
EC91	9.35
EC92	1.44
EC157	276.92
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	1.32
EF41	2.30
EF42	2.30
EF50	1.73
EF54	5.75
EF55	2.88
EF80	0.92
EF83	2.02
EF85	0.92
EF86	1.74
EF89	1.84
EF91	2.07
EF92	6.03
EF93	1.15
EF94	1.24
EF95	6.27
EF98	1.44
EF183	0.92
EF184	0.96
EF804S	12.65
EF805S	8.05
EH90	1.61
EK90	1.24
EL32	1.73
EL33	4.02
EL34TH	2.53
EL34M	2.57
EL36	1.84
EL41	1.44
EL42	2.02
EL81	2.88
EL83	1.44
EL84	1.15
EL86	2.48
EL90	1.10
EL91	8.21
EL95	1.51
EL156	97.60
EL360	6.32
EL500/504	2.16
EL509	3.63
EL821	11.06
EL822	11.38
EM34	5.75
EM80	1.26
EM81	1.15
EM84	1.15
EM85	1.44
EM87	1.73
EN32	16.28
EN91	2.94
EN92	6.18
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	23.23
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	12.80
GY501	2.95
GZ32	1.44
GZ33	4.60
GZ34	2.18
GZ37	4.60
KT61	4.02
KT66	11.50
KT88	13.80
KTW61	2.02
KTW62	2.02
KTW63	2.02
M8079	11.59
M8080	7.68
M8081	9.95
M8082	6.41
M8083	7.59
M8091	10.85
M8096	4.31
M8097	4.09
M8098	4.37
M8099	5.98
M8100	8.23
M8136	8.46
M8137	8.72
M8140	5.17
M8141	5.52
M8142	6.15
M8144	4.31
M8149	5.86
M8161	7.87
M8162	7.59
M8163	5.17
M8190	5.29
M8195	4.25
M8196	7.47
M8204	6.57
M8212	11.76
M8223	3.17
M8224	3.85
M8225	2.99
M8248	11.55
MU14	1.73
MX119	53.82
MX123	63.25
MX145	50.40
MX151	15.18
MX152	115.00
MX161	129.72
MX163	19.55
MX164	21.14
MX166	126.50
MX168	40.25
N78	10.35
OA2	1.96
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	2.82
PCF201	2.45
PCF801	1.84
PCF802	1.82
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	3.68
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	13.91
QQV03-6	5.44
QQV03-20A	20.13
QQV06-40A	40.25
QQV07-50	53.13
QQZ03-20A	59.80
QQZ06-40A	55.10
QU37	14.38
QV03-12	4.31
QV04-7	2.88
QV08-100	118.45
QY3-65	53.74
QY3-125	56.78
QY4-250	65.93
QY4-400	75.67
QY5-500	59.39
QY5-3000A	82.56
QZ06-20	27.72
R10	5.75
R17	1.89
R18	4.89
R19	1.38
R20	1.66
RG3-250	32.49
RG3-250A	34.09
RG3-1250	29.56
RG4-1250	13.13
RG4-3000	75.44
RR3-250	48.68
RR3-1250	86.20
S11E12	30.48
S130	2.30
S130P	2.88
STV280-40	11.50
STV280-80	24.15
SU41	2.88
SU42	10.35
TD03-10	24.73
TD03-10E	[illegible].16
TD03-10F	27.60
TT15	34.50
TT21	14.16
TT22	14.16
TT100	59.51
TY2-125	65.33
TW4-400	71.61
TY4-500	95.40
TY5-500	147.20
TY6-800	165.70
TY6-5000A	263.05
TY6-5000B	236.90
TY6-5000W	23 V44
TY7-6000A	286.93
TY7-6000W	232.47
TZ40	17.25
U18-20	2.88
U19	10.33
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
UF49	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	32.37
XG2-6400	92.98
XG5-500	19.32
XGQ2-6400	106.15
XR1-1600A	27.54
XR1-3200	76.94
XR1-3200A	76.94
XR1-6400	84.24
XR1-6400A	149.30
YD1120	2[illegible].60
YD1240	241.50
Z759	11.04
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	7.82
2J42	89.70
2J55	201.25
2J70A	270.25
2J70B	287.50
2K25	40.25
3-400Z	51.75
3-500Z	63.25
3A5	1.55
3B24	9.20
3B28	5.18
3B29	11.50
3B240M	17.25
3B241M	17.25
3C23	13.89
3C45	22.77
3CX100A5	23.00
3E29	29.67
3S4	1.26
3V4	1.38
465A	29.15
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4-400A	52.05
4B32	29.16
4C35	46.00
4CX250B	28.53
4CX350A	48.88
4X150A	24.41
4X150D	28.75
5B254M	23.12
5B255M	23.12
5C22	46.00
5J180E	851.00
5R7GY	2.30
5U4G	4.35
5U4GB	2.60
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	3.98
6AK6	2.81
6AL5	1.01
6AM4	2.65
6AM5	4.43
6AM6	2.07
6AN5	6.12
6AN8A	3.80
6AQ5	1.10
6AS5	1.84
6AS6	6.42
6AS7G	7.76
6AT6	0.98
6AU5GT	4.81
6AU6	1.24
6AV5GT	4.36
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	4.14
6BR7	4.60
6BR8	2.02
6BS7	4.60
6BW6	4.60
6BW7	1.75
6BX7GT	5.70
6BZ6	2.62
6C4	1.61
CB6A	2.86
6CD6GA	5.64
6CG7	2.55
6CH6	7.48
6CL6	4.12
6CW4	8.33
6D2	1.01
6DK6	2.59
6DQ6B	4.49
6EA8	3.31
6EB8	2.44
6EW6	1.73
6F6	2.02
6F23	1.84
6F28	1.33
6F33	22.08
6H1	14.38
6H2N	1.21
6H3N	1.21
6H6	1.73
6J4	6.10
6J6	6.21
6J7	9.04
6K4N	1.44
6K6GT	1.50
6K7	1.73
6K8	2.02
6KD6	7.08
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	3.24
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	2.83
12AU7	0.83
12AV6	2.30
12AV7	3.98
12AX7	1.01
12AY7	5.24
12B4A	3.50
12BA6	2.42
12BE6	2.55
12BH7	1.29
12BY7	3.01
12E1	8.17
12E11TT	19.26
12E14	34.50
13E1	62.20
19H4	28.75
19H5	40.25
24B9	43.87
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
30PL13	2.07
30PL14	1.93
30PL15	2.07
35W4	0.69
50C5	0.81
75B1	4.26
75C1	2.24
85A1	8.63
85A2	2.42
90AG	9.15
90AV	9.15
90C1	2.47
90CG	15.73
90CV	15.30
92AG	9.15
92AV	9.15
95A1	6.56
150B2	2.76
150B3	5.06
150C2	1.73
150C4	2.42
211	6.90
723AB	40.25
803	11.50
805	23.00
807	2.30
811A	9.78
812A	9.60
813	36.80
833A	86.25
866A	6.61
872A	15.81
922	5.01
931A	14.08
1624	2.59
1625	1.96
2050	8.00
4212E	169.90
4212H	207.00
5544	62.10
5545	67.85
5551A	88.44
5552A	119.54
5553A	259.10
5642	6.05
5654	4.05
5651	2.07
5670	5.29
5675	14.03
5687	7.08
5696	4.53
5718	7.36
5725	6.28
5726	4.05
5727	5.52
5749	5.73
5751	5.36
5763	4.14
5814A	4.8[illegible]
5840	5.06
5842	15.59
5876A	13.06
5879	5.57
5886	12.08
5963	3.45
5965	4.07
6005	6.33
6021	5.13
6057	4.02
6058	10.40
6059	4.60
6061	4.89
6062	4.31
6063	4.20
6064	6.50
6067	4.02
6072	6.53
6080	7.88
6097A×B×C	46.00
6146A	5.89
6146B	6.42
6159	9.18
6189	9.25
6201	5.93
6442	17.25
6883B	6.81
6973	4.05
7025	2.62
7551	6.83
7586	13.09
7587	22.54
7609	36.57
7868	4.53
7895	14.84
8005	34.50
8068	6.33
6122	48.30
8136	2.81
8417	6.14
18042	6.92
18045	10.66

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BASES

Type	Price
B7G unskirted	0.17
B7G skirted	0.35
B9A unskirted	0.17
B9A skirted	0.35
Int Octal	0.29
Loctal	0.63
Nuvistor base	0.86
8 pin DIL	0.17
14 pin DIL	0.17
16 pin DIL	0.20
Valve screening cans all sizes	0.35

CRTs

Type	Price
2AP1	9.78
2BP1	10.35
3BP1	11.50
3DP1	5.75
3EG1	8.05
3FP7	6.90
3GP1	6.90
3JP1	9.20
3JP2	9.20
3JP7	11.50
3KP1	17.25
3RP1	40.25
3WP1	23.00
5ADP1	40.25
5BP1	11.50
5CP1	11.50
5CP1A	46.00
5FP15A	17.25
5UP7	16.10
DG7-5	28.75
DG7-32	41.40
DH3-91	35.65
DH7-11	78.20
VCR97	13.80
VCR138	11.50
VCR138A	14.38
VCR139A	9.20
VCR517A	11.50
VCR517B	11.50
VCR517C	11.50

Tube Bases Prices on application

INTEGRATED CIRCUITS

Type	Price
7400	0.18
7401	0.18
7402	0.18
7403	0.18
7404	0.20
7405	0.18
7406	0.46
7407	0.46
7408	0.23
7409	0.23
7410	0.18
7412	0.30
7413	0.37
7416	0.37
7417	0.37
7420	0.20
7422	0.23
7423	0.37
7425	0.35
7427	0.35
7428	0.49
7430	0.20
7432	0.35
7433	0.41
7437	0.37
7438	0.37
7440	0.21
7441	0.97
7442	0.83
7447AN	1.04
7450	0.21
7451	0.21
7453	0.21
7454	0.21
7460	0.21
7470	0.40
7472	0.38
7473	0.41
7474	0.46
7475	0.62
7476	0.46
7480	0.63
7482	0.88
7483	1.04
7484	1.15
7486	0.40
7490	0.60
7491	0.92
7492	0.69
7493	0.69
7494	0.92
7495	0.83
7496	0.92
7497	3.45
74100	1.73
74107	0.52
74109	0.81
74110	0.58
74111	0.81
74116	2.02
74118	1.15
74119	1.73
74120	0.95
74121	0.46
74122	0.69
74123	1.15
74125	0.63
74126	0.63
74128	0.69
74132	0.81
74136	0.63
74141	0.92
74142	2.65
74143	2.88
74144	2.88
74145	1.04
74147	2.30
74148	2.02
74150	1.84
74151	0.97
74154	2.02
74155	0.97
74156	0.97
74157	0.86
74159	2.42
74170	2.65
74172	5.06
74173	1.61
74174	1.73
74175	1.04
74176	1.44
74178	1.44
74179	1.44
74180	1.32
74190	1.73
74191	1.73
74192	1.55
74193	1.55
74194	1.44
74195	1.15
74196	1.38
74197	1.26
74198	2.59
74199	2.59
76013N	2.02
TAA570	2.65
TAA630S	4.02
TAA700	4.50
TBA480Q	2.12
TBA520Q	2.65
TBA530	2.28
TBA540Q	2.65
TBA550Q	3.70
TBA560CQ	3.70
TBA673	2.52
TBA700	1.75
TBA720Q	2.65
TBA750Q	2.38
TBA800	1.38
TBA920	3.34
TBA920Q	3.34
TBA990Q	3.34
TCA270Q	3.34
TCA760A	1.59

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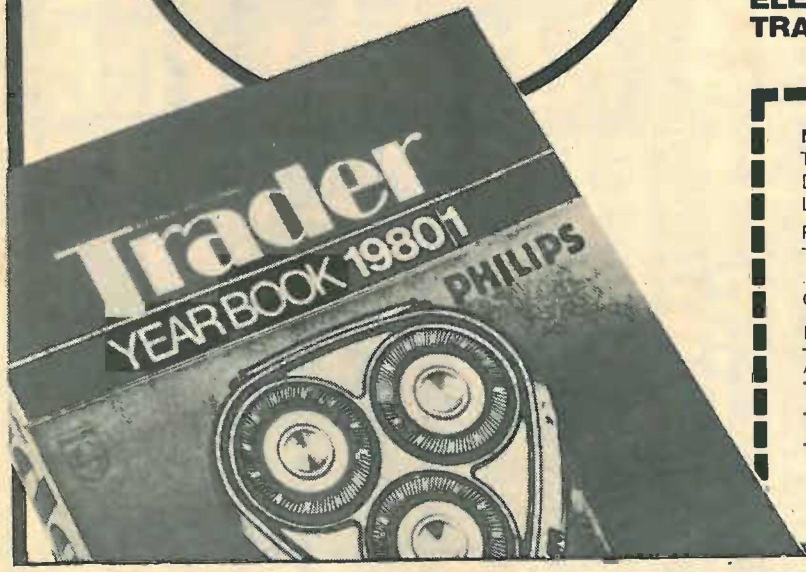

