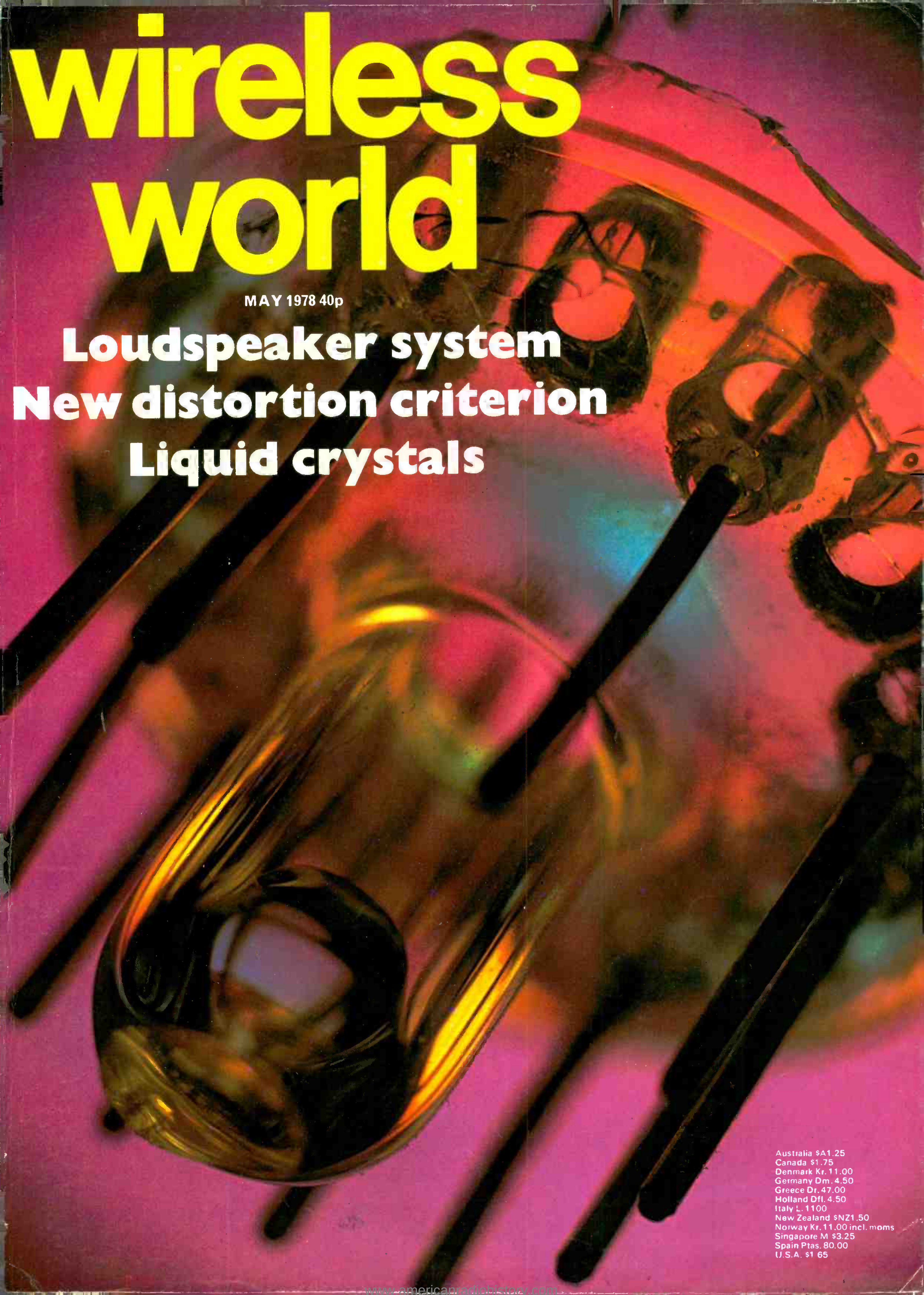
wireless world

MAY 1978 40p

Loudspeaker system
New distortion criterion
Liquid crystals



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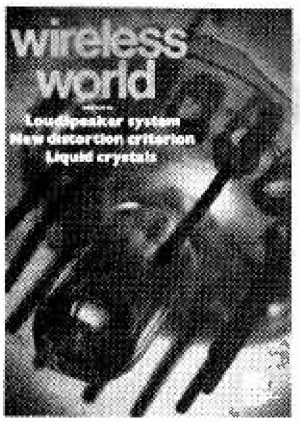

Examination by polarized light for residual strain in the glass foot of a television picture tube. Photograph courtesy Mullard Ltd.

IN OUR NEXT ISSUE

Mobile radio channels **— a new way of using them. Proposing a channel bandwidth unit to be used on its own for speech or in multiples for data.**

The Morsemaker. **A portable instrument which produces a continuous and random string of Morse numbers or letters for teaching purposes.**

Radiating cables. **Coaxial cables deliberately designed to couple with their surroundings are used in tunnels and buildings, where aerials are ineffective or radiate too widely.**

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ELECTRONICS / TELEVISION / RADIO / AUDIO

MAY 1978 VOL 84 NO 1509

GenRad's Top Trio...

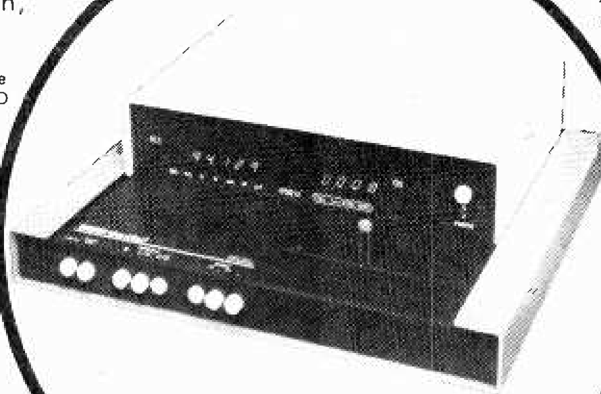
...a low cost/high performance range of μP-based bridges

GenRad's new range of μP-based bridges make full use of advanced technology to meet tomorrow's testing needs today. Check the list of features, and contact us for further information, price and delivery.

1658 RLC Digibridge
* Automatically measures R,L,C, D and Q
* 0.1% Basic accuracy
* 10 Bins for sorting
* Autoranging
* IEEE 488 bus/handler interface option
* Three test speeds
* Selectable continuous, average or single component measurements
* Three types of display programmed bin limits, measured values or bin number
* **Five**-digit display for R,L and C
* **Four**-digit display for D and Q
* Selectable test frequencies of 1 kHz and 120 Hz (100 Hz)
* Series or parallel measurement mode selection
* Built-in Kelvin test fixture tests radial and axial lead components

The 1657 Digibridge
* Automatically measures R,L,C,D and Q
* 0.2% Basic accuracy
* **Five**-digit display for R, L and C
* **Four**-digit display for D and Q
* Microprocessor-directed ranging
* Selectable test frequencies of 1kHz and 120Hz (100 Hz)
* Series or parallel measurement mode selection
* Built-in Kelvin test fixture tests radial and axial lead components

1687 Megahertz LC Digibridge
* Automatically measures Ls & Q, Cs & D, Cs & Rs, Cp & Gp
* 0.1% basic accuracy for **C** 0.2% basic accuracy for L
* Automatic limit-comparison (10 bins)
* Autoranging
* IEEE 488 bus/handler interface option
* Two test speeds
* Selectable continuous, average or single component measurements
* Four types of display - programmed bin limits, measured values, deviation measurement (ΔL or ΔC), or bin number
* **Five**-digit display for L and C
* **Four**-digit display for Q,D,R and G
* Optional Kelvin test fixture tests radial and axial lead components



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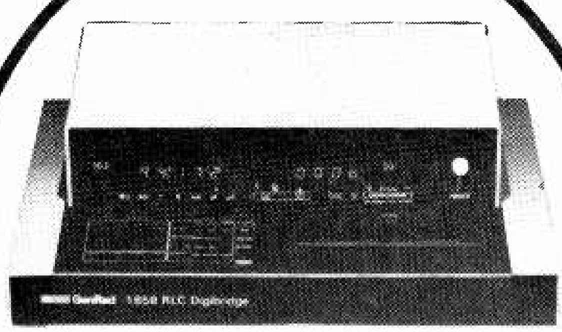

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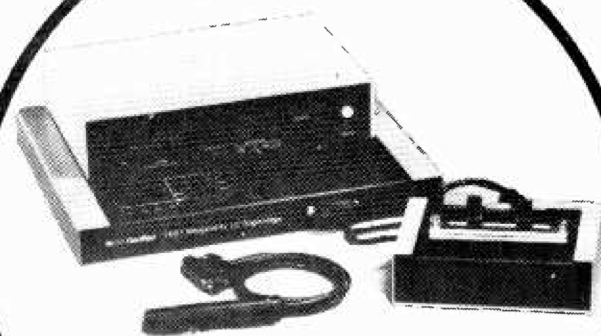
*Under £2,000



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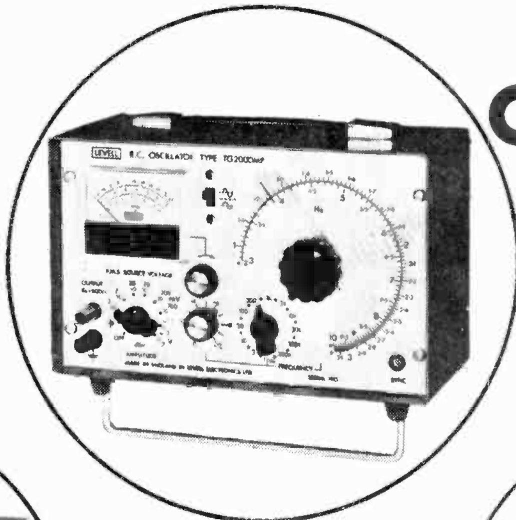
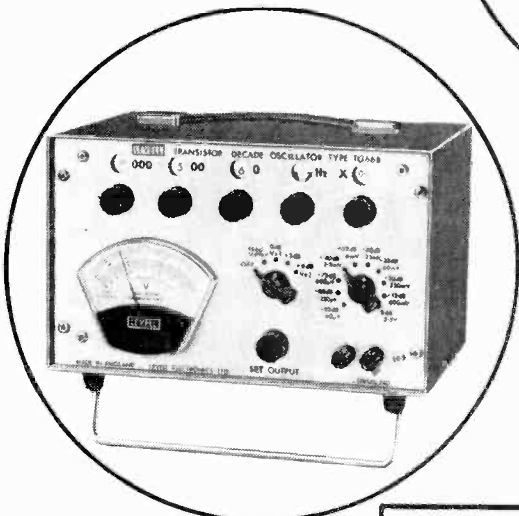
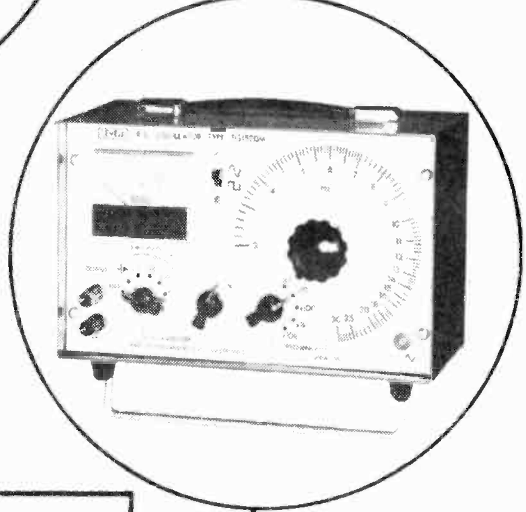
LOW COST OSCILLATORS







FREQUENCY	1Hz to 1MHz in 12 ranges. 0 to 1% fine control on TG200DMP.
ACCURACY	±1.5% ±0.01Hz up to 100kHz. ±2% up to 1MHz.
SINE OUTPUT	7V r.m.s. down to <200µV with Rs=600Ω.
DISTORTION	<0.05% from 50Hz to 15kHz, <0.1% from 10Hz to 50kHz, <0.2% from 5Hz to 150kHz, <1% at 1Hz and 1MHz.
SQUARE OUTPUT	TG200D, DM & DMP only. 7V peak down to <200µV. Rise time <150nS.
SYNC. OUTPUT	>1V r.m.s. sine in phase with output.
SYNC. INPUT	±1% freq. lock range per volt r.m.s.
METER SCALES	TG200M, DM & DPM only. 0/2V, 0/7V & −14/+6dBm.
SIZE & WEIGHT	260 x 130 x 180mm. 4.3kg with batteries.

TG200	TG200D	TG200M	TG200DM	TG200DMP
£75	**£79**	**£91**	**£95**	**£99**

FREQUENCY	0.2Hz to 1.22MHz on four decade controls.
ACCURACY	±0.02Hz below 6Hz. ±0.3% from 6Hz to 100kHz. ±1% from 100kHz to 300 kHz. ±3% above 300 kHz.
SINE OUTPUT	5V r.m.s. down to 30µV with Rs=600Ω.
DISTORTION	<0.15% from 15Hz to 15kHz. <0.5% at 1.5Hz and 150kHz.
METER SCALES	2 Expanded voltage & −2/+4dBm.
SIZE & WEIGHT	260mm x 190mm x 180mm. 5.6kg.

TG66B Battery model **£195**

TG66A Mains & battery model **£210**

FREQUENCY	3Hz to 300kHz in 5 decade ranges.
ACCURACY	±2% ±0.1 Hz up to 100kHz, increasing to ±3% at 300kHz.
SINE OUTPUT	2.5V r.m.s. down to <200µV.
DISTORTION	<0.2% from 50 Hz to 50kHz.
SQUARE OUTPUT	2.5V peak down to <200µV.
SYNC. OUTPUT	2.5V r.m.s. sine.
METER SCALES	0/2.5V & −10/+10dB on TG152DM.
SIZE & WEIGHT	260mm x 130mm x 180mm. 3.4kg.

TG152D Without meter **£59**

TG152DM With meter **£75**

LEVELL ELECTRONICS LTD.
Moxon Street, High Barnet, Herts. EN5 5SD
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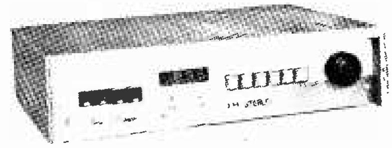
Prices are ex-works with batteries. Carriage and packing extra. VAT extra in U.K. Optional extras are leather cases and mains power units. Send for data covering our range of portable instruments.

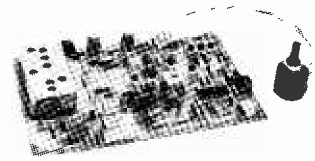
WW—040 FOR FURTHER DETAILS

F.M. TUNERS, MODULES & UNITS by Icon Design

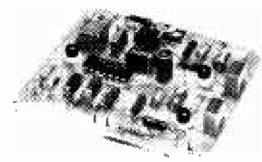
T3 Six touch tuned pre-set stations plus manual tune, with digital frequency readout, combined with 1.8 micro-volt sensitivity and anti-birdy stereo make this one of the finest tuners available. Intelligent tuning indicator, a.f.c. and interstation mute included for easy operation by all the family. Two tone gold and brown front panel with teak veneer cabinet will blend with any surroundings. **£149.00**



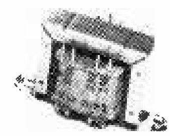
M1 This module is the heart of the above tuner, giving a mono output with a.f.c., mute, and tuning indicator functions. Drift free tuning by 10 turn pot over the range 88 to 108 MHz. This module will not let you hear out-of-tune stations, and the fine tuning lamp is extinguished unless a station is received. The ideal basis for any High quality F.M. system. **£29.95**



M2 The ideal choice for adding stereo to the M1 module or any suitable mono receiver, this module has anti-birdy filters and pilot tone output filters, together with a phase-locked decoder for stable performance. **£8.36**

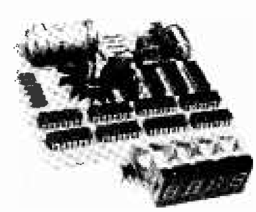


M4 An integrated circuit regulator supplies all the power for the M1, M2 and M5, in addition to being short circuit proof and having automatic thermal shut-down, and ensuring hum free reception. **£6.93**



M5 The M5(mk2) touch module adds 6 touch selected pre-set stations to the manual tuning already provided by the M1 module. Illuminated buttons indicate the channel selected, while remote control using a single contact push button steps the channels in an endless loop, including the manual control channel. Auto power-up channel selection may be set to any of the seven available channels. Remote inhibit and a lamp test facility are provided. **£17.54**

M6 Using the optimum selection of discrete, E.C.L., T.T.L. and C-MOS technologies, this module will add the luxury of digital readout to the M1 module above, or any other LP1186 based receiver. The small (95 x 103mm) board contains all the logic, displays, and regulated power supply. Range is 60 to 99.9MHz, resolution 0.1KHz, and stability better than 40 p.p.m. per deg. C. It comes complete with mains transformer, polarised filter, and list of station frequencies. **£44.40**



★★ PLUS TWO NEW ONES ★★

M7 This new module is a 4 way touch select switch having illuminated touch buttons, and C-MOS logic level outputs. Features pre-set power-up selection, and remote step facility. Multiple units may be cascaded to give 8, 12 or more channels of switching, and two modules may be paralleled to give full remote control from two or more locations. The outputs may be used to control logic etc., or to drive the new M8 channel selector opposite. **£6.95**

M8 Controlled from single pole switches, or the M7 module, this unit will switch 4 mono or two stereo audio channels. Two M8 modules will therefore switch 4 stereo signals driven by one M7 touch switch, or other combinations may be controlled by multiple touch switches, providing a flexible system of audio selection and control. The ideal module for pre-amplifier source selection, avoiding long signal wires to and from control panels, and their associated hum and cross-talk problems. **£4.95**

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Small orders <£5.00 plus 50p handling charge.

U.K. Orders post free, plus 12.5% V.A.T.

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UA78M05	£1.65	P.C.B. M3	£1.65	K112 (T3)	£137.80
SFJ10·7MA	£1.71	P.C.B. M4	£1.65	Descriptive booklet	50p
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Please supply data on (Circle as required)

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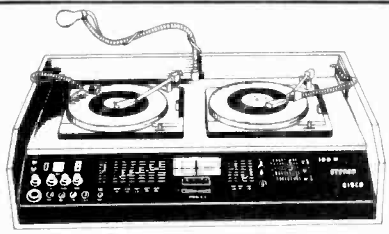
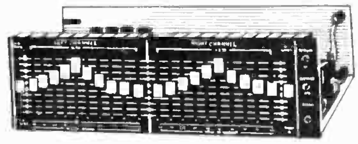


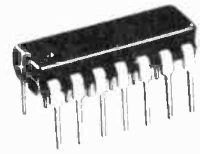
100W RMS STEREO DISCO

A genuine 100W RMS per channel (both channels driven) stereo disco with auto fade on microphone, VU meters, full monitoring and cueing facilities and a very high quality light show. Complete construction booklet MES41 price 25p. Cabinet comes complete with lid and carrying handles.



10 CHANNEL STEREO GRAPHIC EQUALISER

A new design with no difficult coils to wind, but a specification that puts it in the top-flight hi-fi class. All this for around £70 including fully punched and printed metalwork and woodwork. Send for our component schedule now. Full construction details price 25p. (All prices include V.A.T. and p & p.)



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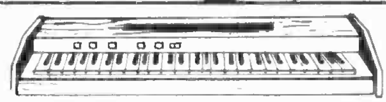
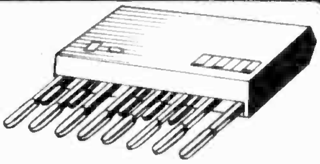


TOUCH-SENSITIVE PIANO

The revolutionary new IC AY-1-1320 first seen on 'Tomorrow's World' is now available. Complete kit of IC's to build a 60-note piano (18 × IC's) order as HQ53H price £36·86. Preliminary circuit details in our October newsletter. Complete design, pcb's attractive veneered wooden cabinet available soon. It's the most realistic-sounding electronic piano we've ever heard and includes simulated damping, loud and soft pedals. Full details in our newsletters. (All prices include V.A.T. and p & p.)



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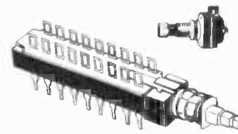

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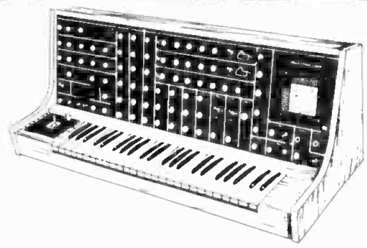
We stock a wide range of switches including a really low-priced high quality interlocking push-button switch system which is extremely versatile. We've got toggle switches, slide switches, push switches, rotary switches—there are dozens to choose from, but it's only a tiny part of our fantastic range.



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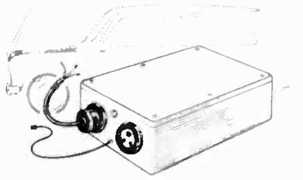
The International 4600 Synthesiser. A very comprehensive unit. Over 400 sold. We stock all the parts costing less than £500 including fully punched and printed metalwork and a smart teak cabinet. Far less than half what you'd pay for a ready made synthesiser of equal quality. Specification on request. Full construction details in our construction book £1·50. (All prices include V.A.T. and p & p.)



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(WW5)

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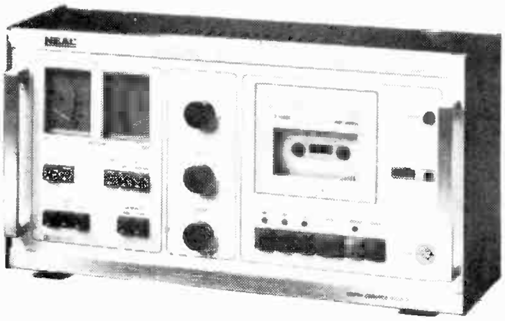
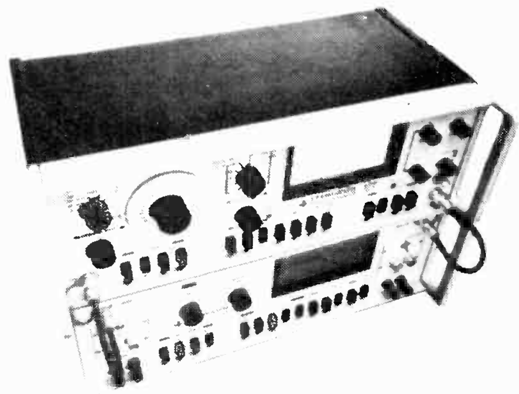


The NEAL 302.
Incorporating a 3-motor mechanism, controlled by a full solid state logic system actuated by ultra light touch buttons, this is the machine used by top recording studios and broadcasting stations, for quality cassette copies and for in - cassette duplication masters.

The Ferrograph Logic 7.
A transportable tape recorder of unrivalled facilities; taking all spool sizes up to 27 cm, and providing three speeds, plus positive action push buttons in association with logic circuits . . . for fast, safe tape handling under all conditions.

Studio 8
A professional studio tape recorder logic controlled for superb tape handling characteristics, offering a choice of stereo, twin track and full or half track mono heads, PPM or VU meters, IEC (CCIR) or NAB equalisation, console or transportable models.



The RTS 2.
Combines in one easy to use compact instrument the measurement of gain, noise, frequency response, input sensitivity, output power, distortion and the parameters relating to recording equipment, such as wow and flutter, crosstalk, drift and erasure. Its range of application can be extended even further by the addition of the Auxiliary Test Unit **ATU 1.**

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WW—008 FOR FURTHER DETAILS

The new, comprehensive JVC ¾" video cassette range

See-and believe

A pioneering electronics organisation with 51 years' experience of high-technology engineering, JVC has been developing and introducing new and better video products for 21 years.

Now, for the first time in Britain, you can choose from a new and comprehensive range of JVC ¾" U-format colour-plus-monochrome video cassette units, up to 38% smaller than directly competitive equipment.

From the compact portable CR-4400E for location work to the versatile CR-8300E for production studios, these easy-to-use models meet every video cassette recorder demand. They give you *exactly the same top-quality recording and playback throughout the range*. Price differences simply reflect the number of facilities available, not the performance.

The range. For those needing NTSC as well as PAL playback (perhaps for shipboard entertainment), JVC has the new CR-5060ED.

If you're looking for stop-action playback and PAL record/playback facilities, the new CR-6060E with its specially engineered still-frame system is the one for you. (Optional remote control available.)

PAL recording, plus PAL *and* NTSC playback, come together in the new CR-6060ED. Again, with optional remote control.

Full electronic editing facilities are built into the superb new CR-8300E, a PAL record/playback unit. For even more flexible editing, add the JVC RM83 editing suite.

Where you must have portable video equipment, able to record cassettes that can also be replayed by a mains cassette unit without an adaptor, it's got to be the new assembly-edit CR-4400E. This comes complete with built-in video/RF replay facilities. And, of course, there's a colour camera to match.

Use the inquiry service to get the literature from Bell & Howell and the name and address of an audio-visual centre where you can test for yourself the versatility of these new JVC units. Admire the outstanding picture quality each provides. Seeing is believing. You'll believe, as we do, that JVC U-format equipment is the best in the world.

WW—055 FOR FURTHER DETAILS

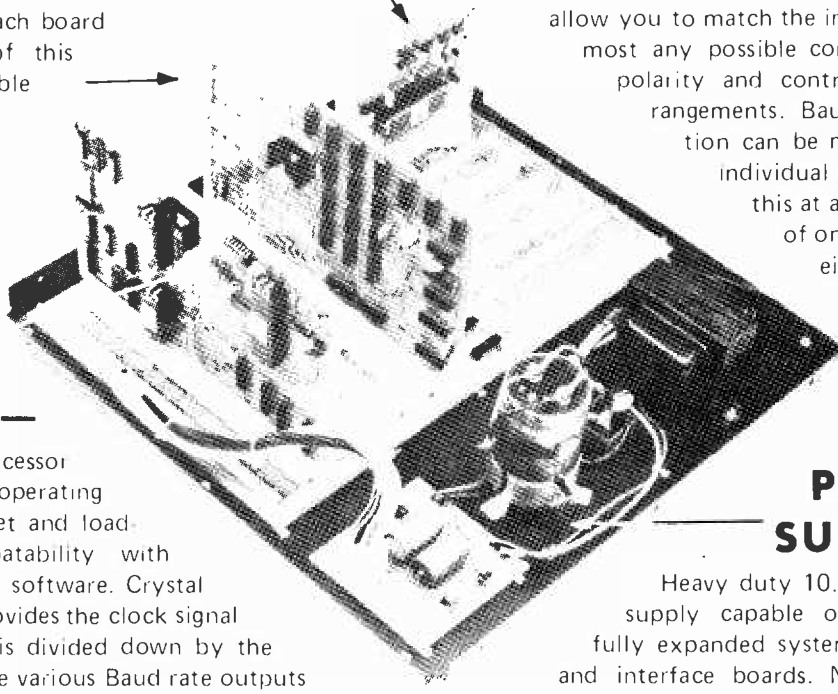
WHY SETTLE FOR LESS— THAN A 6800 SYSTEM

MEMORY—

All static memory with selected 2102 IC's allows processor to run at its maximum speed at all times. No refresh system is needed and no time is lost in memory refresh cycles. Each board holds 4,096 words of this proven reliable and trouble free memory. Cost—only £80.00 for each full 4K memory.

INTERFACE—

Serial control interface connects to any RS-232, or 20 Ma. TTY control terminal. Connectors provided for expansion of up to eight interfaces. Unique programmable interface circuits allow you to match the interface to almost any possible combination of polarity and control signal arrangements. Baud rate selection can be made on each individual interface. All this at a sensible cost of only£30.00for either serial, or parallel type



PROCESSOR—

"Motorola" M6800 processor with Mikbug® ROM operating system. Automatic reset and loading, plus full compatability with Motorola evaluation set software. Crystal controlled oscillator provides the clock signal for the processor and is divided down by the MC14411 to provide the various Baud rate outputs for the interface circuits. Full buffering on all data and address busses insures "glitch" free operation with full expansion of memory and interfaces.

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Heavy duty 10.0 Amp power supply capable of powering a fully expanded system of memory and interface boards. Note 25 Amp rectifier bridge and 91,000 mfd computer grade filter capacitor.

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Probably the most extensive and complete set of data available for any microprocessor system is supplied with our 6800 computer. This includes the Motorola programming manual, our own very complete assembly instructions, plus a notebook full of information that we have compiled on the system hardware and programming. This includes diagnostic programs, sample programs and even a Tic Tac Toe listing.

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with serial interface and 4,096 words of memory £275.00
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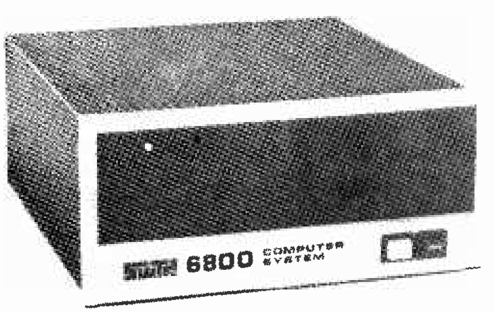

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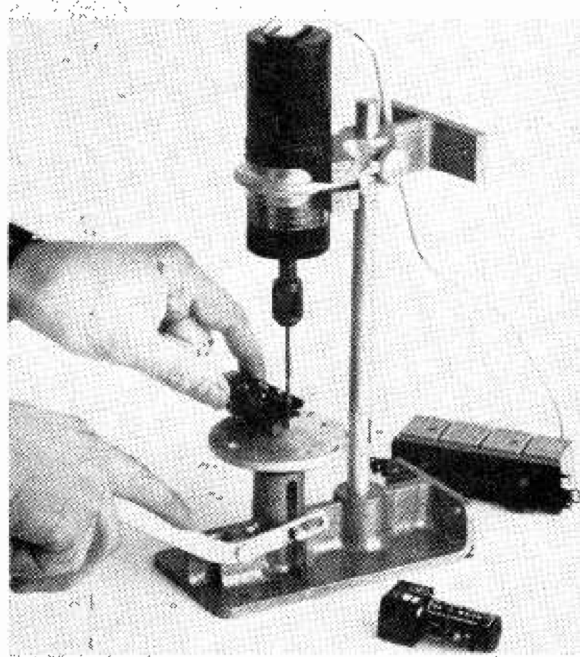

Illustrated right is a **TITAN DRILL**

Mounted in a multi-purpose stand This drill is a powerful tool running on 12v DC at approx 9000 rpm with a torque of 350 grm cm Chuck capacity 3 00 m/m
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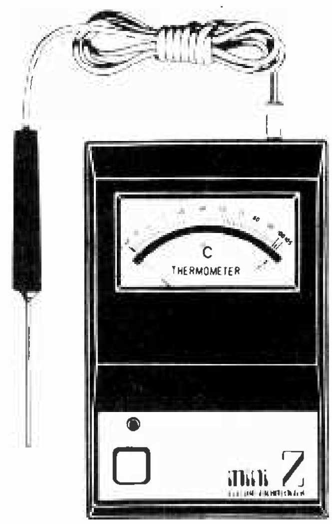

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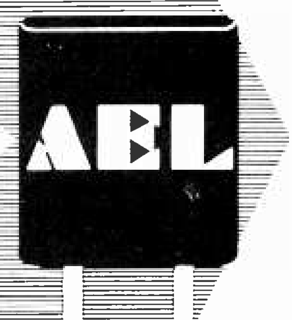

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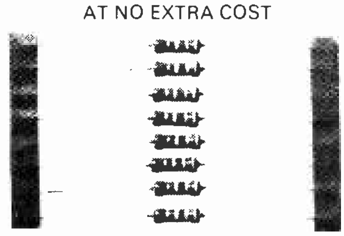

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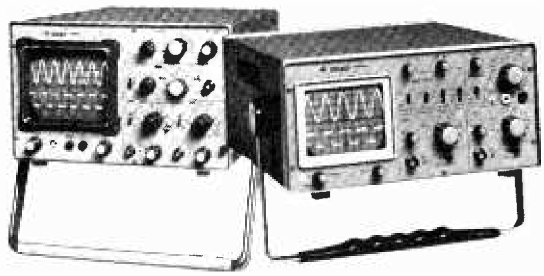

OS245A AND OS250B OSCILLOSCOPES

Two dual trace oscilloscopes, with sensitivity of 5mV/div., and 2mV/cm respectively. The OS250B offers variable trigger level with or without bright line. The OS245A has a bandwidth of 10MHz, the OS250B offers 15MHz. Fully portable, these are the ideal instruments for servicing, educational and general purpose applications.

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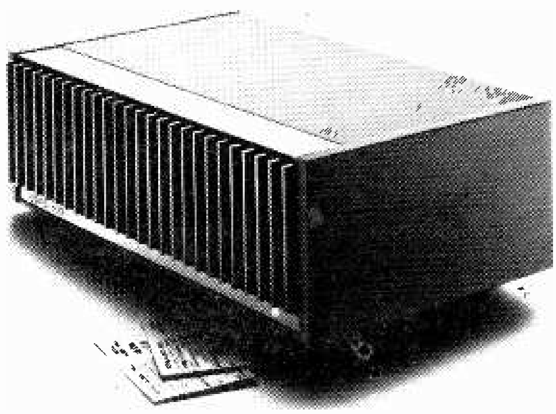


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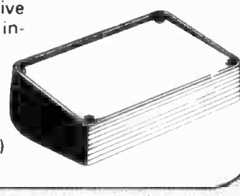
BIMCONSOLES
BIMBOXES
BIMBOARDS
BIMDRILLS
BIMDICATORS

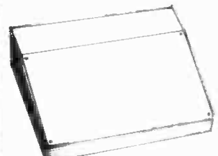
MINI DESK BIMCONSOLES

Moulded in Orange, Blue, Black or Grey ABS and incorporating guides on all sides for holding 1.5mm thick pcb's. 1mm Grey Aluminium panel sits recessed into front of console and held by screws running into integral brass bushes. Stand-off bosses in base for supporting small sub-assemblies etc. 4 self adhesive rubber feet also included.

BIM1005 (161x96x58mm) £2.12*
BIM1006 (215x130x75mm) £2.94*



LOW PROFILE BIMCONSOLES



1mm Grey Aluminium panel sits recessed into front of console base, which is moulded in Orange, Blue, Black or Grey ABS and sits on 4 self adhesive rubber feet. Incorporating guides for holding 1.5mm thick pcb, the base also has stand-off bosses for supporting small sub-assemblies etc. and ventilation slots. Front panel is held by 4 screws which run into integral brass bushes.

BIM6005 (143x105x55.5[31.5] mm) £2.32*
BIM6006 (143x170x55.5[31.5] mm) £3.08*
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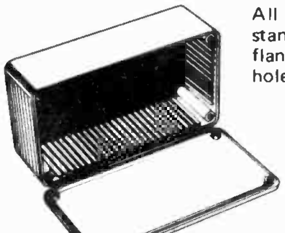
ABS & DIECAST BIMBOXES

5 sizes, in either ABS or Diecast Aluminium
ABS moulded in Orange, Blue, Grey or Black
Diecast Aluminium available in Grey Hammertone or Natural



All boxes incorporate guides on all sides for holding 1.5mm thick pcb's and stand-off bosses in base for supporting small sub-assemblies etc. Close fitting flanged lids held by screws running into integral brass bushes (ABS) or tapped holes (Diecast).

	ABS		Diecast	Hammertone	Natural
(100x50x25mm)	BIM2002/12	£0.95*	BIM5002/12	£1.20*	£0.97*
(112x62x31mm)	BIM2003/13	£1.05*	BIM5003/13	£1.50*	£1.20*
(120x65x40mm)	BIM2004/14	£1.15*	BIM5004/14	£1.86*	£1.49*
(150x80x50mm)	BIM2005/15	£1.30*	BIM5005/15	£2.38*	£1.91*
(190x110x60mm)	BIM2006/16	£2.04*	BIM5006/16	£3.41*	£2.85*

Also available in Grey Polystyrene (112x61x31mm) with no slots and self tapping screws BIM2007/17 £0.88*

MULTI-PURPOSE BIMBOXES

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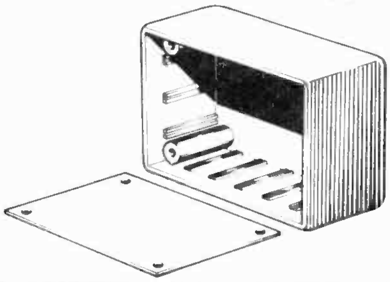
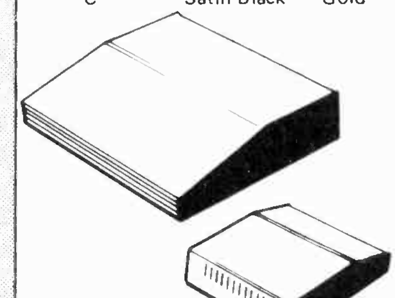
BIM 4003 (85x56x28.5mm) £1.24*
BIM 4004 (111x71x41.5mm) £1.56*
BIM 4005 (161x96x52.5mm) £2.08*



ALL METAL BIMCONSOLES

All aluminium, 2 piece desk consoles with either 15° or 30° sloping fronts, sit on 4 self-adhesive non slip rubber feet. Ventilation slots in base and rear panels permit efficient cooling.

Colour Code	Top Panel	Base
A	Off White	Blue
B	Sand	Green
C	Satin Black	Gold



15° Sloping Panel

BIM7151 (102x140x51[28] mm) £ 9.43*
BIM7152 (165x140x51[28] mm) £10.43*
BIM7153 (165x216x51[28] mm) £11.42*
BIM7154 (165x211x76[33] mm) £12.39*
BIM7155 (254x211x76[33] mm) £13.66*
BIM7156 (254x287x76[33] mm) £14.65*
BIM7157 (356x211x76[33] mm) £15.80*
BIM7158 (356x287x76[33] mm) £16.78*

30° Sloping Panel

BIM7301 (102x140x76[28] mm) £ 9.43*
BIM7302 (165x140x76[28] mm) £10.43*
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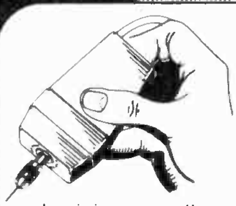
BIM7304 (254x140x76[28] mm) £12.39*
BIM7305 (254x183x102[28] mm) £13.66*
BIM7306 (254x259x102[28] mm) £14.65*
BIM7307 (356x183x102[28] mm) £15.80*
BIM7308 (356x259x102[28] mm) £16.78*

MAINS BIMDRILL



Operates directly from 220-240Vac and supplied with 2 metres long cable fitted with 2 pin DIN plug. Will drill brass, steel and aluminium as well as pcb's etc. Has integral biased-off switch and accepts tools with 1,2 and 3.2mm dia shanks £9.72*
Accessory Kit including 1mm, 2mm, .125" twist drills, 5 burrs and 2.4mm collet £2.20*

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Bimboards accept all sizes of DIL packages as well as resistors, diodes, capacitors and LED's etc. They have integral Bus Strips running up each side for carrying Vcc and ground as well as Component Support Brackets for holding lamps, fuses and switches etc. Available as either single or multiple units, the latter mounted on 1.5mm thick, matt black aluminium back plates which stand on non slip rubber feet and have 4 screw terminals for incoming power.

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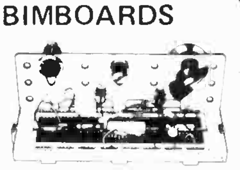
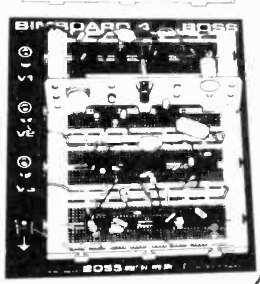
Bimboard 3 £32.40* Bimboard 4 £42.12*





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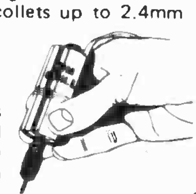

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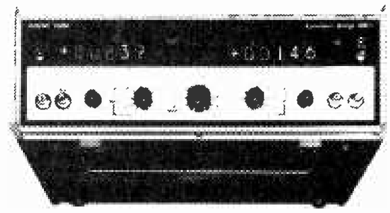

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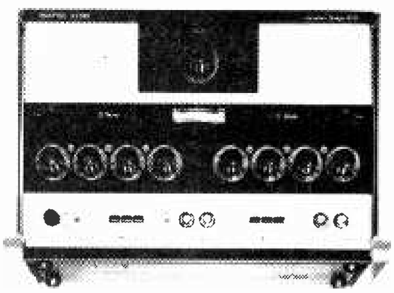

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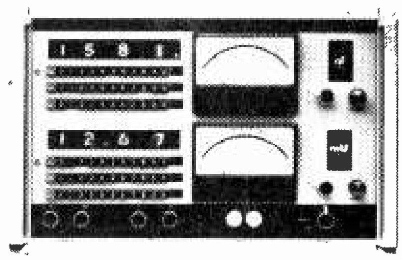

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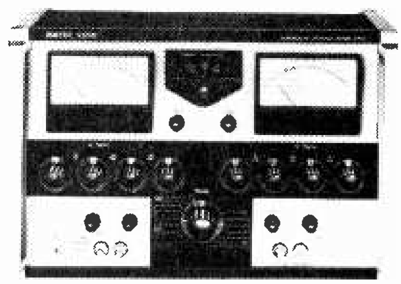

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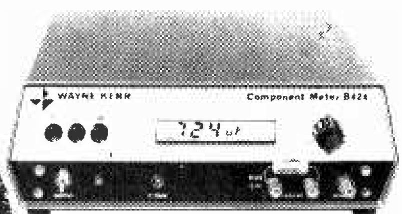

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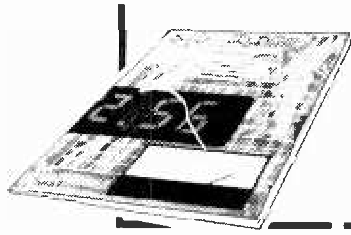

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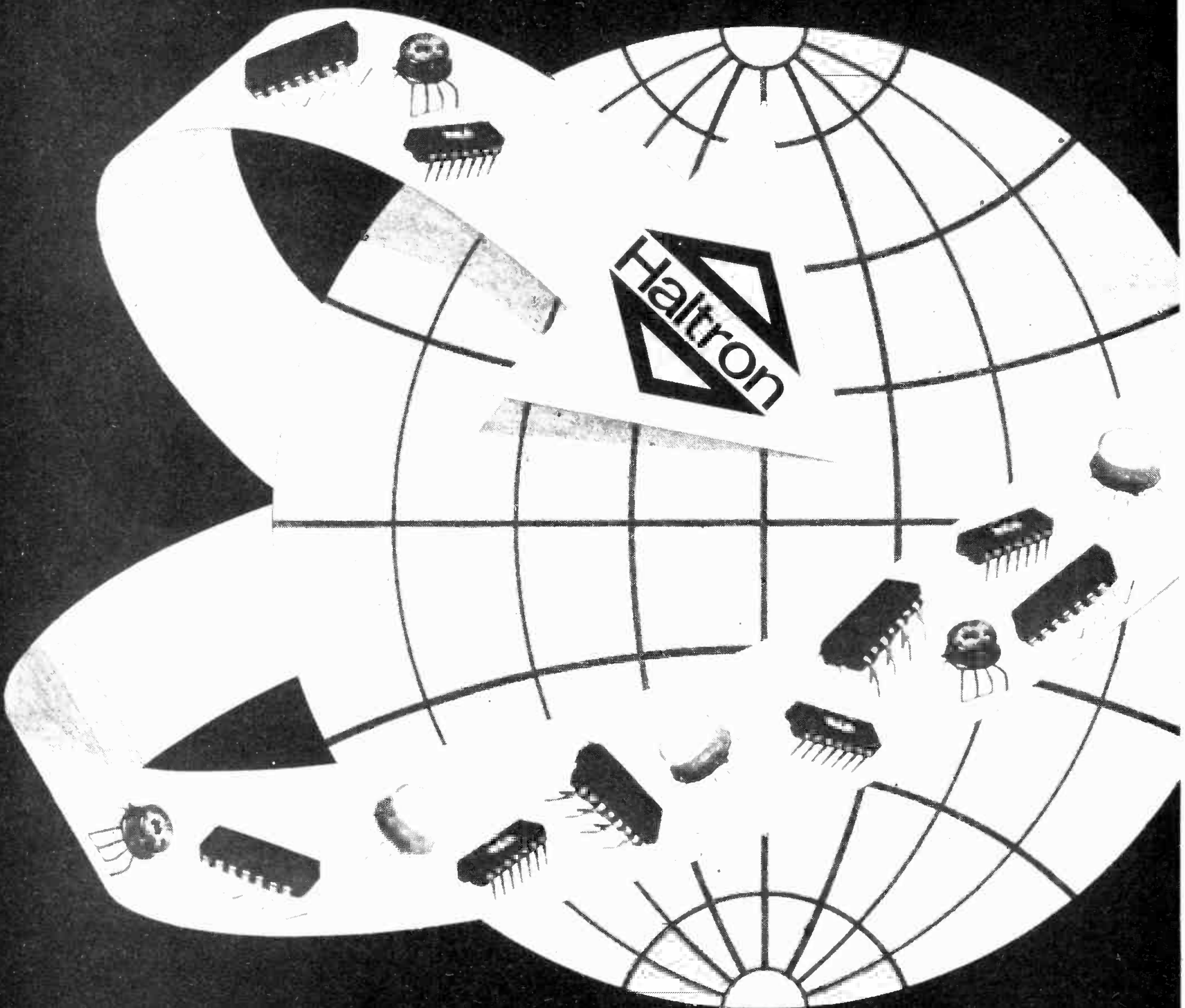

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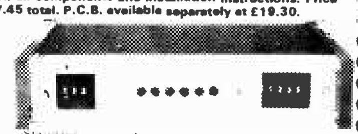
'Board 3' is also available as an additional unit to update the *'Wireless World'* Teletext Decoder to give double height characters, colour background, conceal/reveal, etc., as described in December and January issues of *'Wireless World'*.

Our Kit includes plated-through hole P.C.B., all components and installation instructions. Price £33.68 + VAT (£3.47) + P&P (30p) = £37.45 total. P.C.B. available separately at £19.30.

Our main kits contain all the printed circuit boards and components necessary to build the complete decoder

A reprint of the series of articles is available at £1 50 + large 15p SAE (included free in complete kit)



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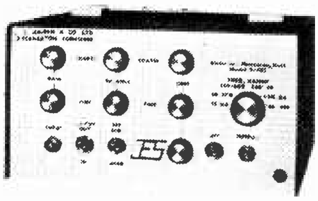

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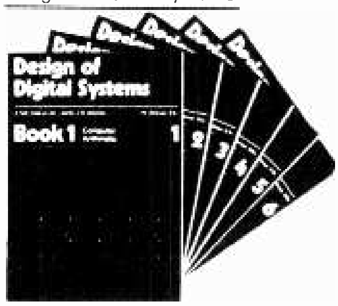

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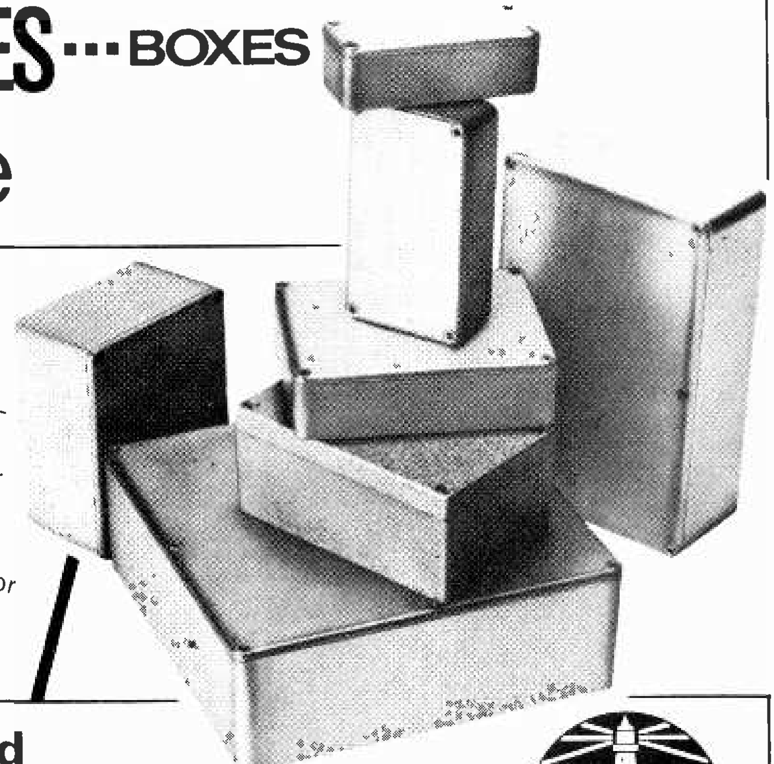

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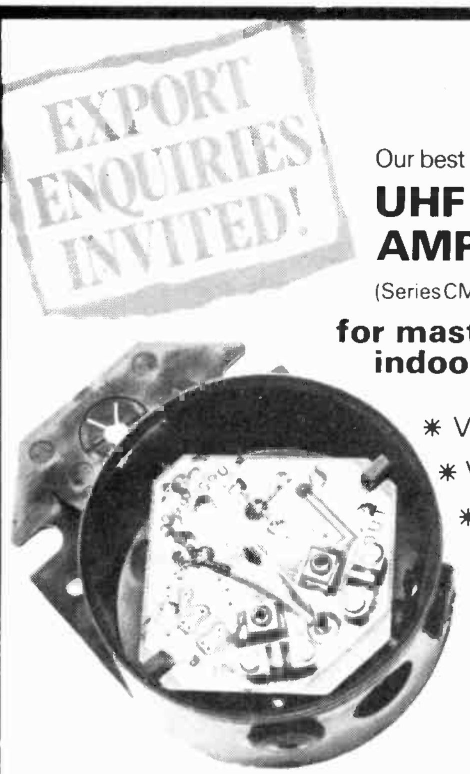

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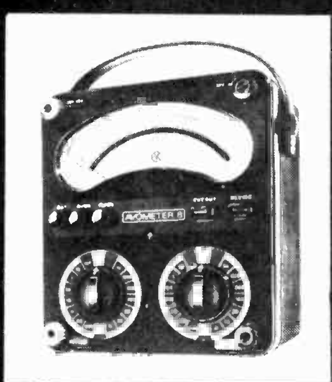

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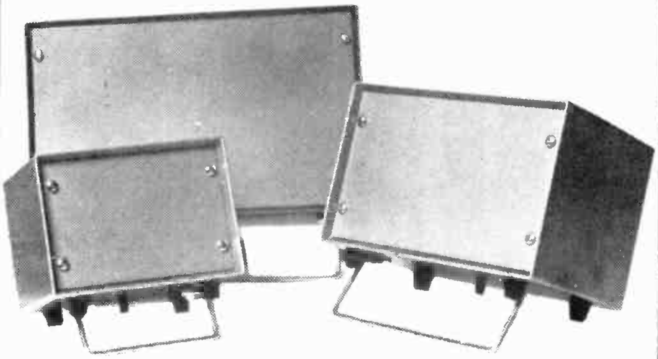

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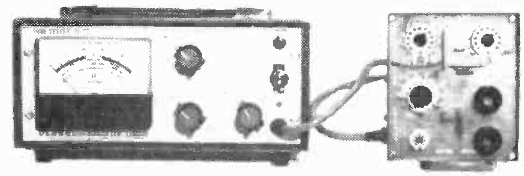

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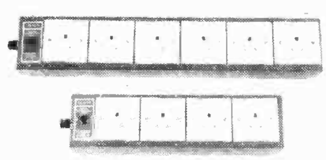

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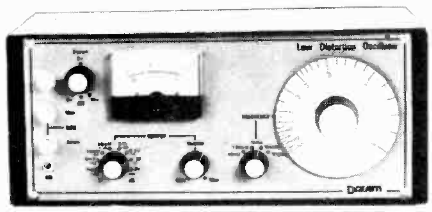

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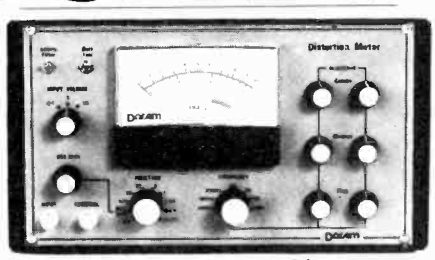

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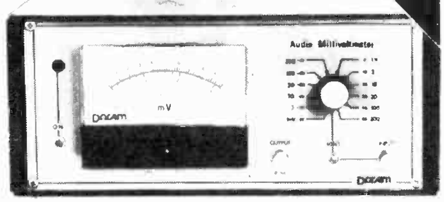

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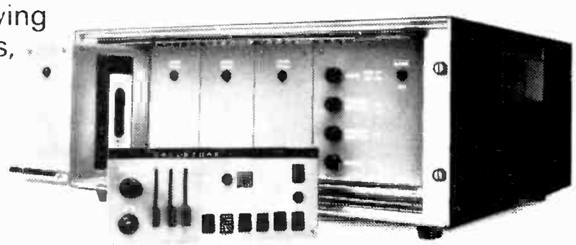

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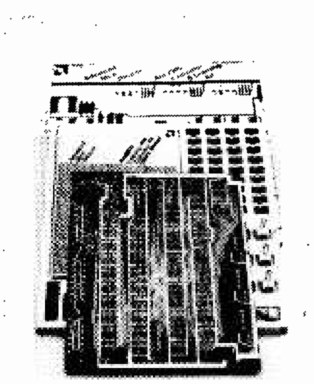

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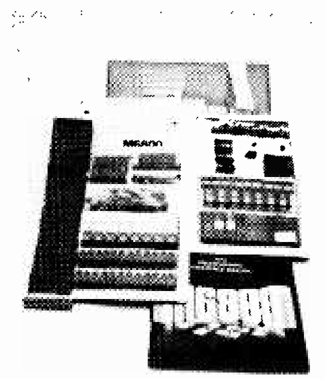

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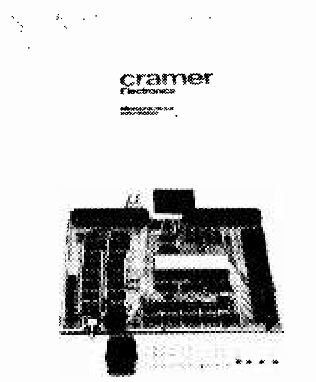

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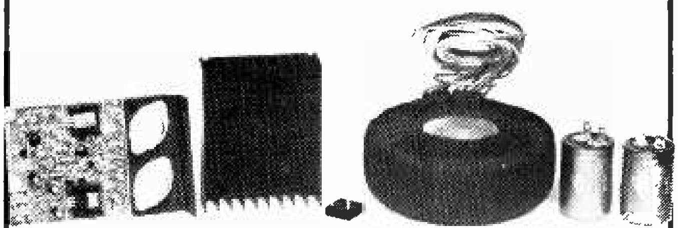

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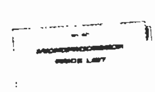

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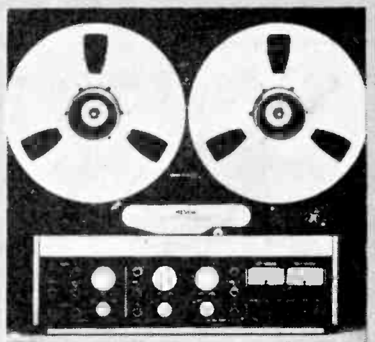

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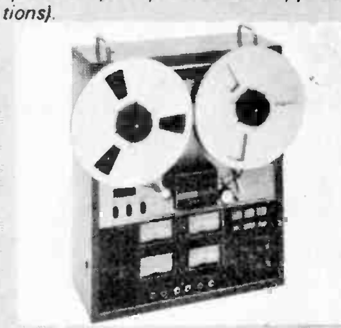

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Thoughts from the drawing-board

TWO RECENT speeches by well-known scientists about the job of the engineer have shown an astonishing vagueness and lack of knowlege of what engineering is all about. Perhaps being a Fellow of the Royal Society gives one an Olympian view of humanity that completely misses all the grubby details of how people actually earn their living. Sir Monty Finniston (who chairs the committee of enquiry into the engineering profession) told the IEE at its annual dinner that the engineer should have more authority, to match his responsibilities, and should be in a position "to influence the national scene more attractively and pertinently" than he does at present. "If the engineer is to play his proper role in society he must make relevant policy contributions to the decisions of political institutions". Sir Ieuan Maddock (one-time chief scientist in the Department of Trade and Industry), in a lecture to Imperial College, said that the engineer's future task will not be so much in applying established engineering skills as in harnessing nature "to solve social needs of growing complexity". He should be a bridge between "knowledge of the laws of nature and the growing and changing needs of society".

All fine stuff, that some like to hear. Of course, the reality is very different. The average engineer is not interested in his "role in society" or the "needs of society". Typically he works for an employer and to earn a living he has to satisfy the particular needs of that employer, quite regardless of whether they are good or bad for society at large. In turn the employer may influence society through the goods or services he supplies, but this process operates through the market mechanism, not according to any ideas or wishes of the engineer. Collectively, engineers do not show any evidence of a desire to do great things for society, only a desire to improve their own incomes and status — and who would blame them for that. Nevertheless, the engineer does take part in public affairs as an individual. Here his personal characteristics are somewhat more important than his engineering knowledge, for value judgments control the way that factual knowledge is applied to human affairs.

What we don't want to see is the engineer elevated to the position of a super-technician of society, chosen simply because of his ability to design and operate systems at maximum efficiency. But Sir Monty Finniston obviously thinks this should be the aim. Because the great issues of the future affecting our lives "are likely to have very large and ever increasing technical content" policy decisions "must give greater weight to the views of those who both conceive the changes and implement them rather than to the non-technical beneficiaries". Note how ordinary people are objectified into "non-technical beneficiaries" in the chill language of total administration as Marcuse calls it. This is the authentic voice of the technocrat.

Raymond Aron, the French sociologist, has pointed out that all societies continue to *train the men they need* but that none, despite its proclaimed objectives, *needs* to have all men realize their individual potentialities and become fully capable of freedom in relation to their environment. In the industrialized countries we have already trained enough technocrats in the shape of economists, lawyers, educationists, bankers and psychiatrists to help us forge our own manacles, without adding engineers to the list. When organization becomes an end in itself, joy flies out of the window.

A new distortion measurement

Better subjective-objective correlation than given by t.h.d.

by **R. A. Belcher**, B.Sc., Ph.D., M.I.E.E., BBC Research Department

This article describes a new technique for measuring non-linearity distortion which gives much better correlation with subjective assessment of sound quality than does the conventional total harmonic distortion measurement. Known as the double comb-filter method, it uses pseudo-random binary test signals and largely digital processing, so the cost of instrumenting it can be expected to fall with the increasing availability of l.s.i. circuits. Ultimately, the hardware may cost less than that used at present for t.h.d. measurement. Ways are suggested for using the new technique to measure cross-over distortion, transient intermodulation distortion and other parameters such as "wow" and "flutter" and linear distortions. The BBC is now testing it on sound-signal transmission circuits and studio equipment.

RECENTLY THE HI-FI PRESS has been particularly interested in discussions about the best way of relating objective measurements to the subjective assessment of non-linearity in audio systems. Several articles have dealt with the relative merits of total harmonic distortion, two-tone intermodulation, or band-limited noise tests. The main conclusion seems to be that there is a lack of hard facts about the degree of correlation which can be expected between the measurement of distortion and the subjective effect.

Over the past decade broadcasting organisations have become increasingly interested in this problem. In particular, the BBC has been studying the use of noise-like test signals. As a result of five years' research work, a test method has been developed which gives distortion figures that correlate much better than total harmonic distortion measurements with subjective estimates of sound programme quality. The new test method uses pseudo-random noise as the test signal and comb-filter techniques to separate the distortion products from the test signal. Equipment for this method should be fairly cheap to produce as it makes use of digital signal processing.

To assess more fully the possible applications of the new method, the BBC is conducting field trials with experimental equipment, and the results of these trials should be available during 1978.

Traditionally, the non-linear distortion of a sound signal circuit has been measured objectively by using a sine-wave test signal; the amount of non-linearity is conveniently expressed as the ratio, measured at the output of the test circuit, of the power level of the harmonic distortion products to the power level of the fundamental plus harmonics. This ratio is known as the total harmonic distortion and is sometimes quoted as a percentage; in this article it will be given as a decibel ratio.

It has long been recognised that total harmonic distortion measurements generally do not give a good indication of the subjective impairment due to non-linearity, and in 1950, in an effort to provide improved subjective agreement, Shorter[1] proposed that the measurement of distortion should be weighted to take more account of high-order harmonics. In 1960 Wigan[2] proposed an improved weighting criterion to be applied to the harmonics of a 1kHz test signal. His subjective data was obtained using a pulsed tone as the programme signal, and the non-linear distortion was produced by an arrangement which ensured that the amount of total harmonic distortion was substantially independent of the applied signal level.

Wigan's findings were of limited application as no way was suggested by which his weighting criterion could predict the unpleasantness of distorted programme (other than pulsed-tone) signals. Further, for experimental convenience he had also excluded circuits in which the amount of distortion was a function of signal frequency and applied signal level.

When a complex programme signal suffers non-linear distortion, unwanted signals arise not only by the generation of harmonics but also by intermodulation between the spectral components of the programme signal. In 1945, Brockbank and Wass published a mathematical analysis[3] of the intermodulation spectrum generated by a multi-frequency programme signal. Their objective was to enable the distortion spectrum of a multi-frequency input signal, e.g. a programme signal, to be predicted from knowledge of the distortion spectrum generated by a single-frequency input signal.

There are two accepted methods of measuring the amount of intermodulation distortion of an audio frequency circuit. That adopted by the Society of Motion Picture and Television Engineers (SMPTE) was proposed by Hilliard[4] in 1946, and the method adopted by the International Telephonic Consultative Committee (CCIF) was proposed by Scott[5] in 1945. Both use two simultaneously applied sine-waves as a test signal, but they have different frequency spacings. The Hilliard method uses 60Hz and 3kHz, and the Scott method 3kHz and 3.05kHz.

To obtain a more complete knowledge of the variation of non-linear distortion with frequency it would be necessary to make measurements of intermodulation distortion over the whole frequency range of interest. This type of intermodulation test has been found to be of use by Harwood[6] in research on improving the performance of loudspeaker units.

Unfortunately, no method has yet been devised to enable intermodulation tests to predict the unpleasantness of distorted programme signals.

One interesting result given by Brockbank and Wass is that if the programme signal is assumed to be represented by n tones, each of equal power, and if n is greater than 30, then the contribution to the total distortion power due to harmonic products is at least two orders of magnitude less than that due to intermodulation products. For complex signals such as those produced by speech and music, n is generally large enough for the distortion power level contributed by harmonic products to be negligible. They also derive an equation for the total distortion power, assuming that n is large enough for harmonic products to be ignored, which shows that the power of the distortion signal resides mainly in products generated by higher order terms in the power series. This emphasis on higher order distortion products is effectively what Wigan and Shorter recommend for improved subjective agreement.

Random noise tests

The work of Brockbank and Wass, and Shorter and Wigan suggests that a noise signal should be a good test signal for sound-signal non-linearity measurements, since n would then be very large, and the power level of the distortion signal would automatically be weighted in favour of higher order terms.

Noise-like test signals have been applied to the routine non-linearity testing of various low-quality sound-signal transmission systems, e.g. multi-channel communication systems[7] and p.c.m. codes for speech signals[8]. The popularity of this type of test stems from the fact that the statistical properties of a speech signal have been treated as Gaussian, and therefore the unwanted noise power spectrum generated by a noise-like test signal was considered to be a good estimate of that produced by speech signals.

In 1963, Danes[9] reported the use of a one-third octave band of noise centred on 8kHz for intermodulation testing in an f.m. sound broadcasting system, and he found some degree of correlation between the measured low-frequency noise power generated from the test signal and the subjective impairment of normal programme signals.

In 1970, a standard test signal was proposed by the CCIR for study[10] by various member broadcasting organisations; it was to be used in measuring crosstalk and non-linearity in high-quality sound-signal transmission circuits. This test signal was to be produced by shaping the spectrum of a random noise signal, to make it representative of an average programme signal.

In 1971, Nikaido and Nitatori[11], of the NHK reported their study of non-linearity measurements on sound broadcasting circuits using random noise as a test signal. Their test signal was similar to that proposed by the CCIR, but it had a ¾ octave wide spectral gap which could be moved in ½ octave steps to cover most of the audio-frequency range. Distortion products were selected in this gap by a ¼ octave-wide filter. The result of each test was a plot of distortion versus centre-frequency. Their work did not include a study of the agreement between the measured distortion and its subjective effect.

In the BBC, tests for non-linearity are routinely made by measuring the total harmonic distortion of a 1kHz tone. This signal is applied to a test circuit at a level 2dB higher than the nominal quasi-peak value of the programme signal. With the advent of f.d.m. transmission circuits routine tests using this high level signal were reported to cause undesirable levels of crosstalk interference. As the use of f.d.m. circuits was likely to increase, the BBC undertook to assess the standard test signal proposed by the CCIR in the hope that crosstalk problems would be less severe (this was confirmed by later work), and also that routine tests for non-linearity using this test signal would give at least as much information as was provided by the total harmonic distortion method.

In the form proposed by the CCIR, the standard test signal had no spectral gap in which to detect non-linearity products and was therefore only suited to crosstalk measurements. The BBC therefore proposed a variant of the test signal, having a spectral gap between 3.5kHz and the upper limit of the audio band, and conducted informal tests to study its use in routine tests for non-linearity. The results showed that the degree of correlation between r.m.s. distortion measurements using this test signal and subjective assessments of the threshold of impairment of a programme item was at least as good as was obtained using a routine total harmonic distortion test, and was probably better.

Pseudo-random noise tests

Later measurements of this type were helped by replacing the random (thermal) noise source with a digitally-generated pseudo-random binary sequence (p.r.b.s.) noise source. This type of source provided a power output which did not vary with temperature; moreover, as the amplitude of distortion products fluctuated regularly at the repetition rate of the pseudo-random noise, a meter with a short integration time (a BBC peak-programme meter[12]) could be employed. This enabled accurate measurements to be made more quickly and allowed the use of the meter which is routinely used within the BBC for circuit testing.

Then various band-splitting arrangements were considered with the aim of increasing the effective bandwidth of the test signal. First, a standard set of ⅓ octave filters was used but was later rejected because their rate of cut-off was insufficient to provide the required measurement resolution. It was then decided to construct a two-band arrangement using specially designed filters to provide high resolutions (approximately 80dB of noise separation) with noise bands of 150Hz to 700Hz, and 1kHz to 3.5kHz approximately.

Concurrently a formal subjective investigation provided data relating to a wider range of programme impairment and more critical listening material than had been used previously. These data related the operating points of four amplifiers to subjective impairment and could therefore be used at a later date to study the subjective agreement obtained with any objective method of non-linearity measurement, simply by making objective measurements on those amplifiers.

Next came the task of optimising various parameter values for the two-band method, using the new subjective data. This work is described more fully in a BBC Research Department report[13]. Work was completed in mid-1973 and it was decided that the two-band method could give estimates of subjective impairment that were much more accurate than those given by the routine total harmonic distortion method. The two-band method was, however, of limited use as it was not designed for testing circuits where non-linearity was pronounced at high signal frequencies.

In 1972, Nikaido[14] reported his use of a sound-programme signal in making measurements of non-linearity. (Since a spectral gap had to be provided, the signal was not suitable for simultaneous broadcasting.) A disadvantage of this approach is that the measurements have to be integrated over a long time interval, as the results are influenced by the changing spectrum of the programme signals. The alternative would be to standardise on particular sound-programme excerpts as test signals but this has the disadvantage that the resolution of the test apparatus would be limited by the distortion in the sound recording system. The practical requirement is for a method which uses a test signal which is accurately reproducible, which simulates a sound programme signal, and in addition is inexpensive to produce. For these reasons, the practice of using the sound-programme signal as a test signal was not considered by the BBC to be appropriate for routine tests.

Meanwhile methods by which band-splitting might be improved were being considered. Multi-band techniques were investigated, but were not developed because of the difficulties of making high resolution comb-filters to provide a comb-like test signal spectrum with many "teeth", and a measurement filter with a complementary comb-like response. Furthermore, this approach would be prohibitively expensive.

Comb-filter methods

In 1974, I proposed an alternative approach to the problem. This new proposal recognised that the pseudo-random noise signal had itself a comb-like spectrum (see Fig. 1(a)). If this noise signal were to be frequency-shifted, its components would be anharmonically related, and most of the distortion products would then fall in the gaps between them as shown at (c). Non-linearity products would be measured by applying an equal and opposite frequency shift (d), followed by a comb-response filter (e) to remove the comb spectrum of the noise signal. The output of the comb-filter (f) would then be registered on a p.p.m.

Apparatus was constructed to test this proposal[15]. The work was completed by mid-1975, and a comparison of the accuracies of this comb-filter method (the "single comb-filter method"), the two-band method, and a total harmonic distortion method revealed that both noise-separation methods were more accurate in their estimates of subjective impairment than the total harmonic distortion method. But the single comb-filter method was to be preferred since it could be used in testing circuits with frequency-dependent non-linearity.

To improve the method a double-comb-filter technique was proposed in which two p.r.b.s. signals were combined to provide a test signal with anharmonic components and two cascaded comb-filters were used to reject the test signal and accept the distortion signal for measurement. This arrangement[16] is attractive as it should be less expensive to instrument and, furthermore, it has been found to be as accurate as the single comb-filter method using the subjective data given in reference 13. This accuracy also applies to frequency-dependent non-linearities studied more recently.

Test signal generator

The test signal used with the double comb-filter method is produced by the addition of two signals, each having a harmonic spectrum but with different fundamental frequencies. The harmonic structure of each spectrum may be likened to a "comb" of frequencies. Intermodulation products generated from this test signal may be conveniently divided into two groups: those which arise by intermodulation within each comb structure and those which arise by intermodulation between comb structures. The first group of products will occupy the same frequency positions as the original comb structure and will therefore be indistinguishable from it. The second group of products will fall in the spectral gaps of the test signal and can therefore be measured. Fortunately, these measurable products represent a significant proportion of the total distortion signal. Two comb-filters having attenuation "teeth" aligned with the "teeth" of the test signal can be used to remove the original components and enable the remaining distortion products to be measured.

The test signal can conveniently be generated by two maximal length pseudo-random binary sequence (p.r.b.s.) generators (m-sequences). Such binary signals can be generated by digital shift-registers with feedback. If an n-bit shift register is used to generate the p.r.b.s. signal then the sequence length is 2^n-1. The spectrum of a p.r.b.s. signal consists of harmonics of the sequence repetition frequency and the harmonics are all substantially of equal power, as illustrated in Fig. 2(a) and (b), provided that the required test signal bandwidth is less than one tenth of the shift-register clock frequency. The repetition frequency of an m-sequence is given by the clock frequency divided by the sequence length.

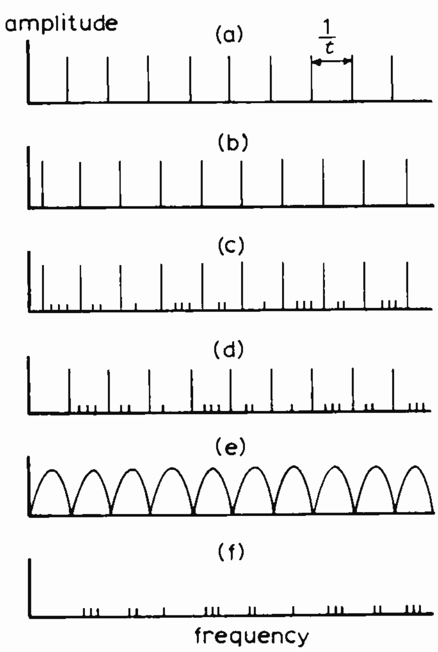
When the two p.r.b.s. signals are added, the test signal spectrum illustrated in Fig. 2(c) is obtained. In practice this test signal is used at the same "peak" level measured with a p.p.m. as the "peak" level of the programme signal which it replaces. Fig. 2(d) shows the modified spectrum when distortion products are generated. A simple comb-filter response as in Fig. 2(e) is used to remove one p.r.b.s. signal, while a second filter (f) in tandem removes the other p.r.b.s. signal, leaving distortion products as illustrated in (g).

Fig. 3 is a simplified block diagram of the test-signal generator. G_1 and G_2 are m-sequence generators with repetition frequencies of 152.6Hz and 109.8Hz. These two frequencies were chosen by experiment. The first (152.6Hz) could be generated using a convenient shift-register and oscillator combination. The second frequency could be changed in steps of approximately 1Hz and within this limitation the second frequency was near optimum, i.e. that which gave best subjective/objective correlation. It should be noted that the more important parameter is the ratio of the two frequencies rather than their absolute values; altering this ratio alters the weighting of odd and even order products, and therefore also the subjective/objective correlation.

The scaling amplifier adds the two binary signals in a given ratio, the optimum value for the ratio being that which gives a test signal spectrum with all components of equal power.

In later tests, a spectrum shaping of the test signal was found to be important as it helped to reduce the spread in subjective impairment attributable to a given distortion figure measured by the new method, taking into account both flat and frequency-dependent non-linear effects. A suitable spectrum shaping characteristic is shown in Fig. 4. It can be produced by connecting a CCIR average programme weighting network[18] in series with a 50μs de-emphasis network. The band-pass characteristic of the shaping filter converts the p.r.b.s. digital signal into one with a multi-level noise-like waveform. If a shaping filter of this type were not used then a low-pass filter would be necessary.

The above filter characteristic agrees closely with that proposed by the UK Post Office[19] as a result of recent measurements of the power loading and average spectra of sound programme signals for broadcasting. Their weighting characteristic is intended to be used to shape the spectrum of a white-noise signal in order to simulate that of an average sound-programme signal. Such a weighted noise signal could be of use in testing, for example, the power handling ability of loudspeakers or audio power amplifiers. It therefore seems likely that the test signal required by the double comb-filter method could also be of use in these areas.



◀ *Fig. 1. Spectra illustrating principle of the single comb-filter distortion measurement method: (a) spectrum of pseudo-random binary sequence; (b) the same p.r.b.s. frequency shifted; (c) signal from system under test, showing distortion products in gaps; (d) signal re-shifted; (e) response of comb-filter for removing comb spectrum of p.r.b.s. test signal; and (f) comb-filter output. (t is repetition period of p.r.b.s.)*

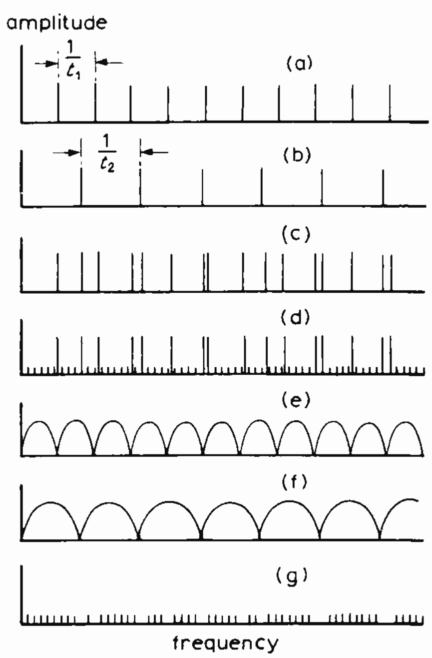


Fig. 2. Spectra illustrating principle of the double comb-filter method (t_1 and t_2 are repetition periods of m-sequences G_1 and G_2 respectively): (a) m-sequence G_1; (b) m-sequence G_2; (c) test signal; (d) signal from system under test; (e) first comb-filter response; (f) second comb-filter response; and (g) output from comb-filters. ▶

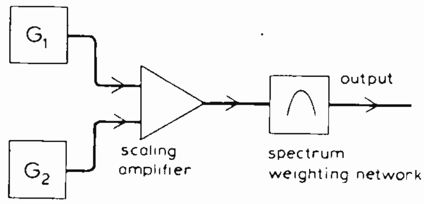


Fig. 3. Essentials of test signal generator for double comb-filter method.

