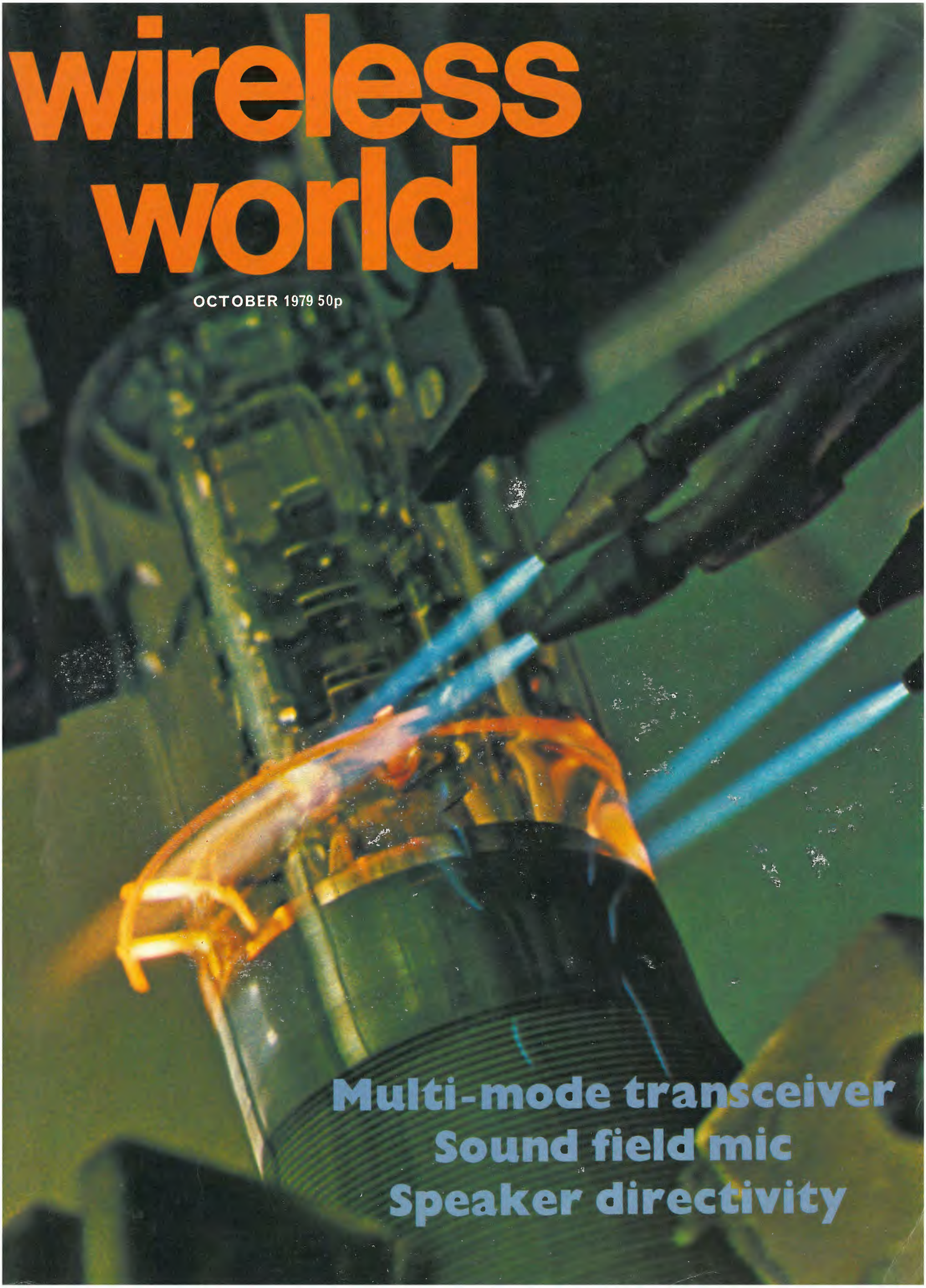
wireless world

OCTOBER 1979 50p

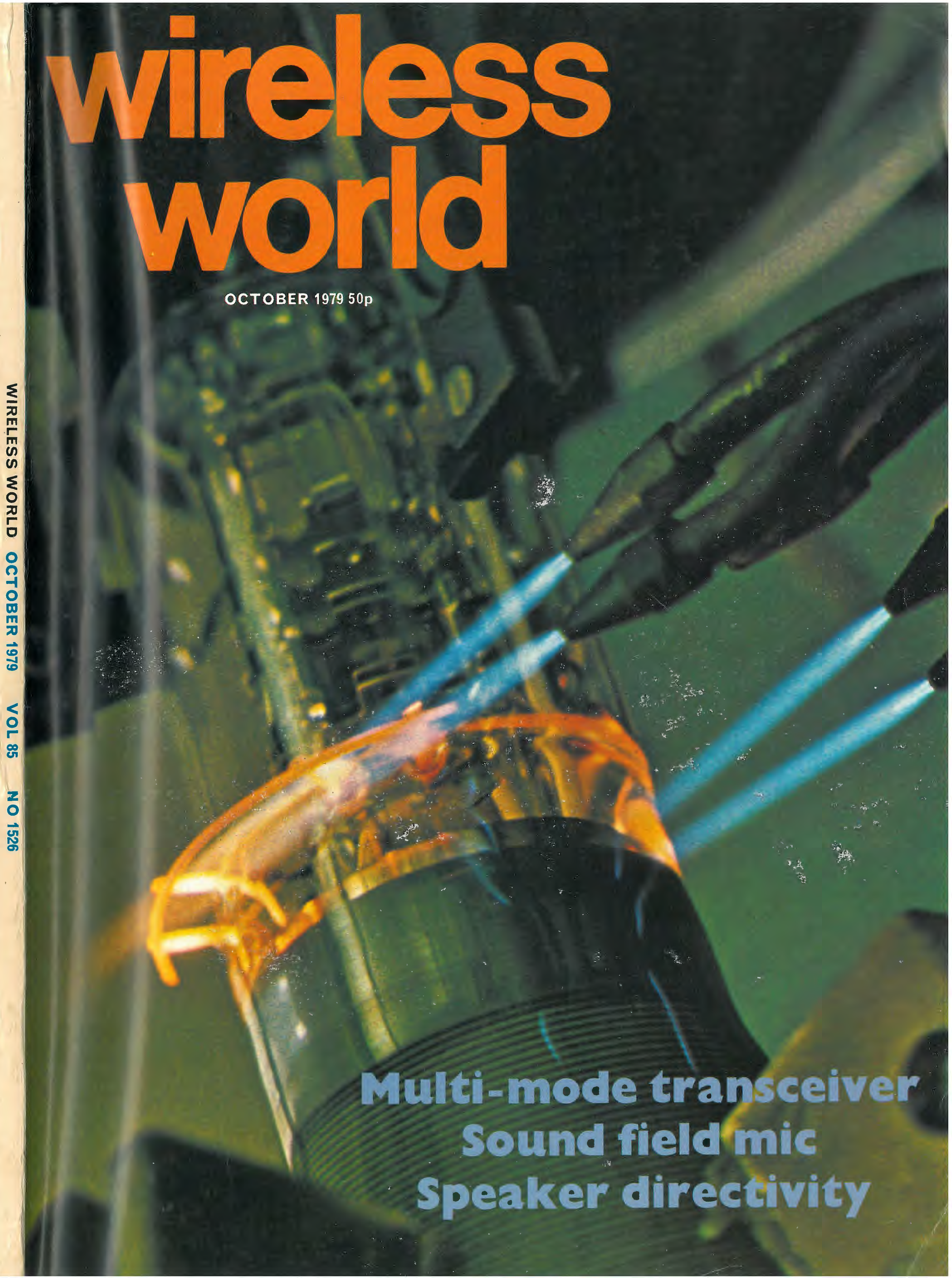


Multi-mode transceiver
Sound field mic
Speaker directivity

WIRELESS WORLD OCTOBER 1979 VOL 85 NO 1526

wireless world

OCTOBER 1979 50p



Multi-mode transceiver
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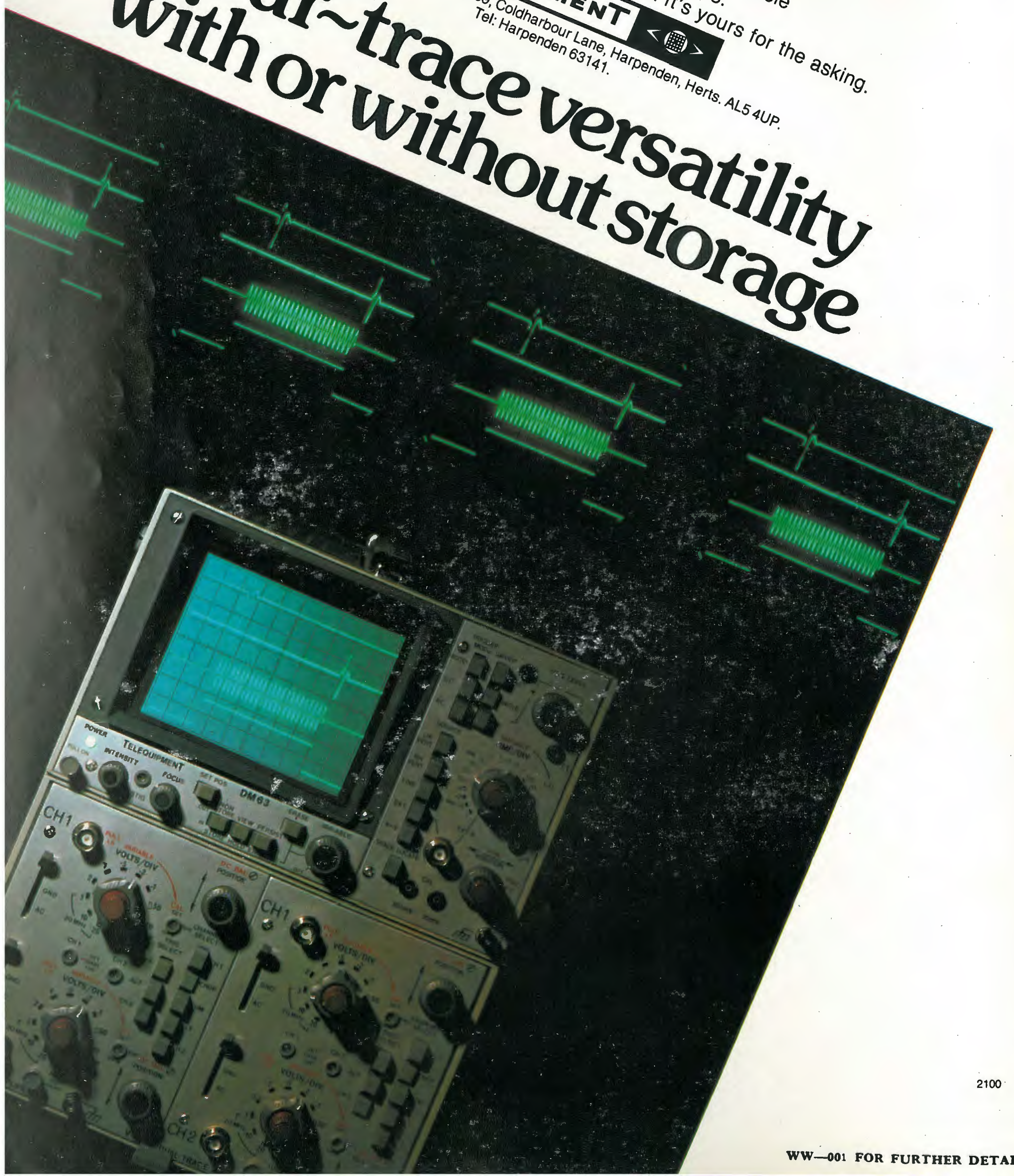

wireless world

ELECTRONICS/TELEVISION/RADIO/AUDIO

OCTOBER 1979 Vol 85 No 1526

Front cover shows a stage in the manufacture of an industrial cathode-ray tube at Thorn Brimar Ltd., now the largest maker of such tubes in the UK.

IN OUR NEXT ISSUE

Electrostatic headphones. **To improve on the limited sound pressure levels of most e.s. headphones, this design uses an 800V h.t. supply to give a high plate drive voltage.**

Electronic speedometer, **operating from 1 pulse per road wheel revolution, allows a large distance between activator and sensor.**

Measuring sound power: **a new technique, easier than measuring electrical power, may replace classical methods specified in standards.**

Current issue price 50p, back issue (if available) £1.00, at Retail and Trade Counter, Paris Garden, London SE1. Available on microfilm: please contact editor.
By post, current issue 79p, back issues (if available) £1.00, order and payments to Room CP34, Dorset House, London SE1 9LU.
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Telegrams/Telex: Wiworld Bisnespres 25137 BISPRS G. Cables Ethaworld, London SE1.
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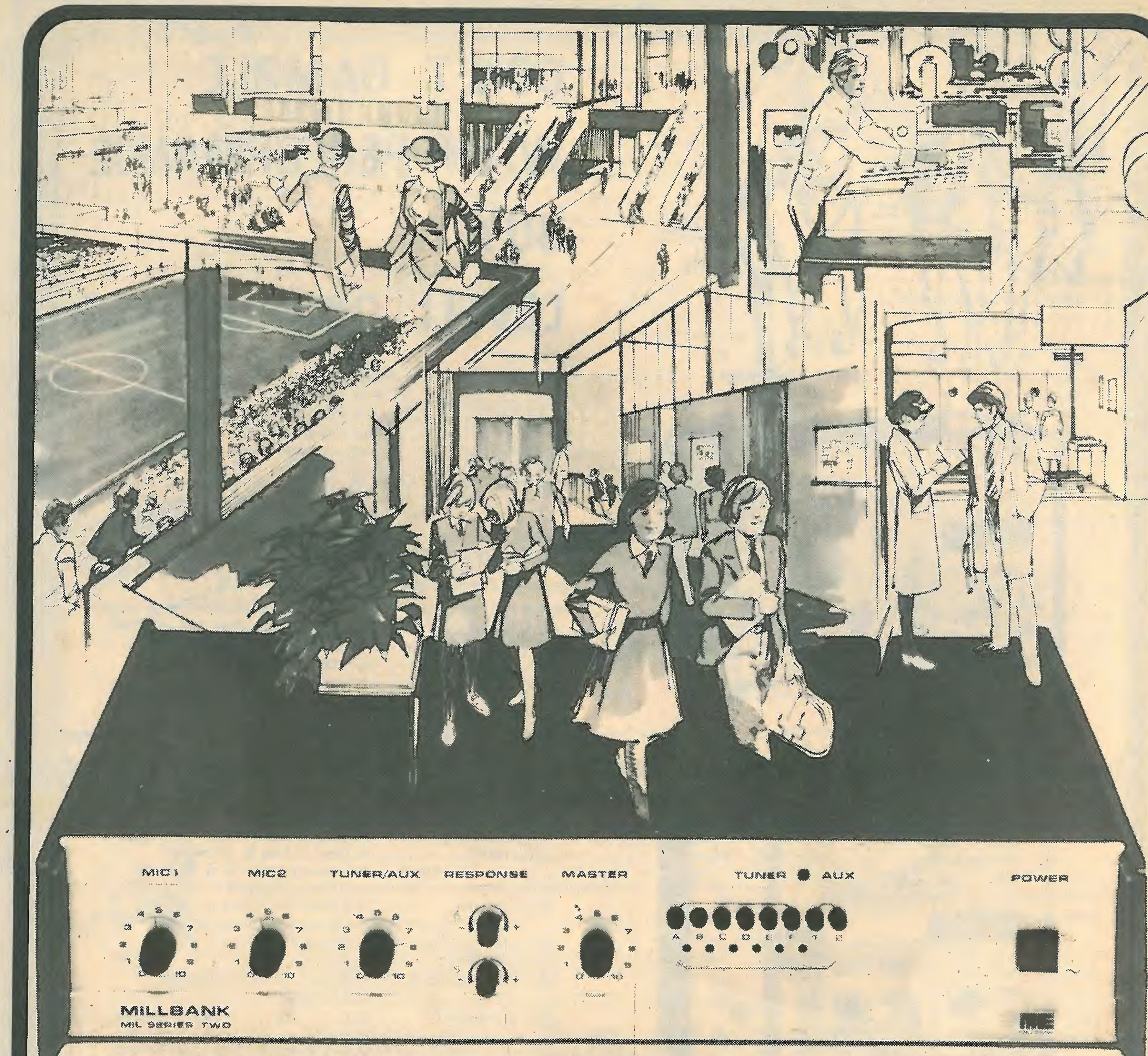
ibpa International Business Press Associates ABC



Your attention please!

MIL series amplifiers are designed and priced for installations in a wide range of applications including churches, schools, restaurants, factories, shops and offices.

Each amplifier is available with input facilities for microphones and music sources; six programme push button AM tuners or FM tuners and preannouncement chimes are available options.

One model incorporates automatic switching to a battery supply in the event of a power failure.

Such a versatile system can confidently satisfy your exact requirements.

Please tick as required.
For further information on this product ☐ Complete range of sound equipment ☐

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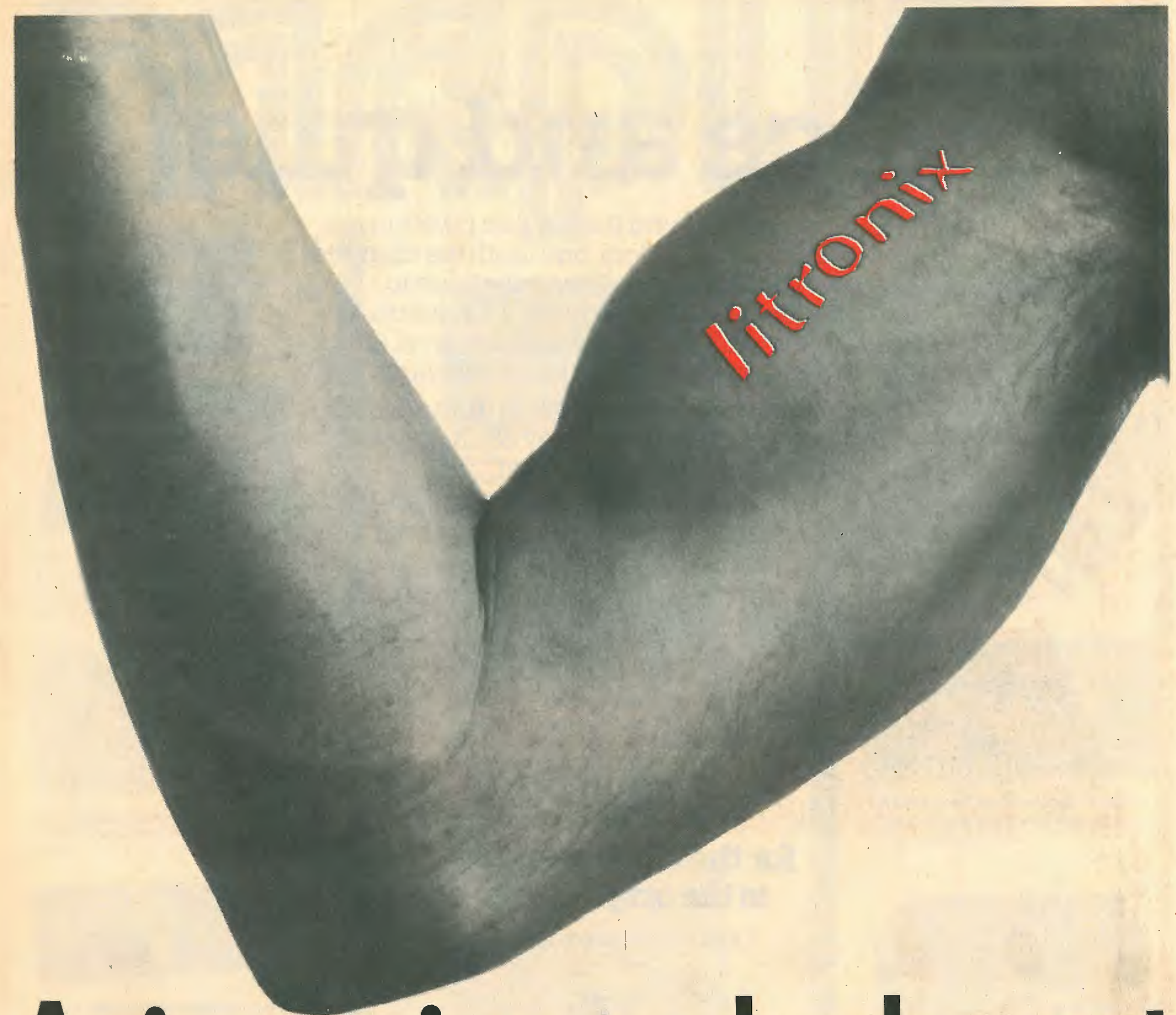
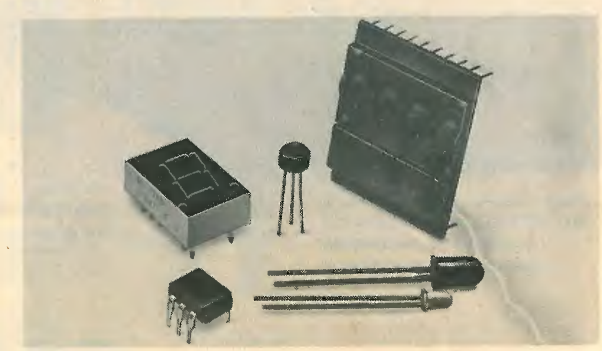
WW—049 FOR FURTHER DETAILS



An impressive new development at Crellon.

Litronix is our most recent newcomer.
This is very much in line with the Crellon policy of acting as distributor for only the finest principals.
The Litronix range is as impressive as its famous name and covers the following products:
LED's —
red, yellow, orange, green and infra-red Photo-transistors.
Opto isolators —
in a range that includes jedec types, high speed, duals and quads.
Displays —
including 7 segment and 16 segment alphanumeric.
Intelligent displays, too, alphanumeric with memory, decoder, driver and control circuitry, new smaller size package and much faster access time.
Add to all this the prompt, helpful and reliable Crellon service and you'll soon see why, when it comes to distribution, we've got plenty of muscle.
There's a very informative data pack available — telephone or complete the reader reply card.



litronix
Ideas with logic.
Crellon Electronics Ltd., 380 Bath Road, Slough, Bucks
Tel: Burnham (06286) 4434. Telex: 847571

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Our early involvement can make all the difference in getting a good idea off the ground.

In this age of advanced technology, design engineers occasionally need the help of a specialist in solving specific problems– above all in the field of electrical connection.

AMP Sales Engineers are qualified to give just such advice. And the earlier they are involved the more help they can give.

The specific knowledge of our engineers is supplemented by the research and development resources and application experience of a multi-national company–the leader in its field.

From specialist aeronautical developments like Concorde to long-run domestic appliance products the experience of AMP is broadly based. And because we're involved in such projects the sophisticated techniques developed to serve extreme environments are readily available to increase reliability and efficiency in other fields.

With manufacturing centres distributed throughout the world, a constant cross-fertilisation of ideas occurs between all AMP companies. Multi-national service of this proportion not only provides prompt world-wide availability, but also safeguards the continuous supply of components by dual-sourcing of manufacture.

So call in AMP on your next design job. Telephone 01-954 2356. You'll certainly find our early involvement a great help.

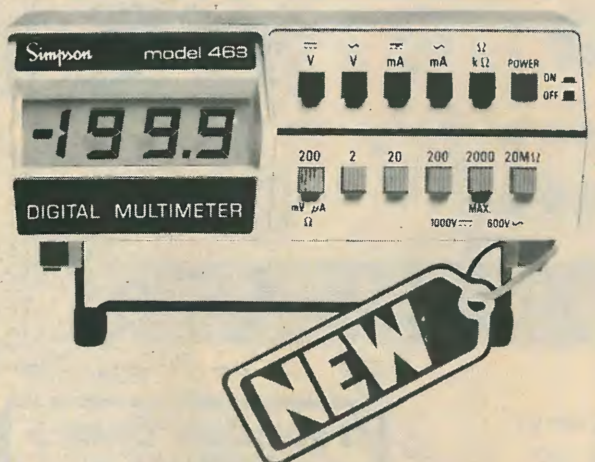
AMP

Our connections fit in with your ideas.

AMP OF GREAT BRITAIN LTD., TERMINAL HOUSE, STANMORE, MIDDX.

WW — 007 FOR FURTHER DETAILS

Before you read another meter, read about our latest ideas on DMMs



Have you got the facts on our new Model 463 giving you 200 hours operation from a transistor battery? Compact and versatile, this new meter is the latest addition to our range of competitively priced DMMs built to high performance standards.
For your up-to-date information pack on our DMMs range write, 'phone or telex now.

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NEW from Anders. Panel-mounted wattmeters that give you a clear, precise digital display. No more mis-reading dials.

Ask for further details on the new Contrology Range of DIGITAL Wattmeters, Voltmeters, Ammeters, Frequency Meters, Power Factor Meters and matching DC panel meters. Standard versions ex-stock.

- **Unique design—no separate transducers required.**
- **Single- and three-phase versions.**
- **Rugged, reliable and accurate.**
- **Measures 'true power', even with distorted wave forms.**
- **From £85.50—discounts for quantity—competitive with analogue equivalents.**

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If we told you the best way to talk to your staff... what would you say?

We can tell you how to talk to your secretary, your accounts clerk, your foreman – or to all of them at once. We can now offer you the first really practical and economical duplex intercom system – for all your communication needs.

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The alternative source that's near to hand . . . KGM. A video production line with high volume capability, here in Europe. Ready to meet your orders for open frame monitor chassis that neatly replace those long-range imports you're using currently. Same mounting, same international-standard connections. But one big, competitive advantage . . .

We're so much nearer, with the stocks, fast production response, spares and service you could only expect from a home based source. KGM prices are highly competitive too, especially on big orders. We can prove that with a quote, but how about product performance? . . .

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THINK OF A SHAPE

S 500D — dual channel up to 500W/RMS per channel DC-20 KHZ

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The H||H 'S' range is designed to handle heavy industrial usage in the fields of vibrator driving, variable frequency power supplies and servo motor systems.

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Dual Channel
19" rack mount 3½" high
500w r.m.s. into 2.5 ohms per channel
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DC—20 KHZ at full power
0.005% harmonic distortion (typical) at 300w r.m.s. into 4 ohms at 1 KHZ
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S 250D
Single Channel
19" rack mount 3½" high
500w r.m.s. into 2.5 ohms
Retro-convertible to dual channel
DC—20 KHZ at full power
Full short and open circuit protection
Drives totally reactive loads with no adverse effects

A complete range of matching transformers and peripheral equipment for closed loop, constant current and voltage use are available.
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How to be 16 places at once.

LM-1 Logic Monitor **£28.70**

When's the last time you had a nice chat with an integrated circuit? All you need is something to translate what's happening in its simple little logical mind. Something like our popular Logic Monitors.

Clip one onto an IC—any DIP up to 16 pins—and the 16 LEDs on top of our Logic Monitor follow the state of each pin. You have, in effect, 16 tiny logic probes in one pocket-size circuit-powered instrument.

And, as everyone knows, 16 LEDs are better than one. Because with just a glance, you can see inputs affecting outputs, a whole IC at a time. When you think about it, it's the logical way to look at IC's!

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Card No. ______ Expiry date ______

WW — 019 FOR FURTHER DETAILS

U.K. Two-way Radio Checklist

	STORNO	MOTOROLA	GEC	PYE
Most EXPERIENCE				✓
Most DEPOTS				✓
Most SITES				✓
Most ENGINEERS				✓
Most SALES				✓

OK

But what does it all add up to?

Big is not always beautiful.

So when we boast more resources than all our competitors put together you might be inclined to think: so what?

We agree.

When *you* are making substantial investments in two-way radio we expect more than facts and figures to be taken into account.

Like the people you are dealing with, starting with the salesman and right up to the top. How good is your relationship with the man up front. Is he thinking long term or looking for a quick sale today?

And who is backing up his promises – a well resourced U.K. based manufacturing and supplying company wholly dedicated to the future growth and development of two-way radio or a remote parent company looking for maximum advantage in whichever markets suit it best at the time? (If the latter, ensure he'll be around next time you have a replacement or extension problem).

We are not suggesting that you look to Pye Telecom for perfection. In this business staying the course for 35 years and making all the running for the future will always have its problems. But if ever those problems happen to be yours, you can count on our full commitment now and our resources whenever you need them.

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Telephone: 0223 61222

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Top Quality Test Equipment at the keenest prices

TEK 465 and 475A now ex-stock

	Prices from £
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BRUEL & KJAER	
2203 Precision sound level meter	400
2204 Precision sound level meter	475
1613 Octave filter set couples directly to 2203 & 2204	250
4216 Artificial Mouth	25
*2624 Charge Amplifier	65
CEL	
112 LEQ meter-digital readout	450
Bridges etc.	
DAWE	
210B Decade Capacitance box 0.1 µF-1 mF 0.1 µf step	20
MUIRHEAD	
D30A Wheatstone bridge test set	75
SULLIVAN	
T1098 Decade resistance bridge	90
WAYNE KERR	
B601Z RF bridge to 5 MHz / SR268 Source for B601Z	275
Cable Test Equipment	
MARCONI	
TF2091A/TF2092A White noise generator/receiver 300 channel system complete	350
*TF2333 Transmission Test Set	575
STC	
74226B Telephone cable test set	120
*74216A Noise Generator CCITT	240
*74261A Psophometer CCITT	475
Circuit Magnification	
MARCONI	
TF1245/46/47 'Q' Meter with Oscillators	525
Counter Timers	
HEWLETT PACKARD	
5263A Time interval plug-in	60
MARCONI	
TF2414A DC-40 MHz 7 digits	170
TF2422 Frequency divider to 300 MHz	30
RACAL	
9024 10 Hz-600 MHz 7 + 1 digits	325
9059 DC-560 MHz with battery pack	300
9835 DC-15 MHz 6 digits	145
9837 DC-80 MHz 6 digits	190
Function Generators	
HEWLETT PACKARD	
3300A 0.01 Hz-100 kHz sine, square triangular / 3301 Auxiliary plug-in	100
Logic Analysers	
HEWLETT PACKARD	
1601L Logic state analyser 12 channel display	600
Mains Monitors	
AMPROBE	
LAV3X Mains voltage recorder	45
GEC	
FB31A Surge monitor records mains spikes + filter	85
RUSTRAK	
288 + CT Clamp-on AC recording ammeter	95
Modulation Meters	
AIRMEC	
*210 1–300 MHz AM/FM	195
*409 3–1500 MHz AM/FM	325
MARCONI	
*TF2300A 1–1000 MHz AM/FM	520
Oscilloscopes	
ADVANCE	
OS1000A DC-20 MHz dual trace	310
COSSOR	
110/111 DC-20 MHz dual trace	325
110/112 DC-1 MHz differential	275
HEWLETT PACKARD	
184A + 1801A + 1822A DC-50 MHz system, T.B. and amplifier included, storage facility (storage de-rated please ask for details)	650
1707B20 DC-75 MHz dual trace D.T.B.	700
1710B DC-200 MHz dual trace	1250
TEKTRONIX	
5103N/D15 Storage system 800 div/ms DC-2 MHz	350
7A13 DC-100 MHz differential comparator	350
7B70 Dual time base with 7B71 delayed sweep (for 7000 series)	275
536 Mainframe 11 MHz X-Y	100
519 1 GHz Real Time. Matching accessories included	850
535A/CA DC-15 MHz dual trace DTB	250
545B/CA DC-24 MHz dual trace DTB	350
585A/81 DC-80 MHz dual trace DTB	550
454 DC-150 MHz dual trace DTB	1350
TELEQUIPMENT	
D54 DC-10 MHz dual trace	240
D75 DC-50 MHz dual trace D.T.B. (Portable)	550
D83 DC-50 MHz dual trace D.T.B. (Bench)	575
D53/CD/G DC-15 MHz Dual Trace with differential amplifier	225
Oscilloscope Probes – Current	
TEKTRONIX	
P6021 AC current probe to 20 MHz	200
Oscilloscope Probes – Voltage	
HEWLETT PACKARD	
1121A 500 MHz	90
TEKTRONIX	
P6046 Differential probe DC-100 MHz	215
Oscilloscope Cameras	
HEWLETT PACKARD	
195A Pack film polaroid	190
198A Pack film polaroid	120
TEKTRONIX	
C30AR Roll film polaroid	130
Power Meters	
HEWLETT PACKARD	
432A/478A 10 MHz-10 GHz wideband with bolometer	350
Power Supplies	
HEWLETT PACKARD	
6265B DC stab. variable 40 V/3 A	195
ROBAND	
T101 50 V 1 A Variable	30
SOLARTRON	
As 751 50 V 1 A Variable	25
STARTRONIC	
117 20 V 0.5 A Variable	25
SYSTRON DONNER	
LNG 16-10 16 V/10 A variable	75
Pressure & Displacement Transducers	
ELECTRO MECHANISMS	
LVDT DC linear variable ±0 50 inches	25
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E. H. RESEARCH	
G710 5 V/50 Ω 30 Hz-50 MHz RT 5 ns	100
132AL 50 V/50 Ω 5 Hz-3 MHz RT 12 ns	175
LYONS INSTRUMENTS	
PG2E 10 V/50 Ω 1 Hz-16 MHz RT 10 ns	130
PG23 10 V/50 Ω 1 Hz-10 MHz RT 5 ns	135
SYSTRON DONNER	
101 10 V/50 Ω 10 Hz-10 MHz RT 5 ns	95
Recorders & Signal Conditioning Equipment	
BRUNO WOELKE	
ME102B Wow and flutter meter	75
ME102C Wow and flutter meter	90
Recorders & Signal Conditioning Equipment	
BRUEL & KJAER	
2305B Stylus Recorder includes 50 db pot	650
HEWLETT PACKARD	
17502A Plug-in for 7100 series recorder temperature module	25
SE LABS	
3006DLT 12 channels UV 6 inch chart	450
A1000 Galvo 600 Hz 0.34 mA/cm	30
MICROMOVEMENTS	
M400 Galvo 300 Hz 50 µA/cm	25
M1000 Galvo 600 Hz 0.34 mA/cm	25
M1600 Galvo 1000 Hz 0.4 maA/cm	25
M8000 Galvo 5 kHz 15.5 mA/cm	25
SIEMENS	
KOMP III 2 pen potentiometric roll chart	425
Signal Sources & Generators	
ADVANCE	
H1 15 Hz-50 KHz	40
DAWE	
410C 0.1 Hz-10 KHz	40
EH RESEARCH	
967 Attenuator 25W.0-40 db	30
HEWLETT PACKARD.	
200CD 5 Hz-600 kHz O/P 10 V RMS	75
8693/100 3.7-8.3 GHz 5 mW, sweeper plug-in	525
* 608E 10–480 MHz AM	410
* 618C 3·8–7·6 GHz FM	1600
* 620B 7–11 GHz FM	1600
MARCONI	
TF791 FM Deviation Meter 4-1024 MHz	95
TF801D1 10-470 MHz AM.PM	150
TF885 0-12 MHz Sine/Square	75
TF995A/2 1.5-220 MHz AM.FM	350
TF995B/5 0.2-220 MHz AM.FM	475
TF1060 0-1.2 GHz AM.PM	150
TF2005A Two tone 20 Hz-20 KHz	200
ROHDE & SCHWARZ	
SWOB I 0.5-400 MHz 75Ω	225
SWOB II 0.5-1200 MHz 50Ω with delay line and accessories	1250
TEXSCAN	
VS40 1-300 MHz sweeper	450
WAYNE KERR	
S121 10 Hz-120 KHz	25
022B 10 Hz-10 MHz	75
Spectrum Analysers	
HEWLETT PACKARD	
141T Display unit storage	845
8552A I.F. Plug-in	1600
8553L 1 kHz-110 kHz Plug-in	1650
8554L 500 kHz-1250 MHz Plug-in	2100
T.V. Test Equipment	
MARCONI	
TF2909 Gray scale generator	250
Temperature & Humidity	
COMARK	
1604BLU Analogue thermometer 0-100 °C	40
LEE-DICKENS	
HP5 Humidity probe	130
HUMIGUN Temp/humidity probe with meter	215
RAYTEK	
T1000 Infra-red thermoprobe	200
Vibration	
DAWE	
1461 CV(M) Portable Vibration Analyser Kit	450
Voltmeters – Analogue	
AIRMEC	
264 Millivoltmeter 3 mV-1 V ranges	45
AVO	
*8 Mk V AC/DC/OHMS	60
BOONTON	
93A 20 Hz–20 MHz True RMS	260
BRADLEY	
CT471C AC/DC/Ω/current multimeter and RF	165
DAWE	
614C Millivoltmeter 0.3 mV-300 V ranges	25
HEWLETT PACKARD	
427A AC/DC/Ω multimeter	275
3406A 10 kHz-1.2 GHz	395
KEITHLEY	
610B Electrometer recorder O/P	330
LINSTEAD	
M2B DC/AC 10 Hz-500 kHz	25
MARCONI	
TF2603 AC voltmeter to 1.5 GHz	300
NORMA	
U-Function Dual channel peak/RMS meter	325
PHILIPS	
PM2454B AC voltmeter to 12 MHz	225
Voltmeters – Digital	
ADVANCE	
DMM3 1999 FSD AC/DC/Ω/current	85
DANA	
5230 119999 FSD AC/DC	175
FLUKE	
8300A 119999 FSD DC only	150
HEWLETT PACKARD	
3474/2 9999 FSD AC/DC/Ω	185
SOLARTRON	
A200 19999 FSD DC only	160
A205 19999 FSD AC/DC/Ω	300
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*7050 99999 Auto AC/DC/OHMS	395
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GENERAL RADIO	
1232A Tuned amplifier and null detector 20 Hz-20 KHz	75
HEWLETT PACKARD	
302A 20 Hz-50 kHz 75 db range	375
WAYNE KERR	
A321 20 Hz-20 KHz. Sens.-75 db	125

*Equipment added this month

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VAT charged at Standard Rate

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note our new telephone number

THE NEW PIL SHOWROOM

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Pil can cater for practically every electrical measurement problem for any user on an ex-stock/short delivery basis.