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The Davis 7208 VHF-UHF Frequency Counter incorporates the latest LSI technology in a wide range portable instrument at a reasonable price. The 7208 offers outstanding features including an all metal cabinet for RF shielding, large 8 digit display, built-in prescaler, automatic DP, and with the built-in VHF-UHF preamp the 7208 can directly measure low level RF signals from RF generators. The 7208 can also be operated completely portable with the Ni-Cad battery option. **Price £145.00 + VAT.**

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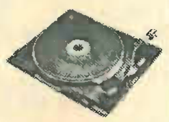

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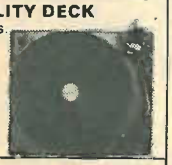

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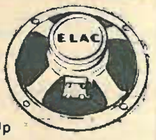

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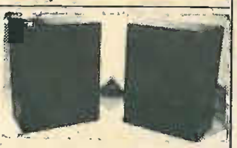

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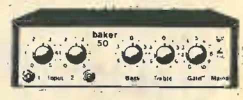

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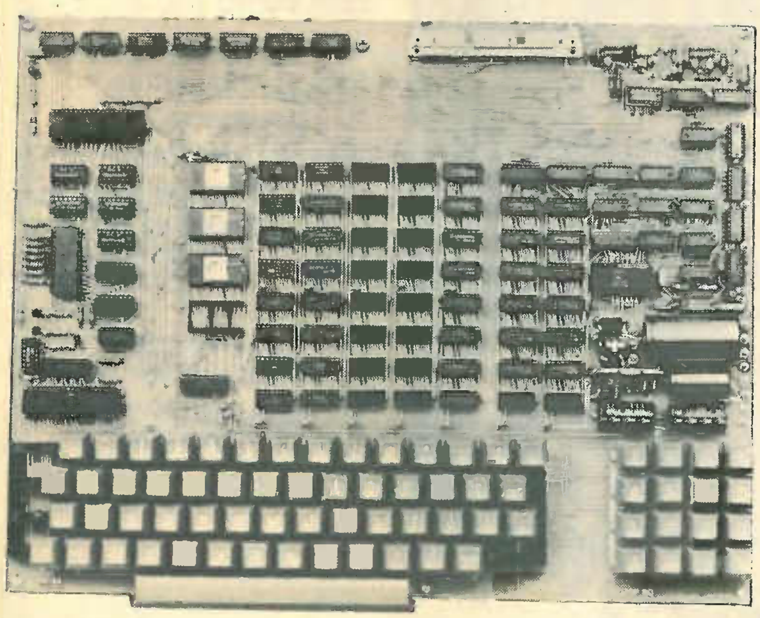

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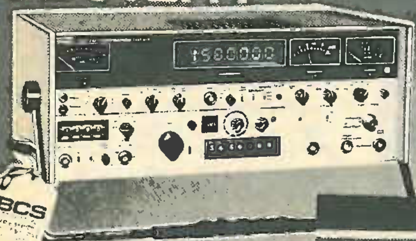

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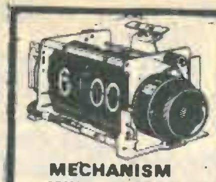

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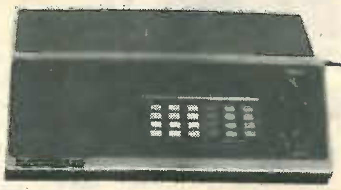

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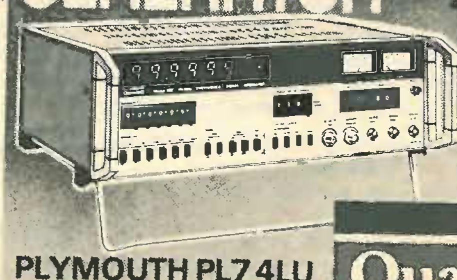

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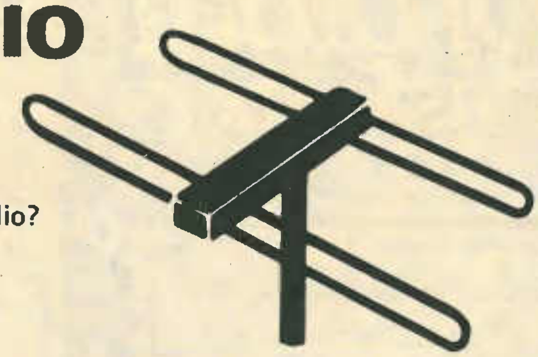

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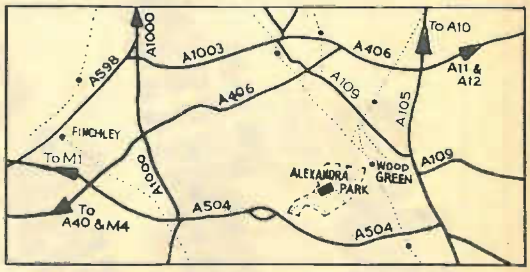

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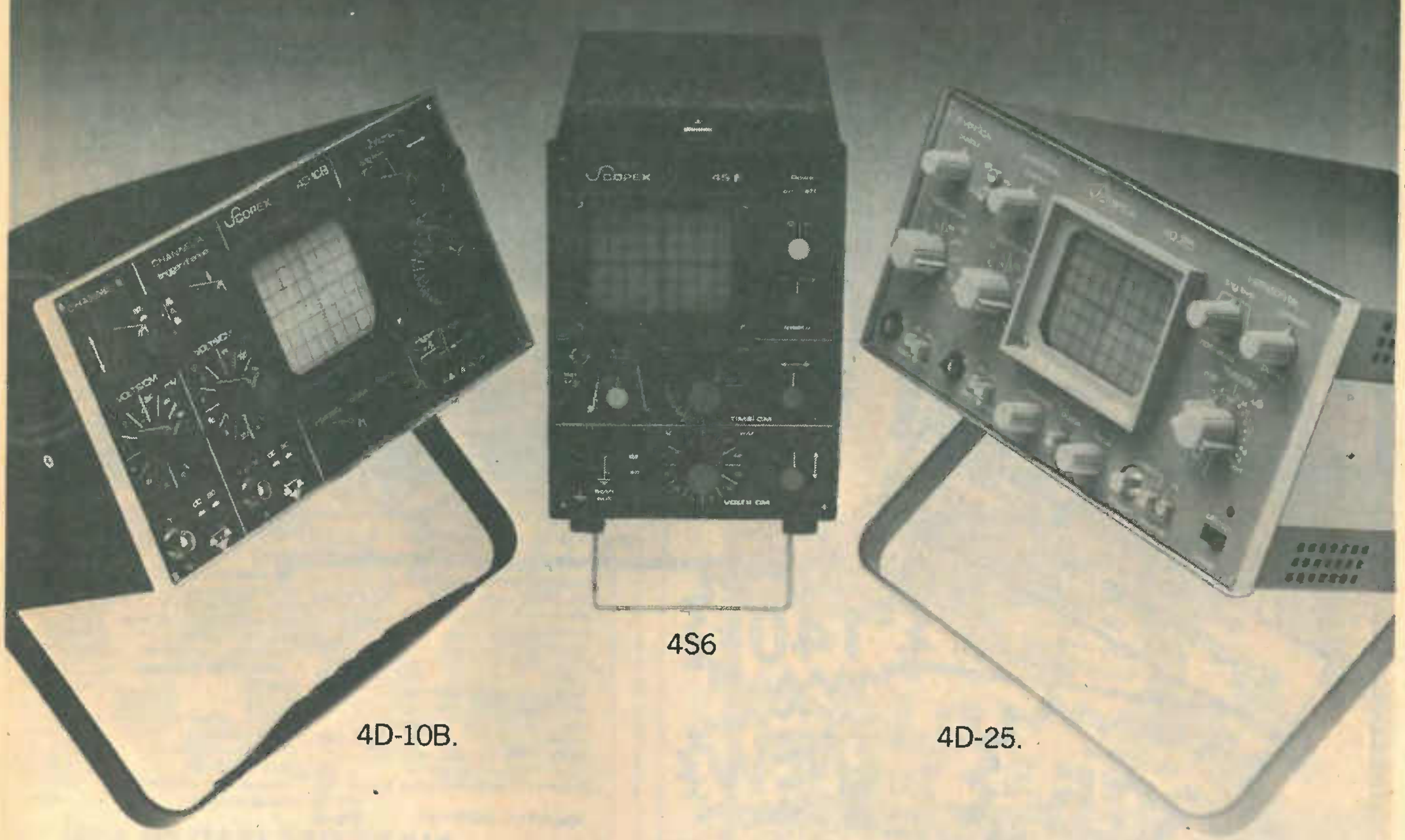

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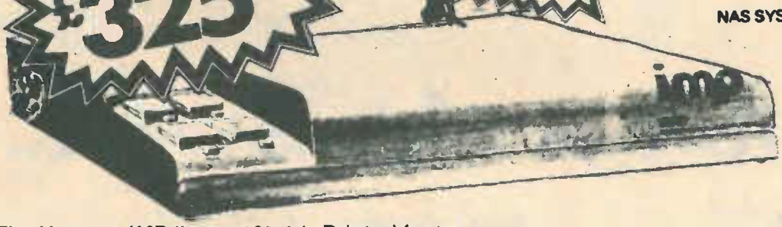

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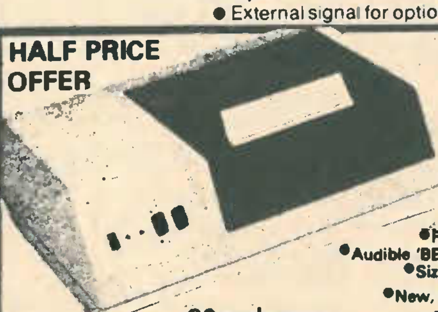

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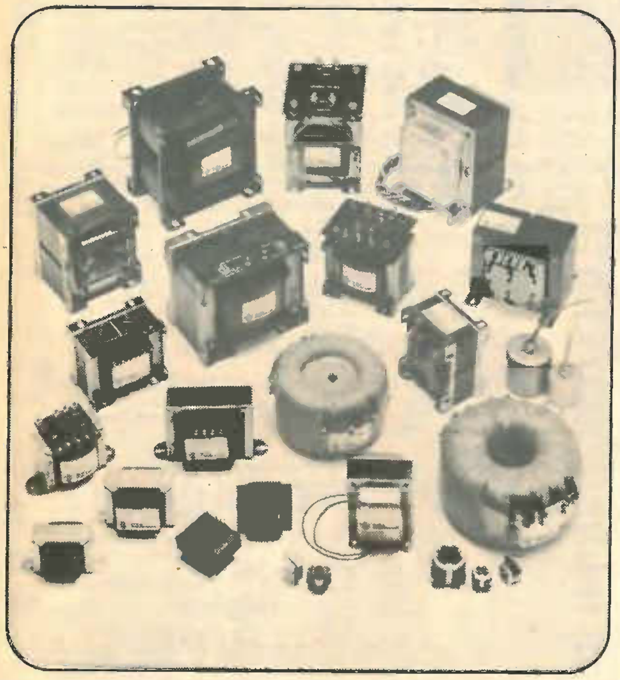

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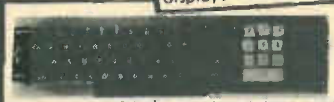

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DISPLAY ELECTRONICS

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Telephone: 01-689 7702

MAIL ORDER INFORMATION
Unless otherwise stated all prices inclusive of VAT. Cash with order. Minimum order value £2.00. Prices and Postage quoted for UK only. Where post and packing not indicated please add 40p per order. Bona Fide account orders minimum £10.00. Export and trade enquiries welcome. Orders despatched same day where possible. Access and Barclaycard Visa welcome.