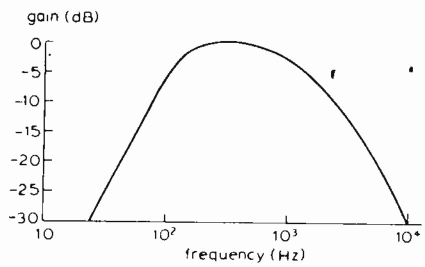


Fig. 4. Test signal frequency shaping characteristic.

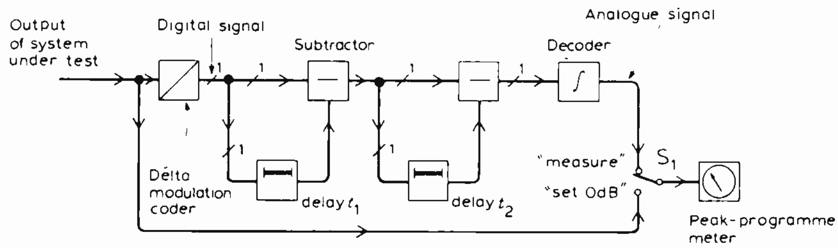


Fig. 5 (above). Analyser for output signal from system under test in double comb-filter method. Levels of test signal and distortion products are measured on a p.p.m.

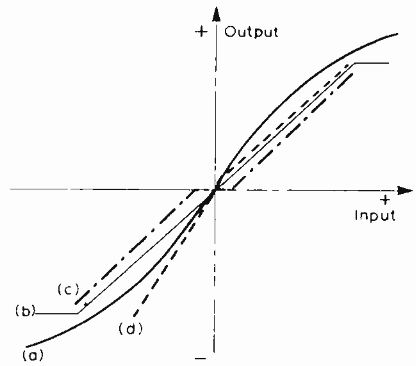


Fig. 6 (right). Typical transfer characteristics of audio circuits: (a) S-type characteristic; (b) op-amp type of characteristic; (c) circuit with cross-over distortion; and (d) t.h.d. constant with applied signal level.

In the experiments with the double comb-filter method it was found to be advantageous to modify the quasi-peak to mean ratio of the test signal by including a dispersive network (four 700Hz single section all-pass circuits in tandem) after the weighting network. This modification allowed the optimum value for the mean test signal power loading to be reduced by 1dB and is of use in testing circuits, e.g. f.d.m. carrier circuits, where it is necessary to keep the mean test power loading to a minimum during routine tests.

Test signal analyser

Fig. 5 is a simplified block diagram of the test signal analyser. Digital signal processing is used because of its stability and relative cheapness in providing the required performance. For further economy in analogue-to-digital and digital-to-analogue conversion, linear delta-modulation coding[20] is used in preference to linear pulse-code modulation (p.c.m.). The quantisation noise of the system limits the measurable separation to 54dB: this is later shown to be 17dB below the threshold of impairment.

The input signal to the analyser is applied to the delta-modulation coder which provides a 1-bit output signal at a rate of 4Mbit/s. This signal is then processed by a digital filter arrangement comprising two subtractors and two shift-register delays t_1 and t_2. This filter is effectively two simple comb-filters in tandem: a comb-filter operates by subtracting from an input signal a delayed version of itself. In Fig. 5 t_1 and t_2 are produced by approximately 27kbit and 37kbit shift registers respectively; time delays t_1 and t_2 are equal to the inverses of the test signal repetition frequencies. The delta-modulation signal is then decoded by analogue integration of the binary output signal. Emitter-coupled logic circuits were used in the delta-modulation coder and decoder in order to produce pulse waveforms with well-matched rise and fall times. This matching is essential in order to maintain low harmonic distortion within the measuring equipment.

A crystal oscillator is used to ensure that the comb-filter responses are maintained in accurate alignment with the "teeth" of the test signal, but for clarity, clock signal paths are omitted from Fig. 5. The gain of the direct path is set so that, at a signal frequency at which minimum loss is produced by the comb-filters, the output level from the "measure" path is equal to that from the "set 0dB" path.

The levels of test signal and distortion products are measured using a BBC peak programme meter (p.p.m.), which is a quasi-peak indicating instrument. It should be noted that the results reported later for the double comb-filter method may not be directly applicable if other meters are used. However, a simple additional circuit could be provided to simulate the action of a p.p.m. and to enable a noise-separation indication to be independent of the ballistics of the measuring instrument.

Using the arrangement in Fig. 5, the switch S_1 is set to the "set 0dB" position and the output test-signal level from the system under test is adjusted until a reading of 0dB is indicated by the p.p.m. Noise-separation in dB is then indicated by the p.p.m. when SW_1 is set to "measure". This reading actually gives a measure of (signal + distortion)/(distortion); and although this is not a true separation figure it has proved to be satisfactory in use.

Listening tests

The purpose of the tests was to obtain subjective estimates of programme quality impairment caused by two circuits (A and B) for a selection of applied signal levels. The general form of the transfer characteristics of these two circuits is illustrated by curves (a) and (b) of Fig. 6. (a) is an "S-type" characteristic in which the total harmonic distortion increases with applied level. (b) is the sort of characteristic given by operational amplifiers, and this type of distortion is sometimes known as "hard-clipping"; the distortion is negligible until clipping occurs and then the total harmonic distortion increases rapidly with applied signal level.

Frequency-dependent distortions such as those that might occur in an f.m. transmission system were also included in the study. High-frequency signals were made more susceptible to nonlinearity distortion by inserting a 50μs pre-emphasis network in the input signal path. When pre-emphasis was used, a network with the complementary characteristic was connected in the output signal path to provide an overall flat amplitude-frequency response.

These tests require great care in the alignment of tape recording and signal level measurement apparatus because in order to correlate objective measurements of non-linearity distortion accurately with subjective impressions, it is essential to ensure that the applied level of test signal bears a known relationship to the previously applied level of programme signal. This is particularly important when the amount of distortion varies rapidly with the applied signal level, e.g. when a hard-clipping circuit is operated near to overload.

For convenience both programme and test signal levels are referred to the operating point of the circuit under test by a parameter termed "relative gain". A more detailed explanation of this parameter is given in Reference 16.

The listening tests explored impairment levels in the range indicated by the six point scale shown in the following table:

Six-point subjective impairment scale

Grade	Impairment
1	Imperceptible
2	Just perceptible
3	Definitely perceptible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

Two programme items, "male speech" and "solo piano" were selected from a library of recorded test-excerpts as they were found to be subjectively more sensitive to distortion in the test-circuits than the other excerpts. The male speech item was used in tests in which non-linearity was not frequency-dependent and the solo piano item was used for the frequency-dependent case.

A companding system was used in the tape recording and reproduction of the test-programme so that recording noise was less likely to mask the distortion produced by the test-circuits. In addition, the programme signals went through the record-replay process only once, i.e. a "master" recording was used for the tests. No amplitude-compression was applied to the programme signals.

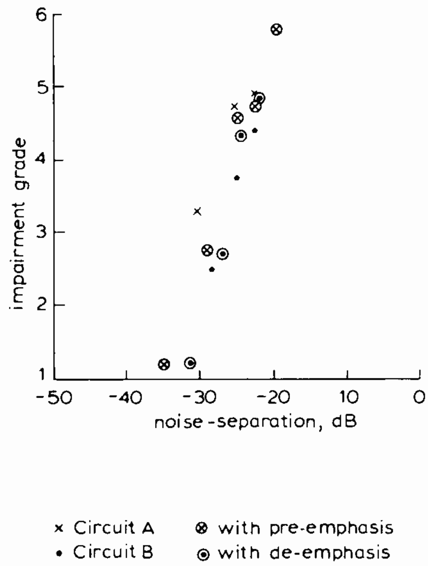
The subjective tests were carried out in a listening room having acoustics similar to those of a domestic living room.

Subjective-objective correlation

After the subjective tests had been completed, objective measurements were made using the two methods (double comb-filter method and total harmonic distortion method) whose correlations were to be compared. It was again essential to set the test levels with great care, and the "relative gain" parameter mentioned earlier was again used to ensure that the operating points of the circuits were the same as used in the subjective tests.

In order to study subjective-objective agreement plots of subjective impairment against objective distortion were drawn. In practice fairly straight but widely spaced, non-parallel lines can usually be obtained by a variety of distortion measurement methods. The best correlation is judged to be obtained by the test method which gives the closest grouping of plots along a straight line of subjective impairment against objective distortion for a variety of test circuits.

Fig. 7 (below). Plotted points showing good correlation between subjective average impairment grade and measured noise-separation in the double comb-filter method, with two circuits A and B. Note that points are closely grouped when compared with those in Fig. 8.



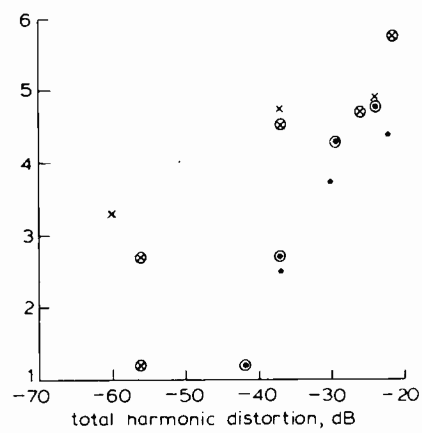


Fig. 8 (above). Plotted points showing lower correlation between subjective average impairment grade and measured total harmonic distortion, for circuits A and B. Note the relatively wide spread of the points compared with those in Fig. 7.

Fig. 7 shows the measured spread in noise-separation against subjective impairment for circuits A and B, both with and without 50µs pre- and de-emphasis. Similarly, Fig. 8 shows the measured spread for total harmonic distortion.

Taking grade 2.5 as a reference point for the comparison, Fig. 8 shows that the spread in total harmonic distortion is 23dB; it is apparent from the data shown that the routine total harmonic distortion method gives a very poor degree of correlation when more than one non-linear circuit is being considered.

Fig. 7 however, shows by the close grouping of plots (spread approximately 6dB at grade 2.5) that the noise-separation test gives much better correlation between subjective and objective measurement than does the total harmonic distortion method.

Possible future developments

An advantage of the total harmonic distortion method is that it employs standard laboratory items of equipment, e.g. a variable-frequency audio oscillator and a signal level meter, which may also be employed in the measurement of other sound circuit parameters such as the amplitude-frequency response.

Similar advantages apply to the double-comb filter test apparatus as it may also be used in the measurement of a wide range of sound signal distortions (both non-linear and linear), but before describing these applications in more detail, it will be useful to consider the various forms of non-linear distortion characteristics which can occur.

Fig. 6 illustrates some input-output transfer characteristics which may be exhibited by audio signal amplifiers. The type of characteristic applicable to a given amplifier can be conveniently identified by examining how the total harmonic distortion of a sine-wave signal varies with the applied signal levels. Curves (a) and (b) are the characteristics of circuits used in the listening tests described earlier. The types of non-linearity shown by curves (c) and (d) are described below, followed by a variant, type, (e). Formal listening tests have not yet been conducted for types (c) to (e), but some initial assessments have been made.

Curve (c) represents "cross-over" distortion, and in this case the total harmonic distortion increases as the applied signal level is reduced. Curve (d) represents the characteristic of a circuit where the total harmonic distortion is constant with applied signal level, and would be obtained with a circuit that gave unequal amplification to positive and negative half-cycles of a sine-wave.

Characteristics (a) to (d) have not included the possibility of the degree of non-linearity distortion being frequency-dependent as well as amplitude-dependent. This therefore is provided in type (e) which includes types (a) to (d) with, for example, pre- and de-emphasis networks to make the distortion more pronounced at high signal frequencies.

In addition, transient intermodulation distortion (t.i.d.) as described by Otala[21] can sometimes occur in audio circuits. Essentially, t.i.d. occurs when the rate-of-change of the input signal is excessive. This type of distortion is generally not measurable using a 1kHz total harmonic distortion test, and at present there is no accepted method for measuring t.i.d. and relating the objective measurement to the audible effect.

Experiments with the double comb-filter apparatus have shown that non-linearity types (c) to (e) and transient intermodulation distortion can readily be measured. The sensitivity of the method in measuring t.i.d. arises from the high slope of the test signal which can be equivalent to that of a full amplitude sine-wave signal at the upper limit of the audio band. Further more lengthy experiments would, however, be required in order to establish the subjective-objective correlation with these types of distortion. It is interesting to note that Levitt and others have determined a subjective threshhold of perceptibility for slope-overload distortion of speech signals[22], and this may be of help in studies of t.i.d.

The double comb-filter apparatus can also be used for objective measurement of amplitude-frequency response errors, and "wow" and "flutter".

An indication of the presence of amplitude/frequency response errors can be obtained by a simple experiment using the test signal part of the apparatus together with a 1kHz signal generator and an r.m.s. meter. Both signals are applied in turn at equal powers to the circuit under test. The output power of the circuit under test is measured: any difference in the power of one signal relative to the other (under linear conditions) indicates an error in the amplitude/frequency response. More detailed results can be obtained by analysing the spectrum of the p.r.b.s. test signal after passing it through the circuit under test. If a correlator is used it is then possible to measure delay and the degree of gain-phase matching of transmission circuits (as may be of interest in stereo or quadraphonic sound systems).

The technique of using a p.r.b.s. signal for testing linear systems is well known, but in the past has required expensive test apparatus (e.g. cross-correlators). With the advent of the microprocessor a relatively inexpensive equipment might well be produced for measuring linear distortions using a p.r.b.s. test signal, and such a microprocessor arrangement could easily be added to the double comb-filter apparatus since a-d and d-a converters are already provided.

When the double comb-filter method is used to measure the non-linearity distortion of sound recording and replay systems, "wow" and "flutter" produce spectral components in the gaps of the test signal. The "wow" and "flutter" components can readily be measured: only one p.r.b.s. signal and its complementary comb-filters are required. With this test signal, non-linearity products are hidden and only "wow" and "flutter" components appear in the spectral gaps. In practice it has been found that the recovered level of products generated by "wow" and "flutter" is much higher than the background noise of high-quality recorders; typical figures for "wow" and "flutter" noise-separation are 35dB at 15in/s and 30dB at 7½in/s. No work has been done to compare these "wow" and "flutter" figures with those measured by more conventional methods and no subjective tests have been conducted to establish tolerable levels of "wow" and "flutter" measured by this new method.

The measurement of non-linearity distortion in the presence of "wow" and "flutter" is likely to require comb-filters with wider stop-bands as the "wow" and "flutter" signals are likely to produce sidebands close to the spectral lines of the test signal. The more complex digital comb-filter required in this application could conveniently be instrumented using a microprocessor arrangement.

The author

R. A. Belcher joined the BBC Research Department in 1969 after graduating from the University College of North Wales. He has worked on many aspects of analogue and digital processing of sound and video signals and has been much involved in the use of subjective tests. In 1976 he was awarded the Gyr and Landis prize by the IEE for work on comb-filter methods of measuring audio distortion, and in 1977 he gained a Ph.D. from the University of Surrey for a thesis on this subject. Since early 1977 he has been doing research in quadraphony. Early this year Dr Belcher left the BBC to become a senior physicist at Velindre Hospital, Cardiff.

ACKNOWLEDGEMENTS

The author is grateful to the many people who have helped during the research described in this article; in particular to Messrs Deane; Manson, Mitchell and Wilkinson, and to those who took part in the subjective tests. The work was conducted at the BBC Research Department and for part of the time the author was a Collaborative Student with the University of Surrey. The author wishes to thank the Director of Engineering of the BBC for permission to publish the article.

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A novel approach to switching regulator design

Simultaneous use of feedback and feedforward for low ripple regulators

by D. M. Divan and V. V. Ghate

The design principle proposed here uses feedback and feedforward simultaneously to allow switching regulators to operate with a very low ripple. Unlike other designs, it requires no compromises in switching frequency, the bulk of filter components, transient response, circuit complexity or efficiency. The example circuit discussed in the text is a 7.6V, 5A, 25kHz switching regulator which is shown to have an output ripple of only 2 to 4mV r.m.s.

SWITCHING REGULATORS, whether of the self-oscillating type or the constant-frequency, pulse-width modulated type, have certain limitations. The high frequency ripple required for regulator operation can be of the order of 50 to 100mV for a d.c. level of 5 volts, and attempts to improve this figure normally require a compromise. The compromise may involve an increased switching frequency or a poor transient response, or both. The best switching regulators available today still have to make do with a 20mV ripple and a settling time that could be of the order of 50ms[1,2,3].

Other regulator problems faced by designers, especially those working with free running switching regulators, are stability, behaviour under light loading, variations of switching frequency with load and supply, the dependence of the output ripple on the filter, hysteresis, and the possibility of the regulator misfunctioning with certain types of reactive loads[2].

This article describes a new approach to regulator design that allows the designer to retain the advantages of the switching regulator without the accompanying disadvantages.

Principle of operation

The method which is to be described here uses feedback and feedforward simultaneously. A similar configuration was first used by P. J. Walker, in what he called a "current dumping amplifier", to get over distortion and thermal runaway problems in class B audio amplifiers[4].

The principle can best be understood by considering the block schematic shown in Fig. 1. Consider the non-linear element N to be an arbitrary non-linear function. It can be shown that, if the voltage obtained at the output is to be

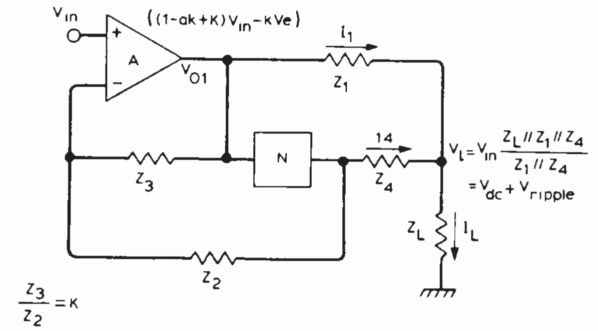
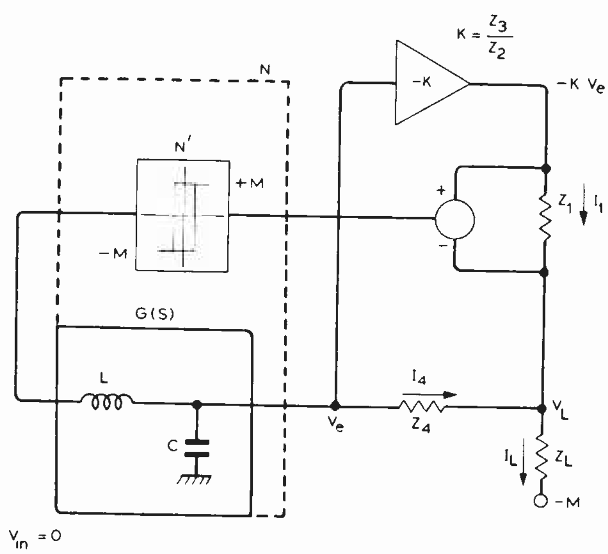


Fig. 1. *Block diagram of a basic circuit showing how the use of both feedback and feedforward can result in error cancellation.*



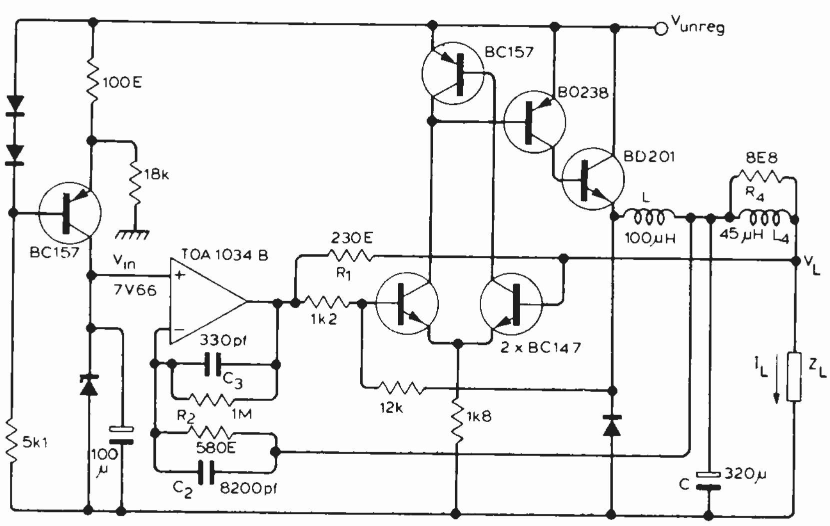


Fig. 2. *(a) Block diagram of a switching regulator which incorporates feedback and feedforward. (b) Actual circuit diagram of switching regulator.*

independent of $N(V_{01})$, the following condition has to be satisfied.

$$(Z_1 Z_2)/(Z_3 Z_4) = 1 \quad (1)$$

Mathematically, the equations indicate that the output is independent of the non-linearity, but it is not easy to get a physical feel of the circuit's operation, or to understand how the principle can be applied to improve the switching regulator design. The voltage $N(V_{01})$ can be said to consist of two parts, one part linearly dependent on V_{in}, aV_{in}, and the other, an error voltage V_e, independent of V_{in}. For the voltage V_{in}, the operational amplifier acts like a non-inverting amplifier and it can be derived that the output voltage is:

$$V_L = V_{in} \cdot \frac{Z_L // Z_1 // Z_4}{Z_1 // Z_4} \quad (2)$$

where// means "in parallel with".

This conforms to the expression calculated for the entire circuit. Considering V_e as an independent voltage source, the operational amplifier output will be $-(Z_3/Z_2)V_e$. The output voltage will be independent of V_e only when Equation 1 is satisfied. This way of looking at the circuit's operation, though not mathematically rigorous, allows the designer to get a feel of how the circuit operates, and to distinguish between the feedforward and the feedback mechanisms in the system.

The next step is the application of the principle to switching regulator design. A switching regulator is obtained if the non-linear block N is considered to be a switch having hysterisis followed by a low pass filter G(s), as indicated in Fig. 2(a). The actual circuit is shown in Fig. 2(b).

Current flowing through Z_1 generates the voltage required to overcome the hysterisis of the comparator. As the capacitor C charges up, the operational-amplifier output voltage starts falling, eventually causing the current through Z_1 to change direction. This, in turn, makes the comparator switch again. The process is therefore self-sustaining. If the bridge, consisting of the elements Z_1, Z_2, Z_3 and Z_4, is balanced, the output will be free of any ripple. In fact, the ripple voltage at the filter output is analogous to the error voltage V_e in the above problem, and it is cancelled by feedforward.

The concept of using feedback and feedforward together, though well known, has not previously been applied to the design of switching regulators. The method is attractive because a number of operations are performed by a single gain element. The operational amplifier provides feedback for precise regulation, feedforward for ripple cancellation, and ripple amplification. By amplifying the ripple the need for a very sensitive comparator is alleviated. The equations given above also hold for a real operational amplifier with a finite gain bandwidth product, albeit with minor modifications. Although the derivations are left for the interested reader, a simplified, nethertheless accurate, stability analysis of the system, using the describing function tchnique, yields an operating limit cycle which gives the switching frequency and the magnitude of the ripple that is to be cancelled[5]. A knowledge of both of these parameters is of prime importance to the designer.

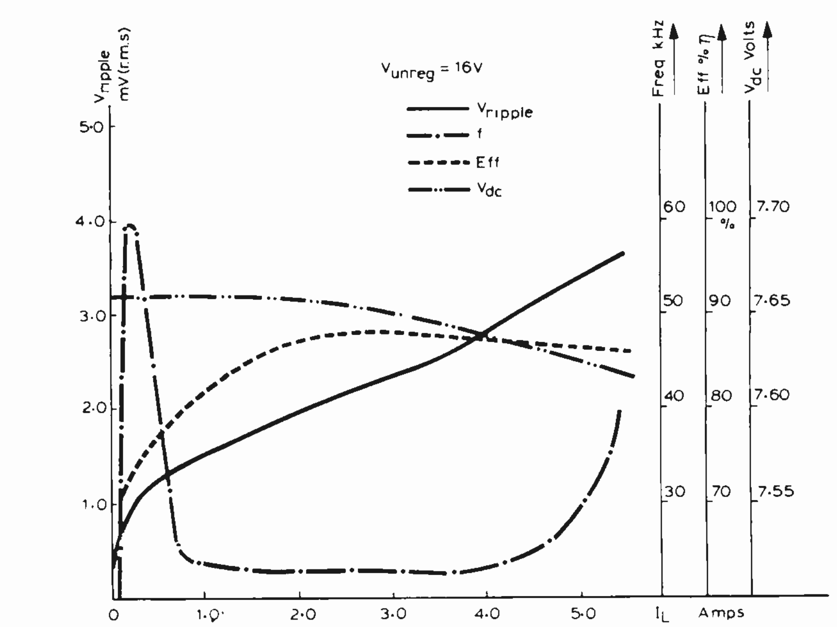


Fig. 3. *Regulator characteristics for variations in load current when an unregulated input voltage of 16V is applied.*

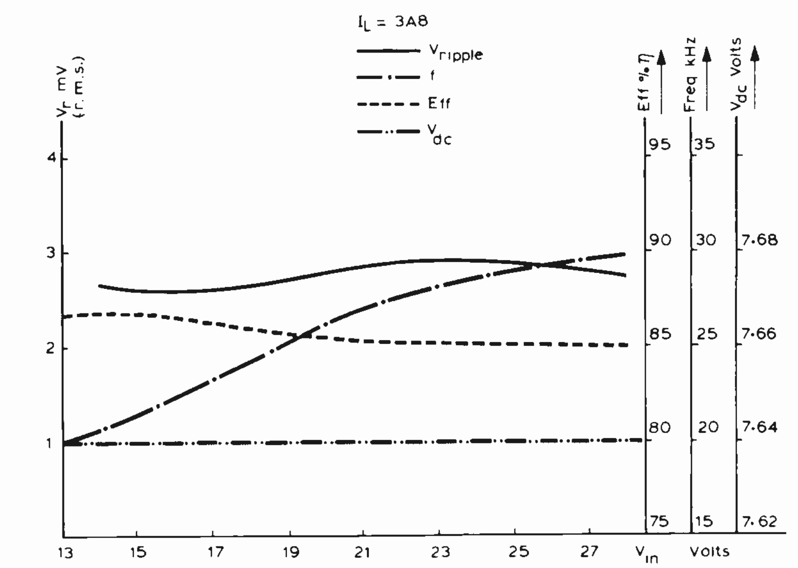


Fig. 4. *Regulator characteristics, plotted against unregulated input voltage, for a load current of 3.8A.*

Design procedure

The output impedance of the power supply can be shown to be equal to Z_1 in parallel with Z_4. Consequently, to obtain good regulation, either Z_1 or Z_4 have to be inductors, so that the d.c. resistance of the branch is zero. Since most of the output current flows through Z_4, making it the inductor helps to minimise power losses. A resistor is used for Z_1 because the current flowing through it activates the comparator. It also allows the regulator to behave like a linear regulator for load currents which are insufficient to activate the comparator. Finally, to balance Equation 1, a resistor is chosen for Z_2 and a capacitor is chosen for Z_3.

To obtain low output impedance, and to avoid (Z_3/Z_2) having a low value at higher frequencies, a resistance is added in parallel with L_4 and a capacitor is added in parallel with R_2. The bridge balance condition is therefore maintained for all frequencies if the following equation is satisfied:

$$\frac{R_1 R_2/(1 + sC_2R_2)}{(1/sC_3)\,(sL_4R_4/(sL_4 + R_4))} = 1 \quad (3)$$

which requires that $R_2C_3 = L_4/R_1$ (4)

and that $L_4/R_4 = R_2C_2$ (5)

Capacitor C_3 can be reduced slightly if a real amplifier with a finite gain bandwidth product is considered.

The switching frequency can be calculated using the describing function technique. The analysis reveals that the switching frequency is independent of the load impedance, which is a desirable feature. An approximate value for the switching frequency can be obtained by the procedure given in the sample design below. However, an important constraint is the short-circuit current limitation of the operational amplifier. By decreasing the maximum current demand from the operational amplifier, the efficiency can be improved but this is detrimental to the transient response.

Regulator design

The following design steps refer to the regulator shown in Fig. 2(b):

For high frequencies, K is chosen as 25.

That is, in the limit ω approaches infinity:

$$(Z_3/Z_2) = C_2/C_3 = 25 \quad (6)$$

where $\omega = 2\pi f$

and from Equations 4, 5 and 6:

$$R_2C_3 = L_4/R_1 = R_2C_2/25 = L_4/25R_4 \quad (7)$$

The operational amplifier has an output current capability of 40mA and a maximum voltage swing of 5V pk-to-pk is to be allowed at its output. To allow a correction current of 10mA, R_1 should be 230Ω, and to allow the same amount of correction current to flow through Z_4, L_4 is fixed at 45μH, corresponding to an operating frequency of 25kHz. Assuming a value of 330pF for C_3, the values of R_2, C_2 and R_4 must be 580Ω, 8200pF and 8.8Ω respectively.

While calculating the exact values of the filter components L and C, it is necessary to consider the load on the filter due to L_4. A complete analysis can only be made using the describing function technique. The relationship between the operating frequency f, L and C can be determined very approximately by considering that, at the frequency of operation, a 16V pk-to-pk square wave is attenuated to a 200mV pk-to-pk triangular wave by a low pass filter having an inductor (L + L_4) and a capacitor C with its equivalent series resistance. A 320μF capacitor was used with an equivalent series resistance of 0.12Ω and an inductor (L) of 100μH.

Performance data

Performance curves for the regulator indicated in Fig. 2(b) are given in Figs 3 and 4. Fig. 3 gives curves for efficiency, output ripple, regulation and switching frequency as functions of the output current and Fig. 4 shows how the same parameters vary for different input voltages.

Referring to the design described, the equations for calculating the frequency of operation are valid only when the ripple current through the inductor L does not decay to zero. For very light loading the equations do not hold and the regulator tends to behave like a linear regulator and operates at very low switching frequencies. The switching frequency is highest at the point beyond which the regulator stops acting in the linear mode. For load currents higher than 600mA, the frequency of operation remains more or less constant until the inductor L starts saturating.

The efficiency of the regulator compares favourably with other switching regulators[1,2]. Also, the load regulation is seen to be within 0.6% and the line regulation is better than 0.15% for a 100% change in the input voltage.

For any input or load condition the output ripple is seen to be within 4mV r.m.s. and spikes on the output are within 40mV pk-to-pk. Better ripple performance can be obtained by improving the bridge balance, minimising stray capacitances and improving ground layout. On a breadboard prototype made by the authors, these factors significantly affected the performance of the regulator. The ripple at the switching regulator output is reduced by 26dB by the feedforward mechanism.

By following the schematic in Fig.5[1], the regulation performance of the regulator can be further improved.

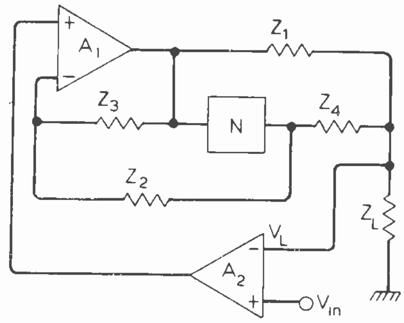


Fig. 5. *Block diagram of circuit giving improved regulation performance. Amplifier A_2 should have a larger time constant than A_1.*

Conclusions

It has been seen that the performance of a self-oscillating switching regulator can be improved by the simultaneous application of feedback and feedforward. This principle can be applied to a constant frequency, pulse-width modulated switching-mode supply without any conceptual changes.

By combining feedback and feedforward, it is possible to design a switching regulator with the following characteristics:

- Extremely low output ripple — despite the use of a low switching frequency and small filter components.
- High efficiency — resulting from a low switching frequency.
- A reasonably constant switching frequency over a large operating range.
- Very good regulation.
- Ripple amplification — enabling the use of an extremely insensitive comparator.

Deepakraj M. Divan received his B. Tech. degree in Electrical Engineering from the Indian Institute of Technology, Kanpur, India in 1975. He worked for two years for Messrs. Philips India Ltd as a development engineer with their electro-acoustic development laboratory where he worked primarily on the design and development of audio system components. Presently, he is working in the field of power electronics towards an M.Sc. in Electrical Engineering at the University of Calgary, Calgary, Canada.

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Liquid crystals

A summary of one of the most widely-used display techniques

by **J. C. Varney**, Ebauches Electroniques SA, Switzerland

Watches containing liquid crystal displays are now widely available and liquid crystal panel displays are becoming more widely used. Yet the name — liquid crystal — appears to be an anomaly and the question "How can a crystal be a liquid?" is continually asked. Then again, when the display is described as a thin film of liquid crystal sandwiched between two transparent, conductively-coated glass plates, the problems involved in making reliable devices are not obvious.

A SOLID CRYSTAL is a material in which the constituent ions or molecules are rigidly held in a specific lattice structure; in other words, they are well ordered. In a liquid crystal the material is fluid but the constituent organic molecules are still ordered to some degree, the degree of ordering determining the type of liquid crystal. Thermotropic liquid crystals[1] occur when a solid crystal is melted and exist until the fluid becomes clear and isotropic. This means the liquid crystal properties occur over a temperature range and, for a display system, this range should cover the operating temperatures likely to be met.

In a nematic liquid crystal, where the molecules generally lie parallel to each other, the main properties are the differences in dielectric constant and in refractive index values parallel with, and perpendicular to, the long axis of the rod-like molecule. These differences are termed the dielectric anisotropy and the optical anisotropy respectively. The former gives rise to a torque on the molecule in response to an electric field such that, with negative anisotropy, the molecule lies perpendicular to the field while with positive anisotropy it will tend to lie parallel to the field. Combined with the optical anisotropy, reorientation of molecules leads to modifications of the light transmission properties of thin films of the material.

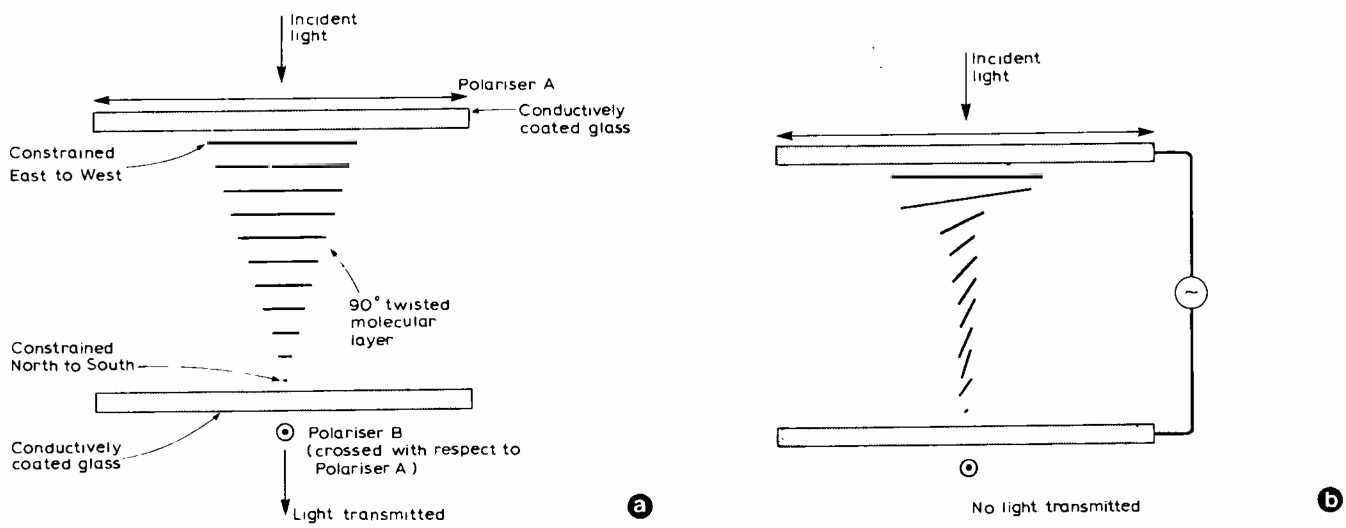
A display device can now be envisaged as a thin film of material whose optical properties are changed by the application of an electric field but the precise ways in which the properties change are many and varied. The first electro-optic phenomenon used practically was termed dynamic scattering. If a negative dielectric anisotropy material is doped to become slightly conductive, the interaction between dielectric realignment and ionic current flow causes turbulence in the film. Ambient light is scattered to produce a cloudy display against a clear background. It should be stressed that liquid crystal displays do not emit light but merely act on light passing through the system.

The thin film is made by sandwiching the liquid crystal between two glass plates each with a transparent, conducting coating of tin or indium-tin oxide. The shape of the display is determined by the pattern selectively etched on the two coatings and the distance between the plates is set by a spacer about 12μm thick. The first room temperature nematic liquid crystals were very sensitive to moisture and a hermetic cell had to be developed to give them a usably long life. Cell fabrication techniques vary throughout the industry but generally the sealing and spacer material used is a glass frit although thermoplastics are also used.

The cells can be filled using the two hole method, where two holes at opposite ends of the cell allow the liquid crystal to be injected at one end and air to escape at the other. More commonly, the vacuum fill technique is used where a cell with one hole is evacuated and then dipped into a liquid crystal, atmospheric pressure forcing the material into the cell. Final seals include indium plugs for the hole, solder end-cap sealing techniques and even laser-heated, glass frit soldering. The cell should be driven by a.c. since the use of d.c. causes electrolysis effects which substantially reduce lifetimes.

While the dynamic scattering effect is still used for large displays, another effect has superseded it in the smaller

Fig. 1. *Twisted nematic crystal with (a) no voltage applied and (b) threshold voltage applied. Note that when a voltage is applied the molecules tilt in the bulk of the cell and the 90° twist throughout the cell is destroyed. However, a remnant of the twisted structure is left at each surface as the molecules on the surface are firmly bonded.*



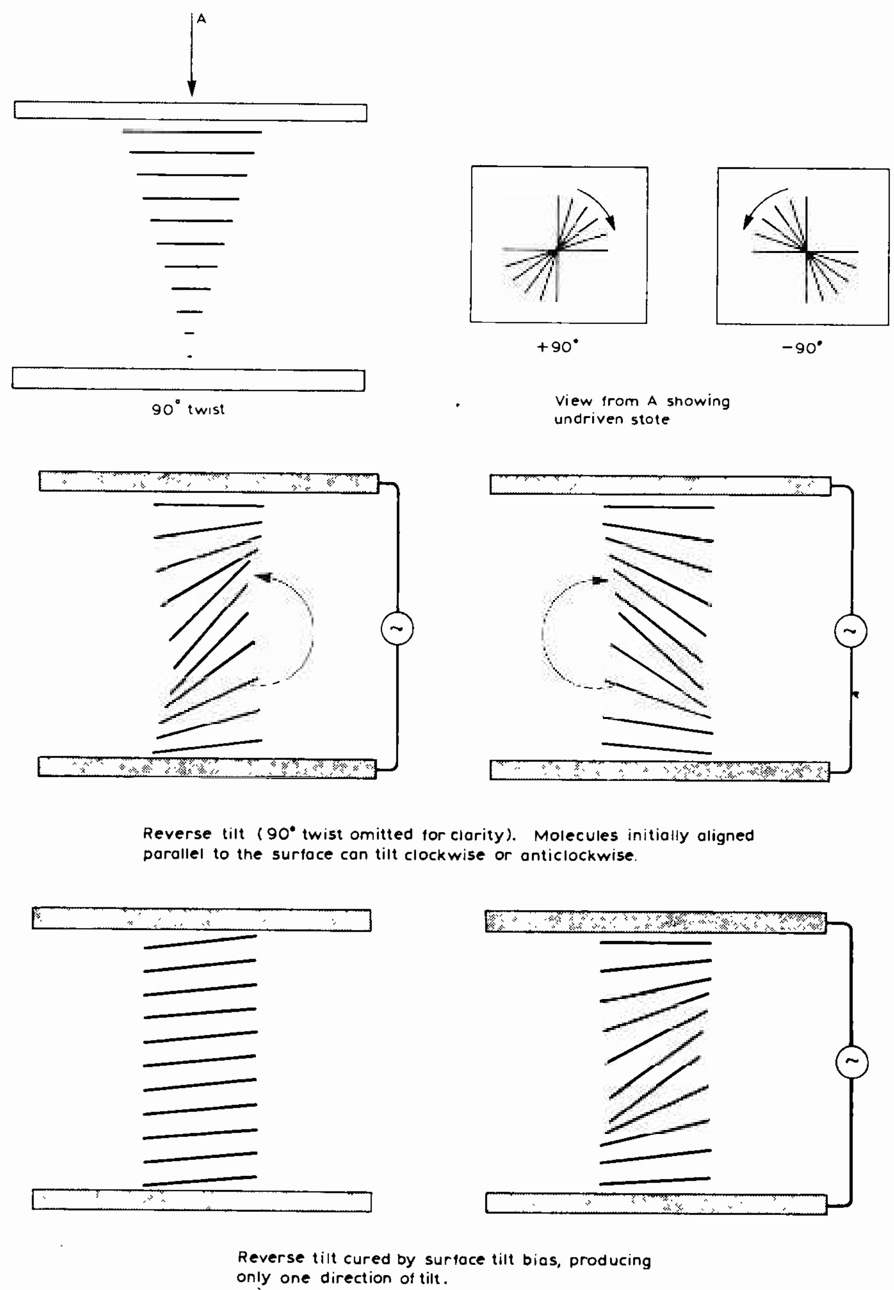


Fig. 2. *Reverse tilt and (at top) reverse twist.*

panel meter and watch displays. This is the twisted nematic[2] (sometimes called the field effect) display where molecules on the glass plates are constrained to lie at ninety degrees to each other so imposing a ninety degree twist in the molecular structure. This molecular structure guides the polarisation of light passing through the cell so that inserting a twisted nematic cell between crossed polarisers allows light to be transmitted (Fig. 1a). Using a positive dielectric anisotropy material, application of an electric field destroys the twisted structure, and stops the guiding effect and so the polariser and cell sandwich does not transmit light. Two types of display are possible: dark on clear with crossed polarisers; or clear on dark with parallel polarisers. Coloured displays[3] can also be made by using optical effects, such as coloured polariser material, or a birefringent layer.

Material stability problems using the original room temperature materials could still exist with the twisted nematic although the cell techniques employed enable these materials to be successfully used. The invention of the extremely stable biphenyl liquid crystal family[4] slightly relaxed the demands made on the cell technology and a positive dielectric anisotropy mixture of the biphenyl family can have a nematic range of −10° to 60°C.

The main problem peculiar to the twisted nematic display has been achieving the desired molecular orientation at the glass surface. Evaporation of a dielectric material[5], e.g. SiO, at an angle to the surface has been generally adopted. The orientation of the molecules at the surface depends on the angle of evaporation, the molecules tending to tilt away from the surface at certain angles. As the tilt angle gets smaller, so the viewing angle of the display increases and the voltage response curve becomes more non-linear, both desirable qualities.

Early twisted nematic displays, and some less well-made present displays, suffer from reverse twist and reverse tilt (Fig. 2a). Reverse twist occurs when the ninety degree twist is in a different sense, i.e. +90° and −90°, in various areas of the cell so giving rise to a patchy appearance in the undriven state. It can be cured by the addition of a small amount of cholesteric liquid crystal[6]. (See *Wireless World*, May 1975 p.229-234.) The cholesteric material is a nematic with an inherent twist which biases the twisted nematic towards one twist sense. Reverse twist occurs when the molecules are parallel to the surface so that when a voltage is applied the molecules in the centre of the film can be reorientated in either direction to produce regions of different tilt angles, and a patchy appearance in the driven state. Reverse tilt in the driven state can be solved by giving the surface molecules a slight tilt to bias the driven-state tilt-angle in one direction.

The main advantages of the twisted nematic over dynamic scattering are the reduced power consumption (because the twisted nematic is a pure field effect while dynamic scattering requires current flow), enhanced contrast and greater aesthetic appeal.

At present the twisted nematic display is the dominant liquid crystal display in the watch and panel meter markets. The best displays have a wide viewing angle, reasonably bright background, no patches in either 'on' or 'off' areas and appear generally uniform. Response times are of the order of tens of milliseconds and, again, the best displays do not have the sluggish appearance of the poorer quality displays. Early liquid crystal displays tended to fail after a short time but, with the improvement in cell fabrication techniques, and the use of a.c. drive and newer materials, lifetimes of five years have been generally quoted, with longer lives anticipated as test data is accumulated.

What of the future? It seems probable that the twisted nematic liquid crystal display is perfectly suited to use in watches with respect to both the power requirements and the interface with c.m.o.s. circuitry. Under development at the present time is the dyed phase change effect[8] where a dichroic dye (absorbing when light is polarised parallel to the long axis of the dye molecule, non absorbing when light is polarised perpendicular to the dye molecule long axis) is dissolved in a cholesteric-nematic mixture. The cholesteric imposes a twist on the nematic so that a helical structure is formed and, because of the dye, this appears coloured in the undriven state.

Application of an electric field to the positive dielectric anisotropy material results in a breakdown of the helical structure so that the display appears

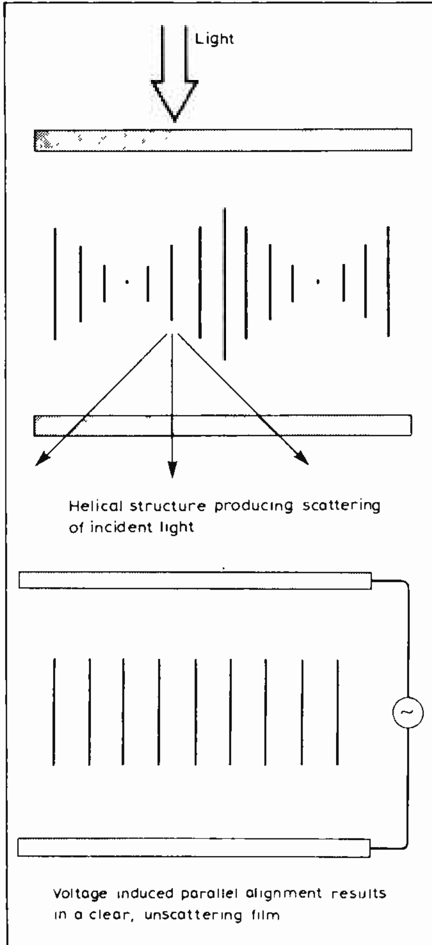


Fig. 3. *Phase change effect.*

clear due to the dye realigning in sympathy with the voltage realignment of the nematic molecules (Fig. 3). This display is brighter than the twisted nematic display since it does not require any polarisers, and it is hoped to make the contrast sufficiently high by the development of suitable dyes. The effect is considerably faster than the twisted nematic but requires higher drive voltages and quite stringent control of cell spacing. The main problem lies in developing dyes with good solubility in the nematic material, good dichroic properties, good colour characteristics and the required resistance to u.v. light. These are not trivial and no satisfactory solution has yet been found.

Many of the liquid-crystal display products on the market now employ multiplexing techniques. This means that instead of each segment being directly driven, the applied voltage is time-shared between several segments. Unlike l.e.ds for example, where multiplexing is easy due to the unidirectional, non-linear behaviour of the device, liquid crystals are not easy to multiplex. Since the device has a poor voltage threshold which also varies with temperature, multiplexing of liquid crystals is usually limited to two or three ways and is used extensively in the Japanese calculators and some watches. As the techniques improve, multiplexing will become commonplace in the field of liquid crystal displays, more especially so if the number of ways can be increased, and dedicated, multiplexing integrated circuits become readily available (the latter being particularly important for the o.e.m. market).

One common criticism of early liquid crystal displays, particularly in watches, was that they could not be seen in the dark. This has been overcome by two techniques; the first uses a filament microbulk plus a plastic light pipe to direct the light behind the display. The second technique uses tritium-activated "betalights" where pressurised tritium gas (radioactive hydrogen), inside a glass tube, emits electrons ('beta' particles) to strike a phosphor coating on the inside surface of the tube. This coating emits the desired light and these devices have a useful life of over 15 years.

Liquid crystal displays have come a long way since the first prototypes were made and the development effort now in full swing throughout the world promises to improve the devices even further. The advantages of low power consumption and continuous display will enable them to dominate the digital watch and calculator markets. With the multiplexing and aesthetic improvements on the way, liquid crystal displays will find applications in many of the markets where l.e.ds and fluorescent displays now dominate. □

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BOOKS RECEIVED

Unique IC Op-Amp Applications, Audio IC Op-Amp Applications, and **IC Op-Amp Cookbook** are three paperback books by Walter G. Jung.

The first two are smaller publications which have been extracted from the third. All of the volumes are packed with circuits, graphs and device information which makes them suitable for practising engineers or amateurs and hobbyists. Many of the circuits have worked examples showing how the component values are calculated which enables readers to design or modify circuits. Howard W. Sams & Co. Inc., 4300 West 62nd Street, Indianapolis, Indiana 46206, U.S.A.

Video Yearbook 1978 edited by Angus Robertson of Video and Audio Review. This second edition now contains 75 categories covering all forms of video equipment as well as audio, teletext and viewdata products. Most of the sections contain an alphabetical list of manufacturers together with brief product details. Other useful categories cover services, books, international television standards, jargon, journals, organisations, programme supplies and libraries. The book is sprinkled with photographs and concludes with an index section. Price £7.95 hardback, pp.440. Blandford Press, Link House, West Street, Poole, Dorset.

Electronic Communications by Dennis Roddy and John Coolen is intended for telecommunications students, and assumes a detailed knowledge of electronics and mathematics. The book is divided into five sections which cover communications fundamentals, electronic communication circuits, modulation of signals, transmission and radiation of signals, and communication systems. Two appendices cover logarithmic units and the transverse electromagnetic wave. Each section concludes with a list of problems. Pp.706 hardback. Reston Publishing Company, Inc., Reston, Virginia, U.S.A.

Digital IC Equivalents and Pin Connections by Adrian Michaels is a useful low cost data book ideally suited to the experimenter. Each listed device has information on its package, pin connections, logic family, function, country of origin, manufacturer, European and American equivalents. Price £2.50 paperback, pp.316. Babani Press, The Grampians, Shepherds Bush Road, London W6 7NF.

Handbook of Linear Integrated Electronics for Research by T. D. S. Hamilton is suitable for engineers and scientists who require a concise description of modern circuit operation. Each section is provided with numerous references for further reading and an index lists authors directly named in the text. Ten chapters cover amplifiers, feedback systems oscillators, power supplies, circuit functions and devices, optoelectronics, and signal detection. A final chapter gives a list of references which describe general circuit applications. These notes have been selected primarily for their use of i.cs in electronic systems. Price £14.50 hardback, pp.469. McGraw-Hill Book Company (UK) Ltd, Shoppenhangers Road, Maidenhead, Berks.

LETTERS TO THE EDITOR

TRAFFIC INFORMATION BROADCASTING

We read with interest the BBC article by S. M. Edwardson on broadcast traffic information systems published in your January issue. We are very disturbed at the suggestion that the BBC system may be less costly than ARI. We disagree. Moreover, the BBC system has not yet proved itself. ARI is already operational.

The BBC's assessments of costs were based on 1976 prices. According to our calculations, we believe that the comparative costs for 1978 should read as follows:

	ARI £	BBC £
Capital cost	12,000	8,000,000
Additional decoder/receiver costs (assuming all motorists with radios add the traffic information system)	117,000,000	156,000,000
Totals:	£117,012,000	£164,000,000

Minimum additional cost of the BBC system: £47 million

If, as is suggested in the BBC article, motorists were also to convert their home radio for breakfast listening, the special receiver cost would double, making the additional cost of the BBC system some £200 million! ARI involves no extra cost at home.

Of course, both the above figures are totally "pie in the sky" and are useful for comparison purposes only. There is no way that many motorists will be prepared to purchase special BBC fixed frequency add-on receivers which are only suited to providing traffic information at £20 or so (plus installation). On top of that, it would be necessary to find space on the crowded, modern car dashboard for the BBC receiver.

ARI, on the other hand, is undergoing dramatic growth on the Continent. It is spreading internationally – well over 2 million motorists have purchased ARI equipment (increasing by over 1 million a year, after only 3 years of life!) and 30% of newly registered cars in West Germany are fitted with ARI radios offered by all leading makes. So in terms of cost and acceptance, ARI is already well ahead.

Furthermore, all motorists with normal car radios can listen to traffic broadcasts put out by the ARI stations.

On the practical side, the BBC system poses many problems. Firstly, the BBC system requires a fixed frequency. With entertainment band transmitters booming in number from 4400 to over 10,000 in ITU regions 1 and 3 from November this year, there can be no chance of a fixed frequency being allocated in the entertainment broadcasting band – either in Britain or anywhere else. So the broadcasts would have to be made on a frequency outside the medium wave, motorists would be *forced* to buy special receivers to receive traffic information. With ARI, listeners can tune into traffic information stations in the normal way on standard radios at no extra cost at all!

Secondly, will broadcasters cease to provide traffic information on entertainment stations if the BBC system were to get under way? At present BBC research shows that 87% of motorists with radios welcome present traffic information services; so would broadcasters be prepared to upset their listeners by ceasing these services? AA research shows that nearly as many people partly listen to their car radio for traffic information as for pop music – so traffic information clearly belongs correctly within the output of entertainment stations.

If we assume that broadcasters continue to issue traffic information, welcomed by 87% how many motorists would be prepared to buy a special BBC traffic-message-only, fixed-tune receiver? We believe very few.

The BBC system requires many more years of research, development and then, perhaps, installation of the necessary 70 or so special transmitters. ARI is tried and proven and can be plugged in overnight at £625 per transmitter. Motorists would receive immediate, urgent help. Moreover, during the time that the BBC system will take to develop, much more sophisticated driver guidance systems will become available. (Our own ALI Driver Guidance System using induction loops and providing individual drivers with directional guidance as well as traffic messages is already developed, ready for installation, and undergoing widescale assessment.)

The BBC has championed the need for an alternative system to ARI largely because in the late 1960s, when ARI was first on the drawing board, it was considered that ARI was an f.m. system and not suited to predominantly medium and long wave Britain. Two things were overlooked. Firstly, ARI was first developed for operation on medium and long waves – and even now is broadcast on these wavebands on the Continent. Secondly, overcrowding of the medium waveband, especially in the next few years, has led to a need for Britain to develop its f.m. broadcasting capability. Even now the BBC is advertising to educate the public to purchase radio sets which include the f.m. bands!

ARI has never been disputed as the only suitable system available for f.m. broadcasting, endorsed as such by the EBU. The BBC has also expressed this view. So ARI is clearly both versatile and better suited to the future needs of broadcasting and reception.

Clearly it is advisable to study and consider new and alternative systems of communication with motorists. We at Bosch and Blaupunkt are actively doing so. But meanwhile, surely, it would be better to accept the ARI system now and provide motorists with immediate help in receiving the services already available.

Andrew Rodger
on behalf of Blaupunkt-Werke GmbH
Watford

Mr Edwardson replies:
Mr Rodger has made so many misleading statements that I hardly know where to start, but perhaps it would be a good idea to make a fundamental point to begin with. Whereas the BBC has proposed a dedicated total system, aimed at providing detailed local traffic information for those who want it, ARI is simply an aid to receiver-tuning *and nothing more.* ARI enables a listener to identify those broadcasting stations that are scheduled to transmit occasional traffic information messages in the way that BBC Radio 2 and BBC local radio stations operate at the moment. The obvious snag with this type of broadcasting is that only general information in limited amounts can be given and all listeners have to receive it whether they want to or not.

Having recognised this truth, further comparisons are almost pointless. Nevertheless, it is perhaps worth noting that Mr Rodger's cost figures boil down to a statement that a v.h.f. receiver with ARI would cost less than an l.f./m.f. receiver with Carfax. Manufacturers' estimates lead us to expect that a complete l.f./m.f. car radio with Carfax will cost about £50, in contrast to at least £150 for the cheapest ARI receiver capable of giving a choice of programme with automatic changeover to other stations broadcasting traffic information service inserts (one such receiver costs £740).

I wonder whether Mr Rodger is really serious when he writes of ARI's dramatic growth? He must surely be aware of the research work now going on into station and programme identification systems for use in radio broadcasting. If he wants a tuning aid, these new digital systems are well advanced and will do the tuning-aid job of ARI using only a fraction of their available capacities.

On the subject of an operating frequency or channel allocation, what more economical use of spectrum space can anyone envisage than a system that provides *local* information, yet potentially requires only one frequency for the whole world?

Carfax is a new but well developed system that will no doubt further evolve and improve with operating experience over the years. During this time, its usage will expand and its cost to the motorist will decrease. I am sure that *Wireless World* readers will appreciate that we have been well aware of the German system for some time and have studied its operation thoroughly. The more we see, the less we like it and the more convinced we are that the BBC proposal is much superior. By the way, when did the BBC endorse ARI? We have no such knowledge.

S. M. Edwardson

THE NRDC—FAILING IN ITS DUTY?

It is a great pity that the NRDC, as a result of one correct investment decision some twenty years ago, has the funding to regularly re-whitewash itself, while those like myself who have suffered severely at its hands lack the funding or motivation to put the record straight.

In the January issue, page 72, you quote the NRDC chairman as saying, "To my knowledge,..... there is no record of anyone leaving, going away from the NRDC and making a success of their invention somewhere else." I am such a case. After the NRDC put £1,000 into my invention, called "C.A.M.", and proclaimed that they wanted to support it further, I told the Secretary for Industry that I would never again try to do business with the NRDC. My inventions have since received over £50,000 of government support. (*Computer Weekly*, Dec. 8, 1977, page 12.)

It is very rare for an inventor to escape from the destructive clutches of the NRDC. in *The Spectator*, Feb. 16, 1974, page 211, I described the technique by which the NRDC sabotages inventors (including myself) who approach them. My charges were never answered. While it is true that the NRDC admitted to mishandling my case, I have come across many other instances of similarly destructive behaviour.

A senior official of the NRDC said to me, "We are not supporting private inventors any more. All inventors hate us. We are a merchant bank now."

So long as it is generally known that the NRDC is not carrying out its proclaimed duty, to support private invention and new industry, it will do much less damage than it has done in the past. The trouble is that they have the funding and the motivation to continually re-whitewash themselves as more and more evidence of their destructive behaviour comes to light.

The damage to myself and my invention was very severe; a direct loss of one year in pushing forward my invention; very severe psychological stress when they played cat and mouse with me during that year. Years later, I still find it difficult to behave in a trusting manner with other government departments. I continue to suffer damage because it is difficult for other government departments to come in and try to fulfil the role that the NRDC should be fulfilling in my case. Mine is exactly the kind of case that the NRDC was set up to support; a major breakthrough in computer architecture and microelectronics requiring an investment of the order of £20,000 to £100,000.

On 24 July 1973, a government select committee called for an urgent enquiry into the behaviour of the NRDC (Third Report from the Select Committee on Science and Technology. Tracked Hovercraft Ltd. Session 1972-73). About a year ago, another report from the same committee, coincidentally also called "Third Report . . . ", again lambasted the NRDC and called for an urgent inquiry into its behaviour.*

If the future of this country depends on the development of new products and new industries, this destructive behaviour over a period of so many years will be perhaps the major cause of our decline. Certainly I believe the NRDC is doing more damage to our economy than shop stewards in the car or shipbuilding industries.

Sir Monty Finniston, currently chairing the government inquiry into the state of the engineering profession, was in the NRDC from 1963 to 1973, the period during which I know they did a great deal of damage. He must at best repudiate the NRDC, or at least explain his attitude to them, if we are to have any confidence that his current activity will be helpful. Does Sir Monty agree with the Select Committee that ". . . the conduct of the NRDC towards the staff of Tracked Hovercraft Limited falls far short of that expected of a good employer."? (Third Report, 24 July 1973, para. 49). Does he agree that ". . . the structure and powers of the NRDC are in need of urgent and fundamental review."? (*ibid*, para. 220).

Speaking more generally, can nothing be done about this cancer in our midst, the NRDC?

Ivor Catt,
Computer Associative Modules Ltd,
St Albans,
Herts.

* "Third Report from the Select Committee on Science and Technology. University — Industry Relations. Session 1975-76." Published 26 Oct. 1976, H.M.S.O., price £1.15.

"There was little indication in the evidence of either the NRDC of the Department of Industry that they were aware of the extent of the criticisms levelled against the Corporation. There was, indeed, an air of complacency about their evidence. This is a matter for concern in itself . . . " — page 70, para. 5.55. Also, "It may well be that these functions would be better performed by a new institution without the accumulated scepticism and indifference which NRDC's policy and activities appear to have generated in some quarters." — page 72, para. 5.59.

AUDIO EQUIPMENT REVIEWS

Allow me to call to your attention errors of fact which appear in Mr Raymond Cooke's letter in your last issue.

This matter really begins with your news item in the February issue (p.34) in which Mr Cooke, on being interviewed, stated that he was not invited to the preliminary discussion of measurement techniques to be employed in the forthcoming issue of *Hi Fi Choice Loudspeakers*. In fact, an oral invitation was given to a representative of his company, but in the event, no representative attended the meeting.

As for laboratory facilities being made available by KEF, the facts are that such computer facilities were made available by KEF in the previous "30 Loudspeaker Tests" for *Hi Fi For Pleasure* in 1976, taking advantage of KEF's then policy of encouraging the use of accurate measurement systems to review products in the British press. I was grateful for this facility. However, in the present project under discussion, I made a point of not asking KEF Electronics for computer facilities, but instead invited another manufacturer with similar capabilities, because I felt it would be fairer to both companies. In any event, the KEF tests that were required and conducted in 1976, were completed in less than one working day, a Saturday, with no apparent disruption of the firm's activities.

With regard to the present testing of 60 loudspeakers, the second manufacturer later withdrew his permission for our use of the computer and other facilities which he had earlier promised. As it happens, this merely meant in practice that we had to spend more time in compiling the test results. In other words, the refusal by the second manufacturer merely cost us more time and did not invalidate the tests themselves.

I would agree with Mr Cooke that a period of four to five months is needed for this type of evaluation, and in fact this was the precise period of time taken for our test and report. His comment of "less than two months" is inaccurate. As for the remark that it was undertaken by "one man with borrowed equipment" I would like to point out that in all, there were in addition to myself one assistant for a large proportion of the time, and a total of three persons engaged in the anechoic testing, plus a hired musician and six panellists, one of whom was an independent consultant who is professionally engaged in the recording industry and who was commissioned to give his professional opinion on the products. In other words, I was the overall director and scientific manager of a team.

As for "borrowed equipment" this amounted to the hiring of a B & K gating unit, the remaining complete B & K audio testing station and ancillary equipment used being my own property. The D.o.E. anechoic facilities at Garston, Watford were hired, not borrowed, as is the case with several major manufacturers.

Finally we have to ask what is a "shoestring"? To my knowledge the allocation of funds for this project was far in access of anything that has been provided to date by other comparable hi-fi periodicals.

I realise that Mr Cooke has the interests of the hi-fi industry and its products at heart. In fact, KEF products usually, and deservedly, receive a good press. In the previous issue of *Hi Fi Choice* KEF products were outstanding. Furthermore, KEF took a great interest in that issue and contributed descriptive material in the introduction.

Finally, may I point out that full details of test philosophy, procedure and limitations are exhaustively discussed in the new issue of *Hi Fi Choice*, and if *Wireless World* readers have any reason to doubt the sincerity of *Hi Fi Choice* or its consultant reviewers, they need only read that issue to judge for themselves.

Martin Colloms
London NW6

AUDIBLE AMPLIFIER DISTORTION

I am not sure just what Mr Howard (February letters) means by "transfer distortion", since it is a term I cannot recollect having seen in the literature. It seems to me that all amplifier distortion is, by the very nature of things, transfer distortion, i.e. distortion introduced while the signal is being transferred from the input to the output of the amplifier. Thus Mr Howard's introductory remark seems to mean simply that Peter Walker and I regard it as important to assess the audible performance of an amplifier by investigating its distortion. What else could we reasonably do?

Mr Howard states that the validity of the technique of listening to the distortion by itself rests firmly on the assumption that interaction of sub-threshold distortion with signal does not take place in the ear/brain complex. However, as he himself points out, the fact that such interaction can be shown to occur under certain highly artificial conditions, as described in the paper by G. Oster, does not necessarily mean that it would produce degradation of music signals. Indeed, there is plenty of evidence to show that, when listening to music, distortion must be considerably above the normal threshold-of-hearing level in order to be heard, or its presence in any way perceived. However, I grant that, in the light of these interesting findings about sub-threshold binaural beat perception, I perhaps ought not to have said that it "quite inescapably" follows that because the distortion of an amplifier is inaudible by itself, the amplifier may be regarded as subjectively perfect. So what is the evidence to show that this conclusion is nevertheless correct? The evidence is of several kinds, as follows.

Firstly, it is always found that with a good amplifier, whose distortion is inaudible when listened to on its own, the distortion has to be increased quite a lot before it begins to produce a just perceptible effect on musical quality. This increased distortion, when listened to on its own, is then found to be easily audible.

Secondly, it is well established that recording most kinds of live programme material on a first-class tape recorder does not result in any readily appreciable degradation in quality, except, perhaps, with regard to signal-to-noise ratio when the dynamic range is very wide. Yet doing this introduces peak distortion which may well be 40dB greater than that of a first-class amplifier, and which, reproduced by itself, is clearly audible far outside the room in which it is reproduced.

Thirdly, it is demonstrable that the distortion produced by a good amplifier is much quieter than the distorted acoustic output from a Dust Bug, which can easily be heard all over the room on heavily modulated passages if the volume control is turned down. But does anyone seriously suggest that the acoustic output from a Dust Bug is of any consequence?

Another method for temporarily increasing the distortion of an amplifier, while keeping the character of the distortion the same, and which is sometimes more convenient than that mentioned in my November 1977 article, is to alter the β-network to give less negative feedback and insert a corresponding amount of passive attenuation in front of the amplifier. This method should only be used, however, by those in a position to make quite sure that no kind of overloading occurs in the amplifier, for drastic overloading would invalidate the soundness of this technique.

For reasons such as the above, particularly the first, I think one is actually very safe indeed in maintaining that if distortion on programme is inaudible by itself, it won't be audible, or in any way perceptible, when accompanied by the masking effect of the programme. Masking effects are quite large and some of the broad facts about them are well established[1]. They are not invalidated by the fact that if a relatively loud tone, at frequency well below 1000 Hz, is presented to one ear by means of an earphone, the other ear can just detect, by means of beats, the presence of a tone of nearly the same frequency at a level somewhat below its normal threshold-of-hearing level. These highly artificial conditions never apply in normal circumstances.

I was sorry to find that Professor Fellgett (February letters) thinks I threw the baby out with the bathwater, in my November 1977 article, and from the rest of his letter I fear he really thinks more than one baby was thus ejected!

With regard to electric bells, I must confess to having taken little specific interest in these since my school days, except for a minor revival of interest at college when someone pointed out that the delayed build-up of current, due to inductance, when the contacts close, is a vital part of the theory. If full magnetization occurred instantly, the mechanical system would lose just as much energy when moving away from the magnet poles, with the contact closed, as it later gained on returning through exactly the same distance with the contacts still closed. Before making reference to "tintinnabular matters" in my article, I did do a few order-of-magnitude mental calculations, which convinced me that the effective build-up time constant would be so long, and the inductance value so high, that parameters of the connecting leads other than d.c. resistance could hardly be significant. A recent experiment on a bell shows the expected slow current rise, lasting several milliseconds, and rapid cut-off, a slight complication, not surprisingly, being a few "cobs" on the current waveform at the start of current flow, due to contact bounce. With this 4-volt bell, I find adding 0.2 ohm of extra series resistance in the supply circuit had a discernible effect on the sound, but even 1mH of added series inductance has no evident influence. I am therefore simply not inclined to believe that, for a given d.c. resistance, it will make a scrap of difference whether one uses Litz wire or not. While recognising that one could spend months investigating the fine details of electric bell behaviour, and still not be able to claim that one totally understood everything, I suggest that it would probably be more worthwhile to devote your attention to other matters!

I do not altogether agree that the lack of comprehensive theory of how the ear and brain act means we are largely deprived of quantitative limits, for these limits can usually be determined fairly satisfactorily by subjective experiments. The danger with mathematical theories of audition is that the assumptions on which they are based can so easily be wrong, and this can be lost sight of, at least temporarily, by those with great enthusiasm for the mathematics itself.

I do not share Professor Fellgett's concern over the supposed difficulty of defining "avoidance of overloading". A really first-class amplifier will have a large amount of negative feedback, and recent suggestions that feedback should be used only in small amounts are simply nonsense and cannot stand up to rational investigation either theoretically or practically. A well-designed amplifier with plenty of feedback will normally have a very sharply-defined overload point, though it is important to remember that the instantaneous output voltage at which overload occurs is liable to depend markedly on the magnitude and nature of the load impedance, and may be at a point on output voltage waveform well below the peak if the overload is due to inability to supply sufficient output current rather than voltage. But, whatever the cause of overload, a large error voltage will rapidly develop in the feedback circuit if the input programme level slightly exceeds a certain critical setting. By arranging for this error voltage to operate an indicator circuit, the occurrence of overloading may be sensitively displayed. I have had an economical circuit of this type in operation for over a year, and it will be described in a later article in my present series. If, on given recorded programme input, the indicator just operates once or twice, then a very slight reduction in volume control setting, say 1dB, will be sufficient to ensure that no overloading occurs. The set-up shown in Fig. 1 of the November article may, of course, be used to perform a similar function if the monitoring loudspeaker is replaced by a c.r.o. or other visual display. Please note that two resistors were inadvertently omitted, in series with S_1 and S_2.

I think that many reported cases of inferior audible performance of amplifiers are due to overload occurring without the user being aware of it. For example, if an amplifier has a maximum instantaneous output current capability of 5A, but plenty of voltage capability, it will just give 100W mean sine-wave power to an 8Ω resistance load. But a nominally 8Ω loudspeaker, whose impedance modulus drops at one frequency to 3Ω—and such devices do exist! – can have a peak instantaneous voltage of only 15V developed across it at this frequency, and this voltage, referred in the usual way to the nominal 8Ω impedance value, yields a mean output power figure of only 14W. When various straightforward effects such as this are appreciated and allowed for, amplifiers are found not to be the subtle and mysterious things they are sometimes imagined to be.

I have carefully read the paper by Leinonen and Otala to which Professor Fellgett refers, and consider the noise intermodulation test there described to be an unreasonable one to apply to an audio amplifier. It will show up to advantage an amplifier having a very high slew-rate capability, but there is no virtue, other things being equal, in designing an audio amplifier to have a slew-rate limit far in excess of the maximum slew-rate of any programme material it will ever have to handle. The test signal is stated to be band-limited white noise, the limiting filter having an attenuation rate above 20kHz of only 6dB/octave, so that the high-frequency part of its transfer function is presumably of the form $1/(1 + pT)$. To determine the slew-rate of the noise coming out of this filter, one must differentiate the output, i.e. multiply it by pT. The differentiator output spectrum is therefore that of white noise fed through a network having a transfer function of the form $pT/(1 + pT)$, which is the transfer function of an ordinary R-C a.c. coupling. If the bandwidth of the white noise source were infinite, the peak slew-rate as thus measured would also, in very idealized theory, be infinte. In practice it would be of infinite value, dependent on the particular white noise generator employed. Surely this is a very undesirable state of affairs for a so-called standardised test?

Peter J. Baxandall
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Worcs.

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COMPUTERS: WORDS FROM A PROFESSIONAL

I see that computers and related subjects are beginning to take up an increasing amount of space in your journal. As a computer professional I take exception to some points in your March issue.

Firstly, in the otherwise excellent article "Integrated-circuit memories" by John Dwyer, the author states that "Floppy discs have a life of three months". After four years of using this medium I would disagree with this inaccurate and totally meaningless statement. I would also suggest that it will take an absolutely new technology to displace magnetic media for data storage, off line, in view of the very low cost, high packing density, and non-volatile nature. In a commercial installation one disk drive may have several hundred diskettes of data associated with it.

Secondly, I write programs, and in all the computer publications I read I see the word referred to as "program." Why does this get translated into "programme" in the pages of *Wireless World*?* I find this similar to reading about silicone chips in the computer press.

Finally, in your editorial on electronics and employment, you miss the point that commuting is a total waste of energy and manpower resources. Unlike some I never found a visit to Waterloo Station had any social value. Also I would suggest that the short staffing and presence of a high proportion of immigrant labour in the transport services suggests that this is not a socially desirable area. The problem of the future is should we provide employment manufacturing goods and services and preserve skills which are totally unwanted and redundant?

J. Watt
Gibraltar Heights
Gibraltar

* On the contrary, the word "programme", which was used in *Wireless World* for about fifty years before computers arrived, has been translated into "program" in the pages of the computer press. We are well aware of the wide use of "program" but think it introduces unnecessary mystification, suggesting that a "program" is somehow different from a "programme". In fact it is the same thing, a "descriptive notice of series of events" or "definite plan of intended proceedings" (Concise Oxford Dictionary). See also "Principles of digital computers" by D. S. Wilde, *Wireless World*, November and December 1960. – *Editor.*

DIRECT PERCEPTION OF RADIO WAVES?

Mr Wood's letter in the December 1977 issue concerning direct sensing of radio waves is most interesting [See also correspondence in February and March. — Ed.]

One day in 1959 while I was drifting quietly in a small boat under the ice cliffs at Port Lockroy, Antarctica, where we were studying ionospherics, including whistlers, I heard what sounded like a shell from a large gun whistling overhead. This was not unreasonable as foreign gunboats had been in the area at that time; however, there was no explosion or crump of a shell hitting its target. Shortly after this I heard, to my considerable amazement, the unmistakable sound of a whistler exactly as recorded on our whistler magnetic tapes. It was so difficult to imagine just how one could hear v.l.f. electromagnetic waves directly that I kept quiet about it to my colleagues — there is always the risk in such cases of being accused of Polar madness!

A few days later two of my colleagues both heard exactly what I had heard and insisted it was whistlers. Needless to say, I accused them of Polar madness or at best of mistaking ice squeaks for whistlers, but after convincing myself of their overwhelming conviction that they had indeed heard whistlers I admitted I too had heard them. Later in the year some American scientists, believing such a thing was possible, asked us to give details of times, directions and so on to add to evidence they had already started collecting on the subject.

Ten years later while listening to a lot of folklore about people being able to hear aurorae in Shetland, where I worked on, and still work on, geomagnetism, I wondered again whether some form of ion/acoustic coupling, together with focusing in the auroral arc, could produce audible sounds directly. An acute human ear only needs a few dBs more gain to be able to listen to Brownian movement of molecules. Alas, I could raise nether the equipment nor the official interest to investigate this type of phenomenon properly, but I do still find it most intriguing.

A few years ago we were asked for advice by a lady concerning a claim that she could sense the N-S direction of the Earth's magnetic field but only when she had the television set on.

As there is growing concern over the whole question of acceptable flux levels of microwave radiation in one's working environment because of, among other things, the eye's ability to focus the radiation on the retina and hence cause possible damage by burning, perhaps readers should be invited to describe any incident at all where they have reason to believe that one or more of their senses has/ have been able to sense directly low level electromagnetic waves of whatever frequency. It might prove extremely enlightening.

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Institute of Geological Sciences
The Observatory
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Editor's note: Whistlers are electromagnetic waves in the audio frequency range. Generated by lightning discharges, they penetrate the ionosphere and are ducted along the lines of the Earth's magnetic field. The whistling character when heard—usually a note descending in pitch – results from the fact that the different frequencies generated travel at different speeds.