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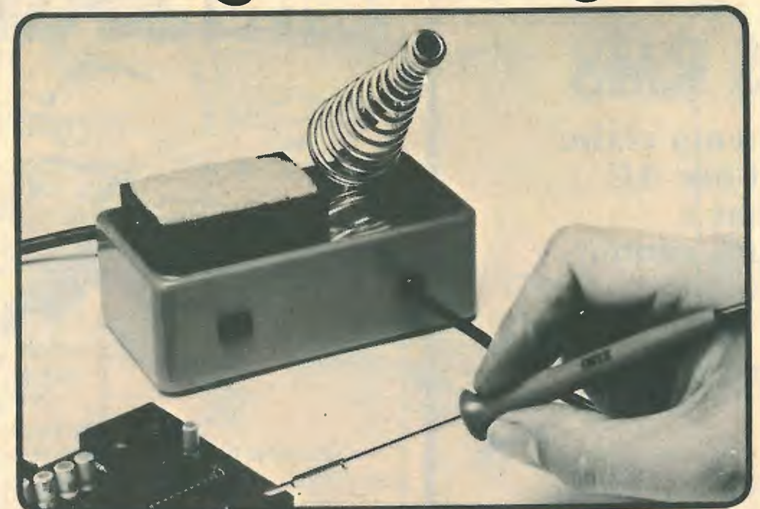
With the new Oryx miniature low voltage soldering station



FIRST EVER COMPLETE 6 WATT SOLDERING STATION

you get precision, operator safety, a choice of soldering iron tips and superb value at £9.95 (+VAT)

The new PSU 6 volt soldering station, operating at 360°C has its own compact power unit, a double insulated transformer and comes complete with an Oryx 6 watt miniature soldering iron, sponge, sponge well, spring holder mounted at an easy load angle, indicator lights and an internal safety fuse.

Obtainable also from our distributors: Electroplan Limited, Orchard Road, Royston, Herts. SG8 5HH. ITT Electronic Services, Edinburgh Way, Harlow, Essex. CM20 2DE. Toolrange Limited, Upton Road, Tilehurst, Reading. RG3 4JA.

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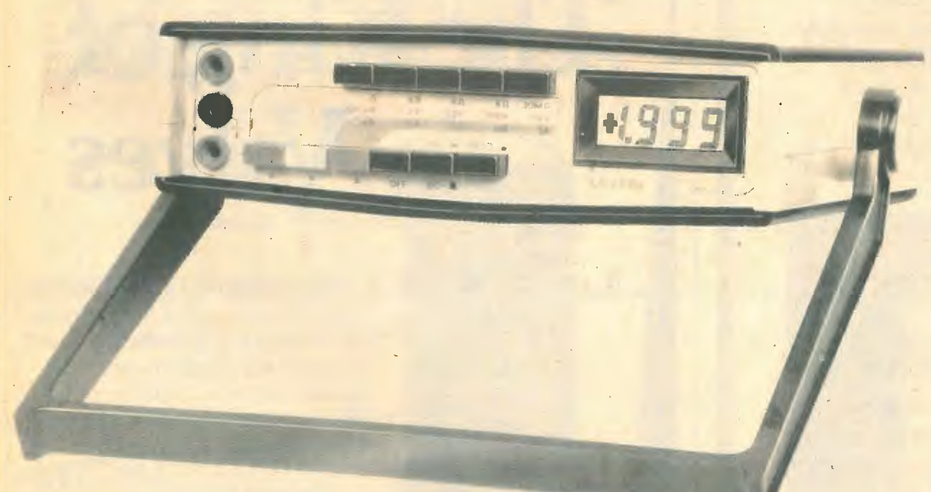

'Portable Precision'

LMM-100 Multimeter

0·1% Accuracy WITH Digital Hold

£69.95 + VAT

Crisp 0.5" LCD read-out gives up to 2,000 hrs. battery life with 'Battery Low' warning. Basic Accuracy 0.1%. Ten voltage (min. reading 0.1mV) ten current (min. reading 0.1µA) and five resistance (min. reading 0.1Ω) ranges. Unique 'digital hold' facility for easy data-logging. Auto-polarity and Auto-zero. Inputs protected against overload. Full 2 year warranty. A rugged ABS case with adjustable handle makes the LMM-100 the ideal instrument for bench or field use.

LMM-100 MULTIMETER £69.95. SUITABLE LEADS £1.95. P & P £1.50. ADD 15% VAT TO ALL PRICES.

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Unit 1, Thomasin Road, Burnt Mills, Basildon, Essex SS13 1LH

WW — 032 FOR FURTHER DETAILS

WATTS & RMS

Some instruments claim true RMS but are AC coupled, so that a composite input cannot be measured without calculation -

not so the WM80!

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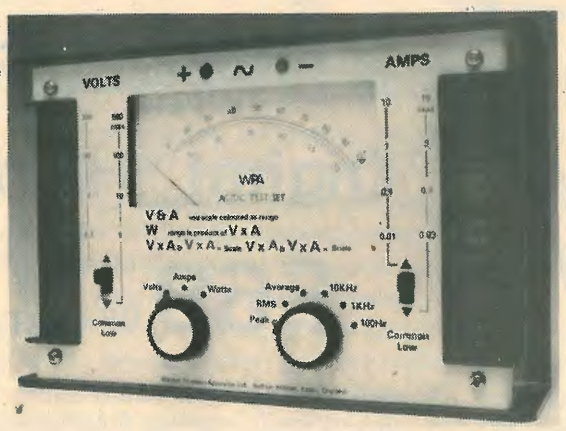

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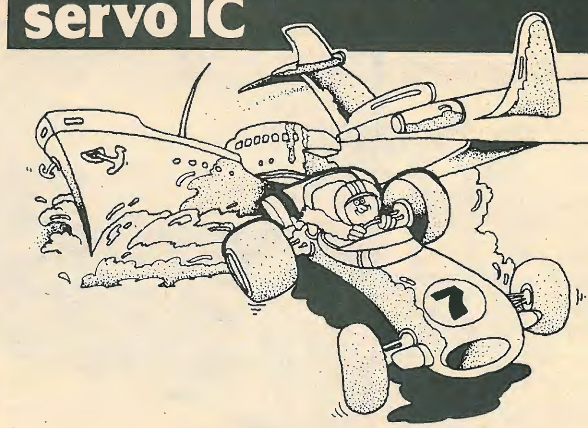

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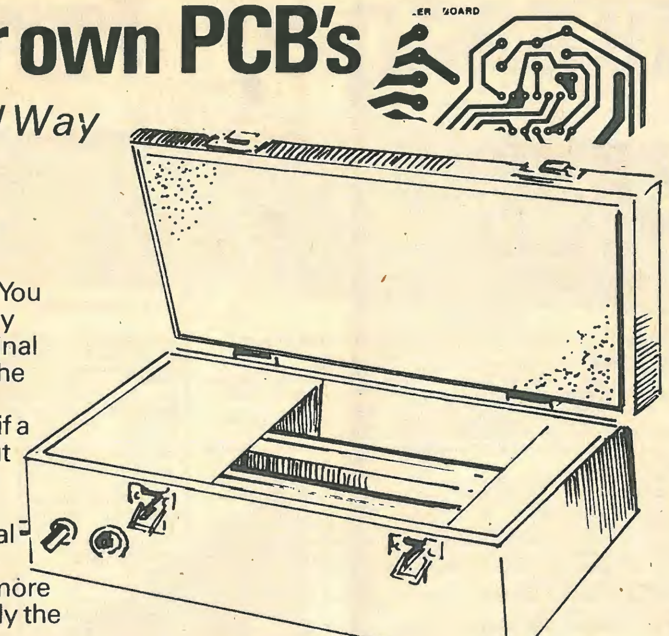

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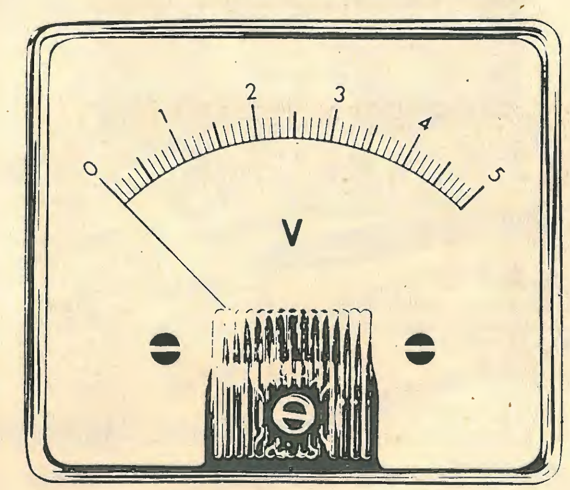

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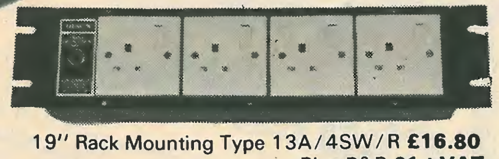

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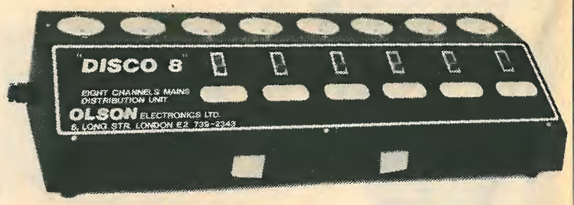

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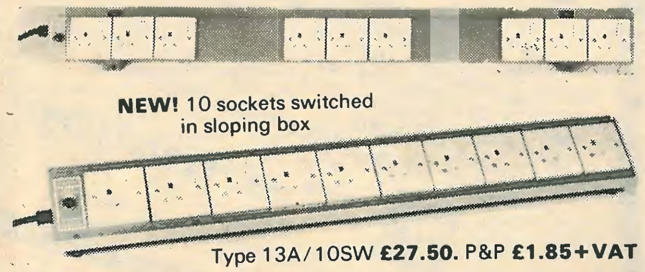

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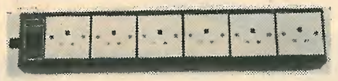

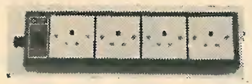

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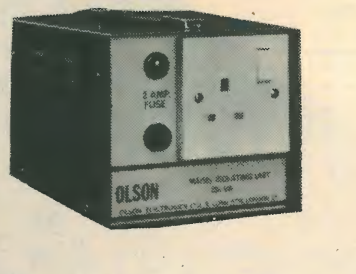

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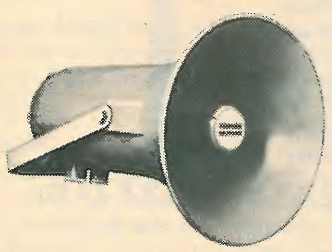

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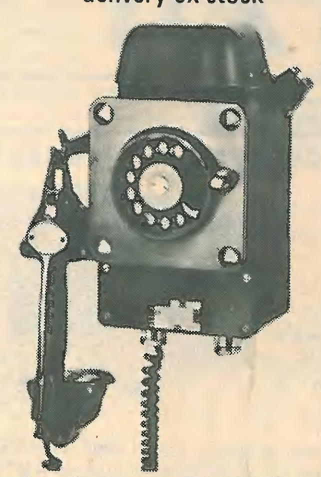

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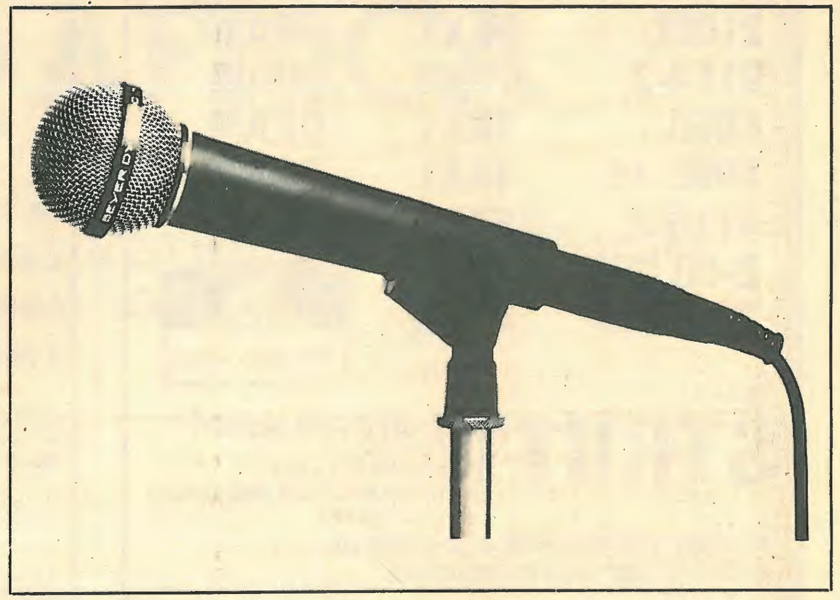

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M 400 N (C)

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wireless world

Power but little glory

The opening of the biggest and most important international radio conference for twenty years, WARC 79, is a good moment to ask ourselves just where we have taken this remarkable technology in the time since the first such conference was held at the beginning of the century (see article in this issue). Or it might be as pertinent to enquire just where this technology is taking *us*. WARC 79 is a major example of a meeting where decisions affecting the future development of a branch of technology are being made not by the technicians and engineers but by government representatives ostensibly acting for the people, the users of the technology. Ostensibly, because it's very doubtful whether these civil servants and others are true representatives of the people's interests or technocrats more concerned with the preservation of political/industrial power structures.

In the early days of radio it was possible to point to such things as the saving of life at sea and declare with confidence that this new technology would be a great boon to mankind. Three-quarters of a century later such breezy Edwardian optimism has gone, for the picture is very different. It's not only that radio and electronics have found terrifying applications in instruments of destruction. A more permanent and insidious development is the immense, silent power that all technology, including ours, has acquired over the ordinary lives of people. It is not wielded by the individual scientists and engineers, but by our political, economic and commercial institutions, the technocracy. The ordinary person sees a great complicated Juggernaut which he is helpless to understand or control and which moves on heedlessly over his prostrate mind. It was an awareness of this helplessness which led Kurt Waldheim, Secretary-General of the United Nations, to warn recently that "failure to assert the primacy of policy over technology is an alarming and increasingly dangerous phenomenon in the modern world".

Two current beliefs foster the growing power of technology: one, if a new technique produces material prosperity it is automatically good, regardless of its side effects; two, if a scientific advance is possible at all it must not be hindered but pursued, objectively, for its own sake. Success at all costs. But the direction the research and commercial development takes is inevitably controlled by those who put the money into it. Whatever the benefits, the major interests of those who provide the finance, as Roszak has said, will continue to be in weapons, in techniques of social control, in commercial gadgetry, in market manipulation and in the subversion of democratic processes by means of information monopoly and "engineered" consensus. In electronics, technical and commercial activity is now dominated by weapons systems on the one hand and consumer toys and trinkets on the other.

One brave if somewhat emasculated attempt to "assert the primacy of policy over technology" is the Office of Technology Assessment which operates in that heart of technical achievement, the USA. It was established by law in 1972 to give Congress early indications of the beneficial and adverse effects to be expected from the applications of technology. Being an arm of the legislature, rather than of the government, it is nominally independent, but because it cannot help being part of the power structure of the country this independence must be suspect. More healthy is the consumer movement and the work of the voluntary groups who believe that communities should monitor technology; this has produced, again in the USA, the National Council for the Public Assessment of Technology. As Lord Mountbatten declared at the end of the first Mountbatten Lecture, hopefully entitled Electronics – the Lifeline, "Science offers us almost unlimited opportunities – but it is up to us, the people, to make the moral and philosophical choices".

Two-metre s.s.b. and f.m. transceiver

Design and construction of an advanced unit for the experienced constructor

by G. R. B. Thornley, G2DAF

The transceiver to be described in this article is the final result of two years development and constructional work. The aim was to provide a unit which would be tunable over the full range of the two metre (144 to 146MHz) band and capable of s.s.b., f.m. and c.w. operation, with an output power of 10 to 20 watts p.e.p. To avoid crystal manipulation and bandpass filter alignment, which some people find difficult, the author decided to generate the initial s.s.b. and f.m. at 10.7MHz using low-cost, easily-obtainable block crystal filters. The transceiver has been in use almost daily over the past three years, and this has given the author ample opportunity to prove the reliability, ease of control, and long term stability of the design. It can be built for under £200.

THE MAIN REQUIREMENTS for the transceiver were as follows: The single conversion format was to be used to improve the receiver cross-modulation and blocking performance and it had to have a straightforward setting-up and alignment procedure. First class carrier, sideband and intermodulation product suppression, together with natural s.s.b. speech quality, was required and the transceiver was to include narrow-band f.m., compatible with amateur band requirements. Easily-repeatable construction was desired, using (with the exception of the final output amplifier) p.c.bs throughout. All the signal frequency circuits were to use push-pull balanced mixers which would provide good discrimination against heterodyning-frequency breakthrough and a clean output with a low order of distortion products. Wherever possible, standard-production, easily-obtainable components were to be used and high cost items were to be avoided.

Constructional features considered to be desirable were also itemised. Unit construction, a clean layout, good accessibility and a professional appearance were considered by the author to be important. The coils were to be home-made using standard, readily-available coil formers, dust cores and screening cans. To simplify operation a press-to-talk control was to be incorporated and the transceiver was to be driven by a separate power supply.

In order to obtain the required stability, a variable-frequency oscillator (v.f.o.) operating on a relatively low frequency is essential. This can be raised to the required heterodyning frequency of 133.3 to 135.3MHz in two ways. The first method uses the so-called "mixer v.f.o." in which the v.f.o. feeds a mixer stage together with the output from a high frequency crystal oscillator. In this case the sum of the two frequencies is extracted at the mixer output circuit. The second method uses a "phase-lock loop v.f.o." in which a voltage-controlled oscillator (v.c.o.) tuning 133.3 to 135.MHz is locked back to a relatively stable v.f.o. on a much lower frequency. This method has the oscillator at signal frequency – which avoids the problems of oscillator harmonics and spurious mixing products – but the stability is as good as that of the low frequency v.f.o.

The second method was preferred and this was adopted using an integrated circuit phase detector, Motorola type MC4044P*, which produces reliable and consistent results, and locks from switch-on. It was the author's desire to construct a workable phase-lock loop v.f.o. which encouraged him to develop the transceiver described here.

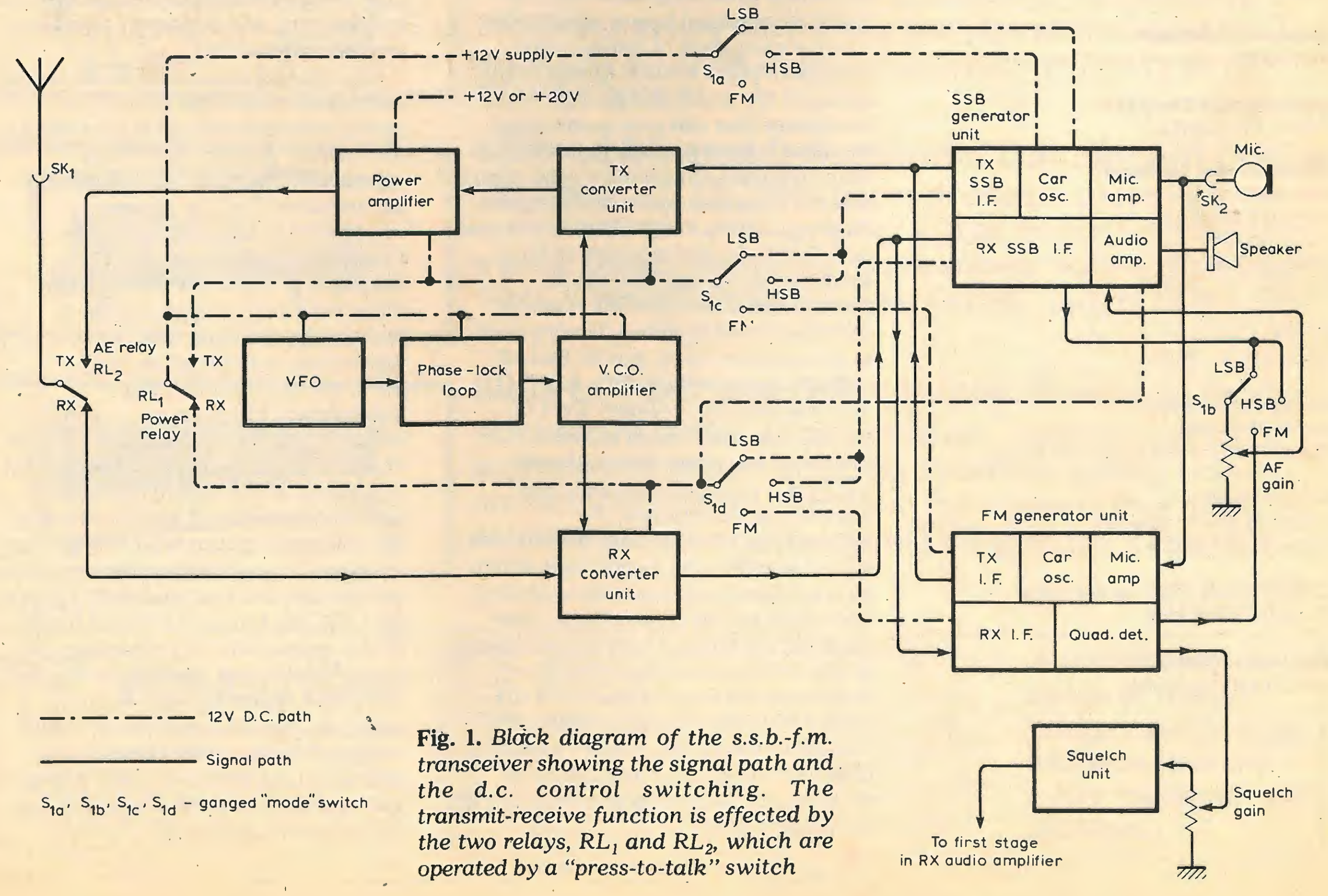


Fig. 1. *Block diagram of the s.s.b.-f.m. transceiver showing the signal path and the d.c. control switching. The transmit-receive function is effected by the two relays, RL_1 and RL_2, which are operated by a "press-to-talk" switch*

Transceiver block diagram

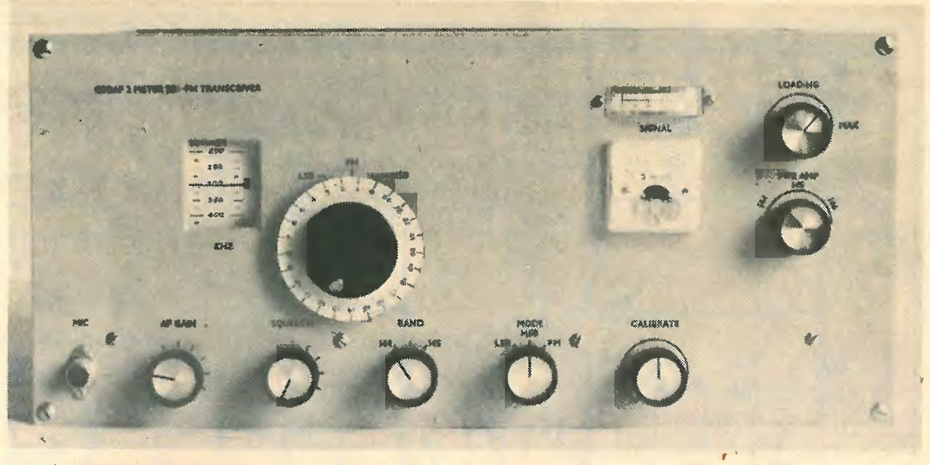
A block diagram of the transceiver is given in Fig. 1 and shows the signal path, the d.c. send-receive control switching and the s.s.b.-f.m. mode switch S_{1a}, S_{1b}, S_{1c}, S_{1d}. On receive, the aerial is connected to the receive converter unit which translates the two-metre band signal to 10.7MHz. The output from this converter simultaneously feeds the f.m. generator unit and the s.s.b. generator unit. Audio signals from both generators feed via S_{1b} to the common "a.f. gain" and the common audio power amplifier.

On transmit, the microphone output simultaneously feeds the s.s.b. and f.m. microphone amplifiers and their respective 10.7MHz i.f. units. Both of the s.s.b. and f.m. outputs connect to the transmit converter unit where the signal is translated to the required two-metre band frequency. The low level output from the converter feeds into the power amplifier unit which gives 10 to 20W of r.f. output power.

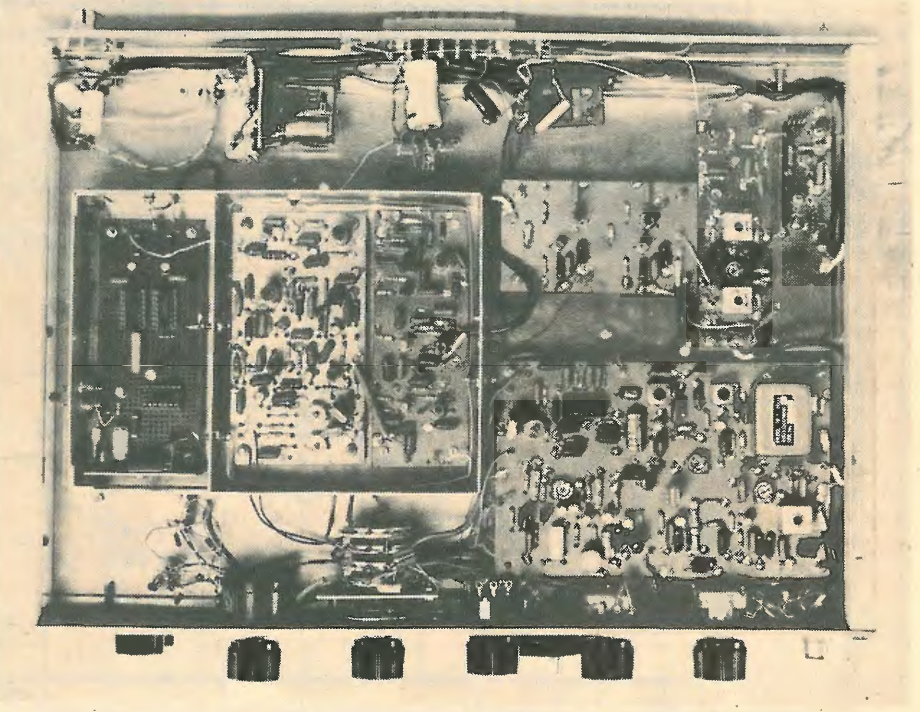
The v.f.o., phase-lock loop circuit and v.c.o. amplifier are common to "transmit" and "receive" and are permanently connected to an unswitched 12V stabilized power supply. Power for the remaining s.s.b. and f.m. units is selected as required by the switch banks S_{1a}, S_{1d} and S_{1c}. Two relays, one for power and one for the aerial, control the transmit-receive function, and are operated during communications by a press-to-talk foot switch. The phase-lock loop unit provides the required heterodyning frequency of 133.3 to 135.3MHz in two ranges each 1,000kHz wide, and is locked back to the relatively stable v.f.o. tuning over the range of 8.3 to 9.3MHz.

S.s.b. generator unit

All the components for the 10.7MHz s.s.b. transmit-receive unit, which has the circuit shown in Fig. 2, are assembled on a p.c.b. measuring 8¼ x 5in. Transistors Tr_1 to Tr_6 form the transmit section and Tr_7 to Tr_{17}, the receive section. Tr_6 is a f.e.t. and offers a high impedance load to the microphone. Audio signals feed via the preset volume control, R_{25}, to a further stage of amplification, Tr_5, and then via a screened cable to the twin diode balanced-modulator D_2 and D_3. The modulator output at low impedance connects to the capacitive tap C_{14} and C_{15} across L_4, and is amplified by two m.o.s.f.e.t. i.f. stages Tr_2 and Tr_1. Overall gain is controlled by the preset resistor R_2.



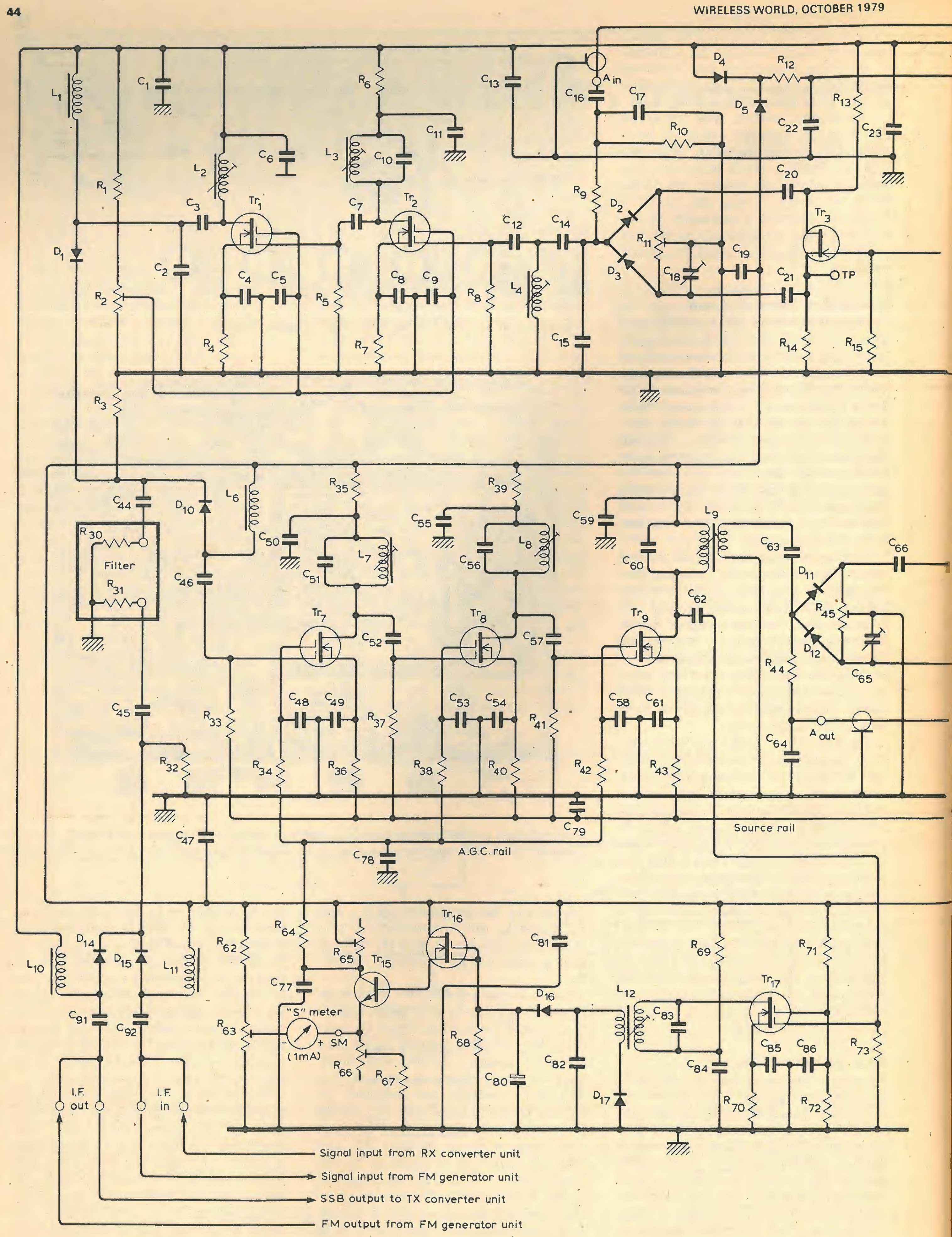
Front view of the transceiver showing the panel layout.



Underchassis of the transceiver showing, left to right, the phase-lock unit, the v.c.o. amplifier p.c.b., the receiver converter p.c.b., and bottom right, the f.m. generator p.c.b.

Coil L_2 is resonated by two capacitors C_2 and C_3 in series to provide an impedance match. Switching diode D_1 connects the 10.7MHz output signal into the low impedance 2.4kHz wide block filter via the d.c. blocking capacitor C_{44} and the filter output then connects, via C_{45} and the switching diode D_{14}, to the two output terminal posts. High and low sideband carrier crystals XL_1 and XL_2 are switched as required by the "mode" switch S_{1a} and diodes D_7 and D_8 to the carrier to be pulled exactly on to the required frequency. In practice, additional capacitance was found to be necessary and this is provided by C_{29} and C_{31}, which are soldered in parallel with each trimmer on the back of the p.c.b. The low impedance output from the secondary of L_5 feeds the receiver demodulator D_{11} and D_{12} and the high impedance output from the collector of Tr_4 drives the f.e.t. phase splitter Tr_3 to provide a balanced r.f. input to the transmitter balanced modulator D_2 and D_3. The carrier oscillator is common to both transmit and receive and, accordingly, the required 12V supply is fed via switching diodes D_4 and D_5 from both the transmit and receive power rails.

On receive the 10.7MHz signal input is switched by diodes D_{15} and D_{10} through the block filter, and then amplified by three a.g.c.-controlled m.o.s.f.e.t. i.f. stages Tr_7, Tr_8 and Tr_9 and the balanced demodulator D_{11} and D_{12} is fed by the low impedance output from the secondary of L_9. The 10.7MHz i.f. input is heterodyned by the push-pull carrier frequency to the demodulator, and the resultant difference frequency in the audio range 300 to 2,700Hz connects to the panel-operated a.f. gain



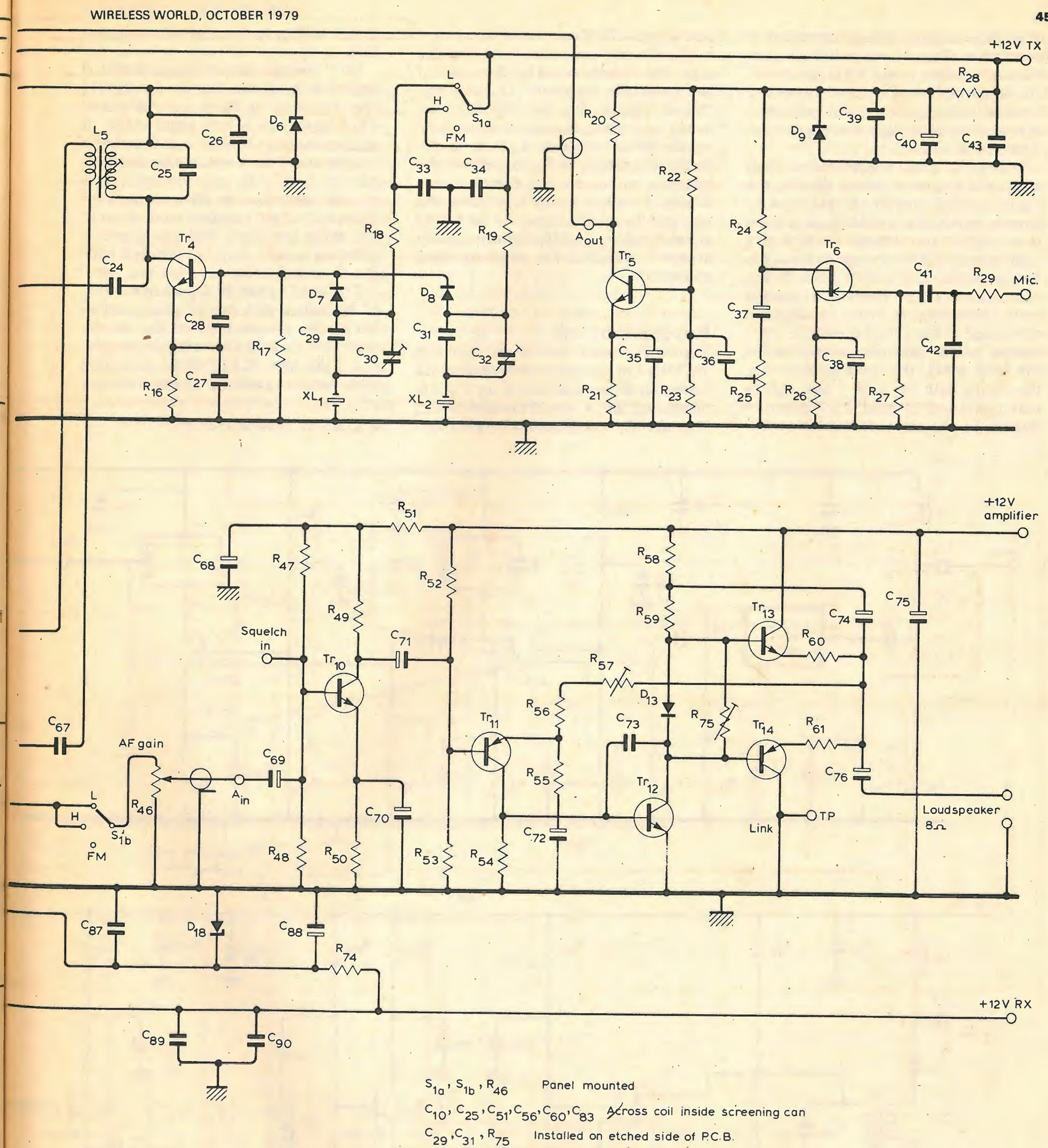


Fig. 2. *10.7MHz s.s.b. generator unit*

control, R_{46}, via the mode switch S_{1b}. Tr_{10} to Tr_{14} form a conventional complementary-pair audio amplifier with approximately one watt output to an eight ohm loudspeaker. These stages are common to both s.s.b. and f.m. reception and are therefore fed from a separate +12V power rail.

During a.m. reception, there is a steady transmitted carrier, and this can be used in a receiver to operate a simple a.g.c. system. However, these conditions do not apply when receiving a s.s.b. transmission. The a.g.c. system must have a fast attack in order to faithfully follow the modulation envelope, and must have a slow release in order to "hold up" in between words. In addition, the a.g.c. is ideally required to hold the audio output at a constant level for incoming signal strengths of 10μV to 100mV – a dynamic range of 80dB. Good a.g.c. performance for s.s.b. reception is an important requirement for satisfactory operation, but has proved difficult to achieve with semiconductor devices. The situation has improved considerably with the advent of the dual gate m.o.s.f.e.t. in which a smooth control of stage gain is available by varying the potential applied to gate 2.

Tr_{17} is the a.g.c. i.f. amplifier. The output signal from L_{12} is rectified by D_{17} and is fed via the gate diode D_{16} to gate 1 and gate 2 of the high impedance amplifier Tr_{16}.

The output from D_{16} follows the s.s.b. modulation envelope and charges C_{80} to approximately the peak level. The attack time is fast, but C_{80} can only discharge through R_{68} giving the required slow release. Phase inversion is effected by Tr_{15} whose collector provides a negative going a.g.c. potential. The emitter of this transistor drives the S-meter which gives a visual indication of relative received signal strength from S zero to S9 + 40dB.

In order to avoid the necessity of an additional negative power supply, the a.g.c. control circuit is returned to chassis earth. An aerial input signal from 0μV to 100mV will give approximately 2.5V change in the a.g.c. line potential, the lowest point being approximately 2.9V relative to chassis earth. Therefore, in order to take full advantage of the gate-2-to-source volts against power gain characteristics for the RCA 40673, the "source line" (i.e. the return path for gate 1 and source bias resistors) is held 3.3V positive relative to chassis earth, and is stabilised with a 2.7V Zener diode D_{18}.

The "hold" time constant for the a.g.c. line is determined by the value of the reservoir capacitor C_{80} and the "bleed" resistor R_{68}. Initially the zero signal a.g.c. line potential is set at 5.5V by the pre-set resistor R_{65} and the S-meter zero setting by R_{63}. R_{66} allows the operator to control the S-meter sensitivity. In other words it enables the operator to set the meter to S9 for an aerial signal input of 50μV (the normally accepted standard for amateur band receivers).