POWER SUPPLY UNITS

5 VOLT 2.5/8 AMP TTL Made for TTL this compact ex computer systems unit features a 10 amp transformer. DC outputs of 5 volts @ 2.5 amps and 7.5 volts @ 5 amps are available. The 5v output is fully regulated and smoothed with electronic current limiting. May be easily moded for 5 volts @ 7-8 amps. Sold complete with circuit, believed working but untested. **£8.25 + £1.60pp.**

5 VOLT 5 AMP An extremely compact unit measuring only 125 x 175 x 83 mm, almost fully enclosed with terminal type connections. Features such as adjustable volts and current limit make it ideal for an MPU system. Sold as new. **£14.99 + £1.60pp.**

"+" & "−" 12-15v @ 250 ma. ITT Powercard. Measuring only 140 x 80 x 40 mm, this precision totally enclosed PSU should meet all your memory and negative rail requirements. Individual pots allow independent adjustment of both the plus and minus supply rails. Supplied BRAND NEW with circuit and edge connector at only **£12.75 + £1.00pp.**

KEYBOARDS

★ 76 KEY ASCII CASED ★

At last a coded 75 key cased ASCII keyboard at the right price. Housed in an attractive light grey case, this unit was originally made for ICL for use in air-port reservation systems so only the BEST parts were used. It has everything, we think, to meet your most exacting requirements, numeric keypad, upper and lower case, cursor controls, single 5 volt rail, serial and parallel data outputs, plus eight LEDs mounted on the case. Supplied with circuits, believed brand new, but may have minor scratches on cases.
Only **£43.50** + £1.60pp

★ LOW PRICE CHASSIS ★

A special bulk purchase enables us to offer the above keyboard at a lowest ever price. 49 coded keys encoded into a direct TTL compatible 7 bit output. Features such as delayed strobe, 5 volt O.C. single rail operation and rollover protection make this an absolute must for the MPU constructor! Supplied complete with connection diagram and edge connector, at a secondhand "no time to test" price of only **£20.00** + P.P. **£1.60**

SUPER CASED VERSION Same as above spec. but housed in attractive two tone moulded, free standing case. Unit also includes an all TTL parallel to serial convertor (no details) etr.

£27.50 + P.P. **£1.85**

TOROIDAL TRANSFORMERS

HP 240v pri. sec. 2 x 30v @ 4 amps 2 x 18v @ 1 amp £11.00 + p.p. £1.95 dimensions $4\frac{3}{4}$" x $2\frac{3}{8}$"
PR 240v pri. sec. 15 0 15 @ 2 amps dimensions 3" x $2\frac{1}{8}$" £4.95 + p.p. 99p.
TM 240v/110v pri. sec. 15 0 15 8vA dimensions $2\frac{1}{2}$" x 1" £1.95 + p.p. 30p.
All voltages measured off load.

HIGH EFFICIENCY SMITHS RADIAL BLOWERS

Are your hot parts sweltering? Then keep them cool with our high efficiency radial snail type blowers. Made by Smiths, designed for continuous use in expensive electronic equipment very powerful and quiet, gives massive air flow to prolong component life and reliability. Easily mounted, air aperture $2\frac{1}{2}$" x 3". Ideal linears etc.
Please state 240v or 110v operation. 50hz only.

BRAND NEW **£4.55** P.P. £1.60

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TRANSFORMERS
CONTINUOUS RATINGS

Please add VAT after P&P

MAINS ISOLATOR

PRI 120 or 240V Sec 120 or 240V
Centre Tapped and Screened

Ref.	VA (Watts)	£	P&P
07★	20	**4.84**	.91
149	60	**7.37**	1.10
150	100	**8.38**	1.31
151	200	**12.28**	1.31
152	250	**14.61**	1.73
153	350	**18.07**	2.12
154	500	**22.52**	2.47
155	750	**32.08**	OA
156	1000	**40.92**	OA
157	1500	**56.52**	OA
158	2000	**67.99**	OA
159	3000	**95.33**	OA

★115 or 240 sec only. State volts required. Pri. 0.220-240V.

VAT 15% 12 or 24-VOLT

Separate 12V windings Pri 220-240V

Ref	Amps 12v	Amps 24v	£	P&P
111	0.5	0.25	**2.42**	.52
213	1.0	0.5	**2.90**	.90
71	2	1	**3.86**	.90
18	4	2	**4.46**	1.10
85	5	2.5	**6.16**	1.10
70	6	3	**6.99**	1.10
108	8	4	**8.16**	1.31
72	10	5	**8.93**	1.31
116	12	6	**9.89**	1.52
17	16	8	**11.79**	1.52
115	20	10	**15.38**	2.39
187	30	15	**19.72**	2.39
226	60	30	**40.41**	OA

50 VOLT RANGE

Pri 220-240V. Sec. 0-20-25-33-40-50V Voltages available 5, 7, 8, 10, 13, 15, 17, 20, 25, 30, 33, 40 or 20V-0-20V and 25V-0-25V Screened

Ref.	Amps	£	P&P
102	0.5	**3.75**	.90
103	1.0	**4.57**	1.10
104	2.0	**7.88**	1.31
105	3.0	**9.42**	1.52
106	4.0	**12.82**	1.75
107	6.0	**16.57**	1.89
118	8.0	**22.29**	2.39
119	10.0	**27.48**	OA
109	12.0	**31.79**	OA

30 VOLT RANGE

Pri 220-240V Sec. 0-12-15-20-24-30V Voltages available 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30V or 12V-0-12V and 15V-0-15V.

Ref.	Amps	£	P&P
112	0.5	**2.90**	.90
79	1.0	**3.93**	1.10
3	2.0	**6.35**	1.10
20	3.0	**6.82**	1.31
21	4.0	**8.79**	1.31
51	5.0	**10.86**	1.52
117	6.0	**12.29**	1.67
88	8.0	**16.45**	1.89
89	10.0	**18.98**	1.89
90	12.0	**21.09**	2.24
91	15.0	**24.16**	2.39
92	20.0	**32.40**	OA

60 VOLT RANGE

Pri 220-240V
Sec 0-24-30-40-48-60V. Voltages available 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60V, or 24V-0-24V and 30V-0-30V

Ref.	Amps	£	P&P
124	0.5	**4.27**	1.10
126	1.0	**6.50**	1.10
127	2.0	**8.36**	1.31
125	3.0	**12.10**	1.39
123	4.0	**13.77**	2.12
40	5.0	**17.42**	1.89
120	6.0	**19.87**	2.12
121	8.0	**27.92**	OA
122	10.0	**32.51**	OA
189	12.0	**37.47**	OA

SCREENED MINIATURES Primary 240V

Ref.	mA	Volts	£	P&P
238	200	3-0-3	**2.83**	.63
212	1A, 1A	0-6, 0-6	**3.14**	.90
13	100	9-0-9	**2.35**	.44
235	330, 330	0-9, 0-9	**2.19**	.44
207	500, 500	0-8-9, 0-8-9	**3.05**	.85
208	1A, 1A	0-8-9, 0-8-9	**3.88**	.90
236	200, 200	0-15, 0-15	**2.19**	.44
239	50MA	12-0-12	**2.88**	.37
214	300, 300	0-20, 2-20	**3.08**	.90
221	700 (DC)	20-12-0-12-20	**3.75**	.90
206	1A, 1A	0-15-20, 0-15-20	**5.09**	1.10
203	500, 500	0-15-27, 0-15-27	**4.39**	1.10
204	1A, 1A	0-15-27, 0-15-27	**6.64**	1.10

HIGH VOLTAGE

MAINS ISOLATING
Pri 200/220 or 400/440
Sec 100/120 or 200/240

VA	Ref.	£	P&P
60	243	**7.37**	1.58
350	247	**18.07**	2.12
1000	250	**45.94**	OA

AUTO TRANSFORMERS

Ref.	VA (Watts)	TAPS	£	P&P
113	15	0-115-210-240V	**2.73**	.81
64	75	0-115-210-240V	**4.41**	1.10
4	150	0-115-200-220-240V	**5.89**	1.10
67	500	" "	**12.09**	1.91
84	1000	" "	**20.64**	2.39
93	1500	" "	**25.61**	OA
95	2000	" "	**38.31**	OA
73	3000	" "	**65.13**	OA
80s	4000	0-10-115-200-220-240	**84.55**	OA
57s	5000	" "	**98.45**	OA

Step Up or Step Down

BRIDGE RECTIFIERS

100v	25A+	**£2.10**
200v	2A	**45p**
400v	2A	**55p**
200v	4A	**65p**
400v	4A	**85p**
400v	6A	**£1.40**
500v	12A	**£2.85**

P&P 17p. VAT 15%

CASED AUTO TRANSFORMERS

240V cable input USA 115V Flat pin outlets

	£	P&P	Ref.
20VA	**£6.55**	1.03	56W
75VA	**£8.50**	1.31	64W
150VA	**£11.00**	1.31	4W
200VA	**£12.02**	1.67	65W
250VA	**£13.38**	1.67	69W
500VA	**£20.13**	1.89	67W
1000VA	**£30.67**	2.65	84W
1500VA	**£42.82**	OA	93W
2000VA	**£54.97**	OA	95W

TEST METERS

AVO8 Mk. 5	**£91.50**
AVO71	**£38.00**
AVO73	**£50.70**
AVOMM5 MINOR	**£35.95**
WEE MEGGER	**£76.28**
EM272 316KΩ/V	**£59.80**
DA116 Digital	**£110.90**
Megger 8M7 (Battery)	**£53.76**
Clamp Meter 300A	**£54.60**

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P&P £1.32 VAT 15%

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DC1000V, AC-1000V
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DC-100mA. Res — 150K
Bargain at **£7.20**
VAT 15% P&P 71p

PANEL METERS

43mm x 43mm		82mm x 78mm	
0-50μA	**£6.20**	0-50μA	**£6.70**
0-500μA	**£5.95**	0-500μA	**£6.70**
0-1mA	**£5.95**	0-1mA	**£6.70**
0-30V	**£5.95**	0-30V	**£6.70**

VU Indicator Edge 54mm x 14mm μa FSD . **£2.60**
VU Panel Ind. 48 x 45mm, 250μa FDS . . . **£2.60**
Carriage 76p VAT 15%

MINIATURE TRANSFORMER

O Centre Tapped 15V 7.5-0-7.5V

Ref.	Amp	Price	P&P
171	500MA	**2.30**	.52
172	1A	**3.26**	.90
173	2A	**3.95**	.90
174	3A	**4.13**	.99
175	4A	**6.30**	1.10

U4315 Budget Meter 20KΩ/V. Rangers to 1000V 2.5A AC/DC 500KΩ. Res in steel case **£15.85.** P&P £1.32. VAT 15%.

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Inset brass nuts, slots to take PC cards (boards) flush fitting lid.

PB1 80mm x 62 x 40	**.80p**
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PB4 215mm x 130 x 85	**£2.68**

P&P 33p. VAT 15%

NEW RANGE TRANSFORMERS

Pri 0-120; 0-100-120; (120V or 220-240V) Sec. 0-36-48 twice to give 72v or 92v.
2A **£13.35** PP £1.40 4A **£20.65** PP £2.11
3A **£16.17** PP £1.70 5A **£29.30** PP £2.47

ANTEX SOLDERING IRONS

15W **£4.58**. 25W **£4.58**
Stand for above **£1.75.** P&P 53p. VAT 15%.

METAL OXIDE RESISTORS 5% ¼W

(Electrosil)

390Ω - 470Ω - 510Ω - 560Ω - 820Ω 1K - 1K1 - 1K2 - 1K6 - 1K8 - 2K - 2K4 - 3K - 16K - 20K - 22K - 24K - 47K - 82K - 100K - 130K - 180K - 220K - 270K - 300K **£1.50** - 100.

ISOLATOR Ref. 30 240V: 240V 200VA **£4.62.** P&P £1.10.

ISOLATOR Ref. 62 240V: 240V 250VA **£5.62.** P&P £1.10.

MAINS ADAPTORS

MVA30. 6. 7. 5. 9V at 300mA plus dorect into 13A socket (fused) 4-way multi plug **£4.00**
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15% VAT. 55p P&P

Send 15p for catalogue. Prices correct at 30/10/79

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1¾" diameter. Requires single low current 3KV to 6KV supply. Individually boxed. With data

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EX-MINISTRY SMALL COMPACT WIDERANGE VOLTMETER SOLID STATE

AC Range 1mV to 500V Full Scale 10HZ-100KHZ. DC Range 4V to 400V Full Scale.
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Type 9140.
£4 each. 8 for **£24.**

BC172	**5p**	BC212B	**5p**	74C20	**25p**	2N5449	**5p**	BC251	**5p**
BZY884V7	**10p**	SN76550	**5p**	74C08	**25p**	2N3053	**15p**	BC171A	**5p**
BZY8813V	**10p**	IC7451	**10p**	74C10	**20p**	TIS92	**10p**	BFT60	**5p**
2N3006	**5p**	MC4001	**15p**	MC4049	**35p**	TIS93	**10p**	4013	**30p**
1N4305	**5p**	MC4012	**15p**	2N3704	**8p**	BC337	**8p**		
BZX79C12	**10p**	MC4020	**75p**	2N5447	**5p**	BC327	**8p**		

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TOROIDAL TRANSFORMER 0-115V-230V Input; 13.5V-0-13.5V rated 8VA output **£1.70** each. P&P 75p.
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all with information. British approx. 2" window **£2** each. British approx. 5" window **£3.50** each. American approx. 2" window **£4** each. Special American version by RCA **£6** each. P&P all photomultipliers **£1.50** each.