CASSETTE DECK MODIFICATIONS

Readers of Mr Linsley Hood's postscript in the February issue on his cassette deck design may be interested in some additional features that I have incorporated in my own unit. The first of these consists in replacing one of the two recording level controls by a 1kΩ linear potentiometer to act as a motor speed control. The existing preset on the p.c.b. is removed. This has many uses – such as when replaying a tape recorder on a different machine (e.g. a portable recorder running slow due to ailing batteries), or when the tape threatens to end before the last chord of the concert! A dual control with independent shafts replaces the other gain control to maintain the original function.

Another change lay in rewiring the 'phones output jack on the front panel as a (mono) microphone input, since the writer's 'phones are of lower impedance than is good for the replay amplifier. The live and earthed *switched* contacts were interconnected so as to earth the input when not in use, and the internal lead taken to the switched contacts of the stereo jack sockets on the ear panel. A microphone plugged into either of these sockets therefore overrides the mono input to that channel.

Finally, the Lenco mechanism has a useful feature which many readers may not have discovered. In normal practice the record control may not be depressed whilst the cassette is in position. However, slight sideways movement of the fast wind/rewind control permits this operation (the pause button may remain depressed meanwhile). A similar movement then terminates recording.

T. Sharot
Stanmore
Middlesex

DIGITAL ELECTRONICS THEORY

Mr Davidson's letter in the March issue contains so many sweeping statements and unjustified generalisations that one can only surmise that it was written to stimulate debate. Otherwise, why should someone having available "clearly defined design rules" and "certain techniques which are not taught in any educational establishment in the country, nor written about in any textbook" not share this privileged knowledge? Similarly one would have to conclude that Mr Davidson's knowledge of educational establishments and textbooks is significantly less universal than he implies. It would also seem that he has not heard of transmission line theory, nor of those of its areas which are particularly relevant to digital techniques, such as line driving and Bergeron diagrams. Further, he seems unaware of the connection between risetime-based (time domain) digital techniques and the corresponding Bode diagram (frequency domain) analogue methods, which is, for example, hinted in Mr Baxandall's article in the same issue.

No doubt other readers will be able to supply reading lists, including *Wireless World* articles, which should demonstrate that "the practical problems" have indeed been studied. I content myself with pointing out to Mr Davidson that within the Post Office engineers are aware of the problems, and courses are available for those who wish to be "taught the important fundamental principles for competent digital system development" including "how 1ns steps propagate".

T. M. Forcer
PO Marine Division
Southampton

GAMES CHIP CONFUSION

The good news is that the Tank Game AY-3-8710 chips are in stock and have been since mid-March as promised. (April News of the Month, p.50.)

The bad news is that we feel you were misled by GI who apparently stated that the chip was not available in February. We knew of three companies who had the chip ex-stock in February, including one of GI's own distributors.

Marshall's are not often misled and we continually obtain products of this kind to maintain our range of 2000 integrated circuits.

Lastly, the price of the chip is £16.50 and the kit £29.95 including VAT, ex-stock from all our branches.

G. J. Clifton
A. Marshall (London) Ltd
London NW2

Loudspeaker system design

Three-enclosure system with active delay and crossovers

by Siegfried Linkwitz

This detailed description of a multiple-driver loudspeaker design is in two parts and covers driver selection, enclosure design, the active crossover, equalization and positioning. Sufficient information is given to duplicate the system or to improve existing systems by equalizing the low-frequency response or adding a separate woofer box.

THE SYSTEM DESCRIBED has evolved over years and out of experimentation with many different configurations and types of drivers and enclosures. Many people have contributed their ideas. It is not "the ultimate loudspeaker", but it reveals enough about microphone placement and recording practices to suggest, that the recording studio is the next weak link in the chain between original and reproduction. The few recordings with good spatial definition are proof that the full potential of stereo has not been exploited. Possibly this potential has gone unnoticed because hardly any commercial loudspeaker reproduces the depth perspective adequately, giving either a diffuse or thin-walled stereo image.

Every driver becomes more directional as frequency increases. The radiation pattern of a rigid piston mounted at the end of a long tube[1] is omnidirectional at frequencies where the ratio of piston diamter d to the wavelength λ of radiated sound is small, Fig. 1. As d/λ increases the on-axis pressure increases but the pressure at 45° off-axis decreases relative to it. Experience shows that wide dispersion of sound is desirable for natural reproduction. Allowing for a maximum 6dB drop-off at 45° off-axis requires that a driver be only used over a frequency range where its equivalent piston diameter is less than one wavelength. This is an idealized assumption because real drivers do not behave exactly like rigid pistons but the general principle still holds that uniform, wide dispersion can only be expected for frequencies where $d/\lambda \leq 1$.

In all loudspeaker designs the physical dimensions of driver, box and room have to be compared to the wavelength of the radiated sound to determine whether a dimension is acoustically small, as when $d/\lambda < 0.5$, or large, Fig. 2. A 200mm diameter driver for example should only be used up to 1.5kHz to maintain wide dispersion.

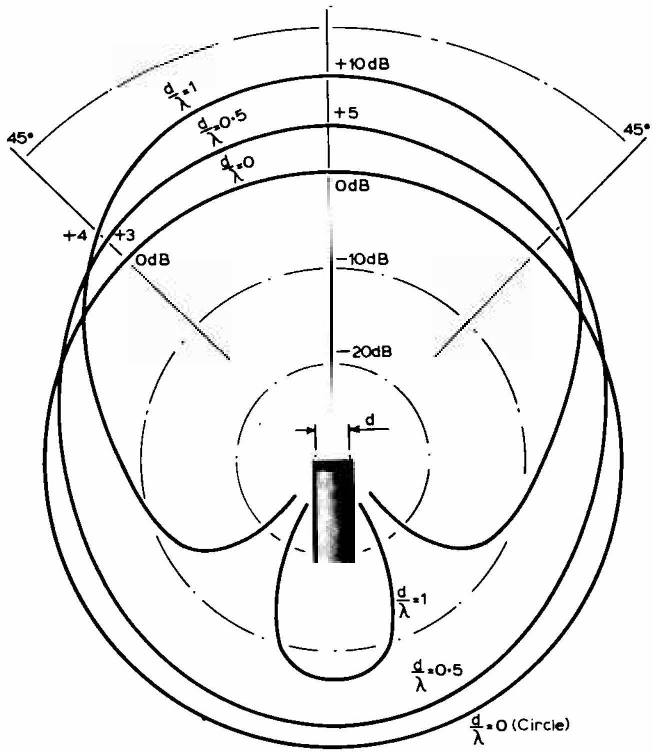


Fig. 1. *Directivity pattern for a rigid circular piston in the end of a long tube as function of d/λ (d is piston diameter, λ is radiated sound wavelength). Wide dispersion can only be obtained for frequencies where d/λ ≤ 1.*

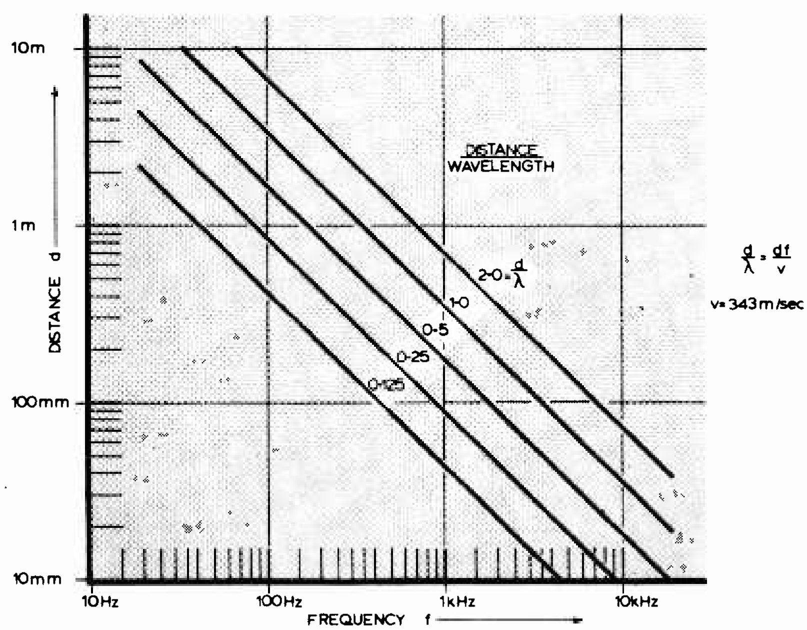


Fig. 2. *Dimension (d) of driver, box or room must be compared to wavelength of sound to determine whether a dimension is acoustically small.*

This is indeed a popular crossover frequency but it is also well within the critical frequency range of fundamentals and lower harmonics of many musical instruments. It is unavoidable that some change in the radiation pattern is introduced around the transition frequency from a larger to a smaller driver. In the design described a 100mm diameter driver is chosen which crosses over to a 25mm diameter unit at 3kHz. The radiation pattern change occurs therefore an octave higher in a relatively less critical frequency range, but still care has been taken in the design of the crossover circuitry to minimize irregularities in the transition region.

Some designers try to obtain wide dispersion or "omni-directionality" by using multiple drivers, covering the same frequency range. The fallacy in this approach can be seen by comparing the radiation pattern of a single driver to the resulting dispersion when two of these units radiate together, Fig. 3. If the distance d between the drivers is greater than half a wavelength signal cancellation can occur. The two outputs will be 180° out of phase whenever the path lengths from each of the drivers to the listener differ by an odd multiple of a half wavelength. As frequency increases the two units move relatively further apart (Fig. 2) and the locations for which the outputs cancel become more frequent. Such a system can only be described as multi-directional. Additional drive units further destroy the phase coherence of the direct sound output from the speaker system. This imparts the illusion of wide dispersion to all program material but lacks the accuracy in sound perspective which can be obtained from a single drive unit.

After establishing from the cone diameter the highest frequency up to which a driver can be used with good dispersion, the lower frequency limit will be determined from the cone excursion capability of the drive unit and the desired sound pressure level.

The radiation from the piston in a long tube was found to be omnidirectional for low frequencies where $d/\lambda \ll 1$, Fig. 1. If the piston moves with a peak-to-peak excursion a_{pp} at frequency f and radiates into free space, then the pressure p at a distance r from the source is

$$p = \frac{\pi^2 p_0}{8\sqrt{2}} \; \frac{a_{pp} f^2 d^2}{r}$$

Normalizing the pressure with respect to the reference pressure $p = 2 \times 10^{-4} \mu$ bar yields an expression for the more familiar sound pressure level (d and a_{pp} increased in mm)

$$20\log(p/p_0) = -86 + 40\log f - 20\log r + 40\log d + 20\log a_{pp}.$$

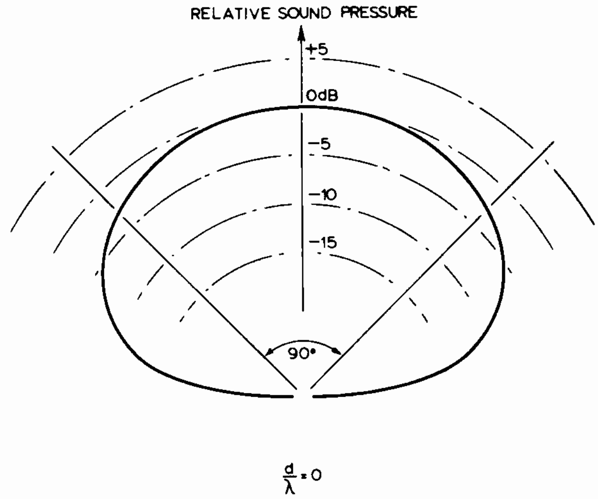
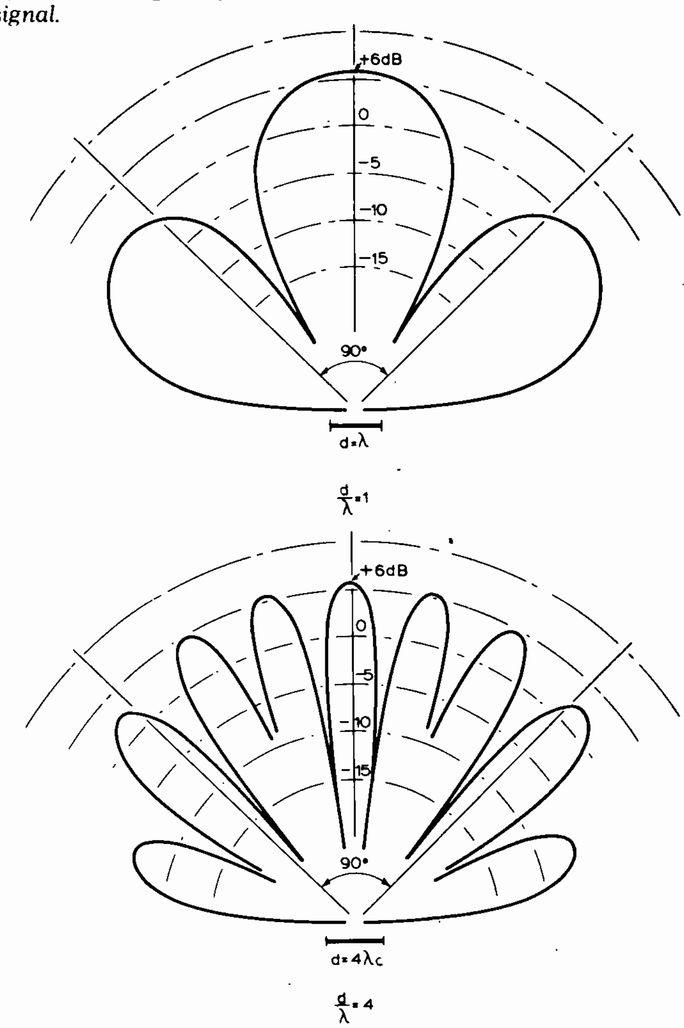


Fig. 3. *Use of multiple drivers to give wide dispersion produces interference effects for d>0 (a) single driver, (b) two drivers one wavelength apart, (c) two drivers four wavelengths apart, all with same signal.*



Assuming a_{pp} is 6mm and f 70Hz a direct pressure level of 83dB at 1m can be obtained from the 100mm driver and 85dB from a 200mm unit.

These s.p.ls may not seem very high but crossing over to a woofer at 70Hz will double the maximally obtainable sound pressure (+6dB) and because signals from the left and right channels of a stereo system are predominantly in phase at such low frequency a further increase of approximately 6dB can be expected. Therefore from a stereo system with 100mm drivers a direct free-field s.p.l. of about 95dB can be expected. Furthermore the normal listening environment is a semi-reverberant room where sound is reinforced by reflections from walls and objects.

Practical experience confirms that a 100mm unit can handle program material down to 70Hz at adequate levels and low distortion. This moves the crossover to the woofer to a less critical frequency range and a single large woofer can be used to cover the remaining frequency range below 70Hz. The large woofer enclosure can be placed separately from the relatively small midrange and tweeter enclosures and still be acoustically close because d/λ is small. Further consideration is given to this aspect of the system design later.

The frequency range below 70Hz could be covered by two 200mm units which will generate 90dB of direct s.p.l. at 35Hz and 1m or two 250mm diameter drivers with 94dB s.p.l. assuming 6mm peak-to-peak excursion capability.

The particular drivers chosen for this design are the 100mm KEF B110 low frequency/midrange unit, the 25mm KEF T27 tweeter and the KEF B139 woofer. A different unit like the KEF B200 or some other make with adequate excursion capability and linearity could be substituted for the B139.

There are of course considerations other than dispersion and cone excursion which must enter into the selection of a drive unit, such as smoothness of frequency response, freedom from high Q resonances, minimum phase behaviour, and low non-linear distortion. Unfortunately few meaningful data are published by many manufacturers. Knowing the magnet weight and flux density is of little help. With some training though the ear can sort out those drive units that seem worth further investigation and the units chosen for this design proved to be very satisfactory.

The selection of drivers was primarily guided by the desite for wide, uniform dispersion and crossover frequencies as high and low as possible. Had emphasis been placed on high power output capability or lower non-linear and Doppler distortion then larger diameter drivers would have to be chosen, or the crossover frequencies shifted to a more critical frequency range. Wide dispersion can only be obtained from a small drive unit which will also have higher distortion than a larger unit. It appears though that psychoacoustically the increased distortion is outweighed by an improved sound perspective which gives a greater sense of realism. Some further investigation of this subject is needed.

Speaker enclosures

Usually the size of a loudspeaker enclosure is dictated by the required low frequency response and efficiency. A different approach is taken here where the enclosure is optimized for minimum secondary radiation over as wide a frequency range as possible. The low frequency output capability is treated as a separate problem.

The purpose of the enclousre is to control the radiation from the back of the cone. A closed box design is chosen as the simplest form of enclosure. If the largest box dimension is less than a quarter wavelength at the highest frequency from the driver then the box is acoustically small and the air volume inside the enclosure will act like a uniform soring. The box has to be made sufficiently stiff so that the internal air pressure changes will not deflect the walls and cause secondary radiation. The woofer enclosure can be made small relative to the 70Hz maximum frequency. It will therefore have no internal air volume resonances and resonances of the box panels can be pushed above 70Hz by crossbracing of the walls.

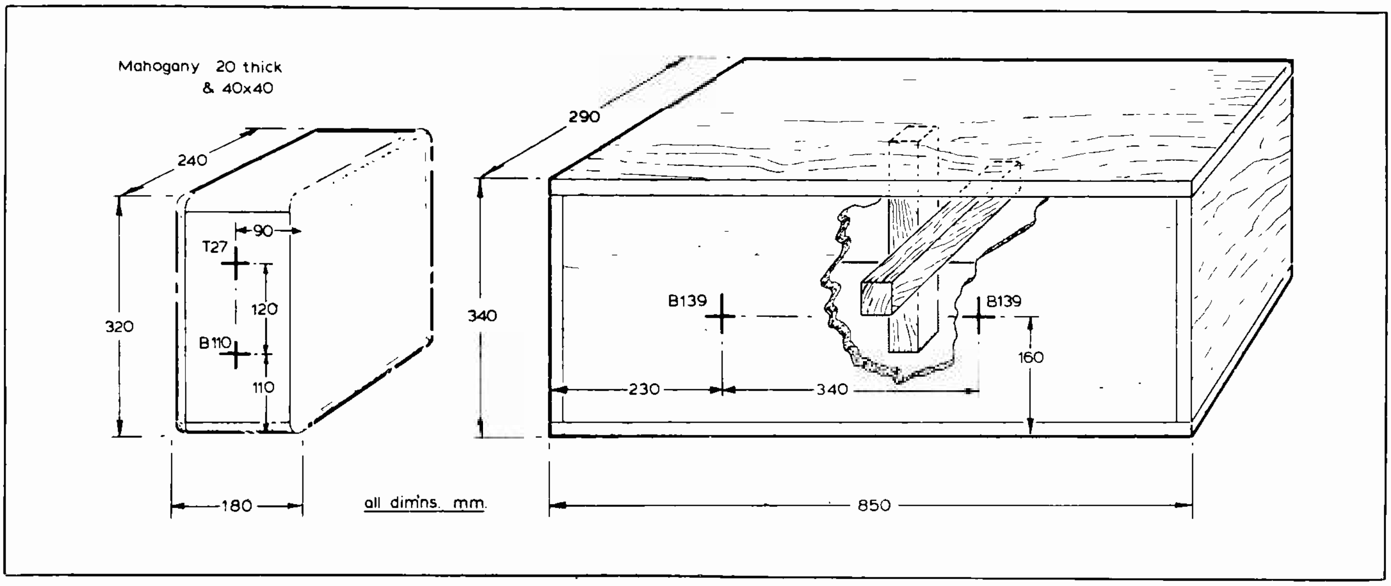
The enclosure for the B110 presents greater difficulties because of the wider frequency range covered. The volume inside the enclosure will exhibit cavity resonances which have to be eliminated. Acoustic energy is stored whenever one of these resonances is excited and gradually released after the excitation has been removed. Most of this acoustic energy exits through the cone: the speaker regurgitates its own characteristic box sound. Fortunately it is not difficult to dampen cavity resonances. The technique of filling the enclosure with long-fibre wool is well established and very effective.[2,3].

Another form of undesired secondary radiation comes from the enclosure walls themselves. The walls can be excited to vibrate by the internal air volume pressure changes, but more serious is the direct transmission of the mechanical vibration of the driver's cone to the enclosure. The walls then radiate the transmitted mechanical energy as sound, particularly when its frequency coincides with a panel resonance.

It is not unusual that more energy is radiated directly from the enclosure walls than from the cone at resonance frequencies. If for example the vibrating enclosure surface has ten times the area of the cone then its acoustic output will already equal that of the cone if it has only one tenth of the cone excursion. The output of most loudspeakers is coloured by radiation from the enclosure walls.

It has been verified experimentally that vibration coupling between the driver and the walls occurs primarily through the rigid mounting of the driver to the enclosure. Vibration-mounting the driver to the enclosure with some form of complaint suspension will significantly reduce the wall excitation, but it poses some difficult mechanical design problems. The natural frequency of the driver mounting has to be well below the acoustical output frequency. The mount has to seal the enclosure air tight and provide sufficient mechanical support for the driver. Another approach would be to enclose the box

Fig. 4. *Loudspeaker enclosure dimensions. As there is little stereo information below the 70Hz limit of the enclosures (left), a centre woofer covers the remaining range down to 25Hz (right).*



to which the driver is mounted by a second box avoiding all rigid coupling between the two.

For the design described here a single, totally enclosed box was chosen, Fig. 4. The B110 driver was attached to it with soft rubber grommets in the four mounting holes of the basket and the sealing foam gasket barely compressed. Comparing this to a directly mounted driver by tapping on either basket indicates a significant reduction in coupling to the box. Some further investigation of this subject is in progress.

The relatively small size for the B110/T27 assembly has the advantage that the internal air volume resonances occur at high frequencies where they can be damped effectively with wool filling. The lowest cavity resonance occurs at 600Hz, the next ones at 800, 1000, 1200Hz etc. The resonances are measured easily with a small omnidirectional electret microphone protruding into the box and applying a sweep signal to the B110. Filling the boxes rather tightly with long-fibre wool attenuates all the resonances to a smooth frequency response inside the box and at the outside cone surface.

The boxes are constructed out of 20mm mohagony boards. The panels are quite stiff. The lowest panel resonance was observed at 430Hz using a magnetic phono pickup in a makeshift tonearm as vibration transducer. A 430Hz tone was measured to decay 40dB in 120msec after the electrical signal was removed. This indicates that the resonance was a Q of 36 according to $0.7f_R T_{40dB}$.

The Q is quite high and the decay time is long. By applying approximately two litres of roof patching tar to the inside of the box the resonant frequency was lowered to 300Hz due to the added mass to the panels. The decay time decreased to 40ms, corresponding to a Q of 8.4. While this treatment proved effective it does point out the problem that a small panel can have a high Q which is difficult to dampen because of its high stiffness and large mass. Better results might be expected from a thin plywood construction, with thick layers of damping material to attenuate resonances and to reduce the direct transmission of sound from the inside of the box.[4]. Ideally of course the panels should not be excited in their resonances at all, neither from the air pressure changes inside the box nor from the mechanical coupling to the driver.

A small box presents a small obstacle to omnidirectional sound propagation. This is a clearly audible advantage when properly placed in the room. As the box is only marginally wider than the B110 driver it can be assumed that the radiation pattern for a piston at the end of a long tube is an adequate first-order approximation to its sound dispersion, Fig. 1. The T27 tweeter is mounted as closed as possible to the B110. At the crossover frequency of 3kHz the spacing corresponds to a distance of one wavelength. In the vertical plane therefore the radiation pattern at the crossover frequency should follow the previously discussed behaviour of two drivers contributing equally, Fig. 3b.

Enclosure design objectives

- Narrow frontal area for optimum horizontal dispersion; tweeter mounted directly above the mid-range unit.
- Box edges rounded to reduce scattering.
- Drivers mounted to minimize direct transmission of vibration.
- Air cavity resonances attenuated with filling materials to eliminate delayed re-transmission through cone.

Ideally the sound from the T27 should be able to disperse freely in all directions, but because of the large width of the front panel relative to the cone diameter a wave emanating from the cone will initially be blocked by the panel and then encounter an abrupt transition where it ends, Fig. 5. A second wave is generated at the cabinet edge which will interfere with the original wave. If a pulse is radiated from the T27 then a secondary pulse of lower amplitude is generated at a time $t = d/c = 260\mu s$ later; the original pulse is smeared out. This scattering of sound should be avoided by eliminating sharp discontinuities through bevelling of the cabinet edges.[5].

Figure 6 shows the on-axis amplitude response of a small driver mounted in the center of a cube and of a sphere.[6] Clearly the sphere with its surface gradually receding from the source produces a much smoother response than the cube with its sharp edges. Therefore the larger box relative to the driver the more closely should it approach the shape of a sphere. It follows that the midrange/tweeter enclosures might be further improved by reducing their size and a more curved driver mounting area. Papier maché, cardboard or epoxy fibreglass with damping materials applied to it rather than wood might be more suitable

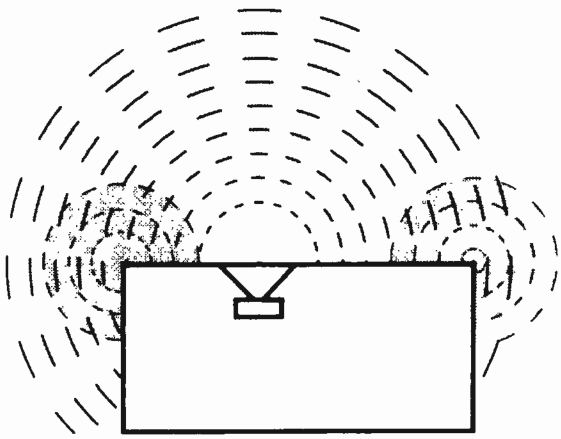


Fig. 5. *Sound scattering from the sharp corners of a loudspeaker enclosure producing a smeared out transient behaviour of the system.*

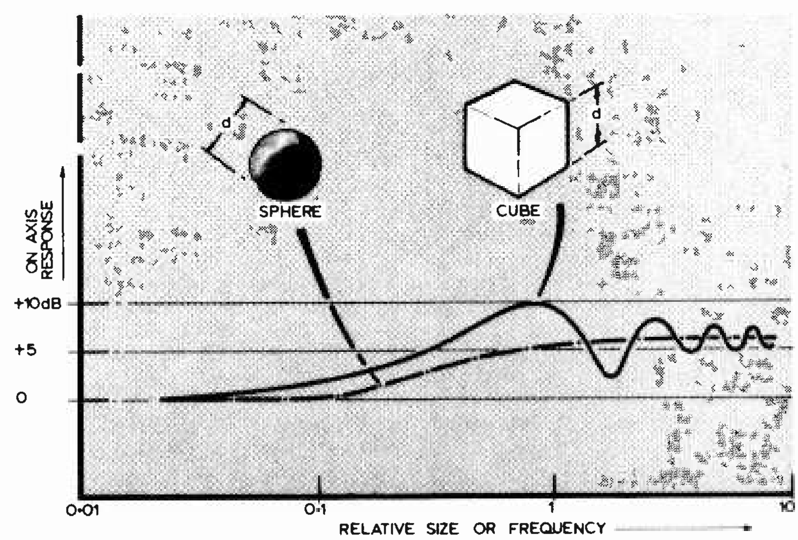


Fig. 6. *On-axis frequency response of a point source mounted in different enclosures shows smoother response of sphere (after ref. 6).*

materials for the unconventional contours of such an enclosure.

For the given design the frequency range extends down to 70Hz where the B110 has its enclosed resonance. As there is little meaningful stereo information below this frequency a single centre-channel woofer box can cover the remaining range down to 25Hz, Fig. 4. This is built with internal bracing to stiffen it and to push panel resonances to frequencies above 70Hz. In addition 25mm- thick heavy felt is glued to all panels to reduce direct transmission. The box is loosely fitted with long-fibre wool.

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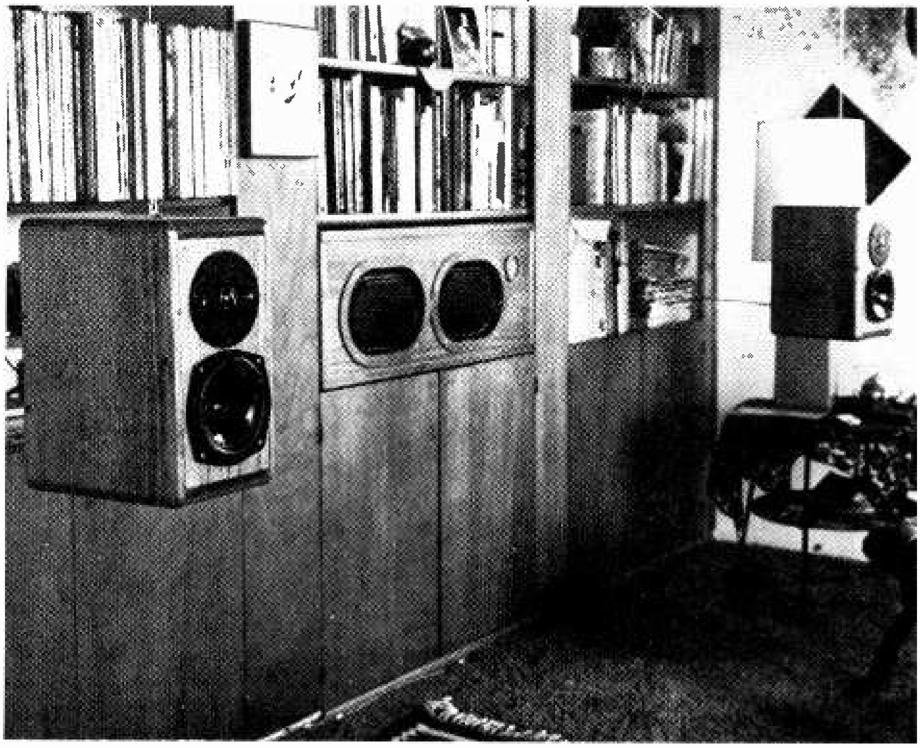
6. Muller, G. G., Black, R. & Davis, T. E., Diffraction produced by cylindrical and cubical obstacles and by circular and square plates, *JASA*, vol. 10, July 1938, p.6 ☐



This article will be concluded with active crossover and equalizer designs and a discussion of speaker location.

Current broadcasting techniques "a hybrid rat-bag of improvisation"

TV engineers may propose a 1875-line tv service for Band III when 405 line transmissions are no longer needed, but it seems unlikely that the frequencies will be used for television, according to Dr Boris Townsend, head of the IBA's engineering information service. Speaking at the first of the three IBA lectures on tomorrow's broadcasting, he said, "I expect that we shall lose the use of these frequencies for television, which will be a pity, for band III has excellent propagation characteristics for our purposes. Nevertheless, I expect the engineers to put up a case for a new television service in the band using the latest advance in engineering terms: for example, better definition, 1875 scanning lines, larger pictures, tone gradation scales tailored to human physiology and, I hope, a certain technical flexibility to make television more helpful in teaching the handicapped child with abnormal physiology."

Speaking of the current state of broadcasting technology he said, "We are stuck with old-fashioned television transmissions which are a hybrid rat-bag of improvisation and almost incompatible technologies, which carry a quite unnecesssary amount of repetitive data yet still reproduce inadequate detail, inadequate contrast, inadequate colour gamut, and pictures which lack most of the attributes of real life. It is a system which gives the viewer and listener little choice and to which any graduate tea-boy engineer could now suggest improvement. What are we going to do about it?

"In the next few years, not much. We did something about our equally outmoded radio transmissions, and duplicated our use of precious wavelengths with our stereo f.m. transmissions using circular polarisation. These transmissions are glorious. What happened? Nothing. The public ignored them. Everyone still listens on antiquated amplitude-modulation receivers — statistically, so to speak."

Dr Townsend warned of the problems technology could bring if it were directed solely at increasing efficiency and reducing costs: "Perhaps unemployment *is* a more important matter than television automation. If it is, then should design engineers be devoting their thinking to making this public service of television an under-capitalised, more labour-intensive operation? It is a naive thought. But the basic dilemma is a matter of concern to many engineers." The problem of deciding among the bewildering array of technical possibilities "is not a problem which should be left to engineers." They were moving so fast in some areas, and not at all in others, "that we may be unable to prevent some massive mistakes on their part unless we speak quickly, and precisely, and regularly with them."

In questions after his speech he said of surround sound, "We can do it. Whether people want it is another matter, whether people will like it when they have got it. I think they will like it, but whether they will think it worth the trouble and the cost I'm dubious." There were also problems of production, and engineers had to get used to it to make the best use of the new forms of drama

Dr Townsend predicted that the changes at the transmission end of the broadcasting chain would be radical: "Engineers are making a two-pronged thrust forward. One is a miniaturisation of the analogue techniques which have been used in our studios since Savoy Place and Alexandra Palace, while the other is based . . . on digits." Both analogue and digital methods were dependent on micro-circuits. "The reduction in costs is staggering. An integrated circuit now costs about the same as an apple." Complex functions could be performed with devices that could be cheaply mass-produced, and circuits were getting, and would continue to get, even smaller, and so even more complex. While mechanisms grew more and more expensive, electronics became cheaper: "Compare the £70 monochrome television receiver, of dubious performance, which sold in 1938, with its contemporary 1938 £100 small motor car; and then take today's large, bright, reliable monochrome television receiver, still at the same £70, and its contemporary £2,000 Mini. So," he added, "whenever we can replace mechanisms by electronics we shall."

Programme labelling for sound broadcasts

Electronic "labelling" of sound broadcast programmes is definitely on the way, according to a BBC spokesman, and the only problem is deciding the best way to do it. This technique (described by Duncan MacEwan in "Radio in the '80s" in the May 1977 issue) uses data signals associated with the broadcast signal to identify particular programmes or channels so that they can be automatically pre-selected at the receiver for, say, an evening's listening or recording purposes. An automatic "search tuning" receiver could be arranged to select programmes of a particular type. The labelling code signals could be transmitted on a subcarrier in or out of band or by frequency modulation of the a.m. carrier. ☐

Cassette tape programmer — 2

Quiz machine and modifications to the calculator

by Evert Olsson

IN QUIZ MODE questions are recorded by voice and after each question the correct answer is recorded in coded form by pushing the appropriate button on the calculator. On replay, i.e. running the quiz, S_2 is in the search position and the tape stops after each question. Selecting the correct answer on the keys makes the tape start again to replay the next question. The calculator display is covered during replay and also the keyboard functions if answers in a form other than figure-encoded are desired.

Comparisons of the answers from the key-board with the correct ones is carried out by ten transistors and resistors in the circuitry marked subunit. The correct answer is left in IC_1 until a matching code has been delivered by the keys. Each bit is compared in an exclusive-OR circuit consisting of two transistors, and all of the outputs are wire-ANDed so that all bits must be correct to make the common output high. Diode D_9 ensures that the comparison result is valid only when the clock oscillator is not running. A capacitor on the comparator output is necessary because the input signals from the matrix may have different fall times which could make the comparator output signal momentarily correct even if the wrong key has been pressed. When the correct answer is obtained the shift register is cleared via D_{43} and S_2 and the start flip-flop is set via D_{42}. The diodes are necessary to make sure that the register is not activated before the start flip-flop.

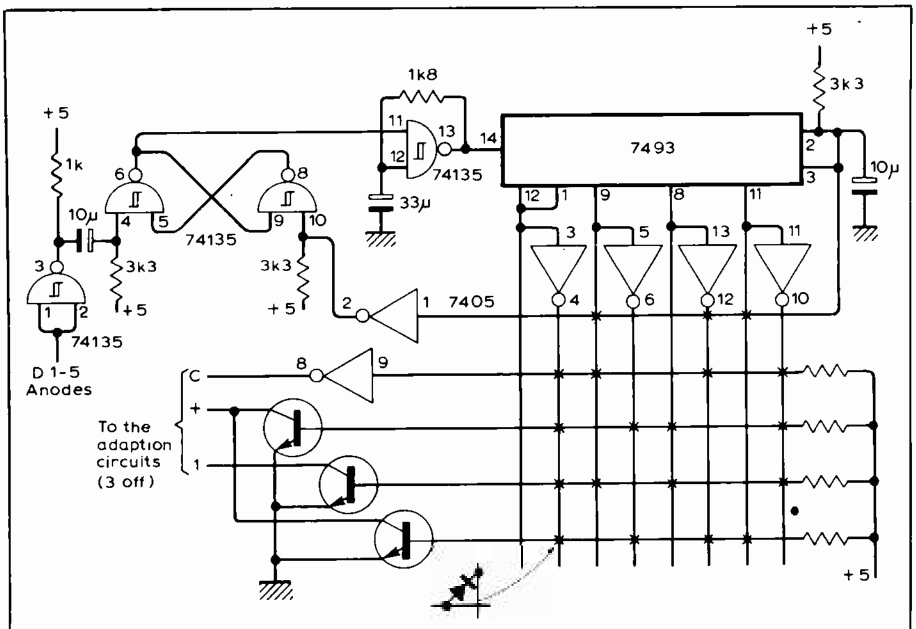


Fig. 5. *Answer counter. This circuit is connected to the calculator via three adaptation circuits.*

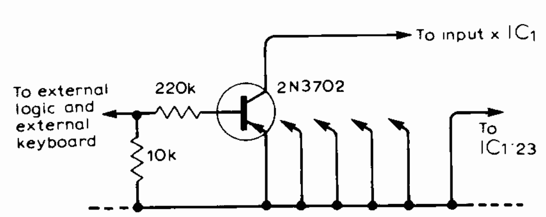


Fig. 6. *Adaptation circuits. Eighteen of these interface the logic to the calculator keys.*

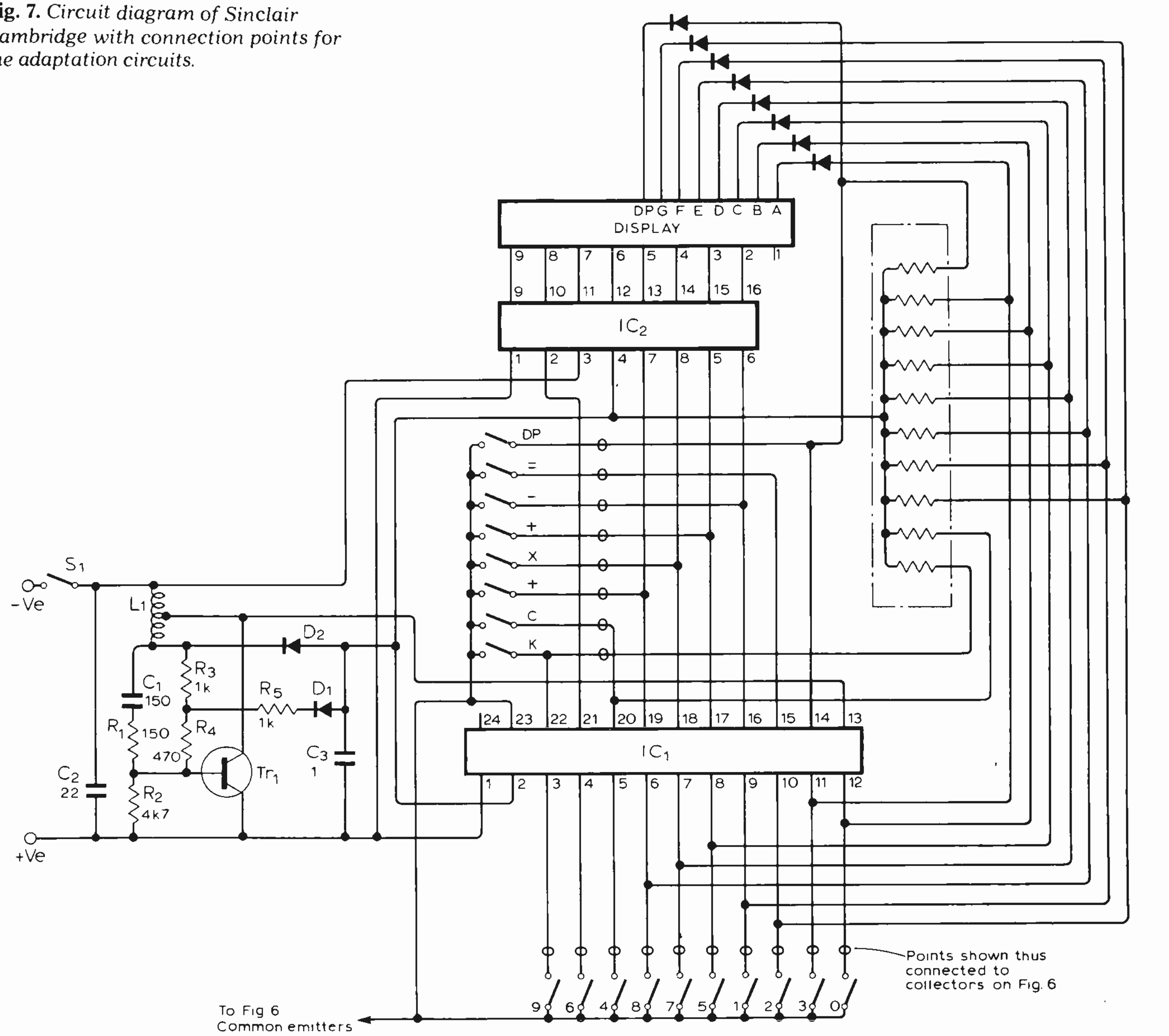
If only the quiz function is required, IC_2, IC_3 and diodes D_{22} to D_{39} can be omitted. In the quiz mode it is useful to count the number of answers, i.e. key depressions, and display them. This can be achieved by the addition of the circuit shown in Fig. 5. Unfortunately a simple addition of the key depressions, i.e. key 1 + key 1 + etc, cannot be used because the sequence is continuously interrupted by answers other than one. This circuit overcomes the problem by using the error correction facility of the calculator. If an incorrect figure is entered during a chain addition it may be corrected without losing the previous calculation. This is achieved by pushing the cancel button and entering the correct number. In Fig. 5 the circuit receives a pulse from D_1 to D_5 for every key depression. This clocks the counter whose outputs are decoded by a diode matrix. Outputs 2, 4, 6, and 8 drive three transistor switches which are in parallel with the calculator cancel, + and 1 keys. Therefore, every answer which is displayed on the calculator is cancelled and replaced by the addition of one. In this way every key depression advances the display by one. Using this system requires the calculator to be completely erased before the start of a quiz so that 1s are not added to a previous total. This circuit must also be disconnected when the programming function is used.

Adaptation circuits

In the Sinclair Cambridge the calculator levels are 0 and -14V so a total of 18 adaptation circuits are required to interface from the key switches to the t.t.l. logic described earlier, and to rectify the signal path from the external logic to the calculator l.s.i. circuit. Rectification is necessary because most of the keyboard input pins are also outputs to the multiplexed display. The circuit in Fig. 6 requires the calculator zero to be connected to the logic +5V and the calculator negative terminal to the t.t.l. 0V. If any of the 18 inputs are taken to a t.t.l. 0V the corresponding p.n.p. transistor is turned on.

Because of a space limitation in the calculator, it is advantageous to use a separate keyboard for the quiz machine. If this is adopted, all of the adaptation circuits can be wired outside the calculator. Also, other instructions can be added such as memory, jumps, and print.

Fig. 7. *Circuit diagram of Sinclair Cambridge with connection points for the adaptation circuits.*



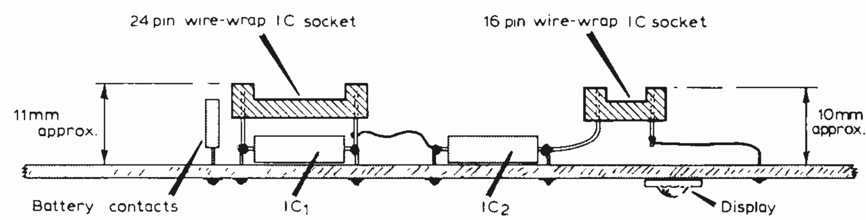


Fig. 8. *Calculator p.c.b. of Sinclair Cambridge.*

Modifications to the calculator

Connections to the Sinclair Cambridge can be made using 24 and 16 pin wire-wrap sockets as shown in Fig. 8. The larger socket is mounted and soldered "piggy-back" on IC_1 with all pins except for 21 cut so that the socket height becomes 11mm. Pin 21 is bent out and soldered to pin 3 of IC_2. Pins 2, 13 and 24 are not used. The resistor network may have to be removed while soldering pins 1 to 12 and if this is done they can be replaced with ⅛W types.

On the smaller socket, pins 9 to 16 are bent at right angles and soldered to the corresponding pins on IC_2. Pins 1 to 8 of the socket are connected to display inputs A to G and the decimal point with enamelled wire. Holes for connection to the d.i.l. sockets have to be made in the rear of the calculator case, suitable male plugs are Augat types 624-AG1 and 616-AG1. These plugs should be mounted on a piece of vero board together with the adaptation circuits. A lead from this board is then connected to the external keyboard and logic.

Although other calculators may be interfaced, the supply voltage, display, and inputs may differ.

Other programme sources

Once the adaptation circuits have been constructed, various programme sources can be used as long as the input pulses are long enough to pass the anti-bounce circuitry of the calculator. Fig. 9 shows a simple programme source which gives up to 15 steps. This can be used for simple but frequent calculations containing sequences or constants. Pause and finish may be programmed to allow the input of variables and the reading of results.

For the calculation of, for example, the cross sectional area of a round piece of wire using the cassette programme source the programme should be written as follows. The formula of $A = \pi.d^2/4$ is well known and does not need rearranging.

Constants and operations		**Spoken comments**
C.C.	double clear	Input wire diameter.
P	pause, tape started with acknowledge key	
=K	input diameter value as a constant	
C	clear constant not result	
× 3.1416		
÷ 4		Read out area.
P	pause — programme finished	

A second example is the calculation of component values in an active three-pole filter as shown in Fig. 10. The following equations are used:

$P = -2G/(3A+1)$ 1
$\quad = G(G(4A+1) + 3A+1)/(4A+1)(3A+1)^2$ 2
$R1 = (1-G^2)/(4A+1)(3A+1)^2$ 3
$A1 = (3-P^2)/3$ 4
$B1 = (2P^3-9P+27R1)/27$ 5
$\quad 1 = (B1)^2/4+(A1)^3/27$ 6
$S1 = {}^3\,1 - BB1/2$ 7
$S2 = -{}^3\,1 + BB1/2$ 8
$Y1 = S1 + S2$ 9
$X = Y1 - P/3$ 10
$Y = 1/2\,AX\,(G-(3A+1)X)$ 11
$Z = 2\,(G-(3A+1)X)$ 12
$C3 = X/R\,2\pi F$ 13
$C2 = Y/R\,2\pi F$ 14
$C1 = Z/R\,2\pi F$ 15

For the input variables, A is the pass-band gain (A = R4/2R), G is a constant which is dependent on whether the three-pole section is used alone or cascaded to make a higher-order filter. For three poles $G = 2$, for six poles $G = 2.3006$ and 1.5412 respectively. F is the 3dB cut-off frequency and R is the resistor value in Fig. 10. The values of C_1, C_2 and C_3 are output variables and all of the others are temporary or auxiliary variables. Other auxiliary variables are created in the programme and are given arbitrary names. The programme sequence follows the order of the equations. It should be noted that in 7 and 8 the third root may be negative in which case the negative sign should be carried along. Before equation 10 is evaluated the expression $(B1)^2/4 + (A1)^3/27 \geqslant 0$ should be checked to determine that the final solution will be real.

The programme shown in the table contains about 400 steps which is the practical limit with comments for one side of a cassette. For a complex programme such as this it is necessary to keep a table with each execution of the auxiliary variables. Their names should be noted so that they can be found for later re-entry.

General programming considerations

When a programme like the one shown is to be written try to determine whether the intermediate results will be negative or too large/small for the display. Also, can a division by zero occur or are there any negative or imaginary roots. It is also necessary to known in detail the properties of the calculator. For example, negative numbers cannot be input directly on the Sinclair Cambridge but this can be overcome by inputting zero minus the number. This only works if the first number in a chain calculation is not preceeded by × or ÷. If it is preceeded by +, the zero is not needed. This procedure has been used in the programme example.

Fig. 11 shows a t.t.l. interface circuit for the digit drive pulses and the segment/decimal-point drive. The digit pulses are already t.t.l. compatible but it is advisable to use this circuit to limit the loading on IC_2. The voltage divider on the input is included to limit the

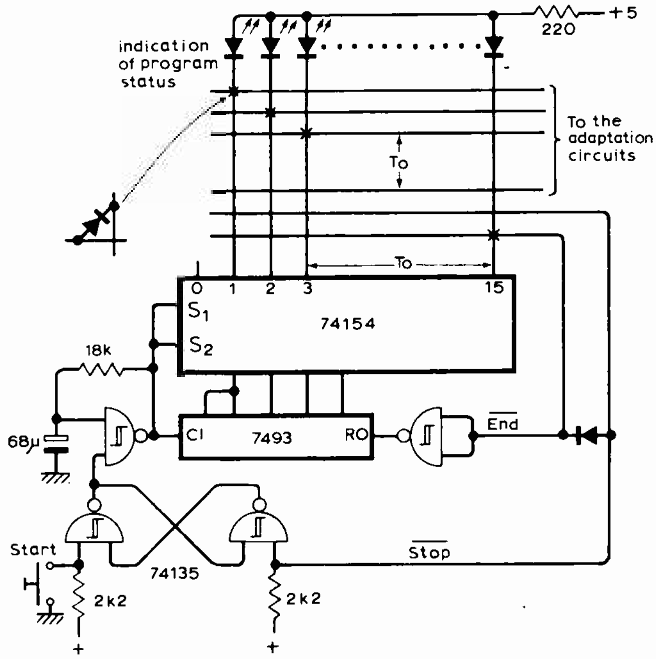


Fig. 9. *Programme source for up to 15 steps*

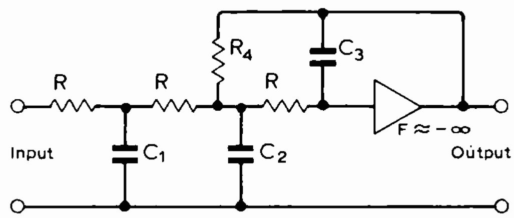


Fig. 10. *Active filter for programme example.*

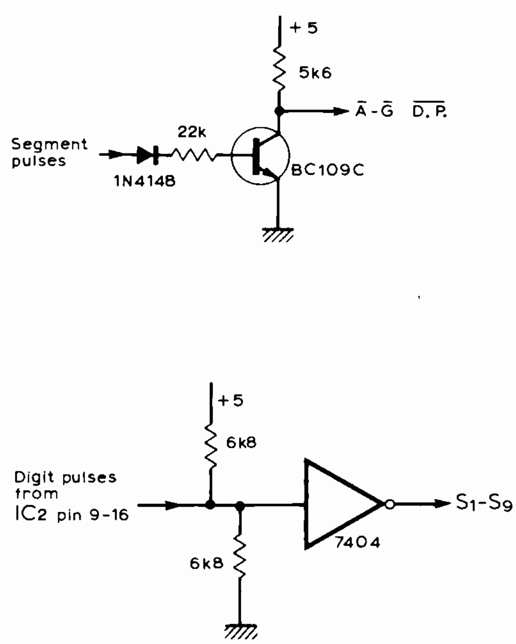


Fig. 11. *T.t.l. interface circuits*

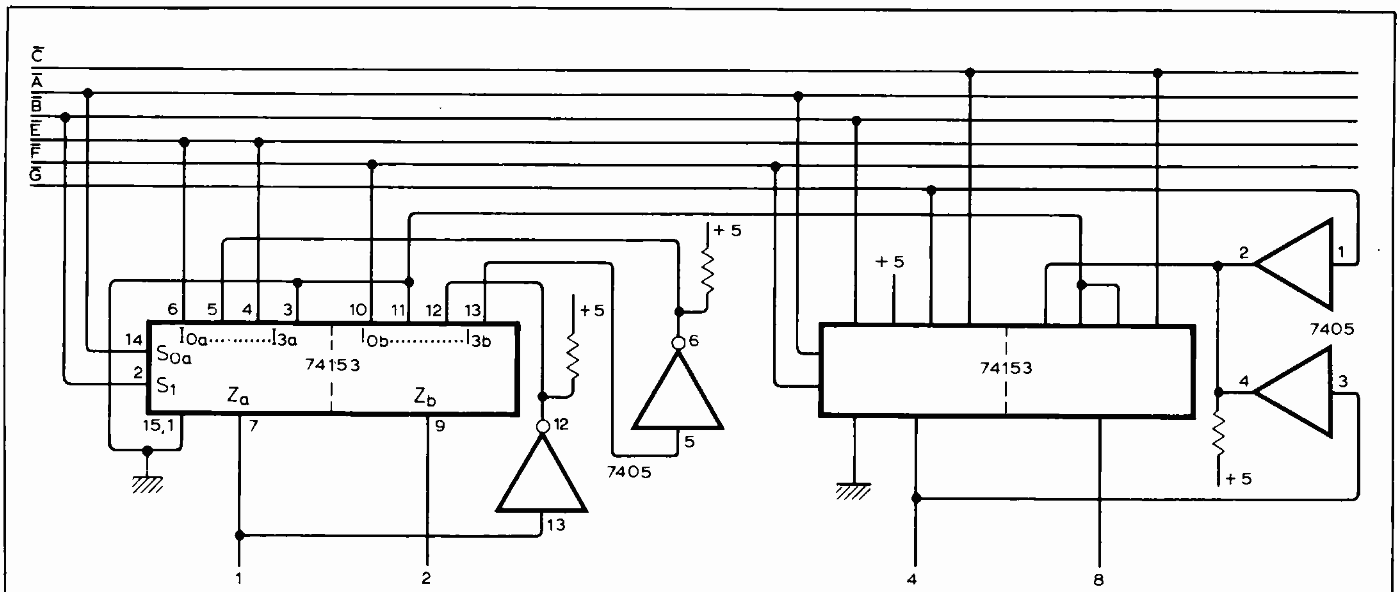


Fig. 12. *Seven-segment to b.c.d. converter.*

Constants and operations	Spoken Comments
CC	Input *A*
Pause × 3 + 1 = *K*	
2/C ×	Input *G*
Pause =	Read *P* change sign
Pause C C	Input *A*
Pause × 4 + 1 ×	Input *G*
Pause + 1 =	Read *Q*′
Pause C C	Input *A*
Pause × 3 +	Input *Q*′
Pause =	Read *Q*″
Pause C C	Input *A*
Pause × 4 + 1 −	Read *Q*‴
	Input *A*
Pause = *K* × C ×	Input *Q*‴
Pause =	Read Q_N
Pause CC	Input *G*
Pause ×	Input *Q*″
Pause/	Input Q_N
Pause =	Read *Q*
Pause C C	Input *G*
Pause = *K* ×	
C − 1/	Input Q_N
Pause =	Read *R*1 change sign
Pause C C	Input/*P*/
Pause = *K* × C	
/3−	Input *Q*
Pause =	Read *A*1 change sign
Pause C C O	Input *P* with sign (+ or −)
Pause = *K* × ×	
C/13.5 =	Read *B* 1′ with sign
Pause C C O	Input *P* with reversed sign
Pause ×	Input *Q*
Pause/3 +	Input *R*1 with sign
Pause +	Input *B*1′ with sign
Pause =	Read *B*1
Pause *K* ×	
C/4 =	Read *SQR*′
Pause C C O	Input *A*1 with sign
Pause = *K* × ×	
C/27 +	Input *SQR*′
Pause =	Read SQR_y Guess square root and input
Pause = *K*	Input SQR_y
Pause/ +C	
/2 = *K*	Input SQR_y
Pause/ +C	
/2=*K*	Input SQR_y
Pause/ +	
C/2=	Read *Q*1
Pause × 2 −	Input *B*1
Pause/2=	Read *S*1′ with sign
Pause C	Guess 3rd root and input
Pause=*K*	Input $\lvert S1\rvert$
Pause/ / + +	
C/3=*K*	Input $\lvert S1\rvert$
Pause/ / + +	
C/3=*K*	Input $\lvert S1\rvert$
Pause/ / + +	
C/3	Read *S*1 with same sign as *S*1′
Pause C	Input *B*1
Pause /2+	Input *Q*1
Pause =	Read *S*2 with sign
Pause C	Guess 3rd root of *S*2′ and input
Pause=*K*	Input $\lvert S2\rvert$
Pause/ / + +	
C/3=*K*	Input $\lvert S2\rvert$
Pause/ / + +	
C/3=*K*	Input $\lvert S2\rvert$
Pause/ / + +	
C/3=	Input *S*2 with opposite sign as *S*2′
Pause C C O	Input *S*2 with sign
Pause	Input *S*1 with sign
Pause=	Read *Y*1
Pause C	Input *B*1
Pause=*K*×C	Read IMTEST′
Pause C O	Input *A*1 with sign
Pause=*K*× ×	
C/27+	Input IMTEST′
Pause=	If result <0 no real solution
Pause C C O	Input *P* changed sign
Pause/3+	Input *Y* 1 with sign
Pause=	Read *X*
Pause ×	Input *A*
Pause×2=	Read 2 *AX*
Pause×1.5=	Read 3 *AX*
Pause C	Input *G*
Pause−	Input *X*
Pause−	Input 3 *AX*
Pause×	Input 2 *AX*
Pause=*K*/ /	Read *Y*
Pause C	Input 3 *AX*
Pause+	Input *X*
Pause−	Input *G*
Pause×2=	Read *Z* change sign
Pause C	
355/113[x]	
×2×	Input *F*
Pause×	Input *R*
Pause=*K*	Input *X*
Pause/	Read *C*3
	Input *Y*
Pause/	*Read C2*
	Input *Z*
Pause/	Read *C*1
Pause	END
Pause	

([x] is approximation of π)

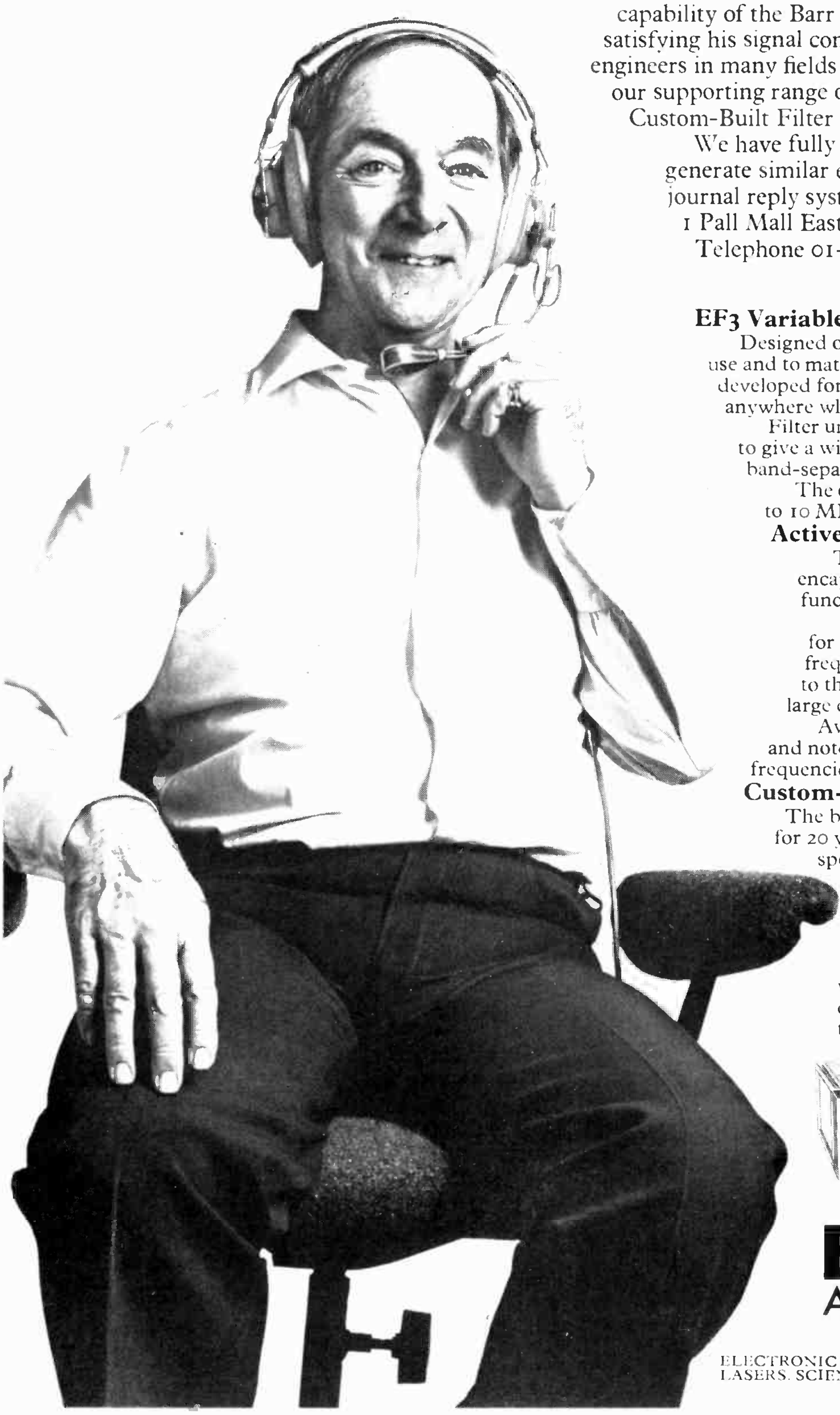
reverse voltage on the l.e.ds. One of the output signals S1 to S8 will be high when the corresponding digit in the calculator is on. For converting the 7-segment code to b.c.d. the circuit in Fig. 12 is used. Note that the Cambridge uses six segments for 6 and 9, whereas some others use only 5. In such cases the circuit in Fig. 12 will not fit directly. The 74153 is used as a double four-way selector where inputs S_0 and S_1 control the switching. A minus sign is encoded as the b.c.d. value 12, and no digit gives the b.c.d. value 0. This may be useful with a calculator that suppresses leading or trailing zeroes. ☐

Into the air with no pilot

The pilot light on your stereo tuner may have been misleading you since February 27. On that day the BBC started to radiate continuous pilot tone on Radios 1/2 and 3. "More than 90% of programmes in Radio 2 and Radio 3 v.h.f. are now transmitted in stereo," said a BBC statement. "At the moment the practice is to switch the pilot tone on and off, according to whether or not a stereophonic programme is being transmitted. With some receivers a loud click is produced whenever the pilot tone is switched on or off. To avoid this inconvenience it has now been decided to radiate the pilot tone continuously on Radios 1/2 and Radio 3." Listeners who wanted to know which programmes were in stereo could consult *Radio Times*.

It seems a strange decision since the click is no worse than that most amplifiers make when they are switched off, but at least the high stereo content of the two stations makes the pilot light less misleading than on London's news station LBC. ☐

At the end of the test session the communications engineer sang the praises of our filters.



"What performance" he said, referring to the capability of the Barr & Stroud EF3 Filter System in satisfying his signal conditioning needs. He and other engineers in many fields are equally complimentary about our supporting range of Active Filter Modules and our Custom-Built Filter Service.

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WW—051 FOR FURTHER DETAILS

Stereo power and phase meter

Power output measurements from 1 mW to 400W in a variable load

by C. T. Hodgson

A twin meter instrument for simultaneous output power and phase measurements on the two channels of an audio frequency stereo system. Power measurements in the range 1 mW to 400 watts per channel can be made by feeding switched internal resistances. The instrument is easily calibrated using either a.c. or d.c. For sinusoidal inputs the meter readings are accurately related to mean power.

OUTPUT POWER is generally one of the first specifications of an audio system to be looked for by the average hi-fi enthusiast. Power levels of 100 watts per channel, and more, are commonplace in present-day hi-fi systems. But there are many variations in power rating quoted in descriptions of audio amplifiers; for example, average power, peak power, music power, continuous power, mean power, and another power rating that is being increasingly used nowadays called r.m.s. power. This is absolute nonsense, of course, like talking about a miniature watt, and a number of authorities, for example Baxandall[1], have aired their strong objections to its continued use. It is important, therefore, to state clearly exactly which units of power this instrument actually measures. A moving coil loudspeaker is far from being purely resistive over the whole audio frequency spectrum, if indeed at any frequency but, unless otherwise stated, it is ordinarily understood that the loading of an amplifier under laboratory tests is predominantly resistive.

In a circuit consisting only of a simple resistance the power in watts is given by the expression I^2R where I is the d.c. or r.m.s. value of the current; this is the mean power. This instrument uses an almost pure resistance to load the amplifier under test and the power it indicates is relative to mean power. Some authorities contend that, where peaky signals are involved, such as noise (and music, in general, can be considered as noise by this definition), there is some justification for an alternative standard unit of power. Whilst this may be true in certain very special circumstances, in the author's opinion the specification of mean power in the established way is more valuable and more easily measured for direct

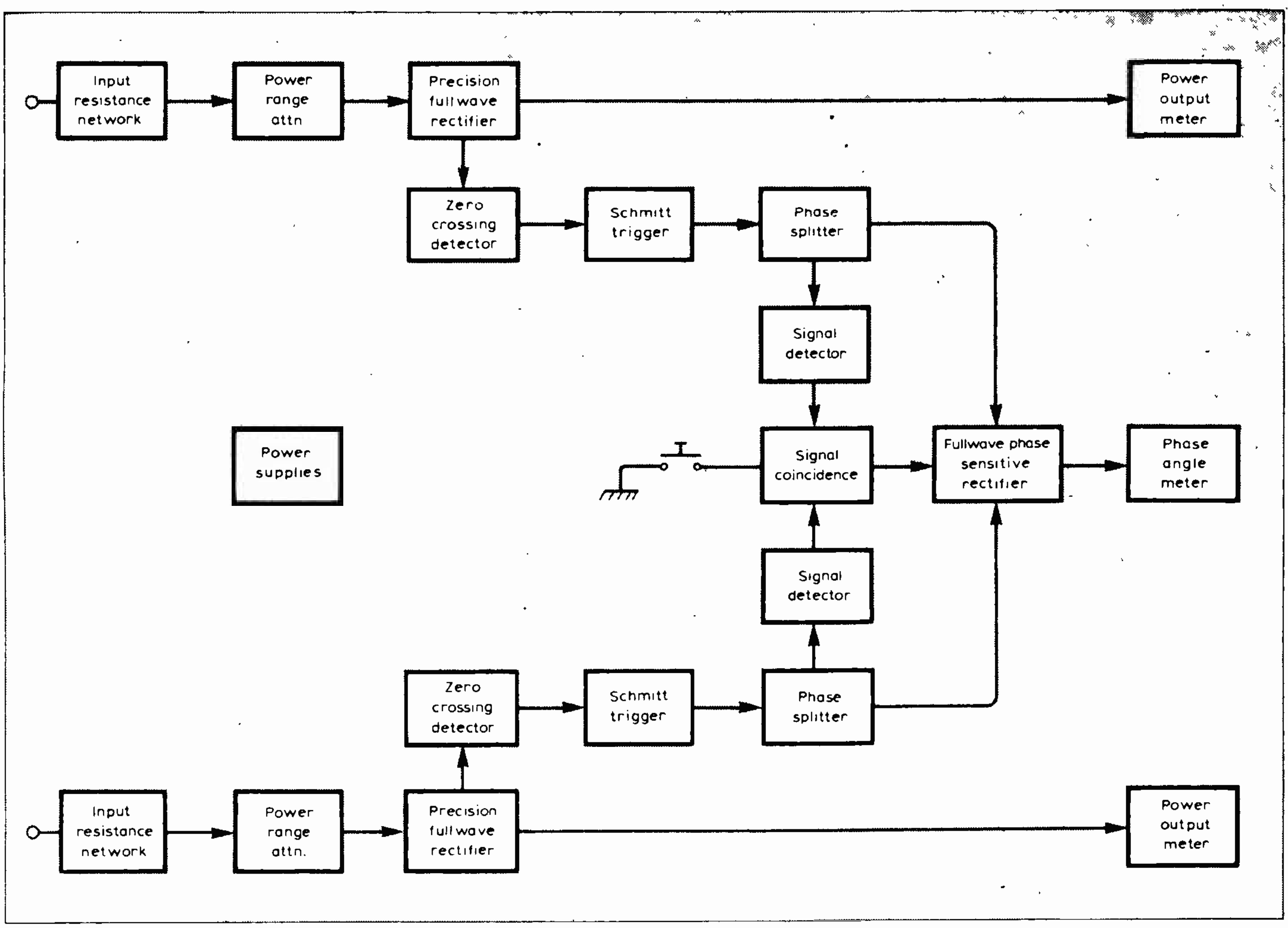


Fig. 1. *Block diagram of complete instrument.*

comparison of systems. Measurement of absolute power by the classical method of determining its thermal or chemical effect is inconvenient in audio engineering practice to say the least.

In this instrument the value of the load resistance is first selected by a switch from a range of built-in commonly used values. The same switch unit selects a tap on the resistor such that the voltage output at the tapping point is the same for the five values of load resistance. This voltage is applied to a precision rectifier circuit through an attenuator calibrated in mean power: 1mW to 100 watts in six decade steps. The rectifier therefore works only over a restricted range of voltages. After rectification the unidirectional half sine-waves are applied directly to a moving coil volt-meter which reads the average value, $2/\pi$ times the maximum value. The meter is actually calibrated in dB, where 0dB is at the centre of the scale and corresponds to the selected value of power on the power range selector switch. A standard VU meter could also be used since these are calibrated in a similar way; the only difference is the percentage f.s.d. for a given power level. This is far from being an absolute method of power measurement, but the accuracy on pure sine-waves or square-waves (and d.c. of course) is excellent and the presentation of power is direct and extremely convenient. It is subject to some degree of error in the presence of waveform distortion and figures are given in the text for values of 2nd and 3rd harmonic distortion up to 50%. Errors for more realistic values of distortion are too small to read on the meters.

The 3dB bandwidth of the amplifier extends to over 200 kHz and is flat from zero to around 30kHz. The twin-channel capability, like that of a double-beam oscilloscope, enables direct comparison of stereo amplifier channel characteristics such as frequency response and output power, etc., to be observed over the whole range of audio frequencies. The inclusion of a precision phase meter is primarily for circuit research and development work. The phase relationship between the two channels from 5Hz to 50kHz is continuously presented in direct form, and the combination of three panel meters is useful for setting-up stereo and quadrophonic systems and for the purpose of demonstration.

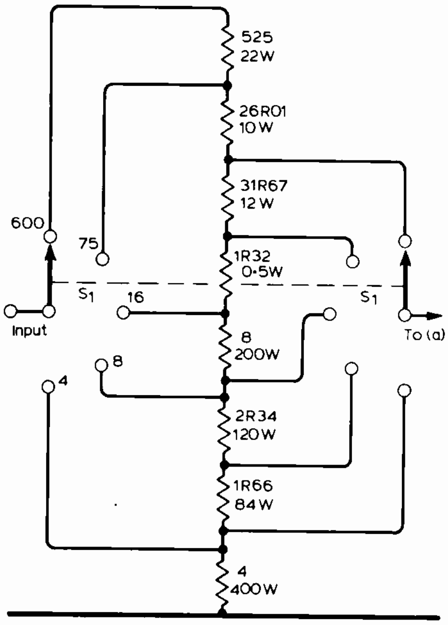


Fig. 2. *Input resistance switching arrangement in its basic form.*

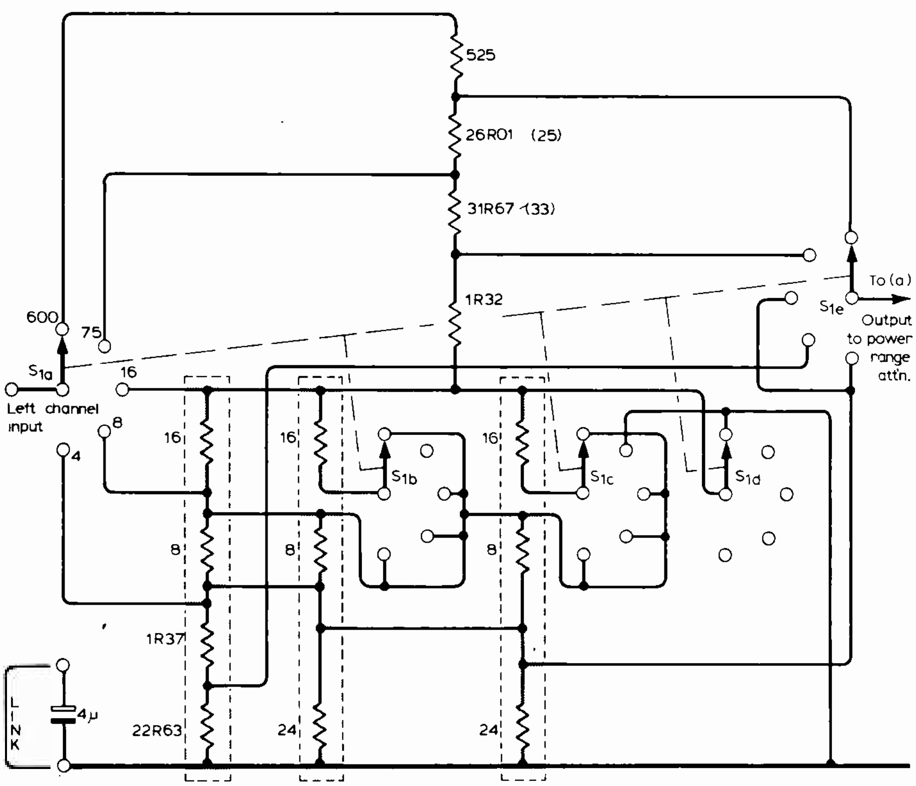


Fig. 3. *Practical arrangement for switching input resistance.*

Circuit design

Load selector. There are five fixed values of input resistance, 4, 8, 16, 75 and 600 ohms. The three lower values are those most commonly used in audio equipment for the British market as well as many other countries whilst the other two are well established values for attenuating networks and source impedances for test gear. The input impedance selector switch has three separate functions apart from the twin channel function; firstly it selects the desired value of load resistance, secondly it controls the distribution of power within the load and thirdly it taps the load network to provide the same output voltage, for a given output power, for any of the five load resistances.

The basic resistance network is shown in Fig. 2. The high-power loads for the three lower resistance values are constructed from commercially available electric fire elements. This is a very cheap and practical method of constructing high-wattage resistors, since any non-standard value can be wound and power can be spread evenly over a large area. The length/diameter ratio of the resistance coils is such that the inductance is small. The switching arrangement of the sections and the close screening provided by the heat sink and mounting rods all help to minimise the inductive reactance. There are three 1kW bars for each channel, making six in all. The heat sink is a prefabricated structure of aluminium alloy.

1kW bar elements, for a 240V supply, have a nominal resistance of 55 ohms. They are rewound, with the original wire, to a value of 48 ohms, in three sections of 8, 16 and 24 ohms. One element in each triple has an additional tap on the 24 ohm section, but all bars could incorporate this tap, if desired for the purpose of standardization. It is unimportant which bar is additionally tapped: indeed all three taps could be connected together in the interests of symmetry. The input impedance selector switch connects the sections in various series-parallel arrangements. For example, each 4 ohm load consists of six parallel paths of 24 ohms, as in Fig. 3, so that the heat generated is evenly spread within the heat sink. Each bar is supported on a 0.25in diameter aluminium alloy rod which effectively conducts heat to the cabinet metalwork. The effectiveness of this arrangement is such that the temperature rise inside the cabinet is approximately 0.12°C/watt; this could be further improved by anodising the sink black, but this has not been done on the prototype. On the two higher resistance ranges (75 and 600 ohms) the power handling capacity is rather lower: using the components specified, 25 watts can be safely handled on both of these ranges.