F.m. generator unit

Figure 3 shows the circuit of the 10.7MHz f.m. transmit-receive unit. All components are assembled on a p.c.b. measuring 6¼ × 4in. Transistors Tr_{18} Tr_{19} and IC_1 comprise the receive section, and Tr_{20} to Tr_{15} the transmit section.

On "receive" the incoming signal is switched by diode D_{19} to the 25kHz channel spacing block crystal filter. This filter has a 6dB bandwidth of approximately 15kHz and has been chosen as the most suitable for amateur narrow band f.m. requirements. For correct operation the filter requires an input and output parallel termination of 910 ohms and 25pF, and this together with the circuit load is obtained with R_{77}, C_{95} and R_{78}, C_{96}.

Tr_{18} and Tr_{19} are dual-gate m.o.s.f.e.t. i.f. amplifiers with overall gain controlled by the pre-set resistor R_{81}. At the time the f.m. unit was being developed, the Toko type KALS4520A screened coils became available in the UK and

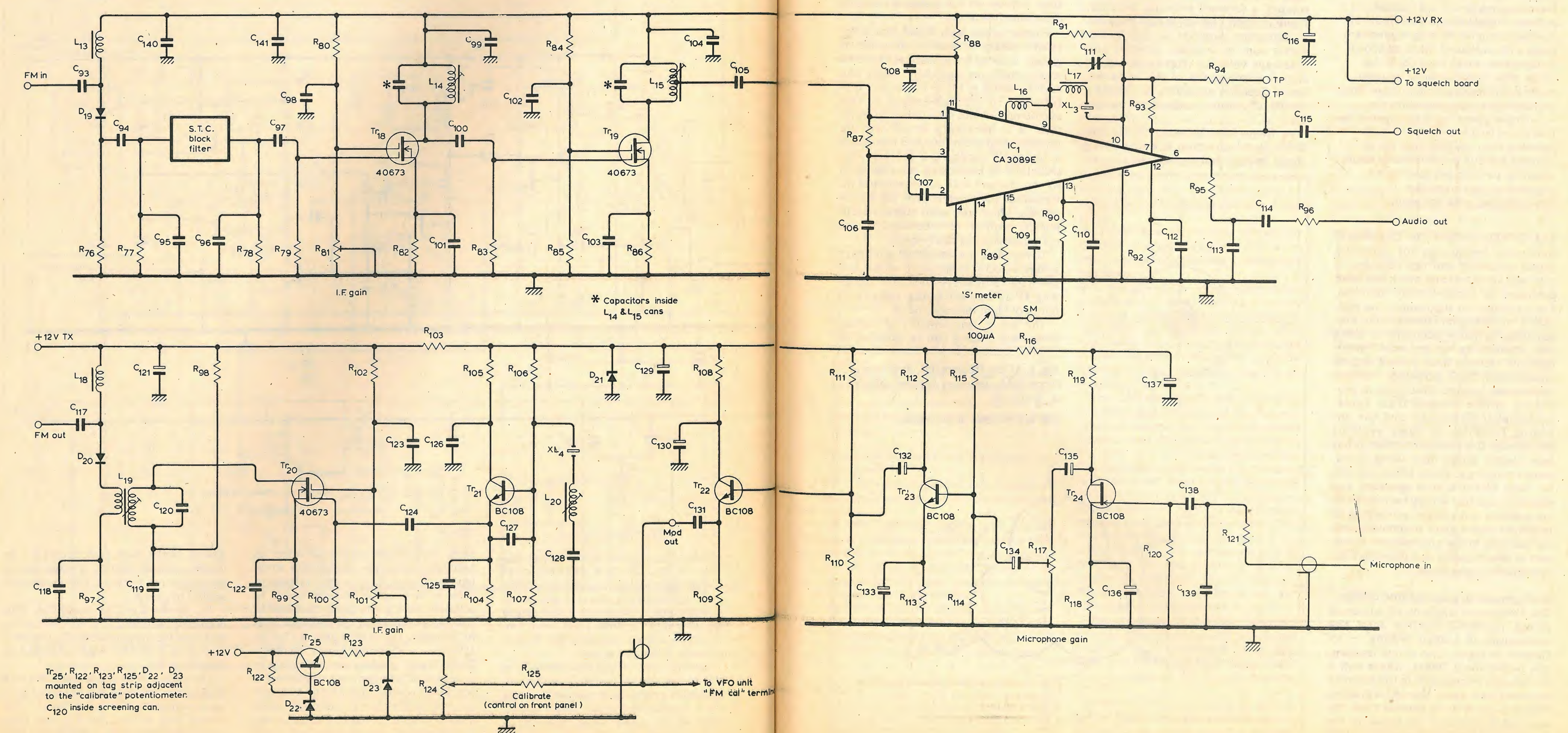
these were used for L_{14} and L_{15}. The resonating capacitor is supplied as part of the internal coil assembly.

IC_1 is an RCA CA3089E incorporating a three-stage limiting amplifier, quadrature detector, muting and tuning meter output. The original development circuit followed the manufacturer's recommendations using a high-Q tuned circuit between pins 9 and 10 of the quadrature detector. This was considered by the author to be unsatisfactory with regard to the recovered audio output and the long term stability of the L/C circuit for amateur narrow-band (nominally ± 5kHz) f.m. reception. The performance has been materially improved by the addition of a crystal discriminator, XL_3 in the circuit diagram. In order to obtain the recovered audio with a low level of distortion, the crystal series-resonant point must be placed exactly at the filter centre frequency, and this is provided by the associated inductance L_{17} and the shunt trimmer C_{111}. The resistor R_{91} ensures a d.c. path between pins 9 and 10 of the detector. Terminal posts marked TP (test point) and the series resistor R_{94} are incorporated to enable an external microammeter to be connected during the setting of C_{111} and the plotting of the resultant S-curve. This will be dealt with in detail under the heading "Alignment". In addition, it was felt that the existing CA3089E muting circuit associated with pins 5 and 12 did not meet the requirements of amateur band operation so the required performance has been obtained by an outboard squelch unit.

On "transmit," the crystal microphone input is amplified by Tr_{24} and Tr_{23}, the amplifier gain being controlled by the preset resistor R_{117}. The output from the emitter Tr_{22} is fed to the varicap diode in the v.f.o. unit and the reference voltage for this diode is fed via R_{125} from the panel-operated "calibrate" potentiometer R_{124}. This control would be very sensitive to a fractional change in power supply voltage or to hum ripple. It is therefore most important that R_{124} is fed from a supply rail incorporating double stabilization, and this requirement is effected by Tr_{25} and D_{23}. XL_4 is the carrier crystal adjusted by L_{20} to exactly 10,700,000Hz. The output of the carrier oscillator Tr_{21} is amplified by the m.o.s.f.e.t. Tr_{20} whose drive level is set by the preset control R_{101}. A low impedance output is taken from the secondary of L_{19} via the switching diode D_{20}.

continued on page 53

Fig. 3. *F.m. generator unit*



Soundfield microphone

Design and development of microphone and control unit

by Ken Farrar, Calrec Audio Ltd

Ambisonics and surround sound technology based on psycho-acoustic theory form the nucleus of the design of the soundfield microphone. The complete design combines advanced acoustical, mechanical and electrical precision engineering in a revolutionary way. Recordings made with the microphone and reproduced through a minimum of loudspeakers produce images which are stable and uncoloured, while additional loudspeakers, which need not be full range, allow reproduction of valuable height and reverberant information. The soundfield microphone enables the recording engineer not only to record the total sound field and thus protect his recording from obsolescence, but to compare and dub to conventional forms, adjusting, panning and steering his synthesised, truly coincident "microphones" after the event.

THE DEVELOPMENT OF THE NRDC Ambisonic technology for surround sound recording and reproduction is now well advanced and much has been published by those directly involved. Early attempts to supplement the restrictive conventional stereophonic presentation by hasty additions of extra rear channels in the so-called "quadraphonic" format have proved largely unsuccessful. Their particular inherent weaknesses include difficulties in producing stable images from inter-loudspeaker directions, and the encoding formulae of some systems exacerbates this problem further. It has been clearly shown that using Ambisonic technology, much better use can be made of extra loud speakers and channels, and that if only two channels are available, a decoding system may be employed which gives psycho-acoustic optimisation of the presentation in respect of directionality and freedom from coloration or "phasiness."

Background to microphone design

The theoretical analysis of surround sound psycho-acoustics into the mechanisms of human hearing — by Gerzon[1] — argues that at low frequencies below about 700Hz, where half a wavelength corresponds to the distance between the ears, the information reaching the brain is derived from the sum and difference of the inputs to the two ears. This corresponds at low frequencies respectively to the pressure component of the sound—equivalent to an omni-directional microphone W — and the velocity (pressure gradient) component of the sound — equivalent to a sideways pointing velocity, figure-of-eight microphone Y. As the head may be rotated, a forward pointing velocity, figure-of-eight pick-up is also required to determine direction X, Fig. 1. The vector sum of in-phase forward and sideways velocity (figure-of-eight) signals corresponds to the apparent sound direction according to Makita's theory of sound localization by the ears.

At frequencies between 700Hz and 5kHz sound direction is detected by signal energy and corresponds to an "energy vector" being the addition of vector components pointing at each loudspeaker whose lengths correspond to the energy in that speaker. Above 5kHz the pinnae (flaps) of the ears appear to offer directional information to the brain by differences in coloration they impose on the sound arriving in different directions.

Further it has been found that a listener's ability to localize direction is greatly assisted by moderately reverberant conditions especially where the reverberation is fairly uniformly distributed. To take advantage of this additional ambient directional information, it is necessary to record the reverberation accurately and reproduce it uniformly around the listener. The technique of restricting reverberation to one channel with no directional information does not satisfy the above criteria. Moreover, with current technology, artificial reverberation is also not satisfactory in this respect.

To complete the soundfield symmetry a third velocity component whose axis lies in the vertical is required, corresponding to an upward facing velocity of figure-of-eight microphone, Z.

The above requirements of human directional hearing can be satisfied by

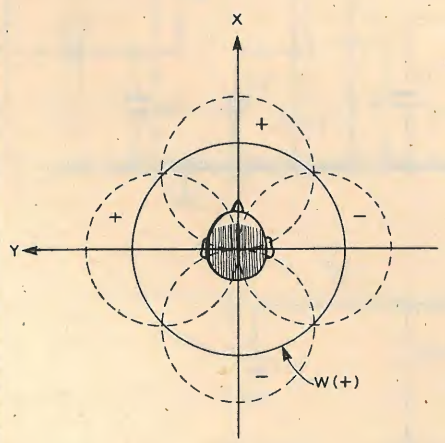


Fig. 1. *At low frequencies, direction is perceived by pressure (w) and velocity (x, y) effects.*

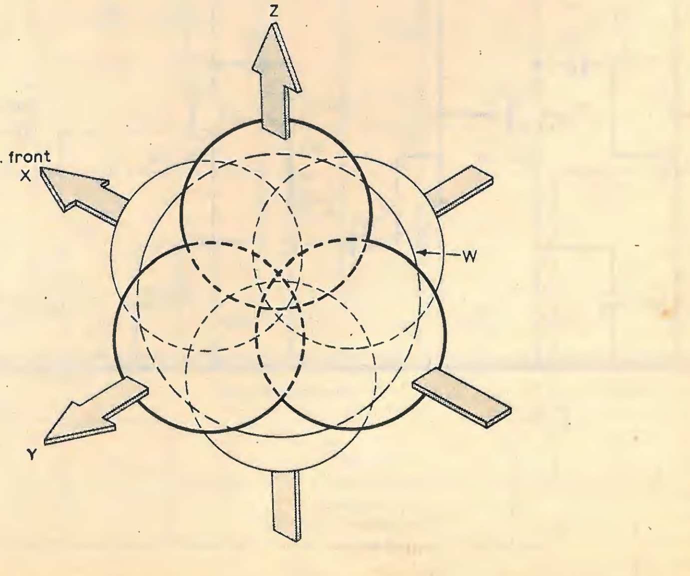


Fig. 2. *B-Format co-ordinates.*

suitable processing of pressure and velocity signal components using an Ambisonic decoder such as that described in references 4 and 7-9. A similar decoder is used in the monitor/output section of the soundfield microphone control unit described later. More detailed aspects of the soundfield microphone principle have been described in references 11 and 13.

Microphone acoustic system

The complete parameters for the design of a microphone to capture the complete soundfield may now be defined as follows. The four signals are known as B-format and soundfield signals should be recorded, stored and generally handled professionally in this form. (Fig. 2).

W–pressure: omni-directional.
X–pressure-gradient (velocity): forward fig.-of-eight.
Y–pressure-gradient (velocity): leftward fig.-of-eight.
Z–pressure-gradient (velocity); upward fig.-of-eight.

The height component Z will probably not be used in reproduction commercially in the immediate future although it is necessary to implement elevation and dominance controls post-session when required and undoubtedly experimental reproduction systems will use it*

The B-format signals are required to be truly coincident and to have good frequency response and well defined polar patterns at all frequencies. It was considered impractical to produce a microphone which generated B-format signals directly; moreover the method chosen has a significant number of advantages over the alternatives. The soundfield microphone uses a unique array of four sub-cardioid capsules mounted as closely as possible in a regular tetrahedron (Fig. 3). They should be imagined as four receivers symmetrically disposed on the surface of a sphere and associated circuits are provided to compensate their practical spacing.

The advantages of this arrangement are as follows: –

- The four capsules are identical single-diaphragm cardioids of proven design.
- They have individually a very good axial frequency response and the response in other directions is regular when set up as sub-cardioids. This means that the polar patterns are well defined at all frequencies.
- Each of the four capsules contributes an equal component to each of the B-format signals thus allowing effective cancellation of endemic capsule variations from the ideal, particularly when the capsules are well matched as they are.
- Arrangement of separating the pressure and pressure-gradient components into B-format allows each component to be compensated separately for frequency and phase response.
- Tetrahedral array used allows for capsule pairing along discrete axes which greatly facilitates testing and alignment.
- Closeness of the array allows compensations to be applied to produce B-format signal components effectively coincident up to about 10kHz. This contrasts vividly with conventional stereo microphones where capsule spacing restricts coincident signals up to about 1.5kHz.

* The author is presently setting up a reproduction system which reproduces height information, in accordance with system HHJ of the universal HJ surround sound encoding standards for Ambisonic technology.

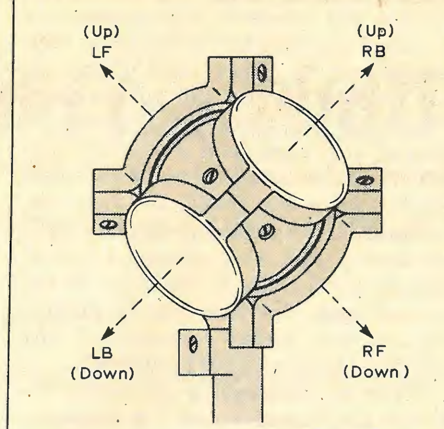


Fig. 3. *The four capsules mounted in tetrahedron.*

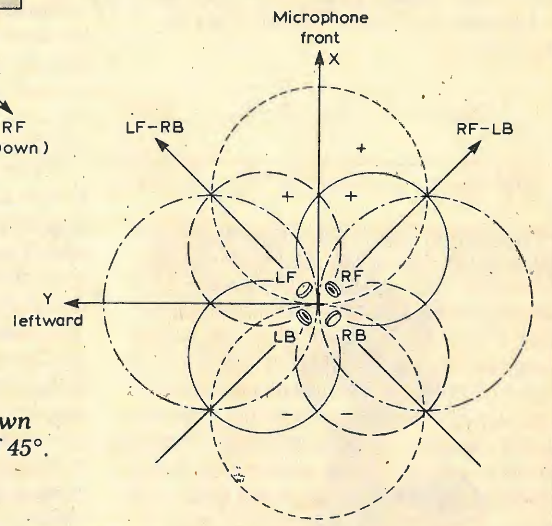


Fig. 4. *Subtracting outputs shown produces horizontal patterns of 45°.*

The capsule signals are known as A-format and correspond to discrete practice except that they are tilted upwards and downwards as shown in Fig. 3, to form the regular tetrahedron. The capsules are paired in the horizontal plane as: left front up and right back up, right front down and left back down. Examination of each of these pairs reveals that they are *symmetrically* tilted from the *vertical* so that if the output signals are subtracted within each pair, the two opposing cardioid patterns produce figure-of-eight patterns whose axes lie along 45° *horizontal* diagonals shown in Fig. 4.

The amplitude of the figure-of-eight patterns thus produced will be reduced from the value obtained if the capsule pairs were back-to-back by cos ϕ, where ϕ is the angle of tilt of each capsule, (35.3°).

If the two diagonal patterns are added, a figure-of-eight pattern facing forward is produced, with an increase in sensitivity of about 3dB (2 cos 45°). This corresponds to

$$X = L_F - R_B + R_F - L_B. \quad (1)$$

Similarly a leftward figure-of-eight pattern is produced by *subtracting* the $R_F - L_B$ figure-of-eight from the $L_F - R_B$ one. This corresponds to

$$Y = L_F - R_B - (R_F - L_B)$$

$$\text{or } Y = L_F - R_B - R_F + L_B. \quad (2)$$

The derivation of an upward figure-of-eight pattern is produced from capsule pairs $L_F - L_B$ and $R_B - R_F$ which produce diagonal figure-of-eight patterns as shown in Fig. 5. This corresponds to

$$Z = L_F - L_B + R_B - R_F. \quad (3)$$

The pressure or omnidirectional component *W* is produced by adding the

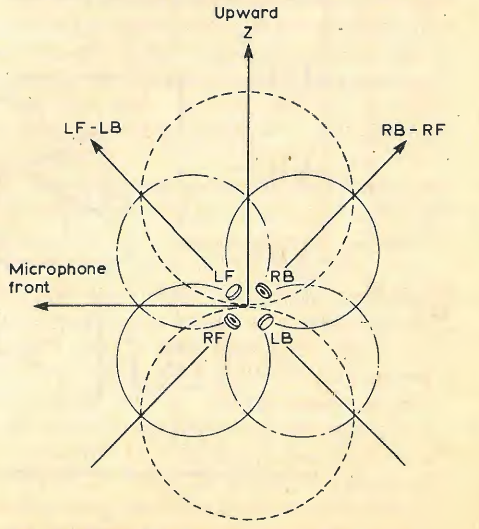


Fig. 5. *Vertical capsule pair outputs.*

four capsule outputs *in-phase* so that

$$W = L_B + L_F + R_F + R_B. \quad (4)$$

If the microphone is to be used inverted e.g., suspended in a concert hall, it is necessary to reverse the phase of Y and Z only; X still points forwards and W remains omnidirectional. This corresponds to

$$Y_{INV} = -L_F + R_B + R_F - L_B. \quad (5)$$

$$\text{and } Z_{INV} = -L_F + L_B - R_B + R_F. \quad (6)$$

The above matrixing and normal/inverted circuit inversion are carried out in the A-B matrix module in the control unit where 16 adjustments are provided allowing for variations in capsule sensitivity. The correct alignment can only be carried out in anechoic conditions where the microphone is rotated in the test field to observe sensitivity and polar patterns of capsules, capsule pairs and finally B-format co-ordinates. To this end, provision is made for muting each of the capsule A-format signals individually at the input to the control unit. The A/B matrix module carries the serial number of the microphone to which it is adjusted.

Fig. 6. *Amplifiers in body of unit.*

There is considerable difference between the sensitivity of the pressure-gradient (velocity) components *X, Y* and *Z* and that of the pressure component *W* due to the following reasons.
1. Capsule signals are added to produce *W* but subtracted to produce *X, Y* and *Z*.
2. The capsules are sub-cardioids, with polar response 2+ cos θ approximately, not cardioids (1+ cos θ), which increases the pressure, *W* component.
3. The tilt of the capsule pairs reduces diagonal velocity components and hence *X, Y* and *Z* signals.
4. The three directional components *X, Y* and *Z* of the pressure-gradient require an additional 3dB to conform with the standardized B-format levels. (This sets the energy levels in *X, Y* and *Z* similar to that in *W* for average programme.)

The pressure-gradient components *X, Y* and *Z* require a total boost of about 13dB so that the B-format signals match correctly at frequencies where the wavelength is long compared to capsule and array dimensions e.g. 500Hz. At very low frequencies, *W* requires some boost since it is made up of signals from velocity type capsules which characteristically do not have an extended l.f. response.

At frequencies where capsule spacing compares with wavelength, equalisation circuits take effect to maintain apparent coincidence in B-format signals to about 10kHz. The overall microphone performance is extremely good to 20kHz beyond which the output is rolled off at 12dB/octave.

All these equalization circuits are contained in the A-B matrix module.

Ken Farrar is managing director in charge of production and design at Calrec Audio, Hebden Bridge, West Yorkshire. He is one of the founders of Calrec and is co-designer of the Calrec range of capacitor microphones and audio designer of Calrec mixing desks. He has spent the last year developing the sound field microphone and control unit.

Microphone amplifiers

The microphone body contains four identical head amplifiers mounted on two similar printed circuit cards, Fig. 6. Each amplifier consists of a field effect transistor low-noise pre-amplifier with a gain of +11dB. The f.e.t. stage drives two operational amplifiers in an electronic balanced configuration effectively adding a further +6dB to make +17dB (×7) overall (Fig. 7) Each pre-amplifier is phantom-powered along its output balanced lines from the control unit, each supply being separately stabilised within the microphone. Each circuit contributes to the polarising of all four capsules so that any or all circuits polarise all capsules. This arrangement together with the stabilised supplies allows signal levels equivalent to 138dB s.p.l. at 1kHz to be handled before clipping occurs. The capacitance of a full length (150 metres) of cable restricts the output to 134dB s.p.l. at 10kHz but this allows an adequate margin over normal loud programme which rarely exceeds 110dB s.p.l. (130dB s.p.l. corresponds to a *very* loud sound). At 138dB s.p.l. the microphone outputs are about 8 volts r.m.s. (+20dBm approx). The microphone signal output level is, in fact, about 5mV/microbar. □

To be continued.

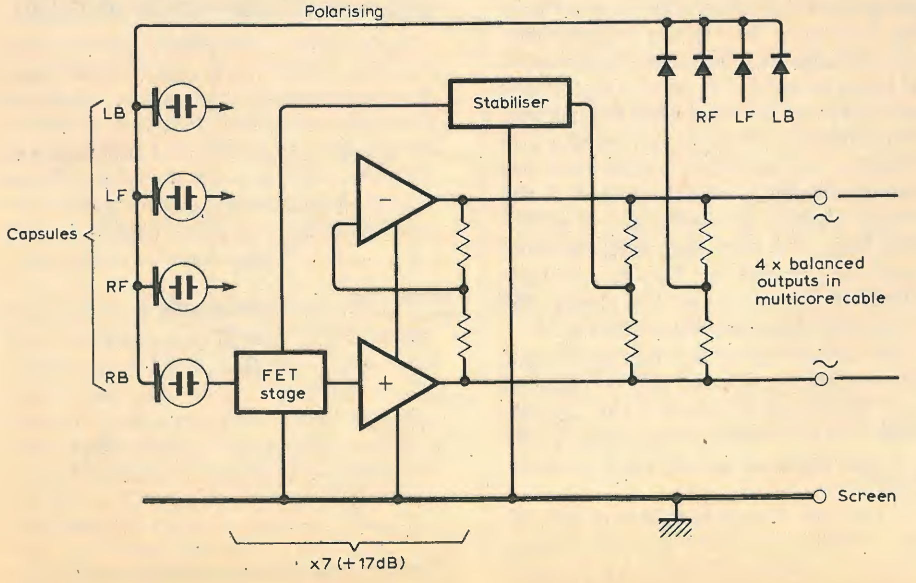


Fig. 7. *One of four identical amplifiers.*

References

The references will appear in Part 2 of the article.

Radio for 2000 A.D.

How the WARCs began: background to the Geneva world conference

For ten weeks, from 24 September till 30 November, government representatives from 154 countries are meeting in Geneva at a world conference organized by the International Telecommunication Union to re-plan the use of the radio spectrum. In particular the 2000 delegates are revising, harmonizing and bringing up to date the 1500 pages of international regulations on radio services, and a large part of their task is to re-allocate frequencies to these various services. Decisions made by this World Administrative Radio Conference (WARC 79)* will have the force of an international treaty and will set the pattern of radio use till the year 2000 or even later. The last conference with comparable powers was held in Geneva in 1959. This article sketches the history of the WARCs from the time they were started by a small incident at the turn of the century.

IT'S A FAR CRY from this year's WARC, with its 154 countries and immensely deliberate preparations, worked out in great detail over several years, to the somewhat hastily convened meeting of only nine nations which started the whole series in 1903. This first conference, held in the Imperial Post Office in Berlin, was in fact triggered by an embarrassing incident on the high seas involving commercial hostility and wounded feelings. It was at the time when radio was radio telegraphy, using spark transmitterss for communication mainly between ships and between ships and shore stations. The scene was dominated by two rival wireless systems, from Germany the Slaby-Arco-Braun system, operated by the Telefunken and AEG companies, and from Britain the Marconi system, developed and operated by the company of that name. Both were trying to capture world markets in wireless equipment. Apart from the straightforward business competition the principal cause of bad feelings was that the Marconi Company had a policy of discouraging radio stations fitted with their system from communicating with other stations equipped with foreign installations. They felt that as they were the only company offering a complete ship-to-shore service they did not want to provide the rival organization with shore facilities for which it was not helping to pay the upkeep.

The whole business came to a head in 1902 when Prince Heinrich of Prussia went on a visit to the USA and sailed for New York in the *Kronprinz Wilhelm*. This ship was fitted with Marconi apparatus and during the voyage the Prince was treated to a demonstration of the then new technique of tuning (called syntony in those days) and, more significantly, of communication with shore stations. But on the return trip to Germany Prince Heinrich sailed in the *Deutschland* which, although owned by the same shipping company, was fitted with the German Slaby-Arco-Braun wireless equipment. On the way out from New York the Prince wanted to send a courtesy message back to President Theodore Roosevelt but found that he was refused service because the apparatus on his ship was of different make from that of the (Marconi-equipped) shore station at Nantucket.

Heinrich, being both a prince and a Prussian, was not amused and, back in Germany, the incident was regarded as something of an insult. The refusal of service stung the Germans into calling for an international conference on wireless telegraphy, ostensibly for the reason that it was for the general good of mankind. This duly took place in August 1903 in Berlin and was attended by representatives of Germany, Austria, Spain, USA, France, Great Britain, Hungary, Italy and Russia. The first proposition put up by the German government, not unexpectedly, was that "Radio-telegrams originating from and destined for ships shall be received and forwarded without regard to the system employed." A final agreed statement in similar terms was ratified by all the delegates except those of Britain and Italy, because these two countries were heavily committed to the Marconi system. (In fact Britain and Italy were not full signatories to the "final protocol" of the conference but made declarations merely as observers.)

Going through channels

From a technical point of view, a more significant decision reached by this first conference was that "The working or wireless telegraph stations must be organized, as far as possible, in such a manner as not to interfere with the working of other stations." Obvious now, but at that time the technique of tuning had only just been invented and the need for radio communication systems to work in separate channels, each defined by a strict band of frequencies, had not been fully appreciated. Thus began, in a simple way, the principle of regulating the use of the radio spectrum by international agreement. The conference, known as the Preliminary Conference on Wireless Telegraphy, was in fact the first attempt to work out, as the French delegate put it, an "inteligent set of regulations" at a time when radio was still in its infancy. They became the basis for the international radio regulations that have existed ever since and are now being revised at WARC 79.

First I.R.C.

The next world conference took place also in Berlin, in 1906 and, because of the preliminary nature of the 1903 gathering, was called the First International Radiotelegraph Conference. It was attended by 30 nations. This was closely modelled on the Convention of the International Telegraph Union of St Petersburg of 1875, which had proved successful. Accepted by the Berlin Radio Conference, it embodied the fundamental structure for all subsequent conferences. Annexed to the decisions made at the conference was a set of radio regulations which was also modelled on the telegraph regulations annexed to the Telegraph Convention. The Berlin Radiotelegraph Convention and the radio regulations went into effect on 1 July 1908 for "an indefinite period".

The principal issue at the 1906 conference, as it had been in 1903, was the question of obligatory intercommunication between stations using different equipment. Thus, one of the noteworthy provisions of the Berlin event was the obligation to connect the coast stations to the international telegraph service. Others were to give absolute priority to all distress messages, and to avoid radio interference as much as possible. The conference also decided that the Bureau of the International Telegraph Union at Berne should act as the central admin-

*See appendix for the agenda of the conference.

istrative organ of the radiotelegraph conferences.*

Questions of a more technical nature were the main work of this 1906 conference, however, as well as of subsequent conferences. In particular it was concerned with the allocation of frequencies. Two wavelengths for public correspondence in the maritime services were established, and another was reserved for "services not open to public correspondence," meaning military and naval stations. In addition, details of all stations, such as their frequencies, call signs and radio systems, were to be sent to the Berne Bureau. Procedure for ship-to-shore (and vice-versa) radio communication was laid down, giving coast stations priority of transmission and the right to determine the order of receiving messages. Although the choice of radio apparatus was unrestricted, technical standards were laid down with the proviso that apparatus should "keep pace with scientific and technical progress".

Sea-going wireless

With the steady progress of radio technology, it became necessary to call a second radio conference, in London, in 1912. By then there were some 479 coast stations, 327 of which were for public use, and 2752 ship stations, of which 1964 were open for public correspondence while the others were mainly naval stations. Aircraft had come onto the scene and some had been fitted with radio, but the conference considered it too early to take official action in this new sphere. Shipping dominated their thoughts for the conference opened only three months after the sinking of the *Titanic*, perhaps the worst maritime disaster to date. Safety at sea through radiocommunication became a major consideration. The British Postmaster-General, in his opening address, said there was a pressing need for a "wider use of radiotelegraphy on the open sea and for the investigation of new methods to make it more effective . . ." Obligatory communication between ships at sea was consecrated in a new article, although the installation of radio aboard all ships could not be ordered since it was considered that this would trespass on the internal jurisdiction of individual countries. However, the conference imposed a system of safety watches aboard ships carrying radio. Allocation of frequencies again came up for revision, including those for the three new services of radio beacons, weather reports and time signals. Decisions were also taken on the routing of radio telegrams via ships and coast stations.

By the time the next International Radiotelegraph Conference took place, in Washington in 1927, three important advances had been made in radio technology: sound broadcasting; radio in aircraft; and the extension of the frequency spectrum into the short wave bands of 3MHz and above. A new Radiotelegraph Convention was drawn up at the Washington conference, together with new general Radio Regulations and Additional Radio regulations. This new Convention included "all radiocommunication stations established, or operated by the contracting Governments, open to the international service of public correspondence," thus including any new public services which had been developed or could be developed later on. In addition, the scope was enlarged to include a large number of services not open to public correspondence and steps were taken to help eliminate interference from and with other services and also with a view to preserving the secrecy of radio communications.

It was the 1927 Washington event that could be called the first truly modern telecommunications conference. Besides the 80 countries represented it included 64 private companies, broadcasting organizations, and other international bodies interested in radio, all of which attended in a non-voting capacity. Foremost among the decisions taken was that which created the International Radio Consultative Committee (CCIR) to "undertake the study of technical and other questions concerning (radio) communications". Another milestone was the drawing up of the first frequency allocation table.

It also agreed at Washington to examine the question of combining the radiotelegraph and telegraph conventions, and it was decided that the next radio telegraph conference would be held in Madrid in 1932, the same place and time scheduled for the next meeting of the Telegraph Union. The 13th International Telegraph Conference and the 3rd International Radiotelegraph Conference which met simultaneously in Madrid in 1932 were two separate legal entities; but liaison was established by the setting up of joint committees to consider common questions. The most important achievement of the Madrid conference of 1932 was the creation of a single convention containing the general principles considered to be common to the telegraph, telephone and radio services.

By this time of course broadcasting had become well established and short-wave transmitters of small power were sending messages round the world. Radar had been invented, and in 1936 aircraft were being tracked on a cathode-ray tube at a distance of 120km. In this year also there were regular television broadcasts from Britain and Germany, and the Olympic Games were televised from Berlin. The first public video telephone service on coaxial cable was opened between Berlin and Leipzig in same year and was extended to Munich in 1938.

The 1938 Cairo Conference was mainly concerned with frequency allocation and also insisted on higher technical standards for transmitters through improved frequency tolerance and bandwidth tables. It produced the first-ever allocation of radio channels for intercontinental air routes in the band 6.5 to 23.38MHz, which provided for existing and future services. In fact this was the first allocation ever made in anticipation of the future. The CCIR was charged to study "operating questions" as well as technical radio questions, and the interval between its meetings was reduced from five to three years.

Post-war conference

In the summer of 1947, some 1600 delegates from 76 countries gathered in Atlantic City, at the invitation of the USA, for an ITU Plenipotentiary Conference, together with an administrative radio conference and an administrative high frequency broadcasting conference. These meetings attempted to bridge the gap caused by the second world war, for many of the old problems had changed because of technical progress in intervening years since 1938. But the most important result of the Atlantic City event was the creation of the International Frequency Registration Board (IFRB) to deal with the notification and registration of frequencies in a master frequency list. Another important outcome was the formulation of an entirely new volume of the Radio Regulations to deal with the phenomenal expansion of radio.

Modern times

The main task of the last WARC, which opened in Geneva on 17 August 1959 and lasted four months – perhaps the longest in the history of the ITU – was to revise the Radio Regulations. This impressive document of 640 pages, with its 1632 paragraphs of regulations and 165 paragraphs of additional regulations, its 27 appendices, its 15 resolutions and 37 recommendations, deals with an astonishingly wide range of radio subjects. The most important is a table of frequency allocations from 10kHz to 40GHz in the three defined regions of the world, with their 26 different users of the radio spectrum. Much space is devoted to the notification and registration of frequencies, there is a table of international call signs to identify radio stations, and the administrative provisions and working conditions of mobile and fixed radio stations are also carefully defined. These and many other provisions, including the order and priority of radio-communications, radio direction-finding, navigation for aircraft and ships, amateur radio, as well as other regulations of a more technical nature, make the Radio Regulations one of the most valuable tools now available for international co-operation.

*The forerunner of the International Telecommunication Union which came into being at the 13th International Telegraph Conference and the 3rd International Radiotelegraph Conference which met simultaneously in Madrid in 1932.

The 1959 conference brought ITU right into the space age, for the Russians had launched the first Sputnik in 1957. In view of the rapid development in communication with space vehicles, the conference decided to convene an Extraordinary Administrative Radio Conference in 1963, "to examine the technical progress in the use of radio-communication for space research and the results of technical studies by the CCIR . . . " and to decide on "the allocation of frequency bands essential for the various categories of space radio-communication." Summing up the work of the 1959 conference in a speech at the closing meeting, its chairman, Mr C. J. Acton, predicted that there would be "an increase in tempo in the development and use of frequencies in the higher part of the radio spectrum. Some of these developments, for example the use of telecommunications relating to outer space, could be of worldwide significance".

And now to WARC 79, which will be the largest gathering ever in the history of the 114-year-old ITU. The results of its work in revising the Radio Regulations and Additional Radio Regulations will not be known for some months, but in due course *Wireless World* will report, in particular on the re-allocation of frequencies to existing services — for example to short-wave broadcasting, where a big increase in its share of the spectrum is likely – and on the allocation of frequencies to possible new services.

Appendix: Agenda of WARC 79

The agenda for WARC 79 is in the form of a resolution of the administrative council of the International Telecommunication Union. The ITU is a specialized agency of the United Nations for telecommunications. It was founded in 1865 to establish international regulations for telegraphy but later concerned itself with telephony and finally radio. With 154 member countries, it has headquarters in Geneva which house its four permanent bodies: the General Secretariat, the International Frequency Registration Board (IFRB), the International Radio Consultative Committee (CCIR) and the International Telephone and Telegraph Consultative Committee (CCITT).

The resolution states that the agenda of the conference shall be (edited here to remove regulation numbers):

- to review and, where necessary, revise the provisions of the Radio Regulations relating to terminology, the allocation of frequency bands and the directly associated regulations.
- to review and, where necessary, revise the provisions applicable to the co-ordination, notification and recording of frequency assignments except those Articles relating to a single service.
- to review and, where necessary, revise the other articles applicable to more than one service and provisions applicable to miscellaneous stations and services.
- to make any necessary consequential editorial amendments to other provisions of the Radio Regulations and the Additional Radio Regulations resulting from the action taken under agenda items, above.
- to review the report on the activity of the IFRB and revise, where necessary, the provisions relating to its methods of work and internal regulations.
- to study the technical aspects for the use of radiocommunications for marking, identifying, locating and communicating with the means of medical transport protected under the 1949 Geneva Conventions and any additional instruments of thse Conventions.
- to take account of Resolution No. Sat-10 of the World Broadcasting-Satellite Administrative Radio Conference, Geneva 1977, on the possible re-arrangement of the Radio Regulations and Additional Radio Regulations, to make such consequential changes as may be necessary to harmonize the Radio Regulations as well as the Additional Radio Regulations and to undertake any further necessary refinement and deletion of superfluous or redundant provisions.
- to consider the proposals based on the CCITT studies carried out in accordance with resolutions adapted as the World Maritime Administrative Radio Conference, Geneva, 1974, on accounting for public correspondence in maritime radiocommunications, and on interpretation of the provisions in the Radio Regulations affecting the public correspondence services and to take appropriate decisions.
- to consider the resolutions and the recommendations adopted by administrative radio conferences, to take such action as may be considered necessary and to adopt such new resolutions and recommendations as may be necessary.
- to propose to the Administrative Council and to the next Plenipotentiary Conference a programme for convening future administrative radio conferences to deal with specific services.
- to provide, for the benefit of future administrative radio conferences, such guidelines as may be found necessary for optimum use of the frequency spectrum.

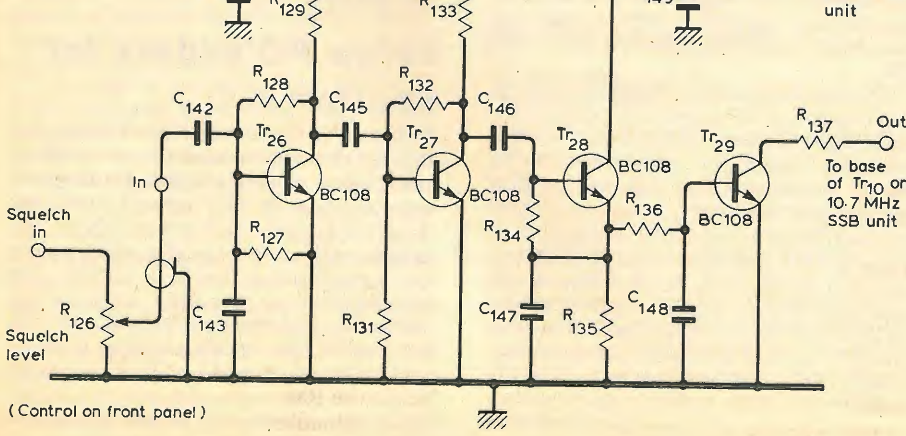
Two-metre transceiver *continued from page 47*

The modulated output from the transmitter is true f.m. and not p.m. (phase modulation) and all reception reports comment on the outstandingly good speech quality.