709 DIL 14-PIN OPERATIONAL AMPLIFIERS

at **8p each**
100 off 25% discount.

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Push contacts, marked 0-9 and A-F and 3 optional function keys. **£1.75 each.** P&P 65p.

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Transistorised hand-held, no leads, standard internal batteries supplied. Howl switch. **£20** each. P&P £2.

STEPPING MOTORS

North American Phillips, 5 volt 3.3 Amp operation. 2 wire PPS 0-200 revs per min 0-250 used. Tested **£16 each.** P&P £1.50.

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5" Display. These are supplied with STU 2 plug-in. 1 to 45 GHZ.
£125 each

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115V AC 1.7 Amp Input. Switching is at 20Khz. Output windings from Pot Core. Can be rewound to suit own purpose or unit can be broken for host of components. Circuits supplied. **£1.25 each.** P&P £2.

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Type CT 316. Single Beam. DC-6mhz. Size 8½ x 11 x 20.
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JUST IN: CONVERT THIS UNIT TO A SUPER BATTERY CHARGER

Attractive green ministry quality case with removable top and bottom plates — heavy duty power switches — high powered resistors to control current — good quality centre mounted amp meter — strip of wing nut terminals on front panel which can be used for connecting leads. ALL THIS FOR **£3.50,** P&P £2.

STEPPING MOTORS

6/12 position with additional where the rotor is coils. Device can be used as a tacho. Diagram supplied. Will actually work on 5 volts. 12/24 recommended.
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ONE ONLY ELECTRONIC TEACHING SYSTEM

Extract out the large circuit board you wish to teach. Hang it on the frame and show the resistive, capacitive etc. symbol and actual component in working electronic circuits. Demonstrate working circuits and remember we can offer a package deal with scopes, sig gens, meter, etc to go with this unique offer. **£250.**

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Size 3x2½x2" high with 12 Alma Reed Switches. Blue keys marked in green 0-9 and a star with one blank.
£4 each, P&P £1, or 5 for **£15** P&P £2.

NOT US ROSS 7 x 50 MONOCULARS

Hence £27.50 each

TANTALUM BEAD CAPACITORS. 4.7uf 25V. 10 off **£1;** 100 off **£7.50.**
TEXAS Low Profile 40pin IC Sockets **45p ea.**
SMALL TRANSFORMER. 240V Input. Output 2 windings 12V and 24V 1 amp. **£2 each.**
SO SIMPLE SO SAFE.
Fit a push button **CIRCUIT BREAKER** Small, compact, 3 ratings 0.8; 1.8 and 10AMP. State which one when ordering. **75p each.**
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100 off **£1.50** — 1,000 off **£10.**

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430ft roll 8½" wide
£2 per roll. P&P £1.75

VARIACS Ex-Equipment. Good condition, 8 Amps **£25 ea.**
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Some 3 phase available. Please enquire.

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19.2KHZ FLAT METAL CASE — **50p each.**
10 MHZ B7G **50p each.**

EX-NAVAL 4ft dia STEEL DISHES. NEW CRATED 1 ft. deep at centre. These are plain steel dishes with holes for various aerial options. **£22.50 ea.** Carriage **£5.** Two for **£40.** Carriage **£6.**

TRANSFORMERS — Standard Mains input
Secondary outputs.
6KV 0-125A **£15** ea. 18KV 30MA **£60.**
12KV 30MA **£20.** 22.5KV 110MA **£50** ea.
3KV 50MA **£8** ea. 60KV 0.0273 **£150.**
MULTI PURPOSE MAINS TRANSFORMER 4 windings each winding 0-10-110-125 at 4 8A **£15 ea.**
425V 50HZ 2 Wire input. Output 8 5KV 2.55KVA. Could be run on 240V at ½ rating **£15 ea.**
STEP DOWN ISOLATING TRANSFORMER. Input 220, 250V 50HZ. Output 115V 1.8KVA. BRAND NEW. These are very conservatively rated **£20 ea.**

CAPACITORS
2mfd 5KV **£4 ea.** 0.5mfd 10KV **£4 ea.**
0.5 mfd 5KV **£4 ea.** 8mfd 2.5KV **£4 ea.**
CARRIAGE on these units will be charged at cost.

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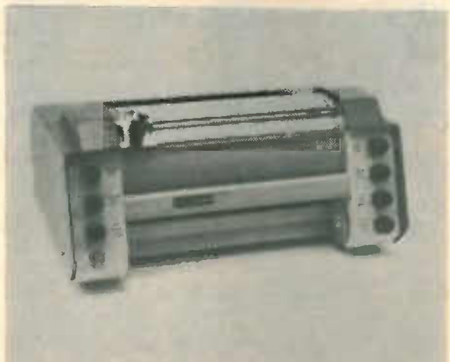

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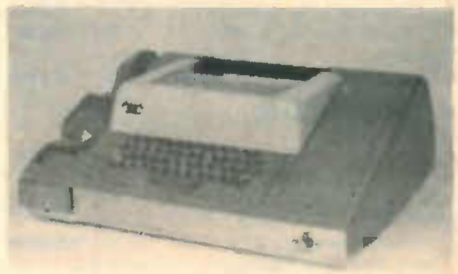

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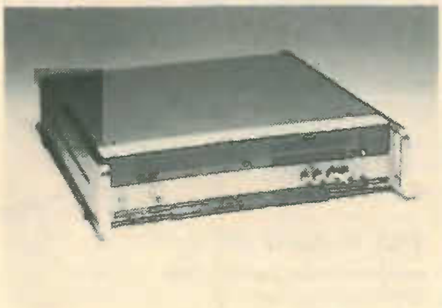

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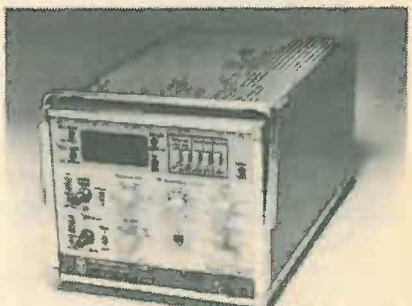

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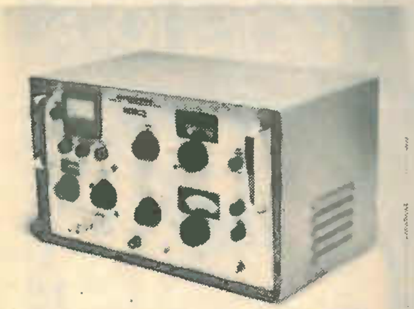

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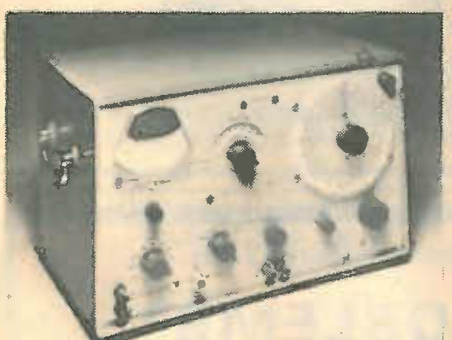

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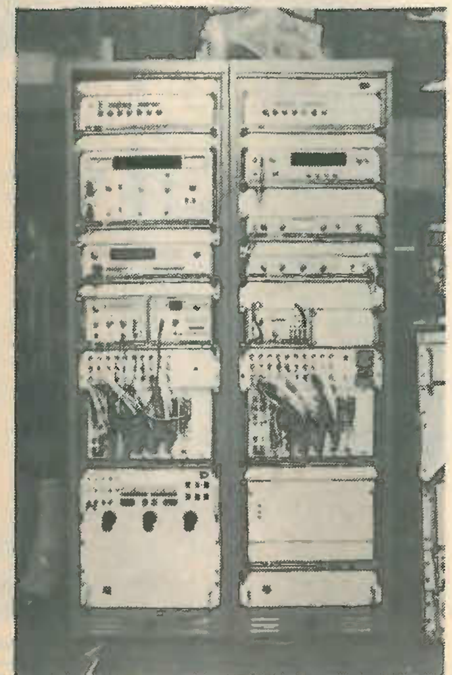

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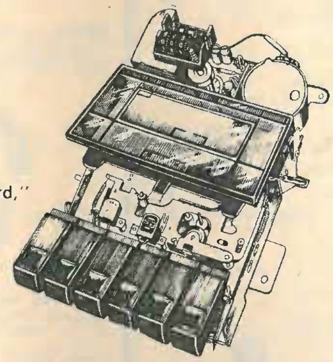

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Included in the kit are two fibreglass PCB's, drilled and plated for immediate assembly, two VU meters, Dual LED Peak Meters, Variable Bias system, Power Supply, over 10 micro-circuit IC's for the most up-to-date performance, as well as monitoring amplifier, test and calibration cassette, etc.

Price of Kit (without transport mech.) £35.95 VAT inc. plus £1.00 P&P

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Identical in most respects to the 8022A but in addition incorporates a conductance range from 2mS-200nS.

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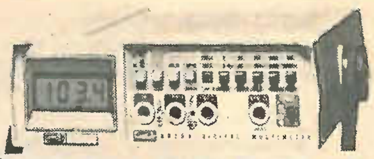

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8010A **£159** 8012A **£199**
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20,000 OPV
AC Volts: 0-10, 50, 250, 500, 1000.
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Resistance 0 3k ohms 300k ohms 3 meg ohms
Decibels −20— +63 db
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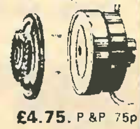

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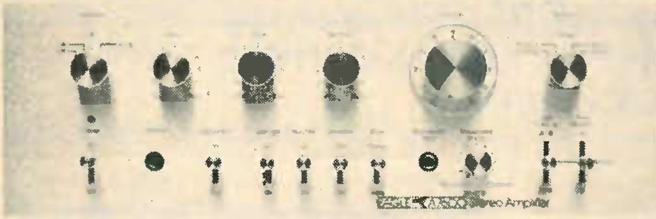

A7600

The top-of-the-range is the A7600 75 watts per channel amplifier. With enough power to fill a hall, it gives you a unique range of facilities.

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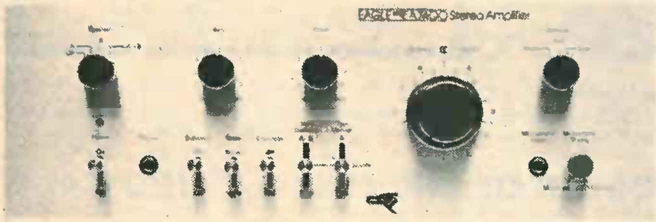

A7400

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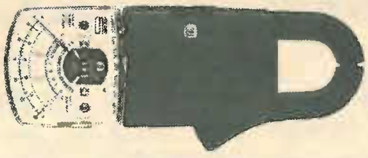

KEW 6

KEW 6. Current ranges Amps 150-30 AC. Voltage ranges 600-300-150 AC. Resistance ranges (mid-scale) 300 ohms (25 ohms). Jaw size 27mm/1 inch. Accuracy A/V ± 3. (% FSD) Ω± 3. Overall length 190mm. Approx. weight 285g. **PRICE £25.95** EX. V.A.T.