Power range selector. There are six preselected values of output power, from 1mW to 100W in 10dB steps, for which the output meter reads 0dB. If the power meter has 0dB as its centre calibration, the full scale deflection on the highest range is +6dB, corresponding to 400 watts per channel. If standard VU meters are used then full scale deflection will be restricted to 200 watts per channel. Using external loads as power shunts in addition to the internal chain of switched resistors can extend the range of power measurements to any desired value.

The power range selector takes the form of a switched attenuator, connected across the output terminals of the input load resistance, see Fig. 4. The total resistance value of the attenuator is 68.89kΩ, so that errors in power measurement and input resistance caused through circuit loading by the attenuator are negligible. For simplicity, only single, standard 1% values of resistance in the E12 range are used in the attenuator, but the errors in attenuation are sufficiently small to make this a most practical arrangement. Output loading in this application is the impedance of the non-inverting input of an operational amplifier and it is sufficiently high to cause negligible error.

Precision rectifier. A number of circuit configurations have been published for minimising the effect of non-linearity of diode I_a/V_a characteristics by incorporating them in the feedback path of a high-gain amplifier. One basic arrangement is simply to connect a diode bridge rectifier in the feedback loop of an operational amplifier and feed a moving-coil meter directly from the common-polarity terminals. Such an arrangement works extremely well in practice, its main drawback being that

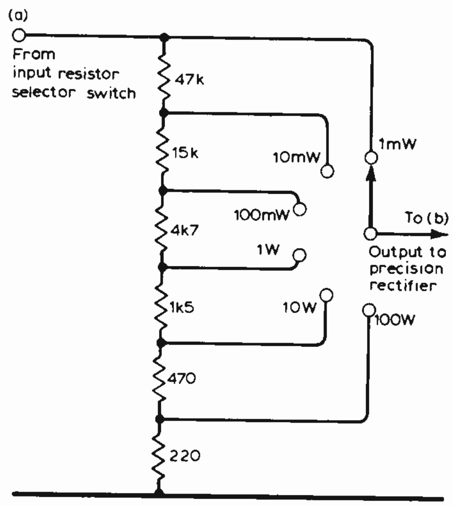


Fig. 4. *Range switch, preferably using 1% resistors.*

neither of the meter terminals can be grounded. Alternative arrangements, using an additional operational amplifier to deal with the positive and negative halves of the input waveform separately, do not have this defect. There is little difference in the performance of any one of them but the arrangement described by Mann[2] is used in this instrument because it is probably the simplest to construct and very easily balanced, an important feature in the present application. The output impedance is low, it has one output terminal grounded and therefore it can be used to drive external recording instruments if desired.

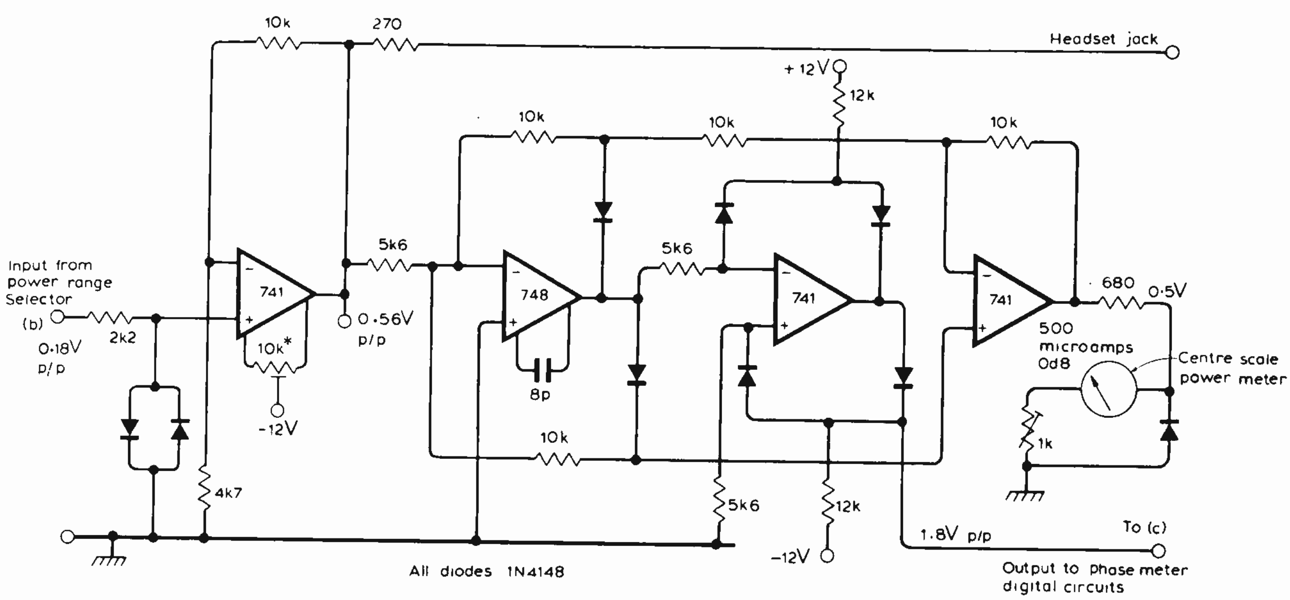
The circuit diagram of the complete rectifier is shown in Fig. 5. For sine-wave input, the output waveform consists of almost perfect, unidirectional, half sine-waves. The average value of the output voltage is therefore 0.637

Fig.5. *Precision full-wave rectifier circuit (748) and zero-crossing detector. The nulling pot. on the first 741 sets the correct balance in the rectifier for meter zero (power).*

times the peak value. A moving-coil voltmeter responds linearly to the average voltage but the scale can be calibrated in any desired units, and in this application the units are dB referred to any one of the six standard power values selected by the power range selector. Thus, on the lowest range 0dB corresponds to 1mW in any of the selected values of load resistance, and on the highest power range it corresponds to 100 watts. The performance figures of an amplifier are so much more easily compared with the specification by this type of presentation. It is not intended as a substitute for an oscilloscope but rather to enable one to reserve the oscilloscope for examination of waveforms in other parts of the circuit whilst continuously monitoring the output power.

Phase-angle meter. Like the full wave rectifier the phase meter, seen in Fig. 6, is also a precision circuit. The principle of operation is well known but the circuit arrangement used in this instrument embodies a number of novel features. The two input signals are first converted into square waves, paying particular attention to the preservation of the 1:1 mark-space ratio over the range of input levels. If the square-waves are simply added by a NAND gate, the output consists of a varying duty-cycle pulse of constant amplitude. The average d.c. output is directly proportional to the duty-cycle ratio, and hence phase angle, but in this simple arrangement the duty-cycle is only 25% for a 90° phase angle. Considerable smoothing is needed to obtain a steady meter indication at low audio frequencies.

The circuit used in this instrument operates in push-pull and full-wave addition is employed. In this way the output for signals in-phase or out-of-phase is d.c. and can be used down to fractional cycle signals. At 90° phase difference the output is a square wave



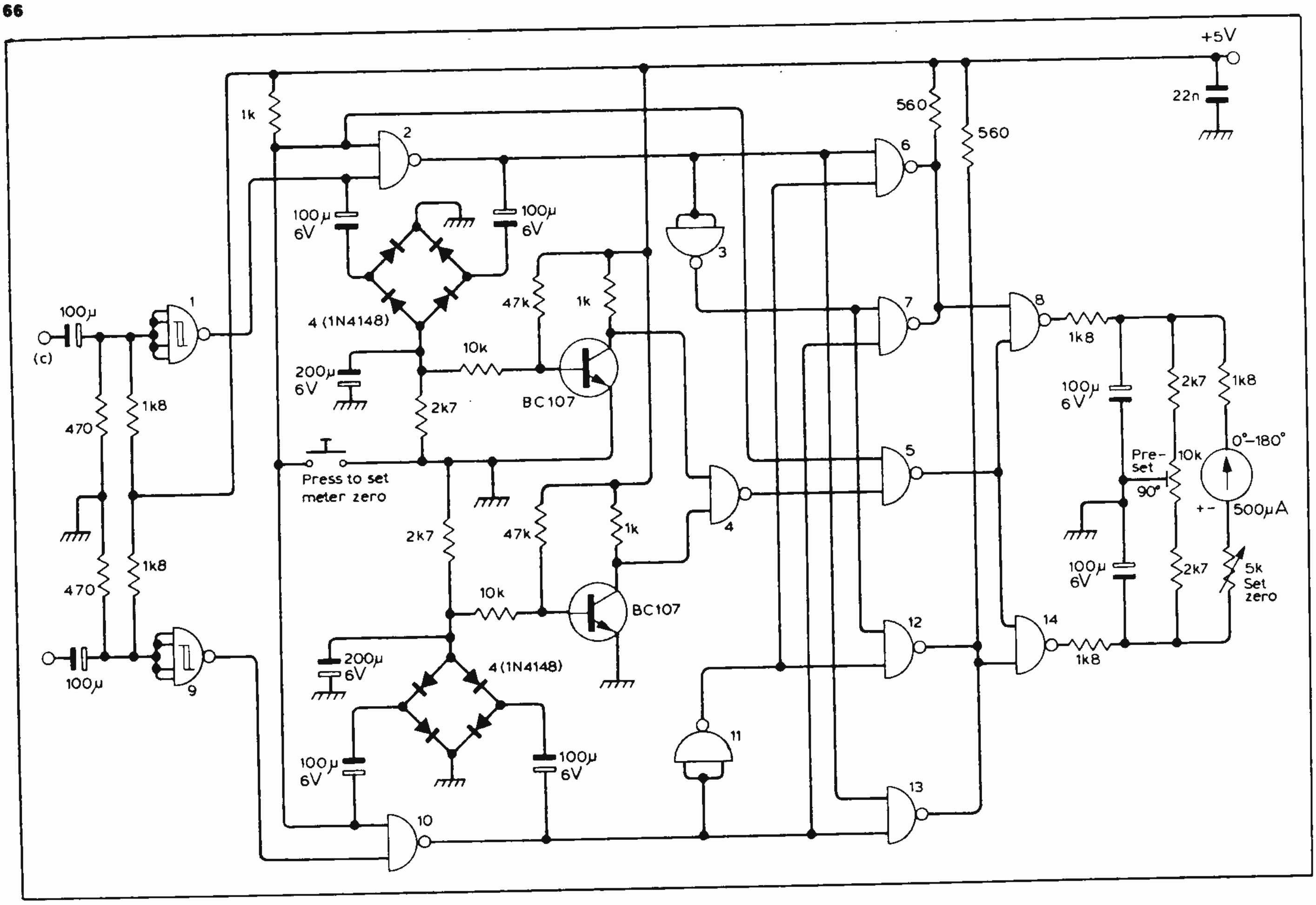


Fig. 6. *Phase meter, fed by zero-crossing detector in Fig. 5.*

at twice the frequency of the input waveform. This is the worst condition and, with a modest degree of smoothing, the system is very effective at frequencies well below 10Hz. The precision depends entirely on the effectiveness of the squaring circuits. Signals from the power range selector switch are in the range 0.057 to 0.36 volts peak/peak (corresponding to 0.18 volts −10dB and +6dB respectively) and perfect squaring has to be achieved only over this restricted range. There are three stages in this operation; firstly the open loop gain of the 748 precision full wave rectifier is used as the first stage of a zero crossing detector. This is followed by a second zero crossing detector designed to drive an integrated-circuit Schmitt trigger, IC_1 in Fig. 6. A NAND gate, IC_2, provides phase-inverted square waves to that, after full-wave rectification, d.c. is obtained. The d.c. output from each signal detector is fed to a NAND gate, IC_4, which switches on the phase sensitive rectifier only when two signals are present.

A second NAND gate in each channel, IC_3 and IC_{11}, provides the bi-phase drive to the phase-conscious rectifier, which uses four open-collector NAND gates connected in push-pull pairs; one pair for each channel sharing a common load resistance. The electronic switching of the meter circuit enables a test condition for 0° to be generated, so that the meter series resistance (5k Ω) can be adjusted to make the directly calibrated meter read accordingly. A simple method of checking that the phase meter is operating correctly is to inject a signal into one channel using the 600 ohm range and to feed the other channel through a capacitor of known value. The input frequency for any phase angle can then be calculated—tan $\theta = X_c/R$, and for a 45° check, $\omega RC = 1$. Using a 0.1μF capacitor, 45° corresponds to a frequency of 2653Hz. The same test condition can be used to verify the independence of the indicated phase angle on the input power over the range f.s.d. to −30dB on the output power meters.

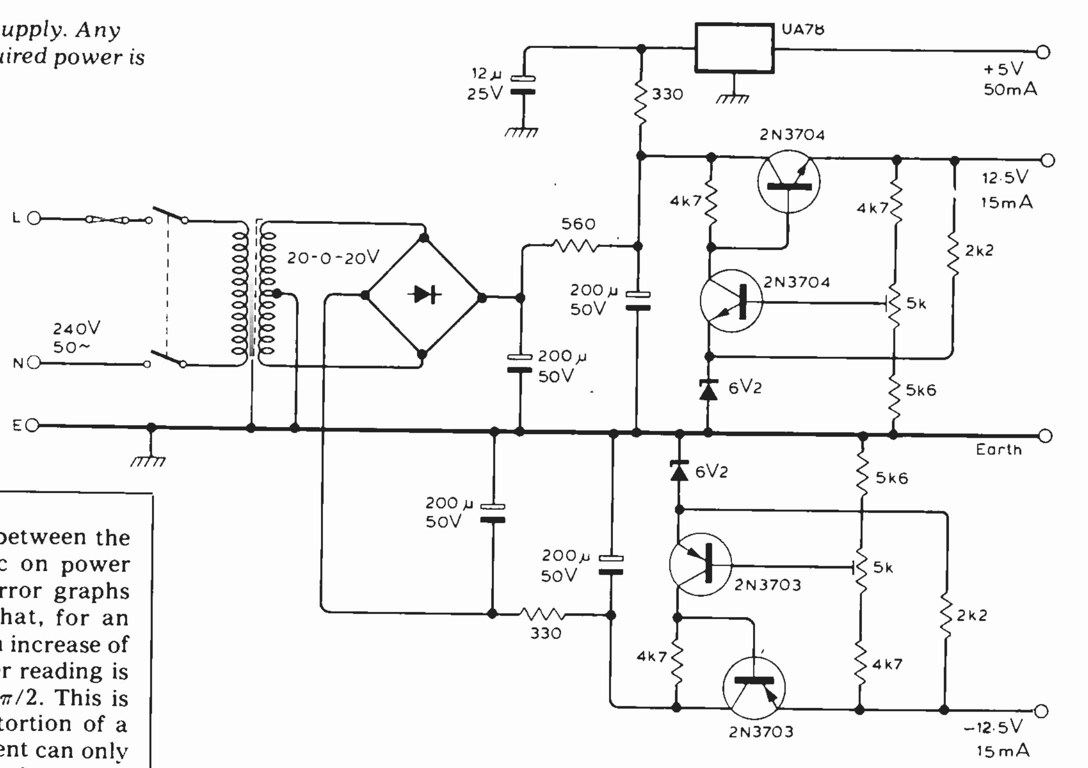
The phase indicating meter is a centre-zero (pointing) movement, actually marked 90° on the scale. A preset potentiometer (10kΩ) connected across the meter circuit enables the circuit d.c. conditions to be balanced at this point. This is an unusual arrangement and may need some clarification. On connexion to a stereo system one wants to know the phasing of the output signals, that is, whether they are in-phase or out-of-phase, and so the meter indication should be unambiguous. A centre zero (reading) meter with full-scale indications of ±90° would be meaningless in this application. For instant verification that a stereo pick-up, microphones or tape recorder heads are correctly phased, two lamp indicators could be used instead of an expensive meter. This is a simple modification since the output at 0° and 180° is d.c. of opposite polarity.

Following education at Hull Technical College and after a brief period as a sea-going wireless operator the author entered the Civil Service, joining Sir Robert Watson-Watt's team at Bawdsey (Radar) research station one year before World War two. Until early 1942 he worked on antennas, receiver installation and calibration of the original chain of radar (CH) stations in the UK. He moved with Telecommunications Research Establishment (TRE, now RSRE) to Malvern in early 1942, where he worked, almost exclusively, on the development of low-noise i.f. amplifiers for radar receivers. After the launch of the first American space satellite, he joined the newly-formed Satellite Tracking Group at Malvern under the direction of Dr. W. A. Scott-Murray, and headed the receiver design team. During the five years prior to retirement he was a Principal Scientific Officer in the Guided Weapons Group at RSRE.

The author now has his own laboratory where he is able actively to continue experimental work in various fields of electronics.

Phase and distortion. It is interesting, especially in view of the volume of correspondence on the effects of phase distortion published in the *Wireless World* recently, to observe (and listen to) sine waveforms with known amounts of harmonic distortion. The illustrations given in Figs. 8 and 9 of 2nd and 3rd harmonic distortion respectively show the horrifying appearance of extreme examples, but the main purpose of these is to illustrate the effect of

Fig. 7. *Suggested power supply. Any similar source of the required power is suitable.*



varying the relative phase between the fundamental and harmonic on power meters of this sort. The error graphs given in Fig. 8(d) show that, for an harmonic content of 50%, an increase of about 0.9 dB in power meter reading is given for a phase angle of $\pi/2$. This is interesting insofar that distortion of a sinewave of voltage or current can only be caused by the addition of "foreign matter" and therefore noise, harmonics or whatever must necessarily add power. At 50% waveform distortion $V_{fundamental} / V_{harmonic} = 2$, corresponding to an increase of 25% in power, i.e. + 0.9691 dB. It is perhaps only a matter of academic interest that, because of this, those points on the graph of Fig. 8(d) corresponding to 0 or π which show almost zero error are, in reality, points of maximum error in actual power and that the 0.9dB error shown at $\pi/2$ is, in fact, very nearly the true value. A similar argument for 3rd or any other harmonic also applies but it must be stressed that the power meter errors given in Figs. 8(d) and 9(d) are the practical result of adding measured percentages of harmonic under controlled phase. In a practical situation one seldom knows what constitutes waveform distortion (let alone phase) hence the specification for amplifiers is usually quoted in terms of total harmonic distortion (t.h.d.) and is given as a percentage of the fundamental at certain spot frequencies. For as much as 10% t.h.d. the maximum error given by meters of this sort is of the order of ± 0.2dB. Practically all of this error is caused by 3rd, and, to a lesser extent, other odd harmonics.

The author is indebted to Mr. E. F. Good for helpful discussions and for checking the manuscript and also to Texas Instruments for permission to reprint the circuit of the 'Full Wave Rectifier' (IC_2 and IC_4 in Fig. 5.

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2. Richard Mann. Applications of Operational Amplifiers. Semiconductor Circuit Design, Vol. 2, Texas Instruments Ltd.

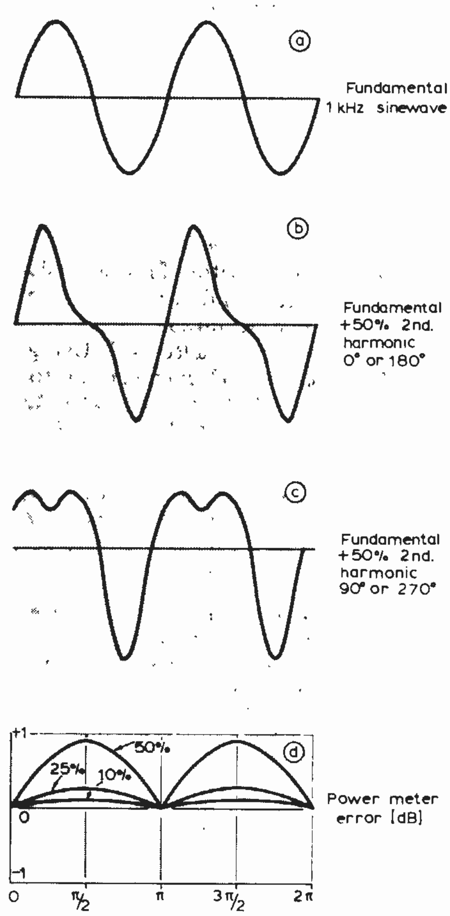


Fig. 8. *Variation of power meter error with change in 2nd harmonic phase relative to zero-crossing of fundamental. Parameters are 10%, 25% and 50% 2nd harmonic.*

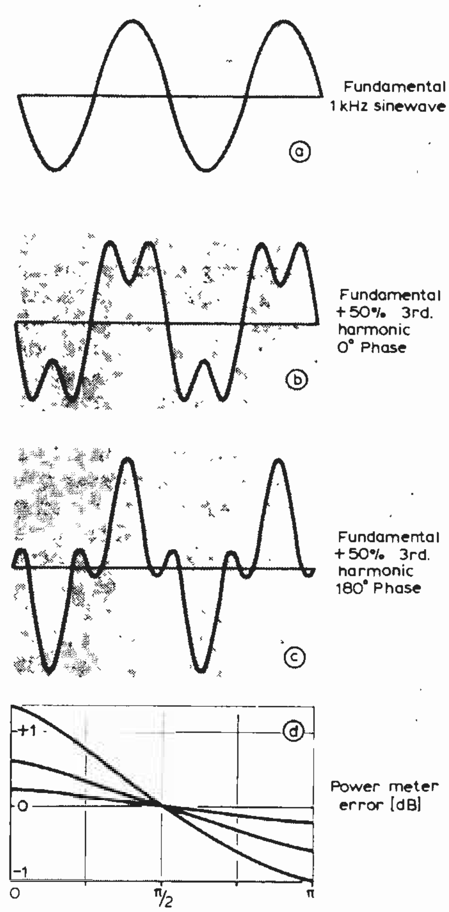


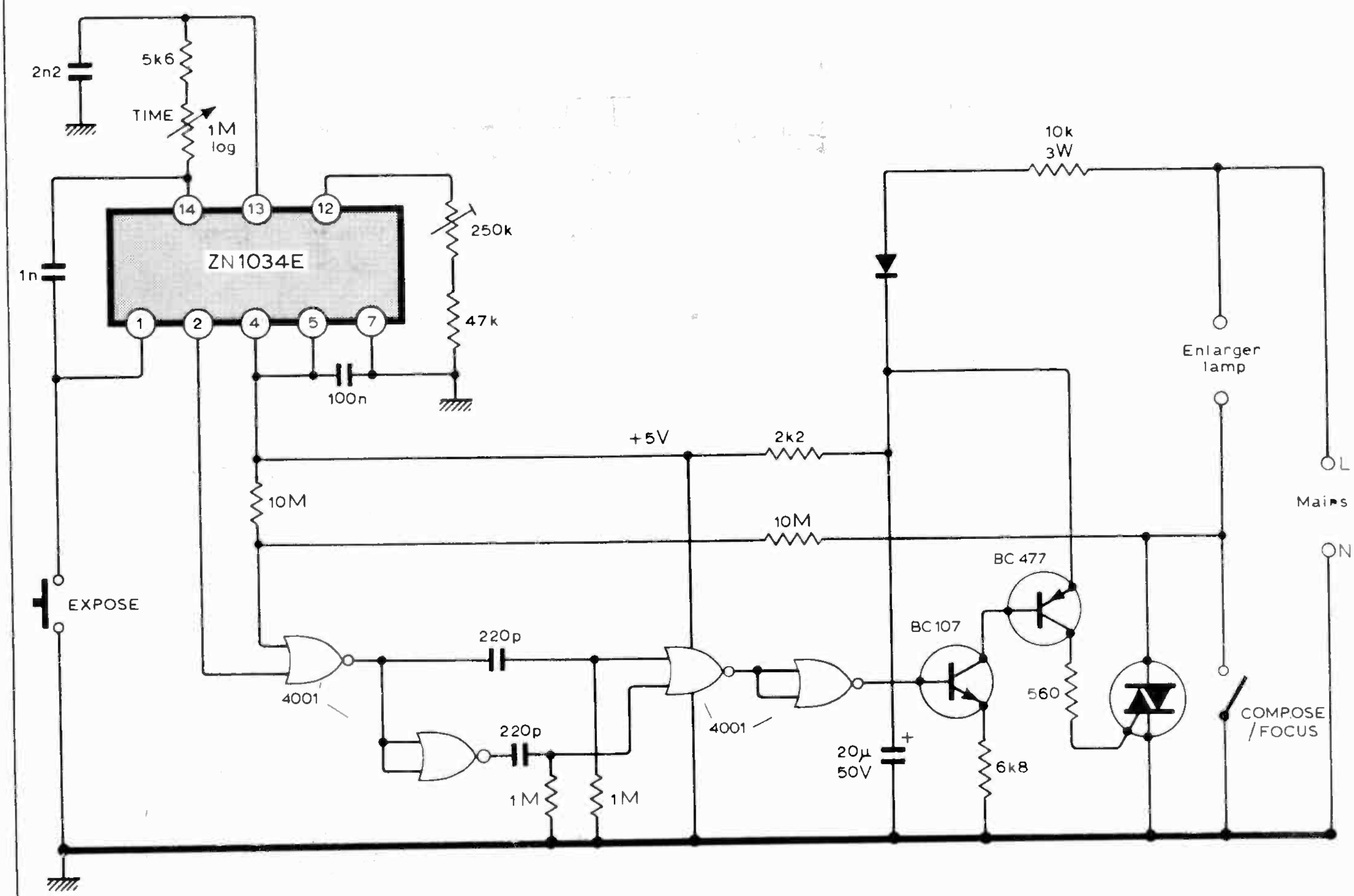
Fig. 9. *Third harmonic distortion and the error caused; the diagrams are similar to those of Fig. 8.*

CIRCUIT IDEAS

Transformerless enlarger timer

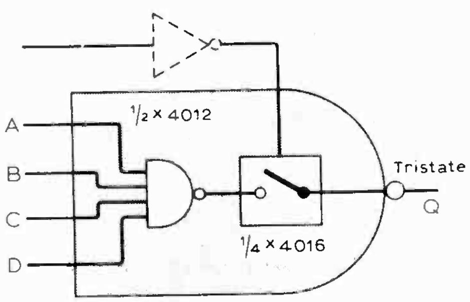
MOST photographic enlarger timers require a transformer for their low voltage d.c. supply. This circuit runs from 1mA supplied by the mains via a 10kΩ resistor and rectifier. A Ferranti ZN1034E timer i.c. generates the delay and supplies +5V for the c.m.o.s. gates. The triac is triggered with 100μs 60mA pulses at the zero-crossing point. The c.m.o.s. logic generates these pulses when activated by the timer's $\overline{Q}$ output. A logarithmic potentiometer may be calibrated from 1 to 120s.

M. J. Mayo,
Gloucester.



Tristate c.m.o.s.

AT PRESENT only a few tristate circuits are produced in c.m.o.s., and frequently the available configuration is unsuitable. For example, the 4502 strobed hex inverter can only be used with all its outputs simultaneously disabled. Any c.m.o.s. logic circuit can be readily converted into a tristate form by the addition of an analogue gate. The circuit shows a four input NAND with an analogue gate, to produce a NAND tristate. The input operates in the opposite sense to a 4502, logic 1 is on, logic 0 is off. The addition of an invertor ensures conformity.



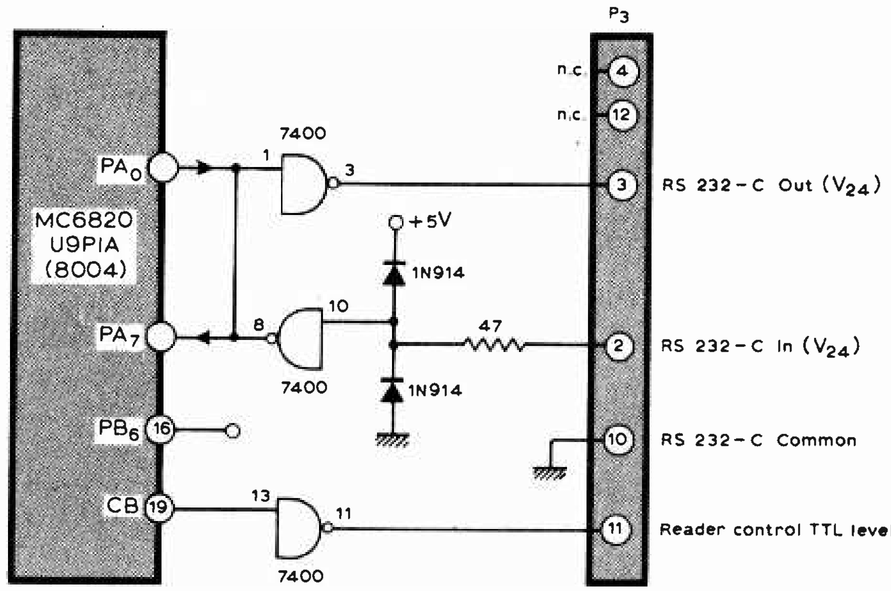
Dr. D. Price,
Knockholt,
Kent.

Simplified console interface for MEK6800D1 microcomputer

A SIMPLIFIED console interface can greatly reduce the cost of a MEK microcomputer. This design is used with either t.t.l. level or RS232-C compatible i.o. terminals. Standard teletypes use the current loop interface which is part of the normal MEK interface.

To construct the circuit the MEK is built following the instructions, but the parts in the console interface (lower right corner of the MEK circuit diagram U9 U17-21) are omitted. No alteration of the board is necessary but jumper leads and the additional components are added where necessary. The 7400 is substituted for the U17 and is a direct replacement. P3 is connected as shown in the MEK instructions but 12 V are not needed. The t.t.l. output of the simplified interface will drive most RS232-C interfaces although it is out of their specification. The diode-resistor network on the input, interfaces the RS232-C output to t.t.l. level and may be eliminated if the console terminal is already at t.t.l. level.

As no modifications to the MEK circuit board are made, it is possible to reconvert to the normal interface if desired.



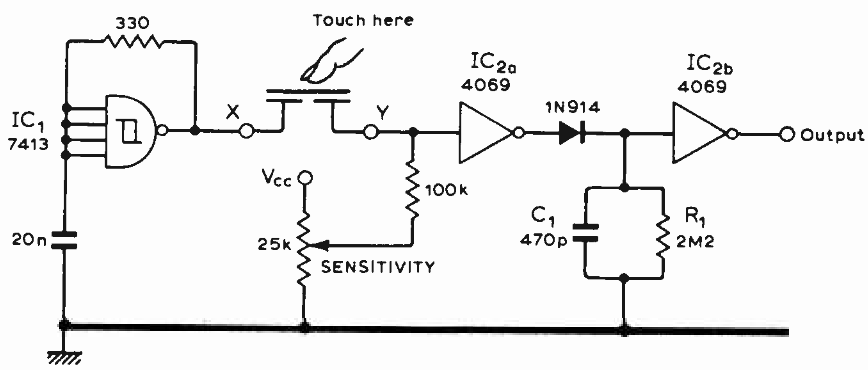
M. F. Smith,
University College,
Galway,
Ireland.

C.m.o.s. touch switch

BECAUSE this c.m.o.s. touch switch does not rely on mains hum for switching, it can be used with battery powered circuits. The design is also immune to noise spikes. Schmitt trigger IC_1 forms a 100kHz oscillator and IC_{2a}, which is biased into the linear region, amplifies the output and charges C_1 via the diode. IC_{2b} acts as a level detector. When the sensor is touched the oscillator signal is severely attenuated which causes C_1 to discharge and IC_{2b} to cleanly change state.

The sensor can be constructed from two capacitors or a piece of double sided printed circuit board etched as shown. Because the oscillator can drive several switches, a multiple sensor can also be constructed. If necessary, the output from IC_{2b} can drive a latch circuit.

N. Sunderland,
Reading,
Berks.



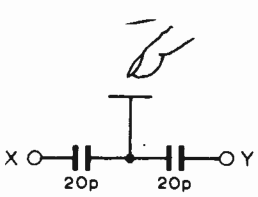


Fig. 1

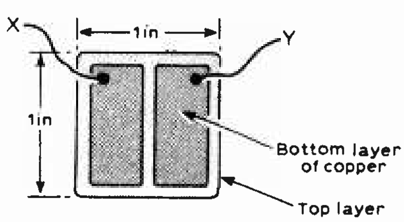


Fig. 2

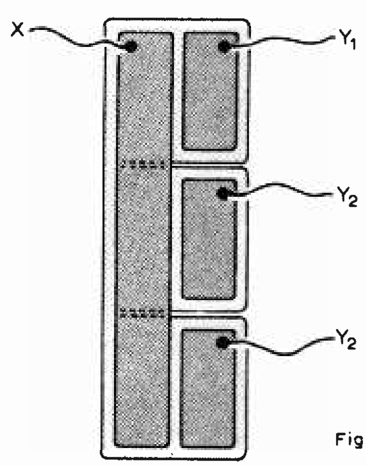
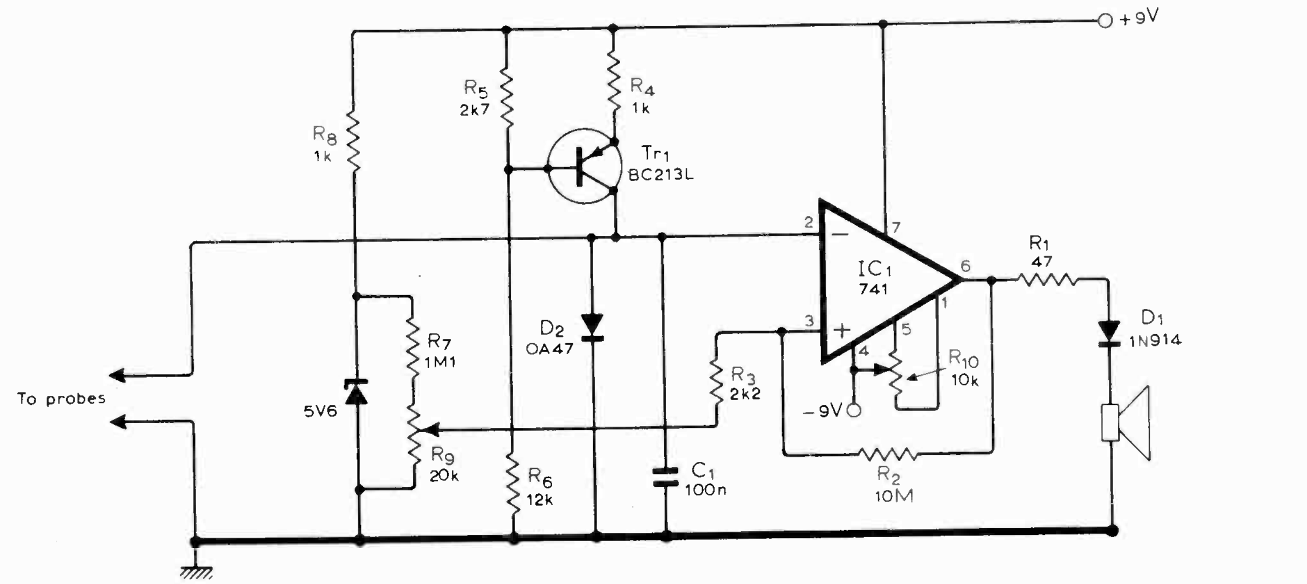


Fig. 3



Continuity tester

THIS INSTRUMENT was designed for testing equipment which has active components connected. The probes have an open circuit output clamped at 0.3V, and the short circuit current is only 1mA. Transistor Tr_1 forms a constant current source of 1mA with the collector, and therefore the probe, held at 0.3V by a germanium diode. The op-amp forms a Schmitt trigger with an adjustable threshold set by R_9. This trigger point determines the maximum resistance that will operate the circuit, and may be preset within the range 0 to 90Ω. Use of R_{10} in conjunction with R_9 eases setting-up for low values of resistance. An ITT miniature sounder type U5-35R is used to indicate continuity. If a non-capacitive sounder is used R_1 can be omitted.

R. Batty,
University of Sheffield.

Feedforward amplifier

THIS VOLTAGE amplifier drives a grounded load and uses feedforward to reduce distortion. Components R_a, C_a and C_b are used to balance any delays between the two amplifiers. If close tolerance components are used it is possible to obtain very low distortion levels for high output signals. If conventional op-amps such as 741s are used for A_1 and A_2, and $C_a = C_b = 0$,

$$V_{main} = +\frac{R_1+R_1//R_2}{R_1//R_2}V_{in} + V_d$$

where V_d is composed of noise and hum

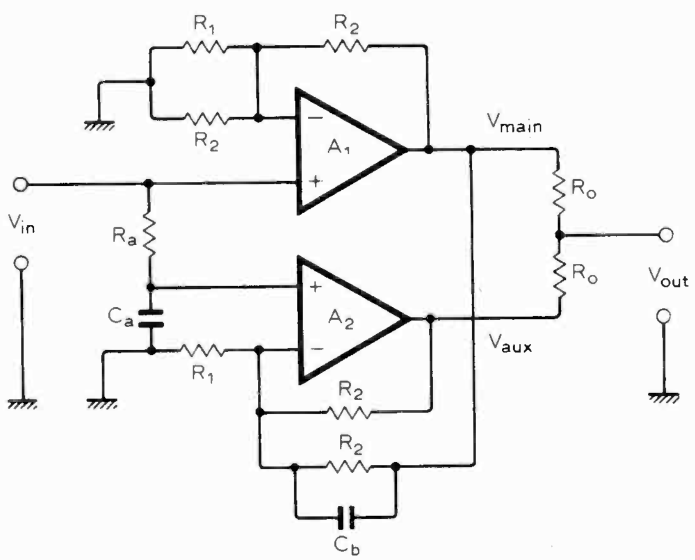
$$V_{aux} = -V_{main} + \frac{R_1+R_1//R_2}{R_1//R_2}V_{in} - V_d$$

Therefore,

$$V_{out}/V_{in} = \tfrac{1}{2}\frac{R_1+R_1//R_2}{R_1//R_2}$$

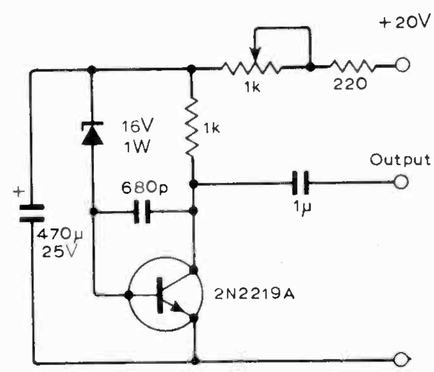
In the prototype R_1 = 100kΩ, R_2 = 10kΩ, and R_9 = 1kΩ.

Giovanni Stocchino,
Rome,
Italy



Simple noise generator

THE CIRCUIT shown was used as an emergency noise generator because it can be assembled quickly. Noise from this generator falls in the audio range and the wideband level is over 1V, adjustable to zero by the potentiometer. Without the 680pF capacitor the noise extends up to 30MHz with a wideband level of more than 5V.



If lower zener and supply voltages are used, the noise level is reduced drastically.

D. Di Mario,
Yeoville,
Johannesburg,
South Africa.

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WW—011 FOR FURTHER DETAILS

The Viewdata computer — 2

More on the software used for information retrieval

by S. Fedida B.Sc(Eng.), M.Sc., F.I.E.E., A.C.G.I., Post Office Research Centre

Now the Post Office has announced that Viewdata is to go ahead as a public service early in 1979 the current articles on this information retrieval system become of more immediate interest. The April issue described the hardware of the computer and some of the software. In this article, the remainder of the software is explained. (See also articles on the overall system, terminals and codes, February-May, 1977.)

It is in the register save area of the master segment of the old process that the contents of the working registers are stored, when a change is made to a new process. These working registers are

S: The sequence register (or programme counter), 16 bits.
L: The local workspace register, 16 bits.
A: Accumulator, 32 bits.
B: Accumulator extension, 32 bits.
X: Index register, 16 bits.
Y: Base register, 16 bits.
Z: Base register, 16 bits.
E:
C: Control register or condition marker, 8 bits.

If the old process is in the RUN or HELD state all its registers are saved — otherwise only the S and L registers are saved. Thus computer information about the status of a process is saved, whenever it relinquishes control of the processor.

(b) *Load hardware and other registers.* Once the working registers of the old process are saved, the hardware segment registers are loaded with the required parameters for the new process.

Hardware segment register. An essential part of the segmentation system described above is the hardware segment register unit (h.s.r.u) which consists of eight hardware registers, each of 20 bits, which define the position and length of certain segments in store in

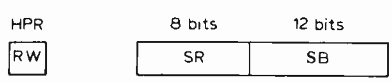


Fig. 8. Layout of hardware segment registers.

the way indicated in Fig. 8. The field SB, which is 12 bits long, defines the segment base as a multiple of 64 bytes (thus covering the complete range of the main store, which has a maximum capacity of 256kbytes), while the length of the segment L is given by field SR (or segment range) as L = 64 (SR + 1) bytes.

The eight registers of the h.s.r.u. contain the following information:
HSR(4) is pointer to master segment from SST entry i.e. $P+4$
HSR(0) to HSR (3) define the four current segments of the current process.
HSR(4) defines the master segment of the current process.
HSR(5) defines the process vector
HSR(6) defines the system segment table.
HSR(7) defines the system buffer area.

Associated with registers HSR(0) to (3) which define the locations of the four current segments of the process are four 2-bit hardware protection registers (h.p.r.), shown in Fig.8, which contain the access permissions of the four segments. The first bit, R, if set, permits reading from the segment for data or instructions while the second bit, W, if set, permits the writing into the segment.

The hardware segment registers thus provide the addresses of systems tables such as system segment table (already dealt with above), the address of the process vector and system buffer area, (which will be dealt with later), the

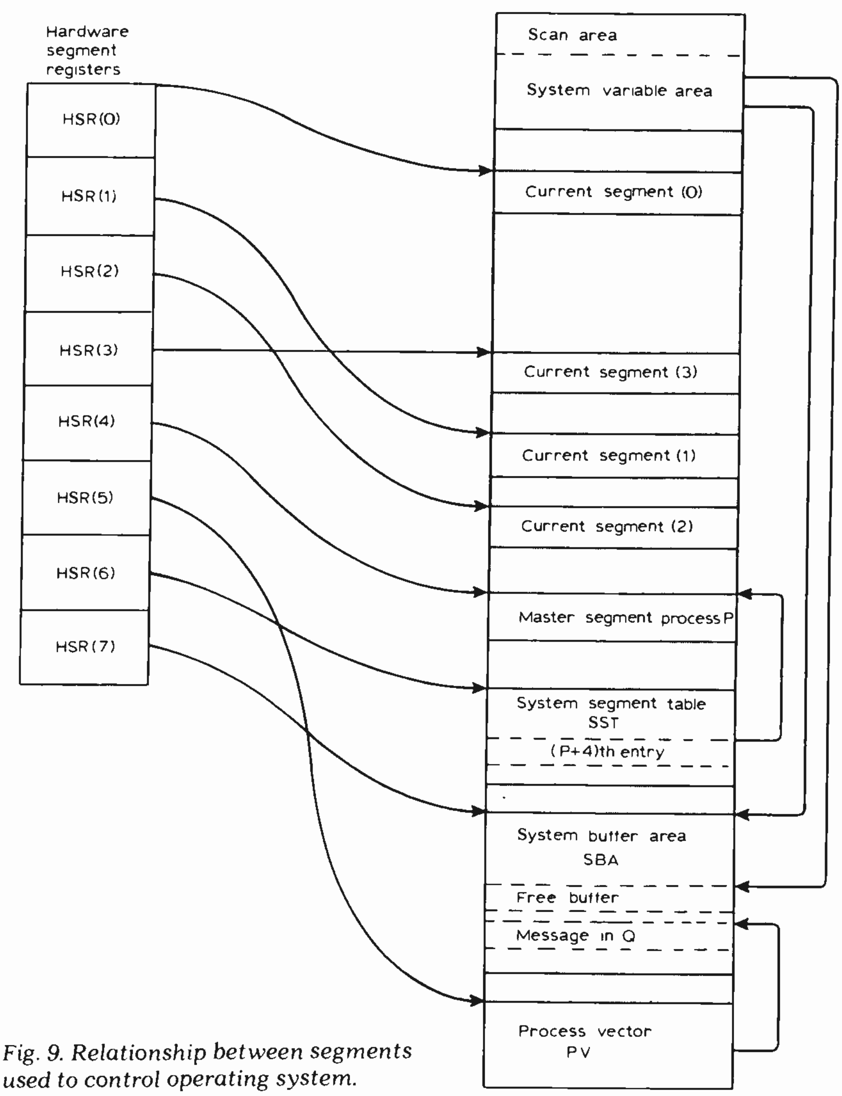


Fig. 9. Relationship between segments used to control operating system.

address of the current segments (with their access permissions) and of the master segment of the current process. They are also used for mapping the virtual address, used within programmes to actual addresses in the main store, as will be indicated in the

Items of storage, i.e. data or code, are accessed by processes using a 16-bit virtual address. The most significant two bits of the virtual address define the segment in which the item to be accessed is located by reference to the appropriate HSR (HSR (0) to HSR (3)). The remaining 14 bits define the displacement of the item for the start of the segment. The mapping from virtual address to real address converts the 14-bit virtual address to an 18-bit real address, using the SR and SB fields of the appropriate hardware segment register as specified by the most significant two bits of the virtual address. The mapping is done entirely by hardware and is consequently very fast. It is in this address mapping and the checking of access permissions that reside a great deal of the store protection against corruption which Nucleus provides.

Hardware segment masters HSR (5) to HSR (7) are loaded initially when the system is first set running, for example following initial programme load.

When the new process is selected to run, HSR(4) is loaded from SST (P + 4), where P is the number of the process, thus specifying the master segment. If the segment is absent the process cannot be run and a special error trap occurs (master segment break). HSR(0) to HSR(3) are loaded using the four CST entries in the master segment, which refer to entries in the SST. These are transferred from the SST to the hardware segment registers. When the hardware segment registers have been loaded, the S and L registers are now loaded from the "save" area of the master segment of the process, thus providing the instruction number from which the programme sequence is to start.

State of the new process

The state of the process is now tested, i.e. whether it is in the READY or the RUN state. This is done by reference to the process vector, which has been mentioned briefly earlier.

The process vector (PV) is a segment accessible to Nucleus for the control of all processes. The starting address of the process vector segment is given by the contents of HSR(5). The process vector contains one 8-byte long entry for each process in the system, starting at byte 8P of the beginning of PV, where P is the process number. The process vector entry for each process contains various details regarding the process, among which are three sub-fields S, L, A in the STATE field which define the state of the process. The READY state corresponds to S=0, L=0 and A=4 while the RUN state corresponds to S=0, L=0, A=1. We shall assume here that the process selected is in the RUN state (i.e. should be run). Nucleus then loads the remaining registers B, A, X, Y, Z, E, C from the "save" area of the master segment, and initiates the execution of the process, starting at the store location indicated by the contents of the S register (programme counter), the code being contained in current segment CST(3). The relationship between segments used to control the operation of the computer is shown in Fig. 9.

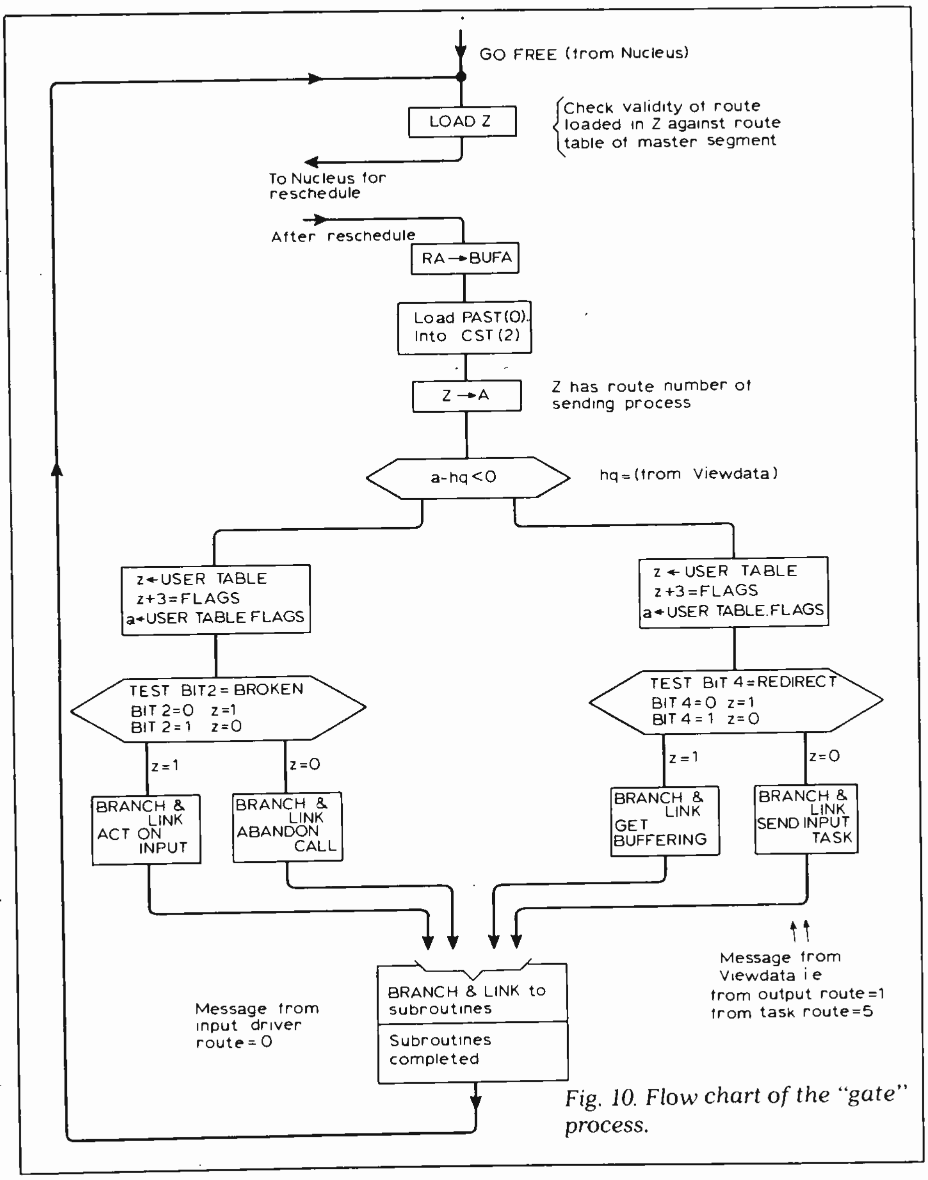


Fig. 10. Flow chart of the "gate" process.

Running a process under control of Nucleus

We shall now look at the interaction of Nucleus and the actual running of a process. For the purpose of illustration we shall choose the GATE process which accepts a character from input, identifies the task to be performed and passes the character on, together with other data (the message) to the task selected.

We enter the sequence of operation where it ended above, i.e. at the point where the process (GATE) is directed to a piece of code starting at a location indicated by the programme counter S (see Figs. 3 and 10).

The reschedule. We had initially set the GATE process (and others) to the RUN state at IPL to set the system to operate. The GATE process first places a *valid* route number in Z and returns to Nucleus for a reschedule, i.e. to ensure that no other process of higher priority (in this case lower process number) is waiting to be given control of the processor.

The GATE process is first set to the FREE state, i.e. inactive state, pending the investigation of whether there is a message requiring processing and, if none exists, the receipt of one. This procedure involves the setting of SCAN bit to 1, and fields S, L and A in the process vector to 0. Other fields in the process vector entry for the GATE process are also examined, see Fig. 11. The fields of interest are:

STIM. This is a set of 16 independent bits used to record the presence of fixed messages and interrupts awaiting processing by the process. In the current Viewdata system fixed messages (as opposed to queued messages) are not used, but interrupts are.

S, L, A. As we have seen above, they define collectively the STATE of the process.

QEND. A pointer to the queue of incoming messages awaiting processing by the process; QEND = 0 if the queue is empty.

We have seen that communications between processes, i.e. the continuity links which ensure that a whole sequence of operations each implemented by a separate process may be carried out *in toto*, is accomplished by messages, called inter-process messages (IPM), which are sent from one process to another. The information passed on in an IPM defines the task to be performed and the data to be used.

When a process sends a message to another process it loads registers A, X and Y with the required information parameters and loads register Z with a route number which is an entry from a table in the master segment of the sending process which specifies the destination (the process which is to receive the message and how the message is to to be retrieved, i.e. the queueing parameters) and then invokes Nucleus to complete the operation. If a data segment is sent with the message the first two bits of register Y indicate the current segment (CST) of the sending process containing this data.

Nucleus then assembles the message in a message buffer (see below) in which it inserts the following data, see Fig.12: (1) parameters A, X and Y from registers A, X and Y; (2) the current segment number of the sending process (CST) containing the data to be included in the message, as indicated by the first two bits of register Y which are then set to zero; and (3) the identity (i.e. number) of the sending and destination processes and a pointer indicating the location of the message buffer.

In the Viewdata system the message buffer is allocated by Nucleus from a list of unused buffers (known as the free queue), the address of which is obtained from an entry in the system variable area called QFREE (Fig.13).

If the current message is the only one waiting to be processed by the destination process an entry is made at QEND in the process vector entry (Fig.11) of the destination process giving the address of the message buffer, which now forms the beginning of an independent message queue awaiting processing by the destination process. If, however, there are already other messages in the message queue of the destination process, its address is found at QEND and the message is added to the tail of the queue. Figs.13 and 14 show the FREEQUEUE and the incoming message queue for a process (process N).

We may now return to the GATE process, and the flow diagram of Fig. 3 (April issue) at the point where Nucleus examines the QEND field of the process vector entry for the GATE process. If QEND is not zero, the value of QEND is a pointer to the tail of the message queue awaiting processing. Nucleus changes the state of GATE from FREE to READY, by setting SCAN(N) = 0 in

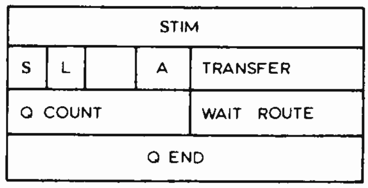


Fig. 11. Process vector entry for a process.

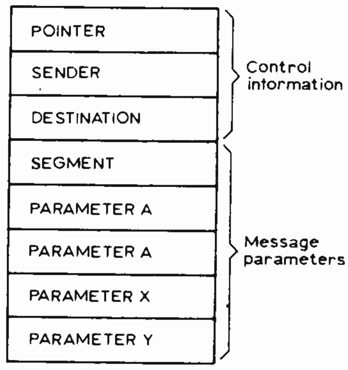


Fig. 12. Message buffer.

SVA and A = 4 in the process vector entry then reschedules (searches in the SCAN field whether there is a process of higher priority, i.e. lower process number, requiring attention) by returning to the top of the flow chart in Fig. 3.

A reschedule is also carried out if QEND= 0, i.e. there are no messages awaiting processing but GATE is left in the FREE state.

Assuming that a message is awaiting processing, GATE has been set at READY, and since no other process has been in control of the processor the old branch is taken. The process state is re-examined. It is at READY and the following procedure takes place: (1) the parameters of the message are loaded from the message buffer to registers A, X, Y; (2) the route number of the sending process is transferred from the message buffer to register Z; (3) the entry of the data segment, CST(2), of the old process is transferred to PAST(0) (programme accessible register) of the GATE process; (4) the GATE process is set to RUN, i.e. field A in the process vector entry is set to 1; and (5) control is returned to GATE process where it had left off and the code pertaining to the GATE process is followed by the processor.

The Viewdata tables

We have seen so far how, starting from IPL, a process such as GATE is initially activated in what may be considered a dummy run, given control of the processor and allowed to comply with the codes specific to that process, which is found always in CST (3) using a valid but not meaningful route number. The code in the process then demands a change of state to the FREE state which invokes Nucleus and leads to a reschedule.

As a result of the reschedule and on the assumption that a message requiring attention is found in the system, control is returned to GATE, together with additional information and data pertaining to that message. This information is deposited in registers A, X and Y and the route number of the sending process is register Z.

The data passed with the message which was located in the CST (2) of the sending process is transferred as a result of the message passing to the PST(0) of the receiving process. On re-entry to the

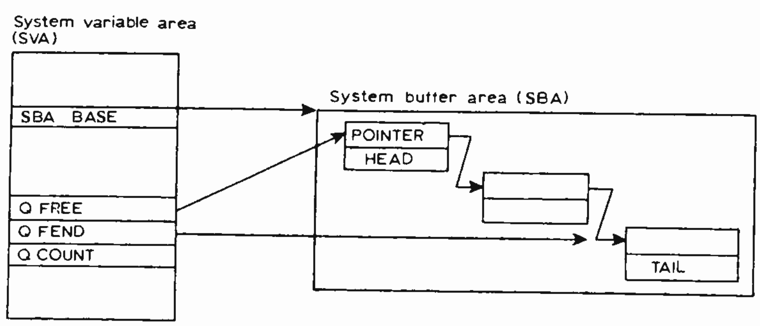


Fig. 13. The free queue.

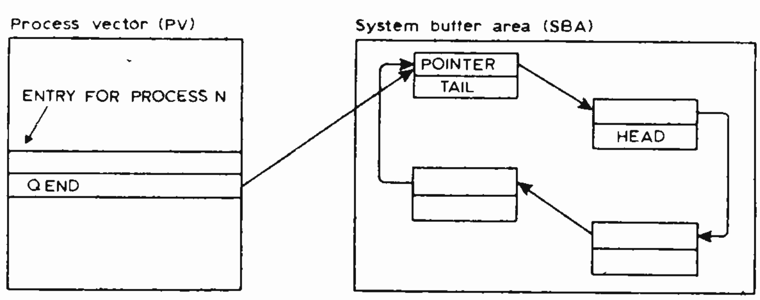


Fig. 14. Incoming message queue for process N.

GATE process, register A is saved in a buffer local to the programme so as to free the register for subsequent use and the data in the PST(0) is transferred to the CST (2) of the GATE process. (In fact only pointer addresses are changed.)

The same procedure follows essentially in all the processes comprising the Viewdata software package as such, with the content of CST(2) being handed over from one process to another throughout the series of transactions of a user session. This data comprises a set of tables which are collected together in a segment specific to a particular user. This segment, although continually changing in content, remains allocated to a user throughout the session. We talk of a user being transferred from one process to another when we mean that the user segment passes from one process to another throughout a session.

The user segment. The user segment of storage is made up of five components: (1) the frame control area; (2) the frame; (3) the frame table; (4) the user table; (5) the input buffer; and (6) the user work area.

The frame control area contains the user number of the user currently connected to the port number corresponding to the segment, and the sequence of four characters made up of one FF (form feed) and three CR (carriage returns) which are output in one transfer clear the screen before a new frame of data is sent down the line for display.

The frame component consists of 960 bytes of storage and receives from disc the data to be displayed to the user. It is not always full, as on the average the content of a page displayed to the user is only 500 to 600 bytes long, since a substantial part of it must be left unused to meet editing requirements as regards appearance, tabulation etc. Nevertheless since the maximum number of character positions in a displayed page is 960 (24 rows of 40 characters) the full amount is allowed in the frame region. The contents of the frame region may be modified, in certain cases, before being sent down the line to the user.

The frame table is a table 64 bytes long which is compiled at the same time as the frame and reflects the data structure of the information provided. It is stored with the frame content in disc storage and transferred to main storage at the same time as the associated frame. The structure of the frame table is shown in Fig. 15. The contents of the frame table determine the action of the system following the user's response to a displayed frame. The frame table contains the identity (i.e. number) of the page, and frame*, the task number, i.e.

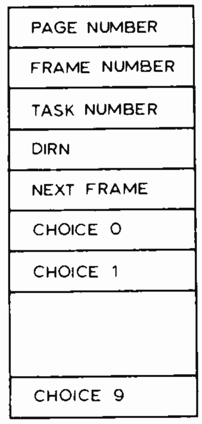


Fig. 15. The frame table.

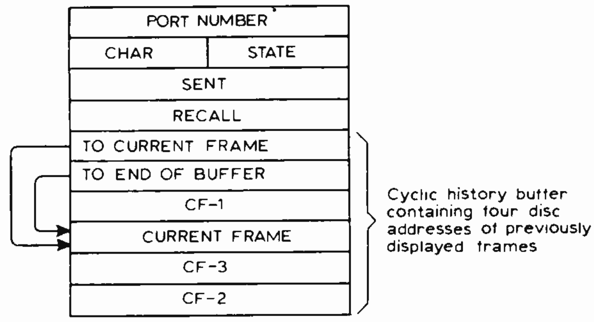


Fig. 16. The user table.

the process number which deals with a user response relating to the frame, and the actual disc addresses of the next frame and the frames corresponding to the choices offered in the current frame. It also contains DIRN (direction) which is used by a task number to decide whether the frame is to be output directly (DIRN = 0) or sent to another task specified for modification (DIRN≠0).

NOOFCHARS specifies the number of significant characters to be output from frame.

The process specified by TASKNUMBER relates to the user's response to the available selection from the list and moves the appropriate disc address to NEXTFRAME, where it will be accessed by process DISC to retrieve the frame selected.

The user table (see Fig.16) contains details pertinent to the user's current transactions. In particular it contains a buffer which maintains a record of the current frame (as a disc address) and the address of the three previous choices, thus enabling a user to retrace his steps. Frame addresses are entered in the user table by the DISC process and retrieved when necessary by one or more of the TASK processes. The user table also contains PORTNUMBER, which is the identity of the computer port to which the user is connected. This is used by the OUTPUT process when sending data to the user. Other parameters are:

SENT. This is set by GATE when it sends a user segment in the system in a message passing operation.

RECALL. If additional characters are received thereafter they are entered by GATE in the input buffer section of the user segment and RECALL is set. When the OUTPUT receives the user segment in due course it will return the user segment to GATE without outputting a frame.

STATE. This gives an indication to TASK as to whether the message consists of a single character or a component of a character string.

CHAR contains the next character of input which the system is required to process.

The input buffer is an area of the user segment for the exclusive use of GATE process in which characters arriving may be stored while the user segment is traversing the Viewdata system.

The user work area is a work space area available to TASK in which intermediate results may be stored, as, for example, when TASK is assembling a character string which is being received one character at a time. □

The next article will describe the optimisation of the Viewdata system to enable it to handle as many simultaneous users as possible.

* A page may consist of several continuation frames. Continuation frames have the same serial number of the page (i.e. the first frame) but end with an alphabetic suffix A to Z.

BOOKS RECEIVED

Electronics II by D. Bishop follows the syllabus of one of the technician courses run under the Technician Education Council which was established in 1973. The book is divided into six sections which cover the elementary theory of semiconductors, thermionic valves, the c.r.t., small signal amplification, waveform generation, logic elements and circuits. Each section concludes with a list of exercises in the form of Q & A. Price £2.95 paperback, pp. 76. Macmillan Press, 4 Little Street, London WC2R 3LF.

CMOS Cookbook by Don Lancaster is a very readable introduction to c.m.o.s. and its uses. Like most books, it starts with a chapter on basics followed by a list of devices together with schematic diagrams and brief descriptions. The following chapters discuss logic techniques and circuits. The last chapter describes some l.s.i. devices for circuits such as a stopwatch, frequency counter, and video game. The book is well illustrated with circuit diagrams, waveforms and truth tables. Price £6.95 paperback. Pp. 414. Prentice/Hall International, 66 Wood Lane End, Hemel Hempstead, Herts HP2 4RG.

NEWS OF THE MONTH

Experimental Post Office facsimile service

THE POST OFFICE are to begin an experimental "Fax Bureau" facsimile transmission service. The experiment, details of which are not yet fully available, is to start later this year, when the first of two stages will be inaugurated in an unspecified regional test area. Post Office sources say the equipment is being ordered from Muirhead for the transmission of "urgent documents" between centres within the UK.

The first part of the experiment, to start in the summer, will be to provide a simple type of machine which will not require much staff training. A directory of facsimile users will be provided similar to that available for the Telex service. The aim is to encourage greater use of public switched telephone network.

The second stage will be to supply a more complicated machine which will enable documents to be transmitted out of office hours when the machine is unattended. These will use electrostatic coated paper. This service has not been given a timetable yet but at the earliest they could start next year.

In 1975 the Post Office arranged a trial in which head post offices up and down the country had facsimile transmission systems installed for public use for a trial period. The Post Office say there was no public demand. Office-to-office transmission is likely to be a very different matter, however. The Post Office have installed a great many machines for their internal use and, for example, their press office sends copies of releases to Manchester for retyping on the Manchester letter-head in the same format.

At the time that Telex was being developed there was no demand for facsimile, but the makers believe that some form of facsimile would now be preferred.

A new document facsimile transmission unit from ITT brings the likelihood of a small, cheap portable machine for the home a step nearer. The Telefax, made by ITT Business Systems, is an office machine small and light enough (8kg) to be carried from one desk to another, though it could not really be described as portable. Two of the machines can receive from or transmit to each other over a telephone line. At the moment they have to be connected through a phone socket but ITT say they will shortly be making an acoustic coupler available. They rent at £45 a month, and sell at £1,500.

Transmission time for a sheet of A4 paper is three minutes. Most of the machines in current use are from group one; they take six minutes to transmit an A4 page. The variety of group one machines available do not conform to any standard, so they are not interworkable. In September last year the CCITT met to agree standards for the newer two and three minute group two machines which were about to appear and ITT say the Telefax conforms to this standard. It requires a scan speed of 360 lines per minute and a.m./p.m./v.s.b. modulation on a 2100Hz carrier. Group three machines with sub-minute transmission times will use digital compression techniques but ITT believe their use will be confined to mail rooms.

ITT's Telefax uses a combination of amplitude and phase modulation and vestigial sideband to reduce the transmission time from six to three minutes, with a resolution of 3.85 lines/mm. Two minute transmissions are possible at 3.1 lines/mm.

There are many reasons for the growth of the facsimile market. The increasing complexity of the information to be sent, often requiring accompanying drawings, makes telex transmission impractical, as does the spread of Japanese as one of the main languages of commerce. Telex also needs an operator at either end, since the machines cannot be used unattended, and not only does this cost money, but it may mean that mistakes are made both in transmission, and in the interpretation of the received information. Facsimile eliminates these, as well as making it possible to sign the document: at least one case is recorded of a solicitor sending a document by facsimile to New York and receiving a facsimile of the signed document back, and it appears that the facsimile signature is acceptable in a court of law. In addition, the charges for the use of the telephone have increased sharply in recent years, making facsimile more attractive.

It appears that Britain's share of the European facsimile machine population is, at 28%, 10% ahead of that of its nearest Europen rival, West Germany. According to a survey by Quantum Science, there are 11,000 machines here. By 1980 that number will have doubled, though we will then only have a quarter of the 90,000 machines in Europe. The group two machines being sold will overtake those of group one towards the end of 1980, the survey says. Over two years ago another report, by Ronald Brown, said that the facsimile market was about to take off as a result of the economic recovery, the need to save fuel, and there being more machines to transmit to.

According to Ronald Brown, the UK market would reach £10 million by 1978, and that in Western Europe would reach £55 million. According to the Quantum Science survey, the UK market is worth £16.5 million, and will reach £32.2 million by 1980. The discrepancy can be accounted for largely by inflation.

On the face of it, it seems odd that the UK market should be so far ahead in anything. ITT admit privately that the reason is Muirhead's "education" of the market. Muirhead have been in facsimile since the end of the last war, but they have largely confined themselves to the professional market, such applications as pictures from news agencies, seismography, oil logs from oil rigs (which can be up to 20 feet long), the transmission of news pages, and weather charts from satellites.

Muirhead say they have 70% of the world market for photo transmission, and 95% of the market for newspaper page transmission. Bearing in mind that Muirhead have developed a documents transmission system with the Ministry of Defence for sending a sheet of A4 over the telephone in one minute, ITT's stated intention to take 30% of the facsimile market in the next three years looks a tall order.

The ITT machine will be made under an agreement with the Qwip Corporation, an Exxon subsidiary, using electronics by ITT Creed at Brighton which bring it into line with the three minute standard. Qwip supply about 1,200 of their machines a month. □

Industry failure to create new jobs "an outrage": Chapple

THE DEVELOPMENT of System X would lead to a major contraction of jobs, yet the companies involved had barely any facilities for retraining workers, according to Mr Frank Chapple, general secretary of the Electrical, Electronic, Telecommunications and Plumbing union.

Speaking at the annual lunch of the British Industrial Measuring and Control Apparatus Manufacturers' Association at the Cafe Royal in mid-February, he said that the British telecommunications industry had failed to consider the effect on workers of introducing advanced electronic equipment. "We are locked on to a technology which will undoubtedly destroy thousands of working people's environment."

The failure of the companies to provide retraining was an outrage because they were among the biggest in the land, even the world. They were not "one man bands overtaken by events," he said. "Their social responsibility is nil."

"We must examine this new sort of technological unemployment. It is too grave for companies to say that redundancies are necessary to protect the jobs of those who remained. Government, industry and unions have got to generate a new vision of society at work. The high risks of the new technologies cannot be left to the market to decide."

In market research, Government co-operation, marketing and protecting the home industry Britain had failed to compete with the Japanese, who intended, he said, to dominate the world's electronic market in the next decade. "Civil servants, predatory companies and trade unions cannot continue to follow their mutually destructive whims and fancies. We must accelerate the advent of the shorter working week. Investment in training is needed and we must work towards education for industrial technology. The situation not only demands co-operation but leadership of a determined character. Technical change must enrich working life." □

Whatever happened to hi-fi?

LAST CHRISTMAS was one of the most dismal on record for the hi-fi industry. In December audio systems made by members of the British Radio Equipment Manufacturers' Association were delivered at half the level in the same month in 1976, according to figures just released by BREMA.

In December the year before that, British manufacturers delivered 53,000 systems, making a total for the year of 733,000 units. In 1976, one of the worst for the British economy since the way, the figures fell to 728,000, though the December figure had reached 82,000, and that for September had made the 112,000 mark.

Last December's figure plummetted to 44,000, less than that for August. Last year the highest total reached was in October, falling to the December low. Altogether, deliveries in 1977 were 568,000, a drop of 22%.

The pattern was repeated for record players. In 1976 deliveries were 181,000, of which 144,000 were UK made. In 1977 the figure was 104,000, with 90,000 made in the UK. Only the radio receiver picture is brighter, with increases in both total sets delivered, from 3.6 million in 1976 to 4.5 million, and UK deliveries up from 322,000 to 423,000, though even here the British makers have a very small piece of the market, and the figures were distorted during the year by changes in the way customs and excise categories imported radios.

Deliveries of television sets were slightly up too, from 2.5 million for 1976 to 2.7 million, with the British share increasing from 1.7 million to 1.8 million, showing an increase in the number of imports.

Some measure of the dent in hi-fi sales can be gauged from the slight but measurable increase in sales volume of other consumer electronics goods, and from the fact that the whole of the Department of Trade figures for the whole of the retail trade show that sales in December were up 16% on those a year earlier, reflecting an increase in disposable income from tax cuts which are said to give the average family an extra £200 a year. Retail sales showed increases in value varying between 11 and 17% right through the year. Sales of durable goods were down in volume on the previous year, but up in value to over twice their 1971 level. The *volume* of retail sales has also been rising since the trough towards the latter half of 1975, according to the Department of Trade.

So why is hi-fi so depressed? BREMA say that the figures for audio should be treated with caution. One reason for the decline has been that some types of product are no longer as popular as they were, and these more than offset the increases in deliveries of those types of audio equipment which replace them. An example is the falling popularity of amplifier-turntables, and another is that of tuner-amplifier-turntables. There has been a significant rise in music centres, however. Another reason for treating the figures carefully is that they are only applicable to BREMA members' products, and they take no account of manufacturers' stocks, which could be high enough to allow a considerable increase in sales without reflecting that increase in the deliveries to the shops. All the same, BREMA say that sales of all consumer electronics products are disappointing, and those for British made equipment in general, and audio in particular, are "just as disappointing".

It is not possible to put any figures on the value or volume of imported audio being sold in recent months because the Department of Trade statistical office only has figures up to the third quarter of 1977. Nevertheless reports from the industry suggest that Japanese manufacturers have done as badly as the British makers.

One reason may be the sheer volume of products that the manufacturers, particularly the Japanese, are putting on to the market.

In addition, the unit price of hi-fi may make it a less attractive buy than a freezer, particularly in a time of rising food prices and a tendency among the public to start turning their rose beds over to carrots and Brussels sprouts.

Dealers have noticed the tendency for more of their business to be done on credit, reflecting the lack of immediately disposable income.

Dealers stress that the hi-fi magazines have a great effect on purchasing. They say they know at once if a certain product has had a good review. This is especially noticeable, as they claim often happens, when a product has not previously merited much attention. They also say the advice given in the magazines is often conflicting, and there is a tendency to concentrate on equipment which is either not easily available or out of the normal price range. They say that no effort is made to stress the difference in price between an enthusiastically-reviewed product and one which is panned but which is at a lower price and may offer good value for money. The slight differences between products are exaggerated to the point where the customer feels the difference is so great that nothing within his price range is worth owning.

Another influence on potential buyers seems to be the conflicting advice given by dealers who are more interested in pushing certain lines than in giving objective advice. Some dealers do not, in any case, know much about what they are selling, particularly when they are expected to take on new lines of Japanese equipment which uses ever more complex techniques.

Manufacturers are now concentrating on changing their methods of selling, appointing selected dealers to distribute their products instead of allowing wholesalers to sell to all and sundry. Wholesale distribution, they say, has led to a price war, with no-one benefiting (except perhaps the customer) because of the low volume of sales. Importers have even been said to have been offering goods for nothing, provided a minimum of stock is ordered, though importers deny this.

According to a survey last autumn by Mintel, more than a third of the adult population have bought goods from a discount warehouse, and hi-fi and audio products came out of the list with 27% of all sales.

Mr Charles Strasser, Vice-chairman of the International Consumer Electronics Association, which represents importers, told *Wireless World* that members of the ICEA were "extremely buoyant" about the market. He said that the Christmas market had been slow to take off but that the British industry had painted too black a picture of the lack of demand.

He said that importers had been hit by import quotas to protect industries which, in many cases, did not exist in this country — "There is nothing to protect" — and by the fall in value of the pound against the yen. The currency fall had been 23% in the last 18 months, to which must be added the effect of Japanese inflation, producing total price rises of 30% or so. To that 14% import duty must be added to most audio products, but "the Japanese are no longer selling on price, they're selling on quality." The rising yen was "the only cloud on the horizon." □

Government focusses on microprocessors

THE PRIME MINISTER has announced the formation of three new working parties to examine the effects of new technology. The first will examine the applications of semiconductors an area where microprocessors are making available cheaply and in great number "capabilities that up to now have required large and expensive computers." The second will look at the effects of technology on unemployment and related matters. The third will examine the best ways of converting these new techniques into profitable industries.

The three working parties will report in June to the Advisory Council for Applied Research and Development, set up in 1976 to advise the government on the effects of science and technology on society. Its chairman is Lord Peart. The council will then report to the government by the end of the year.

The announcement, at a speech towards the end of February to the annual lunch of the Parliamentary and Scientific committee, followed news of the Department of Industry's intention to give financial help to the application of microprocessors in all branches of British Industry. At *Microsystems '78*, the February conference in London of which *Wireless World* was one of the sponsors, Mr Don Harrison, deputy chief scientific officer in the computer systems and electronics division of the DoI, said that the microprocessor is important in its own right and should be treated separately from other microelectronics. If somebody came to the DoI with a new way of using microprocessors – perhaps a world first – in, say, hospital work or beer automation, the Department would be glad to consider support for it. The level of support has not yet been decided but informed sources think it may be comparable to that to be available for microelectronic components. The figure of £80 million over five years has been suggested.