Squelch unit

Figure 4 shows the circuit of the muting unit which is mounted on a p.c.b. measuring 3¾ × 2¼in. The noise output is taken from pin 7 of the CA3089E and is fed via the panel operated squelch control, R_{126}, to wide band amplifier stages Tr_{26}, Tr_{27} and to the noise detector Tr_{28} and the low-pass filter C_{147}, R_{136} and C_{148}. The collector of Tr_{29} is connected to the base of the first audio amplifier stage in the common output amplifier in the s.s.b. generator unit (Tr_{10} in Fig. 2). Tr_{29} operates as a switch remaining "open" while speech is present and "closed" during breaks in a received transmission when noise is present. Any required threshold level can be set by adjustment of R_{126}, the squelch panel control.

Fig. 4. *Squelch unit*



For components list see page 56.

The author is indebted to R. Ray, G8CUB and the article "A practical phase-locked loop for 2 metres", *Radio Communication*, October 1974, for the initial information on the MC4044P.

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NEWS OF THE MONTH

To cut or spread—Home Office studies mobile radio techniques

Two completely opposite ways of making more efficient use of the frequency bands available for mobile radio are now being considered by the Home Office's directorate of radio technology. One is single-sideband operation, in which the bandwidth requirement is reduced theoretically by half; the other is spread-spectrum operation, in which a very much greater amount of frequency space is used but the signal/noise ratio can be very low.

Investigations into the feasibility of s.s.b. for mobile radio have been going on in several research centres, and in our June 1979 issue, p. 96, we reported on demonstrations by Philips Research Laboratories and Pye Telecommunications. Now the Home Office has stated its intention to start trials next year in which s.s.b. with 5kHz channel spacing will be compared with f.m. in 25kHz channels and with a.m. or f.m. in 12.5kHz channels. They say that investigations have arrived at a stage where field trials will be useful but that this does not imply any commitment by them to s.s.b.

Another option, spread spectrum signalling, is being studied at Leeds University on a grant from the Home Office. This technique allows a spread-spectrum transmission to share a channel with other types of transmission, e.g. television broadcasting, and may give better utilization of a multiplexed communications channel. (See August 1978 issue, p. 50, for a report on work by the University of Bath and earlier references.) Typically, it uses a pseudo-random subcarrier, modulated by the baseband information, which produces a noise-like signal occupying a wide band of frequencies. This can be transmitted directly or may go through further modulation processes. As a result of the wide bandwidth of the transmitted signal it is possible to operate with signal/noise ratios of less than unity. (In some applications this means that the signal can be protected from interception and, of course, the large amount of frequency spectrum occupied by the signal makes jamming difficult.) At the receiving end the randomized signal is recovered by cross-correlation with a locally generated pseudo-random sequence corresponding to the transmitted sequence. To make this possible, of course, the local sequence has to be synchronized with the received sequence.

Broadcast-quality lincompex

Standard Telephones and Cables Ltd claim to have introduced the world's first system which will overcome fading and interference on high frequency radio links to a standard acceptable to broadcast operators. During transmissions, received signal levels can change rapidily due, among other things, to multipath propagation, presenting problems to the broadcast engineer. STC's new system is claimed to eliminate these problems and also reduce the noise and interference accompanying the signal. The system, called radio-relay lincompex (linked compressor and expander), is based on the conventional communications lincompex which was first introduced in the late 'sixties.

The equipment, which is intended for point-to-point transmission over a 6kHz audio channel, has been designed to conform generally to British Broadcasting Corporation specifications and, like the conventional lincompex, it consists of a transmit unit and a receive unit. Programme material is fed from a studio through the transmit unit and into the transmitter. At the other end of the link, the receiver passes the signal to the receive unit which feeds the reconstituted programme material to the radio station transmitter for broadcasting. According to STC, the signal quality with the new system is high enough for it to compare with reception from a landline link or local transmitter. With radio-relay lincompex, they say, it is possible to use lower power transmitters for the studio to broadcast station link, and the transmitter's range can also be increased.

Although the communications lincompex was put to the test by the BBC in about 1968, it was used only rarely and, according to a BBC spokesman, is not used at all now. The new radio-relay lincompex has been designed for use between main radio stations' studios and local broadcast transmitters or distant studios and main broadcasting stations, but it remains to be seen whether the BBC or the IBA will use it. STC say, however, that the new equipment has been used by export customers and has proved to comply with the BBC specifications.

The Appleton and Rutherford laboratories merger—SRC chairman

In November 1976 the Science Research Council decided to set up a working party to look into the future of the Appleton Laboratory because for some time there had been concern about the problems of providing proper support for the national space science programme required for the 1980's from the relatively limited resources available at Appleton. This was made worse because at the same time the Engineering Board was seeking to increase the amount and the scope of work in radio propagation and communications systems. Based on the working party's report, which was presented in July 1978, further information supplied afterwards and the views of the SRC staff, the Council decided in October 1978 that the Appleton and Rutherford Laboratories should be brought together under commmon management. It was also decided that the Ditton Park (Appleton Laboratory) site should be closed and as much work as possible transferred from there to the Chilton (Rutherford Laboratory) site.

The SRC chairman, Professor Geoffrey Allen, said in a *SRC Bulletin*, June 1979, that the final decision was principally influenced by the advantages that were seen to be obtainable for the major scientific programmes in space and communications on which the Council expect to be engaged over the next decade. The UK, he said, was at a turning point in its space research programmes and there was already a growing demand for experiments to be conducted from space. If the UK was to remain a major force in space science, he said, the SRC had to have the capability to manage the development of complex projects, especially if it was to exploit the new launching systems that would soon be available outside the UK. By combining the experience and expertise of the two laboratories the Council believed that it could create a team that could call on the resources required to provide a strong focus for the support of space research in the UK.

The Council did consider whether it would be possible to achieve the same result without moving the teams onto one site, but they eventually came to the conclusion that this was not practical. It has been decided that the Appleton Astrophysics Research Division from Culham will move to the Chilton site in October 1980, and the UK team on the Infra Red Astonomical Satellite during the same year. However, the majority of the work on the Ditton Park site will not be moved to Chilton for about two years because accommodation is not yet ready for them.

Large PO orders for Redifon

A recent order for Redifon Telecommunications Ltd to supply racking for a Post Office radio paging contract has brought the total value of orders in the contract to close on £1,500,000. Each six-foot rack will carry two transmitters and control unit, a power supply unit, aerial changeover relay, alarm and telephone units. An earlier order in the contract was for Redifon's PT2100 v.h.f. 100 watt transmitters. The equipment is to be used in the staged nationwide extension of PO radio paging.

News in brief

A symposium on **'Instrumentation in potentially explosive atmospheres'** will be held at the London Press Centre, London EC4, on October 9 and 10. The event is being jointly sponsored by Sira Institute Ltd, GAMBICA (the Group of Associations of Manufacturers of British Instrumentation, Control and Automation) and CBMPE. The aim of the programme is to promote an understanding of the implications of present international standards and codes of practice relating to electrical instrumentation, and to explain and to encourage constructive discussion on technical trends requiring the generation of future standards. Further information can be obtained from Mrs R. G. Keiller, Sira Institute, South Hill, Chislehurst, Kent BR7 5EH.

Crellon Electronics Ltd have announced that they have signed a distribution **agreement with Litronix** who are major suppliers of opto-electronic components in Europe and the UK. Crellon say that this new franchise complements their existing range and they estimate that in the next twelve months it will be worth over £250,000 to them.

Papers on original work relating to research, development or use of non-chemical power sources, such as fuel cells, solar cells, thermo-electric and thermionic generators, are invited for the **12th International Power Sources Symposium** which will be held at the Hotel Metropole, Brighton, England, from September 15 to 18, 1980. Further information may be obtained from the International Power Sources Symposium Committee, P.O. Box 17, Leatherhead, Surrey, KT22 9QB.

Ceefax and the deaf —experimental service

The potential of teletext as a method of increasing the usefulness of television programmes to people with impaired hearing was demonstrated nationally on BBC-1 on September 2 for the first time, anywhere.

Viewers with teletext decoders will see "subtitles" or captions, written to complement a film "Quietly in Switzerland", while those without decoders will not, of course, be distracted by the captions. Following this first transmission, a series of panel games will be captioned, having been selected for the treatment because of the small number of captions needed to explain the game, "Blankety-blank".

The BBC say that the timing of inserted information must be accurate to within one sixth of a second, which means that at the current rate of teletext data transmission (0.25s/page) it will be necessary to interrupt normal page transmissions to synchronize captions with pictures. The effect on normal teletext transmissions will be an increase in access time of less than 5%.

The idea of using teletext for captions on live, unscripted transmission is brought no nearer by the system to be used, in which captions are held in the Ceefax computer store for rapid access. But the BBC, in collaboration with Leicester Polytechnic, is experimenting with the use of the Palantype shorthand system, and has designed a Palantype keyboard whose output is processed by the Leicester computer to give a promising quality of characters.

Peter Rosier or Bob Dulson at the BBC (01-743 8000) would be happy to give advice on the facility, while those with decoders simply dial page 170 on BBC-1 for the panel game captions.

Weed control by microwaves

According to a report from Sydney, Australian researchers are experimenting with microwave weed control techniques in an effort to reduce the use of toxic herbicides. The engineers and biologists, at Deakin University, Geelong, Victoria, are carrying out a one-year project to see whether some common weeds have a chemical composition which will react to microwaves in a different way from crops. If this is so they believe microwaves could then be used to control the weeds, leaving the crop unaffected.

The leader of the project, Dr Van Nguyen Tran, a Vietnamese-born senior lecturer in the university's Electrical Engineering Division, said that the research followed the successful use of microwave techniques in drying and in assisting the germination of different types of seeds. Dr Tran said that they had found some types of seeds with which they had worked, particularly acacia seeds, had characteristics which could be affected by microwaves.

Data communications aids front-line troops

Front-line troops depend on good radio communications, but often electrically-noisy environments make voice communication unreliable and time consuming. In an attempt to overcome this problem, Racal-Datacom Ltd have introduced a new, high-speed, burst data communications device which, when used with existing tactical voice circuits, provides efficient communications in these conditions. The unit, called Merod (Message entry and read out device), has been designed specifically for use by front-line troops and can either be vehicle-mounted or carried with a manpack radio. A number of optional inbuilt modems enable Merod to be used with all u.h.f., v.h.f. or h.f. combat radio networks.

To provide an extremely high error protection the device uses cyclic block code and bit interleaving techniques, together with synchronous transmission. Racal claims that for an average 3dB signal-to-noise ratio, which is below the limit for reliable, clear voice communication by radio, all transmission errors are corrected with a greater-than 99 per cent level of confidence. Burst transmission, at the maximum data rate allowed by the communication system with which Merod is used, in addition to increasing the security of the communications by making message interception more difficult, enables valuable air-time to be used more efficiently.

For example, a message passed over a v.h.f. li[illegible] words per minute will occupy the communications circuit for less than one-twentieth of the time required using voice communications over the same network, according to Racal. An operator can enter and store messages of up to 1000 characters in length on a 32-character keyboard, as shown in the accompanying illustration, ready for transmission or alteration using the built-in editing facilities.

Communications '80 conference and exhibition

The IEE is organising an international conference as part of the Communications '80 exhibition which is to be held at the National Exhibition Centre, Birmingham, England, from April 15 to 18, 1980. The conference will be held at the Metropole Hotel on the NEC site and will cover three themes: public telecommunications, business communications systems, and civil radio and emergency communications. Papers will cover engineering, user and operating interests and factors likely to affect overall strategy in each theme area.

Death of John Scott-Taggart

One of *Wireless World's* first contributors, John Scott-Taggart, [illegible]E., F.Inst. P., has died at the age of 82. Mr Scott-Taggart, who was born in Bolton, was a well-known innovator and writer on radio since the early years. His interest in the subject started when he studied radio as a hobby in 1912 and his first article appeared in *Wireless World* in December 1914.

During the First World War he was an instructor to the First Army and in 1917 he published a series of thirteen articles on valves. He obtained thirty patents from about 1918 and in 1922 founded the Radio Press which published *Modern Wireless* and *Wireless Weekly*. In the 1920s at least 100,000 amateurs built radio sets using his ST100 design, according to one report.

During the Second World War, Mr Scott-Taggart was a Wing Commander responsible for the majority of the radar ground stations in England and Wales, and the training of their personnel. After this war he joined the Admiralty Signal and Radar Establishment, and retired in 1959. In 1963 the Italian President made him a Knight Officer of the Order "Al Merito della Republica Italiana," and in 1975 he was given an OBE for his "services to radio engineering".

Two-metre transceiver

Continued from page 53

Components list for Figs 2, 3 and 4

Resistors (all 10% ½W carbon)

1, 90, 125	33k
3, 5, 8, 20, 32, 112	3k3
4, 6, 7, 12, 28, 35, 36, 39, 40 43, 69, 70	270
38, 42, 50, 9, 21, 26, 34, 113 118	2k2
10, 18, 19, 24, 49, 76, 93, 94 97, 119	4k7
13	1k5
14, 74, 116	470
15, 41, 89, 130	10k
16, 62, 64, 77, 78, 104, 109	1k
17, 95	2k7
22, 27, 33, 37, 47, 52, 71, 73 79, 83, 84, 96, 100, 115, 120 127, 131, 135	100k
23, 29, 53, 92, 111, 114, 121 129, 133, 134	47k
30, 31	560
44, 51	1k2
48, 72, 80, 85, 102, 106, 110	27k
54, 56, 59	680
55	47
58, 82, 86, 99	220
60, 61	2.2
67, 103, 105, 108	150
68	820k
87, 122, 123	330
88, 98	100
91, 107, 136	6k8
128, 132	220k
137	200

Capacitors (μF unless otherwise stated)

1	200n polyester 20%
2, 15, 17, 20, 21 42, 44, 45, 63, 64 66, 67, 93, 94, 105 115, 117, 139, 150	1n polyester 20%
4, 5, 6, 8, 9, 11, 13 19, 22, 23, 26, 33 34, 39, 43, 47, 48 49, 50, 53, 54, 55 58, 59, 61, 77, 78 79, 81, 82, 84, 85 86, 87, 89, 91, 92 98, 99, 101, 102 103, 104, 106, 107 109, 110, 112, 113 118, 119, 122, 123 126, 140, 141	10n polyester 20%
41, 90, 108, 114, 121 131, 138, 147, 148	100n polyester 20%
16	470n polyester 20%
36, 37, 69, 71	2.2 50V single ended
132, 134, 135	2.2 50V
35, 38	10 10V
80	10 25V single ended
130	10 50V
74	47 25V single ended
129	47 25V
40, 70	100 25V single ended
68, 72	100 10V
88	100 25V
76	220 25V
75	470 25V
116, 137, 144, 149	32 16V
133, 136	5 15V
3, 97	150p polystyrene 5%
142, 145 7, 12	47p polystyrene 5%
10, 14, 25, 46, 51 56, 60, 83, 100, 120	130p polystyrene 5%
52, 57	56p polystyrene 5%
73, 125, 127, 143	100p polystyrene 5%
95, 96	22p polystyrene 5%
124	68p polystyrene 5%
146	330p polystyrene 5%
18, 30, 32, 65	35p ceramic trimmer
111	2-15p ceramic trimmer
24	2.2p tubular ceramic
29, 31	20p tubular ceramic
62	3.3p tubular ceramic
27, 28	220p tubular ceramic
128	15p silvered mica

Transistors

1, 2, 7, 8, 9, 16, 17 18, 19, 20	RCA40673
3, 6, 24	2N3819
4, 5, 10, 12, 15, 21 22, 23, 25, 26, 27 28, 29	BC108
11	BCY70
13	AC176
14	AC128

Coils and r.f. chokes

1, 6, 10, 11, 13, 18	1mH 7BA Toko*
2, 3, 4, 7, 8	20 turns 36 s.w.g. enam. close wound
5, 12, 19	20 turns 36 s.w.g. enam. close wound, 6 turn primary overwound at cold end of secondary
9	20 turns 36 s.w.g. enam. close wound, 6 turn secondary overwound at cold end of primary
20	30 turns 36 s.w.g. enam. close wound on 5mm diam. former with dust core
14, 15	KALS4520A Toko*
16	22μH 7BA Toko*
17	33μH 7BA Toko*

Coils L_2 to L_5, L_7 to L_9, L_{12} and L_{19} are wound on 5mm formers, 9mm pin spacing, with 14mm square by 20mm high screening cans, with dust cores.

*available from Ambit International

Switch

1	1 pole 3 way 4 bank RS Components

Meters

1	SR-38P S-meter Shinohara Electrical Ltd.
2	100μA edgewise A.J.H. Electronics

Filters and crystals

YF.107F 2.4	South Midlands Comms Ltd.
XL1	10,701.5kHz
XL2	10,698.5kHz
445-LQU-901B	Kinnie Components
XL3	10,700.00kHz series resonance
XL4	10,700.00kHz parallel resonance P.M. Electronics

Variable resistors

2, 25, 57, 81, 101 117	10k miniature preset
11, 45	1k miniature preset
63, 75	100 miniature preset
65	4k7 miniature preset
66	220 miniature preset
46, 124, 126	5k pot. panel mounting

Diodes

2, 3, 11, 12, 16, 17	OA91
1, 4, 5, 7, 8, 10, 14 15, 19, 20	IN914
6, 9	9.1V BZY88Zener
13	BA156
18	2.7V BZY88 Zener
21, 22	8.2V BZY88 Zener
23	3.9V BZY88 Zener

Integrated circuit

1	CA3089E RCA

Fig. 4 can be found in the continuation of the article on page 53.

Printed circuit boards

A set of ten double-sided glass fibre p.c.bs is available for £35.00 (inclusive of v.a.t. and postage) from M. R. Sagin at 23 Keyes Road, London NW2. The boards are supplied roller tinned and drilled, and have all clearance areas etched in the ground plane. The ten boards accommodate a s.s.b. generator, f.m. generator, Rx converter, Tx converter, crystal oscillator and mixer, phase detector and loop filter, squelch unit, v.f.o. circuit, v.c.o. circuit and v.c.o. amplifier.

Looking into current mirrors

Design criteria for circuits using matched collector currents

by F. J. Lidgey Ph.D., B.Sc. Oxford Polytechnic

Subject to the use of well-matched devices, the current mirror circuit can perform some useful analogue functions. As well as acting as square and square root "calculators", they can perform in several standard amplifier circuits. This outline of the main features of current mirrors also contains practical applications in the form of a current sink/source conversion, a differential to single-ended conversion circuit and a "mirror-aided" output drive stage.

THE CURRENT mirror circuit relies on the collector current matching of two transistors (one strapped as a diode) when connected together base to base and emitter to emitter.

The collector current is related to the emitter base voltage in a forward biased transistor quite closely by the equation

$$I_c = I_s\left(e^{\frac{qV_{be}}{kT}} - 1\right)$$

where q is electron charge, k Boltzman's constant, T the absolute temperature and I_s is the forward-biased saturation current, a parameter particular to the exact transistor. I_s is also a function of temperature in addition to the I/T factor of the exponential.

If we can neglect the base currents compared with collector currents, then

$$I_x = I_{cx} = I_{sx}\left(e^{\frac{qV_{be}}{kT}} - 1\right)$$

$$I_y = I_{cy} = I_{sy}\left(e^{\frac{qV_{be}}{kT}} - 1\right)$$

and $I_x = I_y$ for all temperatures if and only if $I_{sx} = I_{sy}$ for all temperatures i.e. accurately matched devices in very close thermal contact.

Current matching (mirror image size)

Manufacturers quote the matching of a single-chip pair of transistors by the difference in V_{be} necessary to obtain the same collector currents.

i.e. $I_{cx} = I_{cy}$ for $(V_{bex} - V_{bey}) = (\Delta V_{be})$

$$\therefore I_{cx} = I_{sx}e^{\frac{qV_{bex}}{kT}}$$

$$I_{cy} = I_{sy}e^{\frac{qV_{bey}}{kT}}$$

where we have made the assumption that $I_{cx}, I_{cy} \gg I_{sx}, I_{sy}$ which is invariably true since I_s is typically 10^{-12} amps or less for a silicon device at room temperature.

If $V_{bex} = V_{bey} = V_{be}$ but (ΔV_{be}) is quoted then we may estimate the error in the current mirror imaging size by the following:

writing $V_T = k_T/q$ then for $I_{cy} = I_{cy}$

$$V_{bey} = V_{be} \pm \Delta V_{be}$$

and so

$$I_{cx} = I_{sy}e^{\left(\frac{V_{be} \pm \Delta V_{be}}{V_T}\right)}$$

$$I_{cx} = I_{sy}e^{\frac{V_{be}}{V_T}} \cdot e^{\pm\frac{\Delta V_{be}}{V_T}}$$

$$I_{cx} = I_{cy}e^{\pm\frac{\Delta V_{be}}{V_T}}$$

$$\frac{I_{cx}}{I_{cy}} = e^{\pm\frac{\Delta V_{be}}{V_T}}$$

at room temperature $V_T \simeq 26$ mV so a ΔV_{be} of ± 2 mV, which is typical for reasonably well-matched transistors, gives

$$\frac{I_{cx}}{I_{cy}} = e^{\pm\frac{2}{26}}; \frac{I_{cx}}{I_{cy}} \simeq 1 \pm \frac{1}{13}; \frac{I_{cx}}{I_{cy}} \simeq 1 \pm .077$$

i.e. ±7.7% error, which is quite substantial.

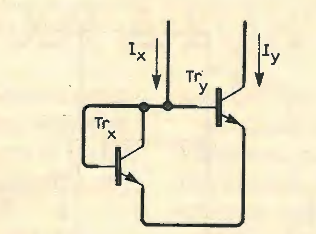


Fig. 1. *Single-chip current mirror circuit*

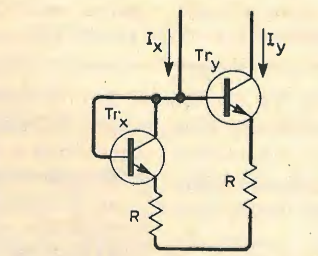


Fig. 2. *"Matched" transistor current mirror*

Thermal matching (mirror buckling)

The relative thermal tracking is not as bad as might at first be expected. Consider

$$I_c = I_s e^{\frac{V_{be}}{V_T}}$$

It is convenient to discuss the temperature variation necessary in V_{be} in order to keep the collector currents the same, given that at a temperature t $V_{bex} = V_{bey}$ for $I_{cx} = I_{cy}$.

Now

$$I_{cx} = I_{cy} = I_{sx}e^{\frac{V_{bex}}{V_T}} = I_{sy}e^{\frac{V_{bey}}{V_T}}$$

Defining the input offset voltage as for $I_{cx} = I_{cy}$ we are interested in the variation of this voltage with temperature

$$\frac{dV_{os}}{dT} = \frac{d}{dT}(V_{bex} - V_{bey})$$

$$= \frac{d}{dT}\left(V_T \ln\frac{I_{cx}}{I_{sx}} - V_T \ln\frac{I_{cy}}{I_{sy}}\right)$$

$$= \frac{V_T}{T}\left(\ln\frac{I_{cx}}{I_{sx}} - \ln\frac{I_{cy}}{I_{sy}}\right)$$

$$+ V_T\left(\frac{1}{I_{sx}}\frac{dI_{sx}}{dT} - \frac{1}{I_{sy}}\frac{dI_{sy}}{dT}\right)$$

the second term is zero since from the physics of the device it may be shown that $1/I_s\ dI_s/dT$ is a constant.

$$\therefore \frac{dV_{os}}{dT} = \frac{V_T}{T}\ln\left(\frac{I_{cx}}{I_{sx}} - \ln\frac{I_{cy}}{I_{sy}}\right)$$

$$= \frac{V_T}{T}\left(\frac{V_{bex} - V_{bey}}{V_T}\right)$$

$$\frac{dV_{os}}{dT} = \frac{V_{os}}{T}$$

so if $V_{os} = V_{bex} - V_{bey} = \pm 2$mV

then $\frac{d}{dT}V_{os} = \frac{\pm 2}{300}$mV/°C $= \pm 6.7$V/°C

Clearly the currents will track well despite a ΔV_{be} of ±2mV but this analysis is valid for transistors at exactly the same temperature. A difference in temperature of a degree or so makes a vast difference in the current mirroring action since the temperature appears in the exponential as well as in I_s.

A discrete "mirror"

If discrete transistors are to be used then we can make use of a form of current mirror by using well-matched resistors in the emitter lines.

If we can again neglect base currents relative to collector currents then

$$I_x \sim I_{sx} e^{\frac{V_{bex}}{V_T}} \; ; I_y = I_{sy} e^{\frac{V_{bey}}{V_T}}$$

but

$$V_z = V_{bex} + I_x R = V_{bey} + I_y R$$

$$\therefore I_y = I_x + \left(\frac{V_{bex} - V_{bey}}{R}\right)$$

From which we see that if we have ΔV_{be} of say ± 10mV for a poorly matched pair, then where R is 10kΩ

$$I_y = I_x \pm 1\mu A$$

and so for currents substantially greater than 1μA the error is small and may be neglected.

Taking base currents into account

Allowing for the base currents then the diode-strapped transistor current I_x in Fig. 1 supplies base current for Tr_x and Tr_y and so clearly since our mirror equation only relates collector currents, $I_y < I_x$, assuming perfect matching.

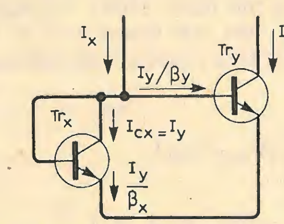


Fig. 3. *Looking at base current*

Examining the currents, since $V_{bex} = V_{bey}$ and assuming matching does exist then $I_{bx} = I_{by}$. Given that the current gains may not be exactly the same then

$$I_x = I_y + \frac{I_y}{\beta_y} + \frac{I_y}{\beta_x}$$

$$\frac{I_x}{I_y} = 1 + \left(\frac{1}{\beta_y} + \frac{1}{\beta_x}\right)$$

Obviously what is needed to ensure a better match of I_x and I_y is to make β_x and β_y as large as possible. Alternatively we need to buffer I_x so that it does not constitute the source for all the base currents.

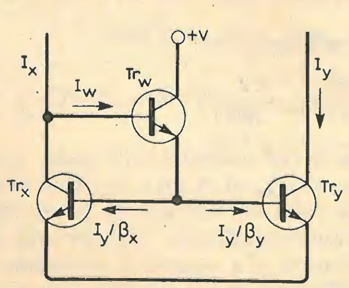


Fig. 4. *Spreading current drain by adding a buffer stage*

Further calculations can reveal information about matching error.

$$I_w = \frac{1}{(\beta_w + 1)} \cdot I_y \left(\frac{1}{\beta_x} + \frac{1}{\beta_y}\right)$$

$$I_x = I_y + I_w$$

$$= I_y \left(1 + \frac{1}{(\beta_w + 1)}\left(\frac{1}{\beta_x} + \frac{1}{\beta_y}\right)\right)$$

From this we can see that the previous error between the matching of I_x and I_y due to the base current loading of I_x is reduced by a factor of $(\beta_w + 1)$. We can go on doing this trick by using a Darlington for Tr_w but then the reverse leakage currents multiply as in all Darlington circuits and so it is sensible to limit this buffering to only one or two transistors in the position occupied by transistor Tr_w.

Some useful applications of current mirrors

(a) Current sink/source conversion

In the circuit of Fig. 5 the current sink I_1 is converted to a current source of the same value. The reverse is also possible where a current source may be converted into a current sink. This may be extended to form a voltage-to-current converter.

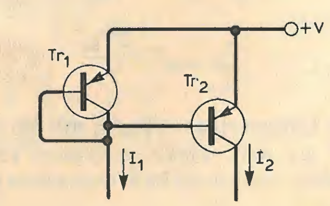


Fig. 5. *Current sink/source circuit*

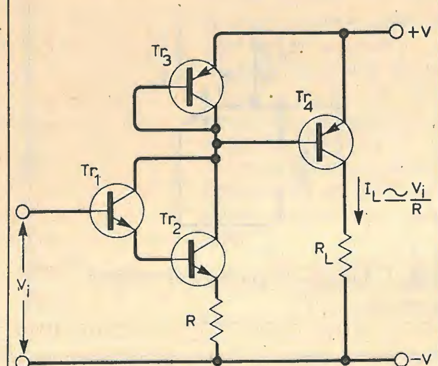


Fig. 6. *Voltage to current converter*

In Fig. 6, Tr_1, Tr_2 and R form a high input impedance (Darlington Tr_1 and Tr_2) transconductance stage which is a current sink drive for Tr_3. This current is mirrored into a current source at Tr_4.

(b) Differential to single-ended conversion

Consider the standard circuit of a differential amplifier shown in Fig. 7.

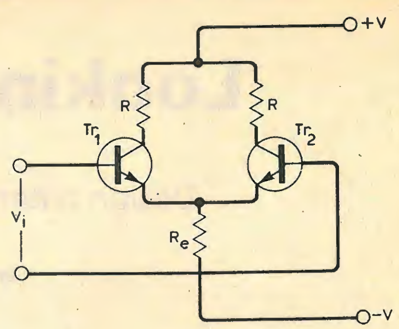


Fig. 7. *Basic differential amplifier*

The small signal voltage gain to a differential input V_i is

$$A_v = +\tfrac{1}{2}\frac{\beta}{(\beta + 1)} R\, g_m$$

Where g_m is the transconductance of a single transistor. Compared with one common emitter transistor we lose half the gain because V_i is driving both transistors equally yet we are only taking the output from one. This problem can be rectified using a current mirror as shown in Fig. 8.

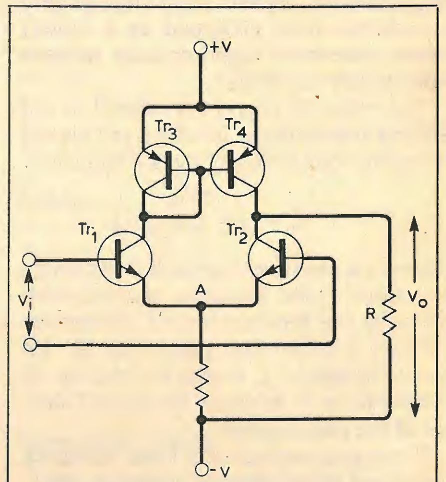


Fig. 8. *Increasing gain by the use of a current mirror*

Point A on the circuit remains at a constant voltage independent of V_i (i.e. a virtual earth) provided the transistors are all well matched. Then, as V_i increases in the direction shown, I_{c1} increases and I_{c2} decreases. As I_{c1} increases this is mirrored by an equal increase in I_{c4}. At the junction of the collectors of Tr_4 and Tr_2 we have an increase of current from Tr_4, yet Tr_2 is decreasing its current. Clearly both components sum into R giving the full differential gain of

$$A_v \simeq \left(\frac{\beta}{\beta + 1}\right) R g_m$$

There is a change in the common mode handling capability of the circuit which must be looked at closely if the circuit is to be used without further modification. This circuit technique is commonplace in the guts of modern op. amps such as the standard 741.

Continued on page 68

Speaker directivity and sound quality

Effects of variation in the loudspeaker polar diagram with frequency

by James Moir, F.I.E.E., James Moir & Associates

The best examples of current loudspeaker design have reached the stage of development where only minor improvements in the overall sound quality can be achieved by further extension or smoothing of the frequency range, or by reduction in the well known effects of harmonic, inter-modulation and Doppler distortion. One distortion, using the word in its widest sense, that has not received its due share of attention is the effect on sound quality of the variation in the speaker polar diagram with frequency. This is discussed in the present article, and also methods of measuring the polar distribution of sound pressure and sound power. "Directivity index" is explained.

A TYPICAL single cone loudspeaker in a closed housing will radiate isotropically at low audio frequencies, the sound pressure being substantially constant at all points equi-distant from the loudspeaker. This is true even at the back of an enclosure that only employs a single forward facing unit. As the frequency is increased the solid angle into which the sound power is concentrated in front of the loudspeaker slowly reduces until it may not be more than 10°-15° at frequencies above 5kHz. This is a fundamental property of all plane surface disk radiators. The sound pressure level produced by an ideal solid disk diaphragm will be down by 3dB at 30° off axis at a frequency of 1kHz, the diaphragm being one wavelength in diameter at this frequency.

The sound pressure generated by a practical loudspeaker diaphragm does not fall off quite so rapidly with increase in the azimuthal angle as that from the rigid disk. Thickness and density graduation, the use of radial and circumferential ribs and similar design tricks can be used by the cone designer to reduce the effective diameter of the diaphragm with increase in frequency and this helps to maintain constant the sound pressure at points well off the axis. At first thought it would appear that the reduction in the off-axis output at high frequencies would be of little consequence to a listener seated on the axis, but experience shows that the effects on the sound quality are indeed obvious to a moderately experienced listener. A loudspeaker having a good (flat) axial frequency response but a poor off-axis response sounds 'hard and tiring' to a listener seated on the axis, while the stereo image tends to jump about with changes in the spectral content of the programme. It is interesting to consider the possible reasons for the effects of the polar distribution on the quality of the sound as this is a subject that is rarely discussed in greater depth than a comment that "cymbals sound better when you sit in front of the speaker, an aspect of the performance that is obvious and will not be further expanded."

The sounds emitted by a loudspeaker arrive at the listener's ears by three routes that require separate consideration if the overall acoustic performance is to be understood.

Group 1. In this group are the sounds that arrive at the listener's ears by the direct and shortest route from the loudspeaker and undergo little modification on the way, for the room boundaries have had no opportunity of affecting the characteristics of the sound. The room acoustics have no effect on these direct sounds.

Group 2. These sounds arrive at the listener's ears during the first few milliseconds after only one reflection from the room boundaries close to the loudspeaker. At each reflection from a boundary the frequency spectrum is modified by the acoustic characteristics of the area of room boundary from which the reflection takes place. In general the higher frequency components in the spectrum suffer greater attenuation at each reflection than do the lower frequency components but this is not inevitable. Thus the first reflections have frequency spectra almost identical to those of the direct sounds which they follow with a delay of only 2-5 milliseconds.

Group 3. These are the sounds that arrive at the listener's ears after many reflections, i.e. after at least ten to twenty reflections from the room boundaraies remote from the loudspeaker. This is the generally reverberant sound that is usually considered to be the 'room reverberation'. As was noted in the preceding paragraph the higher frequencies are generally more heavily attenuated at each impact with a boundary so the frequency spectrum of the reverberant sound gradually changes during the decay of the sound, the later reflections having reduced energy in the higher frequencies.

However, the reverberant sounds differ in another and very significant way. The sound field in a room does not become increasingly diffuse with the passage of time as is generally thought, but instead becomes increasingly ordered, with the sound energy concentrated in well defined spatial patterns even at the lower frequencies. The primary components of the reverberant sound energy are concentrated along the three axes of the room in the frequency bands for which the room length, width, and height are one half wavelength and at the harmonics of these frequencies. There are secondary components of the spatial pattern at frequencies that are determined by combinations of the axial dimensions of the rooms and further groups with frequencies determined by combinations of all three axial dimensions. Thus reverberation is not the decay of a diffuse sound field but the decay of a well defined pattern of sound distribution over the whole of the room volume. The sound field becomes *less* diffuse and more ordered as the decay proceeds, with the sound energy concentrated in the narrow frequency bands that constitute the modes of oscillation characteristic of the room. This is particularly true at the low frequency end of the spectrum.

Following this digression we can go back to consider the effect of the loudspeaker polar diagram on the resultant sound field in the room. There will clearly be no significant effect on the energy in the sounds that arrive first by the most direct path, for the room boundaries will have had no opportunity of reacting on the sound.

The sounds in group 2 that arrive by the second route during the first few milliseconds following the arrival of the direct sound will be affected by the polar distribution of the loudspeaker. At those frequencies at which the polar distribution is very narrow, generally the higher frequencies, the sound energy arriving during the first few milliseconds will be decreased, for less energy will strike the room boundaries in the vicinity of the speaker and be reflected from these boundaries. Thus the first effect of a narrow polar diagram is to minimise the intensity of the sound in the reflections occurring during the first few milliseconds. If the loudspeaker is pointing down the length of the room the sound energy in the reflection from the far end walls will be increased.

The sound energy in the 3rd group of reflections is more radically modified by a loudspeaker having a narrow polar diagram. Assuming the simplest possible case where the direct sound energy is all concentrated in a forward facing beam from a loudspeaker pointing down the room, there is then no energy fed directly into the resonant room modes other than the main length mode and its harmonics. Those modes of room resonance in which the sound energy oscillates along the width and height axes of the room receive no energy from the loudspeaker until it is scattered into these modes after many reflections from the boundaries at the ends of the room. In consequence the width and height modes will have no effect in colouring the early sounds but will colour the sounds arriving at the listener's ears 20 to 300ms after the direct sound.

In contrast a loudspeaker radiating isotropically will feed sound energy into all the room modes immediately it is excited. This energy will then be concentrated into all the mode characteristics of the room shape and the sound intensity in each mode will grow and decay at a rate controlled by the energy absorption in that particular mode. Each individual mode of resonance will have its own characteristic reverberation time with the important difference that all the room modes begin to be excited almost immediately the loudspeaker is excited.

Thus a listener sitting on the axis of a loudspeaker having a narrow polar diagram will hear sound that differs from that heard from a loudspeaker having a wide polar diagram, even though both speakers have a flat on-axis response. If the polar diagram is narrow the earlier reflection will be minimised and the later reflection will carry most of the sound energy. If the polar distribution covers a wide angle then the sound energy tends towards being uniformly distributed over all the early and late reflections, the sound energy/time distribution being determined by factors other than the loudspeaker polar diagram.

A loudspeaker having a "narrowish' polar diagram invariant with frequency will always tend to minimise the effect of the room acoustics on the quality of sound reproduced in the room. Dipole radiators such as the electrostatic speaker or a cone type loudspeaker in a flat baffle will sound rather 'dry' in some rooms, particularly those with a short reverberation time. A dipole radiator has no radiation in the plane of the diaphragm and thus provides the minimum excitation of the height and width room modes. Appropriate placement of the speaker allows one to vary the modal excitation to suit the room characteristics, an advantage not possessed by a speaker having a wider polar diagram.