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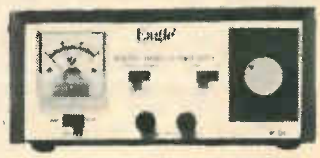

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Regulations: 5% no load to full load
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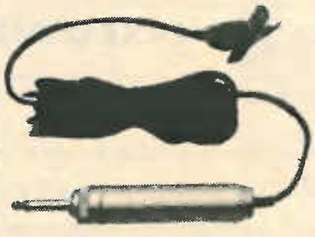

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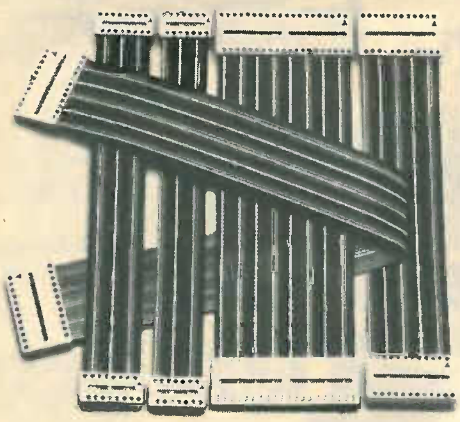

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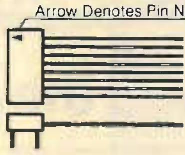

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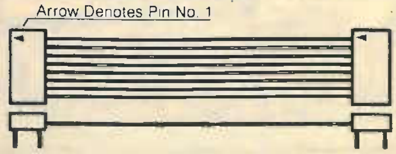

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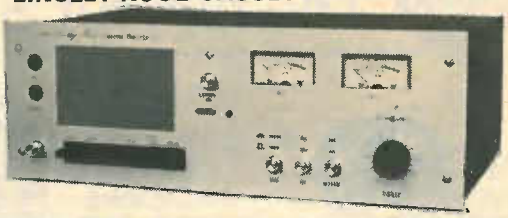
J. L. Linsley Hood High Quality Cassette Recorders

LINSLEY HOOD CASSETTE RECORDER 2



Our new improved performance model of the Linsley Hood Cassette Recorder, incorporates our VFL 910 vertical front mechanism and circuit modifications to increase dynamic range. Board layouts have been altered and improved but retain the outstandingly successful mother and daughter arrangement used on our Linsley Hood Cassette Recorder 1.
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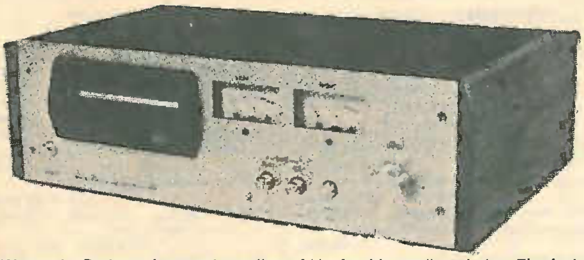
LINSLEY HOOD CASSETTE RECORDER 1



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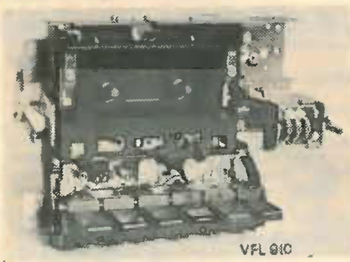

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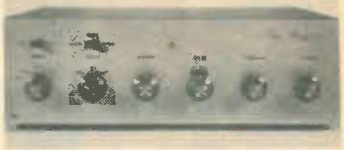

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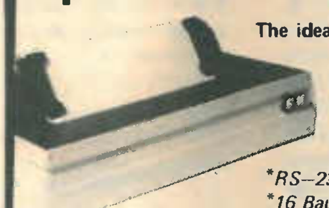

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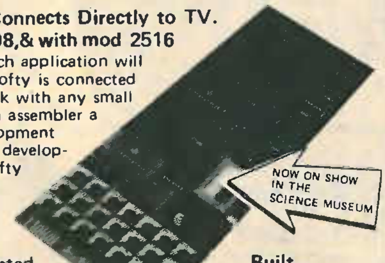

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Careers in the electronics industry

Types of work available and what you need for them

by Ronald C. Slater, F.I.E.R.E. TJB Electrotechnical Personnel Services

This review sets out some of the careers which the electronics industry has to offer, the academic qualifications which are needed and the possible rewards. It is intended to help those who are already employed in the industry but who, for one reason or another, are not satisfied with their present career paths; those who are training for a career in the industry but who have not yet started work and, last but by no means least, the younger readers who, though they have an interest in radio or electronics, have not yet decided on their careers.

Perhaps the first question to be asked is 'Can the electronics industry provide a worthwhile career at all?' This question is not so absurd as it may seem, especially if it is qualified by the words 'in the UK'. Only a decade or so ago it may have been thought that the steel industry or the automobile industry could offer a worthwhile career; the position now is somewhat more doubtful. A young man or woman embarking on a career may have a working life of some 40 years ahead of him or her. It would indeed be rash to forecast the path of any industry over so long a period, especially one such as electronics where changes and advances in technology are so rapid. Yet, while it would be foolhardy to forecast the changes in technology, it can be predicted with almost complete certainty that more and more sophisticated forms of communication will be demanded, that more and more processes in commerce and industry will become automated, and that the use of electronics, in one form or another, will become more widespread in industry, commerce, and the home.

Hand-in-hand with this will go an increasing demand for electronic engineers and technicians at all levels, to design, produce, test, install and service an expanding conglomeration of even more sophisticated equipment.

Education and qualifications

Twenty or thirty years ago formal qualifications were of very much less importance than they are today and many persons rose to the top of the engineering professions by dint of experience, perseverance and 'green fingers'. In the intervening years qualifications have assumed ever increasing importance, partly due to the advancing sophistication and complexity of technology and partly to the increasing availability of technical education. Thus, although it still may be possible to succeed without formal qualifications it is increasingly difficult to do so and almost certainly the entry point on the career ladder will be determined by the educational course which has been followed and by the qualifications which have been attained.

Although in terms of employment there will be considerable overlap, technical personnel in the electronics industry can, in general, be divided into the three grades recognised by the Engineers Registration Board. These are 'Technicians', 'Technician Engineers' and 'Chartered Engineers'. To become registered in any of these grades needs specified academic attainments plus a laid down period of training, experience and responsibility. Registration will normally be made through an appropriate society or institution. For Technicians and Technician Engineers these are the Society of Electronic and Radio Technicians (SERT) and the Institution of Electrical and Electronics Technician Engineers (IEETE); for Chartered Engineers there are also two institutions, these being the Institution of Electrical Engineers (IEE) and the Institution of Electronic and Radio Engineers. Anyone who is seriously attempting to carve a career in electronics should strive for corporate membership of an appropriate professional society or institution; not only for the qualification and the letters it allows one to append after one's name but for the facilities it provides for mixing with persons with similar professional interests and for keeping up-to-date with advances in technology.

Full details of the requirements for registration as a Technician, Technician Engineer or Chartered Engineer are available from the organisations mentioned above, all of which are in the London telephone directory. Very briefly, the choice of 'academic' requirements at present is as follows:

More and more women are making successful careers in electronics. Padmini Sathiaseelan, who won an award in the 1979 "Girl Technician of the Year" competition, is a development engineer at Rank Hi-Fi. She has a B.Sc. (Eng.) degree, having specialised in electronics and communications, and in her present work on acoustics has contributed to the development and design of a new range of loudspeakers.

Technicians
Ordinary National Certificate (ONC) in Engineering with at least one electrical subject.
Approved TEC (Technician Education Council) Certificates and Diplomas in electronics and communications.
City and Guilds of London Institute Part II Certificate in one of the following:
Course 271 — Telecommunications Technicians.
Course 282 — Electrical Technicians (with at least one electronics subject).
Course 272 — Radio and Television Electronics Technicians.
Course 172 — Final Certificate in Electronics Servicing.
Some training courses in the Armed Services are also acceptable, e.g.
Royal Navy — Artificers and Mechanicians in appropriate trades.
Army — Class I Technicians in appropriate trades.
Royal Air Force — Electronic Air or Ground Technicians.

Technician Engineers
Approved TEC Higher Certificates and Diplomas.
Higher National Certificate or Diploma (HNC or HND) in Electrical and Electronic Engineering.
City and Guilds Full Technological Certificate in an appropriate course.

Chartered Engineers
A university or CNAA (Council for National Academic Awards) degree in Electrical and/or Electronic Engineering. Some degrees in associated disciplines such as Physics and Mathematics may also be acceptable.
HND in Electrical and Electronic Engineering plus the CEI (Council of Engineering Institutions) Part II Examination.
The CEI Part I and Part II Examinations.

In all three grades there are certain other qualifications which may be acceptable. There are also several changes which are imminent, particularly in the Technician and Technician Engineer qualifications. Full advice on these will gladly be given by the institutions. It is also a good idea to seek advice from them before embarking on a course of study.

The course of study followed by a young person may be dictated by personal circumstances, such as the mundane need to earn money at an early age. In general, it is possible to obtain Technician or Technician Engineer qualifications by part-time study, e.g. evening classes, day release, block release, or a combination thereof. To obtain qualifications to Chartered Engineer level full-time study is almost essential and this usually will be in the form of a three- or four-year degree course. This, in turn, usually means that it will not be possible to go into full-time paid employment before the age of 21 or 22. Education Authority grants and sponsorships from companies are, of course, available to ease the financial difficulties.

Alternatively the course to be followed may be determined by the failure to secure the necessary 'A' levels for admittance to a degree course.

However, even if none of these limitations applies the question still remains, how high should one aim? Ambition is undoubtedly a very good thing, but it must be a realisable ambition; if it is not, then it can only lead to frustration and discontent. It really comes down to the not easy task of knowing oneself and one's capabilities. We do not all have the ability to become a director of research or the managing director of a large company. It is better, far better, to become a first-rate technician than a mediocre chartered engineer.

There is just one further thing to be said about education and that is quite simply that it is not a 'once and for all exercise'. It is, or should be, a continuing process that will go on for the whole of a person's career. This is particularly necessary in an industry such as electronics where technical advances are so rapid. This continuing education may take the form of 'in-house' courses, short courses at educational establishments, attendance at colloquia and conferences or diligent reading of professional journals and the technical press.

Types of jobs

In electronics there is a very wide range of jobs and careers available, and within the confines of this article it is not possible to give an exhaustive list. In addition the names used to describe various tasks may vary considerably from company to company and, particularly in the smaller companies, there may be considerable overlap in the tasks one is called upon to perform. The following, however, represents the main activities of a typical company:
Research
Design and development
Production engineering
Quality and reliability engineering
Test
Sales and marketing
Installation and commissioning
Service
Which of these you go into may be decided by a number of factors such as educational attainments and personal inclinations, plus, of course, the availability of jobs at the right time and in the desired location. The following paragraphs outline the qualifications and personal attributes which are generally necessary in the various sectors.

Research. The primary reason for research is to extend the frontiers of knowledge. A great deal of fundamental research is carried out in universities and, to some extent in polytechnics. Much original work is also done in the very fine research laboratories of the larger manufacturers. Many research projects will require the services of multidisciplinary teams which may consist of materials scientists, physicists, mathematicians, electronic engineers, chemists etc. To take an active part in research will generally require the acquisition of highly specialised knowledge and will usually call for at least a good first degree and possibly a second degree (e.g. M.Sc., Ph.D.). It also calls for a questioning mind, an ability for innovation and creativity and the pertinacity to continue to seek for a solution where none seems possible. In terms of self-esteem and inner satisfaction the rewards of successful research can be very great, but not all research is successful and it is also necessary to be able to accept defeat, possibly after months, or even years, of endeavour. To be a leader, manager or director of research it is also essential to have that fine judgement to know which projects should be pursued and which should be abandoned.

Design and development. The purpose of design and development is to produce something which can be manufactured and sold. The 'something' may range from a single component such as a resistor or capacitor through to a complex computer-controlled data communication system. It may be a one-man task or it may need the expertise of a number of multidisciplinary teams and it may call for the assistance of outside specialist companies in, for instance, the design and supply of large scale integrated circuits.

In most cases the precise objective will be known and the design and development work may have to be carried out within the constraints of a tight performance specification and against a rigid time scale while at the same time taking account of national, international or military standards.

The most usual qualification for a design and development engineer is a degree in electrical and/or electronic engineering or a related subject such as physics or computer science, but other qualifications such as HND and HNC are often acceptable, especially if backed up by relevant experience.

Apart from technical knowledge the design phase of the project will, more often than not, call for original and innovative thinking and a disciplined and logical approach, plus in many cases, a fair degree of commercial awareness. Also it will often involve close liaison with a customer's own technical staff and the ability to quickly appreciate a problem outside of one's own discipline, as for instance, when electronic equipment is being designed to control some other non-electronic function of process.

Between the original concept, design and building of a laboratory model and the engineering of a product suitable for manufacture and marketing there is often a long path to tread; this is the development phase. This may call for close liaison with component suppliers and with internal departments such as test, production, quality assurance and the drawing office. Thus it requires a knowledge of the availability of materials and components, of manufacturing processes and costs. There's no use in developing a product which cannot be manufactured by the means available or which cannot be produced at a competitive price. Except for the very simplest of products the design and development engineer must have the ability and willingness to work as a member of a team, which very often will be of a multidisciplinary nature. Another essential asset which is often overlooked and neglected by the budding D & D engineer is the ability to communicate. The finest or most revolutionary ideas in the world are completely and utterly useless if they cannot be communicated to others.

To be involved in the design and development of a successful product can be a very satisfying experience. It can also offer a very worthwhile career progression from, say, engineer to senior engineer to section leader to project leader and all the way up to development manager and technical director. Furthermore a few years in design and development can be a very useful stepping stone to a successful career in other areas, such as sales and marketing, production and general management.

So far research and design and development have been treated as the preserve of the holders of degree, or near degree level qualifications. However, in research laboratories and in design and development departments there are many openings for technicians and technician engineers; as assistants to the engineers, for the building and testing of prototypes, for the maintenance of test equipment etc. Most forward looking companies will help their more promising technicians to obtain higher qualifications by sending them on day release or block release or by sponsoring them for sandwich degree or HND courses. There are indeed many men who have entered the electronics industry as apprentice technicians and who, at the company's expense, have progressed through ONC and degree courses and subsequently to positions of high responsibility.