The move is part of the Government's "new industrial strategy" and the DoI will also be asking sector working parties of the NEDC, representing different industries, to study ways in which microprocessors could be used to improve the efficiency of their manufacturing and other processes.

A nationwide series of conferences on the industrial strategy are to be held by the Department of Industry, the NEDO and the British Council of Productivity Associations.

News in brief

The IEEE International Symposium on Circuits and Systems will be held at the Roosevelt Hotel, New York, from May 17 to 19, 1978.

The **British Association** for the Advancement of Science is to hold its annual meeting at Bath University from September 4 to 8.

The National Research and Development Corporation, in its evidence to the **Wilson Commmittee**, to review the working of financial institutions, says it would be better able to meet the needs of innovators if it could accept a lower success rate for joint projects with industry. The NRDC was set up after a bill was introduced into parliament by the young Harold Wilson in 1948.

The **Post Office** have ordered l.s.i. chips for single channel p.c.m. coder/decoders from General Instruments. Licences have been granted for the manufacture of the 9900 chips here and abroad. GI are also to supply m.o.s. i.c.s for Viewdata.

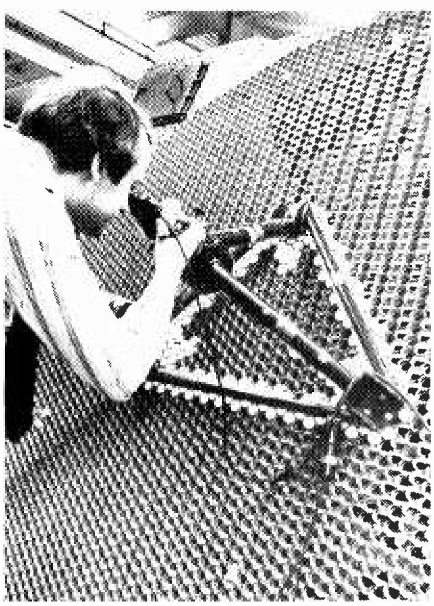
GEC Semiconductors are to hold two more **microprocessor** courses this year, from June 20 to 22, and October 24 to 26. The courses will be on the resident Coral 66 compiler for 8080 and 8085 microprocessors, and will be held at Wembley, Middlesex.

Nasa has been supplied with a **laser beam** recorder to produce faster and better photos from all their satellites. The Operational Laser Beam Recorder has been supplied by RCA.

Correction—"Reliability"

Dr Griffiths of Chelsea Instruments Ltd has directed our attention to an error in the printing of H. R. Henly's article on "Reliability", which appeared in February 1978, p.41. The heading of the last column of Table 1 should read "Joint failure rate/1000 hours". Our apologies to readers and to Mr Henly.

Practical Wireless have asked us to point out that, contrary to our news item on games chips in the April issue (p.50), they did not publish an article on the GI tank game mentioned. They will be publishing a full constructional article on the 8710 in their June issue, however.



An engineer aligns the elements in an electronically-scanned, phased aerial array for the US Army Patriot air defence system. Each element is inserted into a socket on the frame.

Electronics in the defence white paper

THE MINISTRY OF DEFENCE has spent more than £100 million with GEC, in 1976/7 according to the 1978 defence white paper published in February. Plessey won orders worth between £50 and £100 million, and EMI, Ferranti and Lucas were among the seven British companies with whom the MoD spent between £25 and £50 million. The £10 to £25 million group included MEL (part of Philips), Racal, and Smiths Industries. The 13 companies winning orders between £5 and £10 million included Decca, Mullard, Rank, the United Kingdom Atomic Energy Authority and Ultra Electronic Holdings.

The 38 firms listed received £1,600 million in contract payments. The white paper says that around 40% of the military budget is taken up in buying equipment. In 1977/8 this amounted to £2,523 million, and equipment expenditure in 1978/9 will rise to £2,770 million, or £3,060 million if "associated personnel and other costs" are added.

Of total procurement spending 44% (£1,353 million) will go to producing new equipment, 27% (£831 million) to producing new spares, 4% (£121 million) on research and 25% (£755 million) on the development of approved systems including r&d support costs such as headquarters expenses.

Of the £2,184 million to be spent on producing new equipment and spares £1,900 million or more will go to British industry and the Royal Ordnance factories. Of the £1,876 million to be spent on r&d, £608m will be spent outside the MOD. In 1976/77 the MOD spent £2,138m on military equipment of which about 70% was spent on national contracts with British industry, and 20% as the MOD share of collaborative projects. Ten per cent was spent on contracts overseas.

The MOD estimates that 200,000 people are working full time on national military spending, and another 70,000 are working on overseas military sales. In 1978/9 overseas equipment sales "will probably amount to at least £900 million." These sales are supported by the Defence Sales Organisation (see *WW* March 1978 p38). The white paper says that at least as many people again are employed in supporting these various contracts in industry generally, meaning that over half a million people are in some way involved in making military products. "We estimate that about half of those employed in the aerospace industry are engaged on military work including work for export, and warship building accounts for up to a third of those employed in the shipbuilding industry. Defence work will continue to be a major factor in sustaining the levels of employment and technological expertise in British Aerospace, British Shipbuilding and other important associated sectors of industry, notably electronics."

● The navy are developing several new types of sonar which are being fitted to surface ships, submarines and helicopters for the better detection and classification of submarines. "Advanced new electronic warfare and communications equipment are included in national and collaborative development and production programmes. A NATO collaborative development programme is in hand for a decoy system for use against anti-surface ship missiles. Production orders have been placed for an improved inertial navigational system which will be fitted in submarines and the new anti-submarine cruiser. An advanced air surveillance and target indication radar is being developed and will be in service with the surface fleet by the mid-1980s." The Seaspray airborne search radar is being fitted to the Lynx helicopter and will give target information for Sea Skua missiles. A derivative of Seaspray, Blue Fox, is being developed and will be fitted to Sea Harrier "for air to air and air to surface roles". Most of the surface fleet will be fitted with computer-based action information systems and digital data links by the mid-1980s.

● The Army is continuing development of Supervisor, "a battlefield surveillance and target acquisition system using real time data transmission". Supervisor is based around an unmanned miniature helicopter, a prototype of which will make its first flight this spring. The Cervantes trailer-mounted radar to locate rocket launchers and mortars is also continuing development.

Deployment of the Rapier all weather blindfire tracking radar DN181 has now begun. "In July last year and electronic-warfare regiment took its place in the order of battle of 1(BR) Corps. Most of its equipment will be British, although some is being bought from France. Further improvements in our electronic-warfare capability are under consideration."

The replacement for the Bruin tactical trunk communications system Ptarmigan, is now in its final development stages (*WW* September 1977, p.49). Wavell, the new command and control automatic data processing system, will be installed in all formation headquarters in 1(BR) Corps if trials to be carried out in BAOR are successful.

● The DN181 blindfire tracking radar will be fitted to the Rapier systems now in service with the RAF. The planned programme of improvements to the United Kingdom Air-Defence Ground Environment (UKADGE), which is receiving money from NATO, is now well advanced and development will begin this year. A number of early warning stations will also be re-equipped.

The MOD are conducting "feasibility studies" for an Identification Friend or Foe system to replace existing equipment. The new system should be suitable for sale to other NATO countries.

Work has begun on equipment to exchange digital data between fighters, airborne early warning aircraft, ships and UKADGE, and the MOD are investigating the introduction of a general purpose ground communication system, using digital transmission and computer switching techniques. New v.h.f. and u.h.f. airborne radio systems are being installed in most RAF aircraft to replace obsolescent equipment and to satisfy new international standards. New v.h.f. and u.h.f. ground radios are also being introduced. "Techniques to improve beyond-line-of-sight radio systems are being studied and the installation of a new h.f. radio ground/air network for strike command aircraft has begun. The United Kingdom is co-operating closely with its allies to ensure that, where necessary, future communications systems are interoperable."

On electronic warfare the white paper says that passive radar warning equipment is being fitted in a variety of aircraft. □

Europe inches towards a world data network

THE FIRST MEETING of the council of ministers of posts and telecommunications of the EEC since Britain joined the community broke up in December without any decisions being reached. The aim was to harmonise the postal and telecommunications services of the member states, and, though the meeting ended with the European Communities Commission being asked to undertake "further studies" and to report back later, an ECC statement issued towards the end of February said that the president of the Council, Mr L. Défosset of Belgium, had described the meeting as "extremely positive" and had said that the foundations had been laid for "fruitful co-operation at the dawning of extraordinary technological development." The meeting had been called by Belgium.

The statement noted that the rapid development of electronic techniques implied widespread change in the community's telecommunications services. The Commission was asked to draw up a list of the main techniques in use or on the drawing board with a view to working towards an integrated electronic system including telephones and data processing.

The statement noted that in the United States every 100 people of their 210 million population had 70 telephones. The EEC, with its population of 260 million, had only 30 per 100. The Japanese were working on a plan to reach the US density level by 1980, but the EEC had no such target.

One of the greatest sources of growth in telecommunications in the 1980s will be data transmission. A number of different systems are in experimental use around the world on private or public networks, and the members of the ITU sub-agency, the CCITT (International Telegraph and Telephone Consultative Committee) are concerned to arrive at common standards for communications between computers and for access by data terminals of all kinds, especially those which the futurologists imagine most of us will soon have installed in our homes. The new public data networks will provide connections between computers and associated devices bought or rented, not from the telecommunications authorities in the country where the equipment is installed, as is now the case with the telephone and telex services, but from the manufacturers of the various computer devices by the users. Computers and their peripherals are not generally designed to work with or into those of competing manufacturers, so interface standards have to be adopted.

There already exist a number of private networks which companies or other organisations, particularly multinational companies, have built up for themselves. In many cases these are based on data transmission over the public telephone lines, or so-called permanent lines leased from the national PTT. Our Post Office, for example, provides a national and an international data service, Datel 2400/12, which disseminate date at 2,400 bits/s over the public telephone network. Lower speeds are provided as well, as on the Datel 200 service. In each case the Post office provides interface with the public network or leased line, the modulator/demodulator, or Modem. Modems operating at 4.8 and 9.6 kbit/s are now being designed.

But the public network is likely to be of variable quality, and is subject to misrouting and disconnection. Even in the case of a leased line, the PTT can take it away if the authority needs it for itself. In addition, where a number of companies band together to create a network using leased lines, as a group of arilines might do for bookings and so on, they have to operate and maintain the equipment themselves. The lines are also under-used, and the user is not allowed to share his network to make its use more efficient.

Hence the growing enthusiasm for a network of lines dedicated to carrying data and designed for the purpose. And since great emphasis has been placed on the best possible use of the available lines, much of the effort has been placed on developing packet switching systems.

Packet switching is defined by the CCITT as "The transmission of data by means of addressed packets whereby a transmission channel is occupied for the duration of transmission of the packet only. The channel is then available for use by packets being transferred between different data terminal equipments." The data you wish to transmit is put into the network and the switching then takes over. It will either send it on or hold it until its destination is free to accept it. The packet is transmitted by whichever route is free, that is by the quickest route, and there will usually be several routes.

The National Physical Laboratory began to study packet switching 12 years ago. In April, 1977, the Post Office started a full Experimental Packet Switching Service (EPSS) which will run until April, 1979. The full service began, after 15 months of limited customer testing, with the opening of switching centres in London, Manchester and Glasgow. There are now 33 customers for the service, the latest to join being the South West Universities' Regional Computer Centre at Bath. The packet switching exchanges at the three centres use Ferranti Argus 700E computers to switch the packets, and they are interconnected by 48kbit/s circuits.

Customers can choose between packet mode of character mode operation. Simpler terminals transmit serially using ten or 11 bit characters which are assembled into packets at the switching centre before being sent to their destination. "Intelligent" terminals transmit and receive in packets, each with an address code, a data section of up to 2,040 bits, and an error-checking code. Nine of the 14 Argus computers are used to switch packets, six in London operating in pairs to form three packet switching units, two in Manchester and one in Glasgow, each operating singly. One more computer at each exchange monitors and controls the system, another at telecommunications headquarters produces bills and system statistics, and another in London is for research and development. The system is open for eight hours a day, five days a week, but, according to the *Post Office Engineering Union journal*, longer operating periods are planned

The European Commission is anxious to foster a common policy for the EEC within the CEPT.

"Multinational private undertakings have already started to offer international communications services, and unless the member states are prepared to co-operate the community will inevitably lag behind in the new technologies." The statement stressed the need to agree common prices leading to a common integrated electronic system which would enable countries to compete in world markets. "This is particularly important as the community is already lagging behind in the development of microelectronic silicon technologies (v.l.s.i.) which will soon be on offer in international markets from Japan, and will put her in a very competitive position if European know-how in this field is not sufficiently developed."

In 1972 the 17 European PTTs pooled resources to produce a massive study of Europe's data communications needs, the Eurodata study. The work had been done by various consultant firms, but in December, 1976, the Eurodata Foundation was formed to take over the custody and maintenance of the Eurodata information from the consultants. The work on Eurodata will form the basis of the intended future development of European data communications and work is still going on.

With SESA (the French society for the study of automation systems), Logica has been responsible for part of the development of the European Informatics Network, a research project among ten European governments and Euratom, and Euronet, a packet switching network among the nine EEC countries. The haphazard development of packet-switching networks has provided valuable experience of this new technique, experience which is now being pooled in a great effort to ensure that future systems use a common standard for interfacing the several types of terminals with what is hoped will become a worldwide data network. The CCITT has developed a standard, X25, to which Euronet will conform. Terminals in the nine countries will have access to data bases holding specialised scientific, technical and socio-economic information. At the end of 1975 the EEC Commission placed a contract with the PTTs for the supply of an international packet-switching network to be operating by the end of this year. In June, 1977, the French PTT placed a contract on behalf of the EEC PTTs for the development and supply of the Euronet network.

The Euronet system will be managed from London, and there will be packet switching exchanges there and in Paris, Rome and Frankfurt. Remote Access multiplexer sites will be available in Dublin, Amsterdam, Brussels, Luxembourg and Copenhagen. The switching exchanges will be linked by at least two 48kbit/s links, and the rest by 9.6kbit single links.

The tariffs for Euronet, which is due to start in January next year, were announced a few weeks ago. Initially it will operate solely to meet the needs of the EEC commission, but eventually it will be expanded to allow access by companies, private individuals, and non-EEC traffic.

The Post Office's EPSS does not conform to the X25 standard and the BPO has just placed an order with the American Telenet Corporation for the supply of a complete packet switching network because no British supplier makes equipment that conforms to X25. □

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WW—042 FOR FURTHER DETAILS

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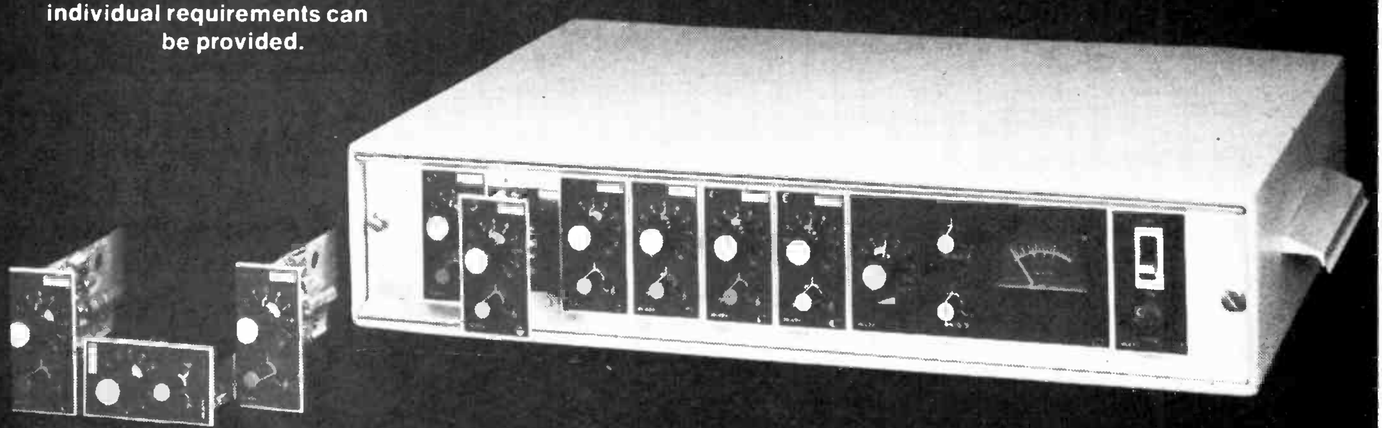

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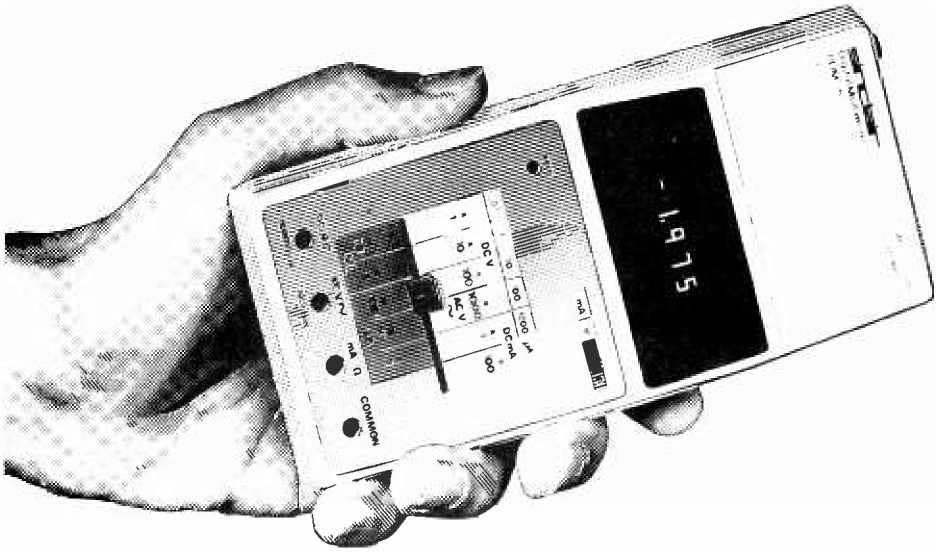

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WW—013 FOR FURTHER DETAILS

Audio power amplifier design — 3

Nyquist and Bode diagrams

"Design methods suitable for a variety of applications can never be reduced entirely to a set of rules" — H. W. Bode

by Peter J. Baxandall, B.Sc.(Eng.), F.I.E.E., F.I.E.R.E.

In the March issue it was explained that, assuming negligible non-linearity distortion, the closed-loop transfer function for a feedback amplifier gives full information about the frequency response, phase response, and transient response. In principle, therefore, all theoretical design work could be done by choosing the circuit configuration and values to yield a desired transfer function. However, this is such a tedious and inflexible approach for most amplifier design purposes that other techniques are much preferred.

ALTHOUGH the Nyquist Diagram is seldom actually drawn by amplifier designers, it is the best starting point one can make to gain an understanding of the preferred techniques used in amplifier design. For clarity, Fig. 1(a) has been included even though it is a repeat of Fig. 1 in the March issue. Figure 1(b) shows a phasor diagram for this circuit, drawn in the conventional manner and, for simplicity, the β-network is assumed to give attenuation but no phase shift. Figure 1(c) gives the phasor diagram for the circuit, drawn in accordance with the neater and generally much preferable scheme advocated by M. G. Scroggie[1], in which points on the phasor diagram are lettered to correspond to points on the circuit diagram, neither arrow heads nor voltage symbols then being required. With either scheme, if one likes, the whole phasor diagram may be envisaged as rotating, conventionally anti-clockwise. Then the *vertical* distances between the ends of the phasors represent instantaneous voltage values. Therefore, at the instant of time depicted by the angular position of the diagram shown in Fig. 1(c), points b and c are positive with respect to e. The lengths of the phasors, of course, represent the corresponding peak, or, if preferred, r.m.s. voltage values. The more I use the Scroggie method of drawing phasor diagrams, the more I like it, and my only regret is that, through sheer inertia, I did not change over to it far sooner.

Both of the phasor diagrams shown represent the conditions in the circuit of Fig. 1(a) at one frequency only, and the Nyquist diagram can be regarded as being derived from a set of such phasor diagrams covering all frequencies. These are drawn on the convenient basis that V' has the same value for all of them, being represented by ea in diagram Fig. 1(d). (Usually only the voltage at c is included in the diagram, b is left out.) Therefore, as the frequency is varied, a succession of voltage phasor diagrams, as shown in Fig. 1(d), is obtained. In this example, for simplicity, the amplifier is assumed to be d.c. coupled, so that at zero frequency the feedback voltage βV_{out}, or $A\beta V'$, is exactly in antiphase with the voltage V'. The locus of c, shown as a broken line in Fig. 1(d), is essentially the Nyquist diagram. Normally, however, the quantities plotted in a Nyquist diagram are not voltages, but gains, and are obtained by dividing all the quantities in the phasor diagrams shown in Figs. 1(b), (c) and (d) by V'. The Nyquist diagram in its normal form therefore appears as shown in Fig. 1(e), and is an Argand diagram showing how the loop gain $A\beta$ varies in amplitude and phase as the frequency is varied. Nevertheless, for some purposes, it is more convenient to think in terms of voltage phasor diagrams.

At low frequencies, especially when the loop gain is much larger than depicted here, the feedback voltage βV_{out}, represented, for example, by ec_1, is nearly equal in magnitude to the signal input voltage c_1a, so that the gain of the

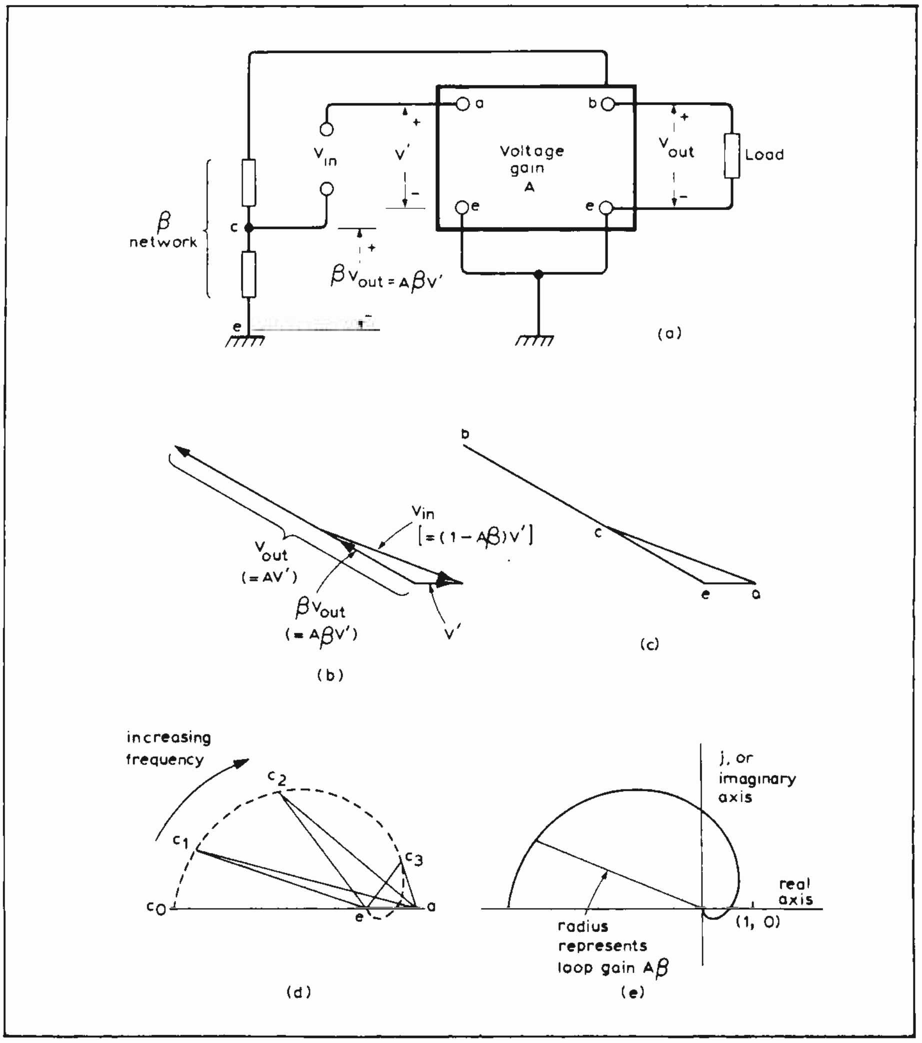

Fig. 1. *Basic feedback-amplifier circuit, with voltage-phasor diagrams and Nyquist diagram.*

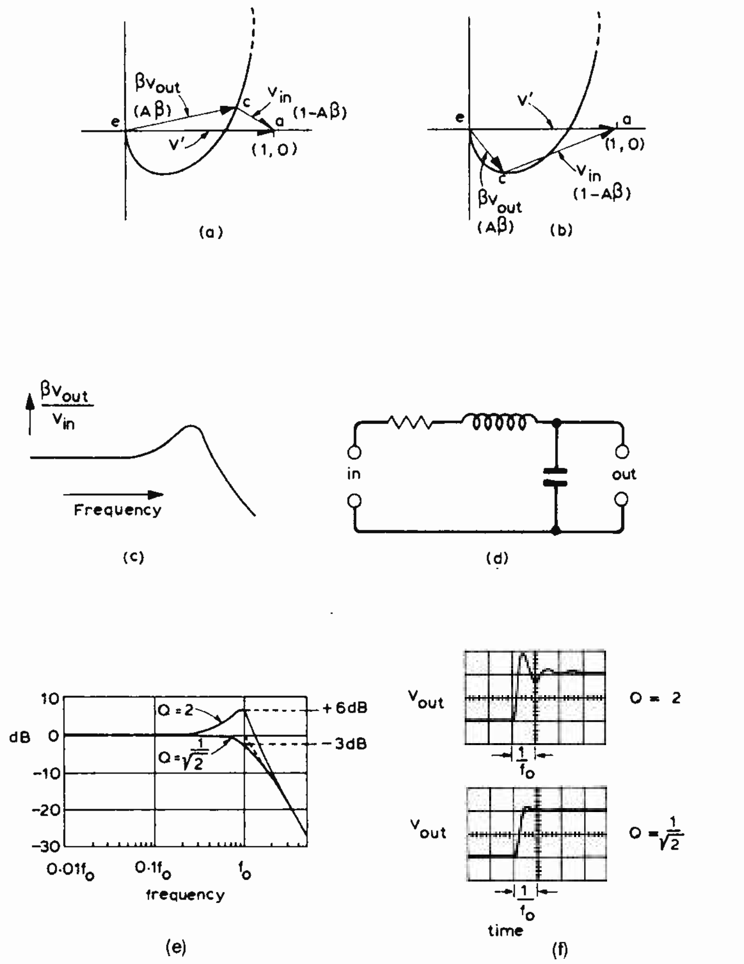

Fig. 2. *(a) and (b) show enlarged Nyquist/voltage-phasor diagrams for the critical region. (c) shows the type of frequency response resulting from (a) and (b), the circuit (d) having an approximately similar sort of response. (e) and (f) show accurate frequency and step responses for the (d) circuit for two values of Q.*

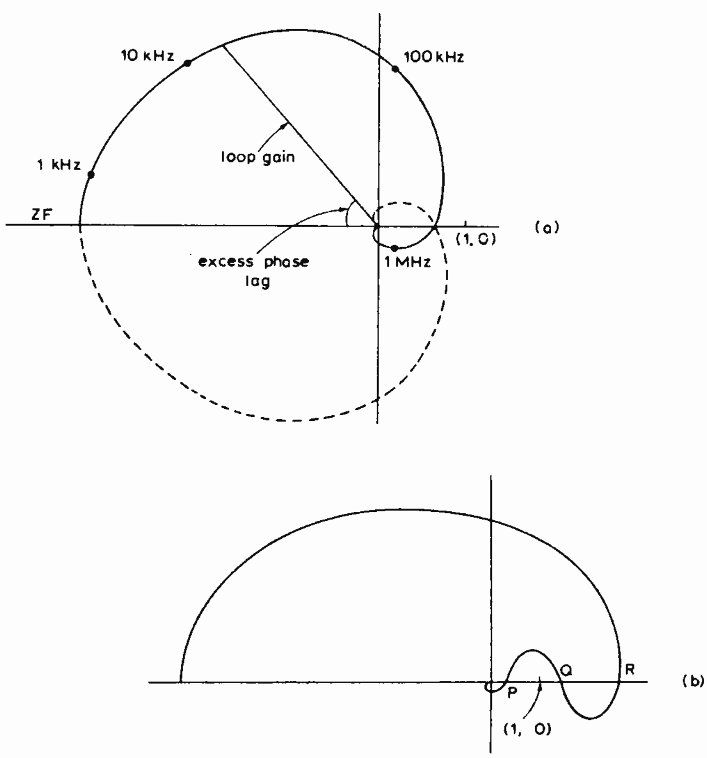

Fig. 3. *Diagrams illustrating Nyquist's criterion.*

amplifier, V_{out}/V_{in}, approximates closely to $1/\beta$*. Consider now the phasor relationship existing at a much higher frequency, when the tip of the $A\beta$ phasor has swung round to the region of the Nyquist diagram (in Fig. 1(e)) which is close to the point (1, 0). The details may be shown more clearly by redrawing just the relevant parts of the diagram to a larger scale. This has been done on a voltage basis in Fig. 2(a) and 2(b), but with the corresponding dimensionless, or gain, quantities shown in brackets. Also, both the conventional and the Scroggie representations have been combined, to suit all readers! In Fig. 2(a) it is seen that the βV_{out} phasor is now much longer than the V_{in} phasor, making the amplifier gain with feedback much greater than $1/\beta$. At even higher frequencies, as shown in Fig. 2(b), βV_{out} has become much less than V_{in}, so that the gain of the complete amplifier is now much less than $1/\beta$. From this it is evident that the closed-loop frequency response will be of the form shown in Fig. 2(c), and that if the Nyquist diagram goes very close to the point (1, 0), the peak in the frequency response will be of large magnitude. To obtain such a frequency response with purely passive elements, an arrangement such as that shown in Fig. 2(d) would be required, and it is obvious that this circuit, if supplied with a voltage step input, will ring if the Q-value is high enough. The frequency and step responses for two values of Q are shown in Figs. 2(e) and 2(f) respectively.

Since the frequency response of an amplifier whose Nyquist diagram passes close to the point (1, 0) is broadly similar to that of a passive circuit such as that shown in Fig. 2(d), it seems reasonable to expect, on these grounds alone, that the amplifier, like the passive circuit, will exhibit very ringy behaviour if the peak in its frequency response is of large magnitude – and this is, indeed, the case.

It is evident from the above simple phasor diagram considerations that if the Nyquist diagram passes through the point (1, 0), the required value of V_{in} for a finite output at that frequency becomes vanishingly small. Oscillation will then occur. A difficult question to answer, however, is whether oscillation can occur under any other conditions. Nyquist, in his famous paper of 1932[2], looked very deeply into this problem and enunciated his stability criterion, which is now universally accepted as being correct.

Nyquist's criterion

Nyquist's criterion states that if a Nyquist diagram, as already described, is plotted for all frequencies from zero to infinity, together with its image in the real axis, as shown in Fig. 3(a), the

* Referring to Fig. 1(b), $V_{out}/V_{in} = AV'/(1-A\beta)V' = (1/\beta)\times A\beta/(1-A\beta)$, showing that the gain becomes approximately $1/\beta$ when $|A\beta| >> 1$.

amplifier will be stable only if the point (1, 0) lies outside the enclosed figure so formed.

The example shown in Fig. 3(a) relates, as before, to a d.c.-coupled amplifier. The angle labelled "excess phase lag" refers to the phase lag that builds up with rising frequency due to shunt capacitances, transistor phase lags etc. The word "excess" is often inserted here to make it clear that the angle referred to does not include the 180° phase angle which is inherent in the fact that the feedback is *negative* at zero frequency. The frequencies marked on the Nyquist diagram are intended to be fairly typical of those which might apply to an audio amplifier. Though the Nyquist criterion, as stated, calls for frequencies from zero to infinity, it is clearly neither feasible nor necessary to cover such a range in practice. It is possible to be caught out, however, if measurements are stopped at too low a frequency, for a Nyquist diagram expected to continue shrinking with rising frequency as it passes the point (1, 0) can occasionally come back away from the origin again in a manner such as to jeopardise stability. This is especially liable to happen when transformers are employed, due to complex resonances involving leakage inductances and winding capacitances.

When complete Nyquist diagrams are plotted, it is usually more convenient to adopt a linear scale of decibels radially, to accommodate the wide range of loop gain magnitudes involved. Sometimes, however, only the part of the diagram fairly near the point (1, 0) need be plotted, and a linear scale may then suffice.

When the loop gain of a feedback amplifier is changed without altering any of the time-constants – for example, by a simple alteration in the value of the overall β – the obvious way to represent this would be to alter the size of the Nyquist diagram, leaving the point (1, 0) fixed. However, a much easier and quicker procedure is to leave the diagram as it is and shift the position of the point (1, 0), effectively altering the scale of the diagram. Usually there is no need to draw the image of the Nyquist diagram in the real axis, as shown in Fig. 3(a), because it is normally obvious whether the point (1, 0) would lie within the complete figure thus formed, without needing to see the broken-line part.

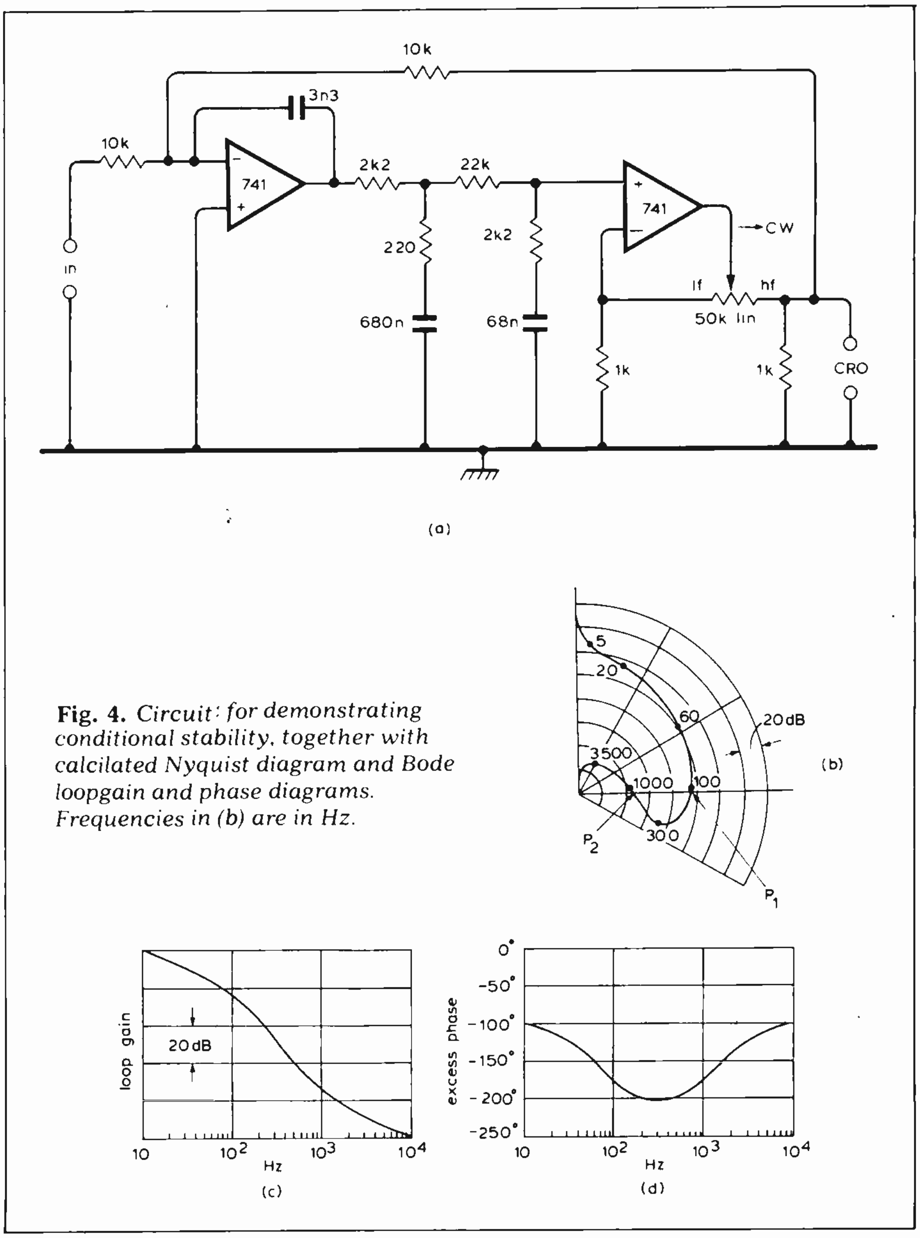

Fig. 4. *Circuit for demonstrating conditional stability, together with calculated Nyquist diagram and Bode loopgain and phase diagrams. Frequencies in (b) are in Hz.*

Conditional stability

It is possible to have an amplifier whose Nyquist diagram is something like that shown in Fig. 3(b). With the loop gain adjusted so that the unity-loop-gain point (1, 0) is in the space between P and Q, the amplifier will be stable, for the diagram does not encircle the point. An increase in loop gain, represented by moving the point (1, 0) to the left, will result in the onset of oscillation once the point (1, 0) reaches P. A decrease in loop gain, represented by moving the point (1, 0) to the right, will also cause oscillation (at a different frequency) by the time the point (1, 0) reaches Q. If the reduction in loop gain is sufficient to move the point (1, 0) beyond R, stability will again be achieved.

When operated with the point (1, 0) between P and Q, the amplifier is said to be *conditionally stable*. In this state, it should be noted that, at the frequencies corresponding to the points Q and R, there is zero phase shift round the loop and a loop gain greater than unity – and yet oscillation does not occur. A conditionally stable amplifier may thus be defined as one in which reducing the loop gain causes it to oscillate. An amplifier which remains stable for all values of loop gain setting between the normal one and zero is said to be *absolutely stable*[3]. It is important to distinguish between the term "conditionally stable", as defined above, and a quite different usage of the same term as applied to an amplifier which is stable only if the load impedance satisfies certain conditions. The converse term in this latter case is "unconditionally stable", meaning that the amplifier remains stable with any passive load impedance whatever connected.

Amplifiers having conditional stability in the sense of a reduction in loop gain causing oscillation, are normally to be avoided, and I have never come across a case of one being intentionally used for an engineering application. Their interest lies rather in the light that they throw on one's understanding of the full significance and correctness of Nyquist's criterion.

It is quite easy to make up a simple circuit exhibiting conditional stability, and Fig. 4(a) shows a suitable recipe. This circuit can be made the basis of an excellent and convincing lecture demonstration. With the potentiometer slider at the left, giving low loop gain, the amplifier is absolutely stable, and gives a fairly well damped square-wave response with, say, a 5Hz input square wave. As the slider is moved to the right, increasing the loop gain, the response becomes more and more ringy, going into continuous oscillation at just over 100Hz with sufficient gain increase. Turning the gain up further produces violent oscillation of increasing frequency, as the point (1, 0) is moved across from P_1 to P_2 in the calculated Nyquist diagram shown in Fig. 4(b). As P_2 is reached, the sustained oscillation becomes gentle only, with a frequency of just over 800Hz. Increasing the loop gain still more gives stability once again, but this time it is conditional stability. The more the gain is turned up, the better the damping of the square-wave response becomes, an appropriate square-wave frequency under these conditions being about 100Hz. For demonstration purposes, the output may be reproduced on a loudspeaker. The rather unusual gain control arrangement adopted enables the gain to be adjusted over a very wide range (about 68dB) without the control becoming too "touchy". It is the same arrangement as that used in the BBC Outside-Broadcast amplifier, type OBA/9[4], and such schemes, which combine passive and feedback gain control using a single potentiometer, have many applications. With a c.r.o. fed from the point shown in Fig. 4(a), it is the forward gain of the demonstration circuit that is controlled, the overall β-value remaining constant. Only a small output level can be produced when the potentiometer slider is over to the left, and a c.r.o. sensitivity of 50mV/cm will be found appropriate. An alternative is to feed the c.r.o. from the potentiometer slider, which enables a high output level to be obtained at all potentiometer settings. Now, however, both the forward gain and the overall β-value of the demonstration circuit are being varied, so that the signal gain in the non-oscillating states is dependent on the potentiometer setting.

In the valve era, a strong argument against the use of conditionally stable amplifiers was that the gradual rise in mutual conductances during warm-up caused oscillation to occur before the final conditionally-stable state was reached. As mentioned on page 163 of reference 3, such oscillation, once it started, was liable to persist indefinitely, because of the reduced effective stage gains under overload conditions. It is interesting to note that the demonstration model in Fig. 4 shows no tendencies of this kind if overloaded while in the conditionally-stable state. The only advantage that can be gained by adopting a conditionally-stable design is that it permits a much more rapid attenuation of loop gain with rising frequency than could otherwise be permitted, so that more feedback can be kept in operation up to a higher frequency, with a greater consequent reduction in distortion. Since extremely low distortion can readily be obtained in more straightforward ways, it is probably best to forget about such possibilities.

Gain and phase curves

During design work on feedback amplifiers, most engineers, rather than using Nyquist diagrams, think in terms of curves of gain magnitude and phase, against frequency. The diagrams drawn, which often use straight-line approximations to the true curves, are sometimes called Bode diagrams[5]. Fig. 5 shows simple examples which may be compared with the curves shown in the table in Part 2. Frequently, it is sufficient to draw only the gain diagrams, for provided the networks involved are so-called *minimum-phase-shift networks*, definite relationships exist between the gain and phase characteristics[3]. Then, provided the loop-gain characteristic is designed to meet certain requirements, discussed below, the phase characteristic will automatically be such that stability is assured. In this context, it is obviously necessary to have a very clear conception of just what does, and what does not, constitute a minimum-phase-shift (m.p.s.) network. It has sometimes been said that all the circuits used in ordinary amplifiers are of the m.p.s. type, but this is not necessarily always true. Any circuit in which there is more than one signal path from input to output, is liable not to have m.p.s. characteristics; that is, it is liable to produce more phase shift than necessary for the given gain characteristic. Such a non-m.p.s. network is always equivalent to a m.p.s. network in cascade with an all-pass network, the latter producing phase shift only, without gain variation. A simple example of such a non-m.p.s. circuit, which frequently occurs in amplifiers, is shown in Fig. 6(a). At the frequencies of present interest, the collector resistor R_c exerts negligible shunting effect and may be ignored. At very high frequencies, where C may be regarded as a short-circuit, $V_{out}=I_{in}\times(1/g_m)$.

At lower frequencies the circuit operates as a Blumlein integrator and gives $V_{out}=-I_{in}\times(1/pC)$, where $p=j\omega$. The general relationship is therefore:

$$V_{out}=I_{in}\left(\frac{1}{g_m}-\frac{1}{pC}\right) \qquad (1)$$

or

$$V_{out}=\frac{I_{in}}{g_m}\left(1-\frac{1}{pT}\right) \qquad (2)$$

where $T=C\times\frac{1}{g_m}$

Now, (2) may be written:

$$V_{out}=-\frac{I_{in}}{g_m}\times\frac{1-pT}{pT}$$

The significance of this may be more vividly seen if it is expressed in the form:

$$V_{out}=-\underbrace{\frac{I_{in}}{g_m}\times\frac{1+pT}{pT}}_{A}\times\underbrace{\frac{1-pT}{1+pT}}_{B} \qquad (3)$$

Part A of Equation 3 represents the response of the network shown in Fig. 6(b), which is relatively innocuous from a feedback-stability point of view. Part B, however, represents an all-pass characteristic (as shown at the bottom of the table on page 44 of the March article), and introduces extra phase lag without affecting the magnitude of the loop gain. Frequently, however, these complications do not significantly affect the stability of an amplifier, be-

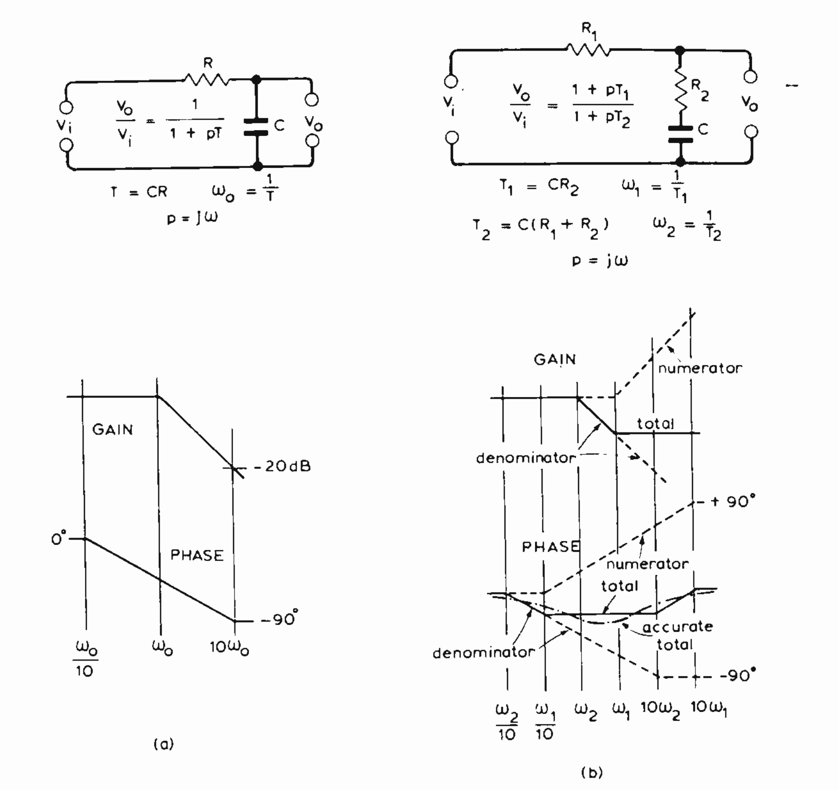

Fig. 5. *Diagrams showing how straightline approximations to the gain and phase characteristics of simple networks may be easily and quickly drawn.*

cause they come in at frequencies well above the unity-loop-gain frequency. For example, with C=100pF and a collector current of 5mA, giving an ideal g_m value of 200mA/V, the frequency at which the all-pass term gives 90° phase lag is, in ideal theory, 320MHz. Sometimes, however, a resistor of, say, 100Ω is included in the transistor emitter lead – maybe as part of a current-limiting scheme – giving much-reduced g_m. This, in association with a higher C value, say 470pF, gives an ideal theoretical all-pass 90° frequency of 3.2MHz, so that the all-pass term will give 10° lag at about 300kHz – not necessarily negligible.

Under overload conditions, the transistor in Fig. 6(a) may be temporarily cut off. Then, the *only* path from input to output is that via C, and the intended phase inversion of the stage is completely lost. With a large amount of overall feedback, which then becomes positive, momentary trigger-action, or high-frequency oscillation, may occur. Unravelling subtle effects such as this – and there are many others – can at times make development work on feedback amplifiers a difficult and demanding exercise.

From the above discussion it will be appreciated that, for most audio amplifier design purposes, it is safe to assume that the networks involved are of the minimum-phase-shift variety, but the possibility of things being otherwise should not be entirely forgotten.

Assuming m.p.s. networks, a high-frequency attenuation rate of 20dB/decade (6dB/octave), if continued over a wide frequency band, say two decades or more, will cause the excess phase lag to reach nearly 90°. A sustained attenuation rate of 40dB/decade will give nearly 180° lag, and will bring the Nyquist diagram in almost horizontally from the right, so that, with sufficient loop gain, it will pass very close to the point (1, 0). This will give a large peak in the frequency response and a very ringy step response.

In the above context it is usual to refer to the stability margins of an amplifier – the gain margin and the phase margin, as shown in Fig. 7. The gain margin is a measure of how much more feedback could be applied without oscillation occurring, and the phase margin shows how much extra internal phase lag would be necessary, at the frequency of unity loop gain, to reach the oscillation point.

The magnitudes of the stability margins that should be left in a practical amplifier design are dependent on a number of considerations, as follows:

(a) The margins, as designed, should be "comfortable", to ensure that likely production variations do not lead to trouble.

(b) The margins should satisfy (a) under all conditions of amplifier loading which it is considered necessary to take into account.

(c) Adequate margins, as in (a) and (b), should be maintained at all signal levels, not just under small-signal conditions.

(d) In many television, radar and c.r.o. amplifier designs, a step response with little or no overshoot is vital, but this is not normally the case with audio amplifiers – except, perhaps, to satisfy the demands of some reviewers and their public! Although a highly ringy step response justifiably arouses one's general suspicions about an audio amplifier design, a high-Q ring at 150kHz, say, will nevertheless not, in itself, have the slightest deleterious effect on the sound reproduction.

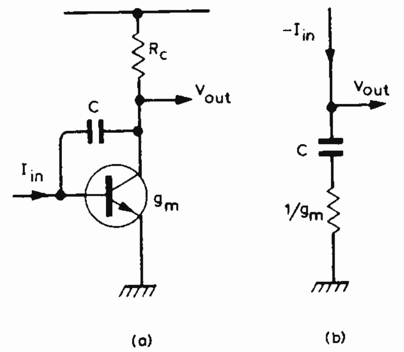

Fig. 6. *(a) Circuit not having minimum-phase shift (m.p.s.) characteristics. (b) Circuit having same amplitude response as (a), but giving less phase lag at high frequencies.*

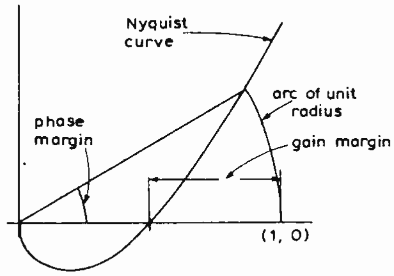

Fig. 7. *Diagram illustrating the definition of gain margin and phase margin.*

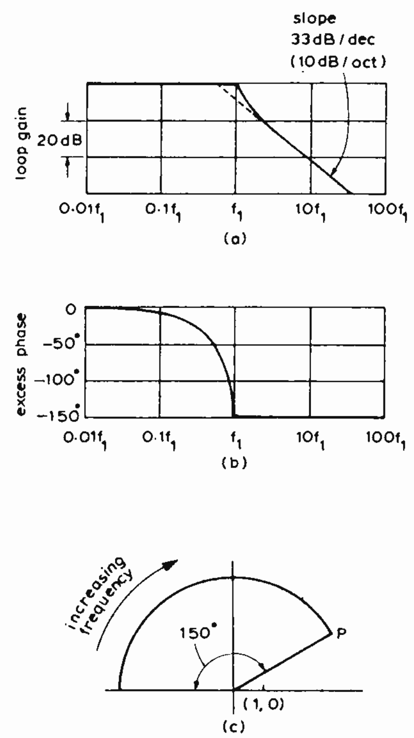

Fig. 8. *Loop-gain, phase and Nyquist diagrams for amplifier having "Bode ideal" loop-gain-attenuation characteristics.*

The argument against designing for excessive stability margins is that any audio amplifier so designed could easily be made to have less non-linearity distortion by altering the design to have more high-frequency feedback and smaller stability margins. However, with modern fast, silicon planar transistors, it is possible to obtain a superb performance, with regard to high-frequency distortion, even when the stability margins are made quite large, giving impressive-looking square-wave response. The present-day tendency is to do this.

A long time ago Bode[3] suggested that for purposes such as low-distortion audio amplifiers, a 30° phase margin is a sensible choice, and argued that a good philosophy, when practicable, is to hold the loop gain at its full value up to some chosen high frequency f_1, such as 10kHz, and then attenuate it as rapidly as possible, consistent with not exceeding 150° excess phase lag. In this way, with good design in other respects, the loop gain may be reduced to well below unity before unpredictable phase lags, due to the complex behaviour of transformers etc., become significant. He also showed that the ideal loop gain attenuation law to achieve a constant 150° phase lag above f_1 is as shown in Fig. 8(a).

If the steep rate of gain attenuation above f_1 were maintained for too long before reaching the 33dB/decade asymptotic rate, the corresponding phase curve would dip below −150°, but recover to −150° asymptotically at very high frequencies. In addition, this effect, if pronounced, would result in an amplifier having conditional stability if the loop gain were set high enough. A comparable state of affairs is shown in Figs. 4(c) and 4(d).

A characteristic of an amplifier with "Bode ideal" loop gain attenuation, assuming a flat β-network, is that the magnitude of the high-frequency response peak (6dB), and the shape of the step response, are independent of the loop-gain setting over a wide range** due to the constant 30° phase margin. This is only true if the loop gain is set high enough for the point (1, 0) to be well to the left of the point P in Fig. 8(c). I have recently set up an experimental amplifier circuit in which the loop gain is attenuated accurately at 33dB/decade, with a minimum-phase-shift network, over a frequency range of 1000:1. With the loop gain set to make the high-frequency peak occur somewhere in the central region of this frequency range, the peak is indeed of 6dB magnitude, as would be predicted from the Nyquist diagram geometry – see Figs. 8(c) and 2(a). It is also interesting to note that the step response, whose shape is almost perfectly independent of loop-gain setting over a wide range, is nearly indistinguishable from the Q=2 waveform of Fig. 2(f). There is no absolutely fixed theoretical relationship between the phase margin and the shape of the closed-loop step response, even when β is constant. Nevertheless, with reasonably "tame" Nyquist diagrams, as illustrated in this article, a 30° phase margin will always give an approximation to a single-mode ring with an effective Q-value in the region of 2.

** A feature perhaps particularly desirable in the valve era, since mutual conductances tended to fall off with valve ageing.

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2. Nyquist, H., Regeneration Theory, *Bell System Tech. J.*, Jan. 1932, p.126.
3. Bode, H. W., Network Analysis and Feedback Amplifier Design. (van Nostrand 1945). (See p.162 re conditional stability; p.303 re gain/phase relationships; p.454 re Bode ideal attentuation characteristics.)
4. Berry, S. D., New Equipment for Outside Broadcasts, *The BBC Quarterly*, Vol. 7 No. 2, pp. 120-128 (Summer 1952).
5. Cherry, E. M. and Hooper, D. E., Amplifying Devices and Low-Pass Amplifier Design, p.501. (John Wiley 1968).

Corrections

Figures 2(e) and 2(f) should have appeared in the March issue as Figs. 6(b) and 6(c). Unfortunately, the dB scaling was produced incorrectly in Fig. 6(b), and Fig. 6(c) was inadvertently omitted.

It was stated on page 43 of the March issue that the closed-loop transfer function of an amplifier contains information about the stability margins. E. F. Good has pointed out that this statement is not strictly correct, for the stability margins are purely functions of Aβ, whereas the transfer function gives the value of A/(1−Aβ) only, i.e. (1/β)×Aβ/(1−Aβ). Aβ, and hence the stability margins as normally specified, are therefore deducible only if the value of β is known as well as that of the whole transfer function. □

P. J. Baxandall, B.Sc.(Eng.), F.I.E.E., F.I.E.R.E.

Peter J. Baxandall was educated at King's College School, Wimbledon, obtaining his degree in electrical power engineering at Cardiff in 1942. After wartime work as a radio instructor, he moved in 1944 to TRE (now RSRE), Malvern, working on microwave techniques for the first two years and then joining Professor F. C. Williams's team on electronic circuit research work.

In 1971 he set up as an independent electro-acoustical consultant, having had a strong hobby interest in this field for many years. He has since done much practical and theoretical work for British audio firms, this work involving the design of capacitor microphone circuits, transformers, oscillators, f.m. receivers, audio amplifiers and loudspeakers.

He is a member of the Audio Engineering Society and a fellow of the British Kinematograph, Sound and Television Society.

BBC Engineering report stresses economy

MR JAMES REDMOND'S foreword to the annual report of BBC Engineering stresses the efforts BBC engineers have made to cut costs. Three two-camera lightweight mobile tv production units were in service, he noted, and a third was ordered. "Productions made in this way in 1977 included the 'The Mayor of Casterbridge', taking full advantage of the realism combined with economy which is possible with this method of programme-making ... More generally BBC engineers have been engaged as usual in a very wide range of activities to maintain, extend and improve existing services and find better (and sometimes more economical) ways of providing the technical tools needed for programme making."

The foreword notes that nearly 98% of the population can now receive colour tv. The Corporation completed the plan for, and started work on, the radio frequency changes "made necessary by the decisions of the 1975 World Administrative Radio Conference". (See *WW* April, p.49)

Elsewhere the report says that new u.h.f. stations were being opened at a rate of one a week, but that the cost per person served had risen to £25. In 1970 it was about £2.08.

Last year the BBC paid £6.6 million for Post Office services, of which £3 million was for telephone bills, £2.4 million for permanently rented programme and communications lines, £0.9 million for satellite circuits, and £0.3 million for o.b. and other temporary circuits.

Next year (1977/8) the BBC plans £28 million worth of capital expenditure of which the greatest part, £8.8 million, will be spent on replacements, and £8.1 million on transmitters and communications. Land and buildings will cost £1.4 million. The capital programme appears to show a disproportionate allocation to London. While Wales, Scotland and Northern Ireland receive a total of £3 million, the English Regions will get £1.9 million, and London another £1.8 million.

In the last two years the capital programme has hovered at around the £18 million mark, and the forecast for 1978/9 is £40 million.

The IBA's annual report for the year to March 31, 1977 also notes that the law of diminishing returns is affecting the spread of their u.h.f. coverage. Like the BBC, they added a mere half million tv viewers for the cost of around 60 new transmitters. Only one person in 100 is now totally dependent on 405 line coverage, says the IBA, but one in 20 probably still has a 405 line set. A further programme of 270 low power relay stations is now under way to reach the 200,000 or so people in groups of between 500 and 1,000.

The Japanese have an even worse problem than we do, since Japan is more fragmented even than the British Isles. The present Japanese tv network covers 97% of Japan but the cost of reaching the remote mountain and island regions is now prohibitive. Japan is now experimenting with satellite broadcasting, and has paid Nasa to launch the experimental direct broadcast to launch their Medium-scale Broadcasting Satellite for Experimental Purposes (BSE). The launch date was fixed for March 23 at the earliest.

According to a Nasa statement the craft will test new methods of transmitting high quality colour tv economically to the Japanese islands and Okinawa. Antenna size will be between 3 and 5ft.

The satellite, built under a Toshiba contract by General Electric, will be the third to experiment in direct satellite broadcasting after ATS6 and the US-Canada Communications Technology Satellite, CTS. □

WORLD OF AMATEUR RADIO

Now TE mode on 432MHz?

The record-breaking long-distance (3,180 miles) contacts made on 144MHz via ionospheric reflection between amateur stations in Venezuela and Argentina, reported in the March issue, have proved to be more than just one-time freaks. During February, world distance records on 144MHz were again broken — and more than once. First the record was extended to 3,825 miles as a result of an s.s.b. phone contact between KP4EOR in Puerto Rico (about 18° North) and LU5DJZ in Argentina, and then again to 3,940 miles when KP4EOR worked a 10-watt station LU8DIN, also in Argentina but over a hundred miles further away. CX8BE in Chile also heard KP4EOR but, perhaps the most sensational of all, is that YV5ZZ in Venezuela is reported to have heard the Argentinian LU3AAT *on 432.1MHz*! All of these contacts and reception reports appear to have been due to transequatorial (TE-mode) propagation. Whereas, until recently, this form of inospheric reception was thought not to extend much above 70 or 100MHz, it has thus been shown now to extend to 144MHz and even above 400MHz, although of course this still has to be confirmed by two-way contacts.

This sudden extension to the upper frequency limits of TE-mode propagation appears to be another reflection of the very rapid rise in sunspot numbers which has re-opened almost daily the 28MHz band during recent weeks and also brought to British listeners the sounds of American citizens' band operation on 27MHz.

Liberated ladies?

Although in the UK the number of "young lady" (YL and XYL) operators has been increasing gradually over the years, they still represent a very small minority of amateurs, considerably fewer than in the United States or even among the "club station" operators of the USSR. In a recent survey of YL amateurs in the USA, several comment how much the hobby has meant to them. "Ham radio can open new worlds to a fuller life" — Lenore Jenson, W6NAZ, a radio actress. "An absolutely great hobby for women" — Jan Shillington, N9YL, mother and housewife. "Outside of my parents, ham radio has been the strongest influence in my life . . . it helped me decide the direction of my education and opened career opportunities" — an electrical engineering student at Purdue University. "If a young girl is physically large or awkward on the dance floor, over the airways she's the same as anyone else . . . women are doers, I build a lot of my own stuff" — Dr Christine Haycok, WB2YBA. "It gave me the chance to build my own circuits" — Sue Heller, K3YL, reading electrical engineering at Drexel University. "You have a friend every place you go . . . I got off the plane in Russia and someone was right there waving my QSL" — Flo Majerus, W7QYA, pilot, teacher and dyed-in-the-wool c.w. operator.

The family approach to amateur radio is underlined in a recent letter from a WoAR reader, Joseph Schwartz of Flushing, NY. He is K2VGV, his wife is WA2JQC, his son is K2VG, his daughter K2ZCS, his son-in-law K2KGF and his grandson is WA2HPS.

Another RAE pre-test

London-area candidates taking this year's Radio Amateurs' Examination have the opportunity of helping the City & Guilds of London Institute by taking a pre-test based on multiple-choice questions, similar to those which will be used in the examination proper from 1979 onwards. The Institute is particularly anxious to check the system on a representative sample of candidates, including those who have been studying on their own. Such pre-tests help City & Guilds by enabling the reviewing panel to judge whether questions are of suitable standard for inclusion in a question bank for use in future examinations. The pre-test will be held at City & Guilds of London Institute, 76 Portland Place, London W1 on Tuesday, May 2 from 10.00 a.m. For candidates it is a useful way of revising their studies and gaining examination experience. Anyone willing to assist should phone Miss Jackie Clifford (01-278 2468, ext. 485).

From all quarters

Don Miller, W9NTP, is developing a form of slow-scan television which should allow the transmission of *moving* pictures in a 35kHz bandwidth, with a field rate of 3.75 per second. It is based on a standard s.s.t.v. unit with extra memory and with audio sent by narrow-band frequency-modulation of the carrier. He hopes to get special authorisation to transmit signals on 29MHz and so become the first to transmit moving pictures across the Atlantic on h.f.

Approximately 70 amateur television enthusiasts are active around Melbourne on 426MHz, 580MHz (channel 34), 1296MHz and shortly on 10GHz.

Oscar 8 success

The entirely successful launch of Oscar 8 (formerly known as AMSAT-Oscar-D) on March 5 means that amateurs now have available a new "Mode J" facility, in the form of a 145.9-to-435.1MHz active transponder, in addition to another "Mode D" 145.9-to-29.4MHz transponder. The 435.095MHz beacon of Oscar 8 was immediately heard in the UK and the following day the 20.402MHz beacon was well received. A number of European stations began working through the satelite soon after it was in orbit although it had been requested this should not be done until a fortnight after launching. The sun-synchronous orbit is very close to that planned, with a provisional period of about 103.23 minutes and an inclination of about 98.989°

In brief

Arthur C. Clarke has become honorary Life Member No 2001 in AMSAT, the amateur satellite organisation . . . . AMSAT-UK now have a secretary for the first time, Ronald J. C. Broadbent, G3AAJ, 94 Herongate Road, Wanstead Park, London E12 5EQ . . . . They hope to have displays at the RSGB's Alexandra Palace exhibition, May 5-6, and Suffolk Wireless Revival Show, May 14 . . . . The Northern Mobile Rally is being held at The Victoria Park Hall, Keighley, on Sunday, May 21 and is organised by the Otley Radio and Electronics Society . . . . A Raynet Symposium covering many aspects of the Radio Amateurs' Emergency Network is being held on April 15 at the Post House Hotel, Leicester from 09.30 a.m. . . . . RSGB affiliated societies in the South London region are consulting members on whether "because of the apparently unstoppable misuse of the London repeater GB3LO" to press the RSGB to use its power as licensee to close it down . . . . A new 432.81MHz beacon station is expected to open soon at Crowborough, Sussex. The callsign GB3WHA has been chosen in memory of the late W. H. (Bert) Allen, G2UJ . . . . An amateur holding an extra class licence has been sentenced to 18 months in jail (to be suspended after 90 days) in the United States for transmitting obscenities and causing malicious interference to repeaters. He was caught after local amateurs had co-operated with the FCC who used sophisticated direction finding equipment to trace transmissions made from fast-travelling cars.

PAT HAWKER, G3VA

NEW PRODUCTS

Low-cost teleprinter

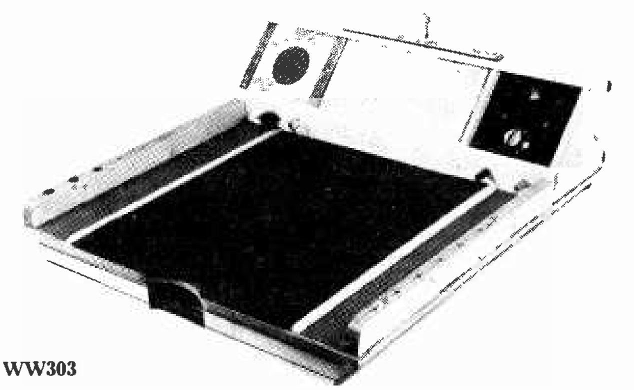
The Teleprinter 800 has been produced specifically for five-unit telegraph operation. It employs many of the modules used in the Printer 800 which entered full production a year ago. A highly-readable 7 × 5 dot matrix head produces conventional black and red printing on standard 210/216mm wide teleprinter paper. A paper roll of up to 130mm diameter can be housed within the printer and, by using a carbon interleaved paper, one original and three copies may be printed. A three-position baud rate switch is fitted enabling speeds of 50 and 75 plus one other optional speed. It has a four-row keyboard, using capacitive key switches and m.o.s. encoding, and includes automatic figures and letters shift coding, and shift controls for the generation of control signals. A buffer is used so that the transmitting speed is limited to that of the line speed, regardless of the typing speed. An audible alarm warns when the buffer becomes full. Trend Comunications Limited, Edric House, Castle Street, High Wycombe, Buckinghamshire, HP13 6RG.
WW 301

Desoldering tools

Three desoldering tools have been made by Electroplan Ltd as an attempt to provide models suitable for every application. The SR2 has a large suction stroke and is suitable for large solder pads and i.cs. It has a safe loading mechanism and the double-action suction chamber is closed while melting solder, and released by a conveniently situated push button. The SR3AS is designed to deal with solder removal where components are tightly grouped or otherwise inaccessible. The third tool, type SR3A, is similar to the SR3AS but it incorporates a safety guard. With these tools, replaceable p.t.f.e. nozzles can be easily removed for cleaning. Electroplan Limited, P.O. Box 19, Orchard Road, Royston, Herts. SG8 5HH.
WW 302

Electronic worktop

This unit was designed to avoid the problem of having to remove one's tools and equipment from the kitchen table. The worktop, which measures 24 x 20 in., has a removable rubber mat, holes drilled into the sides for accommodating small tools, and a lockable tool box in the centre of the rear panel. A variable 20V, 1A power supply is built into the unit, as well as a loudspeaker, volume control and two 13A sockets. The unit is priced at around £49.00 in kit form or about £58.00 ready wired. A small vice is available as an optional extra for £4.50. Home Radio (Components) Limited, 234-240 London Road, Mitcham, Surrey CR4 3HD.
WW 303



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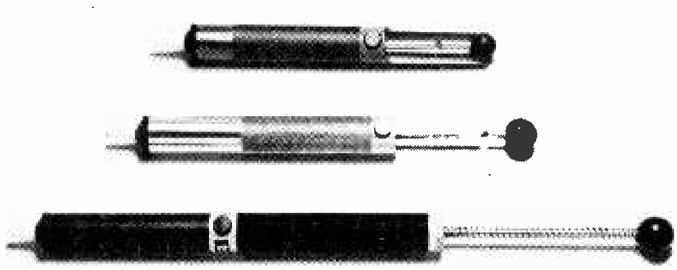


WW302

Keyboard switch

The Erg-KEY RS5020 is a low-profile keyboard push switch having a normally-open s.p.s.t. configuration. Its 12.4mm square key face protrudes only 5.08mm above its mounting plane. The switching action is dual-wiping and effected by torsion beam elements which are claimed to give extremely high reliability and exhibit a typical contact bounce time of only 25μs. To ensure continued reliability and low contact resistance (40mΩ), the phosphor bronze switching elements have a 15×10^{-6} in thick gold plating over a 50×10^{-6} in thick nickel layer. This is claimed to provide a life of more than 10×10^{6} operations for a 12V, 40mA d.c. resistive load over a working temperature range of −40°C to +60°C. Erg Industrial Corporation Limited, Luton Road, Dunstable, Bedfordshire LU5 4LJ.
WW 304

Active filter building blocks

The AF150 and AF151, made by National Semiconductor Ltd., are general-purpose building-block filters which have been designed for use in applications which would otherwise be difficult and costly to design. These devices have been introduced because of the successes of the AF100 Bi-Quad active filter and the AF120 gyrator. The AF150 is a higher-frequency version of the AF100 and extends the upper range from 10kHz to 100kHz, with a centre frequency Q product of 200,000. This has been accomplished using high-frequency op-amps and laser-trimmed resistors. The device has the same configuration as the AF100 in that it simultaneously offers low-pass, high-pass and band-pass outputs, while requiring only four external resistors to set the frequency, Q-value, and gain of the filter. In addition, by using the LF356 op.-amp., all-pass and notch filters can be formed, it is claimed. The AF151 is a dual-configuration filter, providing two separate active filters in one package, the performance of both filters being the same as that of the AF100. This allows the user to design fourth-order filters in a single package. It is also possible, claim the makers, to design eighth-order filters in one package. Delivery is from stock. National Semiconductor Limited, 19 Goldington Road, Bedford MK40 3LF.
WW 305

Communications receivers

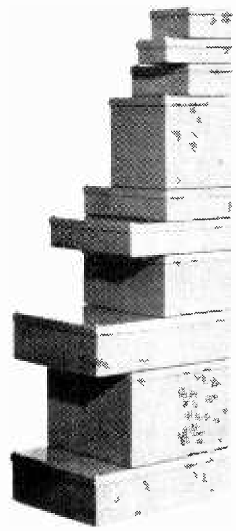
A range of synthesized communications receivers, designed by Redifon Telecommunications Ltd., provide fast, continuous tuning over the frequency range 15kHz to 30MHz, and are fully remotely controlled. The receivers, R1000 series, use a single optical tuning dial (as described in pp65-66, Sept. 77 issue), which allows tuning in either direction at a slow (600Hz per revolution) or fast 600kHz per revolution) rate. Once tuned, a pushbutton may be used to disengage the tuning control and lock the receiver to the chosen frequency. A seven-figure l.e.d. display provides the frequency readout to the nearest 10Hz. Receivers in the R1000 series have a 20-channel memory permitting up to 19 settings of frequency, mode and bandwidth to be stored for later, rapid recall. The remaining channel is used to store the operational status of the receiver, in the event of power failure, so that it can be recalled when power is regained. Also included in the receiver is a scanning facility which enables any of the channels held in store to be scanned with channel dwell times adjustable between 0.1 and 15s. According to the makers, because of its a.g.c. system, an R1000 receiver has excellent dynamic range, blocking and cross modulation characteristics. For example, an unwanted signal of 1mV e.m.f., 20kHz removed from a wanted signal of 1mV e.m.f., will reduce the output by less than 3dB, and an interferring 30 per cent modulated signal at least 20kHz from a wanted signal of 300μV e.m.f. must be greater than 300mV e.m.f. to cause 3% cross modulation. Other specifications include a sensitivity, for a 10db signal-to-noise ratio and 3 kHz bandwidth on s.s.b. and c.w., of between 0.7 and 7.9μV e.m.f., depending on frequency. The selectivity on s.s.b. is from 350 to 2700Hz, or optionally 250 to 3000Hz, at the 6dB point, and the frequency stability is quoted as ±3Hz peak deviation (short term) and within 1 part in 10^6 per year (long term). The extended and remote control facilities of the receiver permit a high degree of flexibility. For example, full duplication of all receiver controls and displays, including tuning and ancillary functions, such as antenna selection, may be provided. As many as 16 receivers can be controlled in this way from a single control unit. The marine version of the R1000 series has received UK type approval to MPT 1201 and is designed to meet other European specifications. Price for the standard main frame is less than £5,000. Redifon Telecommunications Limited, Broomhill Road, Wandsworth, London SW18 4JQ.
WW 306

Fibre-optic devices

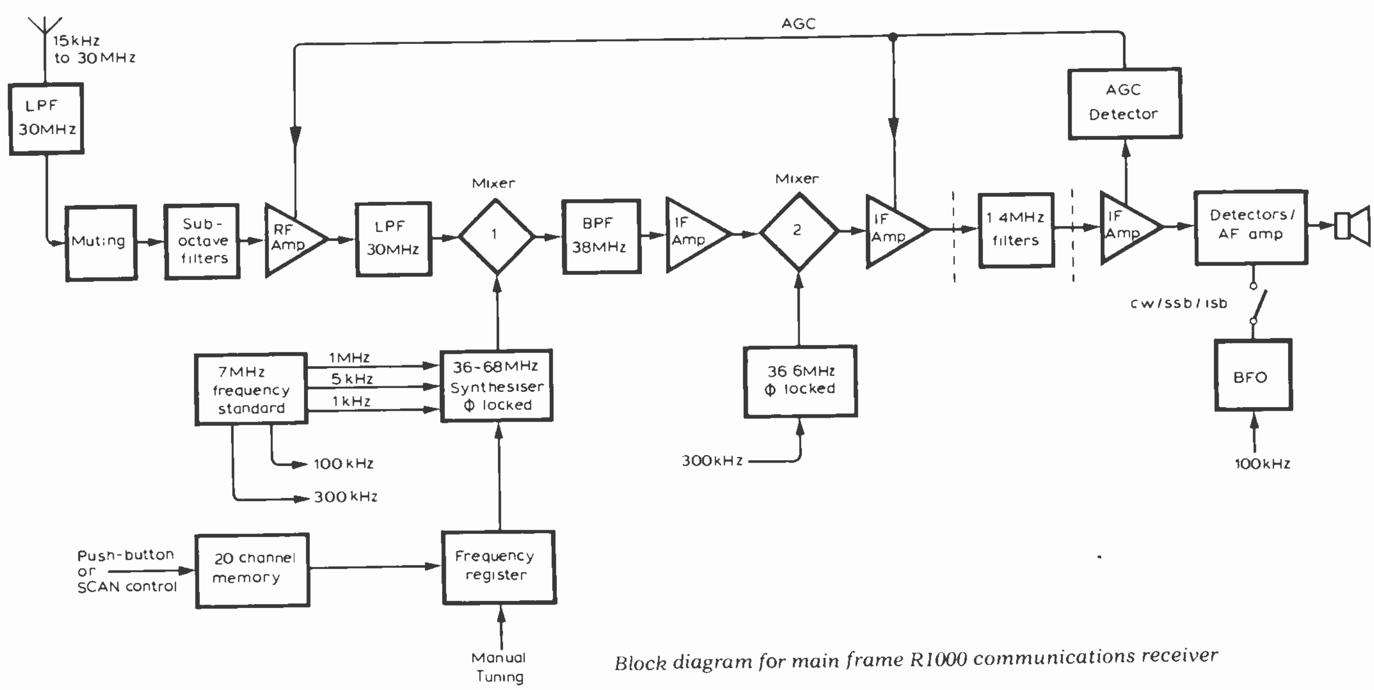
Infrared emitters and detectors from RCA Ltd, have integral fibre-optic cables so that they may easily be connected into optical communication systems with the minimum of encapsulation problems. The range includes a high-speed, gallium-aluminium-arsenide infrared emitter, silicon avalanche photodiodes, and hybrid photodiode/amplifier modules. The infrared emitter, type C30133, is designed for continuous d.c. or pulsed operation, and has a typical power output of 0.5mW at a peak forward current of 1A in the pulsed mode, and 150μW at a forward current of 200mA in the continuous d.c. mode. Its typical rise time is 3ns and its frequency response is 150MHz. The silicon avalanche photodiodes, types C30903E to C30908E, are available with light-pipe diameters of 0.25, 0.5, 1.25 and 2.5mm. They use a double-diffused reach-through structure to achieve high responsivity and very short rise and fall times. The spectral response range is from 400 to 1100nm. Types C30909E to C30911E have an additional m.o.s.f.e.t. preamplifier, giving them a typical system bandwidth of up to 50MHz. RCA Solid State-Europe, Sunbury-on-Thames, Middlesex, TW16 7HW.
WW 307

Sheet metal enclosures

A large range of sheet metal enclosures, manufactured by Actu Boxes, have been made available on an ex-stock delivery basis. The range covers 22 standard units in sizes from 4 × 4 × 1½in to 18 × 18 × 6in. The enclosures have



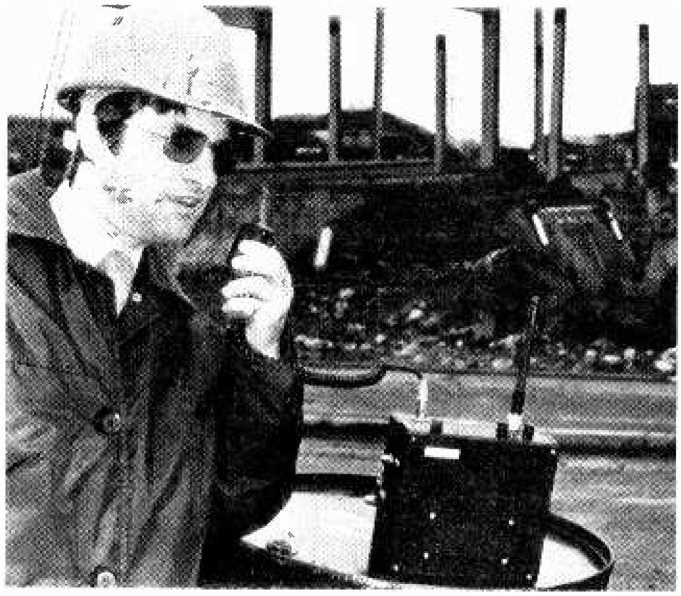
fully-welded seams, deep-threaded lids, corner inserts to retain the lids, and gaskets to seal them. Consequently, they are suitable for use in damp or dusty environments. A comprehensive leaflet giving technical details and prices, is available from Actu Boxes, Vale Lane, Hartcliffe Way, Bristol BS3 5RU.
WW 308

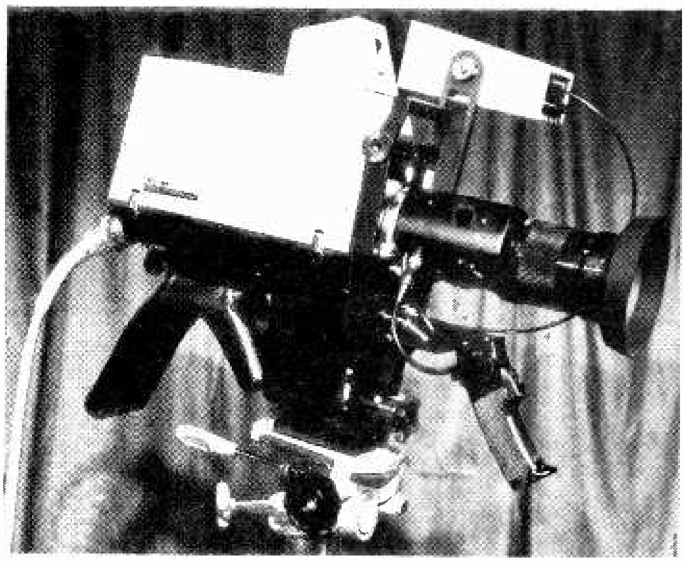


Block diagram for main frame R1000 communications receiver

V.h.f. radiotelephone

The Callbuoy 30T is a 25V portable radiotelephone for v.h.f. communications. It has been introduced as a high power transportable version of the model 30, which Callbuoy introduced last year when they entered the mobile radio market. The equipment is powered by a rapid-rechargeable nicad battery pack, making it, it is claimed, one of the most powerful transportable v.h.f. radiotelephones available. This pack allows up to eleven hours of operation before recharging is necessary. The unit offers up to twelve channels within the v.h.f. high, mid' or low bands. Full selective calling facilities are available. Callbuoy Electronics Limited, Marketing Division, 8 The Grove, Slough, Berkshire.
WW309


WW309


WW310

Colour television camera system

Successor to the widely-adopted Mk VIII colour television camera, the Mk IX has been announced by Marconi Communications Systems. The new equipment is described as a system, since the aim of versatility has meant the use of two camera types, for studio or outside broadcast work, a common control unit and a number of accessories to enable the system to function in almost any situation.