The obvious alternative, the use of a loudspeaker system that radiates equally in all directions, proves to be almost equally unacceptable, the stereo image being diffuse and only vaguely located. It is significant that over the last twenty years many loudspeakers have appeared on the market with claims to a high degree of uniformity of the sound power distribution round the loudspeaker, but almost all of them have vanished from the field after a relatively short burst of popularity. This suggests that there is some optimum distribution of sound energy in front of a loudspeaker if the stereo image is to be well defined and the sound quality is to be 'soft and non-tiring' to the listener.

It would be of considerable value if the optimum polar distribution for a domestic speaker could be specified, but so far this has eluded definition, for it is difficult in the present stage of the art to design an experiment that will provide an even moderately unambiguous answer to the question, particularly in small domestic sized rooms. A start can be made by outlining the methods of defining the polar diagram of a loudspeaker.

The variation in sound pressure level at points off the axis of a loudspeaker is generally indicated by a polar point typified by Fig. 1, showing the sound pressure level round the loudspeaker at a few representative frequencies in the azimuthal plane. This plot does not make the performance particularly obvious when this has to be subjectively judged. The sound pressure level usually changes much more rapidly with change in the vertical angle than with changes in the azimuthal angle. Thus any specification of the polar distribution over the space in front of the loudspeaker requires polar diagrams in two planes at least, but even given this, it requires some mental gymnastics to visualise the distribution over the intermediate angles. It requires even more mental gymnastics to come to any reasoned decision about the subjective results of the variation in polar response with frequency. The off-axis frequency response of most speaker systems is markedly more irregular than the axial frequency response, but the irregularities may not be obvious for the standard form of polar diagram displays the performance at only a few frequencies.

An alternative presentation that has several advantages is to plot the frequency response on the speaker axis and at 15° or 30° intervals off the axis, much as shown in Fig. 2. This makes the change in the frequency response off-axis easier to visualise, but it is still necessary to have a second set of response curves to illustrate the change in frequency response with change in the vertical angle.

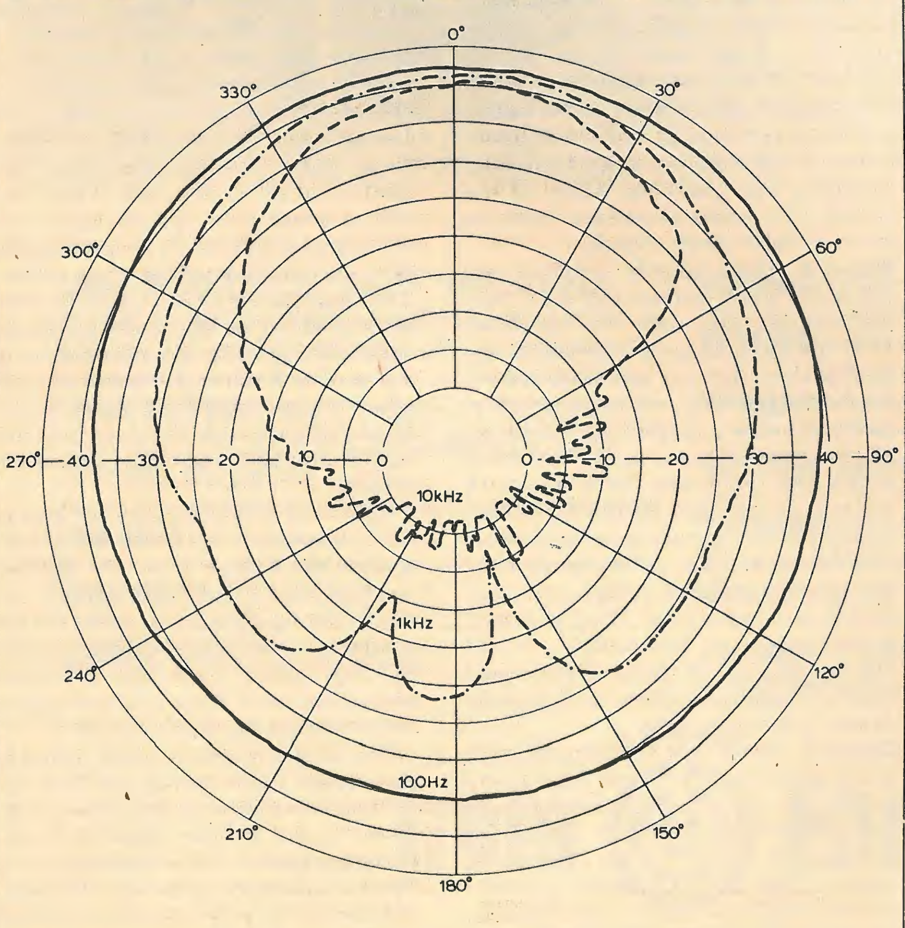


Fig. 1. *Typical polar diagram, giving variation in sound pressure level at points relative to the axis of a loudspeaker. Plots at three different frequencies are shown.*

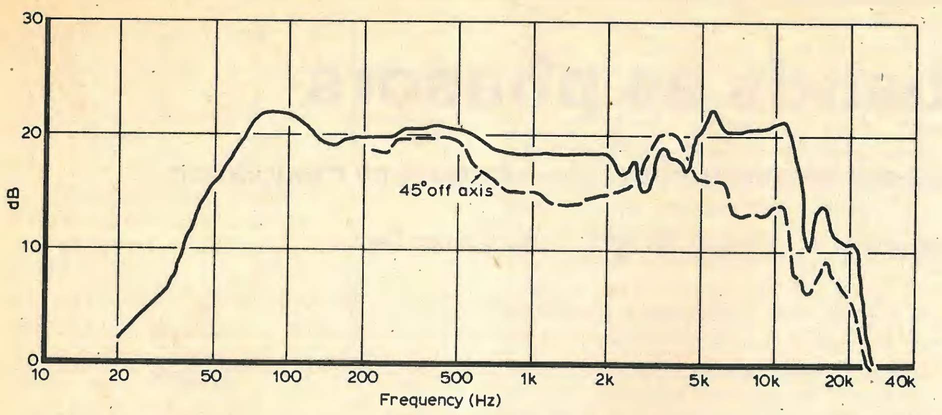


Fig. 2. *An alternative presentation of speaker directivity to that in Fig 1. The frequency response is plotted for the speaker axis and for other angular distances from the axis.*

During the past few years, a third possible presentation has appeared and as it has several advantages it deserves consideration. The basic change is the use of sound power rather than sound pressure as the parameter indicating the change in output with change in the angular displacement of the listener from the axis.

If the sound pressure distribution round the loudspeaker enclosure is not uniform at all frequencies execpt when measured on the axis of the system, it will be obvious that the total radiated sound power will decrease with increase in frequency. Thus a flat axial sound pressure/frequency response usually indicates that the sound power/frequency response is not uniform but falls off with increase in frequency. Conversely a flat (uniform) sound power/frequency relation usually indicates that the axial sound pressure/frequency response rises with increasing frequency.

The extent to which the sound power/frequency response varies with frequency can be conveniently indicated by quoting either the "Q" or the Directivity Index (DI = 10 log "Q") of the loudspeaker. As the use of sound power in specifying speaker directivity is probably a new concept to many readers (and "Q" an unfortunate choice of symbol) it will be explained more fully.

Sound power is proportional to the sound pressure squared so the parameter "Q" is the ratio of the total power actually radiated to the power that would be radiated if the axial sound pressure was maintained constant all round the loudspeaker. When this uniformity of distribution is achieved the loudspeaker has a "Q" of 1. It is a condition that is usually approximated at low frequencies. "Q" is the transatlantic term but the "Directivity Index" appears more appropriate in view of the prior use of Q to describe the performance of tuned circuits etc.

Fig. 3 shows the "Q"/frequency relation for a well-known three-unit system when measured in the open air. When measured in a room with the speaker back against a wall the "Q" will be increased in the low frequency range for the working "Q" is affected by the proximity of the walls. However, when considering the effect of the speaker directivity on the acoustic performance of the room it is the "Q" measured in the open air that is significant and not the "Q" that results from the speaker radiation being controlled by the room walls.

In the higher frequency band, and assuming that the speaker system has a flat frequency response when measured on the axis, the off-axis output will fall away and in consequence "Q" or "DI" will rise. A typical current speaker system will have a "Q" around 4 at frequencies in the 3-5 kHz region.

Omni-directional loudspeakers have been tried by several speaker manufacturers and are generally considered unsatisfactory but the reasons for this are hard to define with any real conviction. Increasing the directivity of a speaker system results in a design that has the radiated acoustic power concentrated in a solid angle less than 360°

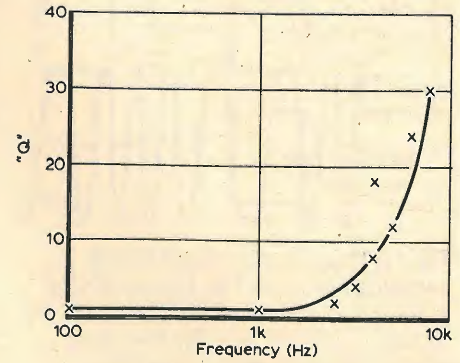


Fig. 3. *Plot of "Q" against frequency for a typical three-unit speaker system.*

and this has proved advantageous. It might even be said to be essential if a good stereo image is to be obtained. Unfortunately if has not yet proved possible to design a loudspeaker that has uniform directivity at all frequencies in the audio band. Though it has not proved possible to achieve this uniformity of distribution it is interesting to speculate on the reasons for thinking that it should be the target.

Achieving a good solid and firm stereo image requires a high ratio of direct to reflected sound, for it is only the direct sound that carries the basic information about the location of the stereo image in the space between the loudspeakers. The sound reflected from the room boundaries, particularly those in the vicinity of the speaker, can only serve to dilute the basic directional information. Thus to achieve a good stereo image we need to minimise the amount of reflected sound. One obvious way of achieving this is to design the loudspeaker and locate it in the room in a position that minimises the amount of sound falling on the room walls. The required result cannot be achieved by covering the room surfaces with sound absorbent, attractively simple though this solution may appear, for this reduces all the wall reflections, whereas an increase in speaker directivity increases the intensity of the direct sound and reduces the intensity of the early reflections and it is this we wish to achieve.

Room sizes

In large rooms of average proportions where the working "Q" is not significantly affected by the proximity of the room boundaries, experiments involving the subjective judgement of the acceptable loss in speech intelligibility suggests that a "Q" in the region of 20 at frequencies above 500Hz is about right. In domestic sized rooms a "Q" around 10 appears reasonable but more evidence on this aspect is required. This is not easy to obtain for design changes are necessary to change the "Q" and in the present stage of our knowledge it is impossible to change "Q" without affecting several other parameters that affect the sound quality. Uniformity of the "Q"/frequency relation over the frequency band between 500Hz and 10kHz seems more important than the absolute value.

At present it appears fundamentally impossible to design a speaker with substantially constant directivity over the audio frequency band. Constant directivity demands a sound radiator having a diameter that is inversely proportional to frequency and this we cannot achieve in a practical design. However, though a direct solution appears impossible it may be possible to circumvent the problem, an aspect

Continued on page 96

Sidebands as phasors

Depicting the mechanism of modulation: 2 — frequency modulation

by **J. M. Osborne** M.A., F.Inst.P. South London Science Centre

A previous article, in the September issue, outlined the general principle of using phasors to represent carriers and sidebands and showed how this could be applied to amplitude modulation, d.s.b. and s.s.b. The author now goes on to use this method of representation to illustrate frequency modulation.

IMAGINE A PHASOR swinging like a pendulum. The fact that it is looked at sideways in Fig. 11 (right) is because we are going to take the equilibrium position of our phasor as horizontal (my whim) whereas of course the bob of a pendulum hangs vertically.

We have a phasor which is periodically gaining and losing phase (θ) relative to an imaginary reference phasor. For comparison with the situation of Fig. 1 (September issue), we might consider the reference phasor as representing a carrier of 1MHz and the swinging phasor as having a period of 1ms, i.e. a frequency of 1kHz. The swinging phasor represents a phase modulation of θ as shown in Fig. 12(a). That it also represents frequency modulation is easily established when we consider the phasor at the instant it is passing through the equilibrium position. In one direction (anticlockwise) it is rotating faster than the imaginary reference phasor and so has a higher frequency; in the clockwise direction it has a lower frequency. At the moment it reaches the extremities of its swing the phasor is stationary and has the same frequency as the reference. This is shown in Fig. 12(b). The frequency is gaining and losing on the 1MHz reference at 1kHz. This is frequency modulation at 1kHz of a carrier of 1MHz as shown diagrammatically in Fig. 12(c) – diagrammatically because we cannot show one thousand cycles of the carrier in one millisecond on our time (t) axis.

So far we have shown the identity in this simple case of phase and frequency modulation. The same swinging phasor of Fig. 11 gains and loses a phase angle θ at the modulation frequency (Fig. 12(a)) and likewise gains and loses frequency on the reference (Fig. 12(b)).

I have said nothing about the depth of frequency modulation, only that f.m. is present. The depth (or should I say, degree) of phase modulation is θ. (See Appendix 1.) In fact the relation is easily derived by any one who has studied the simple pendulum and s.h.m. at school. The relation is $\Delta F/f = \theta$ where ΔF is the frequency excursion added to or subtracted from the carrier frequency F_0. The angular swing θ of the phasor represents the depth of phase modulation (that is θ is proportional to the amplitude of the modulation). ΔF represents the depth of frequency modulation (that is, ΔF is proportional to the amplitude of the modulation).

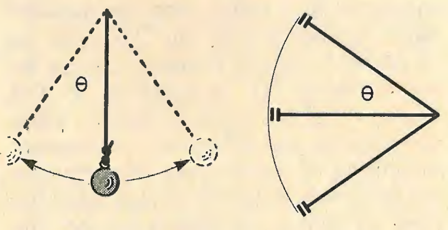


Fig. 11. *A swinging pendulum as the model for a swinging phasor (right), except that the phasor is shown on its side instead of hanging vertically. This represents a signal whose phase angle is periodically gaining and losing relative to an imaginary reference phasor.*

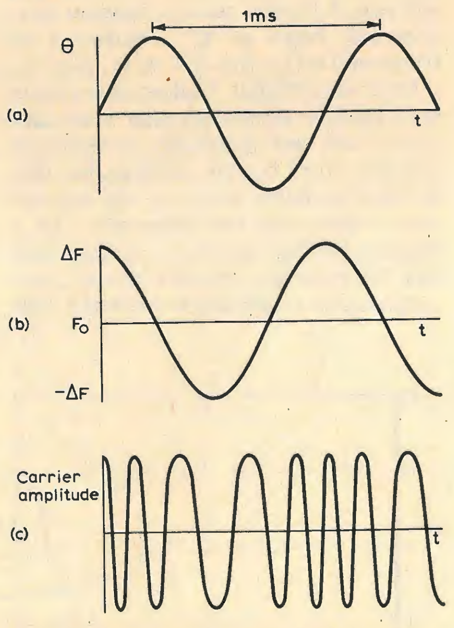


Fig. 12. *Phase modulation θ of the swinging phasor in Fig. 11 is assumed to have a frequency of 1kHz and period of 1ms, (b) shows how the swinging phasor also represents frequency modulation, while (c) is a rough diagram of the frequency modulation of a carrier.*

The higher the modulating frequency f, the faster the phasor swings back and forth through its angular (phase) displacement θ and faster it swings through the mid position. As indicated above the faster it swings, the greater the frequency deviation ΔF above and below the carrier frequency F_0. (See Appendix 2.)

The relation between f.m. and phase modulation (p.m.) is illustrated by considering the effect, one on the other, of modulation by a square wave. In Fig. 13(a) the square wave suddenly flips the frequency from the carrier F_0 to either $F_0+\Delta F$ or $F_0-\Delta F$. In the first case the phasor is rotating faster than the reference F_0 phasor so the phase angle θ is gaining linearly with time. Conversely, during the negative portion of the square wave it loses linearly. The variation of phase with time is therefore of sawtooth form, as shown in Fig. 13(b).

If the phase is modulated with a square wave (see Fig. 14(a)) the frequency remains constant during the time the phasor is advanced or retarded, but (in theory at least) it jumps instantaneously to plus infinity while the phase changes instantaneously to $+\Delta\theta$, and likewise to minus infinity during the phase excursion to $-\Delta\theta$ (see Fig. 14(b)).

The difference between p.m. and f.m. contained in the modulation index is easily thought of in phasor terms. As we increase the amplitude of the modulating signal we increase θ in p.m. and ΔF in f.m. If we increase the frequency of the modulating signal, keeping the amplitude constant, for f.m. ΔF remains constant but θ increases in direct proportion. The faster we swing

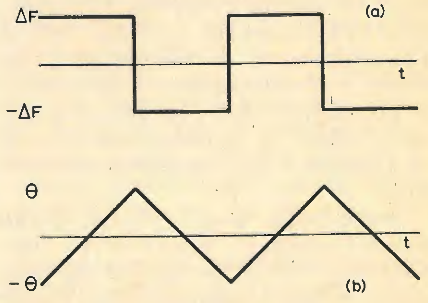


Fig. 13. *Square wave frequency modulation is shown at (a) and the corresponding variation of the phase angle at (b).*

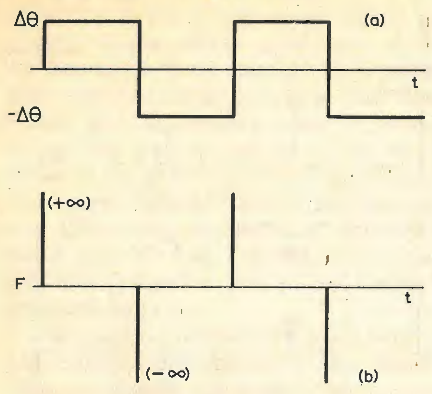


Fig. 14. *Square wave phase modulation is shown at (a) and the corresponding variation of the frequency at (b).*

the phasor through the equilibrium position the further it swings before coming to rest.

This is most important when we come to sidebands in f.m. since, as we shall see, the bandwidth required depends on both the modulating frequency and the angle swept out by the phasor. It will be seen that the combination of the two effects is such as to require approximately the same bandwidth for both high and low modulating frequencies. In this sense f.m., unlike p.m., makes effective use of the channel allocated to a service by occupying it for most of the time, irrespective of whether the instantaneous modulating frequency is high or low. While the bandwidth is much greater, typically about five times for an index of five, than for the corresponding a.m. it brings a significant improvement in noise performance. (The most obvious improvement comes from the receiver amplitude limiter. The receiver discriminator responds only to changes in frequency, not amplitude; noise spikes such as ignition interference give virtually no output. Noise can only produce output if it results in phase distortion of the signal.)

F.m. sidebands

Frequency modulation is sometimes roughly described (for a sine wave modulating signal) as varying the sine wave carrier frequency (of constant amplitude) sinusoidally at the modulating frequency. Such a description is illustrated by Fig. 12(c). However, the same reasoning as we applied to a.m., illustrated in Fig. 4, leads to the same consequence. Fig. 12(c) is not a sine wave changing in frequency. This is a "nonsense statement" since the slope of the wave must be changing (as the frequency changes) and it cannot therefore be part of a frequency modulated "sine" wave. As with a.m., phasors give a rational explanation.

A starting point is to refer to Fig. 9. The phasor resultant is obtained by combining the a.m. sidebands with a carrier in quadrature (90° out of phase with the original a.m. carrier). The consequence of combining three sine waves, upper and lower sidebands and carrier in quadrature, is to produce a swinging phasor resultant of approximately constant amplitude. For phase swings of up to $\pm 30°$ the amplitude is generally acceptable as being constant and this means that we have p.m. In engineering practice this can be achieved from, but shifted 90° in phase from, the original carrier. (The original carrier is that used to drive the balanced modulator, the output of which leaves only the sidebands as the carrier is balanced out.) Such a system of p.m. provides the core of the 'Armstrong' f.m. modulator. However, as θ is proportional to the modulating amplitude, this gives $\Delta F/f$ and not the ΔF required for f.m. The modulating signal, in practice, is processed by a suitable frequency/gain characteristic in the modulating amplifier which precedes the balanced modulator.

This is shown in Fig. 15(a). The original modulating signal is no longer constant with rising modulating frequency but is inversely proportional to frequency owing to the progressive reduction in the reactance of the capacitor, which decreases output as f increases. The output of the combined modulating amplifier, R C, balanced modulator is added to the 90° phase shifted carrier, giving a constant amplitude frequency modulated signal of the required characteristic, $\Delta F/f \propto \theta$. This is shown in Fig. 15(b). As described θ must be limited to $\pm 30°$ if the resultant is to remain of approximately constant amplitude. The approximation is that $\tan\theta \simeq \theta$ (which is true for small values of θ) as may be seen by comparing the Fig. 9 resultant with the ideal swinging phasor of Fig. 11, shown together in Fig. 16.

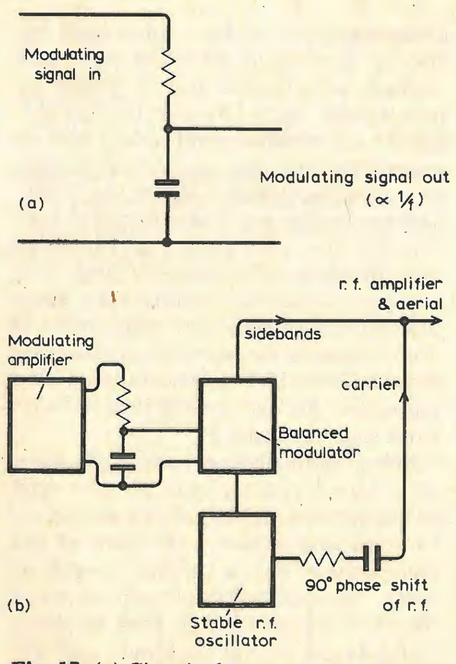


Fig. 15. *(a) Circuit that processes a modulating signal so that it becomes inversely proportional to frequency. (b) Practical system in which output from a modulating amplifier and the (a) circuit is added to 90° phase shifted carrier to give a constant amplitude f.m. signal.*

For a given amplitude of frequency modulation, θ grows as the modulating frequency decreases. For a given ΔF (which is directly proportional to amplitude of modulation in f.m.) the phasor has to swing at a corresponding speed back and forth through the equilibrium position, i.e. the instant when the phasor is passing through the zero phase displacement ($\theta_t = 0$). The lower the modulating frequency (i.e. the period of swing of the phasor) the further it swings before coming to rest (i.e. the bigger is θ, the phase excursion). The consequence of this is that only narrow band (small value ΔF) f.m. is possible with this technique since θ is limited to $\pm 30°$ or so. However, by carrying out the process outlined in Fig. 15(b) at a low crystal oscillator frequency and then multiplying the frequency many times, by a succession of doubler, tripler stages etc. a wide band (large ΔF) f.m. signal can be obtained in, say, the v.h.f. band. The crude, if obvious, technique of directly altering an h.f. or v.h.f. oscillator by a variable reactance across a tuned circuit (e.g. a capacitor microphone as part of the oscillator LC circuit) leaves the carrier frequency too unstable for most practical purposes.

More sidebands in f.m.

If we take a closer look at the approximation implied in Fig.16 we can say that the amplitude of the generated swinging phasor is too long when θ is a maximum or too short when θ is zero. If we could correct the amplitude by a small amount δx as shown in Fig. 17 we should be closer to achieving our perfect fixed amplitude swinging phasor. We have to amplitude modulate the resultant by a small amount δx at *twice* the modulating frequency, the phasor swinging frequency. This can be done by another pair of sidebands of twice the modulating frequency. These are small in amplitude and phase related to the unmodulated reference phasor as in the a.m. of Figs. 7 and 8 (we have turned our diagram through 90° in going from Figs. 7 and 8 to Fig. 17 and reduced the sideband amplitude but have not otherwise changed the situation). Our

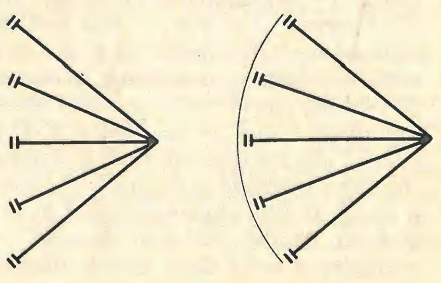


Fig. 16. *Comparing the resultant in Fig. 9 (September issue) with the ideal swinging phasor of Fig. 11 (right).*

frequency spectrum of true f.m., the equivalent of the a.m. in Fig. 1 (a), begins to appear as Fig. 18. We see that the swinging phasor is generated by five sine waves, the carrier, the upper and lower sideband pair separated from it by the modulating frequency, and a smaller upper and lower sideband pair separated from the carrier by twice the modulating frequency.

The phasor treatment of f.m. sidebands can be extended to cover larger swings of θ in a readily intelligible form in this way. To simplify the drawing, this is the moment, before continuing, to emphasize two points. First, from the essential symmetry of the swinging phasor the sidebands always occur in pairs, differing from the carrier frequency by f, $2f$ and, as we shall show, higher harmonics of f, $3f$, $4f$ and so on. Secondly, whatever the amplitude of the pair, the resultant combination is as shown in row 2 of Fig. 7, a resultant whose phase is fixed, whose frequency is fixed but whose amplitude is varying sinusoidally from $+2a$ to $-2a$ at a frequency f, $2f$ etc where a is the amplitude of the particular sideband.

Let us elaborate on the phasor addition of Fig. 17 by considering the detail of the five component phasors over a quarter of a modulation cycle, all that is needed, by virtue of the symmetry, to study a whole cycle. Fig. 19 (a) shows in a quarter cycle of modulation time the resultant of the first pair of sidebands $(F_o - f)$ and $(F_o + f)$. The time intervals are for 0°, 30°, 60° and 90°, as shown in Fig. 19 (a).

In terms of the modulation frequency f the time intervals of Fig. 19 (a) are, respectively, for time zero (0°) to

$\frac{1}{12f}$ $\frac{1}{6f}$ $\frac{1}{4f}$
(30°) (60°) (90°)

Fig. 19 (b) shows the second pair of sidebands ($\pm 2f$) for the same time intervals. In the same time intervals Fig. 19 (c) and 19 (d) show the resultants for the $3f$ and $4f$ sideband pairs (so far not used in the text, but yet to come).

To find the resultant of any number of sideband pairs it is only necessary to project one sideband on to the reference phasor direction (i.e. the mid frequency of the sideband pair). This simplifies the construction and makes plots against time of combinations of sidebands easier to draw. So going back to our quarter cycle and dividing it up into six 15° intervals, 1/6, 2/6 ... and further considering for convenience 0, 2, 3, 4, 6 sixths, we shall be considering, in fact, 0, 30°, 45°, 60° and 90° of the quarter cycle. The phasors may be labelled 0, 2, 3, 4, and 6. Take the first sideband and draw the upper sideband in the first colum for f, $2f$, $3f$, $4f$. The angles involved in the plot are 0°, 30°, 45°, 60° and 90° or multiples thereof. This makes finding the sine of the angles easy. (sine 0 = 0, sine 30° = 0.5, sine 45° = 0.707, sine 60° = 0.866, sine 90° = 1.)

I shall now proceed with a phasor

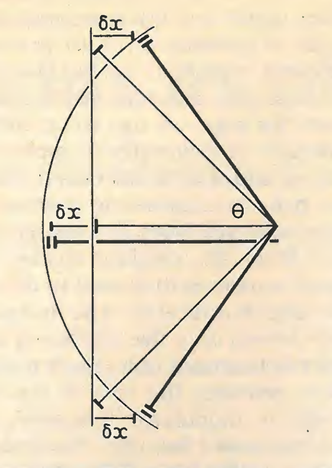


Fig. 17. *Correction required to the length of the generated swinging phasor to make it equivalent to the perfect fixed-amplitude swinging phasor (thick lines).*

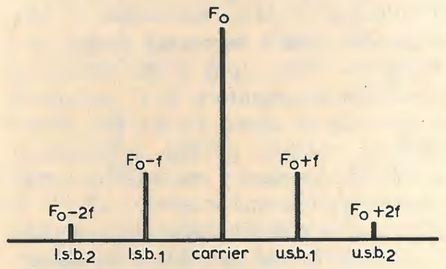


Fig. 18. *Frequency spectrum of true frequency modulation, showing upper and lower sideband pairs.*

demonstration of f.m. sidebands by adding successive sideband pairs (of various amplitudes and in phase or quadrature with the carrier) to the carrier (of various amplitudes) and so generating swinging phasors of various values of modulation index ($\Delta f/f = \theta$). The amplitudes could be guessed in very simple cases, such as in Fig. 18, which only involves sidebands $\pm f$ and $\pm 2f$. However, the mathematicians have worked out the relative amplitudes of the sidebands for various modulation indices. These have been tabulated (like log tables) and are called Bessel Functions (see Appendix 3).

For a modulation index of unity $\Delta F/f = \theta = 1$ radian, our phasor will swing, pendulum like, with a period $1/f$ through one radian each side of the equilibrium. For a phasor length of unity, the carrier amplitude required (Bessel Function) is 0.76, first sideband ($\pm f$) 0.44 and second sideband ($\pm 2f$) 0.11 Plotting the combination as in Fig. 19 for our various times and remembering to scale the amplitudes 0.76 (carrier), 0.88 and 0.22 (doubling the amplitude for the sideband pair resultants), we get Fig. 20. The successive positions superimposed give a clear idea of how the five 'pure' sine waves ($F_0 \pm sb_1 \pm sb_2$)

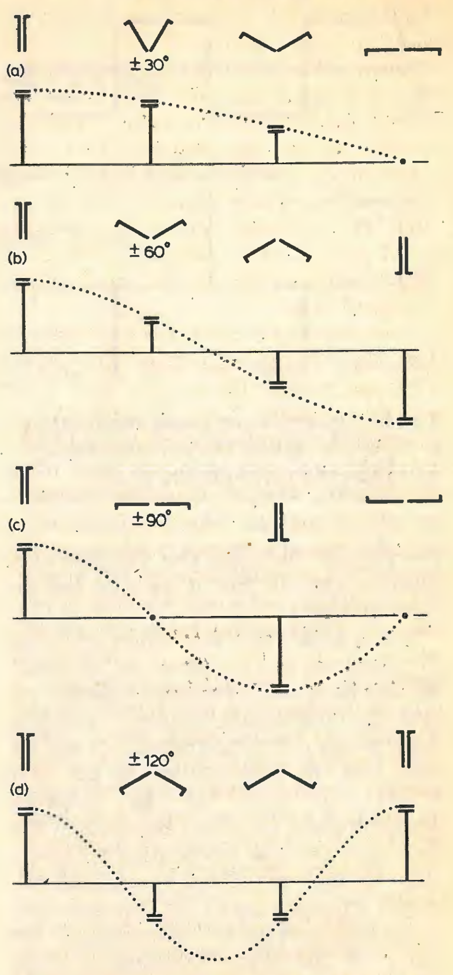


Fig. 19. *Resultant of pairs of sidebands in a quarter cycle of modulation time, at 30° intervals: (a) first pair ($\pm f$); (b) second pair ($\pm 2f$); (c) third pair ($\pm 3f$); and (d) fourth pair ($\pm 4f$).*

generate the swinging phasor.

If we swing our phasor through a bigger angle we find that yet more sidebands ($\pm 3f$, $\pm 4f$ etc.) are required to produce the simple harmonic (pendulum type) motion of sensibly constant amplitude. For larger swings the carrier itself is dramatically altered in amplitude. As a final illustration I shall take an angle of 2.4 radians (137°) swing. For this the amplitudes of the sidebands pairs (obtained by doubling the appropriate readings from the Bessel Function tables) are for f 1.04, $2f$ 0.86, $3f$ 0.40 and $4f$ 0.13. The amplitude of the carrier is zero!

A somewhat crude justification (which does not work out exactly) is to say that, as the swinging phasor spends about as much time more than ±90° out of phase with the carrier as it does less than ±90°, the carrier component reduces to zero. This can be visualised by what follows.

Repeating the process of Fig. 20 but this time for four sideband pairs, we arrive at the equivalent shown in Fig. 21.

It will be noted that each successive sideband pair is added at right angles to its predecessor, (see $t = 0$ on Fig 21) starting with the carrier (this phase

condition is not brought out clearly in conventional texts although it is implicit in the 'pure' maths), and finally that any particular sideband pair can have a zero or negative value (opposite phase), as well as positive. The zero value of sb_2 pair at $t = 3$ in Fig. 20 (and the corresponding phasor position in Fig. 19) is one example of a zero sideband pair. $t = 4$ in Fig. 21 illustrates negative values for the 2nd, 3rd and 4th sideband pairs.

The practical implication of all this to f.m. engineering should be discussed. First, the greater the angle of swing the more sidebands there are and so the greater the bandwidth relative to the modulating frequency. At high modulating frequencies the swing is small, because the swinging phasor is rapidly brought to rest, having swung through the equilibrium position $\pm \Delta f$ with respect to the carrier. Conversely, at low modulating frequencies the swing is large because (for the same amplitude of modulating signal and so ΔF) the swinging phasor, having swung through the equilibrium position at $\pm \Delta F$ with respect to the carrier, only slowly comes to rest, so sweeping out a proportionately greater angle. The lower modulating frequency therefore involves more sideband pairs than the higher.

If we use the data for Fig. 21 and then Fig. 20 to construct spectra (equivalent to Fig. 18) for a modulating frequency f' and for twice that frequency $2f'$ assuming an index of 2.4 for f' we get Fig. 22 and, since the index for $2f'$ ($\Delta F/f = \theta$) is 1.2, we can use the data of Fig. 20 approximately for Fig. 22(b). This illustrates the general f.m. requirement of more or less the same bandwidth requirement over a wide range of modulating frequencies.

In broadcast practice a modulation

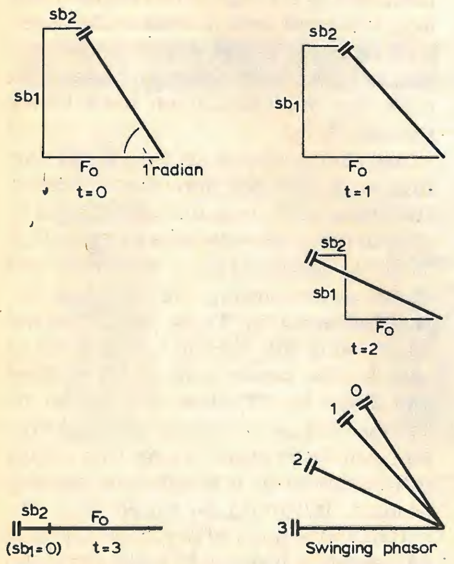


Fig. 20. *Swinging phasor for a modulation index θ of 1 radian. The successive positions at times 0, 1, 2 and 3 are superimposed (bottom right) to show the swinging process more clearly.*

index of 5 is used for the highest modulating frequency, 15kHz, giving a phasor swing of ±5 radians. The effective number of sideband pairs to generate this (from Bessel tables) is 7, making the required bandwidth 7×15kHz on either side of the carrier frequency or some 200kHz in all. The actual frequency deviation is $\Delta F = f\theta$, 15×5±75kHz. It is important to see that the bandwidth for low distortion f.m. is greater than the deviation and, from what has gone before, varying phase shift at different frequencies, say in the receiver i.f. passband, would distort the all important swinging vector in amplitude and angular position. The discriminator needs to be linear only over the deviation ±75kHz, although this requirement is usually increased to compensate for a tendency in conventional discriminators to lose linearity at the extremities of the deviation. See, however, the p.l.l. discriminators available in i.c. form.

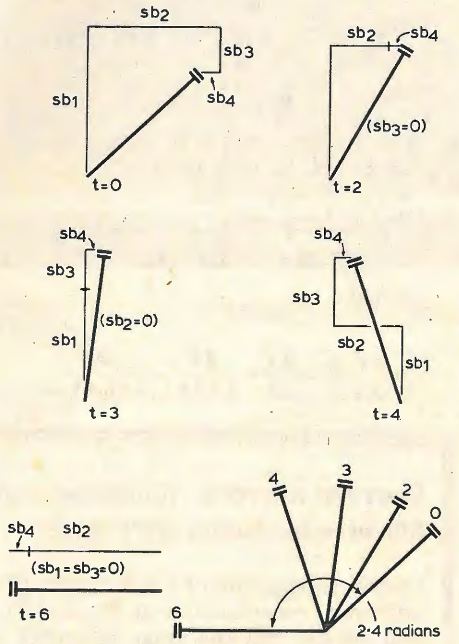


Fig. 21. *A swinging phasor, over a time of a quarter cycle, generated by zero carrier and relevant sidebands $\pm f$, $\pm 2f$, $\pm 3f$ and $\pm 4f$ from F_o.*

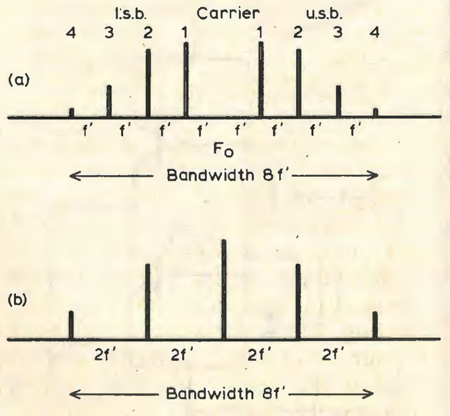


Fig. 22. *The data from Fig. 21 and then Fig. 20 used to construct spectra for modulating frequencies of (a) f' and (b) $2f'$.*

At lower modulating frequencies, say 3kHz, and the same amplitude ±75kHz the index is increased 5 times to 25 radians. This, from the Bessel tables, requires some 30 significant sideband pairs involving sidebands up to 3×30kHz. Again we see the bandwidth remaining around 200kHz (3×30×2).

At lower frequencies still the swinging phasor rotates through many revolutions and when passing through the equilibrium position it is moving at an approximately uniform number of revolutions per second. Watch a torsional pendulum in a glass-cased clock for model. Imagine the swinging phasor as a white line painted as a radius on the pendulum.* Thus it represents a frequency greater or less than the carrier, according to whether it is advancing or retarding. This frequency is, from earlier theory, $\Delta F = f\theta$. Thus if θ is, say 50, we find that sidebands around $\pm 50f$ predominate in the spectrum. Above this the sidebands fall off rapidly to negligible values while the band between is filled with generally a multitude of lower amplitude sidebands. The exceptional noise performance of f.m. can also be explained in these terms, as well as effective use of the bandwidth irrespective of the frequency content of the modulating signal.

First consider large noise spikes in the pass band of the receiver. These are clipped by the limiter to the same level as the signal amplitude. Owing to their normally short duration (e.g. ignition interference) they have little effect on the discriminator output, unlike a.m. White noise, considered as spurious sidebands of small amplitude in comparison with the signal, will shift the phase in a small random fashion. Those near the carrier frequency will be less effective in shifting the phase than the low f, intentional, modulating signal and so giving output less than the lower modulating frequencies. Therefore, unlike a.m., the demodulated noise will tend to zero in the centre of the pass band. Only higher audio frequency hiss will be apparent and then only if the noise is of comparable amplitude to the swinging phasor.