Production engineering. Production is really what industry is all about, yet many, far too many, well qualified technicians and engineers in the UK shy away from it and seem almost to regard it as a dirty word. This is in direct contrast to most other industrialized countries where a large proportion of engineering graduates take up employment in the manufacturing sector. This is probably one factor in explaining why Britain's production record has been so poor in recent years.

For many the words 'production' and 'factory' still conjure up pictures of the dark satanic mills, but modern production, in the electronics industry at least, is not like that. More often than not it will take place in a clean, well lit and congenial environment. It offers a wide range of jobs for junior technicians right through to the best graduates. These include production planning and co-ordination, production equipment maintenance, and, of course, production management. For the person who likes solving problems, seeing the fruits of his labours and who likes working with people it has a great deal to offer. It is also an area where able persons with qualifications can expect promotion with a clear way open to the very top.

Quality control and quality assurance. Although quality assurance and quality control are closely related to production many companies arrange these activities as a separate department. Again, although many of the attributes necessary for a quality control engineer and a quality assurance engineer are similar their functions are slightly different. Quality control is a process through which actual performance is measured and compared with standards and specifications and, if necessary, remedial action is taken. Quality assurance, on the other hand, provides the evidence needed to ensure that the quality function is being properly performed and includes activities such as quality auditing, quality assurance analysis and qualification approval of products.

Generally both QA and QC engineers will be expected to have a minimum qualification of HNC. They must both have, or be willing to acquire, a knowledge of specifications, measurement methods, methods of assessment and an understanding of the manufacturing processes. It is very much a job for the person who is interested in statistics and statistical analysis. With the increasing use of electronics in applications where failure cannot be tolerated the quality function is becoming ever more important. It is, in a way, becoming a profession in its own right and the demand for QA and QC engineers is very good.

Test. For many young technicians the test department will form their first introduction to the electronics industry; that will also be true for a number of new graduates. While the basic task of a test department is to measure whether a component, sub-assembly or a complete equipment meets the specified criteria, there is obviously a great deal of difference between the knowledge and skill required to test a single component or small sub-assembly and those needed to deal with a large complex system. At the higher levels the work will not only involve actual testing but will also include test planning, drawing up test schedules, devising test methods and, in some cases the design of special test equipment. Furthermore, with the influx of advanced automatic test equipment it may also call for further skills, such as computer program writing. Test engineering can offer a good career in its own right; the chief test engineer is usually a person of some importance in his organisation. It also provides a good grounding for a career in other areas such as development or production engineering.

Some people stay in the industry a long time. Wilf Williams, a senior production engineer at Eddystone Radio, has just celebrated his 50th year with the company. He started as a 15 year old "radio mechanic" in 1930.

Sales and marketing. A product without a customer is about as much good as a sick headache and, since few products sell themselves, the role of the salesman or sales engineer is a vital one. Unfortunately many people, engineers and careers advisers among them, somehow conjure up a rather strange picture of a salesman. They either see him as a rather woebegone character peddling his wares from door to door or as a smooth talking 'Flash Harry' who spends most of his time driving around in a company car and eating expense account lunches. True, a technical salesman may have to knock on a few doors and will almost certainly have a company car, but he or she will be very far from those fictitious pictures. First, he or she needs to have a thorough knowledge of his products, and this generally means a good engineering education and background. For this reason many companies prefer to recruit their sales engineers from people who have spent several years in other sectors of the industry such as development or production.

The sales engineer needs the ability and willingness to understand the customers' problems and has to be able to communicate enthusiasm, to stay calm under pressure, to be self-motivated and self-disciplined, to be able to accept setbacks and failures philosophically, and to be at ease with other people whether they be other engineers or top management. The latter is very necessary for the sales engineer selling capital equipment worth, perhaps, many thousands of pounds. Above all he or she must really want to sell and to succeed. It is, perhaps, a rather formidable list of requirements and, certainly, selling is no easy way out for the person who wants a quiet life. On the other hand, for the person who has the necessary attributes it can be an exciting and rewarding life both in terms of job satisfaction and financial benefit. A career in sales engineering is open to persons with all levels of qualification provided that they are sufficient to allow a complete understanding of the product being sold. Clearly, the more complex and advanced the product the greater is the knowledge needed to understand it. Some of the virtues which go to make a successful sales engineer, such as the ability to communicate enthusiasm and to deal effectively and comfortably with people at varying levels, are also among the requisites for successful general management and this is one of the ways in which a sales engineer may progress.

Marketing is allied to sales engineering but is somewhat wider in scope, embracing subjects such as marketing strategy, publicity, possibly pricing and pricing agreements, and is an area into which a sales engineer may transfer.

Installation and commissioning. In many instances, particularly in the case of large equipments or systems, a manufacturer will supply a team to install and commission the equipment; that is, to ensure that it is working satisfactorily before it is handed over to the customer. The 'team' may consist of anything from one person upwards and the installation and commissioning time may be anything from a few hours to several months or more. It is a job which will usually entail periods spent away from home and it will often involve considerable travel both in the UK and overseas; it may also necessitate working unusual hours. For the man or woman who likes to do a practical job combined with travelling and working in different places it can be an enjoyable and rewarding way of life.

A large number of installation and commissioning engineers will come from the ranks of technicians and technician engineers but there are also good openings for graduates, both in a supervisory role and in dealing with the larger and more complex equipments and systems.

Service. Service engineers and technicians are basically of three types: 'in-house', 'field' and 'site'. The in-house service technician will spend his or her time on fault diagnosis and repair in the company's own premises. The field service technician will be working away from the company's premises and will usually have a number of 'customers' within an allotted geographical area. The site service technician will be working permanently on the premises of one of the firm's customers. Each has its advantages and disadvantages. In-house service will usually mean regular hours and working alongside other people, with help close at hand if needed. Field service will entail a certain amount of travel, often working on one's own, and possibly working out of normal hours; thus it calls for self-reliance and self-motivation; on the other hand it provides a certain amount of freedom and often the use of a company car. In site service a person may be working alone but far more likely he or she will be a member of a team; in many instances where site service engineers are employed the equipment concerned will be working round the clock and the service engineers will be expected to work on a shift basis — for which they will, naturally, be compensated.

Many technicians and technician engineers will be employed in servicing but there are many openings for graduates, especially in dealing with the more sophisticated systems where skills such as diagnostic programming may be required. Servicing is a good career for people who like solving problems and 'putting things right'. Field servicing, which provides direct contact with the customer, can be a good stepping off point for a subsequent career in sales engineering.

Specialisation

So far the electronics industry has been treated as an entity and no mention has been made of specialisation. Should one concentrate on analogue techniques or digital techniques? Is there a better future in communications or computers or consumer electronics etc, etc? These questions (and the answers!) are important to everyone in, or entering, the industry but they are, perhaps, of special relevance to the design and development engineer. To attempt to answer them would need another article but a few general remarks may be helpful.

In the first place it will usually be necessary to specialise to some extent, even if only on a temporary basis to deal with the job in hand. Whether or not one should specialise completely and permanently is open to question, but if one decides to do so then clearly it should be in an area which is likely to have a reasonably long future. In any case it is advisable to retain some adaptability by reading as widely as possible outside of one's specialisation. So far as the digital versus analogue argument is concerned this is also a very open question. It is true that the trend in many spheres is towards digital techniques. It is also true that the microprocessor will make an impact in many areas of electronics, even though it may not be the wonder of the age as proclaimed by the lay press. However, it is equally true that there is a widespread demand for good analogue designers and this is likely to continue. Indeed, as a result of the enthusiasm with which so many young engineers have followed the digital and microprocessor trail, acute shortages are becoming apparent in other areas. For example, good r.f. designers are now beginning to have a scarcity value. In other words do not necessarily do what everyone else is doing and do not necessarily try to get on the band wagon of the day — less popular areas may pay off better in the long run.

Most of the above remarks also apply when one is considering the various sectors of the industry such as communications, computers, instrumentation, avionics, components. Excellent careers are available in most sectors and what you choose is really a matter of personal inclination and interest. It may be worth emphasising again that it is not always the superficially most glamorous sector which offers the most interesting and rewarding career. For example, many engineers shy away from component technology whereas in fact this is the sector where many major advances originate.

Footnotes

Because of limited space many points have been treated very briefly and some not at all. One of these is the not unimportant matter of salaries. The only thing that can be said here is that in the past year or two there has been a significant upward trend in the salaries of technicians and engineers. For example in 1975 the average starting salary for a university graduate going into his or her first job was between £2300 and £2600; this year it will be between £4500 and £5200 p.a. Other salaries have increased proportionately. A look through the Appointments section of this issue of *Wireless World* will give some idea of the going rates.

Finally, a word about geographical location. Although companies who manufacture or use electronic equipment are to be found throughout the UK there are many areas where they are very thin on the ground and other areas where they are concentrated. It is clearly rather pointless to decide to live in say, Abermuirig and pursue a career in the design of r.f. instrumentation if the nearest appropriate company is 200 miles away. In other words, to pursue a successful career it is necessary to go where the work is. The difficulties of moving from place to place are not overlooked or minimized but it may sometimes be necessary and many companies now pay relocation expenses on a very generous scale. □

Appointments

Advertisements accepted up to 12 noon Tuesday, May 6th for June issue, subject to space being available.

DISPLAYED APPOINTMENTS VACANT: £10.00 per single col. centimetre (min. 3cm).
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IVS

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We require an Engineer to join the staff of our rapidly expanding Video Cassette Duplicating Facility. The candidate should have a minimum of three years' experience in broadcast television with specific knowledge of Quad and Helican Scan, VTRs, flying spot Telecines and related systems.

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S. LONDON **to £6,000 p.a.**

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(271)

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Applications are invited from engineers with experience of the operation and maintenance of high-powered radio transmitters, and who hold a third-year City and Guilds Certificate in Telecommunications or its equivalent.

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(283)

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We need Production Engineers with experience of assembly and test measures and procedures to undertake process specification and method improvement programmes in our systems test areas, where computers are tested for reliability prior to shipment to the customer's site.

These positions would suit engineers from similar disciplines or customer engineers who wish to return to a manufacturing environment having gained experience of the types of problems seen in the field.

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If you have a degree, HNC or equivalent in an appropriate discipline, together with relevant experience — we'd like to hear from you.

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(260)

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TJB

Please send me a TJB Appointments Registration form:

Name ....

Address ....

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(9238)

AUDIO VISUAL AIDS TECHNICIANS

Two experienced technicians are required by the Croydon Education Service.

One to maintain and repair language laboratories in schools. A knowledge of other visual equipment would be an advantage.

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The second technician will maintain and repair a range of audio and video equipment including TV receivers in schools.

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Apply in writing giving details of age, qualifications, present post, relevant work experience and the names and addresses of two referees to The Superintendent, Education Service Centre, Princes Road, Croydon, Surrey, stating for which post you wish to be considered.

Further information may be obtained from the Superiendent, Mr. A. Bevan, telephone no. 01-684 939.

(264)

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A Technician to work with a wide range of electronic apparatus.

Duties would include the use, maintenance and development of research, practical laboratory, video and sound recording, and CCTV equipment.

Applicants should have HNC, C and G, or equivalent qualifications with experience.

Salary in the range £4,524 to £5,730 (including London Weighting) depending on qualifications and experience.

Please apply in writing to: Chief Technician, Department of Physiology, The Middlesex Hospital Medical School, Cleveland Street, London W1P 6DB.

(261)

UNIVERSITY COLLEGE LONDON DEPARTMENT OF PHYSICS AND ASTRONOMY

An

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Grade 6

is required to work in the Laboratory for Planetary Atmospheres in the design, construction and programming of micro-programmer based equipment. These activities are associated with the Laboratory's image processing studies of the Earth and planets.

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Applications, including Curriculum Vitae and the names and addresses of two referees, should be sent to: Dr. Garry E. Hunt, Laboratory for Planetary Atmospheres, Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT. (286)

Link Electronics is a successful British Company active in the international sales of Broadcast television and radio equipment. We manufacture a range of studio products from colour cameras to simple D.A.s. We are also one of the largest suppliers of Outside Broadcast vehicles, television and radio studios, all designed and built in Andover for a worldwide market.

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Experienced and recently qualified graduates are required to join our research and development team. You will be involved in the design of new studio products including a new range of colour cameras using the very latest analogue and digital techniques. You will have the opportunity to see your designs made in volume production, fulfilling the high technology requirements of the 80's. Applications are invited from engineers who are qualified to degree or HND level and who preferably have some knowledge of video engineering and/or microprocessor techniques.

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We require engineers at senior and intermediate level to assist in the manufacture of our new range of products for the Broadcast studio television market.

Applications are invited from engineers with an up-to-date knowledge of digital and linear circuit techniques gained from experience working on television studio equipment, radar equipment, or similar sophisticated products, and qualified to HNC, HND, or TEC level. Opportunities also exist for recently qualified engineers who are interested in developing skills in the studio broadcast engineering field.