The cameras both incorporate four Plumbicons — 30mm for the studio camera and 25mm in the portable unit — which can be of several different types to provide the required characteristics. Sensitivity is such that an illumination of 800 lux on to an object showing 60% reflectivity will cause a current of 300nA at f4. Monitoring test signals are provided in the studio camera's electronic viewfinder, so that R G and B registration can be carried out at the camera without recourse to remote control. For OB work, the portable camera is small, requires no back pack and yet produces a picture which is comparable in quality with its larger version. Optical viewfinders of mono or binocular form can be provided or the electronic studio type can be fitted. The portable camera is equally useful for studio use, an adaptor taking the complete range of lenses.

Several design features assist in automatic operation: automatic registration of the tube outputs, automatic centering, auto black and auto white balance, auto iris and a dynamic gain control for improving detail resolution in dark or light parts of the picture. Instead of the thin-film circuitry employed in the Mk VIII camera, Marconi have used i.cs in the design of the new system. Marconi Communications System Ltd, Marconi House, Chelmsford, Essex CM 1 7PL
WW 310

Precision voltage reference

Using a differential input circuit, claimed to be unique, National Semiconductor Ltd has developed a 2.5V band-gap reference i.c. that performs as if it were a zener shunt regulator. According to National, this is the first 2.5V reference diode that can be used as either a positive or negative reference device and, in addition, has an adjustable breakdown voltage and adjustable temperature coefficient. The device will also operate with excellent regulation over a current range from 300μA to 10mA. Unlike other 2.5V references on the market the i.c. is a two-terminal device. There are three types of reference in the series, LM136, LM236 and LM336, the main differences being in their package sizes and working temperature ranges. National Semiconductor Limited, 19 Goldington Road, Bedford MK40 3LF.
WW 311

Epoxy resin mix

The hybrid electronics market, according to Teknis Ltd, needs a two-part, simple-mix-ratio gold epoxy resin. The H81E, they say, fulfils this need. It offers a 1:1 non-critical mix ratio and includes the pure gold powder in both the resin and the hardener. The resin, which has a three-day pot life and a two-year shelf life, without refrigeration, is from the same family as the H20E two-part, silver-filled epoxy resin. Teknis Limited, Teknis House, Meadrow, Godalming, Surrey, GU7 3HQ.
WW 312

Solid-state relays

A series of solid-state relays, from Magnecraft, have been made available by a UK distributor. The relays are designed for switching applications and are available in 24 current ratings from 2.5 to 40A, with switching capabilities of up to 480V. All of the devices have optical isolation between the inputs and the outputs and switch at zero volts. Since the coupling capacitance between the input and the output is less than 11pF, and there is no magnetic coupling, the possibility of noise, present on the load side of the relay, being coupled into the control circuit is virtually eliminated. Switching transients are also eliminated because turn-on is at zero volts and turn-off is at zero amps. Diamond H. Controls Limited, Vulcan Road North, Norwich NR6 6AH.
WW 313

U.h.f. power transistors

Three u.h.f. power transistors, types BLW79, BLW80 and BLW81, are suitable for transmitting applications in mobile radio. They may be used in class A, B or C modes of operation. The devices are rated at 2W, 4W and 10W respectively and have high power gains specified down to a 12.5V supply rail. Resistance stabilization enables them to be used without voltage regulation and provides protection against damage due to severe load mismatches for supply voltages up to 16.5V. Mullard Limited, Mullard House, Torrington Place, London WC1E 7HD.
WW 314

Low voltage stabilizers

Two low-voltage stabilizers, types BZV56-C1V5 and C2V0, are intended for applications where the voltage is too low for zener diodes to be used. The devices, which consist of two or three series-connected base-emitter junctions on one planar chip, are suitable for low-power clipping, level shifting and voltage and temperature stabilization of transmitter base-emitter biasing networks. These diodes have a guaranteed, reverse blocking voltage of 4V. Forward voltages and differential resistances for the C1V5 and C2VO are 1.35 to 1.55 and 2.00 to 2.30V and less than 20Ω and 30Ω respectively. Total power dissipation is 250mW up to an ambient temperature of 45°C. Mullard Limited, Mullard House, Torrington Place, London. WC1E 7HD.
WW 315

WW—029 FOR FURTHER DETAILS

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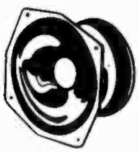

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Smart Badges Free with all above kits (to give that professional touch to your DIY Speakers!).

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Tweeters/Crossovers	40p each
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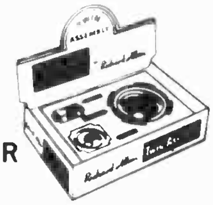
SPEAKER KITS



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WW—018 FOR FURTHER DETAILS

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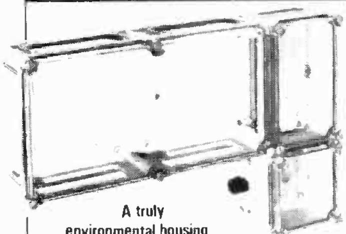
WH ENCASE



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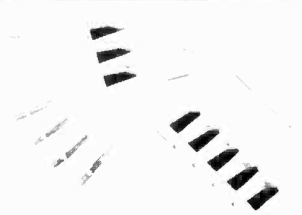
Encase solves your waterproof and dustproof problems and because of its chemical resistance is ideal in the process industries. The polycarbonate is virtually unbreakable. Covers clear PC. Case - glass filled PC. Gaskets (screws incl, gland plates (hinges available)

ENC A	190	190	130	8.87
ENC B	280	190	130	11.56
ENC C	380	190	130	15.40
ENC D	280	280	130	16.03
ENC E	380	280	130	20.51
ENC F	560	280	130	28.51
ENC G	560	380	130	39.29

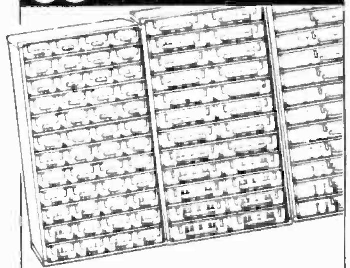
WH CHIRI CONNECTORS



A first class connector system, well thought out, efficient, simple, and the cost is very low. Ideal for board connections, plug-in resistors etc. the pins can be used for arranging different divide ratios or as test points.

	pk 10		pk 10
CHR 400 1	.32	CHR 400 7	1.22
CHR 400 2	.57	CHR 400 9	1.66
CHR 400 3	.65	CHR 401 0	
CHR 400 5	.90	pk 100 pins	£1.04

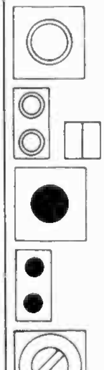
WH STORAGE SYSTEM



Stackable stove enamelled cabinets in three heights, all equal width and depths with movable shelves. Drawers in medium impact styrene with moulded handles and label slots in six sizes. Loose dividers fit lengthwise and crosswise.

Prices from £6.68 to £17.36

WH FRONT FURNITURE

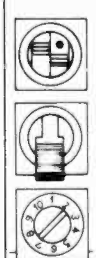


These drawings show some typical modules actual size,

being from top downwards, light emitting diode, dual light emitting diode, test jack, dual test jack, fuse holder, wirewound potentiometer, slide switches, toggle switch and step switch

Send for catalogue

This is logical miniaturisation.



It all fits together on a 0.1" module, look at the front panel work this saves.

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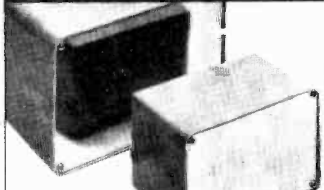
CAGM	.49
CAGN	.49
CAGP	.44
CAGQ	.47
CAGR	.47
CAGS	.54
CAGT	.82
CAGU	1.30

We have a surprisingly large demand for these cable glands. They are suitable for use with any of our weather proof housings and are used for cables up to 24.5 mm dia. Moulded in black nylon, are particularly good for circular PVC and rubber sheathed cables.

WH CONTIL-ELF

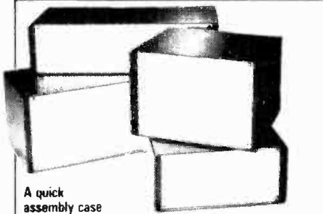


Tough, smart little cases that add very little to the cost of the job

Dough moulded in grey glass polyester with protected aluminium front panel in four sizes with feet and aluminium chassis included. The cases and chassis taper 10 mm from front to back.

	L	B	H	
Elf Long	153	101	101	3.20
Elf Giant	228	76	101	3.60
Elf Jumbo	203	127	138	4.50
Elf	273	130	134	5.40

WH MOD-4

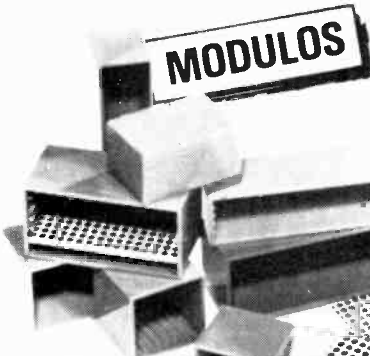


A quick assembly case in eight parts

A mass produced economy case in intensely shiny black or royal blue leather textured PVC steel with bright white steel panel. Eight pieces inc. aluminium chassis assembled with only eight screws.

	L	B	H			L	B	H	
401	178	152	76	4.84	405	279	152	114	6.11
402	178	152	114	5.12	406	279	152	152	6.55
403	178	152	152	5.39	413	165	152	157	5.45
404	279	152	76	5.72	416	305	152	157	6.88

MODULOS



WH WEST HYDE

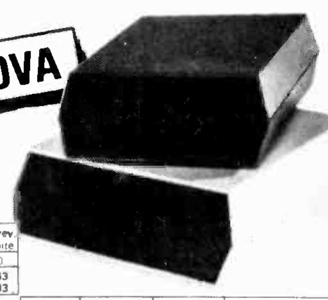
are now sole agents for **TEKO**

A wide range of small and miniature cases in A.B.S. suitable for anything from digital clocks to audio consoles. Low cost with discounts for quantity. **MODULOS** can be used for encapsulation and come with P.C. boards. **NUOVA** have a clear front panel. The very popular **DESKO** & **TEKO** are very widely used in both production and amateur use. **ALBA** are cases with grills top and bottom, for speakers or ventilation.

TEKO MODULOS — Specify colour G = Grey, R = Red, V = Sea Green

Lgth mm	Wth mm	Hgt mm			1 off	10	50
20	20	20	TEK L20 X	Pk 4	0.93	0 79	0 70
30	20	20	TEK L30 X	Pk 4	0 93	0.79	0 70
40	20	20	TEK L40 X	Pk 4	1 05	0 89	0 79
50	20	20	TEK L50 X	Pk 4	1 05	0 89	0.79
19	12 5	17 5	TEK S19 X	Pk 4	0.93	0.79	0 70
27	12 5	17 5	TEK S27 X	Pk 4	0 93	0 79	0 70
38	12 5	17 5	TEK S38 X	Pk 4	1 05	0 89	0 79
51	12 5	17 5	TEK S51 X	Pk 4	1.06	0 89	0.79
Asst of 8 pieces			TEK SL8 X	Pk 8	1 87	1 59	1 40

NUOVA

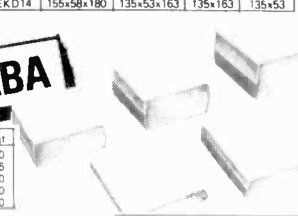


NUOVA — Specify Colour G = Grey, L = Lobster Red, W = White

	1 off	10	50
TEK D13 X	1 91	1.62	1 43
TEK D14 X	2.71	2 30	2 03

	External	Internal	Printed Circuit Size Horizontal	Printed Circuit Size Vertical
TEKD13	135x55x150	120x46x130	120x130	120x46
TEKD14	155x58x180	135x53x163	135x163	135x53

TEKO ALBA

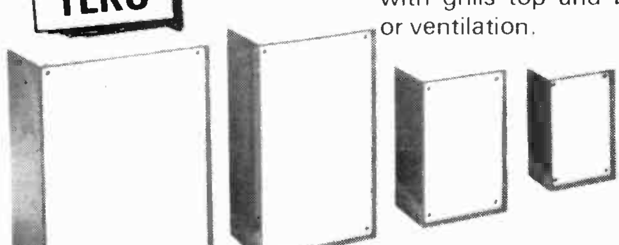


	Lgth	Wth	Hgt
TEK A11	198	180	40
TEK A12	198	180	55
TEK A22	198	180	70
TEK A23	198	180	90
TEK A33	198	180	110

TEKO ALBA — Specify colour G = Grey, L = Lobster Red

	1 off	10	50
TEK A11 X	3 15	2 68	2 36
TEK A12 X	3 40	2 89	2 55
TEK A22 X	3 60	3 06	2 70
TEK A23 X	3 85	3 27	2 89
TEK A33 X	4 10	3 48	3 07

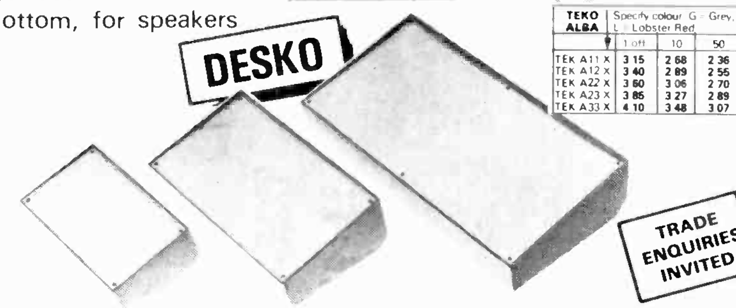
TEKO



Dimensions	Panel Al	Panel Plastic	TEKO 1 off	10	50
80x50x30	TEKP1A	TEKP1P	0 68	0 58	0 51
105x65x40	TEKP2A	TEKP2P	1 01	0 86	0 76
155x90x50	TEKP3A	TEKP3P	1 49	1 27	1 12
210x125x70	TEKP4A	TEKP4P	2.48	2 11	1.86

MINIMUM ORDER £2.00

DESKO



TRADE ENQUIRIES INVITED

A	B	C	D	E	°	Wt gr	DESKO	1 off	10	50
161	95	45	60	40	15	150	TEK 362	1 65	1 40	1 24
215	130	65	75	45	15	300	TEK 363	2 48	2 11	1.86
311	169	65	90	50	15	500	TEK 364	5.21	4.43	3.91

NOTE NEW ADDRESS

All West Hyde cases are available with substantial discounts for quantities. Most cases have discounts at 5, 10 and 25 off with discounts up to 25% at 100 off. Prices include P & P and are less 10% if collected on first two price breaks on cases only. Send for catalogue. Prices correct at press date.

WEST HYDE DEVELOPMENTS LIMITED, Unit 9, Park Street Industrial Estate, AYLESBURY, BUCKS. HP20 1ET. Phone: Aylesbury (0296) 20341. Telex: 83570

WW—082 FOR FURTHER DETAILS

LANGREX SUPPLIES LTD

Climax House, Fallsbrook Rd., Streatham, London SW16 6ED

RST Tel: 01-677 2424 Telex: 946708 RST

SEMICONDUCTORS

AA119	0.20
AAY30	0.13
AAY30	0.13
AAY32	0.15
AAZ13	0.25
AAZ15	0.31
AAZ17	0.25
AC107	0.75
AC125	0.30
AC126	0.25
AC127	0.25
AC128	0.25
AC141	0.20
AC141K	0.35
AC142	0.20
AC142K	0.30
AC176	0.25
AC187	0.25
AC188	0.25
ACY17	0.65
ACY18	0.65
ACY19	0.65
ACY20	0.65
ACY21	0.65
ACY39	1.25
AD149	0.70
AD161	0.75
AD162	0.75
AF106	0.45
AF114	0.25
AF115	0.25
AF116	0.25
AF117	0.25
AF139	0.40
AF186	1.50
AF239	0.45
AFZ11	2.75
AFZ12	2.75
ASY26	0.45
ASY27	0.50
ASZ15	1.25
ASZ16	1.25
ASZ17	1.25
ASZ20	0.75
ASZ21	1.50
AU113	1.70*
AUY10	1.70*
BA145	0.15*
BA148	0.15*
BA154	0.10
BA155	0.12
BA156	0.13
BAW62	0.05
BAX13	0.07
BAX16	0.07
BC107	0.12
BC108	0.12
BC109	0.13
BC113	0.15*
BC114	0.18*
BC115	0.19*
BC116	0.19*
BC117	0.22*
BC118	0.16*
BC125	0.18*
BC126	0.25*
BC135	0.15*
BC136	0.19*
BC137	0.16*
BC147	0.10*
BC148	0.10*
BC149	0.13*
BC157	0.12*
BC158	0.11*
BC159	0.13*
BC167	0.13*
BC170	0.16*
BC171	0.14*
BC172	0.13*
BC173	0.15*
BC177	0.19
BC178	0.18
BC179	0.20
BC182	0.11*
BC183	0.11*
BC184	0.12*
BC212	0.14*
BC213	0.14*
BC214	0.17*
BC237	0.17*
BC238	0.12*
BC301	0.45
BC303	0.60
BC307	0.20*
BC308	0.18*
BC327	0.22*
BC328	0.18*
BC337	0.19*
BC338	0.18*
BCY30	1.00
BCY31	1.00
BCY32	1.00
BCY33	0.90
BCY34	0.90
BCY39	3.00
BCY40	1.25
BCY42	0.30
BCY43	0.32
BCY58	0.23
BCY70	0.18
BCY71	0.22
BCY72	0.17
BCZ11	1.50
BD115	0.60
BD121	1.50
BD123	1.50
BD124	1.30
BD131	0.51
BD132	0.54
BD135	0.35*
BD136	0.36*
BD137	0.37*
BD138	0.40*
BD139	0.43*
BD140	0.47*
BD144	2.00
BD181	1.38
BD182	1.48
BD237	0.80
BD238	0.85
BDX10	0.75
BDX32	2.25
BDY20	1.42
BDY60	0.75
BF115	0.39
BF152	0.25
BF153	0.25
BF154	0.25
BF159	0.35
BF160	0.30
BF167	0.39
BF173	0.39
BF177	0.38
BF178	0.45
BF179	0.48
BF180	0.45
BF181	0.45
BF182	0.45
BF183	0.45
BF184	0.39
BF185	0.37
BF194	0.12*
BF195	0.11*
BF196	0.13*
BF197	0.14*
BF200	0.32
BF224	0.20*
BF244	0.35*
BF257	0.37
BF258	0.42
BF259	0.45
BF336	0.50*
BF337	0.53*
BF338	0.55*
BFS21	2.27
BFS28	1.38
BFS61	0.25*
BFS98	0.25*
BFW10	0.90
BFW11	0.90
BFX84	0.38
BFX85	0.41
BFX87	0.35
BFX88	0.32
BFY50	0.28
BFY51	0.26
BFY52	0.26
BFY64	0.30
BFY90	1.32
BSX19	0.34
BSX20	0.34
BSX21	0.32
BT106	1.25
BTY79/400R	3.19
BU205	2.25*
BU206	2.25*
BU208	2.50*
BY100	0.45
BY126	0.14
BY127	0.15
BZX61 Series	0.20
BZY88 Series	0.13
CRS1/05	0.45
CRS1/40	0.60
CRS3/05	0.45
CRS3/40	0.75
CRS3/60	0.90
GEX66	1.50
GEX541	1.75
GJ3M	0.75
GM0378A	1.50
KS100A	0.40*
MJE340	0.58
MJE370	0.65
MJE371	0.81
MJE520	0.65
MJE521	0.75
MJE2955	1.25
MJE3055	0.75
MPF102	0.30*
MPF103	0.30*
MPF104	0.30*
MPF105	0.30*
MPSA06	0.25*
MPSA56	0.25*
MPSU01	0.32*
MPSU06	0.40*
MPSU56	0.45*
NKT401	2.00
NKT403	1.73
NKT404	1.73
NE555	0.45
OA5	0.75
OA7	0.55
OA10	0.55
OA47	0.14
OA70	0.30
OA79	0.30
OA81	0.30
OA85	0.30
OA90	0.08
OA91	0.08
OA95	0.08
OA200	0.10
OA202	0.11
OA210	0.75
OA211	0.75
OAZ200	0.65
OAZ201	0.65
OAZ206	0.65
OAZ207	0.65
OC16	1.25
OC20	2.00
OC22	2.50
OC23	2.75
OC24	3.50
OC25	0.90
OC26	0.90
OC28	2.00
OC29	2.00
OC35	1.50
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OC45	0.50
OC71	0.45
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OC73	1.00
OC74	0.75
OC75	0.60
OC76	0.50
OC77	1.20
OC81	0.75
OC81Z	1.00
OC82	0.75
OC83	0.55
OC84	0.60
OC122	1.50
OC123	1.55
OC139	2.25
OC140	1.95
OC141	2.25
OC170	0.75
OC171	0.75
OC200	1.00
OC201	1.50
OC202	1.25
OC203	1.75
OC204	1.25
OC205	1.75
OC206	1.75
OC207	1.25
OCP71	1.25
ORP12	0.83
R2008B	2.25*
R2009	2.25*
R2010B	2.25*
TIC44	0.36
TIC226D	1.30
TIL209	0.25
TIP29A	0.50*
TIP30A	0.60*
TIP31A	0.62
TIP32A	0.75
TIP33A	1.00
TIP34A	1.20
TIP41A	0.70
TIP42A	0.90
TIP2955	1.00
TIP3055	0.50
TIS43	0.35*
ZS140	0.25*
ZS170	0.12*
ZS178	0.54*
ZS271	0.22*
ZS278	0.56*
ZTX107	0.11*
ZTX108	0.10*
ZTX109	0.12*
ZTX300	0.12*
ZTX301	0.13*
ZTX302	0.17*
ZTX303	017*
ZTX304	0.19*
ZTX311	0.12*
ZTX314	0.20*
ZTX500	0.13*
ZTX501	0.14*
ZTX502	0.16*
ZTX503	0.17*
ZTX504	0.20*
ZTX531	0.20*
ZTX550	0.16*
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1N916	0.07
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1N4002	0.07
1N4003	0.08
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1N4007	0.15
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1N5400	0.14
1N5401	0.16
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1S920	0.08
1S921	0.08
2G301	1.00
2G302	1.00
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2N404	0.60
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2N4289	0.25*
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2N5459	0.35*
3N125	1.75
2S017	6.50
2S019	6.50
2S026	12.00
2S103	1.50
2S302	0.75
2S303	0.75
2S322	0.80
2S324	1.25
2S701	1.50
2S703	1.50
2S721	3.00
2S745A	0.35
2S746A	0.35

VALVES

A1834	6.00
A2087	10.48
A2134	4.81
A2293	4.10
A2426	8.20
A2521	8.53
A2900	4.85
A3343	18.43
AZ31	1.10*
AZ41	1.15*
BK448	62.70
BK484	84.70
BS90	27.25
BS810	27.75
BT5	31.15
BT17	55.64
BT19	19.00
BT29	169.70
BT69	173.65
BT75	72.25
BT95	66.80
CBL31	1.50*
CL33	2.00*
CY31	1.00*
C1K	10.00
C3A	10.00
C3JA	10.00
DA41	16.85
DA42	8.81
DA100	31.86
DAF91†	0.40*
DAF96	1.00*
DET22	15.12
DET24	41.00
DF91†	0.40*
DF96	1.00*
DK91†	0.55*
DK92	1.25*
DK96	1.10*
DL92	0.75*
DL94	1.20*
DL96	1.10*
DLS10	8.25
DLS15	8.25
DLS16	8.25
DLS19	8.25
DM70	1.25
DM71	1.25
DM160	1.50
DY86/7†	0.45*
DY802	0.80*
E55L	21.89
E80CC	4.97
E80CF	6.40
E80F	5.71
E80L	5.48
E81CC	5.76
E81L	5.75
E82CC	6.12
E83CC	6.23
E86C	8.93
E88C	5.38
E88CC†	1.00
E90CC	5.06
E90F	5.16
E91H	4.65
E92CC	4.97
E99F	5.51
E130L	16.85
E180CC	5.36
E180F	5.80
E182CC	5.71
E186F	7.90
E188CC	5.06
E280F	16.90
E283CC	7.85
E288CC	12.58
EA52	14.20
EA76	1.50
EABC80	0.40*
EAC91†	0.50*
EAF42	1.25*
EAF801	1.75*
EB41	1.75*
EB91†	0.30*
EBC33	1.75*
EBC41	1.25*
EBC81	1.10*
EBC90†	0.65*
EBF80†	0.45*
EBF83	1.25*
EBF89†	0.40*
EBL31	2.50*
EC90†	0.40*
EC91†	2.80*
EC92	1.25*
EC157	208.00
ECC33	3.50*
ECC35	3.50*
ECC40	1.25*
ECC81†	0.50*
ECC82†	0.47*
ECC83†	0.55*
ECC84†	0.50*
ECC85†	0.55*
ECC86	2.00*
ECC88†	0.75*
ECC89	0.75*
ECC91†	0.55
ECC189	1.00*
ECC807	1.75
ECC808	2.25*
ECF80†	0.60*
ECF82†	0.60*
ECF86	0.75*
ECH35	2.00*
ECH42	1.15*
ECH81†	0.50*
ECH83	0.85*
ECH84†	0.85*
ECL80†	0.60*
ECL81	0.75*
ECL82	0.55*
ECL83	1.50*
ECL84	0.90*
ECL85	1.12*
ECL86†	0.65*
ECLL800	7.00*
EF37A†	1.60*
EF39†	1.60*
EF40	1.15*
EF41	1.20*
EF42	2.00*
EF50†	0.60*
EF54	5.00*
EF55	2.50*
EF80†	0.45*
EF83	1.75*
EF85†	0.50*
EF86†	0.45*
EF89	0.60*
EF91†	0.65*
EF92†	0.75*
EF93†	0.50*
EF94†	0.55*
EF95†	0.30*
EF98	1.25*
EF183†	0.50*
EF184†	0.50*
EF804S	6.50
EF805S	7.00
EH90	0.75*
EK90†	0.65*
EL32	1.50*
EL33	3.50*
EL36	0.75*
EL41	1.25*
EL42	1.75*
EL81	1.10*
EL83	1.25*
EL84	0.45*
EL86†	0.50*
EL90†	0.75*
EL91	3.85
EL95†	0.80*
EL156	16.25
EL360	2.75*
EL500/504	1.50*
EL509	3.16*
EL821	4.42
EL822	5.61
EM80	1.10*
EM81	1.00*
EM84	1.00*
EM85	1.25*
EM87	1.50*
EN32	15.66
EN91†	0.55
EN92	5.81
EY51†	0.75*
EY81	1.65*
EY83	1.75*
EY84	3.95
EY86†	0.50*
EY88	1.75*
EY500A	1.36*
EY802	0.82*
EZ35	0.55*
EZ40	1.25*
EZ41	1.25*
EZ80†	0.30*
EZ81†	0.35*
EZ90†	0.45*
FW4-500	2.50*
FW4-800	2.50*
G1-371K	15.00
G55-1K	9.50
G180-2M	12.90
G240-2D	11.75
G400-1K	13.50
GN4	4.50
GN4A	4.50
GS16	9.00
GT1C	6.95
GU50	9.66
GU51	9.80
GXU1	10.43
GXU2	17.20
GXU3	21.42
GXU4	21.94
GY501	1.32*
GZ32	0.75*
GZ33	4.00*
GZ34†	1.52*
GZ37	4.00*
KT61	3.50*
KT66	4.50*
KT88	6.25*
KTW61	1.75*
KTW62	1.75*
KTW63	1.75*
M8079	8.40
M8080	3.80
M8081	6.33
M8082	4.65
M8083	5.61
M8091	7.71
M8096	3.75
M8097	3.56
M8098	3.20
M8099	5.20
M8100	5.92
M8136	6.12
M8137	6.23
M8140	4.50
M8141	4.85
M8142	4.00
M8144	3.75
M8149	5.10
M8161	5.76
M8162	5.75
M8163	4.50
M8190	4.60
M8195	3.70
M8196	3.40
M8204	3.50
M8212	8.63
M8223	2.30
M8224	2.80
M8225	2.60
M8248	6.72
MU14	1.00*
MX119	20.00
MX123	34.50
MX145	27.15
MX151	11.69
MX152	74.00
MX161	76.50
MX163	12.60
MX164	12.56
MX166	105.00
MX168	24.00
N78	7.50*
OA2†	0.45
OA3	1.10
OA4	1.10
OB2†	0.45
OB3	0.75
OC2	2.30
OC3†	0.45
OD3†	0.45
OZ4	0.75*
PC86†	0.85*
PC88†	0.85*
PC95	0.70*
PC97	1.08*
PC900†	0.75*
PCC84†	0.45*
PCC85	0.45*
PCC88	0.65*
PCC89†	1.05*
PCC189†	0.65*
PCC805†	0.95*
PCC806†	0.95*
PCE82†	1.72
PCF80	0.72*
PCF82†	0.50*
PCF86†	0.65*
PCF87†	1.00*
PCF200†	1.05*
PCF201†	1.05*
PCF801†	0.55*
PCF802†	0.88*
PCF805	1.44*
PCF806	0.80*
PCF808	1.44*
PCL82†	0.50*
PCL83†	0.92*
PCL84†	0.50*
PCL85†	0.96*
PCL86†	0.65*
PCL805/85†	0.96*
PD500	3.60*
PE06-40N	27.30
PFL200	1.12*
PL36†	1.12*
PL81	0.55*
PL81A†	1.12*
PL82	0.60*
PL83†	0.55*
PL84†	0.60*
PL504/505†	1.20*
PL508†	1.60*
PL509†	2.72*
PL519†	3.60*
PL801	1.10*
PL802†	2.16*
PY33	0.68*
PY81†	0.72*
PY82	0.45*
PY83	0.60*
PY88†	1.16*
PY500A†	1.60*
PY800/81†	0.92*
PY801	0.92*
QQV02-6	9.60
QQV03-10†	2.00
QQV03-20A†	10.50
QQV06-40A†	13.00
QQV07-50	36.70
QQZ03-20A	27.50
QQZ06-40A	42.60
QU37	11.00
QV03-12	3.00
QV04-7	2.50
QV08-100	85.60
QY3-65	42.80
QY3-125†	12.00
QY4-250	51.30
QY4-400	58.30
QY5-500	127.50
QY5-3000A	212.00
QZ06-20	18.40
R10	5.00
R17	1.65*
R18	3.95
R19	1.00*
R20	1.44
RG3-250	21.51
RG3-250A	23.28
RG3-1250	20.95
RG4-1250	27.50
RG4-3000	113.09
RR3-250	34.77
RR3-1250	62.37
S11E12	18.00
S130	2.00
S130P	2.50
STV280-40	10.00
STV280-80	20.00
SU41	2.50
SU42	9.00
TD03-10	15.00
TD03-10E	17.50
TD03-10F	17.50
TT15	22.00
TT21	7.00
TT22	7.00
TT100	37.50
TY2-125	40.20
TY4-400	56.10
TY4-500	73.20
TY5-500	160.00
TY6-800	145.00
TY6-5000A	198.00
TY6-5000B	206.00
TY6-5000W	178.00
TY7-6000A	216.00
TY7-6000W	175.00
TZ40	15.00
U18-20	2.50*
U19	8.11
U25	1.16*
U26	1.44*
U37	11.00
UABC80†	0.50*
UAF42	0.75*
UB41	1.25*
UBC41†	0.75*
UBF89	0.50
UCC84	0.75*
UCC85†	0.50*
UCF80	0.75*
UCH42	1.20*
UCH81†	0.50*
UCL82†	0.50*
UCL83	1.44*
UF41	0.75*
UF42	1.25*
UF80†	0.50*
UF85†	0.50*
UF89†	0.50*
UL41	1.00*
UL84†	0.60*
UM80	1.00*
UY41†	0.75*
UY85†	0.65*
VL5631	8.22
XG1-2500	23.10
XG5-500	16.80
XG2-6400	64.95
XGQ2-6400	74.15
XR1-1600A	19.05
XR1-3200	54.00
XR1-3200A	54.00
XR1-6400	59.10
XR1-6400A	59.10
YD1120	206.00
YD1240	206.00
Z759	6.50
ZM1000	4.60
ZM1001	5.38
ZM1020	8.55
ZM1021	7.96
ZM1022	8.23
ZM1023	7.66
ZM1040	11.57
ZM1041	9.67
ZM1042	11.08
ZX1051	87.00
1B3GT†	0.55
1B24	10.00
1B35A	17.00
1B63	45.00
1R5†	0.55*
1S5†	0.40*
1T4†	0.40*
2A515	10.00
2C39A†	9.00
2C43	18.00
2D21†	0.55
2E26	3.00
2J42	60.00
2J55	175.00
2J70A	235.00
2J70B	250.00
2K25†	9.50
3-400Z	35.00
3-500Z	35.00
3A5	1.35
3B24	5.00
3B28†	4.00
3B29	10.00
3B-240M	15.00
3B241M	15.00
3C23	10.00
3C45†	6.00
3CX100A5	20.00
3E29†	5.50
3S4†	0.75*
3V4†	1.00*
4-65A	25.35
4-125A†	12.00
4-250A	36.00
4-400A	37.00
4B32	10.00
4C35	40.00
4CX250B	17.50
4CX350A	31.35
4CX150A	21.00
4X150D	25.00
5B-254M	11.25
5B-255M	11.25
5C22	40.00
5J-180E	495.00
5R4GY†	1.00*
5U4G	1.52*
5U4GB	1.00*
5V4G†	0.65*
5Y3GT	0.85*
5Z3	1.50*
5Z4G	1.12
5Z4GT	1.00*
6-30L2	1.00*
6AB4	0.75*
6AB7	0.75*
6AC7	0.75*
6AF4A†	0.70*
6AG7	0.75*
6AH6†	0.70*
6AK5†	0.30
6AK6	0.95*
6AL5†	0.30*
6AM4	2.30*
6AM5	3.85
6AM6†	0.65*
6AN5	2.50*
6AN8A†	0.70*
6AQ5†	0.75*
6AR5	0.70*
6AS6†	0.80*
6AS7G†	1.50*
6AT6†	0.65
6AU5GT	4.26*
6AU6†	0.55*
6AV5GT	3.74*
6AV6†	0.50*
6AX5GT	3.10*
6B7	0.75
6B8	0.75
6BA6†	0.50
6BA7	5.12
6BA8A	3.75
6BC4	3.71
6BE6†	0.45*
6BH6†	1.20*
6BJ6†	0.80*
6BK4	4.21*
6BL6	85.00
6BL7GT	3.86*
6BM6	85.00
6BN6	0.80*
6BQ7A	1.55*
6BR7	4.00*
6BR8†	1.20*
6BS7	4.00*
6BW6	3.75*
6BW7	1.40*
6BX7GT	4.96*
6BZ6	1.78*
6C4†	0.40*
6CB6A†	0.50*
6CD6GA	4.00*
6CG7	1.72*
6CH6	4.42
6CL6†	0.75*
6CW4	4.72*
6D2†	0.30*
6DK6	2.49*
6DQ6B	3.04*
6EA8	2.21*
6EB8	2.12*
6EW6	0.80*
6F6	0.75*
6F23	1.60*
6F28	1.16*
6F33	10.75
6H1	8.00
6H2N	0.75*
6H3N	0.75*
6H6	0.75*
6J4†	0.75*
6J6†	0.55
6J7	0.75*
6K4N	0.75*
6K6GT	0.75*
6K7	0.75*
6K8	0.75*
6KD6	4.79*
6L6G	2.50*
6L6GA	1.50*
6L6GT	0.85*
6L6GC	1.75*
6L7	0.75*
6N2P	0.75*
6N3P	0.75*
6N7	0.75*
6P25	3.60*
6Q7	0.80*
6R7	0.80*
6SA7	0.80*
6SC7	0.80*
6SF7	0.80*
6SH7	0.80*
6SJ7	0.80*
6SK7	0.80*
6SL7GT†	0.70*
6SN7GT†	0.70*
6SQ7	0.75*
6SR7	0.75*
6SS7	0.75*
6U5G	2.00*
6U8†	0.40*
6U8A†	0.55*
6V6GT†	0.60*
6X4†	0.45*
6X5GT†	0.55*
7B7	1.00*
7C5	1.75*
7C6	1.25*
7H7	1.00*
7R7	1.50*
7S7	2.25*
7Y4	0.75*
7Z4	0.75*
11E3	34.00
12AT6	0.45*
12AT7†	0.45*
12AU6	0.50*
12AU7†	0.45*
12AV6	0.60*
12AV7	2.84*
12AX7†	0.45*
12AY7†	0.82*
12B4A†	1.00*
12BA6	0.50*
12BE6	1.60*
12BH7†	0.60*
12BY7†	0.80*
12E1	4.00
12E14	19.80
13E1	43.55
19H4	16.88
19H5	22.50
24B9	30.50
30C15	1.56*
30C17	1.56*
30C18	1.44*
30F5	1.60
30FL1/2	1.12*
30FL12	1.72*
30FL14	1.44*
30L1	0.84*
30L15	1.72*
30L17	1.72*
30P4	0.92*
30P19	1.12*
30PL1	1.32*
30PL13	1.72*
30PL14	1.68*
30PL15	1.72*
35W4	0.60*
50C5	0.70*
75B1	3.15
75C1	1.55
85A1	7.50
85A2	1.50
90AG	7.26
90AV	7.16
90C1	1.50
90CG	5.74
90CV	5.99
92AG	7.26
92AV	7.16
95A1	4.15
150B2	1.80
150B3	3.30
150C2	1.50
150C4	2.30
211	5.00
723AB†	8.00
803	10.00
805	20.00
807†	1.00
811A†	3.80
812A	7.25
813†	10.00
833A	30.00
866A	8.85
872A	11.40
922	4.36
931A	12.24
1624	1.25
1625	1.00
2050	2.50
4212E	118.95
4212H	118.95
5544	54.00
5545	59.00
5551A	62.70
5552A	84.70
5553A	225.30
5642	3.16*
5654	3.61*
5651	180*
5670	2.86*
5675	9.09*
5687	4.30*
5696	1.94*
5718	3.36*
5725	3.40*
5726	2.20
5727	3.50*
5749	3.30*
5751	2.93*
5763	3.12*
5814A	2.60*
5840	4.40
5842	6.90
5876A	9.38
5879	3.16*
5886	10.50
5963	1.87*
5965	2.36*
6005	3.65*
6021	4.46
6057	6.23
6058	8.40
6059	4.00
6061	4.25
6062	3.75
6063	3.65
6064	5.60
6067	6.12
6072	3.77
6080	6.85
6097A × B × C	40.00
6146A	4.27
6146B	4.65
6159	6.00
6189	6.08
6201	4.84
6442	15.00
6883B	4.93
6973	2.61
7025†	1.20
7551	3.65
7586	6.79
7587	12.54
7609	31.80
7868	2.93*
7895	7.48
8005	25.00*
8068	5.50
8122	33.15
8136	1.54
8417	3.40
18042	5.31
18045	5.71

BASES

B7G unskirted	0.15
B7G skirted	0.30
B9A unskirted	0.15
B9A skirted	0.30
Int Octal	0.20
Nuvistor	0.55
Loctal	0.55
8 pin DIL	0.15
14 pin DIL	0.15
16 pin DIL	0.17
Valve screening cans all sizes	0.30

CRTs

2AP1*	8.50
2BP1*	9.00
3BP1	8.00
3DP1*	5.00
3EG1*	7.00
3FP7*	3.00
3GP1	6.00
3JP1*	8.00
3JP2*	8.00
3JP7*	10.00
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3RP1*	35.00
4EP1	25.00
4EP7	25.00
4EP11	25.00
5ADP1	35.00
5BP1*	10.00
5CP1*	5.00
5CP1A	40.00
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5UP7*	5.00
DG7-5	25.00
DG7-32	36.00
DH3-91	31.00
DH7-11	68.00
VCR97*	5.00
VCR138*	10.00
VCR138A*	12.50
VCR139A*	8.00
VCR517A*	10.00
VCR517B*	6.00
VCR517C	6.00

Tube Bases 0.75
* = Surplus
VAT 8%

INTEGRATED CIRCUITS

7400	0.20
7401	0.20
7402	0.20
7403	0.20
7404	0.26
7405	0.23
7406	0.55
7407	0.55
7408	0.28
7409	0.28
7410	0.20
7412	0.26
7413	0.45
7416	0.40
7417	0.40
7420	0.20
7422	0.25
7423	0.35
7425	0.35
7427	0.35
7428	0.50
7430	0.20
7432	0.36
7433	0.37
7437	0.42
7438	0.37
7440	0.22
7441AN	0.92
7442	0.78
7447AN	1.20
7450	0.20
7451	0.20
7453	0.20
7454	0.20
7460	0.20
7470	0.35
7472	0.36
7473	0.36
7474	0.40
7475	0.59
7476	0.42
7480	0.60
7482	0.85
7483	1.00
7484	1.00
7486	0.40
7490	0.52
7491AN	0.85
7492	0.60
7493	0.70
7494	0.80
7495	0.80
7496	0.90
7497	3.67
74100	1.75
74107	0.45
74109	0.86
74110	0.57
74111	0.86
74116	1.89
74118	0.95
74119	2.00
74120	1.10
74121	0.45
74122	0.60
74123	1.00
74125	0.80
74126	0.80
74128	0.80
74132	0.80
74136	0.68
74141	0.85
74142	3.00
74143	3.00
74144	3.00
74145	1.00
74147	2.45
74148	2.00
74150	1.75
74151	0.90
74154	2.00
74155	0.90
74156	0.90
74157	0.90
74159	2.50
74170	2.60
74172	5.00
74173	1.75
74174	1.57
74175	1.00
74176	1.10
74178	1.65
74179	1.65
74180	1.65
74190	1.48
74191	1.48
74192	1.25
74193	1.25
74194	1.25
74195	1.10
74196	1.20
74197	1.00
74198	2.25
74199	2.25
76013N	1.75*
TAA570	2.30*
TAA630S	3.50*
TBA480Q	1.84*
TBA520Q	2.30*
TBA530	1.98*
TBA540Q	2.30*
TBA550Q	3.22*
TBA 560CQ	3.22*
TBA673	2.19*
TBA700	1.52*
TBA720Q	2.30*
TBA750Q	2.07*
TBA990Q	2.99*
TCA270Q	2.99*
TCA760A	1.38*

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	R25	300	10%	½ watt	£2.03
	R30	100	5%	1 watt	£2.36
	R35	300	5%	1 watt	£6.24
	R40	100	10%	1 watt	£1.13
	R45	300	10%	1 watt	£3.04
	R50	100	5%	¼ watt	£2.08
	R55	300	5%	¼ watt	£5.40
	R60	100	10%	¼ watt	£1.13
	R65	300	10%	¼ watt	£3.04

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Transistor Amplifier Kit.

(70 Watts into 8 ohms)

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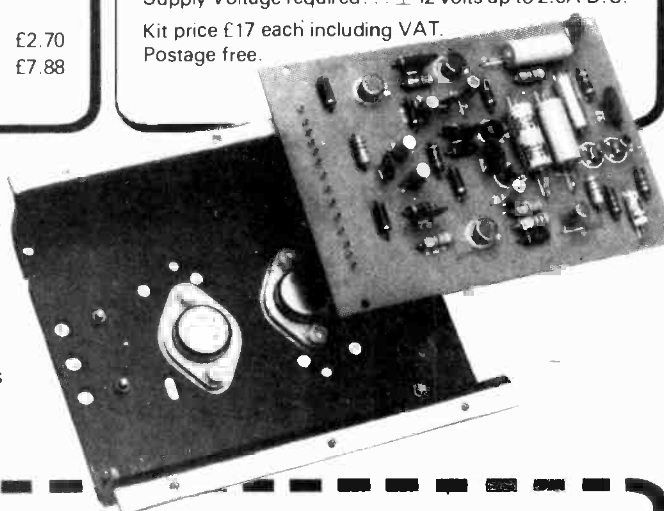
There are many applications for the Mainline 70 including Hi-Fi, Disco, Public Address, Guitar Amplifier, etc.

Specification

Input sensitivity .... 700mV.
Output Power ..... 70 Watts into 8 ohm load at 1 Khz.
Distortion generally .... ≤ 0.05% (up to 70W ≤ 0.15%)
Supply Voltage required ... ± 42 volts up to 2.5A D.C.

Kit price £17 each including VAT.
Postage free.



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WW 5/78

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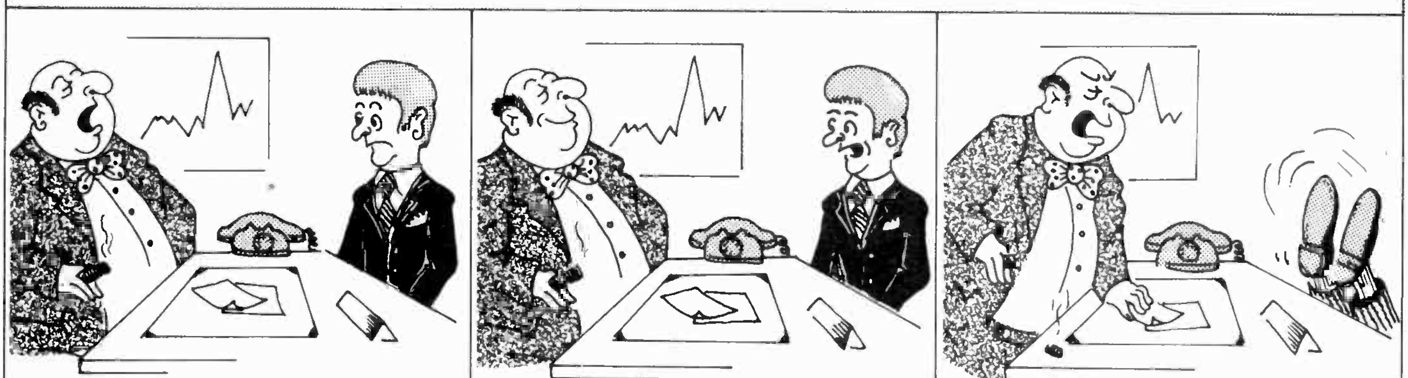

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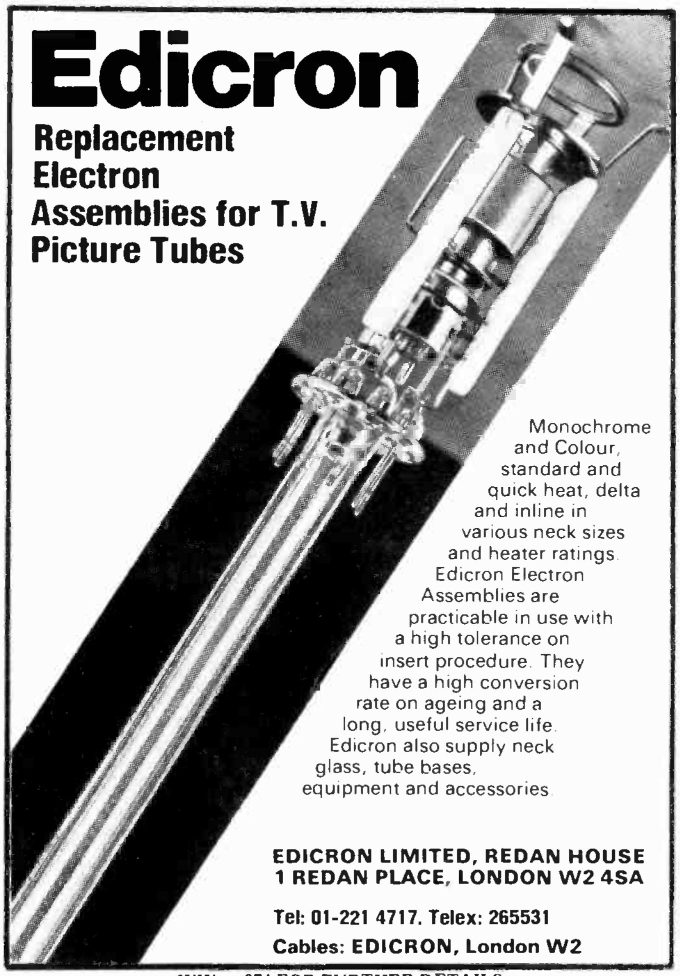

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INTERPROJECTS LTD. *Technical Services*

In association with the UNIVERSITY OF LIVERPOOL'S COMPUTER LABORATORY are organising a FOUR-DAY INTENSIVE COURSE on

LOGIC AND MICROPROCESSOR SYSTEM DESIGN

Conducted by Prof. D. Zissos, University of Calgary and Dr. M. Taylor, Computer Laboratory, University of Liverpool.

JULY 10-13, 1978 — 9 am to 5 pm

at the University of Liverpool's Greenbank House University Club.

Proceedings to be opened by Dr. J. Alty, Director of the Computer Laboratory, University of Liverpool.

An intensive four-day course aimed to enable engineers, technical managers, physicists, medics and academics to design and implement their own microprocessor systems using methods that require no specialist knowhow of electronics or programming other than a basic knowledge of logic.

D. Zissos has written numerous books and articles on the subject and he is a practising design consultant known for his pragmatic approach — M. Taylor Hardware Specialist is responsible for Microprocessor applications.

Fees: Residential — £185.00. *Non Residential — £165.00
*Includes course dinner and buffet luncheons only.

To INTERPROJECTS Ltd., *Technical Services*
29 Church Street, Edmonton, London N9 9DY
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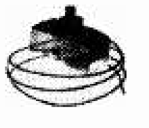


THERMOSTATS

Refrigeration. As illustrated with 36" capillary **£1.62.**
Limpet Stat. Must be mounted in close contact calibrated 90°-190°F 15 amp contacts **£1.62.**
Appliance Stat. Fix like a volume control — 15 amp contact 30°-80°F **85p.**
Ditto but for high temps **£1.25.**
Over Stat. With sensor and capillary **85p.**

MAINS OPERATED SOLENOIDS

Model 772 Small but powerful 1" pull — approx. size 1½ x 1½ x 1¼" **£2.00.** Model 4001 — ⅞" pull Size 2¾ x 2 x 1½". **£2.50.** Model TT10 — 1¼" pull Size 3 x 2½ x 2" **£4.50.** Prices include VAT & postage

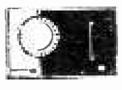
DELAY SWITCH

Mains operated — delay can be accurately set with pointers knob for periods of up to 2½ hrs. 2 contacts suitable to switch 10 amps — second contact opens few minutes after 1st contact **95p.**

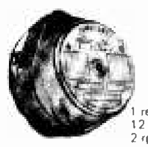
MOTORISED DISCO SWITCH

With 10 amp changeover switches, multi-adjustable. Switches are rated at 10 amp each so a total of 200w can be controlled and this would provide a magnificent display. The motors are 50V, but they are of such a low wattage, only 2 watts, that they can be driven by a resistor or condenser voltage dropper. 8 Switch model **£5.25.** 10 Switch model **£5.75.** 12 Switch model **£6.75.**

SMITHS CENTRAL HEATING CONTROLLER



push-button gives 10 variations as follows (1) continuous hot water and continuous central heating (2) continuous hot water but central heating off at night (3) continuous hot water but central heating on only for 2 periods during the day (4) hot water and central heating both on but day time only (5) hot water all day but central heating only for 2 periods during the day (6) hot water and central heating on for 2 periods during the day time only — then for summer time use with central heating off (7) hot water continuous (8) hot water day time only (9) hot water twice daily (10) everything off. A handsome looking unit with 24-hour movement and the switches and other parts necessary to select the desired programme of heating. Supplied complete with wiring diagram. Originally sold we believe at over **£15** — we offer these, while stocks last at **£7.50** each including VAT & Postage



LOW R.P.M. MOTORS

Made by Crouzet — Smiths — SAIWA — Venner and similar famous companies — all supplied ready for 230/240v 50hz mains working all **£2.75** each. Following speeds in stock when preparing this advertisement

1 rev per day	6 revs per day	1 rev per hour
12 revs per hour	½ rev per min	1 rev per min
2 rpm 1½ rpm	5 rpm 15 rpm	16 rpm 20 rpm 25 rpm
30 rpm		

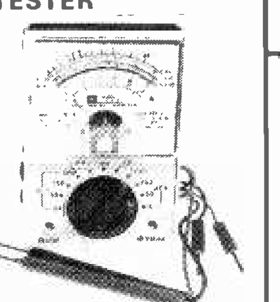
EXTRACTOR FAN

Ex-computers made by Woods of Colchester ideal for fixing through panel — reasonably quiet running — very powerful 2500 rpm. Choice of two sizes 5" or 6½" dia **£5** and **£6.**

FLUORESCENT INVERTOR

For camping — car repairing — emergency lighting from a 12v battery you can't beat fluorescent lighting. It will offer plenty of well distributed light and is economical. We offer invertor for 21" and 13 watt miniature tube for only **£3.75** with tube and tube holders as well.

MINI-MULTI TESTER



Amazing, deluxe pocket size precision moving coil instrument — jewelled bearings — 1000 opv — mirrored scale
11 instant ranges measures —
DC volts 10 50 250 1000
AC volts 10 50 150 1000
DC amps 0-1 mA and 0-100 mA
Continuity and resistance 0-150K ohms
Complete with insulated probes leads battery, circuit diagram and instructions
Unbelievable value only **£5.50** + 50p post and insurance

FREE

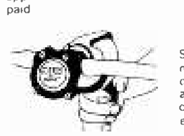
Amps ranges kit enable you to read DC current from 0-10 amps directly on the 0-10 scale. It's free if you purchase quickly but if you already own a mini tester and would like one send £1.50

HUMIDITY SWITCH

American made by Ranco their type No. J11. The action of this device depends upon the dampness causing a membrane to stretch and trigger a sensitive microswitch adjustable by a screw quite sensitive — breathing on it for instance will switch it on. Micro 3 amp at 250V a.c. Overall size of the device approx. 3⅜in long 1in wide and 1⅛in deep **75p.**

MICRO SWITCH BARGAINS

Rated at 5 amps 250V ideal to make a switch panel for a calculator and for dozens of other applications. Parcel of 10 for **£1** VAT and post paid

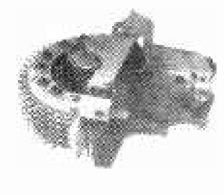


ROTARY PUMP

Self priming portable fits drill or electric motor pumps up to 200 gallons per hour depending upon revs. Virtually uncorrod able use to suck water oil petrol fertiliser chemicals, anything liquid. Hose connectors each end **£2** post paid

MULLARD UNILEX

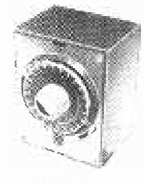
A mains operated 4 + 4 stereo system. Rated one of the finest performers in the stereo field this would make a wonderful gift for almost anyone in easy-to-assemble modular form and complete with a pair of Plessey speakers this should sell at about £30 — but due to a special bulk buy and as an incentive for you to buy this month we offer the system complete at only **£15** including VAT and postage
10 watt amps to upgrade unilex **£3.50** each



UNISELECTORS

These are pulse operated switches as used in automatic telephone switchboards etc. The pulse moves the switch arm through one position. Except where indicated the selectors are 25 position types and 50v. Coil is standard 24v or 12v operation extra at **£2** per switch

3 pole	**£4.80**
4 pole	**£5.94**
5 pole	**£7.02**
8 pole	**£9.72**
10 pole	**£10.80**
12 pole	**£12.96**
3 pole 50 way	**£10.58**
4 pole 50 way	**£12.74**



24 HOUR TIMERS

The one illustrated is the E control this uses the Smiths mechanism as in their autoset 2 on/offs per 24 hours. 13 amp contacts override switch **£6.50.**
Smiths 100 amp model one on/off per 24 hours **£10.50.** extra contacts **£1.00** per set
AEG 60 amp model with clockwork standby one on/off per 24 hours **£9.50.** extra contacts **£1.00** per set

INDUCTION MOTORS

One illustrated is our reference MM11 made for ITT ¼" stack 1½" spindle **£2.25.** ½" stack model **£1.75.** 1" stack **£2.75.** 1½" stack **£3.25.**

MAINS TRANSFORMERS

20v ½ amp **£1.50**
18v ¾ amp **£1.75**
6.3v 2 amp **£1.75**
25v 1½ amp **£2.25**
24v 2 amp **£2.50**
50v 2 amp **£4.50**
9v 1 amp **£1.50**
8.5v-0-8.5v ½ amp **£1.50**
100w auto 230-115v **£2**
8.5kv **£9.50**

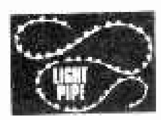
MANY OTHERS — REQUEST LIST

SPIT MOTOR WITH CARTER GEAR BOX

Probably one of the best spit motors made. Originally intended to be used in very high priced cookers, however its scope is [illegible] plenty of other uses for instance your garden barbeque or to drive a tumbler for stone polishing in fact there are no ends to its uses. Normal mains operated **£4.32** including post & VAT

THIS MONTH'S SNIP

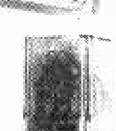
THE LIGHT PIPE



A 20-feet flexible pipe or tube holding miniature camps, along which a band of light travels must attract attention. Similarly, a string of fairy lights re-arranged so that the light chases along it looks really attractive.
We supply a switching kit for this travelling array and the price is only £7.50 complete with instructions.

STEREO TUNER

Japanese made FM tuner and matching decoder. Two items for less than average price of the tuner only — £11.20 the two. Don't miss this — stocks will not last long. Ditto but in cabinet with glass front. £14.50.



RELAYS

12 volt two 10 amp changeover plug in **95p.** 12v three 10 amp changeover plug in **£1.28.** 12v two changeover miniature wire ended **95p.** 12 volt open single screw fixing two 10 amp changeovers **85p.** 12 volt open three 10 amp changeovers **£1.25.** Latching relay mains operated 2 c/o contacts **£2.11.** Mains operated three 10 amp changeovers open type one screw fixing **£1.25.** Many other types with different coil voltages and contact arrangements are in stock enquiries invited

PAPST MOTORS

[illegible]

1. Ref. No. KL? 20.50 [illegible] 50Hz **£6.30**
2. Ref. No. KL? 32.50-4 [illegible] 50Hz **£7.28**
3. Ref. same as above 115 volts 50Hz **£3.30**
4. Ref. same as above 110 volts 60Hz **£3.30**

TERMS:
Prices include Post & VAT but orders under £6.00 please add 50p to offset packing etc. Bulk enquiries please phone for generous discount 01-688 1833

J. BULL (ELECTRICAL) LTD.

(Dept. WW)
103 TAMWORTH ROAD
CROYDON CR9 1SG

IT'S FREE!

Our monthly Advance Advertising Bargains List gives details of bargains arriving or just arrived — often bargains which sell out before our advertisement can appear. — It's an interesting list and it's free — just send S.A.E. Below are a few of the Bargains still available from previous lists.

MAINS TRANSFORMERS

All these have 230/240v 50hz Primary

VOLTAGE	CURRENT	REF.	PRICE
1v	2 amp	TM 1	£1.94
2.4v	5 amp	TM 2	£1.62
4v	7 amp	TM 32	£2.70
6v	¼ amp	TM 3	85
6.5v	¼ amp	TM 37	85
6.5v	200 mA	TM 21	£1.62
6.5v-0-0.5v	100 mA	TM 21	£1.62
6.5v-0-6.5v	750 mA	TM 7	£2.16
6.3v-0-6.3v	100 mA	TM 33	£1.62
6.3v	2 amp	TM 4	£1.89
8.5v	1 amp	TM 12	£1.62
8.5v + 8.5v sep winding	½ amp	TM 12	£1.62
9v	1 amp	TM 5	£1.62
9v	1 amp c. core	TM6	£1.80
9v	3½ amp	TM 11	£2.70
9v	5 amp	TM 38	£3.24
10v	25 amp	TM 15	£4.86
10v-0-10v	12½ amp	TM 15	£4.86
12v-0-12v	4 amp	TM 27	£4.32
12v	½ amp	TM 9	£1.05
13v	¼ amp	TM 7	£2.16
12v	1 amp	TM 10	£1.89
12v-0-12v	50mA	TM 19	£1.62
12v-0-12v	1 amp	TM 41	£3.24
15v tapped 9v	2 amp	TM 11	£2.70
15v	7 amp	TM 27	£4.32
15v-0-15v	3½ amp	TM 27	£4.32
15v-0-15v	3½ amp	TM 35	£4.86
17v	½ amp	TM 12	£1.62
18v	¾ amp	TM 13	£1.90
20v	½ amp	TM 14	£1.62
20v	5 amp	TM 27	£4.32
20v	12½ amp	TM 15	£4.86
20v-0-20v	6 amp	TM 15	£4.86
13v	100 mA	TM 21	£1.62
24v	1½ amp	TM 16	£2.12
24v	2 amp	TM 17	£2.70
24v + 2v 7 amp	2 amp	TM 39	£2.97
24v	4 amp	TM 40	£3.78
25v	1½ amp	TM 18	£2.43
26v	2 amp	TM 39	£2.98
30v tapped 24-20-15 & 12	3½ amp	TM 27	£4.32
30v	8 amp	TM 15	£4.86
37v	37 amps	TM 34	£31.86
40v tapped @ 30v 20v & 10v	6 amp	TM 15	£4.86
50v—2 amp with 6.3v shrouded		TM 22	£4.86
50v	8 amp	TM 29	£11.65
60v	5 amp	TM 24	£7.02
75v—3 amp with 6.3v shrouded		TM 23	£8.10
75v	4½ amp	TM 24	£7.02
80v tapped 60v & 75v	4 amp	TM 24	£7.02
100v	1 amp	TM 25	£7.02
100v-0-100v	½ amp	TM 25	£7.02
130v tapped 120v	½ amp	TM 28	£3.78
200v	½ amp	TM 25	£7.02
250v-0-250v with 6.3v 2A	50 mA	TM 36	£3.78
250v	100 mA	TM 36	£3.78
500v	50 mA	TM 36	£3.78

350mA 6-VOLT MAINS UNIT
Ideal for power 6 volt equipment cassettes tape recorder or amplifier or other appliances requiring more than the average mount of current. This is a really well made unit in plastic case made for Crown Radio intended originally to clip into position this has external battery type contacts but it is a simple matter to solder leads straight on to these contacts and this unit employs full wave rectification and is recommended in every way. Price **£4.30**

CALCULATORS
By famous makers like Texas intended originally to be sold at quite high prices new and unused. **Type 1.** Basic functions — add subtract, multiply divide etc. price **£5.15. Type 2** — again basic functions but with rechargeable nicad batteries price **£7.02. Battery chargers** for same **£2.70. Type 3** — basic functions but with memory **£9.18. Type 4,** basic functions memory and rechargeable batteries price **£11.34** + 84p

AM/FM RADIO
Complete chassis has turning scale with pointer volume control on/off etc. Controls have edgewise knobs. These radios can be mounted on or just inside extension speaker then you have a first-class music while you work receiver. Reception on both AM FM is better than average and even in areas where FM is notoriously bad good results have been obtained. The output also is above average the speaker power is probably around 1½-2 watts. They can be powered by 6v batteries or 6v power supply in fact the Crown Radio One mention above is ideal would no doubt function as an AM/FM Tuner — real bargain @ **£5.50** + 69p

UV TUBES (PHILIPS ATINIC)
Useful for bringing out water marks in stamps and special colours in rocks similar specimens. We have these in two sizes 9" 6w price **£1.50** + 12p post 50p + 4p 2ft 20 watt **£2.00** + 16p post 75p + 6p

1 POLE 10 WAY SWITCH
For digital displays the 10 positions being evenly spaced through the 360 turn and there is no stop. Silver-plated contacts are rated @ 5 amps normally an expensive switch but offered @ **86p** each

SKELETON PRE-SET
Miniature size 2.2k 10 for **£1.00** + 12½p

RELAY BASE
14 pin standard for many plug in relays **50p** + 4p

AC MAINS RELAY
Plug in to standard base three 10 amp changeover contacts price **£1.90** + 14p but 2 x 10 amp c.o contacts **£1.26,** bases **35p** extra

HEAVY DUTY 12v RELAY
This has 3 pairs of changeover contacts which are rather bigger than usual and look capable of dealing with 15 amp loads. Price **£2.16.**

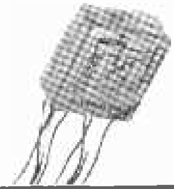
DITTO BUT 6 VOLT COIL
Price **£2.16** + 16p

TERMINALS
Very good quality British made screw down type top accepts a 4mm plug. The screw down section also has a hole through which which solid wire may be passed with insulators for metal panel mounting 5 popular colours. Price **16p** each ref TS1 or 10 in a bag for **£1.30,** ref TS1 10

SPRING TRIGGER TERMINALS
Red and black terminals mounted on insulated panel approximate size 2¼" x 1". These terminals grip like a vice but connection in the first place is quick and simple. Hold back the trigger — push in wire — let go of trigger definitely a time-saver. Price **54p** the pair

VOLTAGE	CURRENT	REF.	PRICE
260v	60 mA	TM 26	£3.24
1 Kv		TM 44	Please apply
2 Kv		TM 44	Please apply
5 Kv	5 mA	TM 30	£7.02
8.5 Kv	10 mA	TM 31	£10.26

Quantity prices available. Please unless you are calling add 25% to your order to cover the cost of carriage. Also if you want to collect telephone the day before



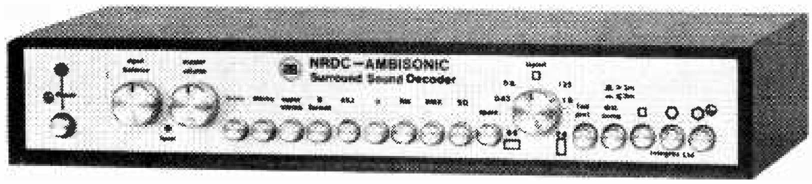
MINIATURE RELAY

12v dc operated with two sets of changeover contacts. The unique feature of this relay is its heavy lead out wires. These provide adequate support and therefore the relay needs no fixing. On the other hand there is a fixing bolt through one side so if you wish you can fix the relay and use its very strong lead outs to secure circuit components — an expensive relay, we are offering them at only 87p each.

Don't miss this exceptional bargain.

NEW PRODUCTS!

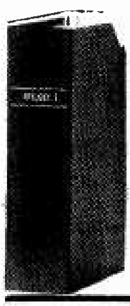
NRDC-AMBISONIC UHJ



SURROUND SOUND DECODER

The **first ever** kit specialy produced by Integrex for this British NRDC backed surround sound system which is the result of 7 years' research by the Ambisonic team. W.W. July, Aug., '77.
The unit is designed to decode not only UHJ but virtually all other 'quadrophonic' systems (Not CD4), including the new BBC HJ 10 input selections
The decoder is linear throughout and does not rely on listener fatiguing logic enhancement techniques. Both 2 or 3 input signals and 4 or 6 output signals are provided in this most versatile unit. Complete with mains power supply, wooden cabinet, panel, knobs, etc.

Complete kit, including licence fee **£45.00** + VAT
or ready built and tested **£61.50** + VAT



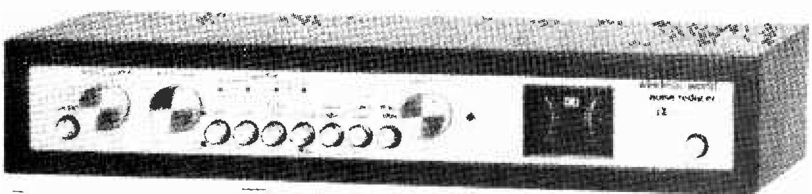
INTRUDER 1 RADAR ALARM

With Home Office Type approval
As in "Wireless World", designed by Mike Hosking, 240V ac mains operated and disguised as a hardbacked book. Detection range up to 30 feet.

Complete exclusive designer approved kit **£46.00** + VAT
or ready built and tested, **£54.00** + VAT

Wireless World Dolby(TM) noise reducer

Trademark of Dolby Laboratories Inc.



Featuring:
- switching for both encoding (low-level h.f. compression) and decoding
- a switchable f.m. stereo multiplex and bias filter.
- provision for decoding Dolby f.m. radio transmissions (as in USA).
- no equipment needed for alignment.
- suitability for both open-reel and cassette tape machines.
- check tape switch for encoded monitoring in three-head machines.

Typical performance
Noise reduction better than 9dB weighted.
Clipping level 16.5dB above Dolby level (measured at 1% third harmonic content)

Harmonic distortion 0.1% at Dolby level typically 0.05% over most of band, rising to a maximum of 0.12%

Signal-to-noise ratio: 75dB (20Hz to 20kHz, signal at Dolby level) at Monitor output

Dynamic Range >90db

30mV sensitivity.

Complete Kit **PRICE: £39.90**+VAT

Also available ready built and tested . . . . **Price £54.00**+VAT

Calibration tapes are available for open-reel use and for cassette (specify which) . . . . **Price £2.20**+VAT *

Single channel plug-in Dolby(TM) PROCESSOR BOARDS (92 x 87mm) with gold plated contacts are available with all components . . . . **Price £8.20**+VAT

Single channel board with selected fet . . . . **Price £2.50**+VAT

Gold Plated edge connector . . . . **Price £1.50**+VAT *

Selected FETs **60p** each+VAT, **100p**+VAT for two, **£1.90**+VAT for four

Please add VAT @ 12½% unless marked thus*, when 8% applies (or current rates)

Buy it with Access · EUROCARD · BARCLAYCARD · master charge

We guarantee full after-sales technical and servicing facilities on all our kits, have you checked that these services are available from other suppliers?

Please send SAE for complete lists and specifications

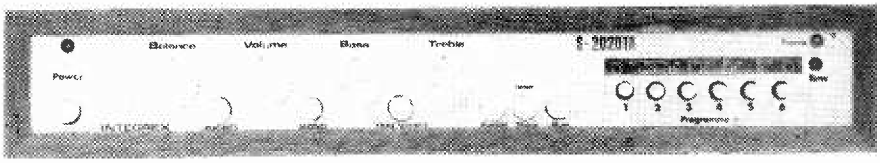
INTEGREX LTD.

Portwood Industrial Estate, Church Gresley,
Burton-on-Trent, Staffs DE11 9PT
Burton-on-Trent (0283) 215432 Telex 377106

INTEGREX

S-2020TA STEREO TUNER/AMPLIFIER KIT

SOLID MAHOGANY CABINET



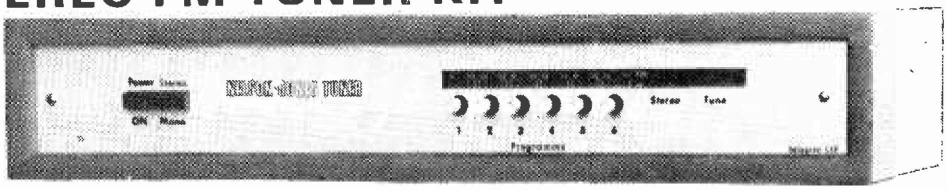
A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.