Further, since the frequency deviation is, perhaps, five times those higher frequencies towards the edge of the receiver pass band, the signal will be five times more effective in amplitude than noise. The noise in sidebands out-

*Since we have frequently considered large angles of phasor swing (many revolutions), a better analogy than the simple pendulum (typical swing ± 10° or less) would be the torsional pendulum. This is a massive wheel on a vertical axis, rotating back and forth through large angles due to the torsion in the supporting wire. When used in clocks the long period of the escapement allows the clock to run for a year on one winding. Since these clocks are always in glass cases, an imaginary (or white painted) radius on the wheel would give an accurate model of our swinging phasor.

side the audio pass band will not produce audible output in the receiver.

Likewise adjacent channel interference will be of very much less consequence than with a.m. The closer the frequency to the interfering carrier the less the output. (The lower frequency shifts the F less as above.) Further, the amplitude of the one determines its ability to shift the phase and give output from the other. Unless the intefering signal is of similar amplitude it will cause negligible output from the discriminator. It is for this reason that, in common or close channel working, there is a very small area between two stations where strengths are sufficiently comparable for interference to occur. Outside this area the stronger station captures the receiver and only its signal gives output from the discriminator.

Measuring ΔF — a test procedure

If it is required to set the audio gain of the modulating section of an f.m. transmitter to give a particular deviation, a test procedure is available which depends on the absence of the carrier under certain conditions. First an a.m. receiver with a very narrow pass band and equipped with an S-meter is set up to receive the f.m. (unmodulated) carrier. The transmitter is then modulated with a frequency giving sidebands outside the receiver pass band so that the first and higher sidebands ($F_0 \pm f$) do not register on the S-meter. The amplitude of modulation and corresponding ΔF is then increased. The meter will indicate zero as the modulation index reaches 2.4 because the carrier is of zero. These occur when the phasor swings through complete extra half revolutions on top of the 2.4 radians, that is $2.4+\pi$, $2.4+2\pi$ etc. Thus increasing the modulation amplitude and noting the setting for successive zeros of the carrier we calibrate the 2.4, 5.5, 8.7 index points.

Appendix 1: Mathematical expression of p.m.

P.m. of carrier can be expressed as

$$(\theta \text{ sine } \omega t) \text{ sine } \Omega t$$

where ω is the modulating signal and Ω is the carrier expressed in radians/s. In terms of modulating frequency f and carrier frequency F_0 this would be

$$(\theta \text{ sine } 2\pi ft). \text{ sine } 2\pi F_0 t$$

The term in the bracket is modulating the carrier phase.

Appendix 2: Mathematical expression of f.m.

The frequency modulation of carrier can be expressed as

$$(\Delta F \text{ sine } \omega t) \text{ sine } \Omega t$$

where ω is the modulating signal and Ω is the carrier expressed in radians/s. In terms of the modulating frequency f and carrier frequency F_0 this would read (ΔF sine $2\pi ft$) sine $2\pi F_0 t$.

If the phase θ is modulated by the (audio) frequency ω the phase angle at a time t is given by

$$\theta_t = \theta \text{ sine } \omega t$$

The rate of swing is, using calculus,

$$\frac{d}{dt}(\theta_t) = \theta\omega \cos\omega t$$

Hence the maximum rate of swing, $\Delta\Omega$, is $\theta\omega$ in radians/s (when $\cos\omega t = 1$). Putting this in terms of frequency instead angular velocity, $\Delta\Omega = 2\pi\Delta F$ and $\omega = 2\pi f$, we have

$$2\pi\Delta F = \theta 2\Delta f$$

and hence $\Delta F = f\theta$

This may be written as

$$\frac{\Delta F}{f} = \theta$$

where $\Delta F/f$ is known as the modulation index, a very important term in the theoretical treatment of f.m.

Appendix 3: Bessel Functions

The amplitude of successive sidebands is given by a convergent series viz.

$$A_n = \frac{\theta^n}{2^n(n^!)}\left\{1 - \frac{\theta^2}{2(2n+2)} + \frac{\theta^4}{2.4(2n+2)(2n+4)} - \frac{\theta^6}{2.4.6(2n+2)(2n+4)(2n+6)}\right.$$

where n = the number of the sideband ($n=0$ is the carrier). Thus for $\theta = 2.4$

$$A_1 = \frac{2.4}{2}\left\{1 - \frac{2.4^2}{2.4} + \frac{2.4^4}{2.4.4.6} - \frac{2.4^6}{2.4.6.4.6.8}\right.$$

$$= 1.2\left\{1 - 0.72 + 0.172 - 0.021\right.$$

$$= 0.52$$

$$A_2 = \frac{2.4^2}{4.2}\left\{1 - \frac{2.4^2}{2.6} + \frac{2.4^4}{2.4.6.8} - \frac{2.4^6}{2.4.6.4.8.10}\right.$$

$$= 0.72\left\{1 - 0.48 + 0.035 - 0.012\right.$$

$$= 0.39$$

$$A^3 = \frac{2.4^3}{8.6}\left\{1 - \frac{2.4^2}{2.8} + \frac{2.4^4}{2.4.8.10} - \frac{2.4^6}{2.4.6.8.10.12}\right.$$

$$= 0.29\left\{1 - 0.36 + 0.052 - 0.004\right.$$

$$= 0.2$$

$$A_0 = \frac{2.4}{1}\left\{1 - \frac{2.4^2}{2.2} + \frac{2.4^4}{2.4.2.2} - \frac{2.4^6}{2.4.6.2.4.6}\right.$$

$$= 2.4\left\{1 - 1.44 + 0.52 - 0.08\right.$$

$$= 2.4 \times 0 = 0$$

$$A_4 = \frac{2.4^4}{16.24}\left\{1 - \frac{2.4^2}{2.10} + \frac{2.4^4}{2.4.10.12} - \frac{2.4^6}{2.4.6.10.12.14}\right.$$

$$= 0.086\left\{1 - 0.29 + 0.035 - 0.0024\right.$$

$$= 0.064$$

Bessel Function table for θ = 2.4

1st sideband pair	each 0.52	sum 1.04
2nd sideband pair	each 0.39	sum 0.78
3rd sideband pair	each 0.20	sum 0.40
4th sideband pair	each 0.064	sum 0.13

It would be out of place here to justify the series by rigorous maths. However, this example confirms the figures used for the construction used in Fig. 21. One can have therefore the same confidence in the Bessel tables as one has in logs – they always work, though one is not likely to construct one's own tables in either case. Indeed the writer would never have justified these values, evaluated above, without a pocket calculator to do the arithmetic.

Current mirrors (Continued from page 58)

Mirror-aided output drive stage

Consider the circuit of Fig. 9. Ignore the additional complication of Tr_2 and Tr_3 and we see that the stage is simply a common emitter with Tr_1 followed by an output common collector buffer Tr_4 feeding the load. Common collector circuits are notoriously poor at feeding capacitive loads – every load will have some shunt capacitance and in the case

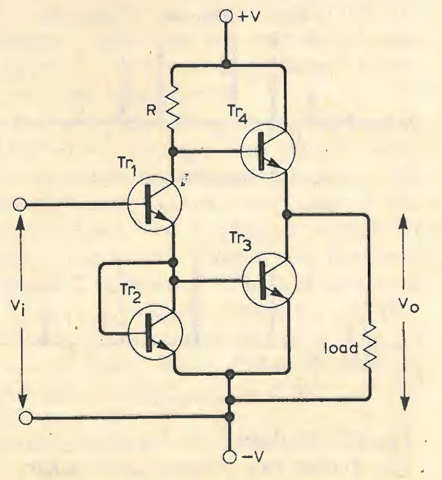


Fig. 9. *Output drive circuit with current mirror*

of an npn transistor for $dV_o/dt > 0$ this capacitance is charged rapidly as the current through Tr_4 increases while it is turned harder on. However, on the down swing ($dV_o/dt < 0$) a common collector element with a resistor between emitter and negative supply (R_e) is unable to sink current; the only discharge path for the capacitive load being through R_e.

The circuit shown in Fig. 9 has the advantage that not only has a current sink replaced R_e but the current sink is now driven. On the upswing ($dV_o/dt > 0$) I_{c3} decreases as I_{c1} increases, and as this aids charging the load the voltage following by Tr_4 is good. On the down swing ($dV_o/dt < 0$) I_{c1} increases as does I_{c2}. The result is an active current pull down by Tr_3. The circuit can be summarised as a voltage pull-up, current pull-down stage. Again this circuit can be found in a number of op-amp designs. It should be noted that the output impedance of large signals will be very non-linear as in the limit on pull-up the output "sees" the very low output impedance of the active common collector stage of Tr_4. On pull-down the output "sees" only the collector sink of Tr_3 with Tr_4 tending to turn off.

WIRELESS WORLD, OCTOBER 1979

LETTERS TO THE EDITOR

INFORMATION GAP

It is all very well to protest in your leader for July that data banks and computers are really harmless, cuddly morons which, in the absence of humans, would be as naught, but that is exactly the problem. It is the fallibility of controllers, not that of machines, that causes the moderately-imaginative citizen to view the computer state with misgiving.

The world is, for most people not in a position to inform or control, divided into the two archetypal groups — them and us. Before the computer was employed on a large scale, newspapers were decidedly 'them': a statement appearing in a newspaper article had an aura of truth about it, however wrong-headed the responsible journalist. Now, many people are considerably more aware, perhaps because of television, that words in print carry no more weight than spoken ones.

Computer systems have taken over the mantle of infallibility. A system, however, includes the programmer and can be extended to include the person who uses the processed information in his work as a police data collator or bank official. Such a person is not normally technically-inclined and may well be disposed to accept the information provided as impeccable, even though it may not be — computers, being programmed and operated by humans and being nothing but machines anyway, can produce spurious output. When one is refused a bank loan, therefore, or asked to 'help the police in their enquiries', it could be that the spurious output has prompted the refusal or request. Any query of the validity of the information is barely possible, since its existence will not be referred to. Credit will simply be refused and the police will offer no explanation. Eventually, it is possible that misunderstanding and computer hiccup would be sorted out by concerned officials, but what if they are not concerned and caring?

No, it is not the machines that cause the nightmares — it is the fact that a petty official will believe the word of a computer in preference to that of a person every time, and some of the time the person won't know the computer is involved.

W. Dampier
Wallington
Surrey

PERSONAL RADIO SERVICES

The system described by Howard Tillotson in your August issue (Citizens' band communication system, pp.61-62) is magnificent but it is not c.b. Research in countries where c.b. is legal shows that a large part of the attraction of c.b. for the consumer is the facility which it offers to talk to nearby c.b. users *even if they are not known to the operator*. Mr Tillotson's system depends on the operator knowing which station he wishes to contact and also the "address code" of that station.

Such a system would be easy to implement with modern digital techniques but I do not think it would be very popular if it was the only system available. If it were one option among many, however, I think that it would be very attractive and could lead to an increase in c.b. use and in the services available to c.b. users.

When the Citizens' Band Association originally proposed the idea of automatic identification for British c.b. equipment it was for the sole purpose of enabling the authorities to monitor the system and detect and identify people who misused it. Since then we have realised that auto-ident offers all sorts of other possibilities including selective calling (in this case the receiver must also recognise its own identity but this is a trivial problem once the necessary digital circuitry is installed in the set), linking the c.b. user to the Post Office telephone network (since auto-ident provides a means by which the user may be billed for the service), and now Mr Tillotson's proposals for digital message transmission and storage (which includes a low cost paging facility).

When the Government legalises c.b. it should ensure that the frequency allocated can be expanded in the future to allow for such growths of personal radio services. By 1990 we could have a personal radio service in Britain which offered some or all of the following options:

1. Simple c.b. where a voice transmission is heard by any other user within range and listening on the same channel.
2. Selective call c.b. where the receiver is set to unsequelch only on receipt of signals directed to its own unique "address". Other users could still, of course, listen to such traffic so this option offers no increase in privacy, merely freedom from unwanted signals.
3. "Carfax c.b." where mobile equipments were also capable of receiving v.h.f. "Carfax"-type signals on a channel adjacent to the c.b. channels. Although "Carfax" is at present envisaged as an m.f. service there might be advantages to a v.h.f. system if Britain also had v.h.f. c.b., not least of which is the possibility of police cars carrying short-range "Carfax" transmitters with tape loop messages for deployment near major accidents or diversions.
4. Access to the Post Office telephone network from c.b. transceivers. The auto-ident would allow billing for the service but quality would not be high and there would be no privacy. However the Post Office part of the system could be cheap and deployed every few miles in towns or along major roads so that large numbers of people could use the service.
5. Nationwide digital message handling and paging using a system similar to Mr Tillotson's. For short ranges user-user contacts would suffice but over longer ranges the Post Office would again be involved. In the latter case costs would be higher since the system would need to know where any user was at any time so a central computer "log" of locations would be necessary — updated whenever the user made a transmission on any channel in the system.

Such a system approaches the notorious "Flash Gordon wrist radio" system in science fiction content but is in fact practicable with present day technology. The infrastructure would probably cost under £350 million and the sets could be made for as little as £200 at present day prices. Such facilities would be in advance of anything planned anywhere else in the world and could provide Britain with a huge export market as other countries planned similar systems.

James M. Bryant
President, Citizens' Band Association
Cheltenham
Glos

WHAT IS AN ELECTRON?

Dazzled as I always am by the subtlety, sophistication and sanctity of many modern physics texts and articles, I often feel it brutal and brutish to enquire whether this is really science they are talking about; or is it, rather, a badly confused mixture of science with plenty of hierophantic divinity, whence an aura of metaphysical mystique cloaks and obscures the real facts and phenomena of nature, and, if so, why is this confused nonsense still insistently presented as genuine science? I fear that Professor R. C. Jennison (June, 1979, issue) is one of those amusingly ingenious experimentalists who, having been duped by Planck, Einstein, Dirac and their mystic school of "transcendental symbolism" into believing that their sacred theories are valid descriptions of nature, have added insult to injury by ridiculously proceeding to "prove" these follies by experiment!

Jennison writes about electrons, positrons, photons, etc, bumping into each other as if they were cars bumping into each other. Attempts, however, to extrapolate conceptions from our common pool of human experience to the realm of the microcosm to which we sadly have no direct sensual, and inadequate instrumental, access are totally unjustified and, unhappily, lead to meaningless theories and nonsensical corollaries. Such dubious theories should not be accepted, let alone be proposed, however attractive and temporarily successful they may *seemingly* be. I am afraid that Jennison's peculiar "phase-locked cavity" model of the electron is the most recent example of this weak-minded extrapolation.

Certain phenomena are "explained" in terms of radiation being waves; yet other phenomena are "explained" if radiation is assumed to be photons. To conclude that radiation can be *both* waves and/or particles is incredibly unwise, and the fact that this conclusion is regularly reached by persons occupying the highest positions simply shows the desperate plight of modern physics. A billiards ball is, by definition, a particle; ripples on the surface of a pond are, by definition, waves. What is an electron? What is light? I am afraid that responsible science cannot, with present-day means, provide any answer nor can Professor Jennison, however much research he does, and however many irksome pages he may wish to use.

It was, of course, to be expected that the naive attempt to apply the "transcendental symbolism" to physical reality and, on the other hand, to effect the improper extrapolation which I mentioned earlier would inescapably involve great difficulties; it would also produce embarrassing contradictions; and it would unhappily conclude impossible corollaries. The genuine contradictions had to be concealed, somehow, and were, therefore, masqueraded as paradoxes — apparent contradictions, the existence of which almost everybody admits but few have claimed to have resolved. Further, several patently impossible conclusions (e.g. time-dilation) were, amazingly, believed to be true. But in order to believe impossible things, one has to live, along with Lewis Carroll's celebrated Alice in Wonderland . . . Likewise, the philosophical proposition of "equivalent descriptions" (e.g. wave/particle), notwithstanding the crazy incompatibility of the various descriptions and a convenient way of deluding themselves; it serves no useful purpose, apart from deceiving and mystifying the lay public.

Jennison's doubtful derivation of $F=ma$ and $E=mc^2$ from his peculiar hypotheses is neither compelling nor impressive. The fact that the careless use of mathematics and/or of funny thought-experiments in ivory towers cannot prove anything, apparently escapes him. Nevertheless, in Jennison's sense, and with his poor, unscientific methods, one can "prove" anything, of course. It is not surprising that even meaningless theories (e.g. relativity) and impossible corollaries are regularly "proved" in this way.

Jennison also writes about inertia, charge, magnetic moment, etc, of electrons as if they were real, measurable things. Contrary to popular belief, this is, of course, wrong and all ill-conceived and impatient attempts to find superficial "explanations" of these concepts usually prove unproductive, if not misleading and wasteful. It is *not*, in any case, the business of science to make such presumptuous attempts, and those who do, and there are so many, regrettably make a travesty of science.

The errors surrounding the concept of inertia are typical and they demonstrate the utter confusion prevalent in theoretical physics. If Jennison cared at all to study Ernst Mach himself (second- or third-hand accounts are no good for they are almost always hopelessly misleading) he might have realised that Mach's concern was *not* "explaining" inertia but the search for a satisfactory answer to the pressing question: "with respect to what should one describe the position and the motion of a body?" Mach suggested "the entire universe"[1] and, as is well authenticated but little publicised, he dismissed instantly Einstein's answers: the principles of relativity, equivalence and similar rubbish.[2] So do all genuine physicists, of course (for instance, L. Essen, October 1978 and April 1979 issues). What is astonishing, however, and, for that matter, particularly disturbing is the foolish insistence of Einstein and his followers that they have implemented Mach's teachings and vindicated his ideas . . . With regard to inertia Mach wrote:

> As soon therefore as we, our attention being drawn to the fact by experience, have perceived in bodies the existence of a special property [inertia] determinative of accelerations, our task with regard to it ends with the recognition and unequivocal designation of this *fact*. Beyond the recognition of this fact we shall not get, and every venture beyond it will only be productive of obscurity.[3]

Einstein and his disciples did not heed Mach's words, so the obscurity and confusion which resulted is simply and truly abysmal, and may be evidenced in Jennison's article.

It is high time that a revolution should take place in physics.

Theo Theocharis
Department of Mathematics
Imperial College
London, SW7

References
1. E. Mach, The Science of Mechanics, Open Court, Sixth American Edition, 1960; p. 286.
2. E. Mach, The Principles of Physical Optics, Methuen, London, 1926; pp vii-viii.
3. Ref. 1; pp 270-271.

The author replies:
Dr Theocharis's sermon is pure fire and brimstone and I would not dare to question his dogmas lest I be smitten with inexplicable annihilation. I am only flattered that I am categorised as writing similar rubbish to Einstein!

I have, of course, studied the relevant parts of Mach's original works and I quote a line from his opening argument: "When we reflect that we cannot abolish the isolated bodies . . . it will be found expedient provisionally to regard all motion as *determined* by these bodies". As I have stated elsewhere, one cannot abolish a wealth of parameters in almost every physical problem but inability to abolish does not necessarily identify the criminal. The criminal in this case lurks in the test particle which Mach assumed to be a point. Having shown that kinematic motion requires a system of reference, Mach calls upon this frame of reference, the isolated (distant) bodies, for an explanation of the dynamics. His only argument in support of this is that there must be a reason for the dynamical behaviour but, on looking around the test particle for cause, all that can be observed are the other isolated bodies against which the kinematic motion may be measured. The fallacy lies in the assumption that the test particle is a point; he therefore looked around and not *inside* the test particle. Strictly a point mass cannot exist and the principle of the phase-locked cavity recognises the finite dimensions and relativistic rigidity of the smallest particles of matter. It recognises the need for a kinematic reference frame but accounts entirely for the dynamics within the test particle itself when it is accelerated relative to that frame. Mach's clearly stated assumption of point masses caused him to be quite dogmatic in developing the theme that there could be no other explanation for the dynamics than that provided by the relative motion of the reference system of the distant isolated bodies. Although he initially stated that he would use it as "expedient provisionally", he applied it didactically as a law of nature.

In terms of classical dynamics it is clear that Mach's argument is an extension of Boscovich's hypothesis of separate rigid bodies rather than d'Alembert's principle of systems analysis. My own analysis fully vindicates d'Alembert at the expense of Boscovich.

Perhaps Dr Theocharis can tell us how to construct a rigid body and with what he proposes to replace Einstein's special theory?

I am accused of being "duped by Planck, Einstein and Dirac," to whom I admit I willingly kneel, but I regret that I cannot cope with the theological theories of Theo Theocharis.
R. C. Jennison

Further letters on this subject will be published later.

C-D IGNITION FOR MOTORCYCLES

Having read with interest J. H. J. Dawson's letter in the August issue on the subject of modifying the R. M. Marston capacitor discharge ignition unit for motorcycles I think you may be interested in my own practical observations. I have done a similar modification to a commercial (Sparkrite) unit and originally found the same sort of false triggering to which Mr Dawson refers. It is perhaps hardly surprising that this 'crosstalk' occurs, bearing in mind the enormous difference between the input trigger voltage of the unit and the voltage appearing across the secondary of the ignition coils – some 70 dB! In my case, the effect could be eliminated entirely by keeping the contact-breaker connections apart, preferably screened, and by keeping them well away from the h.t. leads.

Mr Dawson makes the point that these precautions, including his own circuit to inhibit false triggering, should only be necessary on 90° V twin motorcycles or three cylinder machines. In fact I can assure him that it's also necessary on many of the larger parallel twins or four-cylinder engines. Whilst the effect on his 90° V twin is perhaps one of the worst cases, a redundant spark is extremely detrimental to the performance of a 180° parallel twin or four-cylinder engine. In these cases an unwanted spark can occur at the end of an intake stroke when the inlet valve is just closing. Obviously, the mixture is not under compression, but the effects seen in practice suggest that some combustion occurs. If the c-d units are experimentally linked together (i.e. 100% crosstalk), the engine still runs, but at reduced power. As most two- and four-cylinder motorcycles employ the 180° system, there is indeed no need for most motorcyclists to employ a circuit as sophisticated as Mr Dawson's merely to guard against the one-in-a-million chance of a false spark – it would pass unnoticed. There is, however, every need to guard against *substantial* crosstalk.

Finally, rather than tackle the problem electronically, it might be an even better approach to use an optical system and to convey the pulses from the camshaft to the c-d unit by means of twin optical fibres. In this way there would be no sensitive circuits around to pick up the stray pulses.
John S. Wilson
Amersham
Bucks

DISPLACEMENT CURRENT IN A VACUUM

Whilst one may agree with the excellent logical argument via Maxwell's equations, in Professor D. A. Bell's interesting article "No radio without displacement current" in your August issue, I still find myself needing a further empirical justification of the displacement current, i.e. what is displaced in a vacuum?

Now a Dr James Dodd has recently written, in *New Scientist*, 1st March, 1979, in an article entitled "Colouring in the quark theory", that "Only naively does the vacuum live up to its name. In relativistic quantum theory it is a sea of virtual electron-positron pairs . . ." If Dr Dodd is right, could it not be that this could constitute an ether capable of

displacement? Moreover, on this assumption, would it not be possible to devise a simple theory to derive an expression for the impedance of free-space, or vacuo, normally obtained in textbooks (e.g. Telecommunications, by A. T. Starr) via Ampere's Law, as 377 ohms, or 120 π ohms? I would be very interested in your comments.

Moreover, I still cannot understand how a vacuum can offer an impedance to an electromagnetic wave, unless there is something there to do so! Perhaps someone could explain this to me.
Peter G. M. Dawe
Botley
Oxford

The author replies:
The question of intrinsic impedance of free space is fairly easily dealt with. The term 'impedance' is here merely a figure of speech, introduced because there is a close analogy with the characteristic impedance of a uniform transmission line. It merely means that in a radiated wave the ratio of electric field-strength to magnetic field-strength has a constant value which is a function only of the medium through which the wave is propagated. If the medium is free space, $E/H=377$ and since E and H are measured in volts/metre and amps/metre respectively, the ratio has the dimension of ohms.

I am afraid "a sea of virtual electron-positron pairs" does not seem to me any more tangible than 'free space', especially as the word *virtual* is included. There are other aspects of physics which to me seem equally 'unreal': from Newton to Einstein it was accepted that gravitation was action-at-a-distance, and although 'curved space' can be described by good mathematics, I cannot see that it fits with any everyday experience. One can only say that much of our knowledge of the universe today can be expressed coherently in a mathematical formalism which does not correspond with everyday experience of the approximate behaviour of sizeable objects, i.e. with mechanical models.
D. A. Bell

VHF RADIO AND THE OPEN UNIVERSITY

As with the BBC's fulsome, irrelevant, contradictory and evasive reply given to me when I made the same complaints as your correspondents Dr Crook and Mr Blanchard (July letters), their reply is just not good enough.

Long before there was any talk of Open University broadcasts the Corporation repeatedly told us that within a few years all their broadcasting would be on v.h.f. only and advised us to equip ourselves accordingly. And, indeed, all their music programmes were then available on v.h.f. Personally, with the age of retirement approaching and the possibility that the cost of changing over might then be beyond me, I did as exhorted by them, scrapped as good an a.m. receiver as money could buy or build and invested in v.h.f.

As one of your correspondents says, many of their best music programmes are now on a.m. only, and for what reason the Open University requires v.h.f. and stereo goodness only knows. Very, very few of these broadcasts require more than a low cost a.m. transistor set and, with most students already having them, they would well attract more listeners.

As one of your correspondents suggests, one has to reach the conclusion that it is all a matter of empire building, that the BBC has too many whiz-kids being clever without knowing what they are doing and too arrogant, despite their smooth talk, to have regard to their previous commitments to listeners and makers.
T. F. Mackay
Broadway
Worcs

In his reply to Dr Crook and Mr Blanchard (July letters) Mr Sturge of the BBC Engineering Information Department says "unfortunately the v.h.f. channel has to be used for educational programmes . . . ."

It does not have to be used for anything of the kind. That the BBC has agreed, possibly under pressure, to this abuse does not alter the fact that it is a continuing betrayal of those who took the BBC's advice and changed to v.h.f.
D. J. Watson
Hayfield
Derbyshire

3D TELEVISION

I have felt for some time that it is impossible to provide stereoscopic viewing of a moving image on a flat screen which can be viewed for more than a short period without eye discomfort, for reasons connected with the mechanism which the brain uses to perceive distance.

The brain uses two systems to estimate the distance of a viewed object, the first and probably the most important being the stereoscopic separation simulated by the various systems in use some years ago in the cinema. However, it is also necessary for the eye to focus to the correct distance to render a sharp image of the viewed object, and this focusing mechanism must be controlled by the brain.

When attempting to view an artificial stereoscopic image there must be conflict between the two systems, since stereoscopy is telling the brain that the moving object is, say, coming towards one, whilst feedback from the focusing mechanism insists that the object is moving only at a fixed distance on a flat screen.

The result of this conflict must be discomfort, eyestrain and headaches, and this seems to be an insuperable barrier to 3D viewing until it is possible to construct a genuine three-dimensional scene in the middle of the living room.
K. P. Wood
Wakefield
West Yorkshire

HIJACKING CARFAX?

Peter Manson (August letters) raised the question of possible 'hijacking' of a Carfax service, and asks whether the designers of Carfax are considering this problem. The answer is that they certainly are, although you would not expect us to say anything about the methods which could be used to prevent such intrusions.
D. P. Leggatt,
Head of Engineering Information Dept
BBC
London W1

WHAT'S WRONG WITH TELETEXT?

I was interested to see the editorial in the August issue bemoaning the non-popularity of teletext; especially as I have just about finished the construction of a stand-alone teletext receiver, but have somewhat 'gone off' what it receives.

The writer suggests "A hundred or so letters-to-the-editor broadcast every day. The trouble is your have to wait up to 30 seconds for the 'next time round' for a particular page to be transmitted (on ITV the cycle time is over a minute) and, with only four lines of text transmitted per television frame, there is no room for much expansion unless a whole tv channel is devoted to teletext alone. Even if more lines could be transmitted, it takes about half a minute to read a page, so that to read these suggested hundreds of pages would take all night!

I agree that the content could be improved, but there does not seem to be any room for *more* pages.

I read that the set making industry would like to get the price of the teletext facility down to about £65. I heartily agree with this figure – the present service is certainly worth no more. Small criticisms I have at the moment include:
1. Frequent spelling and punctuation errors (no, *not* decoder faults!)
2. Pages mentioned in indexes, but not actually transmitted.
3. Pages that are transmitted but not indexed. (I only recently discovered the existence of several Oracle news pages that are not summarised anywhere – you have to sample a range of numbers to find what's there, and if a page is not being transmitted the only way you *know* it's not being transmitted is by waiting for more than a minute for its non-appearance!)
4. Stocks and shares. These are of no use to the ordinary viewer, and are too generalised to be of use to the stockbroker, who has much better sources of information already.
5. The information should be more localised. On Oracle especially, one has to wait for all the regional pages to be transmitted before getting to one's own.

Finally, a word of thanks to *Wireless World* for publishing constructional details of the tv tuner, teletext decoder, and digital PAL encoder; and to advertisers who sell 200 "untested" i.cs for £1, enabling me to construct my teletext unit with under £40-worth of materials.
David Williams
London SE12

Why is it that British electronics invariably gets it wrong! If BREMA had asked the man in the street how he saw teletext he would have replied "a black box with coax input/output sockets at around £30-40".

O.K. it's not an ideal solution and is technically far more complicated than is really necessary, but at least it would retain the framework of teletext and prevent it from becoming extinct.

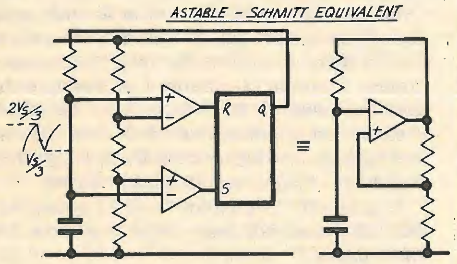
The only glimmer of hope is that our Asian brothers will produce a 'pluggable module' in time to save its "swan-song".
David Jack
Over Hulton
Bolton

Letters continued on page 76

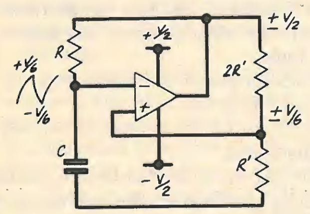
Schmitt-type astable circuits

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

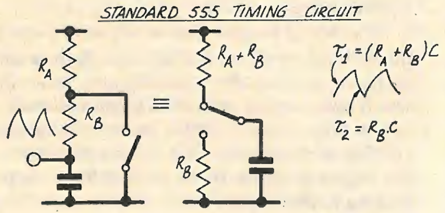
ASTABLE - SCHMITT EQUIVALENT



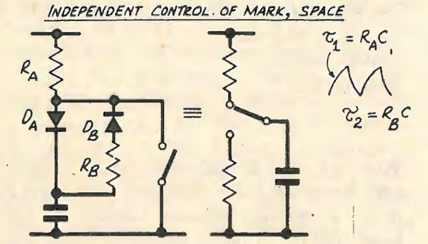
OP AMP ASTABLE



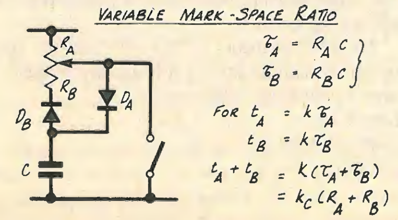
STANDARD 555 TIMING CIRCUIT



INDEPENDENT CONTROL OF MARK, SPACE



VARIABLE MARK-SPACE RATIO



The success of the comparators/flip-flop configuration in duplicating the behaviour of a Schmitt trigger suggests that it can be applied to all the other functions normally using a Schmitt. A good example is that of the op.-amp. astable, and the two forms are shown for comparison. The Q output of the flip-flop is returned via a resistor to charge the capacitor. The thresholds are $V_S/3$ and $2V_S/3$, the capacitor charging and discharging between these limits. The time constant is the same for the two parts of the cycle but, since the output voltage does not necessarily swing to 0 and V_S, the charge and discharge times will differ. It is to avoid this uncontrolled error that the open-collector output is provided in the 555 form; this allows better definition in the voltage swing. However, the 555 does function in the form shown, releasing the open-collector output for other functions if required, e.g. as a chopper, firing thyristors etc. The 555 can also be used with dual polarity supplies if desired, giving bipolar outputs, but the d.c. offset cannot be guaranteed since it depends on the matching of the three internal resistors.

In the simplest form to analyse, the output voltage switches between equal positive and negative values. These can be $\pm V/2$ for op.-amps. having c.m.o.s. output stages (e.g. CA3130). Alternatively, breakdown diodes may be used to clip less well-defined outputs to lower but more accurate values. The values chosen result in switching levels of $\pm V/6$ with a hysteresis of $V/3$ or one-third of the total supply. This is identical with that for a standard 555 and is a good compromise between excessive common-mode swings and offset difficulties at lower levels. The bridge configuration is discussed later in connection with a general classification of astable circuits using a single capacitor. Capacitor waveform cannot be fed directly to a load without both the waveform and the frequency being affected. The square wave can be used, since it appears at the op.-amp. output. Even if the load reduces the output, it need have little effect on the frequency, since both the thresholds and charging voltages remain proportional, i.e. the rate-of-change of capacitor voltage varies with the voltage excursions required for switching, and the times between switching points should be comparable.

A cautionary note: the two-transistor astable has long been described as 'the basic' form of astable because it was the most widely used. It had many advantages and was appropriate to discrete circuit design. It is far from basic in the sense of embodying the operating principles in the simplest and most clearly understood form — it depends in a complex way on the input and output characteristics of the transistors. The 555 and its close relations are more attractive candidates for the title of 'basic' because operation is best explained in terms of idealized amplifiers and flip-flops. The same risk attaches to the claim, viz. that wide usage may trigger the mental reaction that this class of circuits is of greater theoretical and fundamental importance. The next generation of i.cs may produce circuits that are both simpler to use and understand, and the concentration on the 555 is justifiable because it offers the best combination available at present of low cost, convenience and flexibility, and sound operating principles. The most widely used astable configuration has the open-collector switch connected to a tapping on the charging path. With the switch open the capacitor charges through R_A+R_B; with it closed the capacitor discharges through R_B. This gives time constants that are very different for $R_A \gg R_B$ and almost equal for $R_B \gg R_A$.

In the previous circuit, R_A may be used to charge the capacitor, while R_B may be placed in series with the switch to achieve a very rapid discharge if $R_B \ll R_A$. Comparison with the unijunction transistor and its circuits, described later, shows that the behaviour is then very similar. It is often desirable to have independent control of the two time constants. The placing of the thresholds at $V/3$ and $2V/3$ then translates equal time constants into equal mark and space. Alternatively only one time constant at a time need be varied if it is desired to produce, say, a pulse train of constant width but variable frequency. One method of achieving this uses diodes to isolate the resistors. When the switch is open D_A conducts and D_B is reverse biased. Hence R_B has no effect and the charging time constant depends only on R_A. When the switch is closed D_B conducts, bringing R_B into the time-constant, while D_A is reverse-biased and R_A is grounded. The diodes introduce small departures from the simple theory; the frequency of oscillation becomes more supply and temperature-dependent but the errors are small except at low supply voltages. The circuit is again equivalent to connecting the capacitor successively to two different resistors connected to the supply and ground lines.

Another desirable property of an astable is that its mark-space ratio be variable with no change in the frequency. A modification of the previous circuit allows this in a way that has application to numerous other astable circuits. If the locations of R_B and D_B are interchanged there is no change in performance, since they comprise a simple series sub-section. Then R_B and R_A can form a single potential divider, the tap on which represents the junction of R_A and R_B. If this tapping point is varied then the individual time constants are varied in opposite senses. Since τ and the time taken to charge between the thresholds are related by the same factor in this circuit because of the symmetrical disposition of the threshold voltages, it follows that the waveform period and frequency are constant. The ratio $R_A.R_B$ may vary but the sum is constant, and the period depends on the sum. Again second-order effects result in some change in frequency, especially at extreme ratios. The principle can be extended to other astables where two resistors separately determine the two parts of the cycle, and where they have a common point.

Schmitt-type astable circuits

THEORY

● The RC network is returned to the output which switches between V_A and V_B with

$$V_A \approx (V_s - 1)V$$
$$V_B \approx 0$$

For the positive-going part of the cycle,

$$V_1 = V_A - V_s/3$$
$$V_2 = V_A - 2V_s/3$$
$$t_+ = t_2 - t_1 = \tau \log_e\left[\frac{V_A - V_s/3}{V_A - 2V_s/3}\right] \quad \text{where } \tau = RC$$
$$\tau \log_e\left[\frac{\frac{2V_s}{3} - 1}{V_s/3}\right]$$
$$\tau \log_e\left[2 - \frac{3}{V_s}\right]$$

For the negative-going part of the cycle

$$t_- = \tau \log_e\left[\frac{-2V_s/3}{-V_s/3}\right]$$
$$= \tau \log_e 2$$

Thus for $V_s >> 3$, the period T is given by

$$\approx 2\tau \log_e 2$$
$$T \approx 1.38\tau$$

● The op. amp is assumed to be operated from the same *total* supply voltage, i.e. from $\pm V_s/2$ and is assumed to have an output capable of swinging between these limits. With the chosen resistors the thresholds are $\pm(V_s/2) \times 1/3$

i.e. $\pm V_s/6$

∴ for positive-going ramp

$$t_+ = t_2 - t_1 = \tau \log_e\left[\frac{V_s/2 - (-V_s/6)}{V_s/2 - V_s/6}\right]$$
$$= \tau \log_e\left[\frac{4/6}{2/6}\right] = \tau \log_e 2$$

Similarly $t_- = \tau \log_e 2$ leading to the same period and frequency as for the comparator flip-flop based circuit.

● Switch open: $\tau_1 = (R_A + R_B)C$

$$t_2 - t_1 = \tau_1 \log_e\left(\frac{2V_s/3}{V_s/3}\right)$$
$$= 0.69\tau_1$$

Switch closed: $\tau_2 = R_B C$

$$t_2 - t_1 = \tau_2 \log_e\left(\frac{-2V_s/3}{-V_s/3}\right)$$
$$= 0.69\tau_2$$
$$\text{Period} = 0.69(\tau + \tau_2)$$

For $R_B >> R_A$ then $\tau_1 \approx \tau_2$

For $R_A >> R_B$ then $\tau_1 >> \tau_2$ and time constants depend mainly on R_A and R_B respectively.

● For this case $\tau_1 = R_A C$
$\tau_2 = R_B C$

i.e. independent control over the two parts of the cycle

● Again $\tau_1 = R_A C$
$\tau_2 = R_B C$

i.e. period $= 0.69C(R_A + R_B)$

But $R_A + R_B = R =$ constant, hence period and frequency are constant but the mark-space ratio is controlled by the ratio R_A/R_B.