TV SYSTEMS ENGINEERS

Experienced senior engineers to work on the design and project management of Outside Broadcast vehicles and television studios. This is an opportunity for engineers to become involved in projects from their initial design concept through manufacture to delivery and installation.

Our custom-built systems require a high degree of customer contact at engineering level from the initial design, to customer training after completion of the contract, both within the UK and overseas.

Applications are invited from engineers with a knowledge of TV studio engineering gained from experience in this type of work or from experience on the operational side of television.

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Please apply for further details and application forms to Jean Smith at the address given below.

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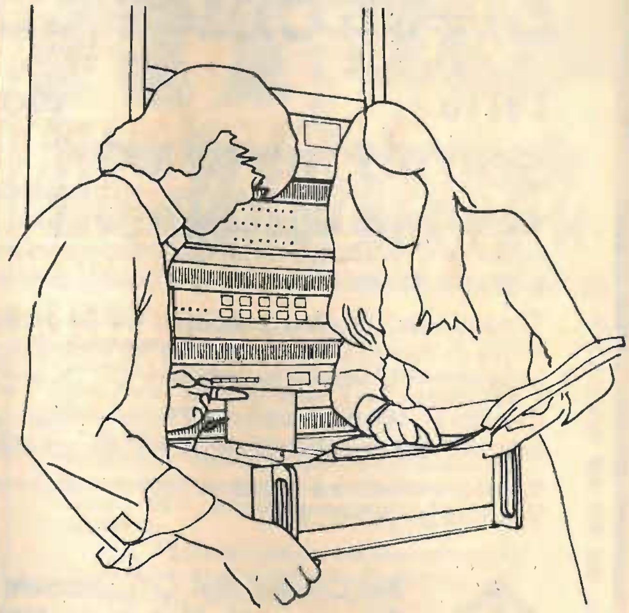

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Write to me with full details of your qualifications and experience by Wednesday April 23rd.

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GRANADA TELEVISION

(327)

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A vacancy exists in the Electronics Section of the Physics Department at St. George's Hospital, S.W.17. The work of this section includes the design, development and manufacture of a wide range of medical and research instruments.

Experience with both digital and analogue devices would be very desireable.

Appointment will be made to Medical Physics Technician Grade III for the person with the appropriate skill and experience.

Present salary scale: £4,605-£5,952 + £398 London Weighting per annum.

Minimum academic qualifications are O.N.C. or equivalent, but an H.N.C. in electronics or an allied subject would normally be expected.

For further details of the post, contact Mr. D. Ritchie, Chief Technician, Department of Medical Physics, on 01-672 1255, Ext. 4058.

Application forms and job descriptions are available from Mrs. Katherine Goodacre, Administrative Assistant, St. George's Hospital, Blackshaw Road, Tooting, SW17 0QT.noel. No. 01-672 1255, Ext. 4121.

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Closing date for return of application forms 14 days after publication.

BBC *ENGINEERING TRAINING DEPARTMENT*

(279)

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To join our expanding R&D Laboratories covering a wide range of R.F. spectrum, from L.F. to V.H.F. Equipments include transmitters and receivers for marine- and land-based use, radio navaids and radio monitoring remote computer-controlled systems.

Electronics Engineers should have experience in transmitter or receiver design, analogue or digital circuit design, microprocessor applications. Software Designers should be experienced Programmers with an interest in control, signal processing or navigational software.

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(9938)

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(284)

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Dolby Laboratories manufacture professional audio noise reduction equipment which is widely used by major recording studios.

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John Iles or Elmar Stetter

DOLBY LABORATORIES INC.

346 Clapham Road
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Telephone: 01-720 1111

(274)

Technical and Operational Training

Thames Television will be running its Technical Training Scheme beginning September 1980. The course will be of 9 months duration and traineeships will be available in the following areas:-

1) Technicians covering VTR, Telecine and Vision Control operations and maintenance;
2) Engineering, covering planning, design and installation;
3) Television Camera Operations;
4) Television Sound Operations;
5) Film covering Camera, Sound, Editing.

The course will consist of 5 months broad based training and 4 months specialist training and will take place at the Training Centre, Teddington, with additional experience gained on attachment at each of the Company Sites.

Salary during training will be 1-3 months £4,400 per annum, 4-9 months £5,000 per annum.

Successful Trainees will then be absorbed into operational departments at one of the Company's sites and go on to a salary structure applicable to the grade.

Candidates should preferably be 20-30 years of age and have academic qualifications, specialist training or experience relevant to their chosen area.

For an application form and full details please write (indicating area of preference) to:-

Miss Pat Evans, Staff Relations Dept., Thames Television Ltd., Teddington Lock, Middlesex. Tel: 01-977 3252, ext. 325.

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Address ____________________

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Lansdowne

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By Electrosonic, leaders in the fields of lighting control and audio visual systems. Work will involve testing analogue, digital and microprocessor circuits. Applicants should be qualified to ONC or HNC level and have experience in analogue and testing digital techniques.

Salary will be around £5,000, please contact:

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815 Woolwich Road
London SE7
or **Tel: 01-855 1101 ext. 37**

(323)

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You will be part of a team responsible for the maintenance of 3 large scale (B6800), 3 medium scale (B1800), 24 small scale (B90) computer systems and peripherals and over 150 terminals which are linked to these various systems.

For this challenging position, we prefer that you are qualified to HNC or equivalent level. Engineers experienced in the maintenance of any major computer systems will be considered. We will provide all necessary training on our mainframes and peripherals as part of the successful applicant's personal development.

You will be offered an attractive salary and excellent conditions of employment.

If you're looking for more stability and excellent career prospects contact:

Recruitment Manager, Ref. WW,
Burroughs, Cumbernauld G68 0BN.
Telephone 023-67-35457.

An Equal Opportunity Employer.

Burroughs

(313)

RADIO OFFICERS

If your trade or training involves radio operating, you qualify to be considered for a Radio Officer post with the Composite Signals Organisation.

A number of vacancies will be available in 1980/81 for suitably qualified candidates to be appointed as Trainee Radio Officers. Candidates must have had at least 2 years' radio operating experience or hold a PMG, MPT or MRGC certificate, or expect to obtain this shortly. Registered disabled people may be considered.

On successful completion of 40 weeks' specialist training, appointees move to the Radio Office Grade.

Salary Scales:

Trainee Radio Officer	Radio Officer
Age 19 **£3271**	Age 19 **£4493**
Age 20 **£3382**	Age 20 **£4655**
Age 21 **£3485**	Age 21 **£4844**
Age 22 **£3611**	Age 22 **£4989**
Age 23 **£3685**	Age 23 **£5249**
Age 24 **£3767**	Age 24 **£5559**
Age 25+ **£3856**	Age 25+ **£5899**

then by 5 annual increments to £7892 inclusive of shift working and Saturday, Sunday elements.

For further details telephone **Cheltenham 21491 Ext. 2269,** or write to the address below.

GCHQ

Recruitment Office
Government Communications Headquarters
Oakley, Priors Road, Cheltenham GL52 5AJ (109)

VIDEO RECORDING EQUIPMENT SERVICE ENGINEER

With the outstanding success in marketing a new range of airborne and high speed video tape equipment we need to appoint a top rate video service engineer. Full product training will be given in either America or Japan to a suitably qualified or experienced person.

The successful applicant will probably be aged between 25 and 35. A Company car will be provided, after a probationary period, as extensive travel within the UK will be necessary.

We pay top rates and the salary will be commensurate with experience and ability. We offer 4 weeks' annual holiday, free life assurance, sick scheme and free canteen facilities.

For further details and application form please apply to:

JHPI

Ann Janes
Personnel Officer
John Hadland (P.I.) Ltd
Newhouse Laboratories
Newhouse Road, Bovingdon
Hemel Hempstead
Herts. HP3 0EL

(218)

LWT
London Weekend Television

require

ELECTRONIC ENGINEERS

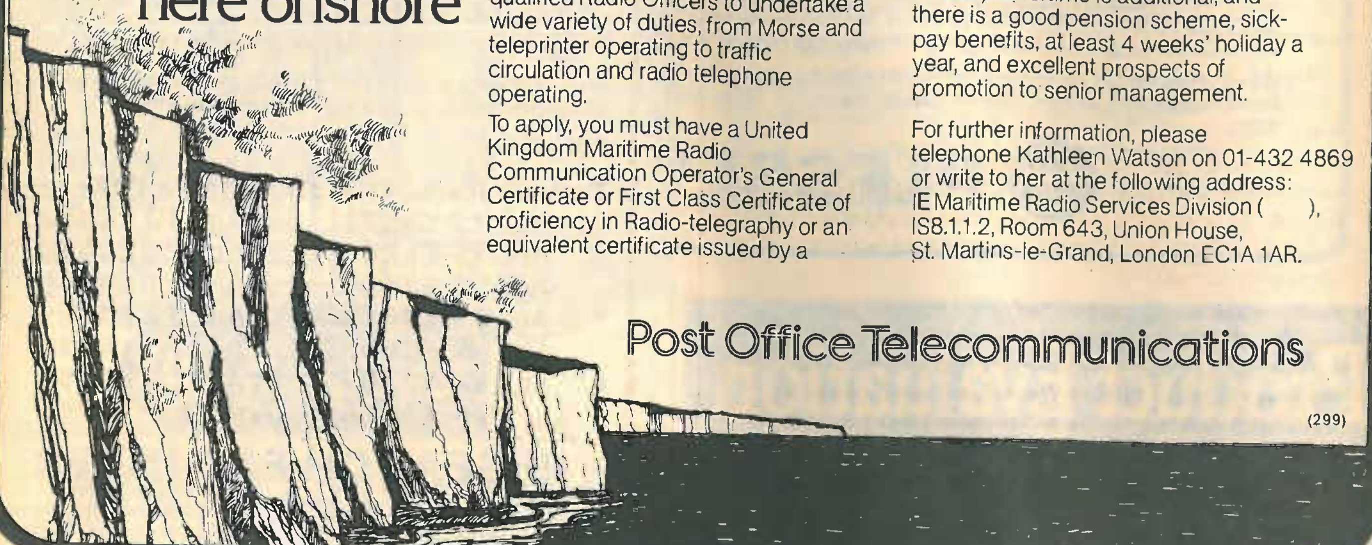
to work in their Projects Dept. The work will include the selection, purchase, installation and commissioning of the electronic equipment used in television studios and O.B. vehicles. Applicants should be H.N.C. standard but engineers with suitable Broadcast Television experience will be considered. Salary will be in the range of £5501 to £7482 rising to £8325 p.a. increasing July 1, 1980, to £6716 to £8495 rising to £9465 p.a. Applications to be made to:

Personnel Department
LONDON WEEKEND TELEVISION
Kent House, Upper Ground, London, SE1 9LT

(278)

Land a good job

Your Radio Officer's qualifications could mean a lot here onshore



If you're thinking of a shore-based job, here's where you'll find interesting work, job security, good money, and the opportunity to enjoy all the comforts of home where you appreciate them most – at home!

The Post Office Maritime Service has vacancies at Portishead Radio and some of its other coast stations for qualified Radio Officers to undertake a wide variety of duties, from Morse and teleprinter operating to traffic circulation and radio telephone operating.

To apply, you must have a United Kingdom Maritime Radio Communication Operator's General Certificate or First Class Certificate of proficiency in Radio-telegraphy or an equivalent certificate issued by a Commonwealth Administration or the Irish Republic. Preferably you should have some sea-going experience.

The starting pay at 25 or over will be about £5381; after 3 years' service this figure rises to around £7087. (If you are between 19 and 24 your pay on entry will vary between approximately £4229 and £4937). Overtime is additional, and there is a good pension scheme, sick-pay benefits, at least 4 weeks' holiday a year, and excellent prospects of promotion to senior management.

For further information, please telephone Kathleen Watson on 01-432 4869 or write to her at the following address:
IE Maritime Radio Services Division ( ),
IS8.1.1.2, Room 643, Union House,
St. Martins-le-Grand, London EC1A 1AR.

Post Office Telecommunications

(299)

COLOUR TELEVISION

If you have experience in television or test equipment engineering, there could be an interesting and rewarding future for you at Rediffusion Consumer Electronics Ltd. We are currently manufacturing an advanced range of colour television receivers at our factories in County Durham and Cleveland and wish to make the following appointments.

GROUP LEADER – Test Equipment

Effective testing of television receivers plays an important role in ensuring that our very high quality standards are maintained, and we now wish to appoint an experienced engineer of proven ability, to control a team of engineers and technicians responsible for all aspects of production test equipment.

Responsibilities will include the calibration and maintenance of a sophisticated range of test and signal origination equipment, employing both digital and analogue techniques. Although some test gear is designed and constructed locally, close liaison will be required with the design team, based at Chessington, Surrey, both to keep abreast of new developments and influence the new design of new equipment in the light of production experience.