Brief Spec. Amplifier Low field Toroidal transformer, Mag, input, Tape In/Out facility (for noise reduction unit, etc.), THD less than 0.1% at 20W into 8 ohms. Power on/off FET transient protection. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section uses 3302 FET module requiring no RF alignment, ceramic IF INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.2μV. THD 0.3%. Pre-decoder 'birdy' filter.

PRICE: £58.95+VAT

NELSON-JONES STEREO FM TUNER KIT

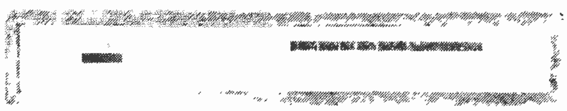
A very high performance tuner with dual gate MOSFET RF and Mixer front end, triple gang varicap tuning, and dual ceramic filter/dual IC IF amp.



Brief Spec. Tuning range 88—104MHz. 20dB mono quieting @ 0.75μV. Image rejection — 70dB. IF rejection — 85dB. THD typically 0.4%.
IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.
Compare this spec. with tuners costing twice the price.

Mono £32.40+VAT
With ICPL Decoder £36.67+VAT
With Portus-Haywood Decoder £39.20+VAT

STEREO MODULE TUNER KIT

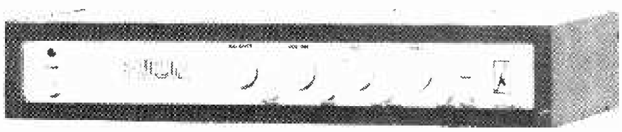


A low-cost Stereo Tuner based on the 3302 FET RF module requiring no alignment. The IF comprises a ceramic filter and high-performance IC Variable INTERSTATION MUTE. PLL stereo decoder IC. Pre-decoder 'birdy' filter Push-button tuning

Sens. 30dB S/N mono @ 1.2μV
THD typically 0.3%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

PRICE: Stereo £31.95+VAT

S-2020A AMPLIFIER KIT



Developed in our laboratories from the highly successful "TEXAN" design. PC mounting potentiometers, switches, sockets and fuses are used for ease of assembly and to minimize wiring

Power 'on/off' FET transient protection.

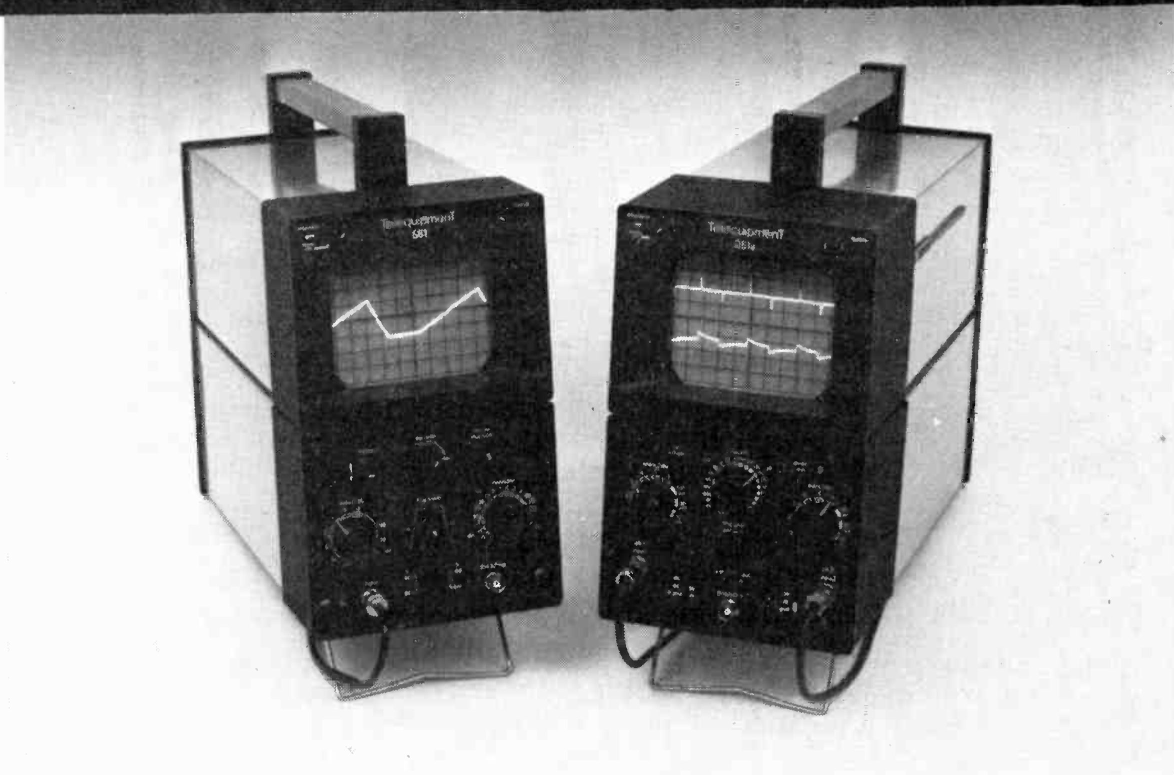
Typ Spec. 24+24W r.m.s. into 8-ohm load at less than 0.1% THD. Mag. PU input S/N 60dB. Radio input S/N 72dB. Headphone output. Tape In/Out facility (for noise reduction unit, etc.). Toroidal mains transformer.

PRICE: £33.95+VAT

ALL THE ABOVE KITS ARE SUPPLIED COMPLETE WITH ALL METALWORK, SOCKETS, FUSES, NUTS AND BOLTS, KNOBS, FRONT PANELS, SOLID MAHOGANY CABINETS AND COMPREHENSIVE INSTRUCTIONS

BASIC NELSON-JONES TUNER KIT £14.28+VAT
BASIC MODULE TUNER KIT (stereo) £16.75+VAT
PHASE-LOCKED IC DECODER KIT ... £4.47+VAT
PUSH-BUTTON UNIT .... £5.00+VAT
PORTUS-HAYWOOD PHASE-LOCKED STEREO DECODER KIT .... £8.00+VAT

The choice is yours



Prices at Feb '78

S61. £150 plus VAT and Nominal Delivery Charge.   D61a. £220 plus VAT and Nominal Delivery Charge.

When it comes to deciding on a general purpose oscilloscope for the laboratory or the service department, you have a choice between single or dual trace models and medium or high bandwidth.

Telequipment's D61a is an excellent instrument for the service bench, particularly for TV work when dual trace 10MHz bandwidth and special triggering features are needed.

For less demanding applications, the single trace 5MHz S61 will make most of your routine measurements.

You will get the same Telequipment reliability and Telequipment value – whatever your choice.

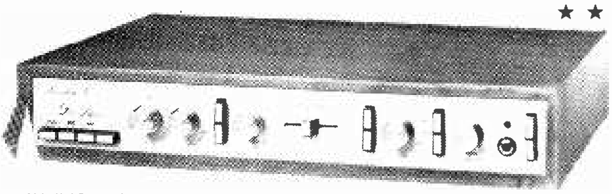
For your full catalogue and price list for Telequipment products – Circle No. 151

TELEQUIPMENT

Tektronix UK Ltd, P.O. Box 69, Coldharbour Lane, Harpenden, Herts.
Tel: 05827 63141 Telex: 25559

AUDIO KITS OF DISTINCTION FROM POWERTRAN

NEW! DE LUXE EASY TO BUILD LINSLEY-HOOD 75W AMPLIFIER



★ ★

AVAILABLE AS SEPARATE PACKS
PRICES IN OUR FREE CATALOGUE

SPECIAL PRICE FOR COMPLETE KIT £99.30

The standard model of our kit for Mr Linsley Hood s 75 watt design has for a long time offered exceptional performance at a very modest cost with high quality high power ready-built units of comparable quality generally being over three times the price

Features of the amplifier include very low distortion (less than 0 01%) 75W rms per channel power output rumble filter variable slope scratch filter variable transition frequency tone controls tape monitoring facilities and individually adjustable inputs This model is based on 5 circuit boards which not having the controls mounted on them can if desired be effectively used separately in high performance audio systems not based on our metalwork

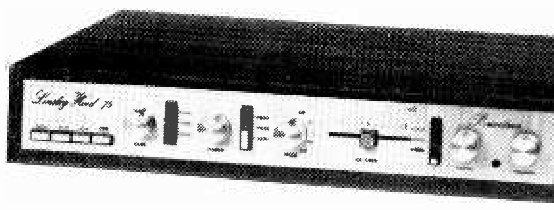
Our new De Luxe model uses 14 boards which interconnect with gold plated contacts and are designed to have the potentiometers and switches mounted upon them This system almost eliminates internal wiring, making installation after their assembly, delightfully straightforward and as each board can be easily removed in seconds from the chassis checking and maintenance is so simple that even newcomers to electronics will be able to cope competently with the kit Additional features of our new model are inclusion of the latest circuit improvements generously sized heat sinks for heavy duty use even in tropical climates and metal oxide resistors throughout for long term stability and reliability

PACK PRICES FOR STANDARD KIT

Pack	Price
1. Fibreglass printed circuit board for power amp	£1.15
2. Set of resistors. capacitors. pre-sets for power amp	£2.50
3. Set of semiconductors for power amp	£6.50
4. Pair of 2 drilled. tinned heat sinks	£1.10
5. Fibreglass printed-circuit board for pre-amp	£1.90
6. Set of low noise resistors. capacitors. pre-sets for pre-amp	£4.10
7. Set of low noise. high gain semiconductors for pre-amp	£2.40
8. Set of potentiometers (including mains switch)	£3.50
9. Set of 4 push-button switches. rotary mode switch	£5.40
10. Toroidal transformer complete with magnetic screen/ housing primary: 0 117-234 V; secondaries: 33-0-33 V. 25-0-25 V	£12.95
11. Fibreglass printed-circuit board for power supply	£0.85
12. Set of resistors. capacitors. secondary fuses. semiconductors for power supply	£5.40
13. Set of miscellaneous parts including DIN skts.. mains input skt.. fuse holder. interconnecting cable. control knobs	£6.20
14. Set of metalwork parts including silk screen printed fascia panel and all brackets. fixing parts. etc.	£8.20
15. Handbook	£0.30
16. Teak cabinet 18.3" x 12.7" x 3.1"	£10.70

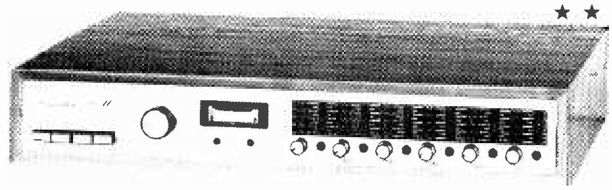
2 each of packs 1-7. 1 each of packs 8-16 inclusive are required for complete stereo amplifier. Total cost of individually purchased packs £92.80

STANDARD LINSLEY-HOOD 75W AMPLIFIER



SPECIAL PRICE FOR COMPLETE KIT £79.80

WIRELESS WORLD FM TUNER



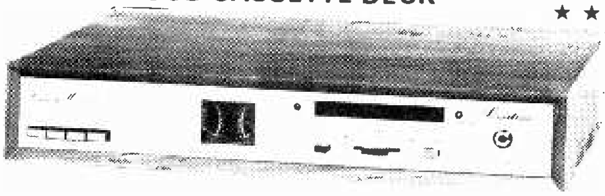
★ ★

SPECIAL PRICE FOR COMPLETE KIT £70.20

Designed in response to demand for a tuner to complement the world-wide acclaimed Linsley-Hood 75W Amplifier, this kit provides the perfect match. The Wireless World (Skingley and Thompson) published original circuit has been developed further for inclusion into this outstanding slimline unit and features a pre-aligned front end module, excellent a.m. rejection and temperature compensated varicap tuning, which may be controlled either continuously or by push-button pre-selection. Frequencies are indicated by a frequency meter and sliding LED indicators, attached to each channel selector pre-set The PLL stereo decoder incorporates active filters for "birdy" suppression and power is supplied via a toroidal transformer and integrated regulator For long term stability metal oxide resistors are used throughout

AVAILABLE AS SEPARATE PACKS — PRICES IN OUR FREE CATALOGUE

LINSLEY-HOOD CASSETTE DECK



★ ★

SPECIAL PRICE FOR COMPLETE KIT £79.60

Pack	Price
1. Stereo PCB (accommodates 2 rep. amps. 2 meter amps. bias/erase osc. relay)	£3.35
2. Stereo set of capacitors. M.O. resistors. potentiometers for above	£7.95
3. Stereo set of semiconductors for above	£8.50
4. Miniature relay with socket	£2.90
5. PCB. all components for solenoid. speed control circuits	£3.80
6. Goldring-Lenco mechanism as specified	£18.50
7. Function switch. knobs	£1.90
8. Dual VU meter with illuminating lamp	£6.95
9. Toroidal transformer with E.S. screen prim. 0-117V. 234V. Sec. 15V	£4.90
10. Set of capacitors. rectifiers. I.C. voltage regulator P.C.B. for power supply (Powertran design)	£2.80
11. Set of miscellaneous parts. including sockets. fuse holder. fuses. interconnecting wire. etc	£3.40
12. Set of metalwork including silk screened fascia panel. internal screen. fixing parts. etc	£7.10
13. Construction notes	£0.25
14. Teak cabinet 18.3" x 12.7" x 3.1"	£10.70

One each of packs 1-14 inclusive are required for complete stereo cassette deck. Total cost of individually purchased packs £83.00

Matsushita WY 436 AZ head (optional extra) . £4.50 (free with compete kit)

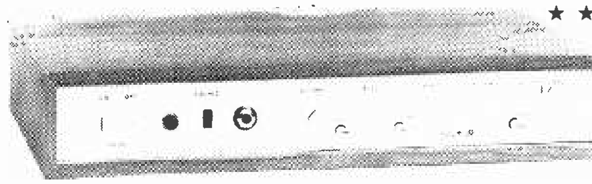
Published in Wireless World (May. June. August 1976) by Mr Linsley-Hood, this design, although straightforward and relatively low cost, nevertheless provides a very high standard of performance To permit circuit optimization separate record and replay amplifiers are used, the latter using a discrete component front-end designed such that the noise level is below that of the tape back ground Push button switches are used to provide a choice of equalization time constants, a choice of bias levels and also an option of using an additional pre-amplifier for microphone use. The mechanism used is the Goldring-Lenco CRV, a unit distinguished in its robustness and ease of operation. Speed control and automatic cassette ejection are both implemented by electronic circuitry This unit which is powered by a toroidal transformer and uses metal oxide resistors throughout offers an excellent match for the Wireless World Tuner and the Linsley-Hood 75 Watt Amplifier Circuit changes as published in February, 1978, follow-up article are included in the kit AT NO EXTRA COST! A higher performance head (Matsushita WY 436 AZ head as recommended in the follow-up article) is offered as an optional extra but this will be automatically supplied FREE OF CHARGE with all orders for complete kits!

T20+20 AND T30+30 20W, 30W AMPLIFIERS

Pack	T20	T30
1. Set of low noise resistors	£1.60	£1.70
2. Set of small capacitors	£2.60	£3.40
3. Set of power supply capacitors	£2.20	£2.50
4. Set of miscellaneous parts	£3.50	£3.50
5. Set of slide. mains. P.B. switches	£1.50	£1.50
6. Set of pots.. selector switch	£2.80	£2.80
7. Set of semiconductors. ICs. skts.	£7.25	£7.75
8. Toroidal transformer—240V prim. e.s. screen	£5.60	£7.20
9. Fibreglass PCB	£3.50	£3.90
10. Set of metalwork. fixing parts	£5.20	£6.20
11. Set of cables. mains lead	£0.40	£0.40
12. Handbook	£0.25	£0.25
13. Teak cabinet 15.4" x 6.7" x 2.8"	£4.50	£4.50

One each of Pack 1-13 are required for complete stereo amplifier. Total cost of individually purchased packs T20+20 £40.90. T30+30 £45.60.

Designed by Texas engineers and described in Practical Wireless the Texan was an immediate success Now developed further in our laboratories to include a Toroidal transformer and additional improvements the slimline T20+20 delivers 20W rms per channel of true Hi Fi at exceptionally low cost The **easy to build** design is based on a single F Glass PCB and features all the normal facilities found on quality amplifiers including scratch and rumble filters adaptable input selector and headphones socket In a follow-up article in Practical Wireless further modifications were suggested and these have been incorporated into the T30+30 These include RF interference filters and a tape monitor facility Power output of this model is 30W rms per channel



★ ★

SPECIAL PRICES FOR COMPLETE KITS

T20+20 KIT PRICE £33.10

T30+30 KIT PRICE £38.40

EXPORT A SPECIALITY!

Our Export Department can readily despatch orders of any size to any country in the world Some of the countries to which we sent kits last year are shown in this advertisement To assist in estimating postal costs our catalogue gives the weights of all packs and kits This will be sent free on request, by airmail, together with our Export Postal Guide which gives current postage prices

EXPORT ORDERS: No minimum order charge! Prices same as for U K customers but no Value Added Tax charged Postage charged at actual cost plus 50p documentation and handling Please send payment with order by Bank Draft Postal Order International Money Order or cheque drawn on an account in the U K Alternatively for orders over £500 we will accept Irrevocable Letter of Credit payable at sight in London

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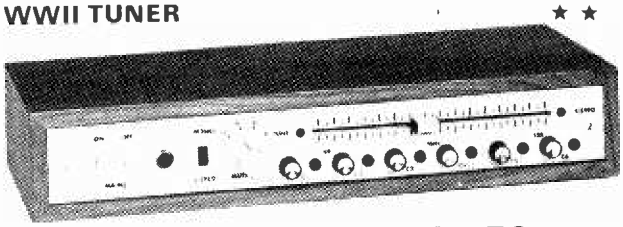
EIRE GRENADA SAUDI ARABIA NEW ZEALAND NORWAY SINGAPORE ICELAND SWEDEN MALAYA INDONESIA BRAZIL SWITZERLAND ZAMBIA GIBRALTAR CHILE SPAIN

WWII TUNER ★★

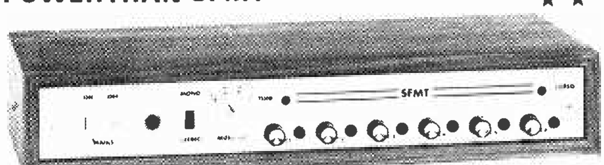


SPECIAL PRICE FOR COMPLETE KIT **£47.70**

AVAILABLE AS SEPARATE PACKS — PRICES IN OUR FREE CATALOGUE

Following the success of our **Wireless World FM Tuner Kit** this cost reduced model was designed to complement the **T20+20** and **T30+30** amplifiers and the cabinet size, front panel format and electrical characteristics make this tuner compatible with either The frequency meter of the more advanced model has been omitted and the mechanics simplified, however the circuitry is identical and this kit offers most outstanding value for money Facilities included are switchable afc, adjustable, switchable muting, LED tuning indication and both continuous and push-button channel selection (readily adjusted by controls on the front panel)

POWERTRAN SFMT TUNER ★★



PRICE FOR COMPLETE KIT **£35.90**

AVAILABLE AS COMPLETE KIT ONLY

The requirement was a simple, low cost design which could be constructed easily without special alignment equipment but which still gives a first class output suitable for feeding any of our very popular amplifiers or any other high quality audio equipment Not finding a suitable published circuit, the requirement was met by design and development work in our own laboratories and this tuner, which uses a pre-aligned front end module can be set up with the aid of nothing more sophisticated than a multi-meter A phase-locked-loop is used for stereo decoding and controls include switchable afc switchable muting and push-button channel selection (adjustable by controls on the front panel) This unit matches well with the **T20+20** and **T30+30** amplifiers

INTERNATIONAL POWERSLAVE 200+200 watt AMPLIFIER NEW!

COMPLETE KIT AS FEATURED IN ELECTRONICS TODAY INTERNATIONAL

Super-Fi performance for studio/monitoring/h-fi use with the inherent reliability and ruggedness for the most demanding group/disco applications.

Features

- ★ over 200W rms continuous from each of 2 totally independent DC coupled amplifiers — over 800W peak power!
- ★ highly original fully complementary high linearity o/p stage utilizing the inherent symmetry of no less than 4 differential pairs!
- ★ ultra low feedback (an incredible low 14dB overall!) together with super high slewing rate (20V/μs) banish ricochet effects and TID!
- ★ distortion only 0 03% at FULL power 1KHz rising to only 0.07% at 10KHz (how many high power amplifier producers dare to quote at this frequency?)
- ★ independent stabilized power supplies driven by custom designed TOROIDAL transformers
- ★ inherent reliability — monster heat sinks for cool running at the hottest venues — electronic open and short circuit protection — 4 rugged power transistors/amplifier — each 250W rating
- ★ professional quality — metal oxide resistors, cermet adjusters, fibre glass boards, sturdy 19" rack mounting cabinet complete with sleeve and feet for free standing work too
- ★ easy to build — plenty of working space with ready access to all components minimal wiring, extensive instructions suitable for both experienced constructors and newcomers to electronics — can be purchased one channel at a time
- ★ value for money — quality and performance comparable with ready-built amplifiers costing over £600!

★★

PSI 4001 SLAVE MODEL

OVER 800W PEAK POWER!

★★

PSI 4002 STUDIO MODEL

Pack	Price
1. Fibre glass printed circuit board for power amp	£4.20
2. Set of capacitors, metal oxide resistors, thermistor, cermet pre-sets for power amp	£6.40
3. Set of semiconductors for power amp with mounting hardware, cooling tabs	£27.60
4. Pair of monster black drilled heat sinks, transistor mounting bracket	£6.90
5. Toroidal transformer. Primary 0-117V-234V. Secondaries 42-0-42V. 0-15V. 0-15V. Electrostatic screen	£19.20
6. Set of all parts for stabilized power supply including fibre glass printed circuit board, mounting bracket, semiconductors, resistors, capacitors, etc	£20.50
7A. Set of all parts for buffer/overdrive unit including fibre glass printed circuit board, semiconductors, resistors, capacitors, controls — required for PSI 4001 only	£3.80
7B. Set of parts for peak power meter including professional quality meter, fibre glass printed circuit board, components, controls — required for PSI 4002 only	£11.50
8. Set of all miscellaneous parts including sockets, illum. mains switches, fuse holders, fuses, cut-outs, cable, etc	£12.10
9. Cabinet, including chassis, anodised silver on black panels, fixing parts etc. Please state whether Slave or Studio model required	£27.50
10. Handbook £0.50 or free on request when ordering any of above packs.	

2 each of packs 1-7 (A or B), 1 each 8, 9 and 10 are required for complete 200 + 200W professional amplifier.

Total cost of individually purchased packs (200 + 200W) PSI 4001 £216.00, PSI 4002 £232.20

PSI 4001 kit price **£205.00**

PSI 4002 kit price **£220.00**

SPECIAL OFFER PRICES FOR COMPLETE KITS —

Wireless World Designs: Full kits are not available for the projects below but PCBs and component sets are stocked Further details of these and other packs are in our Free Catalogue

30W Bailey Amplifier	
BAIL Pk 1 F/Glass PCB	£1.00
BAIL Pk 2 Resistors, Capacitors	£2.35
BAIL Pk 3 Semiconductors	£4.70
Bailey Burrows Stereo Pre-Amp.	
BBPA Pk 1 F Glass PCB (stereo)	£2.80
BBPA Pk 2 Resistor capacitors (stereo)	£6.70
BBPA Pk 3R Rotary potentiometers (stereo)	£2.85
BBPA Pk 4R Rotary switches (stereo)	£3.60
Linsley-Hood Low Distortion Oscillator.	
LDO Pk 1 Fibreglass PCB	£1.65
LDO Pk 2 M O Resistors capacitors	£2.60
LDO Pk 3 Semiconductors	£3.90
Regulated Power Supply for Bailey Amplifier	
60VS Pk 1 F/Glass PCB	£0.85
60VS Pk 2 Resistors, Capacitors	£2.20
60VS Pk 3 Semiconductors	£3.10
60VS Pk 6A Toroidal transformer	£8.80
Stuart Tape Recorder	
TRRC Pk 1 Replay Amp F/G PCB (stereo)	£1.30
TRRC Pk 1 Record Amp F/G PCB (stereo)	£1.70
TROS Pk 1 Bias/Erase F/G PCB (stereo)	£1.20
E. F. Taylor Pre-Amplifier	
EFTP Pk 1 Fibreglass PCB (stereo)	£1.45
EFTP Pk 2 M O Res caps (stereo)	£3.20
EFTP Pk 3 Semiconductors (stereo)	£4.20

NEW! Improved stereo decoder (as described in April 1978 W W) F/Glass PCB, M O Res, Caps, Cermet pre-sets, IC, IC socket **£6.30**

SQ QUADRAPHONIC DECODERS

These state-of-the-art circuits described by CBS are offered as kits of superior quality with close tolerance capacitors metal oxide resistors and Fibreglass PCBs designed for edge connector insertion Further information on these kits is given in our FREE CATALOGUE

M1 Basic matrix decoder	£5.90
L1 Full logic decoder	£17.20
L2A Full logic decoder with variable blend	£22.60
L3A As L2A but with high performance discrete component front end	£30.10
(or with carbon film resistors)	£25.90
SQM1-30 Decoder complete with 30W rear channel amplifiers Complete kit matches T30+30 amplifier	£40.75

Value Added Tax not included in prices
UK Carriage FREE

SERVICING FACILITIES: Available for all ★★complete kits

PRICE STABILITY: Order with confidence irrespective of any price changes we will honour all prices in this advertisement until June 30th, 1978, if this month's advertisement is mentioned with your order Errors and VAT rate changes excluded

U.K. ORDERS: Subject to 12½%* surcharge for VAT (i e add ⅛ to the price) No charge is made for carriage *or current rate if charged

SECURICOR DELIVERY: For this optional service (U K. mainland only) add £2 50 (VAT inclusive) per kit.

SALES COUNTER: If you prefer to collect your kit from the factory, call at Sales Counter (at rear of factory) Open 9 a m -4 30 p m Monday-Thursday

QUALITY: All components are brand new first grade full specification guaranteed devices All resistors (except where stated as metal oxide) are low noise carbon film types All printed circuit boards are fibreglass, drilled roller tinned and supplied with circuit diagrams and construction layouts

FOR FURTHER INFORMATION PLEASE WRITE OR TELEPHONE FOR OUR FREE CATALOGUE

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POPULAR SEMICONDUCTORS. (A very small selection from our vast stocks, please enquire about devices not listed.)

2N697	0.31	2N3402	0.45	2N4036	0.72	2N5190	0.65	ACY17	1.00	BC171B	0.17
2N698	0.49	2N3414	0.18	2N4058	0.62	2N5210	0.38	ACY22	0.65	BC172C	0.15
2N700	0.28	2N3415	0.18	2N4059	0.17	2N5220	0.15	ACY30	0.60	BC173C	0.17
2N914	0.38	2N3416	0.21	2N4060	0.22	2N5225	0.16	AD150	3.10	BC177	0.22
2N918	0.37	2N3417	0.25	2N4061	0.19	2N5232	0.22	AD161	1.00	BC178B	0.35
2N930	0.37	2N3439	0.85	2N4062	0.20	2N5245	0.37	AD162	1.00	BC179B	0.25
2N1131	0.32	2N3441	0.92	2N4121	0.27	2N5248	0.14	AF106	0.60	BC182A	0.12
2N1303	0.80	2N3442	1.45	2N4122	0.27	2N5293	0.44	AF109	0.82	BC182L	0.15
2N1305	0.80	2N3565	0.25	2N4123	0.19	2N5294	0.44	AF114	0.70	BC183A	0.12
2N1501	0.35	2N3566	0.25	2N4124	0.19	2N5401	0.44	AF115	0.70	BC183LA	0.15
2N1613	0.30	2N3567	0.25	2N4125	0.19	2N5416	1.65	AF118	0.70	BC184	0.12
2N1637	0.72	2N3638	0.17	2N4126	0.19	2N5447	0.16	AF124	0.70	BC184L	0.15
2N1890	0.30	2N3639	0.38	2N4235	1.35	2N5448	0.16	AF139	0.75	BC205	0.17
2N1893	0.30	2N3644	0.40	2N4236	1.65	2N5449	0.20	AF200	1.30	BC212A	0.15
2N1991	1.10	2N3662	0.25	2N4237	1.65	2N5457	0.35	AF201	1.30	BC212LA	0.13
2N2193	0.50	2N3663	0.29	2N4240	1.70	2N5458	0.35	AF239	0.70	BC213B	0.15
2N2194	0.42	2N3702	0.14	2N4250	0.26	2N5555	0.65	AF240	1.25	BC213LA	0.17
2N2217	0.55	2N3703	0.14	2N4266	0.32	2N6109	0.55	AF279	0.88	BC214	0.17
2N2218	0.35	2N3704	0.14	2N4284	0.38	2N6122	0.44	AF280	0.95	BC214L	0.18
2N2219	0.38	2N3705	0.14	2N4286	0.32	2N6123	0.48	ASY28	1.30	BC237B	0.15
2N2221	0.25	2N3706	0.14	2N4287	0.22	2N6124	0.45	ASY55	0.70	BC238B	0.13
2N2222	0.25	2N3707	0.14	2N4288	0.22	2N6125	0.47	BC107	0.15	BC239C	0.17
2N2270	0.49	2N3708	0.12	2N4292	0.27	2N6288	0.50	BC108	0.15	BC256A	0.29
2N2368	0.27	2N3709	0.12	2N4302	0.31	2S702	3.30	BC109	0.16	BC257A	0.18
2N2369	0.27	2N3710	0.12	2N4303	0.33	2S703	3.95	BC113	0.22	BC258B	0.24
2N2483	0.30	2N3711	0.12	2N4342	0.60	40232	0.60	BC114	0.22	BC259B	0.19
2N2613	0.90	2N3712	1.39	2N4401	0.20	40311	0.55	BC115	0.22	BC261A	0.25
2N2646	0.80	2N3714	1.55	2N4402	0.20	40316	0.95	BC116	0.21	BC262B	0.26
2N2848	1.10	2N3716	1.70	2N4403	0.20	40363	1.45	BC118	0.22	BC263B	0.28
2N2904	0.31	2N3794	0.21	2N4822	0.83	40389	0.70	BC135	0.22	BC264B	0.65
2N2905	0.31	2N3819	0.36	2N4870L	0.58	40408	0.82	BC136	0.21	BC307B	0.16
2N2906	0.25	2N3820	0.39	2N4871L	0.51	40440	0.70	BC137	0.22	BC308B	0.16
2N2907	0.25	2N3821	0.95	2N4898	1.55	40512	1.70	BC138	0.44	BC309C	0.16
2N2923	0.17	2N3827	0.27	2N4901	1.65	40594	0.87	BC140	0.30	BC327	0.22
2N2924	0.17	2N3854A	0.30	2N4902	2.20	40595	0.98	BC141	0.32	BC328	0.20
2N2925	0.19	2N3855	0.30	2N4903	2.75	40573	0.80	BC142	0.32	BC337	0.20
2N3011	0.37	2N3856A	0.19	2N4904	1.85	AC126	0.48	BC147	0.13	BC414	0.17
2N3020	0.75	2N3858A	0.20	2N4905	2.40	AC127	0.48	BC148	0.15	BC415	0.16
2N3053	0.25	2N3859A	0.22	2N4920	0.83	AC128	0.48	BC149	0.15	BC416	0.17
2N3054	0.72	2N3860	0.18	2N5086	0.30	AC151	0.43	BC153	0.30	BC547A	0.13
2N3055	0.75	2N3866	1.98	2N5087	0.30	AC152	0.54	BC154	0.30	BC547B	0.13
2N3108	0.75	2N3901	0.30	2N5088	0.30	AC153	0.59	BC157A	0.15	BC548	0.13
2N3133	0.50	2N3904	0.18	2N5089	0.30	AC153K	0.59	BC158B	0.15	BC549B	0.14
2N3242	0.68	2N3905	0.18	2N5129	0.62	AC176	0.54	BC159B	0.17	BC558	0.13
2N3250	0.35	2N3906	0.18	2N5130	0.22	AC176K	0.90	BC160	0.33	BC559	0.15
2N3301	0.45	2N3962	0.95	2N5131	0.22	AC187	0.50	BC167B	0.13	BCY54	2.40
2N3302	0.39	2N4031	0.55	2N5137	0.22	AC187K	0.65	BC168B	0.13	BCY56	0.27
2N3392	0.17	2N4032	0.65	2N5143	0.22	AC188	0.54	BC169B	0.13	BCY70	0.21
2N3394	0.17	2N4033	0.65	2N5180	0.58	AC188K	0.65	BC170B	0.19	BCY71	0.26
2N3397	0.19									BCY72	0.18

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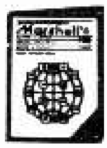

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1LN5	0.70	6BW6	3.75	6SC7GT	1.00	12Q7GT	0.50	50CD6G	4.00	DF96	1.00	ECC82	0.62
1N5GT	0.75	6BW7	0.65	6SG7	0.70	12SA7GT	0.75	50EH5	0.85	DH63	0.75	ECC83	0.52
1R5	0.50	6BX6	0.40	6SH7	0.70	12SC7	0.50	50L6GT	1.00	DH76	0.50	ECC84	0.50
1S4	0.40	6BY7	0.45	6SJ7	0.70	12SG7	0.55	66KU	1.00	DH77	0.60	ECC85	0.50
1S5	0.35	6BZ6	1.50	6SK7	1.00	12SH7	0.50	72	0.70	DH81	1.00	ECC86	2.00
1T4	0.30	6C4	0.50	6SK7GT	0.70	12SJ7	0.60	77	0.45	DK32	0.80	ECC88	0.72
1U4	0.70	6C6	0.45	6SQ7	0.70	12SK7	0.60	85A2	1.40	DK40	1.00	ECC91	0.35
1U5	0.85	6C9	2.00	6U4GT	1.00	12SN7GT	0.75	85A3	1.40	DK91	0.50	ECC189	1.00
2D21	0.55	6C10	1.00	6U7G	0.55	12SQ7	0.80	90C1	1.50	DK92	1.00	ECC804	0.90
2GK5	0.75	6CB6A	0.65	6U8	0.50	12SQ7GT	0.80	90CV	5.50	DK96	1.00	ECC807	2.80
2X2	0.70	6C12	0.55	6V6G	0.50	12SR7	0.75	108C1	0.40	DL33	0.70	ECF80	0.65
3A4	0.55	6CD6G	4.00	6X2	0.80	13D8	2.00	150C2	1.20	DL63	0.70	ECF82	0.50
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3S4	0.65	6CS6	0.75	7A7	1.00	19AQ5	0.65	956	0.50	DM70	1.25	ECH83	1.00
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5T4	2.00	6E5	1.00	7R7	2.00	20D4	2.50	6060	2.00	E80CC	4.75	ECL85	0.80
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5Z3	1.40	6F14	0.90	8D2	0.50	20P3	1.00	7025	2.00	E82CC	2.00	EF40	1.00
5Z4G	0.75	6F15	0.85	8D8	0.52	20P4	0.84	7193	0.60	E83F	3.50	EF41	1.00
5Z4GT	1.00	6F16	1.00	9BW6	0.90	20P5	1.50	7475	1.20	E88CC	1.20	EF73	1.75
6 30L2	0.90	6F18	0.60	9D7	0.70	25A6G	1.00	9002	0.55	E92CC	4.50	EF80	0.40
6A8G	1.40	6F23	1.00	9U8	0.45	25L6G	1.00	9006	0.45	E180CC	5.00	EF83	1.70
6AC7	0.70	6F24	0.80	10C2	0.70	25Y5	0.80	A1834	1.50	E180F	5.50	EF85	0.45
6AG5	0.35	6F25	1.00	10C14	0.60	25Z4G	0.50	A3042	6.00	E182CC	5.50	EF86	0.52
6AG7	0.70	6F26	0.45	10D1	1.00	25Z5	0.75	AC2PEN	1.00	E188CC	4.50	EF89	0.55
6AH6	0.70	6F28	0.85	10DE7	0.80	25Z6G	0.80	AC2PENDD	1.00	E280F	12.50	EF91	0.70
6AJ5	0.70	6F32	1.00	10F1	1.00	28D7	2.00	AC6/PEN	1.00	E283CC	2.00	EF92	0.70
6AJ8	0.55	6G6G	1.00	10F9	0.65	30A5	0.75	AC P4	1.50	E1148	0.80	EF93	0.65
6AK5	0.45	6GH8A	0.80	10F18	0.65	30C1	0.80	AC PEN(7)	1.20	EA50	0.40	EF94	0.55
6AK6	1.50	6GK5	0.75	10FD12	0.39	30C15	1.00	AC THI	1.00	EA76	1.30	EF95	0.45
6AK8	0.48	6GK6	2.00	10L14	0.45	30C17	0.90	AL60	1.50	EABC80	0.48	EF97	0.90
6AL5	0.25	6GU7	0.90	10LD11	0.75	30C18	2.25	ARP3	0.80	EAC91	0.55	EF98	0.90
6AM6	0.70	6H6GT	0.50	10LD12	0.45	30F5	0.70	ATP4	0.50	EAF42	1.00	EF183	0.50
6AM8A	0.70	6J5GT	0.65	10PL12	0.75	30L1	0.39	AZ1	0.50	EAF801	1.50	EF184	0.50
6AN8	0.70	6J6	0.35	10P13	0.80	30L15	0.75	AZ31	1.00	EB34	0.50	EF804	6.25
6AQ5	0.75	6J7G	0.50	10P14	2.50	30L17	0.70	AZ41	0.50	EB91	0.25	EH90	0.75
6AQ8	0.50	6J7M	0.65	10P18	0.90	30P4MR	0.98	B36	0.75	EBC41	1.00	EK90	0.70
6AR5	1.05	6JU8A	0.90	12A6	1.00	30P12	0.74	B719	0.50	EBC81	1.00	EL32	1.00
6AS7	1.50	6K7G	0.50	12AC6	0.80	30P19		B729	0.90	EBC90	0.80	EL34	2.50
6AT6	0.80	6K8G	0.50	12AD6	0.80	30P4	0.90	BL63	2.00	EBC91	0.65	EL35	3.00
6AU6	0.62	6K8GT	0.55	12AE6	0.80	30P16	0.50	CL33	2.00	EBF80	1.00	EL37	3.00
6AV6	0.65	6L1	2.50	12AT6	0.45	30P18	0.50			EBF83	0.45	EL41	1.00
6AW8A	1.15	6L7(M)	1.50	12AT7	0.52	30PL1	2.20			EBF89	0.40	EL81	1.00

EL83	1.00	N339	1.25	PY31	0.50	UY42	0.70	X63	1.40	ACY28	0.35	BYZ12	0.30	OC44	0.12
EL84	0.48	N379	0.50	PY33/2	0.50	UY85	0.70	X65	2.00	AD140	0.50	BYZ13	0.30	OC45	0.13
EL86	0.80	N709	0.48	PY80	0.50	U10	1.00	X66	2.00	AD161	0.53	BYZ15	2.03	OC65	1.31
EL90	0.75	P61	0.80	PY81	0.80	U12/14	1.15	X76M	0.75	AD162	0.53	CG12E	0.23	OC70	0.14
EL96	0.95	PABC80	0.45	PY82	0.40	U16	1.00	X119	0.80	AF102	1.04	CG64H	0.23	OC71	0.13
EL360	2.50	PC86	0.80	PY83	0.60	U17	1.00	X142	1.00	AF106	0.58	FSY11A	0.26	OC72	0.13
FL506	2.00	PC88	0.80	PY88	1.12	U18/20	2.50	X150	1.00	AF114	0.30	FSY41A	0.26	OC74	0.26
EL509	2.50	PC92	0.65	PY301	0.50	U19	4.00	X719	0.55	AF115	0.30	GD4	0.38	OC75	0.13
EM80	1.00	PC95	1.00	PY500	2.05	U22	0.85	Z145	1.00	AF117	0.23	GD5	0.32	OC76	0.18
EM81	1.00	PC97	0.75	PY500A	2.05	U25	1.00	Z152	0.40	AF121	0.35	GD6	0.32	OC77	0.32
EM83	1.00	PC900	0.85	PY800	0.60	U26	0.90	Z329	0.70	AF124	0.36	GD8	0.23	OC78	0.18
EM84	1.00	PCC84	0.39	PY801	0.60	U31	0.50	Z719	0.40	AF125	0.50	GD9	0.23	OC78D	0.18
EM85	1.20	PCC85	0.47	PZ30	0.50	U33	1.75	Z729	0.52	AF139	0.76	GD11	0.23	OC79	0.47
EM87	1.45	PCC88	0.61	QP21	1.10	U35	1.75	Z749	1.00	AF178	0.79	GD12	0.23	OC81	0.13
EMM803	2.50	PCC89	0.49	QQV03/10	2.00	U37	2.00	Z759	6.50	AF180	0.56	GD14	0.58	OC81D	0.13
EY51	0.80	PCC189	0.60	QS75/20	1.00	U43	0.80	**Transistors and Diodes**		AF186	0.64	GD15	0.47	OC82	0.13
EY81	1.50	PCC805	0.75	QS95/10	1.00	U45	1.20	1N1124A	0.61	AF239	0.44	GD16	0.23	OC82D	0.13
EY83	1.50	PCC806	0.70	QV03/12	2.75	U47	1.00	1N4744A	0.16	ASY27	0.50	GET119	0.30	OC83	0.23
EY86/7	0.45	PCF80	0.80	QV04/7	3.00	U49	0.90	1N4952	0.58	ASY28	0.38	GET573	0.44	OC84	0.28
EY88	1.00	PCF82	0.45	QV06/20	4.70	U50	0.65	2N404	0.21	ASY29	0.58	GET587	0.50	OC123	0.26
EY91	0.50	PCF84	0.70	R10	5.00	U52	1.00	2N966	0.61	BA115	0.16	GET872	1.11	OC140	1.11
EY500A	1.45	PCF86	0.57	R11	1.00	U76	0.70	2N1756	0.58	BA116	0.21	GET873	0.18	OC169	0.50
EZ35	0.50	PCF87	0.90	R12	0.90	U78	0.95	2N2147	0.99	BA129	0.14	GET882	0.58	OC171	0.40
FZ40	1.00	PCF200	1.55	R16	2.00	U81	0.80	2N2297	0.26	BA130	0.12	GET887	0.26	OC172	0.41
EZ41	1.00	PCF201	1.45	R17	1.50	U150	1.00	2N2369	0.16	BA148	0.20	GET889	0.26	OC204	0.50
EZ80	0.42	PCF800	1.00	R19	0.75	U151	0.80	2N2613	0.45	BA153	0.18	GFT896	0.26	OC206	1.05
EZ81	0.45	PCF801	0.49	R20	0.90	U153	0.60	2N3053	0.38	BCY10	0.53	GET897	0.26	ORP12	0.61
EZ90	0.95	PCF802	0.80	R52	0.75	U191	0.50	2N3121	2.90	BCY12	0.58	GET898	0.26	SFT237	0.50
FC4	1.00	PCF805	2.25	RK34	1.00	U192	0.40	2N3703	0.23	BCY33	0.23	GEX113	0.21	SM1036	0.58
FW4/500	2.50	PCF806	0.70	SP4	1.50	U193	0.60	2N3709	0.23	BCY34	0.26	GEX36	0.58	ST1276	0.58
FW4/800	2.50	PCH200	1.20	SP13C	0.75	U251	1.00	2N3866	1.16	BCY38	0.26	GEX45	0.38	SX1 6	0.21
GY501	1.40	PCL82	0.62	TH4B	1.00	U281	0.75	2N3988	0.58	BC107	0.14	GEX55	0.87	U14706	0.30
GZ30	0.75	PCL83	1.20	TH233	1.00	U282	0.70	2S323	0.58	BC108	0.14	GT3	0.30	XZ30	0.30
GZ32	1.00	PCL84	0.50	TP2620	1.00	U291	0.50	AA119	0.18	BC109	0.14	M1	0.18	Y543	0.21
GZ33	4.00	PCL86	0.85	TP22	1.00	U301	1.00	AA120	0.18	BC113	0.30	MAT100	0.45	Y728	0.21
GZ34	2.25	PC188	1.50	TP25	1.00	U329	1.00	AA129	0.18	BC115	0.18	MAT101	0.50		
GZ37	4.00	PCL800	1.30	UABC80	0.45	U339	0.50	AAZ13	0.21	BC116	0.30	OA9	0.14		
HABC80	0.80	PCL801	2.20	UAF42	0.70	U349	0.80	AC107	0.18	BC118	0.26	OA47	0.12		
HL13C	0.80	PCL805/85	0.65	UBC41	0.70	U381	0.70	AC113	0.30	BF154	0.30	OA70	0.18		
HL23	0.70	PEN4DD	2.00	UBC81	0.55	U403	0.90	AC114	0.47	BF158	0.21	OA73	0.18		
HL23DD	0.68	PEN25	1.00	UBF80	0.50	U404	0.75	AC126	0.14	BF159	0.30	OA79	0.11		
HL41	1.00	PEN45	1.00	UBF89	0.39	U709	0.45	AC127	0.20	BF163	0.23	OA81	0.11		
HL41DD	1.00	PEN45DD	1.00	UBL21	2.00	U801	1.00	AC128	0.26	BF173	0.44	OA85	0.11		
HL42DD	1.00	PEN46	1.00	UC92	0.50	U4020	1.00	AC132	0.23	BF180	0.35	OA86	0.23		
HN309	1.70	PEN453DD	2.00	UCC84	0.90	VLS492	9.50	AC154	0.30	BF181	0.47	OA90	0.14		
HVR2	1.00	PENA4	1.00	UCC85	0.50	VP2	1.50	AC156	0.23	BF185	0.47	OA91	0.11		
HVR2A	1.00	PENDD/4020	1.00	UCF80	0.80	VP4(5)	2.00	AC157	0.30	BFY50	0.26	OA95	0.11		
HY90	0.55	PFL200	1.35	UCH21	2.00	VP13C	0.60	AC165	0.30	BFY51	0.23	OA200	0.11		
KT2	0.90	PL33	1.00	UCH42	1.00	VP23	0.65	AC166	0.30	BFY52	0.23	OA202	0.12		
KT8	3.00	PL36	0.80	UCH81	0.60	VP41	0.90	AC168	0.44	BTX34/400	2.31	OC19	1.46		
KT32	1.00	PL81	0.49	UCL82	0.75	VT61A	0.75	AC169	0.38	BY100	0.21	OC22	0.44		
KT41	1.00	PL81A	0.75	UCL83	1.00	VU111	1.00	AC176	0.64	BY101	0.18	OC23	0.44		
KT44	1.00	PL82	0.50	UF41	0.70	VU120	1.00	AC177	0.32	BY105	0.21	OC24	0.44		
KT63	0.70	PL83	0.50	UF42	1.00	VU120A	1.00	ACY17	0.35	BY114	0.21	OC28	0.69		
KT66	3.50	PL84	0.50	UF80	0.40	VU133	1.00	ACY18	0.35	BY126	0.18	OC29	0.73		
KT71	1.00	PL95	1.00	UF85	0.50	VX6020	1.00	ACY19	0.35	BY127	0.21	OC36	1.00		
KT81	2.00	PL302	0.90	UF89	0.52	W76	0.50	ACY20	0.35	BYY23	1.16	OC38	0.50		
KT88	6.75	PL504 500	1.05	UL41	0.90	W81M	1.20	ACY21	0.35	BYZ10	0.30	OC41	0.58		
L63	0.65	PL505	2.55	UL46	1.00	W107	1.00	ACY22	0.35	BYZ11	0.30	OC42	0.73		
LN119	0.75	PL508	1.85	UL84	0.90	W719	0.45					OC43	1.37		
LN152	0.55	PL509	3.10	UM80	1.00	W729	1.20								
LN309	1.20	PL519	3.75	UM84	2.50	WD709	1.00								
LZ319	0.80	PL801	0.74	UR1C	1.00	XE3	0.80								
LZ329	0.80	PM84	0.75	UU5	1.15	XFY12	0.60								
M8083	3.00			UU9	1.00	XH15	0.60								
M8136	2.00			UU12	0.45	XSG15	1.20								
M8137	2.00			UY41	0.70	X41	1.00								
M8162	2.00					X61	2.00								
M8195	3.00														
MHL4	1.00														
MHLD6	0.99														
MKT4	1.20														
MUI2/14	1.15														
MX40	1.00														
N150	1.00														
N308	0.98														

ALL PRICES INCLUDE V.A.T. NOTHING EXTRA TO PAY

MATCHED TRANSISTOR SETS
LP15 (AC113, AC154, AC157 AA120). **61p** per pack
1 OC81D and 2 OC81, **50p.**
1 OC44 and 2 OC45, **50p.**
1 OC82D and 2 OC82 **56p.** Set of 3 OC83 **76p.**
1 watt Zeners. 2 4v 2 7v, 3v, 3 6v, 4 3v, 4 7v 5 1v, 13v 15v, 16v 18v, 20v, 24v 30v, **12p each.**

All goods are unused and subject to the manufacturers guarantee
Terms of business Cash or cheque with order Despatch charges — Orders below £25 in value add 50p for post and packing Orders over £25 post and packing free of charge All orders cleared same day Any parcel insured against damage in transit for 5p extra per parcel Conditions of sale available on request Many others in stock too numerous to list Please enclose S.A.E for reply to any enquiries
All prices subject to change without notice.
Special offer of EF50 valves, soiled but new and tested £1 each

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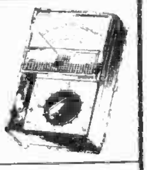
WHY PAY MORE?!



MULTI RANGE METERS Type MF15A A.C./D.C. volts 10 50 250 500 1000 Ma 0.5 0-10 0-100 Sensitivity 2000V 24 range, diameter 133 × 93 × 46mm Price **£6.50** plus 50p P&P (**£7.56** inc VAT & P)

TRIAC.

Raytheon tag symmetrical Triac Type Tag 250/500v 10 amp 500 piv Glass passivated plastic triac Swiss precision product for long term reliability **£1.25** P&P 10p (**£1.46** inc VAT & P) (inclusive of date and application sheet) Suitable Diac **22p**.

0 to 60 MINUTES CLOCKWORK TIMER.

Double pole 15 amp 230AC. Contacts (no dial) **£1.50.** P&P 30p (**£1.94** inc VAT & P)

MERCURY SWITCH

Size 27mm x 5mm 10 for **£5.00** (inc VAT **£5.72**) Min quantity 10

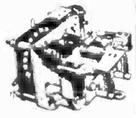
CONTACTOR

Mfg by Hendrey Relays type C2839 220/250 AC ops Contact 4C/O at 20 amp at 440 volts AC price **£6.00** P&P 75p (**£7.29** inc VAT & P)

230 VOLT AC FAN ASSEMBLY

Powerful continuously rated AC motor complete with 5 blade 6½" aluminium fan New reduced price **£3.00** P&P 65p (**£3.94** inc VAT & P)

21-WAY SELECTOR SWITCH with reset coil



The ingenious electro mechanical device can be switched up to 21 positions and can be reset from any position by energising the reset coil 230/240v A.C. operation Unit is mounted on strong chassis Complete with cover Price **£5.50** P&P 75p (**£6.75** inc VAT & P)

VORTEX BLOWER AND VACUUM UNIT

Dynamically balanced to tally enclosed 9" rotor with max air delivery of 1.5 cubic metres per min Max static pressure 600mm W.G. Suction or blow from 2 side-by-side 37mm I.D. circular apertures fitted to base of unit Powerful continuously rated 115v a.c. motor mounted on alloy base with fixing facilities Dimensions Length 22cm x width 25cm x height 25cm

These units are ex-equipment but have had minimum use Fully tested prior to despatch Price **£12** + £1.50 P&P (**£14.58** inc VAT & P) Suitable transformer for 230/240v a.c. **£6** + £1 P&P (**£7.56** inc VAT & P)

CENTRIFUGAL BLOWER

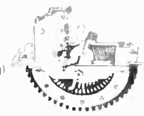
Smith type FFB 1906 022 220 240v A.C. Aperture 10x4½cm overall size 18x14cm Price **£3.75** p&p 75p (inc VAT **£4.86**). Other types available phone for details

NI-CAD BATTERY

	Height (mm)	Width (mm)	Length (mm)
35 AH 1.2v Metal	219	75	29

Postage 30p per unit

MINIATURE UNISELECTOR



12v 11 way 4 bank (3 non-bridging 1 homing) **£2.50** P&P 35p (**£3.08** inc VAT & P)

MICRO SWITCHES

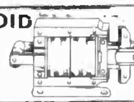
Sub min lever m/switch type MML46 10 for **£2.50.**

Type 3 115M 906T 10 for **£2.50** post paid (**£2.70** inc VAT & P)

BF lever operated 20a c/o mf Unimax USA 10 for **£4.00** plus 50p P&P (min. order 10) (**£4.86** inc VAT & P)

D.P. C/O lever m/switch mfg by Cherry Co. USA Precious metal low resistance contacts. 10 for **£2.50.** P&P 30p Total inc VAT £3.02 (min 10)

NEW HEAVY DUTY SOLENOID



Mfg by Magnetic Devices 240v A.C. Operation approx 20lb pull at 1.25" Price **£7.00** P&P 75p (**£8.37** inc VAT & P)
Similar to above approx 10lb pull **£3.50** P&P 60p (**£4.43** inc VAT & P)

230-250 VOLT A.C. SOLENOID

Similar in appearance to illustration
Approximately 1½lb pull Size of feet 1⅝"×13/16"
Price **£1.00** Post 25p (**£1.35** inc VAT & P)

24 VOLT D.C. SOLENOIDS

UNIT containing **1 heavy duty solenoid approx. 25 lb. pull** at 1 in travel 2 solenoids of approx 1 lb pull at ½ in travel 6 solenoids of approx 4 oz pull at ½ in travel Plus 1 24V D.C. 1 heavy duty 1 make relay Price **£3.00** Post £1.00 (**£4.32** inc VAT & P) **ABSOLUTE BARGAIN**

240 A.C. SOLENOID OPERATED FLUID VALVE

Rated 1 p.s.i. will handle up to 7 p.s.i. Forged brass body, stainless steel core and spring ½ in b.s.p. inlet outlet Precision made British mfg
PRICE **£2.75** Post 50p (**£3.57** inc VAT & P)

VARIABLE VOLTAGE TRANSFORMERS

INPUT 230 v. A.C. 50/60
OUTPUT VARIABLE 0/260v. A.C.

BRAND NEW. All types.

200W (1 Amp) fitted A/C volt meter	£12.50
0.5 KVA (Max. 2½ Amp)	£15.00
1 KVA (Max. 5 Amp)	£19.50
2 KVA (Max. 10 Amp)	£32.00
3 KVA (Max. 15 Amp)	£39.50
4 KVA (Max. 20 Amp)	£60.00

Carriage extra

LT TRANSFORMERS

0-12v 24v at 1 amp **£2.50** p&p 50p (**£3.24** inc VAT & P)
0-15v at 1 amp + 0-15v at 1 amp 30v 1 amp **£2.50** p&p 50p (**£3.24** inc VAT & P)
25-0-25v at 2½ amp **£4.50** p&p 75p (**£5.67** inc VAT & P)
0-12v/24v 10 amp **£12.35** p&p £1.50 (**£14.96** inc VAT & P)
0-4v/6v/24v/32v at 12 amp **£13.00** p&p £1.50 (**£15.66** inc VAT & P)
0-12v at 20 amp or 0-24v at 10 amp **£12.00** p&p £1.50 (**£14.58** inc VAT & P)
0-6v/12v/17v/18v/20v at 20 amp **£14.00** p&p £1.50 (**£16.74** inc VAT & P)
0-6v 12v at 20 amp **£11.85** p&p £1.00 (**£13.88** inc VAT & P)
Other types in stock phone in enquiries

COMPRESSOR,

precision built by Emerson USA Horizontally opposed twin head diaphram type producing 20lbs Plus P.S.I. per head 3.5 plus C.F.M. Output virtually pulse free Powered by 110v A.C. motor size 30x23x15cm Weight 7 kilos **Price £20** p&p £2.00 (inc VAT **£23.76**). Suitable transformer for 230/240v A.C. **£8.00** p&p £1.00 (inc VAT **£9.72**).

STROBE! STROBE! STROBE!

HY-LIGHT STROBE KIT Mk. IV

Latest type Xenon white light tube Solid state timing and triggering circuit 230/240 volt A.C. operation Speed adjustable 1-20 f.p.s. Designed for large rooms halls etc Light output greater than many (so called 4 Joule) strobes Price **£18.00** post £1 (**£20.56** inc VAT & P) Specially designed case and reflector for Hy-Light **£8.25** Post £1.00 (**£9.99** inc VAT & P)

ULTRA VIOLET BLACK LIGHT FLUORESCENT TUBES

4ft. 40 watt £7.75 (callers only). **2ft. 20 watt £5.50.** Post 60p (For use in stan bi-pin fittings) Mini **12in. 8 watt £2.50.** Post 25p (**£2.97** inc VAT & P) 9in 6watt **£2.00** Post 25p (**£2.43** inc VAT & P) 6in 4 watt **£1.75** Post 25p) (**£2.16** inc VAT & P)
Complete ballast unit Either 6" 9" or 12" tube 230V A.C. op **£3.50** plus P&P 40p (**£4.21** inc VAT & P) Also available for 12V D.C. op **£3.50** plus P&P 40p (**£4.21** inc VAT & P)

WIDE RANGE OF DISCO LIGHTING EQUIPMENT

S.A.E. (Foolscap) for details

XENON FLASH GUN TUBES

Range of Xenon tubes available from stock S.A.E. for full details

RELAYS

Wide range of AC and DC relays available from stock Phone or write in your enquiries

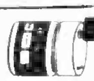
230/240V A.C. Relays: Arrow 2 c/o 15 amp **£1.50** (**£1.84** inc VAT & P)
T.E.C. open type 3 c/o 10 amp **£1.10** (**£1.40** inc VAT & P) Mag Devices 2 c/o 20 amp **£1.50** (**£1.84** inc VAT & P) Omoron or Keyswitch 1 c/o 7 amp **£1.00** (**£1.30** inc VAT & P)

D.C. Relays: Open type 9/12V 3 c/o 7 amp **£1.00** (**£1.30** inc VAT & P) Sealed 12V 1 c/o 7 amp octal base **£1.00** (**£1.30** inc VAT & P) Sealed 12V 2 c/o 7 amp octal base **£1.25** (**£1.56** inc VAT & P) Sealed 12V 3 c/o 7 amp 11-pin **£1.35** (**£1.67** inc VAT & P) 24V Sealed 3 c/o 7 amp 11-pin **£1.35** (**£1.67** inc VAT & P) (amps = contact rating) P&P on any Relay 20p
Other types available – phone for details

RESET COUNTER

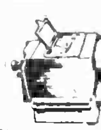
230 volts AC 3 digits mfg Veeder Root type LL 144L **£1.75** P&P 25p (**£2.16** inc VAT & P)
7 fig 24v d.c. non set **£1.50** P&P 25p (**£1.89** inc VAT & P)
6 fig 24v d.c. resetable **£3.00** P&P 25p (**£3.51** inc VAT & P)

BIG INCH



Tiny precision built 3 rpm USA motor size only 1 x 1 100 volt AC op supplied with resistor for 230 volt AC price **£2.37** p&p 20p 4 for **£5.40** post paid

INSULATION TESTERS (NEW)



Test to I.E.E. spec Rugged metal construction suitable for bench or field work constant speed clutch Size L 8 in W 4 in H 6 in weight 6 lb
500 VOLTS 500 megohms
£49.00 Post 80p (**£57.78** inc VAT & P)
1000 VOLTS 1000 megohms
£55.00 Post 80p (**£60.26** inc VAT & P) SAE for leaflet

VAT AT CURRENT RATE MUST BE ADDED TO ALL ORDERS FOR THE TOTAL VALUE OF GOODS INCLUDING POSTAGE UNLESS OTHERWISE STATED

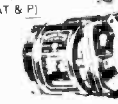
ACCOUNT CUSTOMERS MIN. ORDER £10.00

GEARED MOTORS

100 R.P.M. 115 lbs. ins.!!

115 lb ins 110 volt 50Hz 2.8 amp single phase split capacitor motor Immense power Continuously rated Totally enclosed Fan cooled In-line gearbox Length 250mm Dia 135mm Spindle Dia 15.5mm Length 145mm ex-equipment tested **£12.00** Post £1.50 (**£14.58** inc VAT & P) Suitable transformer 230/240 volt **£8.00** Post 75p (**£9.45** inc VAT & P)

BODINE TYPE GEARED MOTOR



(Type 1) 71 r.p.m. torque 10 lb in
Reversible 1/70th h.p. cycle 38 amp This U.S.A. motor is offered in with transformer for 230/240v AC input Price type **£6.25** Post 75p (**£7.56** inc VAT & P) or less transformer **£3.75** Post 65p (**£4.75** inc VAT & P) (Type 3) 71 r.p.m. 230 volt A.C. Continuously rated Non reversible **£6.50** Post 75p (**£7.83** inc VAT & P)

28 r.p.m., 20lb. inch approx 115v a.c. Reversible similar to above drawing Mag by Wynstruments Price **£4.75** + 75p p&p Total inc VAT £5.94 Supplied complete with transformer for 240v AC operation **£7.25** P&P £1 inc VAT **£8.91**.

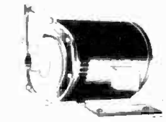
FRACMO

56 rpm 50lbs inch 240vAC reversible 0.7 amp Shaft length 35mm dia 16mm weight 6 kilos 600 grams Price **£15.00** P&P 1.50 (**£17.82**).

PARVALUX GEARED MOTOR

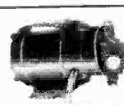
Type 5018 240v AC reversible 30 rpm 50lbs inch Price **£15.00** P&P 1.50 (£17.82 inc VAT)

A.E.G. WATER PUMP



200/240v a.c. motor 2850 rpm 480w approx 1/3 hp driving a centrifugal pump with 1½" inlet and outlet delivering approx 40 galls per min at 10ft head Ideal for pumping or circulating any non corrosive light viscosity liquid Dozens of uses in industrial labs etc Note this pump is not self-priming Price **£15** + 75p P&P (**£17.01** inc VAT & P)

CITENCO 19 RPM



FHP motor type C 7333/15 220/240v a.c. 19 rpm reversible motor torque 14.5 kg Gear ratio 144.1 Brand new incl capacitor our price **£14.25** + £1.25 P&P (**£16.20** inc VAT & P)

REVERSIBLE MOTOR 230V A.C.

General Electric 230v A.C. 1,600 r.p.m. 0.25 amp Complete with anti-vibration mounting bracket and capacitor O/A size 110mm x 95mm Spindle 5/16" dia 20mm long Ex-equipment tested **£3.00** Post 50p (**£3.78** inc VAT & P).

METERS 90mm Diameter

DC Amps type 65C5 0.2A 0.5A 0.20A 0.50A 0.100A AC Amps type 62T2 0.1A 0.5A 0.50A DC Volts type 65C5 0.15v 0.30v AC Volts type 62T2 0.150V 0.300V All at **£3.50** P&P 50p **£4.32** inc VAT

'VENNER TYPE' ERD TIME SWITCH

200/250V A.C. 30 amp. 2 on/2 off every 24 hrs. at any manually pre-set time. 36 hour spring reserve and day omitting device. Built to highest Electricity Board specification Price **£7.75** P&P 75p (**£9.18**).

SANGAMO WESTON TIME SWITCH

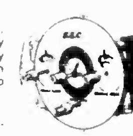
Type S251 200/250 v.a.c. 2 on 2 off every 24 hours 20 amps contacts with override switch diam 4" x 3" price **£6.00** P&P 50p (**£7.02** inc VAT & P)
Also available with Solar dial

A.E.G. TIME SWITCH

200/250V A.C. 1 on/1 off every 24 hrs 80 amps contacts (ideal storage heater), spring reserve Price **£10.00** P&P 50p (**£11.34**).

11-pin top entry plug complete with 11-pin PC socket **35p** for pair 10 for **£3.50.** P&P 60p + VAT **£4.43.** Min 10 pair

A.C. MAINS TIMER UNIT



Based on an electric clock with 25 amp single-pole switch which can be preset for any period up to 12 hrs ahead to switch on for any length of time from 10 mins to 6 hrs then switch off An additional 60 min audible timer is also incorporated Ideal for Tape Recorders Lights Electric Blankets etc Attractive satin copper finish Size 135 mm x 130 mm x 60 mm Price **£2.25.** Post 40p. (Total inc VAT & Post **£2.87**).

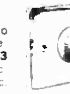
POWER RHEOSTATS

New ceramic construction, vitreous enamel embedded winding, heavy duty brush assembly, continuously rated

25 WATT 10 25 100 150 250 500 1k 1.5k ohm **£2.40** Post 20p (**£2.81** inc VAT & P) **50 WATT** 100 500 1k ohm **£2.90** Post 25p (**£3.40** inc VAT & P) **100 WATT** 1/5/10/25/50/100/250/500/1k 1.5k/2.5k/5k ohm **£5.50.** Post 35p (**£6.32** inc VAT & P)

Black Silver Skirted knob calibrated in Nos 1-9 1½ in dia brass bush Ideal for above Rheostats **24p ea.**

600 WATT DIMMER SWITCH



Easily fitted Fully guaranteed by makers Will control up to 600w of lighting except fluorescent at mains voltage Complete with simple instructions **£3.95** Post 25p (**£4.53** inc VAT & P) 1000 watt model **£5.60** Post 25p (**£6.32** inc VAT & P) 2000 watt model **£9.75** Post 40p (**£10.96** inc VAT & P)

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EASY BUILD SPEAKER DIY KITS
Specially designed by RT-VC for cost conscious hi-fi enthusiasts, these kits incorporate two teak-simulate enclosures, two EMI 13" × 8" (approx.) woofers, two tweeters and a pair of matching crossovers. Supplied complete with an easy-to-follow circuit diagram, and crossover components. Input 15 watts rms, 30 watts peak, each unit. Cabinet size 20" × 11" × 9½" (approx.).
£28.00 STEREO PAIR + p & p £5.50

• SPEAKERS AVAILABLE WITHOUT CABINETS.
It's the units which we supply with the enclosures illustrated. Size 13" × 8" (approx.) woofer (EMI), tweeter, and matching crossover components. Power handling 15 watts rms, 30 watts peak. £17.00 per stereo pair + p & p £3.40

COMPACT FOR TOP VALUE These infinite baffle enclosures come to you ready mitred and professionally finished. Each cabinet measures approx. 12" × 9" × 5" deep, and is in wood simulate. Complete with two 8" (approx.) speakers for maximum power handling of 7 watts. £8.50 per stereo pair + p & p £2.20

SPEAKERS Two models – Duo IIb, teak veneer, 12 watts rms, 24 watts peak, 18½" × 13½" × 7¾" (approx.). Duo III, 20 watts rms, 40 watts peak, 27" × 13" × 11½" appx.
Duo IIb £17 PER PAIR p & p £6.50 Duo III £52 PER PAIR p & p £7.50

DECCA 20 WATTS STEREO SPEAKER stereo pair
This matching loudspeaker system is hand made, kit comprises of two 8" diameter approx. base drive unit, with heavy die cast chassis laminated cones with rolled P.V.C. surrounds, two 3½" diameter approx. domed tweeters complete with crossover networks. £20.00 £4.00 p & p

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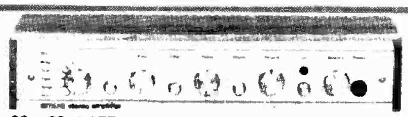

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Size 12"x8½" approx.