EXAMPLES

1. The output of a 555 i.c. switches to 0 and to $(V_s - 1)V$ when the input falls below $V_s/3$ and rises $2V_s/3$ respectively. An RC network feeds back from the output to the input as shown opposite with $R = 1M\Omega$. What value of C is required for a frequency of 1Hz if $V_s = 12V$? What is the mark-space ratio of the output rectangular waveform?

For the positive going part of the cycle, the initial voltage across the resistor is $V_1 = (V_s - 1) - V_s/3$ and the final voltage is $V_2 = (V_s - 1) - 2V_s/3$

$$V_1 = 7V$$
$$V_2 = 3V$$
$$\therefore t_+ = t_2 - t_1 = \tau \log_e \frac{V_1}{V_2} = \tau \log_e \frac{7}{3}$$
$$= 0.847\tau$$

Similarly for the negative going portion

$$V_1' = 0 - 2V_s/3 = -8$$
$$V_2' = 0 - V_s/3 = -4$$
$$t_- = t_2' - t_1' = \tau \log_e\left(\frac{-8}{-4}\right) = \tau \log_e \frac{8}{4}$$
$$= 0.693\tau$$
$$\therefore \text{Period} = (0.847 + 0.693)\tau$$
$$= 1.54\tau$$
$$\text{But } f = 1Hz,\ T = 1s$$
$$\therefore \tau = 0.649s$$
$$\therefore C = 0.649\mu F$$

Mark-space ratio of output square wave is $\frac{0.847}{0.693} = 1.22.$

2. The standing timing circuit of a 555 i.c. has the capacitor charged through a series pair of resistors R_A, R_B with the junction shorted to ground when the upper threshold $2V_s/3$ is exceeded, and open-circuited when the lower threshold $V_s/3$ is reached. Choose values of R_A, R_B that produce an output with a repetition frequency of 1kHz and with a mark-space ratio of 3:1. The current in the capacitor should not fall below 5µA to minimize the loading effect of the device input currents. Supply voltage = +15V.

The positive-going interval has

$$V_1 = 2V_s/3$$
$$V_2 = V_s/3$$
$$\text{and } \tau_+ = (R_A + R_B)C$$
$$t_+ = t_2 - t_1 = \tau_+ \log_e \frac{V_1}{V_2}$$
$$= 0.69(R_A + R_B)C$$

Similarly for the negative-going interval

$$V_1' = -2V_s/3$$
$$V_2' = -V_2/3$$
$$\tau_- = R_B C$$
$$t_- = 0.69R_B C$$
$$\frac{t_+}{t_-} = 3$$
$$\therefore R_A + R_B = 3R_B$$
$$R_A = 2R_B \qquad 1$$
$$T = 1/f = 10^{-3}s = t_+ + t_-$$
$$= 0.69(R_A + 2R_B)C$$
$$(R_A + 2R_B)C = 1.45 \times 10^{-3} \qquad 2$$
$$\frac{V_s/3}{(R_A + R_B)} \geq 5\ .\ 10^{-6} \qquad 3$$

Solving these, from equation 3, $R_A + R_B = 1M\Omega$

Therefore from equation 1 $R_A = 0.69M\Omega$. 680kΩ preferred

$R_B = 0.33M\Omega$. 330kΩ preferred

From equation 2 $C = \frac{1.45\ .\ 10^{-3}}{1.33\ .\ 10^{6}}$

$C = 1.09nF$

LETTERS

continued from page 73

SSB FOR MOBILE RADIO

Your correspondent S. Walding (August issue) is correct in his comments on the difficulties of making a 300Hz wide quartz crystal filter capable of meeting the mobile radio needs of good performance over a wide temperature range at a low cost.

What we, and the other workers in the field at the University of Bath and at Stanford University in the USA, have demonstrated is the viability of s.s.b. as a form of modulation for mobile radio. We have used the minimum circuit design effort necessary to reach this objective.

We are not advocating only pilot carrier, but any form of pilot signal which provides a useful a.f.c. and a.g.c. All of the systems proposed, pilot carrier, tone in band and tone above band have potentially low cost solutions with good performance.

J. S. Palfreeman
Philips Research Laboratories
Redhill
Surrey

MILITARY ELECTRONICS

I feel that Mr Johnson's letter (August issue) rather misses the point. It is one thing to produce weapons in order to deter Russian aggression, but it is quite another to sell weapons to other countries for purely commercial reasons.

Advanced weapons can be used to cause appalling suffering to innocent civilians (or equally innocent conscripted soldiers), and those who earn their living in this way are no less guilty than those who used to earn their living from the slave trade. I wonder how many vile regimes are in power today solely because of the weapons which we sell them.

Furthermore, the only reason to produce weapons for Western use is to deter the Russians until they develop a more peaceful style of government. If ever these weapons are used *we all lose*. Is it not therefore highly dangerous to let so many companies depend on the arms trade? If ever we succeed in deterring the Russians and are able to sign a comprehensive disarmament treaty a very large number of people will become unemployed.

D. Bailey
Manchester

CITIZENS' BAND ON 27MHz

In July letters Mr A Blackmore seemed to want the UK to follow other European countries into allowing a 27MHz amplitude modulation citizens' radio service.

I am not connected in any way with any electronics manufacturing but do not want to see such frequencies used for c.b.

1. Existing users of those frequencies around 27MHz are already experiencing severe interference to their licensed equipment by c.b. sets operating in close vicinity. Users include medical and business paging systems and model control enthusiasts. Proponents of a 27MHz c.b. service must realise that there are already many thousands of legitimate users in that part of the e-m spectrum and that c.b. has not the right to plop down on channels being already used.

2. Interference from 27MHz c.b. equipment is increasing due to insufficient harmonic filtering in most equipment and the use of 'burners' to boost power output. All amplifiers have non-linear characteristics, and 27MHz amplifiers produce outputs on 54MHz, 81MHz, 104MHz etc. Essential life saving and police services are at risk from users aware or unaware of the poor spurious/harmonic radiation of their equipment. A deluge of 27MHz a.m. type equipment would result in chaotic interference to v.h.f. services.

3. Skip interference so prevalent in the 27MHz region will mean that use of low power equipment or equipment in remote areas will result in calls going unheard. It would be no use to be stuck with an inefficient 1-watt 27MHz c.b. on a dangerous mountainside if you were competing with skip and 100-watt 'burners'. At least with v.h.f. there would be a chance of being heard on an emergency channel at distances ranging from 10 miles upwards.

No, no, no to useless 27MHz a.m. citizens' band! V.h.f. is a must.

Des Walsh, E15CD
Carrick on Suir
Co Tipperary
Republic of Ireland

DISPLACEMENT CURRENT

In your December 1978 issue, Catt, Davidson and Walton purport to show that Maxwell's concept of displacement current is incorrect and their "true" model, which replaces a capacitor by a collection of pie-shaped transmission-lines, is correct. They argue that this dispenses with the need for displacement current, and go on to say: "Since any capacitor has now become a transmission line, it is no more necessary to postulate displacement current in a capacitor than it is necessary to do so for a transmission line." Unfortunately, it is necessary to do so for a transmission line, or have they forgotten Kelvin's (1873) original equation:

$$-\frac{dI}{dx}=GV+C\frac{dV}{dt}$$

G being leakance and *C* the capacitance per unit length. The second term on the r.h.s. of this equation is the displacement current.

What they have done in their subsequent algebra is to show that the transmission line approach and the lumped capacitance approach agree very closely. In no sense have they dealt with the topic indicated in their title: "Displacement current – and how to get rid of it." It looks as if Maxwell's equations may be right after all!

E. P. George (Professor)
University of New South Wales
Sydney, Australia

Reference
Lord Kelvin, Soc. Tel. Eng. Journ. I (1873), 397.

The authors reply:
Professor E. P. George's letter raises some interesting points:

1. The reference to the Kelvin model of the transmission line is irrelevant and misleading. It is irrelevant because the point he is making could have been made by reference to the equation for a charging capacitor,

$$i=C\frac{dV}{dt}$$

In this equation one could say that the right hand side 'is' the displacement current, which it is in Maxwell's theory by definition, but not in ours. It is misleading to introduce the Kelvin model since, as was shown by Oliver Heaviside, the Kelvin model is incomplete since it does not take account of effects due to the distributed inductance of the line.

2. What we have been proposing is that Maxwell's theory is 'inside out,' since it employs **E** and **H** and, in circuit theory, leads to the concepts *C* and *L*. In our theory the travelling **E, H** signal is the primitive and the transmission line the basic circuit element. Insofar as this change of viewpoint leads to Maxwell's equations then we would consider them to be correct. In this sense therefore Professor George's statement "It looks as if Maxwell's equations may be right after all" is correct at that level.

To show how Maxwell's equations relate to our view would require more space than is proper for a note of this sort but we hope that our further article in the March issue will have helped with this point

I. Catt, M. F. Davidson, D. S. Walton

STEREO TOGETHERNESS?

The death of Mr Airey Neave reminds me that some years ago he was on Sub-Committee D of the Select Committee on Science and Technology, if memory serves. I had not then learnt properly about the Government attitude to science and technology so well defined in Miss A. M. Clerke's article on Charles Babbage in the Dictionary of National Biography, which so ably shows HMG setting statistics and computer science simultaneously back 50-100 years for lack of a few thousand pounds, while withholding an answer to a letter for eight years, in the 1830s.

In my ignorance I suggested to Mr Neave a primitive idea from the plane on which I function. This was that f.m. portable receivers should bear a stereo decoder and switch to enable the user to listen to mono or to left or right channel only. The result would be that on meeting socially a person with a similarly equipped radio, albeit of a different size and make, the two could combine to listen in stereo. The idea is a little cumbersome, but so is the idea of setting up a rig like the Sanyo G2600 'casseiver' when you take coffee at an open-air cafe, this being one with speakers in detachable half-lids. I do not decry the large, portable 'casseiver' as one composer of my acquaintance is well content to use one without spaced external microphones, but with the analogue circuitry of my youth effortlessly absorbed into the black hole which the national press so insistently describes as the "silicone chip" (an amorphous semiconductor perhaps?) my suggestion could be absorbed into radio production without a second thought, and suitable tv commercials would suggest themselves automatically. The late Mr Neave may well have expended considerable effort in the idea at the time, but I now feel it is a good idea for 1979.

Bernard Jones
London W1

Microcomputer interfaces — 2

by **Ian H. Witten,** M.A., M.Sc., Ph.D., M.I.E.E.
Department of Electrical Engineering Science, University of Essex

The first part of this article, in the September issue, dealt with parallel inputs and outputs of a microcomputer, introducing serial communication with remote devices. In this part the author goes on to examine the interface devices needed for the serial mode of operation and brings in the concept of direct memory access.

Parallel-to-serial and serial-to-parallel conversion is accomplished by a device called a u.a.r.t. – universal asynchronous receiver/transmitter. The block diagram of Fig. 10 shows that the u.a.r.t. is divided into two subsystems, the transmitter and the receiver. The transmitter accepts eight parallel data bits together with five parallel control bits. After they have been latched in the parallel register, the data bits are transferred to the transmitter shift register and shifted out one by one to the serial output. The control bits select some of the options which were discussed earlier in the section on serial devices. The data rate is determined by the transmitter clock.

The receiver subsystem is the complement of the transmitter. Bits from the serial line are shifted in to the receiver shift register. When the data word is complete, the format is checked for parity errors and framing errors (stop bits not encountered when expected), and the word is transferred in parallel to the holding register. "Data available" shows that a new word has been received, and "read data word" reads it out of the device. If the latter has not been asserted by the time the next word is received, the previous word is lost when the new one is transferred to the holding register. In this case the "over-run error" bit is set.

The u.a.r.t. as described makes a perfectly good serial/parallel converter for microcomputer use. However, with its plethora of inputs and outputs, it is not particularly convenient for interfacing to the bus. Special u.a.r.t.s, often called a.c.i.as (asynchronous communications interface adaptor), are manufactured specifically for microcomputer use. With these, the control and status information is addressed as a single word, with a read from it returning the status information and a write setting the control bits. The "transmission done" signal is included as a status bit, and some interrupt facilities added.

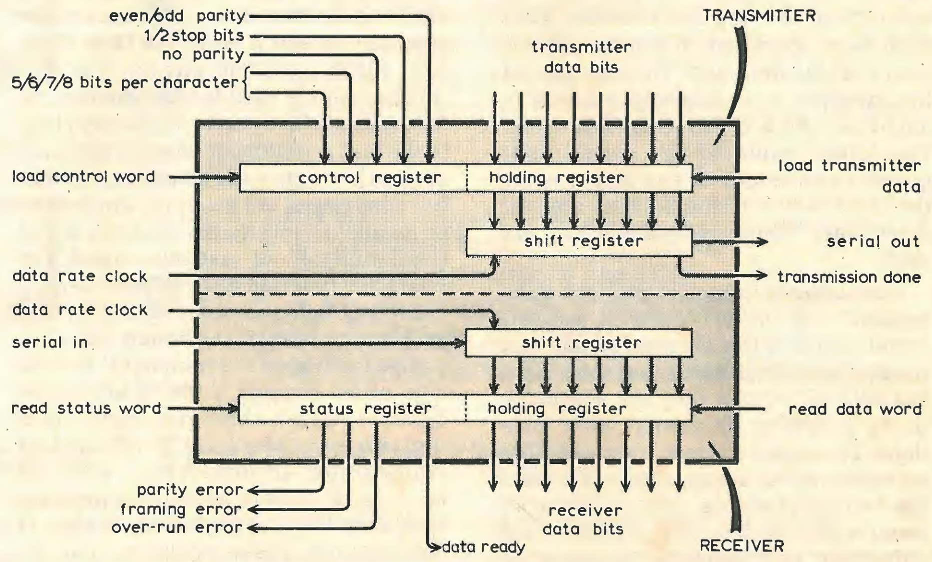


Fig. 10. *Block diagram of universal asynchronous receiver/transmitter.*

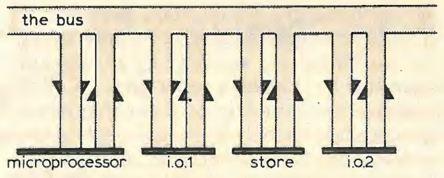


Fig. 11. *Bus-centred computer model*

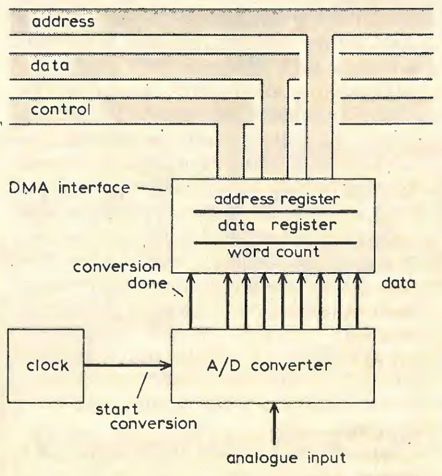


Fig. 12. *A-to-d converter with direct memory access interface.*

Similarly, the transmitter and receiver data are combined into the same register as far as the bus is concerned. All outputs will, of course, be tri-state so that they can be connected directly to the bus.

Direct memory access

So far, we have said very little about the role of the bus in interfacing. The reason for this is simply that connecting to the bus is easy: the tricky part of the interface is that which connects with the outside world, be it the world of light (l.e.d. interfaces), analogue electronics (d/a and a/d interfaces), serial data transmission (a.c.i.as), smells, car engines, or whatever. In fact all the interfaces we have considered are converted to the bus in the same way as the simple output port of Fig. 6. In terms of the bus of Fig. 11, the communication is between an input/output device and the processor, with the processor acting as bus master.

However, one of the reasons for using a bus in the first place is to allow possibilities for direct communication between devices other than the processor, particularly between peripheral devices and the store. This is called d.m.a. (direct memory access) communication, and to accomplish it the device interface must take over bus mastership, temporarily, from the processor.

Figure 12 shows an a/d converter with a d.m.a. interface. At each clock tick, the analogue voltage is converted to digital and passed to the interface. The task of the interface is to transfer the value to an appropriate place in store (i.e. to an appropriate bus address). To do this, it contains an address register which holds the address where the next value is to be placed. The address register is incremented after each "write" operation, so that successive values are stored in successive store locations. If this goes on for ever, all of store (including any programs) would be over-written, and so there is a word count register in the interface which counts words to go, and the contents of this are decremented after each store operation. When it becomes zero, the transfers stop. Thus the task of the interface is to transmit a block of data from the a/d converter into store. The initial value of the word count governs the length of the block, while the initial value of the address register determines which store locations are used.

Although the transfers proceed independently of the processor, it sets the initial values of the address register and word count. Thus these registers have bus address, so that they are accessible to the processor as normal store locations. To initiate a d.m.a. operation, the processor writes appropriate values into the two registers. As soon as the word count is set non-zero, the interface steps into action, and thereafter the operation proceeds autonomously, without bothering the processor. There must, of course, be some way of signalling to the processor when the operation is finished. For example, it could find out for itself by reading the word count register, and waiting until it becomes zero.

While the word count is non-zero, the interface monitors the "conversion done" line from the a/d converter. When this is asserted, it transfers the a/d output into the data register and then proceeds to request bus mastership. As described in the article in Reference 1 (Fig. 22), this involves quite a complicated protocol, using the bus request, bus busy, and bus grant lines.

Once mastership is granted, the interface puts the contents of its address and data registers onto the address and data bus, operates "read/write", and enters the handshaking sequence with the store by asserting "address valid". When handshaking is complete, it relinquishes the bus by releasing "bus busy" and the transfer is done. Now it decrements its local address register, decrements the word count register, and if this is still non-zero begins the whole operation again.

Computer subsystems can be divided into those that can initiate transfers on the bus and those that can't. The former will become bus master on occasion, while the latter will not and so can ignore the whole problem of bus contention, including the bus request, bus busy, and bus grant lines. Simple input/output devices only respond to processor requests and so are of the second type, while to transfer data directly from an input/output device to the store the device must be able to handle the bus-mastership protocol.

Another important distinction is between devices that use parallel data transmission and those that use serial transmission. In the former there are several wires (typically 8), one to carry each of the data bits. In the latter, only one wire is used and the data bits follow each other along it. Serial transmission is used when the path from the bus interface to the device itself is quite long and the device does not accept or generate data at a high rate (less than, say, 10000 or 20000 bits/s). Parallel transmission is used for fast devices, or for devices which reside physically close to the bus. A multitude of miscellaneous devices like lights and switches, a/d and d/a converters, are generally connected in parallel to interfaces, whereas serial transmission is usually used for character-oriented devices like v.d.us.

Driving lights is complicated by the problem of refresh. Although the data can be latched at the peripheral device, it is often cheaper if there are many lights to refresh them repeatedly from the processor to create an illusion of continuous illumination without latching. A loosely analogous problem with switches and keyboards is that of debouncing. These problems can be solved either with hardware (data latching, or debouncing circuits) or with software (refreshing, or imposing a delay in the program after a change of state), and illustrate nicely the trade-off, typical of microcomputer systems, between software and hardware complexity.

A/d and d/a converters, and lights and switches, are parallel devices. Even so, interfacing them to a parallel bus is usually done with the help of an interface chip which handles the control lines, latches and buffers the data, and accommodates interrupts.

The major difficulty with serial transmission is mastering the various combinations of options that are part of all serial interface standards. Interface chips exist to handle the basic serial/parallel conversion and the formatting bits (start, stop and parity).

Reference

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Further reading

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Radiometer monitors atmosphere

The earth's upper atmosphere between 30 and 130 kilometres altitude is now being monitored by an advanced radiometer operating in the infra-red region. Called SAMS (stratospheric and mesospheric sounder), it is the only European experiment carried in the American Nimbus 7 atmospheric research satellite now circling the earth in a near-polar orbit. The experiment was originated by Professor J. T. Houghton of the Department of Atmospheric Physics at Oxford University.

Infra-red radiation from the atmosphere between the wavelengths of 2.7 and 100μm is focused within the instrument on a number of detectors, each equipped with a different set of filters, to enable specific lines of the test spectrum to be detected separately. Sixteen different wavelengths are examined. The device is situated at the base of Nimbus 7 and is oriented to look tangentially towards the horizon at the limb of the atmosphere and not directly downwards. A two-axis scanning mirror changes the direction of view and enables SAMS to scan the atmosphere vertically. Because Nimbus 7 has been placed in a near-polar orbit and completes approximately 14 orbits per day, the radiometer records the variation in infra-red radiation throughout the atmosphere on a global basis.

From the data obtained the quantity, distribution and movement of the selected gases, ranging from carbon dioxide and water vapour to rare constituents such as oxides of nitrogen, can be assessed. Many of the gases are the result of atmospheric pollution. The projected twelve-month operational life of the radiometer will also enable seasonal variations in the distribution of these gases to be determined.

The cost of SAMS — about £1M — was met by the Science Research Council, while the design and development of the instrument was a collaborative endeavour of the Department of Atmospheric Physics, Oxford University, the Science Research Council's Rutherford Laboratory and British Aerospace Dynamics Group Stevenage space engineering department. As prime industrial contractor to the project, British Aerospace was given particular responsibility for the design and manufacture of the thermal subsystem, the electronics, and the setting-up and the alignment of the instrument including the integration of all the systems and testing of the complete radiometer. □

The Audio Engineering Society is calling for papers to be presented at their 65th Convention to be held in the London Hilton from February 25 to 27, 1980. Anyone wishing to present a technical paper on audio engineering or related subjects at this event should contact Dr J. M. Bowsher, Audio Engineering Society, Physics Department, University of Surrey, Guildford, Surrey GU2 5XH. The deadline for the receipt of complete papers will be the end of December 1979.

Low distortion amplification

Audio system offers a t.h.d. content of 0.003%

by B. J. Codd

Although the amount of harmonic distortion generated by audio amplifiers has received a good deal of coverage in *Wireless World*, most approaches have relied upon a study of specific distortion origins such as common-mode non-linearity and the pros and cons of shunt and series feedback arrangements. The author of this article puts forward a different approach based upon conventional design techniques where amplifier stages are compatible throughout, in an attempt to keep distortion to a minimum. While corners have been cut, notably in the preamplifier for magnetic cartridge, which has been optimised for low distortion rather than low noise, the figures for t.h.d (2nd and 3rd harmonics) are down to 0.003% where a complementary current source has been employed.

ONE WAY of holding harmonic distortion at a minimum level is to make each amplifying stage as compatible with its partners as possible, and in this outline a low-distortion voltage amplifier, of the form show in Fig. 1, is used. Here, the input stage is a voltage-controlled current source and the second and third stages are current-driven voltage sources. Overall negative feedback in this type of circuit increases the output impedance of the first stage and reduces the input and output impedance of the second stage. However, these two stages are already compatible and the application of negative feedback improves the performance of the combined amplifier.

Power bandwidth limitation

For reasons of stability it is usual to connect a capacitor between collector and base of Tr_3. Its value is determined by the open loop unity gain point (ω_μ) required to keep the amplifier stable when overall feedback is applied. This point can be calculated, to a first approximation, from

$$\omega_\mu = \frac{\text{mut. cond. of 1st stage } (g_m)}{\text{compensation capacitor } (C_c)}$$

The current required to charge C_c is derived from the first stage, the maximum being the tail current of the differential amplifier. If a signal is applied at the input, faster than the speed at which C_c can be charged, then the amplifier reverts from a linear mode to a slew-rate limited mode.

Slew rate

$$= \frac{i_{ql}(Tr_1)}{C_c}$$

where I_q = quiescent current (2)

Combining 1 and 2 we derive slew rate as

$$\frac{\omega\mu \times I_{ql}}{g_m} \qquad (3)$$

As w_μ is fixed for a particular amplifier, slew rate can only be improved by increasing I_{ql} or decreasing the g_m of the first stage. Power bandwidth is related to slew rate (for a sine wave) by:

$$\omega\,\max = \frac{1}{Vp}\,\frac{dv_o}{dt}\max \qquad (4)$$

Thus the maximum usable sine wave frequency is a function of both the peak voltage and the slew rate and is given by

$$f_{(max)} = \frac{\text{slew rate}}{\text{peak output voltage} \times 2\pi}$$

$$= \frac{\omega_{max}}{2\pi}$$

Distortion

It is convenient to discuss the distortion level by separating the amplifier into three sections — the input stage, the voltage amplifying stage, and the output stage.

The operation of the differential amplifier, used for the first stage, is normally described in terms of mutual conductance (g_m) whose units are mA/V. If g_m is plotted, it is found to vary in a non-linear manner with input voltage (V_{in}), g_m reaching its highest level when $V_{in} = 0$. The linear region can be extended, at the expense of g_m, by the use of emitter degeneration. The internal emitter impedance (r_e) should be kept small compared with the fixed emitter resistor, which necessitates a "tail" current of the order of 2mA if g_m is to be kept at a reasonable figure.

A serious form of distortion associated with this stage arises due to "early effect." This is also known as "base width modulation" and occurs due to changes in the width of the depletion layer of the collector/base junction as the potential across it is varied. This phenomenon generates distortion components at the input which are not reduced by negative feedback. Series voltage feedback can be the source of another form of distortion due to the common mode voltage modulating altering the depletion capacitance and the quiescent current I_q. To minimise these effects V_{ce} should be high, collector/modulation kept low, and a current source used to provide I_q.

Once these design steps have been taken, "even harmonic" distortion can be reduced to a very low value by matching IC_1 and IC_2.

The criteria for low distortion do not necessarily satisfy the requirements for the lowest possible noise; however, the use of low noise devices for Tr_1-Tr_2 provides a reasonable noise figure over a wide range of source impedances.

The second stage operates as a current amplifier, this task being best

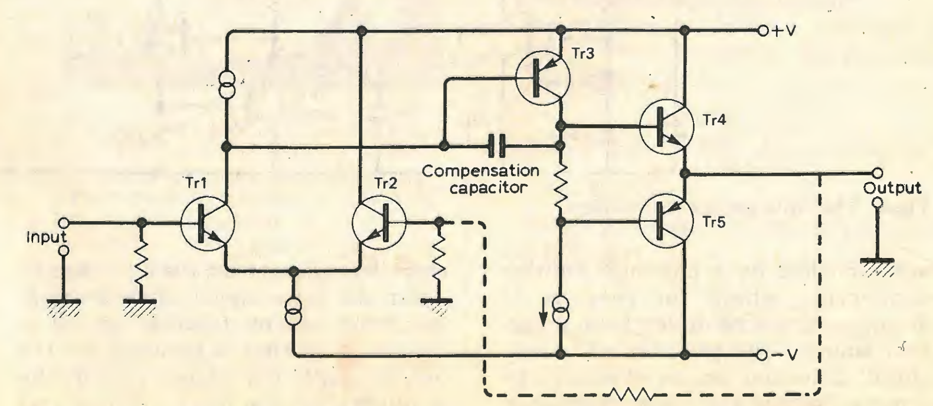


Fig.1. *Low distortion voltage amplifier*

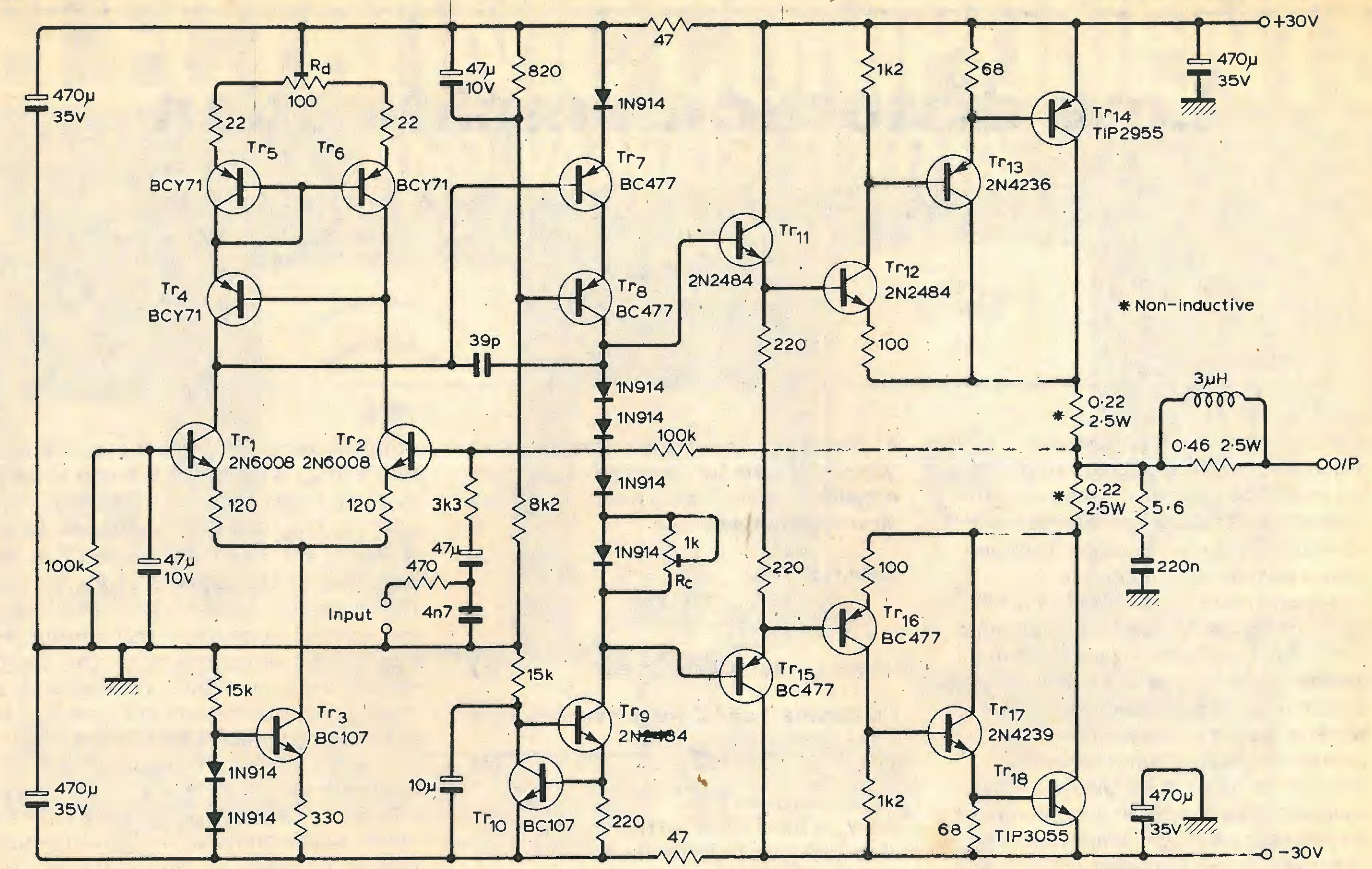
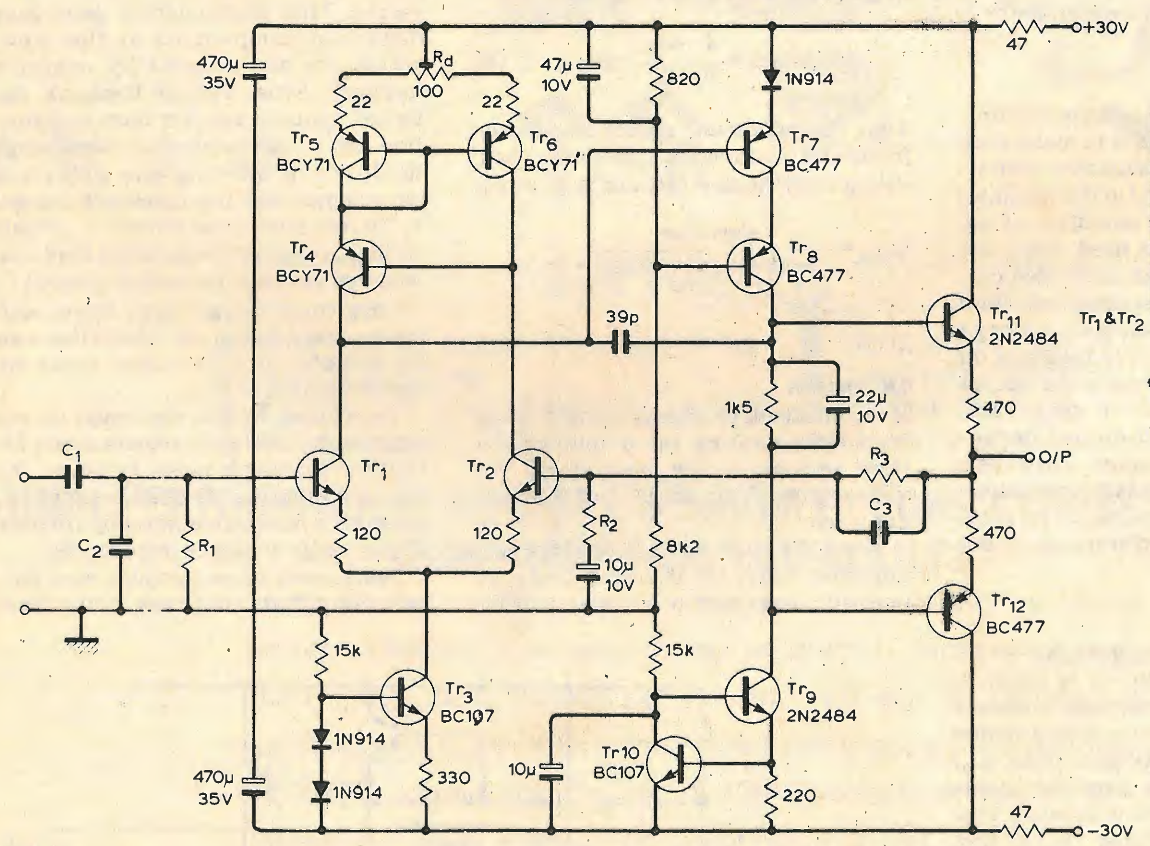


Fig.2. *Main power amplifier circuit. This is an extended version of Fig.1*



Preamplifiers

	1	2	3
R_1	47k	100k	220k
R_2	1k	3k3	10
R_3	47k	100k	220k
C_1	†	0·5μ	0·5μ
C_2	*	–	–
C_3	10p	–	–
Tr_1 & Tr_2	2N3117	2N6008	2N6008

* Depends on cartridge manufacturer's spec.

† See rumble filter

Fig.3. *The "low power" amplifier*

accomplished by a common emitter connection which for reasons of linearity, should be driven from a current source. The problem of "early effect" distortion can be overcome by using a cascode composite transistor, which decouples the generated capacitive effects from the input signal.

For low power applications a complementary emitter follower biased in class A is all that is required for the output stage. For higher power, the problems become more difficult, especially when the stage is operated in class B. The four major contributors to the distortion were found to be. crossover distortion, variations in h_{fe} of the power devices with current and frequency, high current wiring and changes in drive requirements at varying power levels and frequencies.

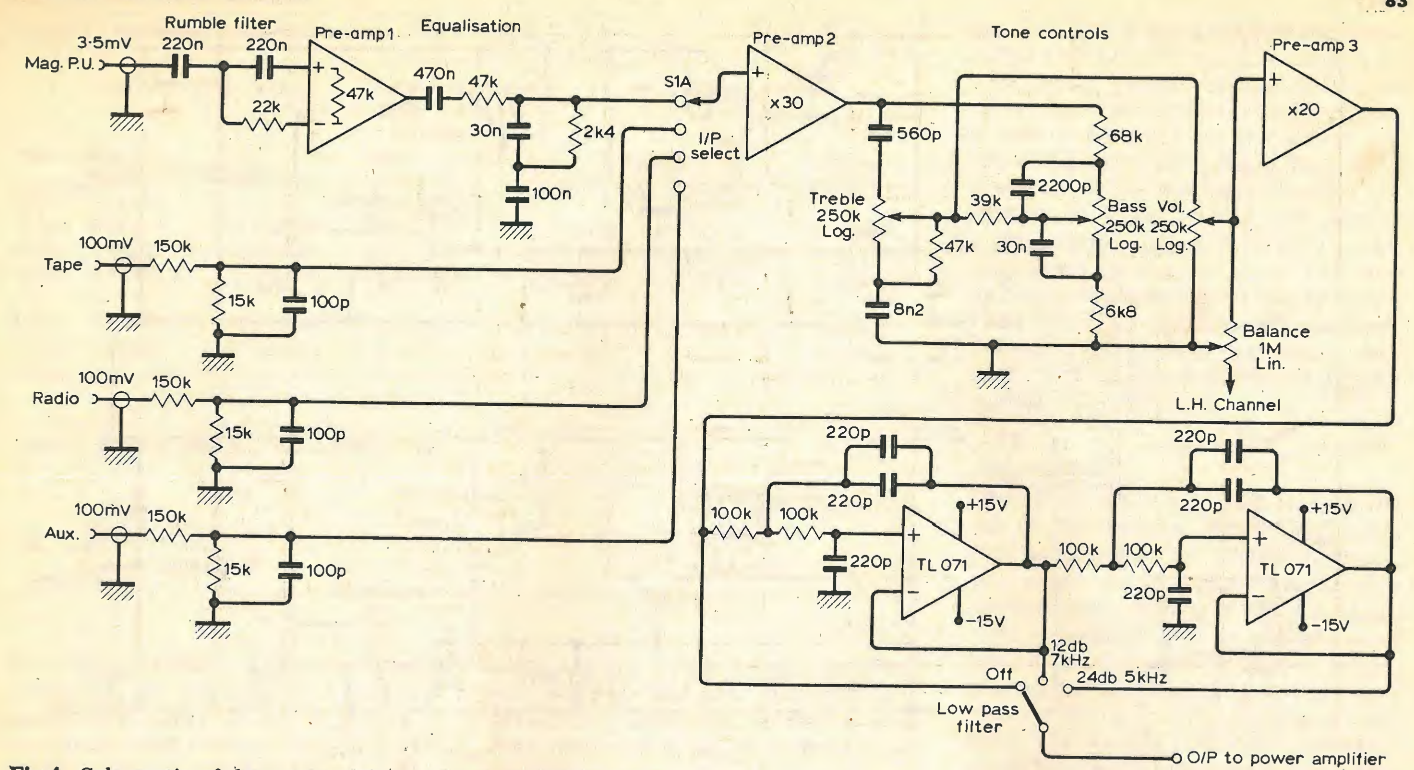


Fig.4. *Schematic of the preamplifier and tone control stages*

Points 1 and 2 can be minimised by the use of a "triple" which has excellent linearity, whilst the thermal isolation of the output devices gives a stable operating current. The quiescent current is still important, and should be set such that the "crossover spikes" just disappear.

Whilst measuring the distortion of this stage it was apparent that the layout of the high current wiring was extremely critical. In fact, any meaningful figures proved impossible to ascertain until certain modifications were carried out:

Star-configuration wiring was employed, high current wiring was kept to a minimum length and screened cable used for high current wiring, including earth returns.

A class A complementary emitter follower was used to interface the second-stage to the triple so as to reduce the influence of varying power levels and frequencies.

Circuit description

Figures 2 and 3 show a practical realisation of an amplifier based upon the design principles previously discussed. As both circuits are of similar design, one circuit description will suffice.