SENIOR ENGINEER – Production Support

A senior engineer with a sound understanding of television systems and receiver circuits is required to assist production departments with technical problems arising during receiver manufacture. Responsibilities will include investigation of design problems, component fault assessment and the origination of quality assurance procedures to check that the product conforms to design specifications.

Both positions are based at our factory in Bishop Auckland, County Durham, which is within easy reach of attractive countryside and has excellent road, rail and air connections. A wide range of good quality housing is available and assistance with re-location expenses will be available where appropriate.

Attractive salaries will be offered, together with the benefits of a good pension scheme, free life insurance and 4 weeks' holiday with a choice of leave period.

If you are interested in these challenging positions and would like more details, please write to or telephone:

Mr. D. Abbott
Engineering Product Manager
Rediffusion Consumer Electronics Ltd.
Fullers Way South
Chessington, Surrey KT9 1HJ
Telephone: 01-397 5411

REDIFFUSION

(276)

Support Engineer

SWINDON

We are looking for a Support Engineer to become involved in professional technical support to a sophisticated production test area in the semiconductor industry. Production equipment consists mainly of computer-based test systems and instrumentation.

You should hold HNC/City & Guilds Tech. Certificate or equivalent in electronics. Experience of DEC and Teredyne equipment would be desirable but training will be given where necessary.

The normal range of fringe benefits expected from a large company plus a competitive salary and a good working atmosphere are part of what we have to offer. In addition you would be working in the industry of the future: The exciting world of microelectronics.

Write or phone for an application form to Shirley Cave, Resourcing Officer, Plessey Semiconductors Limited, Cheney Manor, Swindon, Wilts SN2 2QW. Tel: Swindon 36251.

PLESSEY

(288)

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ELECTRONICS RECRUITMENT SERVICE
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Posts in Computers, Medical, Comms, etc. ONC to Ph.D. Free service.

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(8994)

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Dixons are Britain's leading and most successful photographic and home entertainment specialists. We are now looking for a product evaluation engineer for audio, video and similar electronic products.

This interesting vacancy, based at Edgware, has arisen from an internal promotion. You would be responsible for accurately assessing the specifications and performance of new and sometimes untried products. This information is vital to the success of our marketing department and you will often be working under pressure to meet tight deadlines.

The person we are looking for will have the technical skill and ability to devise and implement appropriate test systems. He or she will also need to be self-motivated and able to work unsupervised.

Preference will be given to applicants who possess a City & Guilds (Full Technical Certificate), ONC or HNC qualification or equivalent. Test and calibration experience, preferably in radio and TV will be a great advantage. Some knowledge of current safety specifications for consumer electronic products would also be useful.

The successful applicant can expect an attractive salary which reflects the importance and responsibilities of the job. Other benefits include a subsidised restaurant, four weeks' holiday, excellent pension and insurance schemes and generous staff discount.

If you are interested in this opportunity to broaden your career with a dynamic and rapidly expanding company, contact Janet Gearing on Stevenage 4371, or write to her giving brief details at Dixons Photographic (UK) Ltd., Camera House, Cartwright Road, Stevenage, Herts.

Dixons

A GREAT COMPANY TO BE WITH

(289)

OXLEY®

RESEARCH ENGINEER

Oxley Developments Company are Manufacturers and Consultants in the field of passive electronic components and supply into the control systems, instrumentation and communications industries throughout the world.

We are currently seeking a Research Enginner with a natural enthusiasm, backed up by extensive experience of radio and electronic design and development. Whilst a high standard of academic achievement is a prime requirement, considerable importance is also attached to the practical application of knowledge.

Oxley Developments Company is privately owned and has enjoyed steady and consistent international growth built upon an extensive range of unique products specially developed to fulfil needs within industry. As a result, the successful candidate will have unrivalled opportunities to expand work horizons and to pursue professional advancements both at home and abroad.

The factory and research facilities are located on the edge of the Lake District National Park.

In the first instance, please request an application from from:

The Personnel Director
Oxley Developments Company Limited
Priory Park, ULVERSTON
Cumbria LA12 9QG
Telephone: (0229) 52621

(262)

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(328)

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186

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A vital role for Electrical / Electronic Engineers

These opportunities are in the Scientific and Technical Branch which provides the scientific, engineering and other professional services essential to the provision of medical apparatus, instrumentation and supplies to hospitals.

The successful candidates will join a London-based team working on the specification, laboratory testing, inspection and quality control of a wide range of medical electrical and electronic equipment used in the National Health Service. Some UK travel required.

Candidates must have a degree or an equivalent qualification in electronics or electrical engineering, at least 2 years' training in electrical engineering, and subsequent experience in the design, testing and/or inspection of electronic equipment. Experience of medical electrical equipment advantageous.

Salary *(under review)* starting between £5955 and £7680 depending on qualifications and experience. Promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 8 May 1980) write to Civil Service Commission, Alencon Link, Basingstoke, Hants, RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). *Please quote T(23)85.*

Department of Health and Social Security

(311)

Essex County Council
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SENIOR TECHNICIAN

A with Degree Allowance is required to assist in research work. The person appointed should be prepared to travel on a limited basis.
Salary: T3/T4 £4080-£5067 per annum.
The person appointed will have at least an ONC or OND, but an HNC in digital electronics or telecommunications will be preferred. Experience in prototype construction and interpretation of developmental circuit drawings, and in the field of radio communications, microprocessors and radio circuitry, both transmitters and receivers, will be an advantage.
Application forms and further details available from the Institute Secretary, Chelmer Institute of Higher Education, Victoria Road South, Chelmsford, CM1 1LL. Closing date 2nd May 1980. Telephone: Chelmsford 354491, Ext. 221. (302)

Piccadilly Radio require a

BROADCAST ENGINEER

grade I.L.R.2 to be involved in all aspects of station engineering. Preference will be given to people having experience in this field.

***Apply:* Phil Thompson**
Chief Engineer
Piccadilly Radio
P.O. Box 261
Manchester M60 1QU

PICCADILLY RADIO 261

(9993)

CORPORATION OF LONDON

Department of Architecture and Planning

SENIOR ELECTRONICS ENGINEER

£6878 to £8165 inclusive
(under review)

Applications are invited from suitably qualified and experienced Engineers with wide experience in Electronics. This is a new post and the person appointed will be responsible for, among other things, advice, installation, operation and maintenance of telecommunications and electronic equipment. Matters covered besides public address systems for important State and other functions at Guildhall and elsewhere, will include fire alarms, call systems, television, surveillance, computer and other applications. Liaison with BBC and ITV regarding outside broadcasts from Corporation premises will be required.

Job Outlines and application forms from City Architect and Planning Officer, Guildhall, London EC2P 2EJ, 01-606 3030, extension 2725.

(332)

TECHNICIANS, ELECTRICAL/ELECTRONIC, required to support Academic staff in teaching and/or Research Laboratories. Work involves maintenance, construction and setting up of Electronic experiments for Teaching and Research. Opportunity to work in an environment of Electronics being continually up-dated. Salary according to experience in range £4,374-£4,872 or £4,728-£5,325 inclusive of London Weighting. Application form from Personnel Officer (Technical Staff EE10) University College London, Gower Street, WC1E 6BT. (298)

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TESTERS, TEST TECHNICIANS, TEST ENGINEERS. Earn what you're **really** worth in London working for a World Leader in Radio & Telecommunications. Phone Len Porter on 01-874 7281, or write: REDIFON TELECOMMUNICATIONS Ltd., Broomhill Road, Wandsworth, London, SW18. (9856

Radio Technicians

Work in Communications R&D and add to your skills

At the Government Communications Headquarters we carry out research and development in radio communications and their security, including related computer applications. Practically every type of system is under investigation, including long-range radio, satellite, microwave and telephony.

Your job as a Radio Technician will concern you in developing, constructing, installing, commissioning, testing, and maintaining our equipment. In performing these tasks you will become familiar with a wide range of processing equipment in the audio to microwave range, involving modern logic techniques, microprocessors, and computer systems. Such work will take you to the frontiers of technology on a broad front and widen your area of expertise — positive career assets whatever the future brings. In the rapidly expanding field of digital communications, valuable experience in modern logic and software techniques will be gained.

Training is comprehensive: special courses, both in-house and with manufacturers, will develop particular aspects of your knowledge and you will be encouraged to take advantage of appropriate day release facilities.

You could travel — we are based in Cheltenham, but we have other centres in the UK, most of which, 'e Cheltenham, are situated in environmentally attractive locations. All our centres require resident Radio Technicians and can call for others to make working visits. There will also be some opportunities for short trips abroad, or for longer periods of service overseas.

You should be at least 19 years of age, hold or expect to obtain shortly the City and Guilds Telecommunications Technician Certificate Part I (Intermediate), or its equivalent, and have a sound knowledge of the principles of telecommunications and radio, together with experience of maintenance and the use of test equipment. If you are, or have been in HM Forces your Service trade may allow us to dispense with the need for formal qualifications.

Registered disabled people may be considered.

Pay scales for Radio Technicians start at £3900 per annum , rising to £5530, and promotion will put you on the road to posts carrying substantially more; there are also opportunities for overtime and on-call work, paying good rates.

Get full details from our **Recruitment Officer, Robby Robinson, on Cheltenham (0242) 21491, Ext 2269,** or write to him at **GCHQ, Oakley, Priors Road, Cheltenham, Glos GL52 5AJ.** We will invite suitable applicants (expenses paid) for interview at Cheltenham.

GCHQ

Recruitment Office

Government Communications Headquarters

Oakley, Priors Road, Cheltenham GL52 5AJ

(9813)

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CHELSEA COLLEGE
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A SOFTWARE SPECIALIST is required to develop software for microprocessor applications. on mainframe and development systems. The Centre runs a Harris interactive computing system for general use and it is planned to use this to develop high-level language tools for microprocessor programming. In turn, the mainframes will connect to various development systems in the Laboratory. The post offers an opportunity to an enthusiastic microprocessor specialist to participate in the planning and development of a major new College facility.

Candidates should have a degree in Computer Science or Physical/Engineering Sciences. Industrial and/or research experience with microprocessors would be an advantage.

Salary will be in the range £5792-£9509 p.a. inclusive.

Further details and an application form may be obtained from the Personnel Officer, Chelsea College, Chelsea Manor Street, London SW3 3TW. (333)

GRADUATE ELECTRONICS ENGINEER required to work on interesting applications of electronics to medicine. Applicants should have digital design experience and be interested in working with microprocessors and microcomputers. Day release may be possible to study for a higher degree. For further information, please contact Miss J. Newbigin, Personnel Department, Charing Cross Hospital (Fulham). Tel: 01-748 2040 ext. 2992, and for more details contact Mr. A. Brewer on ext. 2593/3. (295)

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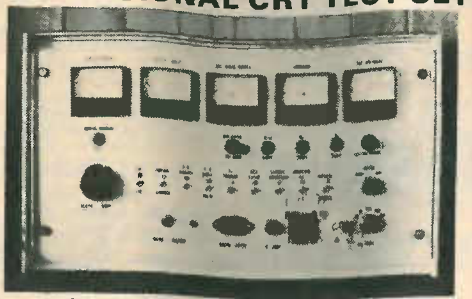

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POLYSKOP SWOB 1 with 1 probe, 1 input cable, 1 inline attenuator, 1 adaptor R&S-BNC, 1 adaptor R&S-N. plus manual book. The lot £395. Signal generator TF 801D/8/S freq. 10 MH/z-485 MH/z £285. Pulse gen. modular CT578/3 with P1A, P2A & p6 plug-in units £95. A226 programmer. The A226 programmer is a simple means of automating any Master Series Digital Voltmeter. It provides programming of DVM range and mode, off-limit detection and scanning of analogue inputs. Mint condition. £95 only. Gaumont-Kalee Wow & Flutter meter, £48. Cohu D.C. Voltage standard type 303B, £195. HP 624C X-Band test set freq. 8.5 GH/z-10GH/z, £195. Pulse generator Type 109 Fast Rise, £95. Plug-in Unit Type 10AL, £95. N Type £50. Valve Voltmeter Type 613C, £75. R&S Noise Generator, 3-1000 MH/z 50 OHMS £95. Eddystone Communication Receiver Type 770S £450. Tektronix Oscilloscope Type 585 with L Plug-in Unit, £165. CDU 150 Oscilloscope £295. All goods subject to VAT and being unsold in the meantime. P&P extra or by arrangment. — Please phone Mr. Galka, 01-543 2515 or 01-404 5011. Personal callers welcome by appointment only. (326)

TEKTRONIX 555 dual beam 'scope. 30mhz four plug-ins plus probes, trolley and manuals. Bargain, £375. Tel. 0202 875065 (Bournemouth). (285)

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