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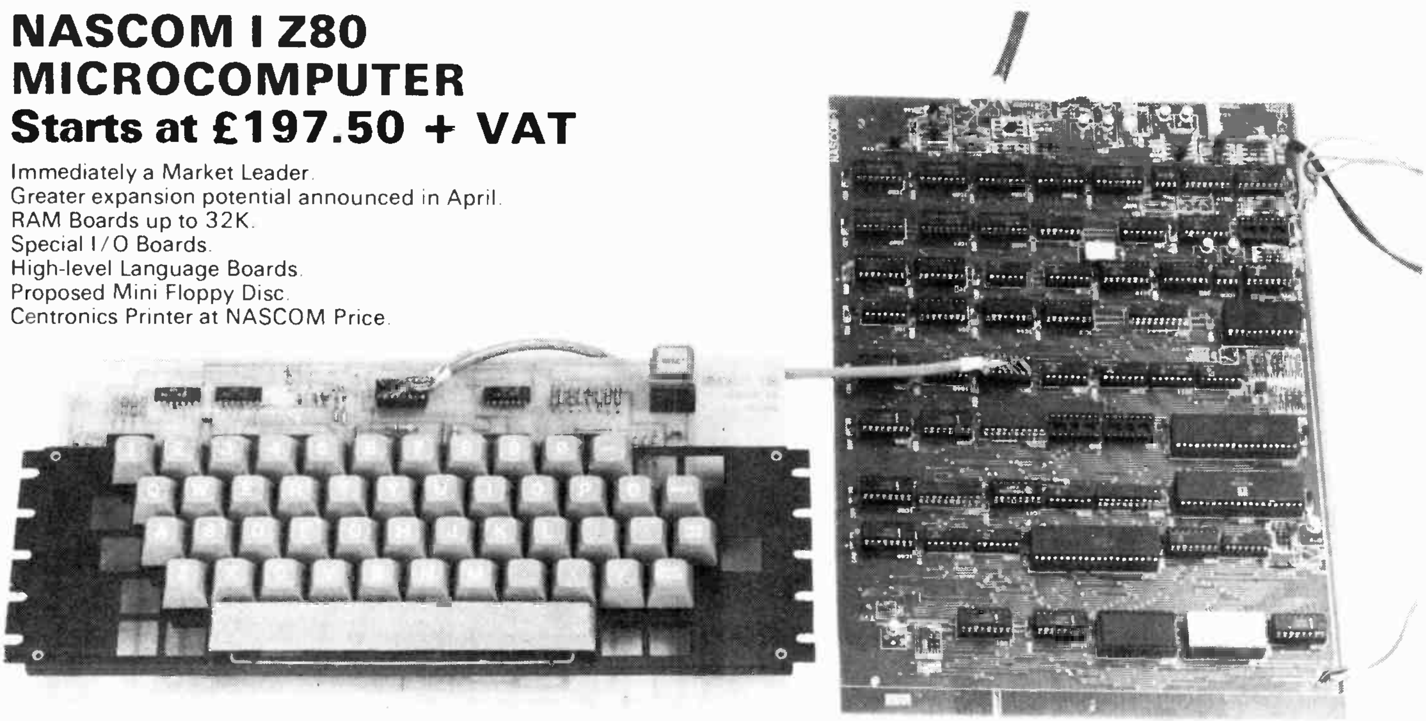

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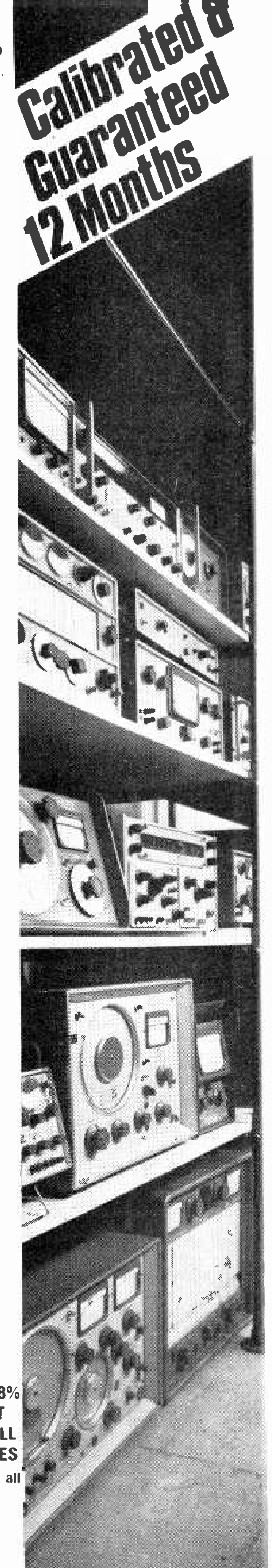

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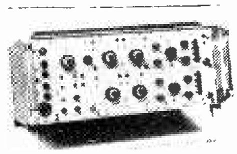

Pulse Generator PG59 (Type CT600). Produces a pulse controllable in frequency, width, amplitude, delay and rise and fall times. Also produces prepulse and gate outputs Repetition frequency 1Hz to 10MHz. Pulse width 25nsec to 1sec Rise and fall times 12nsec to 1 sec. Delay 25usec to 1sec. Trigger; Internal, external and single shot **£595.00**
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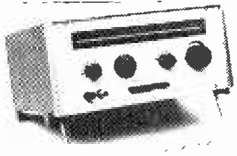

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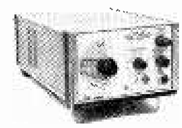

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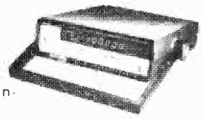

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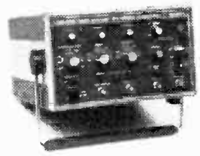

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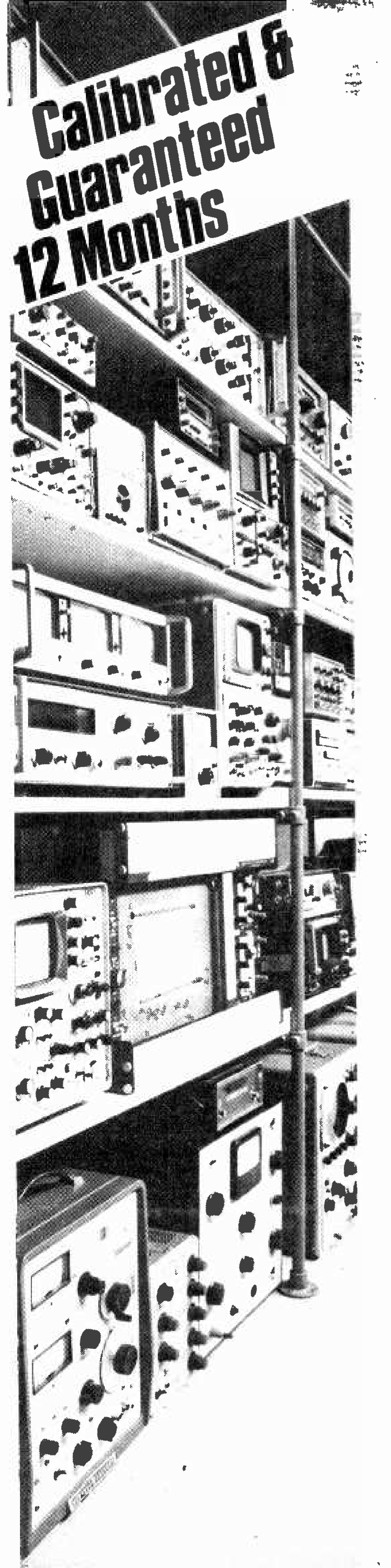

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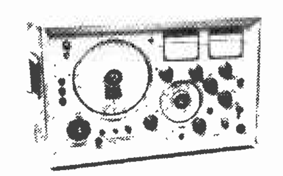
A.M. Signal Generator TF144H & H/S. Frequency range 10kHz to 72MHz in twelve overlapping bands. Output Attenuator. 2μV to 2V. Output Impedance 50Ω Modulation Internal AM 400Hz & 1kHz to 0 to 80% External AM 20Hz to 20kHz, 0 to 80% £275.00-£400.00

A.M. Signal Generator TF144H/4. A later version of TF144H with similar spec £375.00-£600.00

A.M. Signal Generator TF144H/4S. Electrical specification, as TF144H/4 £375.00-£700.00



A.M. Signal Generator TF801D/1. Frequency Range 10MHz to 470MHz in five bands. Output Attenuator 0 1μV to 1V Output Impedance 50Ω (Type N connector). Modulation Internal AM 1kHz, 0 to 90% External AM 30Hz to 20kHz, 0 to 90% £400.00-£750.00

A.M. Signal Generator TF801D/1/S. Special military version of TF801D/1 having fully sealed meters and carrier on/off switch. The electrical specification is similar to the TF801D, except for extended carrier and modulation frequency ranges as shown below Frequency Range 10MHz to 485MHz in five bands Modulation External AM 30Hz to 50kHz 0-90% £450.00-£600.00

Carrier Deviation Meter TF791D. Carrier Freq. range 4 to 1024MHz Deviation range up to ±125kHz Modulating Frequency range Up to 35kHz Late models £295.00

20MHz Sweep Generator TF1099. Video sweep output Lower limit 100kHz fixed. Upper limit continuously variable up to 20MHz 0.3 to 3V p-p Z=75Ω. Input & Output detector probes Markers at 1MHz intervals £295.00

Oscillator TF1247 (can be used with Q Meter TF1245) 20MHz-300MHz £350.00

A.M. Signal Generator TF801D/8S. Same spec as TF801D/1S + freq. counter o/p facility £695.00

F.M./A.M. Signal Generator TF995A/2M. 1.5 to 220MHz. 2μV to 200mV int & Ext. A M Int F M. at 1kHz deviation 0-75kHz £375.00-£475.00

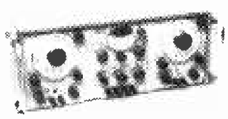
Sensitive Valve Voltmeter TF2600. 12 ranges 1mV-300V f.s d. 1% accuracy up to 500kHz Usable up to 10MHz £175.00

R.F. Electronic Voltmeter TF2604. 7 ranges 300mV-300V f s d from 20Hz-1500MHz 8 ranges 300mV-1kV DC 7 ranges Resistance 500Ω to 500MΩ £225.00

U.H.F. Signal Generator TF1060/3A. Frequency range 500 to 1200MHz Remainder of spec on TF1060 £575.00

R-C Oscillator TF1101. Frequency Range 20Hz to 200kHz in four bands. Output Attenuator 1mV to 20V Maximum Output 20V across external 600Ω load. Output impedance 600Ω £120.00

Phase A.M. Signal Generator TF2003. 0 4-12MHz £150.00



Two-Tone Signal Source TF2005R. The instrument comprises two identical low-distortion a f. oscillators and a monitored attenuator unit, to form a compact test set for the measurement of inter modulation distortion using the methods recommended by S.M.P.T.E and C.C.I.F Frequency Range 20Hz-20kHz in six bands (each oscillator can be adjusted and used independently). Harmonic Distortion Less than 0 05% between 63Hz and 6kHz when using unbalanced output Generally less than 0 1% under other conditions Intermodulation Below -80dB with respect to the wanted signal Amplitude Reference Level Up to +10dBm from each oscillator. Output Attenuator 111dB in 0 1dB steps £415.00

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L.F. Extension Unit TM6448. For use with Spectrum Analyser OA 1094A series 100Hz to 3MHz £200.00

Wide Range R.C. Oscillator TF1370A. 10Hz to 10MHz sine wave. 10Hz to 100kHz square wave. Output up to 31.6V £275.00

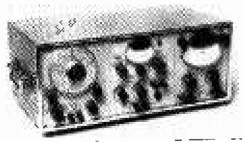
DC Multiplier TM5033A. HV probe up to 30kV Impedance 3000MΩ for use with TF1041 series or TF2604 £25.00

5 watt Dummy Load TM5582 for use with TF2604 £25.00

A.F. Oscillator TF2100. 20kc/s to 20Kc/s Extremely low distortion Output Impedance 600Ω unbalanced £150.00

M.F. Oscillator TF2101. 30c/s to 550kc/s Stable frequency Low distortion. Output Impedance 600Ω unbalanced £115.00

F.M./A.M. Modulation meter TF2300S. Incorporating Oscillator TM8045/1 3.5 to 1000MHz Full specification on request £825.00



M.F. Transmission Measuring Set TF2333. Frequency range 30Hz to 550kHz. The TF2333 is a transmission measuring set of the conventional type that normally forms part of the essential test gear for audio and baseband equipment of multi-channel telecommunications systems Signal Source, oscillator-frequency range 30Hz to 550kHz in five ranges. Attenuator, Range 70dB in 10dB and 1dB steps £600.00

F.M. Signal Generator TF1066B/6. 10-470MHz. R.F output 0.2μV-200mV e.m.f. Output Impedance 50Ω. Modulation Internal AM 1kHz & 5kHz 0-40% External AM 30Hz to 15kHz 0-40%. Internal FM 1kHz & 5kHz deviation 0 to 100kHz or up to 400KHz according to carrier freq. range. External FM 30Hz to 100kHz deviation same as int Crystal Calibrator facility £685.00

Variable Attenuator TF338C. 0-105dB Freqs. up to 100KHz. 600Ω impedance £90.00

M.F. Attenuator TF2162. DC-1MHz 0-111dB in steps of 0 1dB £120.00
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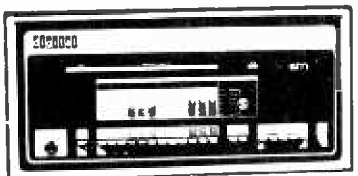

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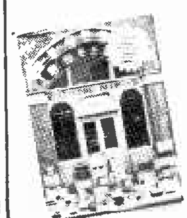

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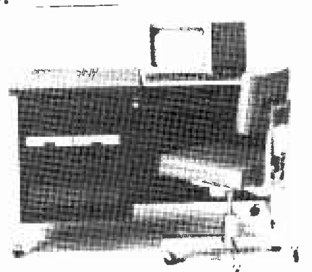

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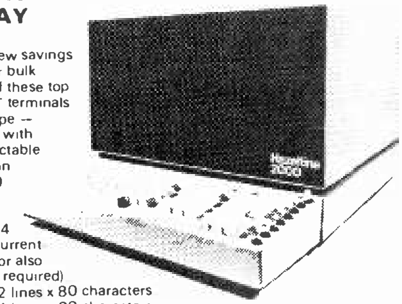

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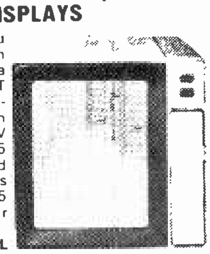

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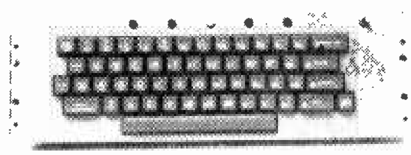

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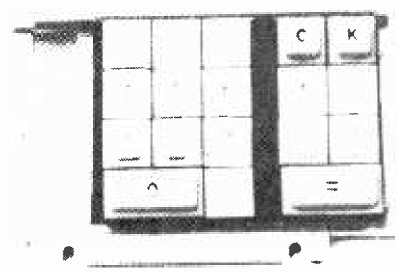

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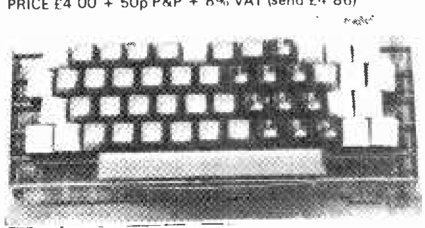

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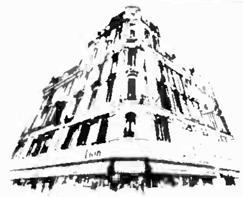

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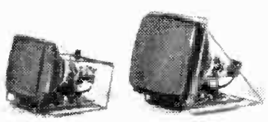

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LM309H 100mA 5V TO5 **75p** LM323K 3A 5V **700p**
78H05K 5A 5V TO3 **£7**

100mA TO92: +5V **70p**; +12V **70p**; +15V **70p**; −5V **80p**; −12V **80p**

VARIABLE VOLTAGE REGULATOR
723 2V to 37V 150mA 14 pin DIL **45p**
LM317T 2V to 37V 1.5 Amp TO220 **300p**
78MGT2C 0.5A DIL **135p**
TL470 2V to 30V 100mA TO-92 **70p**

SCR-THYRISTORS

1A 50V	TO5		70p
1A 100V	TO5		80p
1A 400V	TO5		90p
3A 400V	Stud		100p
7A 400V	TO5+HS		90p
12A 400V	Plastic		160p
16A 100V	Plastic		160p
16A 400V	Plastic		180p
16A 600V	Plastic		220p
8T106 Stud			110p
C106D 4A/400V	Plastic		63p
★MCR101 0.5A/15V	TO-92		35p
2N3525 5A/400V	TO-66		120p
2N4444 8A/600V	Plastic		185p
★2N5060 0.8A/30V	TO-92		34p

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8 pin **13p**, 14 pin **14p**, 16 pin **15p**, 18 pin **36p**, 22 pin **40p**, 24 pin **44p**, 28 pin **50p**, 40 pin **56p**.

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Approx 3.18mm thick	Single-sided **£1.25** square foot
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Positive resist in handy aerosol form. Just spray board, allow to dry, place positive of required circuit on sensitised surface, expose, develop and etch. **You** can produce your own perfect circuits within minutes rather than weeks! Widely accepted by industry as the perfect medium for all prototype work. One can will coat 1 1½ square metres of board. **£1.80** per can inclusive.

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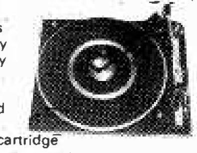

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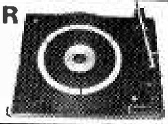

Ideal replacement or disco deck with cueing device and stereo ceramic cartridge 3 speeds Large turntable, modern design
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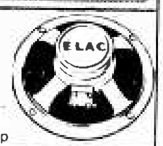

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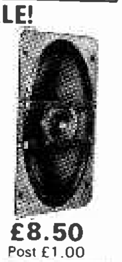

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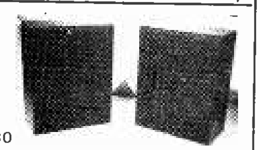

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50 to 14,000 cps.
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These little marvels of modern sound reproduction are ideally suited for today's domestic audio set-up Two of these smart spheres, each with 5 watt deep throated ceramic magnets, will produce superb stereo reproduction.
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Impedance 8 ohms
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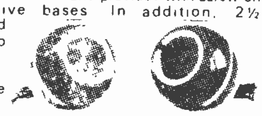

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1 5V d c. operation over 300 hours continuous on SP2 battery, fully adjustable swing and speed Ideal displays, teaching electro magnetism or for metronome, strobe, etc.
95p Post 30p.

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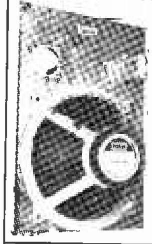

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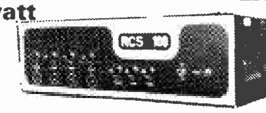
R.C.S. 100 watt VALVE AMPLIFIER CHASSIS



Four inputs Four way mixing, master volume, treble and bass controls Suits all speakers This professional quality amplifier chassis is suitable for all groups, disco, P A., where high quality power is required 5 speaker outputs A/C mains operated Slave output socket Produced by demand for a quality valve amplifier. 100V line output to order.
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Handles up to 100 watts No crossover required

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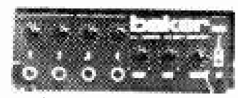

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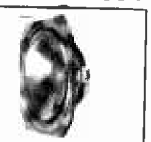
100 WATT DISCO AMPLIFIER
volume, treble, bass controls 500 M V or 1 volt input Four loudspeaker outputs 4 to 16 ohm All transistor **£59**

GOODMANS COMPACT 12-INCH BASS WOOFER



Standard 12in. diameter fixing with cut sides 10⅜ square 14,000 Gauss magnet. 30 watts R.M S 4 ohm imp. Bass resonance = 30 cps Frequency response 30-8000 c p s.
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Sizes 6½" × 4½" × 2¼" **95p.** 6½" × 2" × 2¼" **65p.**
BALANCED TWIN RIBBON FEEDER 300 ohms. 5p yd.
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Values = 5 7, 10, 20, 50 100, 200, 250, 470, 2000 ohms

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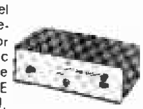

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154	500	19.15	2 15
155	750	29.06	OA
156	1000	37.20	OA
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★115 or 240 sec only. State volts required

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Separate 12V windings Pri 220-240V

Ref	Amps 12v	Amps 24v	£	P&P
111	0 5	0 25	2.20	45
213	1 0	0 5	2.64	78
71	2	1	3.51	78
18	4	2	4.03	96
70	6	3	5.35	96
108	8	4	6.98	1 14
72	10	5	7.67	1 14
116	12	6	8.99	1 32
17	16	8	10.39	1 32
115	20	10	13.18	2 08
187	30	15	17.05	2 08
226	60	30	26.82	OA

50 VOLT RANGE

Primary 220-240V
SEC. TAPS 0-20-25-33-40-50V
20v-0-20v or 25v-0-25V available by connection to appropriate taps

Ref.	Amps	£	P&P
102	0.5	3.41	78
103	1.0	4.57	96
104	2.0	6.98	1 14
105	3.0	8.45	1 32
106	4.0	10.70	1 50
107	6.0	14.62	1 64
118	8.0	17.05	2.08
119	10.0	21.70	OA

30 VOLT RANGE

Primary 220-240V
SEC TAPS 0-12-15-20-24-30V
12v-0-12v or 15v-0-15v available by connection to appropriate taps

Ref.	Amps	£	P&P
112	0 5	2.64	78
79	1 0	3.57	96
3	2 0	5.27	96
20	3 0	6.20	1 14
21	4 0	7.44	1 14
51	5.0	8.37	1 32
117	6 0	9.92	1 45
88	8 0	11.73	1 64
89	10.0	13.33	1 84

60 VOLT RANGE

Primary 220-240V
SEC TAPS 0-24-30-40-48-60V
24v-0-24v or 30v-0-30v available by connection to appropriate taps

Ref.	Amps	£	P&P
124	0.5	3.88	96
126	1 0	5.58	96
127	2.0	7.60	1 14
125	3 0	10.54	1 32
123	4 0	12.23	1 84
40	5.0	13.95	1 64
120	6 0	15.66	1 84
121	8.0	20.15	OA
122	10 0	24.03	OA
189	12 0	27.13	OA

AUTO TRANSFORMERS

Ref.	VA (Watts)	TAPS	£	P&P
113	15	0-115-210-240V	2.48	71
64	75	0-115-210-240V	3.95	96
4	150	0-115-200-220-240V	5.35	96
66	300	"	7.75	1 14
67	500	"	10.99	1 64
84	1000	"	18.76	2 08
93	1500	"	23.28	OA
95	2000	"	34.82	OA
73	3000	"	48.00	OA

HIGH VOLTAGE

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

VA	Ref.	£	P&P
60	243	5.89	1 32
350	247	14.11	1 84
1000	250	41.76	OA
2000	252	54.25	OA

SCREENED MINIATURES Primary 240V

Ref.	mA	Volts	£	P&P
238	200	3-0-3	1.99	55
212	1A, 1A	0-6, 0-6	2.85	78
13	100	9-0-9	2.14	38
235	330, 330	0-9, 0-9	1.99	38
207	500, 500	0-8-9, 0-8-9	2.59	71
208	1A, 1A	0-8-9, 0-8-9	3.53	78
236	200, 200	0-15, 0-15	1.99	38
239	50MA	12-0-12	1.99	38
214	300, 300	0-20, 0-20	2.56	78
221	700 (DC)	20-12-0-12-20	3.41	78
206	1A, 1A	0-15-20, 0-15-20	4.63	96
203	500, 500	0-15-27, 0-15-27	3.99	96
204	1A, 1A	0-15-27, 0-15-27	5.39	96
S112	500	0-12-15-20-24-30	2.64	78

BRIDGE RECTIFIERS

200v	2A	45p
400v	2A	55p
200v	4A	65p
400v	4A	80p
400v	6A	£1.05
500v	10A★	£2.35

★P&P 15p. VAT 12½% ★VAT 8%

CASED AUTO. TRANSFORMERS

240V Cable Input USA 115V Flat pin outlets

	£	P&P	Ref.
15VA	£4.96	96	113W
75VA	£6.03	1 14	64W
150VA	£8.48	1 14	4W
200VA	£9.92	1 45	65W
500VA	£15.73	1 64	67W
750VA	£18.55	1 76	83W
1000VA	£22.68	OA	84W
1500VA	£26.02	OA	93W
2000VA	£37.65	OA	95W

TEST METERS

AVO8 Mk 5	£71.00
AVO71	£29.00
AVO73	£39.10
AVOMM5 MINOR	£24.00
WEE MEGGER	£58.80

AVO TT169 (tests transistors in circuit, no soldering) **£30.00**
U4315 budget meter (42 ranges) 20Km/VDC 1000V AC/DC (9 ranges) 2 5A AC/DC 500Km resistance, in robust steel case with leads, full instructions **£15.85**
Avo Cases and Accessories
Ex-stock. P&P £1.15. VAT 8%

HIGH QUALITY MODULES

10 watt RMS Amplifier (AL30)	£3.66
35 watt RMS Amplifier (AL80)	£6.95
25 watt RMS Amplifier (AL60)	£4.57
125 watt RMS Amplifier (AL350)	£15.95
Pre-Amp for 10w (PA12)	£6.70
Pre-Amp for 25w (PA100)	£13.88
Power Supplies for 10w (PS12)	£1.30
Power Supplies for 25w (SPM80)	£3.75
Transformer for 10w	£3.09
Transformer for 25w (one module)	£4.79

P&P Modules **35p**. Trans **96p**. VAT 12½%

MINI-MULTIMETER

DC1000V, AC-1000V
AC/DC-1000Ω/V
DC-100mA Res — 150K
Bargain at **£5.86**
VAT 8% P&P 62p

NEW RANGE HIGH QUALITY TRANSFORMERS. Sec 45-36-0-36-45 sec to give 36-0-36, 45-0-45 72V or 90V pp. 2A 9-89 1-38, 3A 11-47 1-48, 4A 13-90 1-48, 5A 11-74 2-15, 6A 2-77 2-30

PLASTIC CASES

P81—77 x 56 x 37mm	.46p
P82—95 x 71 x 35mm	.56p
P83—115 x 95 x 37mm	.60p

p&p 29p VAT 8%

PLUG-IN — SAVE BATTERIES

3300. 6, 7.5, 9v at 300mA plugs direct into 13A socket (fused) **£3.30**
STABILISED 3, 6, 7.5, 9v at 400mA **£6.61**

STEREO F.M. TUNER

Phase lock loop 4 pre-selected stations, varicap tuning, switched AFC Beacon **£20.45**
P&P 40p (VAT 12½%)

ANTEX SOLDERING IRONS

15W **£3.75**, 18W **£3.75**, 25W **£3.95**
Stand for above **£1.40**. P&P 46p VAT 8%

Special offer: Trans BE2 — Pri.0-90-110-200-220-240V. Sec. 0-110V 0-20-24V 2.5A £2.25. P&P 95p.

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SEMICONDUCTOR, RESISTOR, CAPACITOR, SEMI CONDUCTOR, AUDIO ACCESSORIES & BARGAIN PAKS. SAVE POSTAGE. CALLERS WELCOME (MON-FRI) OR SEND 15p STAMP FOR LISTS
PRICES CORRECT AT 25/12/77

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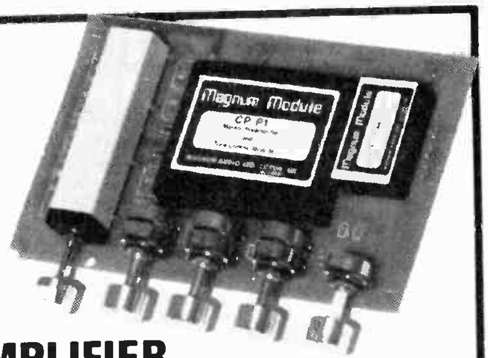
3,THE MINORIES, LONDON EC3N 1BJ
TELEPHONE: 01-488 3316/8
NEAREST TUBE STATIONS: ALDGATE & LIVERPOOL ST.

WW—070 FOR FURTHER DETAILS



PRE-AMPLIFIER CP-P1

Shown here mounted with its associated components (and the **CP-TM1** Peak Programme Monitor) on the **CP-MPC1** interconnection board; the **CP-P1** is a complete stereo pre-amplifier and tone control module. Performance features >70 db S/N ratio and >30 db overload margin (both ref. 3 mV) and distortion of 0.02%. The internal R.I.A.A. feedback compensation around the low-level pre-amp may be replaced with external networks and the tone control circuits can be programmed to give different turnover frequencies if required (including separate bass and treble 'defeat' facilities).

CP-P1 £14.96 incl. (U.K.)

Also Available: Power Amplifiers, Filters, Stereo Image Width Control, Compressor/Expander, Active Crossovers, Power Supplies plus all pots, switches, etc.

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LUTON, BEDS. LU1 1DF
TEL: 0582 28887
SEND LARGE S.A.E. FOR DETAILS

WW—115 FOR FURTHER DETAILS

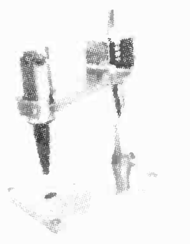
NEW for electronic design engineers!

FIX-PRINT JIG for printed circuits

Invaluable for holding P.C.B.'s and other panels when inserting and soldering components. Can be adjusted to suit work up to 28mm, rotating to gain access to reverse side and locks in any position. All metal.

Price **£10** inc. VAT. P&P **£1**. Write or phone for full details.

S2 Drill Stand

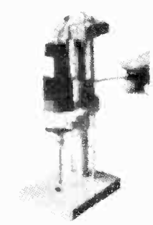


Robust, all metal with ample throat dimensions. Adjustable height cantilever with lever actuated feed. Spring return. Will accept both P1 & P2 drills.
Price **£18.50** inc. VAT. P&P 106p
P2 Mk 2 Drill **£18** inc. VAT P&P 86p

S1 Drill Stand

Constructed to take the popular P1 drill and ensure a high degree of accuracy in all types of electrical precision work

Price **£5.13** inc. VAT. P&P 38p



P1 Drill **£9.67** inc. VAT. P&P 38p

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TEL: 01-977 0878

WW—016 FOR FURTHER DETAILS

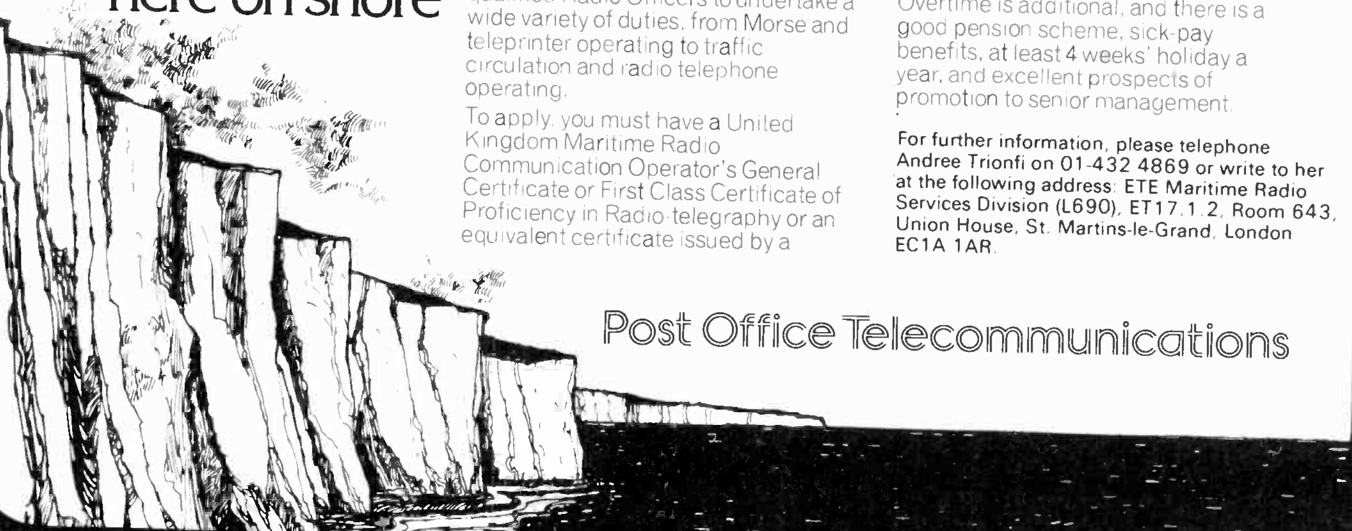
Appointments

Advertisements accepted up to 12 noon Monday, May 1, for the June issue, subject to space being available.

DISPLAYED APPOINTMENTS VACANT: £7.50 per single col. centimetre (min. 3cm).
LINE advertisements (run on): £1.10 per line, minimum three lines.
BOX NUMBERS: 50p extra. (Replies should be addressed to the Box Number in the advertisement, c/o Wireless World, Dorset House, Stamford Street, London SE1 9LU.)
PHONE: Eddie Farrell on 01-261 8508
Classified Advertisement Rates are currently zero rated for the purpose of V.A.T.

Land a good job

Your Radio Officer's qualifications can mean a lot here on shore



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. And, ideally, you should have some sea-going experience.

The starting pay at 25 or over works out at around £4093; after three years' service this figure rises to around £5093. (If you are between 19 and 24 your pay on entry will vary between approximately £3222 and £3732). 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 Andree Trionfi on 01-432 4869 or write to her at the following address: ETE Maritime Radio Services Division (L690), ET17.1.2, Room 643, Union House, St. Martins-le-Grand, London EC1A 1AR.

Post Office Telecommunications

THE CITY UNIVERSITY

COMPUTER ENGINEER

A vacancy exists for an engineer (male or female) to work on the maintenance and development of computing equipment (electrical and mechanical).

Experience of ICL1900 series computers and EAL equipment would be an advantage. Applicants may eventually be required to work unsupervised shifts. The equipment includes 2 x 1900 series computers, an EAL690 hybrid system and a PDP11/34.

Salary will be in the range £3345 to £3966 or £3966 to £4722 per annum inclusive of London Allowance. Shift Allowance is paid and annual leave is 3 weeks plus one week at Christmas and Easter, inclusive of Bank Holidays.

Application forms and further details can be obtained form the Personnel Office, The City University, St. John Street, London EC1V 4PB. (Tel. 253 4399 extn 334). (8030)

ELECTROSONIC

S.E. LONDON

TEST/TECHNICAL SUPPORT ENGINEERS

STARTING SALARY £3300-£3700

Electrosonic Ltd. is a leading company in the rapidly expanding fields of lighting control and audio visual systems situated in South East London, within easy reach of rural Kent.

Experienced electronic engineers are required initially for testing and fault finding of unit and systems electronic equipment employing some of the latest digital and analogue circuitry.

Applicants should have considerable experience in the testing and fault finding of modern electronic equipment, academic training to HNC/Degree level is desirable.

The jobs offer opportunities for gaining broad based experience in electronic technology with prospects for transfer to technical support positions in the company's software or hardware design teams and project engineering section after two years in the test department.

Applications to:

Mr. R. D. Naisbitt, Personnel Director
ELECTROSONIC LTD.
815 WOOLWICH ROAD, LONDON SE7
TELEPHONE: 01-855 1101

(8094)

ELECTRONICS TECHNICIAN

Salary Scale £3162-£4708

This is a new post, created to help improve audiology (hearing testing) services in the area covered by the North West Thames Regional Health Authority. It is intended to provide a calibration and equipment advisory service for audiology and hearing aid centres throughout the Region.

The work includes routine calibration and servicing, and some development work in the Audiology Department at Charing Cross Hospital.

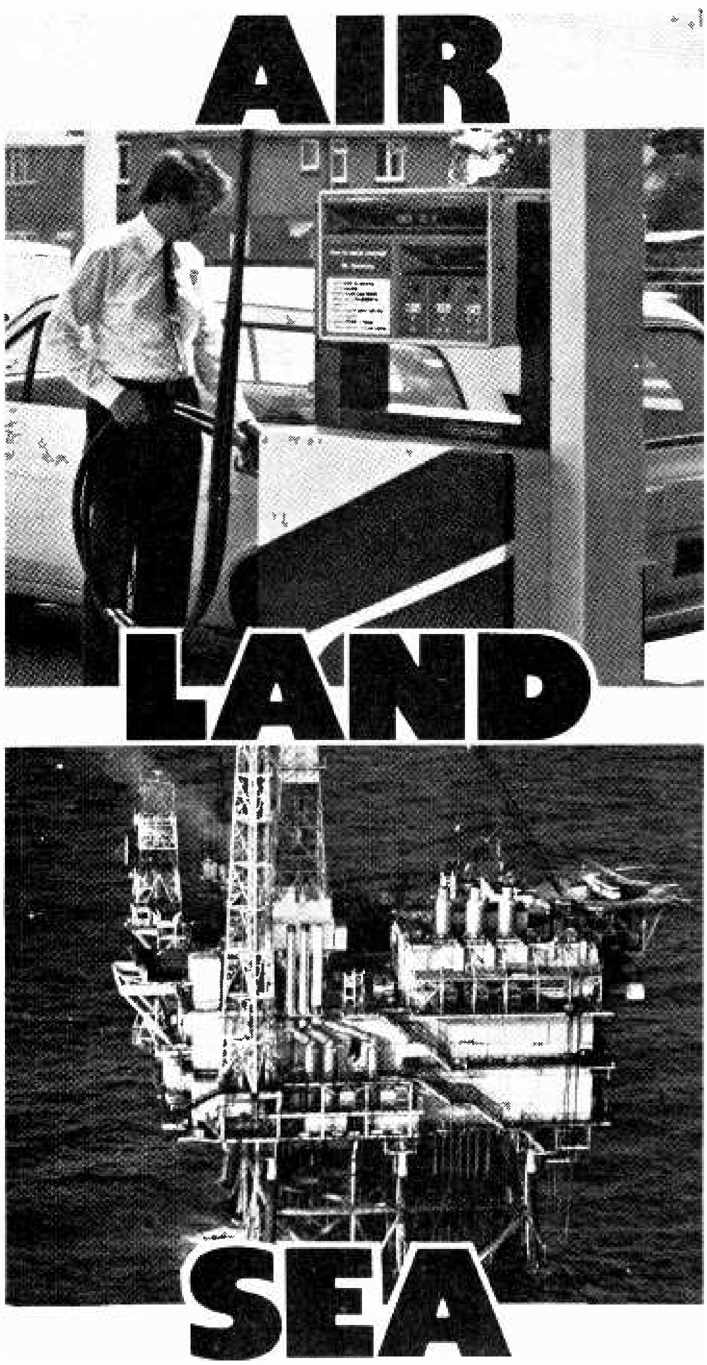
The technician will work under the supervision of, and to the standards defined by, the Audiological Scientist. He or she will work in conjunction with the Electronics Section of the Department of Medical Physics. Applicants should have an interest in audiology electronics but can be trained in the use of calibration. Own transport would be an advantage.

Further details and an application form for either of the above posts obtainable from the District Personnel Department, Charing Cross Hospital, Fulham Palace Road, LONDON W6 8RF. Tel. 748 2040 ext. 2997.

Closing date for receipt of applications 28th April, 1978.

8039

ELECTRONICS ENGINEERS
We have openings everywhere from 300 fathoms up to 70,000 feet



The launch of our new expansion programme means a total of 1500 new jobs in Scotland over the next five years and we are looking for people like you to fill some of the most vital ones.

It is our belief that we hold a bright future for electronic and mechanical design/development engineers in our organisation which has established a world-wide reputation for designing and producing technologically advanced systems for the world's armed forces.

Even so, the major avionic systems being produced for Tornado, the Sea Harrier, the Jaguar, the Nimrod, the Japanese F-1 and the Lynx Helicopter represent only one level of our operation.

We are now in the business of applying our technology to land and sea. Revolutionary Ferranti Systems made in the Edinburgh area, in the form of communication technology, are being used throughout the world to increase industrial efficiency. And revolutionising petrol station forecourts throughout Britain is Ferranti Autocourt.

The technology, which the company has developed over the years for military applications, is even being used to solve problems in the North Sea. Current interests include equipment for surveying the precise position of oil well holes, a navigator for mini-submarines, crane load transfer systems, tele-control and communications systems.

Test Engineers: Technical Authors:
Draughtsmen/women:
Design and Development Engineers:
Service Engineers: Spares Engineers:
Planning Engineers:
Production Engineers:

These are the people we are looking for, to be based in one of Europe's finest cities with excellent recreational and cultural amenities. Ferranti offers you an ideal situation in which to bring up your family. We operate a Staff Contributory Pension Scheme, pay realistic relocation expenses and we shall endeavour to advise on housing. What more could you ask for, except an application form?

If you would like one, please write or ring: John McPhee,
Staff Appointments Officer,
Ferranti Limited, Ferry Road,
EDINBURGH EH5 2XS.
031-332 2411, Ext. 226.

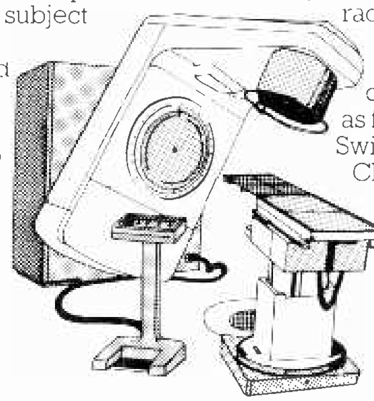
FERRANTI

(8027)

Installation Engineers around the World.

M.E.L. a Division of Philips Electronic and Associated Industries is committed to the Development, Manufacture and Marketing of advanced Linear Accelerators. They are installed in major hospitals throughout the world. These machines play an important role in the treatment of Cancer, a subject which demands sustained developments, sophisticated equipment and highly professional Engineers.

If you are a self-reliant, mature and adaptable Engineer prepared to spend periods of six to sixteen weeks away from base, join our team and share the challenge and rewards of worldwide installation work.

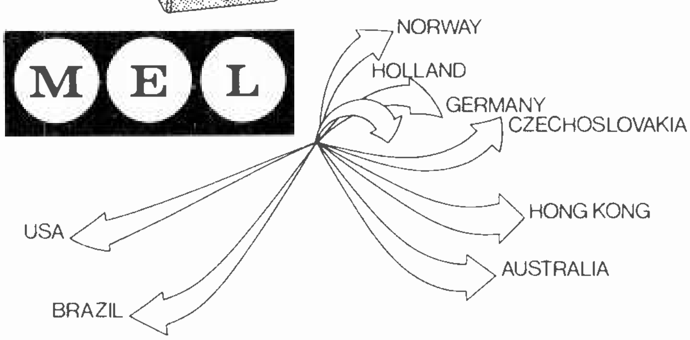


Male or female, you will need to be qualified to HNC level with a good knowledge of semi-conductor and digital circuitry and ideally with experience of modern high power radar and computer systems.

Based in Crawley, Sussex midway between London and Brighton you could become involved in projects as far afield as the USA, Austria, Switzerland, Yugoslavia, Holland, China, Brazil and Norway. So if you are looking for the opportunity to carry out worthwhile medical installation work on a worldwide basis, get in touch – NOW.

Contact Alistair Budd,
Personnel Officer,
M E L , Manor Royal, Crawley, Sussex.
Telephone Crawley 28787.

M E L



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FIELD SERVICE ENGINEERS BASIC SALARIES TO £5,000 + CAR

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A CHALLENGING CAREER IN TV

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Engineers in various categories are wanted Salary scale within the range £3.500 to £5.500

Why not call Cliff Carroll now on 01-850 7161.
(0896)

A challenging career in the Medical Field

International X-Ray Company, a leader in its field, has several interesting positions for

X-RAY ENGINEERS

These vacancies occur in the Middle East, Far East and Australia.

Very generous salaries will be paid to the successful applicants together with free accommodation.

A Company Car will also be provided.

There are excellent promotion prospects for the right persons.

Those applying should be suitably qualified electronically and preferably have some experience in the X-Ray Field.

An additional advantage would be a working knowledge of one of the following languages: French, Spanish, or Arabic.

Please apply in writing to:

C. G. R. Medical Ltd.
Astronaut House, Feltham, Middlesex

Giving full details of education and career to date.

(8118)

SOUTH HAMMERSMITH HEALTH DISTRICT

ELECTRONICS TECHNICIAN

Salary scale £3162-£4129

Required to work on a wide range of service, electrical safety, and development work in the Electronics section of the Medical Physics Department at Charing Cross Hospital

Applicants should hold at least an O.N C. or equivalent and have had recognised practical training

Further details and an application form from District Personnel Department, Fulham Palace Road, Charing Cross Hospital, Fulham Palace Road, London W6 8RF.
Tel 748 2040 ext 2997.

Closing date for receipt of application 28th April. (8026)

CAPITAL APPTS.

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FREE LISTS
101 Design / Development and Test Jobs
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To £6,000
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H.M.G.C.C.

Has vacancies for:

ELECTRONIC ENGINEERS

to work in the fields of:

a) HF/VHF/UHF communications equipment design and development

b) General circuit design, analogue and digital.

Appointment will be in the grades of Higher Scientific Officer and Scientific Officer for which the minimum academic qualification is HNC or equivalent. For Higher Scientific Officer 5 years' post-qualification experience is required except for candidates with First or Second Class Honours degree when this is reduced to 2 years' post graduate experience.

Salaries are:

Scientific Officer £2593 - £4032
Higher Scientific Officer £3746 - £4976

Also required are:

ELECTRONIC DRAUGHTSMEN/WOMEN

Minimum qualification is Ordinary National Certificate or equivalent but preference will be given to more experienced candidates with higher qualifications.

Lower Salary Scale £2875 - £3951 for minimum qualifications
Higher Salary Scale £3951 - £4447

All above salary scales include Phase I and II Pay Supplements.

For application forms please apply to:

The Administration Officer (Dept. W4/78)
HM Government Communications Centre
Hanslope Park
Hanslope
Milton Keynes
Bucks
MK19 7BH

8071

Technical People

Communications, Instrumentation and Control

Potters Bar

The Telecommunications Department of Eastern Gas has a number of attractive career opportunities within its technical team.

It's Eastern Gas policy to give young technical talent every encouragement to gain extra qualifications. Those displaying ambition and potential are given the opportunity to attend our Management College allowing them to progress and to fill the Senior Management Posts of the future.

These posts are open to young men and women aged 23 or over with ONC in Electrical Engineering or City and Guilds certificate in Telecommunications. Ideally you will have previous experience in maintenance or installation in either microwave, digital systems or instrumentation.
Reference 8528/WW.

Start a career now in Telecommunications Instrumentation and Control

Potters Bar

Do you have 'O' levels in science based subjects and are currently studying for ONC/OND or 'A' levels? If so we are willing to provide training for an absorbing and well paid career in telecommunications, instrumentation and control systems. This could possibly include sponsorship to attend colleges to obtain further technical qualifications.

The work is concerned with the design, maintenance and operation of large and sophisticated integrated communications networks a field which is developing fast.
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We offer attractive salaries, excellent conditions of employment, including a pension scheme and sports and social facilities.

If you are interested please write or phone for further information to Senior Recruitment Officer, Eastern Gas, Star House, Mutton Lane, Potters Bar, Herts EN6 2PD.
Telephone: Potters Bar 51151 ext 426.

(8056)

EASTERN GAS

UNIVERSITY OF YORK DEPARTMENT OF PSYCHOLOGY

A vacancy exists for a

TECHNICIAN GRADE III

in the Department's electronic/mechanical workshop. The appointee as a member of a small team will be employed to assemble, maintain and repair primarily electronic equipment used in the Department's teaching and research laboratories. The successful applicant will be qualified to OND/ONC, electronic apprenticeship or equivalent level. Experience of analogue or digital circuitry is particularly relevant.

Salary scale according to age and experience within scale £2,688-£3,060. Applications in writing giving the names and addresses of two referees to the Deputy Bursar, University of York, Heslington, York YO1 5DD, by 6 May, 1978.

(8031)

We pay top salaries for the right engineers Starting at £4000 p.a. for Bench Engineers Increasing appreciably for Field Service Engineers

London's largest independent radio-telephone company is expanding fast! We have built a reputation for reliable efficient service. If you have the capability we need you urgently

Knowledge or experience of mobile V.H.F. equipment is what we're looking for Call Mike Rawlings or Bill Clarke on 01-328 5344 Now!

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Communications
(Equipment) Ltd
30 Boundary Road London NW8 01 328 5344

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A company operating in the horse racing industry has a vacancy for an engineer with a good general educational background and experience of colour cameras, VTR and VCR machines and associated equipment. Opportunity to join a lively team and assist in operating and maintaining our mobile colour control room on racecourses throughout the UK. The work is interesting and varied. Salary £3000-£3600 according to qualifications and experience plus overtime and expenses when on location.

Please write for company application form to:
The Company Secretary
RACECOURSE TECHNICAL SERVICES LTD.
88 Bushey Road, Raynes Park, SW20
Tel. 01-947 3333

(8047)

Electronics Engineer

Herts To £5,000

Are you an electronics engineer looking for a job with real prospects, who is flexible, enthusiastic and ambitious enough to be really involved in a small growing company? The Technical Director, an acknowledged expert in his field, has developed a unique power saving electronic control system for discharge lighting giving the company genuine growth potential.

An engineer is required to assist with further development work with particular emphasis on turning ideas and prototypes into economic hardware.

Candidates, ideally with an HNC or degree and aged 24 to 40, must have sound design experience preferably with an analogue bias. Experience of electronic control gear or of production processes would be useful.

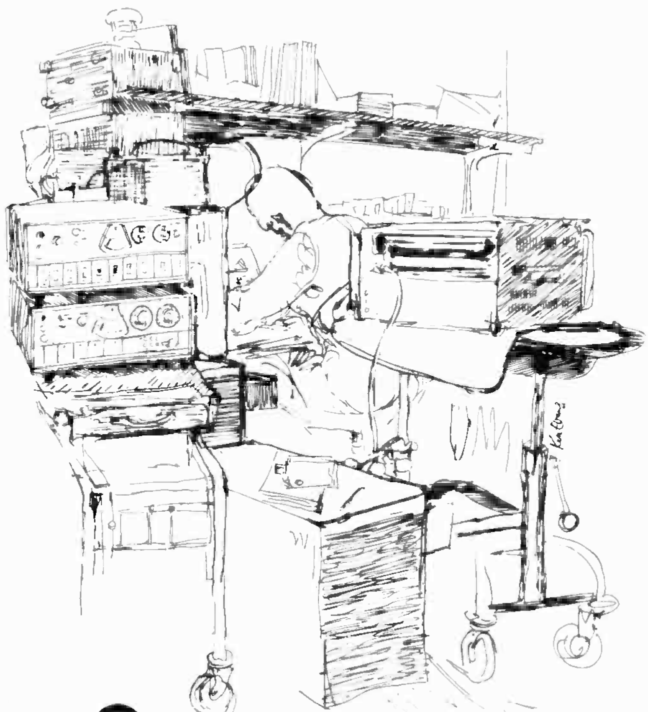
If you can match the potential that this company have to offer

Contact Graham Ince—
Luton (0582) 417562
PER, 56 Park Street, Luton, Beds.
8100

PER
Professional & Executive Recruitment

Applications are welcome from both men and women.

Marconi Instruments



ELECTRONIC TECHNICIANS

Opportunities for the experienced and sometimes inexperienced in St. Albans and Luton.
Work situations range from fault finding on PCB's and components, to batch product testing of equipment that utilise very advanced techniques including microprocessors and the repair/calibration of all manner and types of test instruments.
Attractive salaries and, where appropriate, relocation are offered for the right candidates.
Further information may be obtained in confidence from John Prodger
Marconi Instruments Limited,
Longacres, St. Albans, Herts. tel: St. Albans, 59292

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TEST ENGINEERS

When reliability matters, people come to Pye

When the 1952 expedition, led by Sir John Hunt, made the first successful ascent of Everest, they carried with them Pye portable radiophone equipment – equipment with a long reputation for efficiency and reliability under arduous conditions.

Part of that reliability comes from the quality of the design and the components used, but the final seal is set by the highly skilled men and women who check our UHF/VHF systems to our very exacting specifications prior to delivery.

If you already have experience of fault diagnosis, alignment and testing of electronic equipment, especially communication equipment, perhaps gained in the Armed Forces, then why not get in touch and find out for yourself exactly why people come to Pye.

There's not room to tell you all the details here, but we can assure you of a competitive salary, company stability, job security and satisfaction, well equipped workshops and a variety of equipment, using both IC's and transistor.

Openings are available at Haverhill, Suffolk and at Cambridge, both extremely pleasant places to live, with key-worker housing available at Haverhill. In addition, considerable assistance is provided for those moving from other parts of the country.

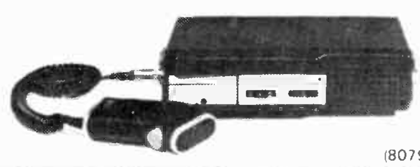
Write or phone (reversing charges if necessary) to

Claire Barton, Pye Telecommunications Ltd., Dept. W.1
St. Andrew's Road, Cambridge CB4 1OW
Tel: Cambridge 61222

or

Catherine Dawe, Pye Telecommunications Ltd., Dept. W.1
Colne Valley Road, Haverhill, Suffolk CB9 8DU
Tel: Haverhill 4422

Pye Telecommunications Ltd



(8079)

Service and Test Engineers

As aircraft and electronics equipments become more sophisticated and our servicing programme expands, the need for experienced Service and Test Engineers increases.

At Stanmore, we are involved in the provision of spares and the repair, maintenance and overhaul of a variety of British and American airborne electronic equipment.

We need Engineers who can successfully maintain the high standards and efficiency required both in the aircraft and the workshop.

It's skilled work, calling for sound practical experience of radio and electronics theory, ranging from audio to microwave and including the use of advanced test equipment for fault diagnosis. Training in this field will be given to suitable, less experienced engineers.

The Company offers excellent salaries and benefits together with first-class working conditions in well-equipped workshops. This Unit is conveniently situated in pleasant surroundings within easy reach of the A1 and M1.

MARCONI ELLIOTT AVIONICS
A GEC Marconi Electronics Company

If the job sounds interesting and you'd like to put us to the test, write with details of experience to:
Mrs. E. Wagg,
Marconi-Elliott Avionic Systems Ltd.,
22-26 Dalston Gardens, Stanmore, Middlesex
HA7 1BZ. Tel: 01-204 3322.

7917

The RFI/EMC Division of Belling & Lee, A Member of the Pye/Philips Group, provides a comprehensive Design, manufacturing and installation service on a world wide basis. To consolidate on substantial business gains over the last year, the Division has been re-organised and the following position is now available for an experienced man or woman.

Chief Engineer

Reporting to the Divisional Manager, he/she will be involved with R.F. shield enclosures and a wide range of electrical power filters, signal and control line circuits.

Directing the activities of the design and development team and being responsible for design approval the Chief Engineer will be expected to make a positive contribution to technical development in this competitive field.

Candidates should be qualified up to Chartered Engineering standard and should possess experience in the power, radio or microwave engineering spheres.

The above vacancy offers an attractive salary, generous benefits, and the opportunity to broaden your experience and expand with a thriving company. Contact us now for more information:-

**The Personnel Manager,
Belling & Lee Limited,
Great Cambridge Road,
Enfield,
Middx.
Tel: 01-363 5393**

Belling & Lee
BL
Electronic Components for Tomorrow

ELECTRONICS TECHNICIANS FOR COMPUTER COMMUNICATIONS

TASK TERMINALS LIMITED have vacancies in central London for young, energetic Electronics Technicians. Responsibilities would include some design and construction, and installation and maintenance of computer communications equipment. This means working with microprocessors, minicomputers, and electro-mechanical computer peripherals of varying complexity.

Specific qualifications and experience are not essential, but a working knowledge of digital electronics is important. Our preference is for people with a little experience, and who are adaptable and keen to mould themselves into the job, taking advantage of training courses and on-the-job training. This is a good opportunity to enter a very interesting and rewarding industry with a small company well known in its field.

Salaries are negotiable from £3,000 p.a., plus additional benefits. Some travel will be necessary, and applicants should hold a full U.K. driving licence. If you are interested please write to Steve Clifford giving brief details, and we will arrange an informal interview at your convenience.

**TASK TERMINALS LIMITED
117 Cleveland Street
London, W1. 01-637 4516**

(8046)

APPOINTMENTS IN ELECTRONICS

Take your pick of the permanent posts in:

MISSILES — MEDICAL
COMPUTERS — COMMS
MICROWAVE — MARINE
HARDWARE — SOFTWARE

For expert advice and immediate action on career improvement, 'phone, or write to, Mike Gernat BSc

Technomark
Engineering and Technical Recruitment

11 Westbourne Grove
London W2. 01-229 9239

7098

UNIVERSITY OF SURREY
Department of Physics

RESEARCH OFFICER (ULTRASONIC EXPOSIMETRY)

Broadminded electronics engineer or physicist with initiative required to work as Research Officer on the development of ultrasonic piezoelectric sensing devices in an active group. The appointment is for one year.

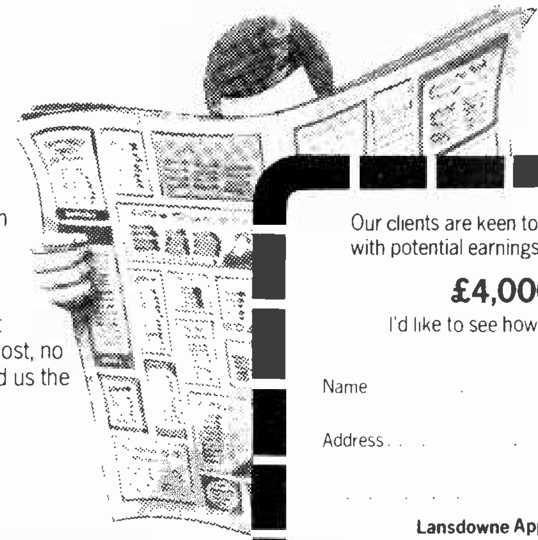
Salary will be on the Research Staff Range IB Scale £2904-£3547, depending on age, qualifications and experience.

Further details and an application form may be obtained from the **Staff Officer, University of Surrey, Guildford, Surrey GU25XH, or telephone Guildford 71281, Ext. 452.** Completed forms should be returned by 28 April 1978

(8028)

The job you're now looking for we've probably already found.

We're in touch with over 3000 major companies who are continually looking for key personnel like you – but who don't always advertise.
Instead, they send us a brief which we compare to the requirements of candidates on our register. Then we draw up a shortlist.
The next time we're asked, we could mention your name.
All you have to do is clip the coupon, we'll send you a confidential application form . . . consider it an interview and give us relevant details about yourself. There's no risk, no cost, no obligation and no time-wasting. Simply send us the form and we'll do the rest.
We'll find you one of those jobs you usually hear about after they've been filled.



Our clients are keen to meet men and women, aged 20-40 years with potential earnings of between

£4,000 and £7,000 p.a.

I'd like to see how Lansdowne can help further my career

Name

Address

WW19 4

Lansdowne Appointments Register, Design House, The Mall, London W5 5LS. Tel: 01-579 2282 (24 hour answering service).

Lansdowne

For those too busy doing a good job to find a better one.

8077

Lansdowne Appointments Register, Design House, The Mall, London W5 5LS. Tel: 01-579 2282 (24 hour answering service).

WANT TO JOIN THE JET SET?

We can't guarantee you a tax haven, a penthouse, yachts, caviar or crumpet, so think of ulcers and angina and let us tell you the best alternative.

Join the rapidly expanding field of distributed sound, T.V., and room managements systems; travel the world and get a butler's eye-view of life at the top and a duke's eye-view of bingo halls. Room management systems have advanced from piped music and tannoys — there are computer controlled private bars in the bedrooms, and T.V. screens receiving dot dot dot you'll know what.

Our client company in this fascinating industry has won many new contracts. Their technology is extremely advanced, they move quickly, have style. And above all, they encourage all engineers and sales personnel to develop their financial acumen, thereby advancing as part of the firm.

Current vacancies include:

SENIOR ENGINEERS
U.K. SALES EXECUTIVES
OVERSEAS SALES EXECUTIVES
PROJECT ENGINEERS
Frequent overseas travel
TRAINING OFFICER
TECHNICIANS, all grades

For further details of qualifications and experience required, salary levels and precise geographical locations, telephone 01-581 0286, or write to

8032

Charles Airey Associates
RECRUITMENT CONSULTANTS TO THE INDUSTRY 155 Knightsbridge, LONDON SW1 Tel 01-581 0286

Mechanical Designers

Invest your future with us!

As Europe's largest exporter of two-way radio systems, we intend expanding several of our design teams by the appointment of high-calibre draughtsmen and women.
Join Pye Telecom, and you'll join a group attached to one of our Development Laboratories, working on electrically orientated mechanical product design.
Ideally, you should have wide experience of medium and high production methods, and of design in sheet metal, plastics, die-casting and P.W.B.s.
An ONC, a C & G, or better still, an HNC is desirable.
We offer a good salary + a generous relocation allowance and good career prospects. You will also discover an extremely attractive working environment and the most modern facilities available.
Apply by phone or letter to Alan Depauw, Pye Telecom, Newmarket Road, Cambridge. Telephone Cambridge 61222, Ext. 138.

(8033)

Pye Telecommunications Ltd

RADIO TECHNICIANS

Government Communications Headquarters has vacancies for Radio Technicians. Applicants should be 19 or over.

STANDARDS required call for a sound knowledge of the principles of electricity and radio, together with 2 years experience of using and maintaining radio and electronic test gear.

DUTIES cover highly skilled telecommunications/electronic work, including the construction, installation, maintenance and testing of radio and radar telecommunications equipment and advanced computer and analytic machinery.

QUALIFICATIONS: Candidates must hold either the City and Guilds Telecommunications Part 1 (Intermediate) Certificate or equivalent HM Forces qualification.

SALARY (inc. supps.) from £2,673 at 19 to £3,379 at 25 (highest pay on entry) rising to £3,883 with opportunity for advancement to higher grades up to £4,297 with a few posts carrying still higher salaries.

Opportunities for service overseas.

Further particulars and application forms available from:

GCHQ

Recruitment Officer (Ref. WW/5)
GCHQ, Oakley
Priors Road, Cheltenham, GL52 5AJ
Cheltenham (0242) 21491 ext 2270

(8035)

VIDEO RECORDING & STUDIO ENGINEER

£3861 - £4615 p.a.

To supervise work in new recording and editing area using state of the art techniques including Plumbicon colour telecine and a wide range of VTRs — some to broadcast standard. Also to assist with work in two adjoining studios which contain Video 80 colour cameras and sophisticated ENG post-production systems with colour corrections and multi-track sound.

Operational experience of sound and colour video systems, preferably in a broadcasting or educational institution, and an HNC or equivalent educational qualification are desirable.

Application forms and details from the Personnel Officer, Brighton Polytechnic, Moulsecomb, Brighton BN2 4GJ. Tel. Brighton 693655. Ext. 2536.
Closing date: 17th May, 1978. (8072)

ITN

SENIOR ENGINEER

Independent Television News Ltd. has a vacancy for a Senior Engineer to work in their Radio Links section. The work involves the installation and maintenance of temporary microwave links and R.T. systems for Outside Broadcasts.

Candidates should be qualified to H.N.C. or above and have experience of SHF, UHF and VHF radio systems. Television experience would be an added advantage.

Salary: £5,920 per annum.

Please telephone the Personnel Office on 01-637 3144 for an application form, quoting reference 3514. (8073)

Apply your skills to

INTERACTIVE COMPUTING FOR ENGINEERS

Rutherford Laboratory

The Engineering Board of the Science Research Council is setting up a national Interactive Computing Facility This is being managed by staff at the Rutherford Laboratory, in Oxfordshire, (where some of the country's most powerful computing resources are sited) Based on a network with major nodes at Chilton, Edinburgh and Manchester, the computing equipment includes a twin processor IBM 360/195 two DEC 10's a Prime 400, a GEC 4070 a III FR80 colour microfilm recorder and numerous other computers and peripheral devices An electron beam lithography unit is also planned

We now have opportunities for **GRADUATE ENGINEERS AND PHYSICISTS** to help in the nationally important work of developing applications software for the new facility

Analogue & Digital Systems

To develop new applications software for CAD in Analogue and Digital Systems, we now wish to fill the following posts

1 To establish and maintain programs providing a comprehensive digital design system Areas to be covered range from specification languages through simulation and test generation to placement and routing on both LSI chips and PC boards
2 To mount and maintain packages for circuit analysis, analogue simulation optimisation and some circuit synthesis.
3 To construct and maintain a device and materials library for use in conjunction with the analogue and digital design software.

These appointments will either be at HSO level or as Research Associates (on a fixed term basis of three years) Considerable experience in the relevant disciplines is necessary and appointed staff will be expected to co-operate with University Research workers in making substantial contributions to this field The posts may also involve attachment to an appropriate University group **(701)**

Finite Elements

1 To mount and maintain established finite elements packages and to assist users in their use. Some experience of finite element modelling on computers is necessary for this post at SO level.
2 To establish a finite element software library suitable for use in advanced research Substantial experience of finite element techniques is necessary for this post, which may be held either at an appropriate University or at the Rutherford Laboratory. This post will either be at HSO level or as a Research Associate

We expect successful applicants to collaborate with University researchers in making major contributions to finite element techniques **(702)**

Depending on qualifications and experience salaries will be within the following scales:

Scientific Officer	**£2743 – 4218)**	(includes supplements
Higher Scientific Officer	**£3928 – 5213)**	Salaries are currently
Research Associate	**£4943 – 7443)**	under review)

Except where indicated, you will be based at the Rutherford Laboratory at Chilton 18 miles south of Oxford Accommodation may be available and we have daily travel facilities to most of the neighbouring towns and villages

The Rutherford has its own restaurant and recreational facilities Shops, banks and sports social clubs are available on the adjoining AERE Harwell site

Please write for further details and application form **quoting the appropriate reference number,** *to* **Ruth Jeans of the Personnel Group** 8037

RUTHERFORD
Science Research Council
Rutherford Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX. Tel Abingdon 21900

The British Council invites applications for the following posts:

ENGINEER/ SUPERVISOR (Singapore)

British Council English Language Institute, Singapore

Required for August, 1978 — one Engineer/Supervisor to assist teachers in the technical aspects of producing programmes for CCTV and the language laboratory.

He/She will be responsible for the extensive educational technology installed by the Representation. Candidates should be qualified to HNC/City and Guilds Final Certificate level and have at least 3 years' operations and maintenance experience in colour broadcasting or high quality CCTV studio. Experience in studio-lighting and electronic editing of ¾" video cassette recorders and a knowledge of language laboratory equipment would be an advantage.

Salary range: £4734-£5618 p.a.

Benefits Overseas and children's allowances; free furnished accommodation; medical scheme; employers portion of superannuation contrubution; 2-year Sub-Formula contract, renewable.

Return fares are paid. Local contracts are guaranteed by the British Council.

Please write briefly stating qualifications and length of appropriate experience, quoting reference number 78 PO 71-73 and title of post, for further details and application form, to the British Council (Appointments), 65 Davies Street, London W1Y 2AA. (8087)

UNIVERSITY OF GLASGOW ELECTRONIC MUSIC STUDIO

TECHNICIAN — GRADE V

This 16-track Studio has an improved Synthi 100 with PDP8 control (EMS Computer Synthi), Ampex MM1000, various Revox and Teac tape machines, partial Dolby A (to be expanded). Technician's workshop adjacent with good facilities, inc. Tektronix 'scope. Technician's duties include responsibility for general maintenance of studio and other Music Department facilities; designing, building and modifying equipment, including digital devices; providing technical support for electronic music courses.

Relevant ONC/HNC qualification and minimum of 7 years experience. Salary range £3186-£3720. All applications should be addressed to the Personnel Officer, University of Glasgow, Glasgow G12 8QQ.

In reply please quote Ref. No. 4105FH.

8041

ST. LOYE'S COLLEGE, EXETER

For training the physically disabled for open commerce and industry

R/TV INSTRUCTOR

Applications invited for person to instruct practical skills and related theory in repair of radio and television receivers and other electronic equipment to a standard equivalent to City & Guilds 222 Part III.

The successful candidate will be mature and have considerable skilled trade experience an advantage.

Excellent pension scheme and canteen facilities. Over 4 weeks' leave a year. Salary currently starting at £3,698 rising by 4 annual increments to £4,447 due for Stage 3 review on 1st April.

Written applications giving 2 referees (1 technical) to the principal. (8110)

Royal Holloway College
(University of London)

Egham Hill, Egham, Surrey

GRADE 5 INSTRUMENT TECHNICIAN

CHEMISTRY DEPARTMENT

required to provide a comprehensive service of maintenance, repair, modification and calibration for a wide range of scientific instruments. Salary on the scale £3,186-£3,720 plus £275 London allowance. Applications should be sent to the Personnel Officer, from whom further details may be obtained. (8080)

Electronics Engineers

Have you heard the one about the R. and D. Engineer that studied the intricacies of sockets for three years?

Too many potentially expanding Research and Development careers die young, stifled by boredom and enforced specialisation.

If you see yourself excelling, the last thing you'll want is to hide away in an albeit superbly equipped lab delving into the finer points of something less than absorbing.

The Rank Organisation are proud of the diversity of their R + D function. As front-runners in a number of original fields, eg thermal imaging, we understand the importance of keeping creative flair glowing bright.

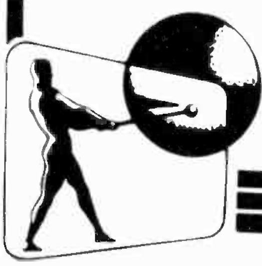
At Rank Research Laboratories you'll be given the opportunity to use your talents in a small, unstructured unit where you'll have a real chance to demonstrate your abilities both theoretically and practically at the applied research end of the R + D Spectrum.

To fit the bill, initially we'll expect you to have a degree or HND in Electronics or Physics coupled with 2-3 years' experience ideally in circuit design, transducers, electro-optics or instrument development.

Your salary will be competitive and negotiable, supplemented by the excellent Rank Organisation benefits package.

But more than that, we are offering a positive step away from the "socket" syndrome.

If interested, please drop a line to the Director of Rank Research Laboratories for an application form at: Phoenix Works, Great West Road, Brentford, Middlesex. Telephone: 01-568 9766.



THE RANK ORGANISATION

8086

Senior Export Sales Engineers

Belling & Lee Limited, a member of the Pye/Philips Group, designs, manufactures and markets a comprehensive range of electromechanical components for the Electronics Industry world wide.

Further opportunities have been identified to expand sales overseas, particularly in Western Europe.

We are looking for a person (male or female) to join an existing team to assist in exploiting these opportunities.

The successful applicant will have a background and knowledge of engineering, be fluent in at least one major European language and preferably experienced in overseas sales activities.

Whilst this position is based at Enfield it is expected that approx 50% of the Sales Engineers time will be spent overseas.

Full product training will be given.

Applications are confidential and should be addressed to:

Belling & Lee

Mr. J. D. Bostock,
Personnel Manager,
Belling & Lee Limited,
Great Cambridge Road,
Enfield, Middlesex.
'phone 01-363 5393 ext 214

(8055)

Electronic Components for Tomorrow

FIELD SERVICE ENGINEER
£3,172-£3,512 based Ewell

To carry out part-time on-site service to schools' audio visual aids equipment and part time repair/service work to equipment at the Media Resources Centre, Ewell.

The successful applicant will be experienced in some of the following: Colour TV/Video, language laboratories, radio speaker systems, Hi/Fi installations. The department is responsible for the repair of all A/V items in schools i.e. projectors, record players, tape recorders, radio, TV/video etc and practical experience in the work is essential.

For applications see below.

ELECTRONIC SERVICE ENGINEER
£2,749-£3,172 Pirbright

To be based at the Media Resources Centre near Woking, and carry out bench service to schools' audio visual equipment. Experience on one of the following: radio, television, video, projectors, tape recorders, language laboratory decks essential. The ability to diagnose and correct service faults and work to a high standard also essential.

For both posts application form from Media Resources Centre, Glyn House, Church Street, Ewell, Surrey. Tel: 01-393 0208.

SURREY COUNTY COUNCIL

(8029)

TV Broadcasting Engineer

Thames Television are seeking a TV Broadcasting Engineer, male or female, who has a relevant qualification, degree or a HND, to join us at our excellent studios in Teddington, Middlesex.

This position involves operation and maintenance of VTR, Telecine and general TV equipment in a Central Apparatus Room. Experience in one of these fields is desirable but not essential for the 'right' person.

A salary from £3750 for regular shift pattern working will be negotiated based upon your age, qualifications and experience. We have a choice of excellent staff restaurants plus the sort of facilities and benefits which you would expect from a major, go-ahead company.

For application form, please phone or write to The Staff Relations Officer, Thames Television, Teddington Lock, Teddington, Middlesex. Tel. 01-977 3252.

THAMES

8119

Brunei

This is a new vacancy in the Telecommunications Department which is currently undertaking an extensive improvement and development programme.

Senior Telecommunications Engineer

The successful candidate will be a corporate member of the IEE, IERE or equivalent, and will be responsible for the management and operation of international circuits via an earth satellite ground station, connecting microwave circuits, and an SPC international exchange.

Applicants should have at least 5 years experience in a senior position in a telecommunications operating or manufacturing organisation on microwave radio and multiplex work. Preference will be given to those with experience in the operation or commissioning of earth satellite ground stations or on international automatic switching.

Salary for a contract of 3 years, is in a range equivalent to £8610-£9230 pa tax free including a special allowance, and attracts 25% tax free gratuity.

Benefits include free first class passages, generous paid leave, children's holiday visit passages and education allowances, outfit allowance, subsidised housing, and interest-free car loan.

For full details and application form write quoting MT/318/W.D.

Crown Agents

The Crown Agents for Oversea Governments and Administrations, Recruitment Division, 4 Millbank, London SW1P 3JD.

OUTSTANDING OPPORTUNITY FOR SERVICE ENGINEER

The service department of a small expanding electronic/computer company requires an additional Service/Calibration engineer. The work is varied and involves the repair, refurbishment and final calibration of the complete spectrum of Test Equipment.

A thorough knowledge of fault finding techniques and measurement methods is essential, also a basic knowledge of logic would be advantageous.

The company is situated at King's Cross, London, and an excellent salary is negotiable according to experience.

For further details, please contact:

Mike Jones, Service Manager
49-53 Pancras Road, London NW1 2QB
Telephone: 01-837 7781 Ext. 31

(8069)

THE UNIVERSITY OF SUSSEX

Electronics Technician

Male/Female

Grade 3, in the Social Psychology Laboratory, starting as soon as possible. The vacancy in a small growing department is for a technician with experience of transistor circuit. Applicants should be capable of desinging and constructing simple apparatus and should preferably be interested in CCTV or computing.

Salary scale £2688-£3060 per annum.

Further particulars and application form, returnable by 3rd May, are available from the Assistant Secretary (Establishment), Office of Arts and Social Studies, University of Sussex, Falmer, Brighton BN1 9QN (66755 ext. 1050 Mrs. Boterhoven). (8053)

UNIVERSITY OF WARWICK

TECHNICIAN

Applications are invited for the post of Grade 4 Technician in the Department of Chemistry and Molecular Sciences, to assist in maintaining and servicing electrical and electronic equipment. Previous experience of laboratory instrumentation is desirable but not essential, training will be provided where necessary. The post offers scope for initiative and opportunities arise to assist research staff in the building of 'one-off' items of equipment. The Department occupies well equipped laboratories in pleasant rural surroundings between Coventry and Kenilworth both of which are within easy commuting distance. Salary on an incremental scale £2,995-£3,402 p.a. The post carries four weeks annual holiday together with a generous entitlement for customary and statutory holidays.

Applications giving full details of age past experience etc. and naming two referees should be sent to the Academic Registrar, University of Warwick, Coventry CV4 7AL as soon as possible. Please quote Ref No 32/T/78

(8025)

AUDIO VISUAL UNIT
University of London
King's College

AUDIO TECHNICIAN GRADE 4

required with experience in sound recording and electronic servicing, to be responsible for the use and maintenance of audio-visual equipment including language laboratory facilities. Knowledge of a foreign language an advantage. Qualifications O.N.C. or equivalent. 4 weeks' annual holiday. Contributory pension scheme. Salary on scale £3420 p.a. rising to £3868 p.a. inclusive.

Apply in writing with full details to The Head Clerk, Ref. 191139/WW, King's College London, Strand WC2R 2SL

(8050)

PRODUCTION TEST TECHNICIAN

required for work on our range of commercial metal detectors. Must have at least five years' experience in testing, fault finding and mechanical and electrical inspection, and be prepared to work at a fast production pace.
We offer good wages, three weeks' holiday plus sickness benefits, and work that is interesting and rewarding.
Excellent opportunity for right person with small expanding company.
Application form from

YOUNG ELECTRONICS LTD.
132-134 Grafton Road
London NW5 4BA
Telephone: 01-267 0201

(7996)

RF, Analogue or Radar Experience?

At STL our specialist team approach has successfully pioneered new solutions to long-standing problems in the radio and radar fields and we're now expanding to apply these developments to different areas.

The new teams we're establishing need Engineers, men and women, at degree or equivalent level, with experience of:

RF/Analogue Circuitry Design
To work on state-of-the-art projects in VHF and UHF. Quote position ref. 58/77.

Radar Research
To work on antenna and receiver design, digital signal processing and system analysis. Quote position ref. 12/78.

Your sound, practical knowledge of these areas should be coupled with the analytical competence neccessary to validate your work and the ability to think creatively. You will, preferably, have been actively engaged on RF or radar projects for a few years.

The STL environment is stimulating and encourages the development of *every* individual's ideas. As the main research centre for ITT's European business, both the scope of the projects and the back-up available are second to none—with salaries and benefits to match. These include generous expenses for relocation.

Please write with brief details or phone, quoting the appropriate position reference, to: V. Hartridge, Standard Telecommunication Laboratories Ltd., London Road, Harlow, Essex CM17 9NA. Tel: Harlow 29531

STL

Customer Service Engineers-Electronics

North London c. £4,000 + car

Opportunities within our General Service Section for engineers to work on a wide range of phototypesetters, VDU's and keyboards.
The successful candidates should hold HND, HNC or equivalent and have at least two years' experience in servicing electronic equipment.
Product training will take place at our Kingsbury Works and will take 2/3 months.
Candidates should already reside or be prepared to move to within one hour's driving distance of London NW9. Relocation expenses will be met where appropriate.
Salaries will be negotiated on the basis of individual experience and qualifications.
Expenses and a company car, which may be used for private purposes, will be provided.
Please ring or write to David Hilton, Personnel Manager, Linotype-Paul Limited, Kingsbury Works, Kingsbury Road, London NW9 8UT. Tel: 01-205 0123

Linotype-Paul 1974

NATIONAL INSTITUTE FOR MEDICAL RESEARCH

RESEARCH OFFICER — ELECTRONICS

A graduate, or equivalent, electronics engineer or physicist is required to assist in the development of novel instrumentation for fundamental biomedical research. The appointment will be in the Electronics Laboratory of the Institute's Engineering Department. Experience in analog techniques is desirable and the successful applicant will be expected to design and construct electronics for a new laser-based biomedical measurement system. Salary on an incremental scale between £3629 and £4810 according to age and experience. (Phase 3 increase being negotiated payable 1.4.78) Excellent social and sports facilities and pleasant surroundings.

Please apply quoting reference RO/ENG to Mrs P. A. Wilde, Personnel Officer, NIMR, The Ridgeway, Mill Hill, LONDON NW7 1AA, or telephone 01-959 3666 extension 221

(8070)

SENIOR SYSTEMS TEST ENGINEERS

A leading company in the phototypesetting industry requires test engineers who feel capable of testing and installing a brand new range of minicomputer based V.D.U. terminal equipment, incorporating the latest in MS1 and LS1 techniques in real-time applications. The right candidates will be qualified to at least HNC level and/or have considerable experience in digital electronics with knowledge of 74 series T.T.L. A background of the word processing or printing industry would be advantageous. One of the positions would involve some U.K. and European travel to handle system installations and back-up service for our overseas Agents.
The company provides 4 weeks' holiday and pension scheme, salary circa £5000.
Phone for application form to

Miss Bux
DATEK SYSTEMS LTD.
849 Harrow Road
Wembley, Middlesex
Tel. 01-904 0061

(8101)

ELECTRICAL/ ELECTRONIC ENGINEERS

Design unique computer/ communication systems

This is an opportunity to design, plan and manage the implementation of a wide range of interesting and unique computer/communication systems. The computer systems range from the use of microprocessors for specific applications, through mini computers to large main frame systems employing the whole range of peripheral devices. The communication systems range from line communications through the full spectrum of radio communications including satellite communications.

Most posts are designated project officer/manager, and involve the interpretation of internal customer requirements, and the preparation of project studies, designs and plans which provide technical solutions and define and cost all resource requirements to implement the solution.

Candidates must have passed, or been exempted from, examinations qualifying them for corporate membership of IEE or IERE, and have an aggregate of at least 5 years' recognised study, professional training and experience. Project management experience in the computer/communications field an advantage.

Starting salary between £3950 and £5240, depending on qualifications and experience. **Salaries under review.** Promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 19 May 1978) write to Civil Service Commission, Alencon Link, Basingstoke, Hants. RG21 2JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). *Please quote T(16)85/1.*

(8112)

GCHQ Cheltenham

ENGINEER

The BBC requires an Engineer in its Site Acquisition Section. The successful candidate would be involved in establishing the reception qualities at sites being considered for extending the Transmitter network. He/she would need to be able to carry out precision field strength measurements and the subjective and objective assessment of the received signal quality both sound and vision and be competent to undertake the calibration, alignment and maintenance of reception and test equipment.

Minimum qualifications required: an appropriate HND, HNC, or C&G Full Technological Certificate (Telecommunications).

The successful candidate will be based in London, but will be required to spend a considerable time away from base. A driving licence is essential.

Commencing salary will be between £3975 and £4305 depending upon experience. A higher starting salary might be considered if experience exceptional.

Requests for application forms to **The Engineering Recruitment Officer, BBC Broadcasting House, London, W1A 1AA,** quoting reference number 78.E.4033/WW and enclosing a self addressed envelope at least 9 in x 4 in. Closing date for completed application forms is fourteen days after publication.

BBC

8078

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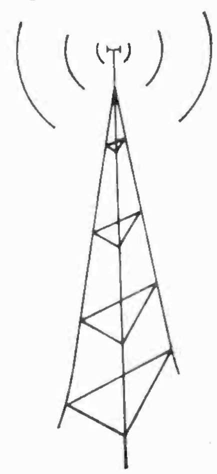

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(8051)

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TECHNICAL ENGINEER

REF: 192

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REF: 285

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(8036)

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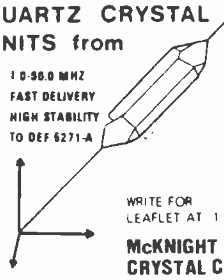

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Printed in Great Britain by QB Ltd, Sheepen Place, Colchester and Published by the Proprietors IPC ELECTRICAL-ELECTRONIC PRESS LTD., Dorset House, Stamford St., London, SE1 9LU, telephone 01-261 8000. *Wireless World* can be obtained abroad from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd. INDIA: A. H. Wheeler & Co. CANADA: The Wm. Dawson Subscription Service Ltd, Gordon & Gotch Ltd. SOUTH AFRICA: Central News Agency Ltd: William Dawson & Sons (S.A.) Ltd. UNITED STATES: Eastern News Distributors Inc., 14th Floor, 111 Eighth Avenue, New York, N.Y. 10011.