Tr_1-Tr_2 form a conventional differential amplifier, whose tail current, defined by Tr_3, is 2mA. Emitter degeneration has been added to increase the slew rate and flatten the g_m curve. The load for this stage comprises Tr_4, with Tr_5 and Tr_6 connected as a current mirror. This configuration also provides a push-pull current source to drive the next stage. The 100Ω potentiometer which connects the emitters of Tr_5 and Tr_6 is adjusted for cancellation of even harmonic distortion.

Tr_7 is operated as a common emitter amplifier using the emitter impedance of Tr_8 as its load, ensuring the collector-base modulation is kept low. Tr_8 is connected as a common base amplifier and retains all the advantages of this mode of connection. The modulation of the internal collector-base capacitance of Tr_8 is now decoupled from the base of Tr_7, thus eliminating "early effect" and increasing bandwidth.

After several years in industrial electronics, B. J. Codd joined the Electronics Development section of Leicester Royal Infirmary's Medical Physics Department as its senior technician. During the intervening 9 years he has been responsible for the development of a six-channel foetal e.c.g. monitor, now in use in the Infirmary's maternity wing, and an ultrasonic 2MHz doppler system for use in aortic blood flow analysis.

The output stages are fairly conventional and their typical problems have already been discussed. Of general consideration is the mode of feedback used in the power amplifier. Shunt feedback was used as it gave marginally better results. Series feedback may be used with a slight increase in even harmonic distortion.

The setting-up procedure for the amplifier depends on the equipment available, and for the best results a distortion factor meter should be used. R_d is adjusted for minimum distortion whilst R_c is adjusted such that the "crossover spikes" just disappear. If only a multimeter is available, then R_d should be set such that $I_{c1} = I_{c2}$, and R_c is adjusted for 20mA quiescent current through the output transistors. Where appropriate all adjustments should be made at 10kHz.

Low power amplifier, results

The amplifier exhibited a slew rate of 40V/μs which is close to the predicted value shown by (1).

$$(1)\ \text{slew rate} = \frac{I_q}{C_c} = \frac{2\times10^{-3}}{39\times10^{-12}} \approx 50V/\mu s$$

This gives a maximum usable frequency at 50Vp-p of

$$(5)\ f_{max} = \frac{\omega_{max}}{2\pi} = \frac{40\times10^6}{25\times6.28} = 250\text{kHz}$$

To define the closed loop frequency response, a single pole low pass filter

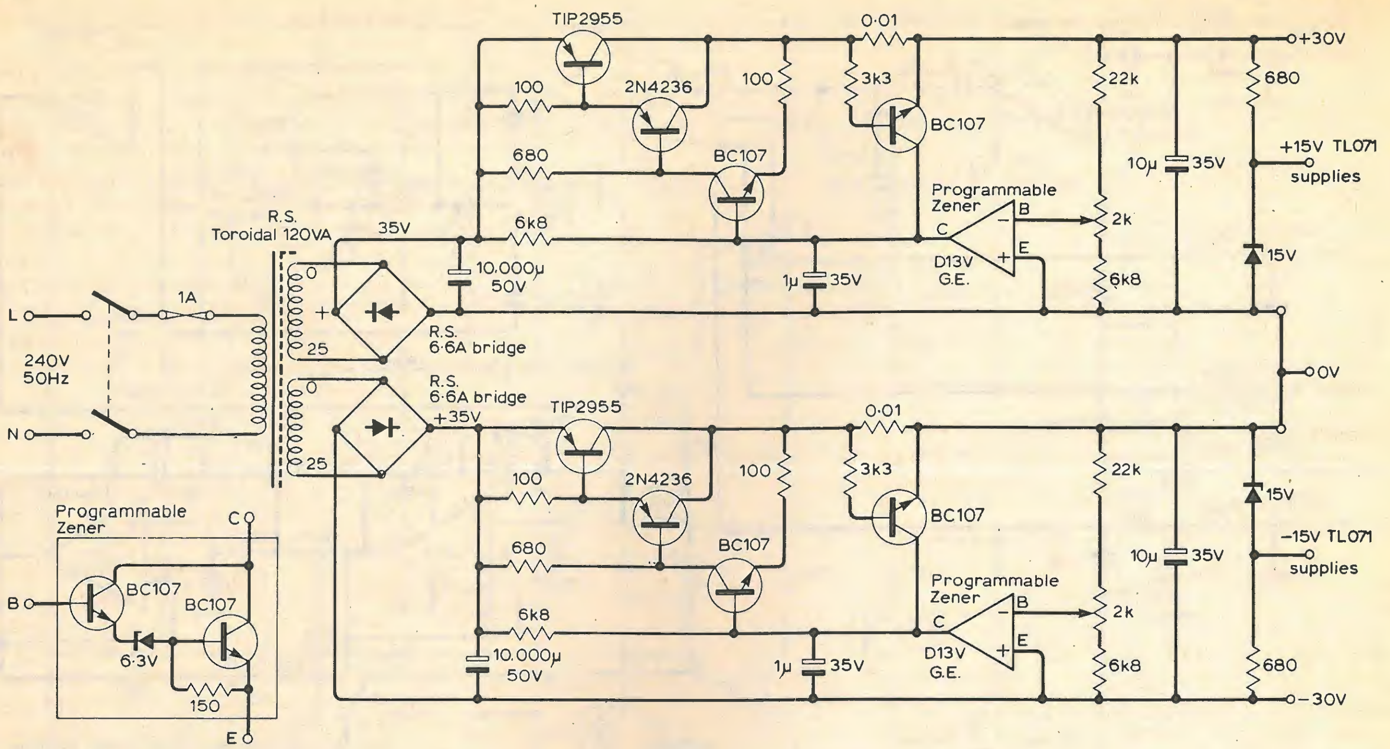


Fig.5. *Power supplies*

was incorporated in the input circuit, with a 3dB point at 70kHz.

The inherent distortion of the system is shown in table 1, along with the results for the amplifier. All measurements taken on the amplifier were made with IC_1-IC_2 matched, at 50Vp-p into a 10k load, and a closed loop gain of 50. The noise figure of this stage depends upon the devices used for Tr_1 and Tr_2. For a magnetic cartridge, low noise transistors gave marginally better results than low noise f.e.ts, although for higher resistances, low noise f.e.ts such as the BF818 can be used to advantage.

Power amplifier

The frequency characteristics were as for the preamplifier and again a low pass 70kHz filter was incorporated into the input circuit.

The distortion results for the power amplifier are shown in table 1. These figures were taken at 40W continuous into 8Ω with IC_1 and IC_2 matched, and the quiescent current adjusted for minimum third harmonic distortion. All figures fell as power was reduced. If the quiescent current is adjusted above its optimum value, the third harmonic distortion rises to 0.008% at 40W continuous into 8Ω at 20kHz, and falls to a low value when the stage operates in class A.

The amplifier was stable with both capacitive and inductive loads, and showed little ringing when driving a 2.2μF capacitor with a 20kHz square wave. Although the distortion figures can be improved if the output stage is biased in class A, it is felt that the amplifier presents an acceptable compromise between minimising distortion and the convenience of class B.

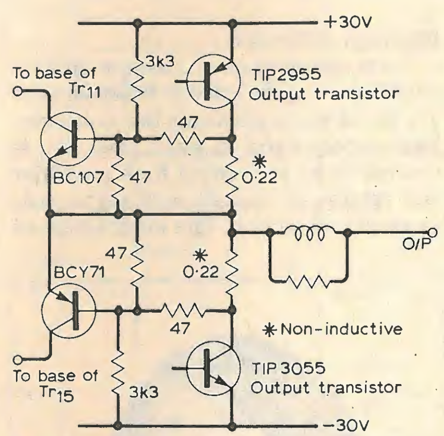


Fig.6. *Suitable output transistor protection circuit*

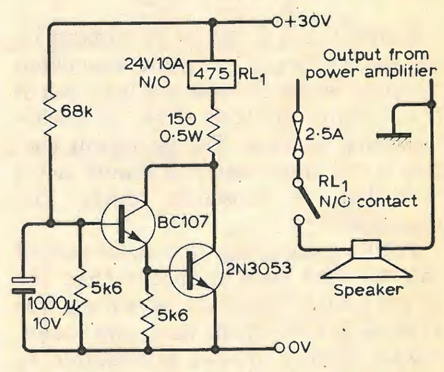


Fig.7. *Delayed relay speaker protection circuit*

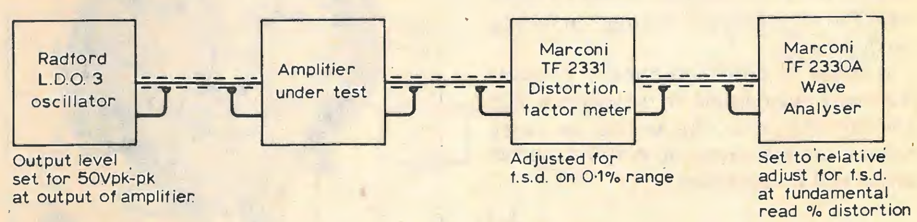


Fig.8. *Block diagram of harmonic distortion test set-up*

The audio system

Figure 4 shows a complete audio system based upon the amplifiers just described. Passive equalisation and tone controls have been used, ensuring that the amplifiers are always operated under optimum conditions. An active high pass (rumble) filter was incorporated into the input circuit of the magnetic pick-up preamplifier. This filter has a 12dB/octave slope with a 3dB point at 25Hz.

The gain of the preamplifier is 34dB and this circuit is followed by a passive equalisation network which has an insertion loss of 23.5dB at 1kHz. The next stage, which is used for auxiliary inputs, has a gain of 30dB. Thus the overall sensitivity in the magnetic pick-up position is 3.5mV at 1kHz, giving a maximum input of 500mV p-p at 1kHz, 1V p-p at 20kHz, and 50mV p-p at 50Hz, i.e. an overload capability (with reference to the nominal sensitivity) of 33dB, 40dB, and 17dB respectively.

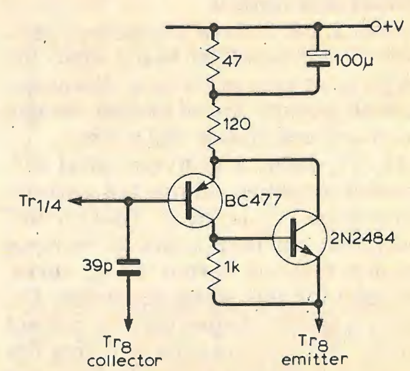


Fig.9. *Complementary current source. This modification to the "low power" amplifier output stage further reduces harmonic distortion content*

Table 1. Harmonic distortion results.

	Oscillator		Lower power amp (50V p-p/10kΩ)		High power amp 40W continuous/8Ω	
	2nd Harmonic	3rd Harmonic	2nd Haronic	3rd Harmonic	2nd Harmonic	3rd Harmonic
60Hz	0.003%		0.003%		0.003%	
100Hz	0.003%	0.0003%	0.003%	0.0004%	0.003%	0.0008%
1kHz	0.003%	0.0003%	0.003%	0.0005%	0.0025%	0.0015%
5kHz	0.003%	0.0004%	0.0035%	0.0006%	0.002%	0.003%
10kHz	0.004%	0.0004%	0.003%	0.0006%	0.003%	0.003%
20kHz	0.005%	0.0005%	0.004%	0.0006%	0.003%	0.004%

Table 2. Second and third harmonic levels.

	2nd harmonic	3rd harmonic
original circuit	0.007%	0.006%
modified circuit	0.003%	0.003%
oscillator distortion	0.0025%	0.0003%

The signal/noise ratio for this combined stage depends upon the devices used for the input transistors, these being shown in the Fig. 3 table.

The passive tone control (borrowed from the Mullard 3-valve preamplifier) features 15dB cut and boost with an insertion loss, in the flat position, of 20dB. The final stage has a gain of 26dB which drives either the power amplifier or the low pass filter.

This filter has a 12 or 24dB/octave slope, the 3dB points being 7kHz and 5kHz respectively. The f.e.t. input operational amplifier used for this stage has a slew rate of 13V/μs and a unity gain distortion of 0.01% at 30V p-p. at 10kHz.

Auxiliary circuits

The power supply used was a series pass circuit, supplying high currents with only a small voltage across the series transistor, thus keeping the dissipation to a minimum.

A delayed relay was used to protect the speakers against switch-on transients and the output transistors were protected by the now conventional circuit first described by Bailey and were mounted on a 4in x 4in finned heatsink.

Signal/noise ratios

The measurement of signal/noise ratios was achieved by using the TF2330A wave analyser, taking figures one octave apart over a 15kHz bandwidth with reference to a 5mV, 1kHz signal. Figures are also shown corrected for curve A weighting (A.S.A. sound measurements) which corrects for the response of the ear for low level signals.

Signal/noise ratio, magnetic cartridge input

50Hz-15kHz bandwidth	70dB
corrected for 'curve A'	78dB

Sensitivity

"magnetic" preamp	3.5mV
aux	100mV
power amp	700mV

for full output at 1kHz

The distortion figures for both amplifiers include oscillator distortion, hum, and noise. The distortion for both amplifiers fell with falling power output. The low power amplifier was measured with a closed loop gain of 50.

So as to realise the low distortion capability of the complete audio system it was necessary to provide a separate power supply for the preamplifier. Also, it is possible to reduce even further the distortion level in the low power amplifier by replacing Tr_7 with a complementary current source. The two circuits were compared at 10kHz with a closed loop gain of 66dB and an output voltage of 50V peak to peak into a 10k-load. The results are shown in the related table. (Table 2).

Conclusion

The object of this approach was, by the use of conventional techniques, to design an amplifier with levels of distortion which would make it competitive with current commercial designs. However, a possible area of improvement remain in the class B output stage, although if biased in class A, third harmonic distortion falls to an insignificant level. The s/noise ratio on "magnetic" could have been improved but the fact that at normal operating levels the distortion content was below the sensitivity of the test instrument, and the s/noise ratio is really only 6dB above the theoretical minimum for a magnetic cartridge, means that the compromise seems to have been justified.

The design of the complete system lends itself very well to operational amplifier techniques, and it may well be that, at some future date, an enterprising company will convert it into i.c. form, leaving the audio designer free to optimise the associated circuits, with a consequent improvement in audio amplifier quality.

Printed circuit boards

A set of glass fibre printed circuit boards will be available for £16 (inclusive of v.a.t. and UK postage) from M. R. Sagin at 23 Keyes Road, London, NW2. The set comprises three identical stereo pre-amp boards and one power amp board. The p.c.bs are also available separately for £4.20.

Book Received

Audio System Design for Schools and Colleges, by R. H. Welch, is designed to provide impetus for CSE, 'O' and 'A' level students to take an interest in the workings of sound reproduction equipment. The preface expresses the view that the book will help students and teachers to design and construct audio gear, but one feels that the design aspect of this work has received a fairly shabby deal. On the other hand, it is an attractive and up-to-date introduction to the field and is a practical guide to the technical side of disc reproducing equipment. Circuits for amplifiers are presented — many using linear i.cs — and a very useful chapter goes quite fully into the design and building of loudspeaker enclosures. Turntables, too, receive a good deal of attention — again more practical than theoretical. A good glossary is provided, albeit with one or two errors and ambiguities, and a list of suppliers of materials and components is included. A small, but irritating point is that references are not numbered and are difficult to relate to the text. The book has 195 A5-size pages, is ring-backed in paper covers and costs £2.75 plus postage and packing from Trent Polytechnic, Burton Street, Nottingham.

Volunteers wanted

The British Talking Book Service for the Blind, which has supplied records and tapes to blind people for many years, is in need of volunteers to instal and maintain the tape cassette players currently in use. A complete spares service and assistance are available, if required, and the work consists mainly of routine maintenance and assistance to blind people in learning to use the machines. Anyone willing to assist in this way should write to E. L. Wade, British Talking Book Service for the Blind, Mount Pleasant Road, Alperton, Wembley, Middx.

CIRCUIT IDEAS

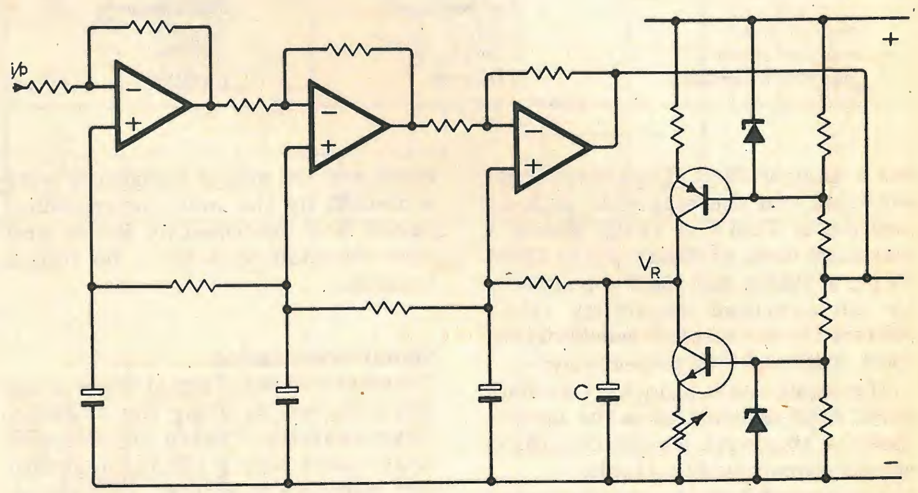
Zero-crossing detector

A square wave with any mark-to-space ratio can be obtained from input signals with a wide range of amplitudes. Offset voltage and current compensation are not required.

The two transistors form constant current sources and, when fed with a square wave, switch as a complementary pair. Capacitor C is alternately charged and discharged and if the current sources are balanced, V_R drifts up or down until a 1 to 1 ratio is achieved. If one emitter resistor is twice the value of the other, a 2 to 1 ratio is achieved. The reference voltage feeds all of the op-amps so the mark-to-space ratio is maintained wherever saturation occurs.

This arrangement produces little phase shift and is stable when used in a phase comparator, even with an input signal varying from 500μV to several volts.

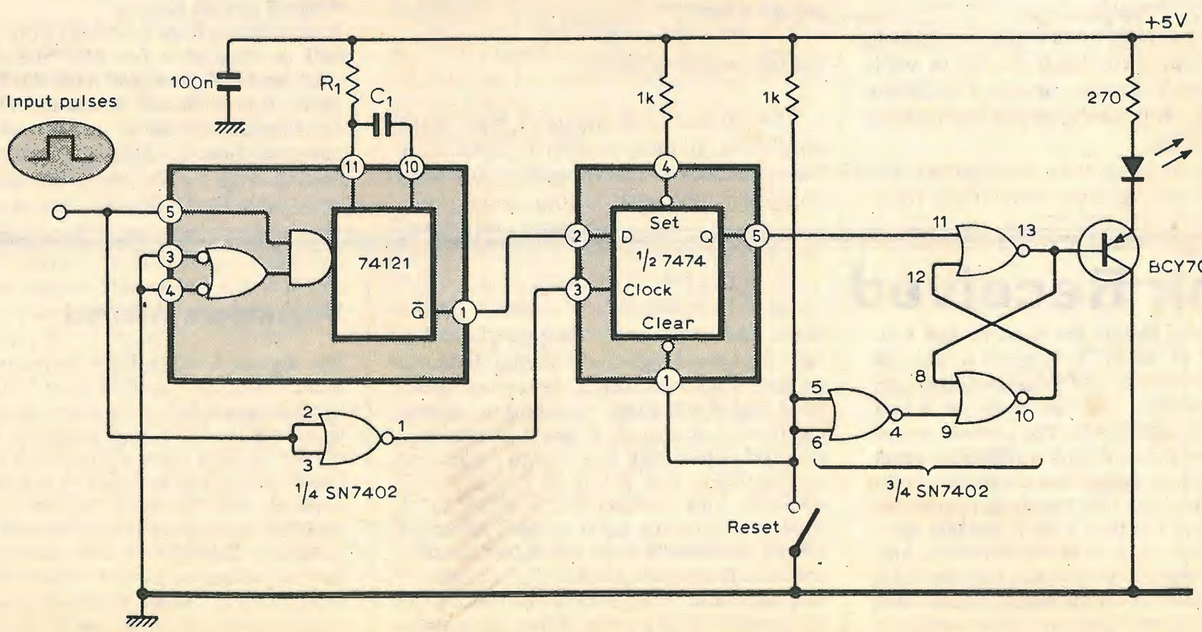
J. C. Milward
Wokingham
Berks

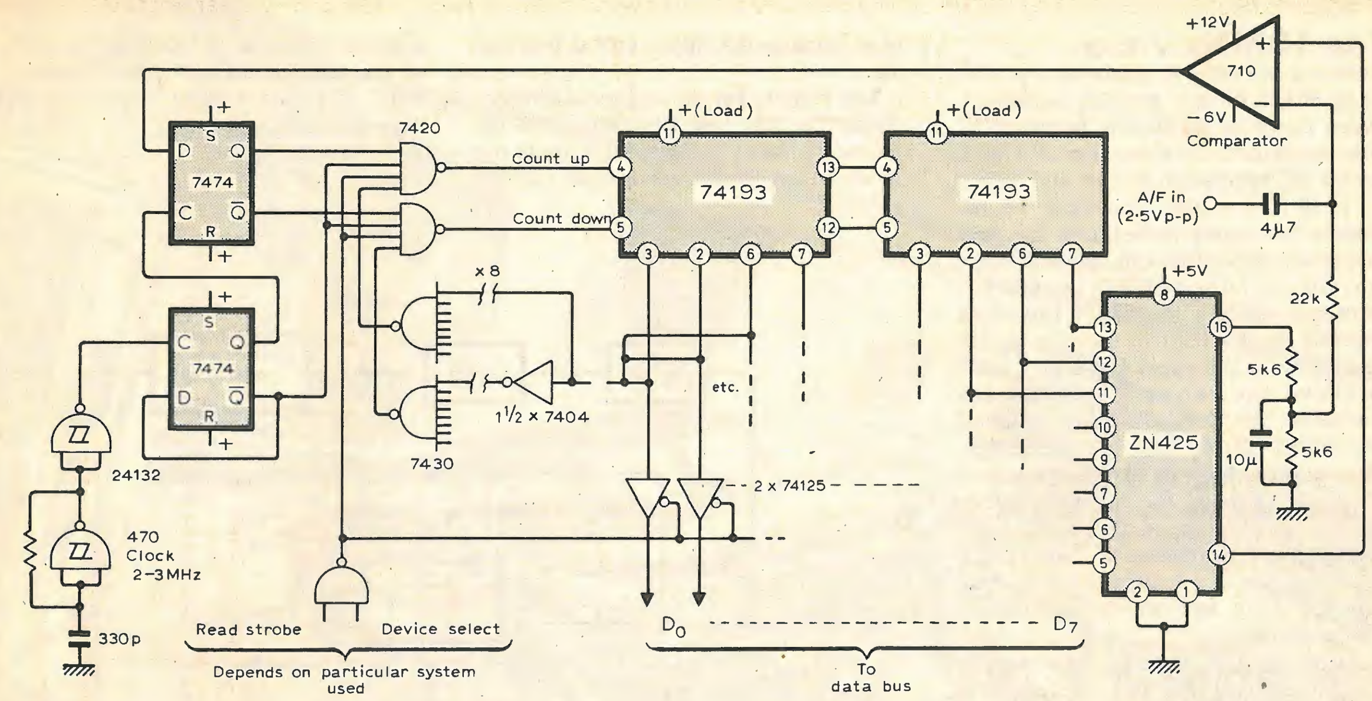


Pulse width detector

If the width of the input pulse does not exceed the width of the monostable pulse determined by C_1 R_1, the positive edge of the clock input to the 7474 produces a 0 at the bistable input and the transistor remains switched off. If the input pulse width is greater than the 74121 pulse, the flip-flop feeds a logic 1 to the bistable which then switches the transistor and l.e.d. on. Because the bistable acts as a latch, the l.e.d. remains on until the reset switch is activated.

R. E. S. Abdel-Aal
Sunderland Polytechnic





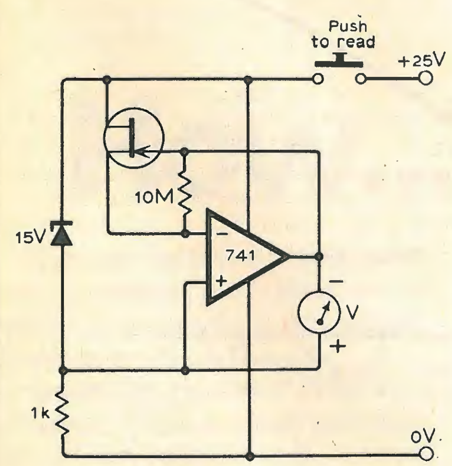
8-bit tracking a-to-d converter

This converter is suitable for encoding audio signals onto an 8-bit microprocessor bus. The output of an up-down counter formed by two 74193 i.cs, is converted to an analogue signal by the ZN425E. This signal is compared with the analogue input to determine the direction of count, and the 7404 and 7430 provide an end stop to prevent counting over from FF to 00. The 7474 bistables control the count direction by allowing it to change only when the counter clock is inactive. The clock must run at a higher speed than the ZN425 settling time. Tri-state buffers interface the 8-bit output with a data bus, and are enabled/disabled by the device select and read data strobe inputs.

The converter can be interrogated asynchronously because a correct value is always obtainable. Because the circuit has an inherent low-pass action, analogue signal conditioning is not necessary and a sample/hold gate is not required.

Although noise performance is slightly inferior to successive approximation type p.c.m. encoders, it is not obtrusive.

M. D. Usher
Manchester



V_p meter

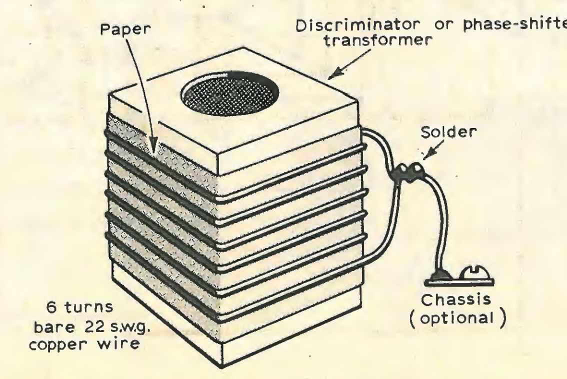
This economical circuit measures the gate-to-source pinch-off voltage of an n-channel f.e.t. without the need to manually adjust V_{gs}. The unit is particularly useful when selecting f.e.ts for matched pairs in constant current sources.

J. F. Gregg
Co. Wicklow
Eire

Magnetic screen for f.m. tuners

Because it has become common to stack audio equipment, modulation hum on v.h.f. is sometimes a problem due to magnetic fields from transformers. A simple and well tried solution is to wrap the discriminator or phase-shift coil case with a short-circuited coil of copper wire. Six turns of 22 s.w.g. will suffice in most cases and earthing the wire is a convenient method of anchoring the spiral in place.

R. G. Young
Peacehaven
Sussex



1 to 10MHz v.c.o.

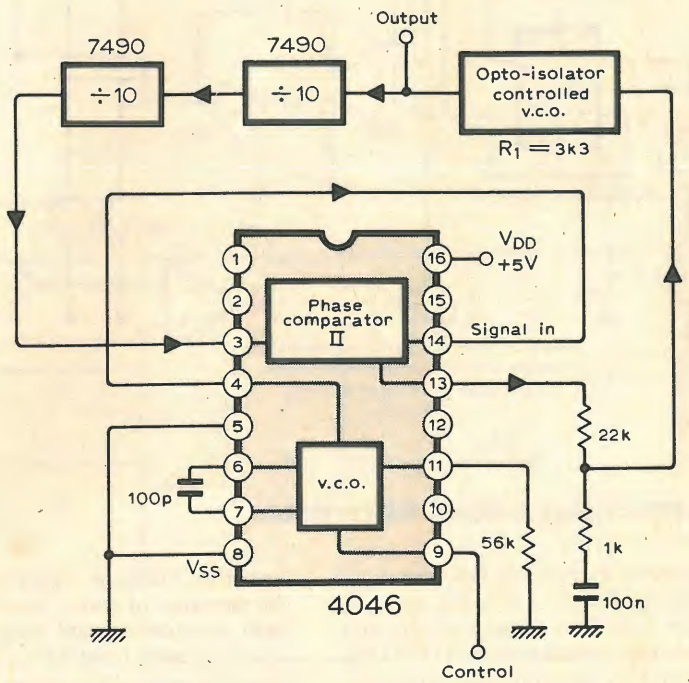
Most i.c. waveform generators and v.c.os either do not provide sufficient sweep range or sufficient bandwidth. This oscillator is an extension of a well known RC relaxation circuit and offers a 1 to 10 MHz range. Transistor Tr_1 increases the input impedance for low frequency operation and the feedback current is supplied via a photo-transistor. Output frequency therefore depends on the control current in the l.e.d. Because the upper frequency limit is above the range of the photo-transistor, the device is only supplied with direct current from a diode bridge. This arrangement also enables one photo-transistor to handle both halves of the oscillation cycle. Fast, low-capacitance germanium diodes are necessary in the bridge to minimise voltage drop and unwanted direct charge transfer.

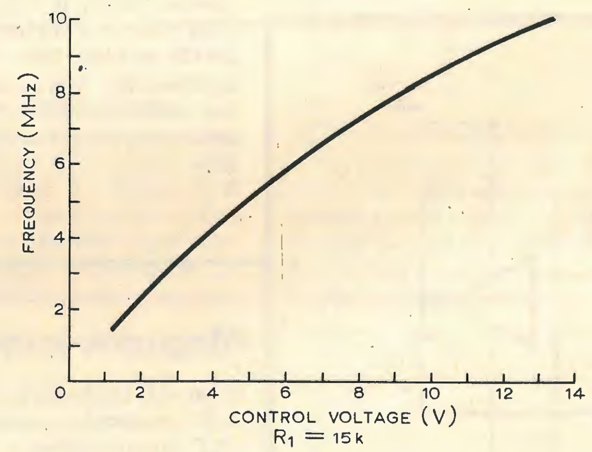
An op-amp is used as a voltage to current converter, and to minimise thermal drift in the control opto-isolator, a dual device is used with one half in the amplifier feedback path. This technique also improves transfer linearity. At maximum frequency the control current in the relaxation oscillator and R_1 is about 1mA, so R_1 is selected for the required control voltage at the input.

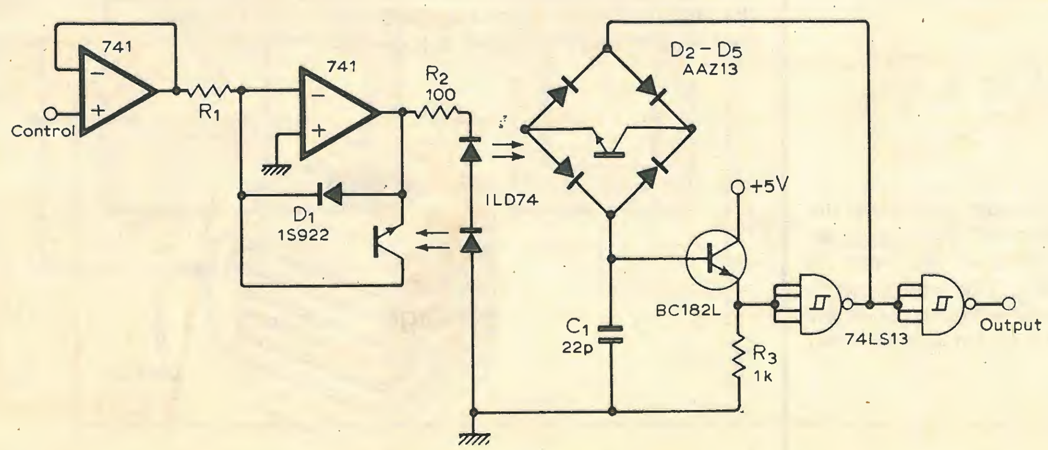
Although the circuit is simple, it will cover more than a decade range, about 0.5 to 13 MHz in the prototype, and can also be modulated. The output has an approximately equal mark-to-space ratio at 10MHz but this varies at lower frequencies. Linearity is not ideal, primarily because the waveform at Tr_1 base is not the ideal saw-tooth. However, this can be improved by a phase-lock loop as shown. The internal v.c.o. of a 4046 provides the signal input, and is not within the loop. The comparator input is provided by a divided output from the opto-isolator v.c.o. Linearity, thermal stability etc. of the circuit are now determined by the 4046 v.c.o. The values of C_2 and R_4, which determine the frequency, are chosen so that only the lower half of the control range is used because the upper half is less linear.

The penalty for an improved characteristic is that low frequency roll-off (about 75 Hz) of the loop filter limits the modulation frequencies that can be applied. However, a LOCMOS version of the 4046 offers a higher frequency limit of about 4 MHz which should overcome this problem.

D. H. Fallett
Bristol







WORLD OF AMATEUR RADIO

Date with destiny

For radio amateurs, the most important event for many years – the ITU World Administrative Radio Conference at Geneva – opens on September 24 and is due to last until November 30. While theoretically the conference could re-write completely the entire International Table of Frequency Allocations for all services a more realistic view of the outcome is that much of the table will remain recognizably similar to the present allocations (which are still based largely on the Atlantic City, 1947 conference, although these were modified in 1959 at Geneva and have also been affected by specialized conferences on space satellites, etc.). Nevertheless, important changes affecting the amateur service are anticipated – always assuming that WARC is able to reach real agreements and does not result mainly in a proliferation of footnotes and further regionalization.

Radio amateurs will be represented at Geneva by an IARU team of accredited "observers", and some countries including the U.K. have invited amateurs to attend as members of national delegations.

There is a feeling that the proposals submitted in advance pose few serious threats to the current Region 1 allocations to amateurs either on h.f. or above 30MHz, but it is realised that at any time during the conference dangers could emerge as part of the inevitable 'horse-trading' needed to reach compromise agreements. The official U.K. proposals include the three additional h.f. bands at 10.1, 18.6 and 24.0 MHz, although Roy Stevens, G2BVN, the RSGB's Telecommunications Liaison Officer has described support for these extra bands from other Region 1 countries as "rather disappointing".

Further evidence of the continuing value of the amateur service in contributing to radio propagation research is contained in a recent article in the ITU's *"Telecommunication Journal"* (Vol 46, VI/1979) by K. J. Hortenbach and F. Rogler of the German broadcasting service, Deutsche Welle. This underlines the importance of "chordal hop long-path" h.f. propagation in providing a reliable broadcast service to Australia from West Germany. The chordal hop mode was first described some twenty years ago by H. J. Albrecht as a result of careful observations on 3.5, 7 and 14MHz signals from West European amateurs as received in New South Wales, Australia. He realised that these signals were heard at times and at strengths which could not be accounted for by conventional multi-hop propagation modes, with their losses due to multiple ground reflections and D-layer crossings.

It is now at last becoming accepted that dawn and dusk tilts in the ionosphere regularly result in long-distance chordal hop, making transmission to Australia and New Zealand extremely reliable. It is worth noting that if amateur bands at 10 and 18 MHz had been available during the past twenty years, the work of confirming the chordal hop theories would have been eased considerably.

Top band activity

Since the disappearance of the 1.9 to 2.0 MHz loran pulses, Top Band (1.8 to 2.0MHz) has become a much more attractive night-time amateur band. This has been reinforced by the increasing number of countries (now including the USSR and Spain) which permit amateur operation in segments of this band. Stew Parry, W1BB, doyen of the 1.8MHz enthusiasts, has pointed out that good conditions on this band have little relationship to normal h.f. propagation predictions and he advises "the only real way to success is to monitor the band constantly".

The band remains a useful testing ground for low-power equipment with a continuing mixture of s.s.b./c.w./a.m. modes. Recent contacts have shown, for example, that Ray Coley, G3IFF, of Havant uses an all-band direct-conversion transceiver from a motorcycle battery, while a flat-dweller in Northern Ireland has a 135ft "invisible" aerial using 28s.w.g. steel wire. The band is also a good place to try-out the new low-cost v.m.o.s. power f.e.ts such as the VN10KM and VN67AF devices, both of which cost under £1 and which can readily be used in parallel to provide a few watts of r.f. output.

From all quarters

The RSGB Telecommunications Liaison Committee has set up a sub-committee to investigate the recent proposals (WoAR, June 1979) of the European CW Association that there should be a U.K. c.w.-only "Novice" licence. It is expected that if the idea is approved by the committee, an official approach will be made to the Home Office.

It is now clear that no further activity can be expected from the Russian amateur radio satellites, RS1 and RS2, launched in October 1978. The relatively short operational lifetimes have been ascribed to excessive radiation problems during the launch period. Oscar 7 and 8 are still operational, although Oscar 7 launched in November 1974 is thought to be reaching the end of its long operational life. There is apparently a good possibility of a Phase III Oscar (geostationary orbit) launch in Spring 1980.

John St Clair, ZS2JR, of Port Elizabeth is believed to be the only amateur in southern Africa receiving weather pictures from the geostationary satellite, Meteosat, on 1691MHz. For an antenna he uses a 2-metre dish cut from a surplus Post Office 4-m diameter dish.

Tropospheric ducting between Hawaii and California is reported to have resulted in the setting up of a new world record on 432MHz. A contact between WB6NMT in California and KH6HME in Hawaii spanned some 4000km.

The Home Office has agreed that any r.t.t.y. (radio-teleprinter) mode defined by CCIR documents may now be used by UK amateurs on any band where r.t.t.y. is permitted. Among those taking advantage of these new facilities are Peter Martinez, G3PLX, and Dave Wicks, G3YYD, who have developed a microprocessor-based system that meets CCIR Recommendation 476 (known commercially as Spector, Sitor and Microtor etc). Their system, termed Amtor, is proving highly reliable over a 200km path on 144MHz.

In brief

During 1978 the number of Australian amateur licences increased from 8483 to 10587, of whom 5611 held 'full' licences, 2933 held 'limited' (Class B-type) licences and 2024 held the more recently introduced 'novice' licences .... Membership of the New Zealand Association of Radio Transmitters increased from 3175 to 3410 during 1978 .... The sixth Welsh Amateur Radio Convention will be held on September 30 at Oakdale Community College, Blackwood, Gwent .... A Scottish VHF Convention is to be held on September 22 at Dundee Technical College, Dundee .... An "EI/GI Convention 1979" is being held on October 14 at Ballymascanion House Hotel, Dundalk, Co Louth .... A "Jersey Radio Convention" is at Hotel de France, St Saviour Road, St Helier on September 22-23 .... The RSGB HF Convention, announced for September 15 in Birmingham had to be cancelled due to lack of support .... An amateur radio seminar is being held in the Palais des Expositions, Geneva on September 22 as part of "Telecom 79" .... The Amateur Radio Retailers Association's national amateur radio exhibition will be at the Granby Halls, Leicester from November 8 to 10.

PAT HAWKER, G3VA

Passive notch filters — 3

How to design narrow-band filters for the range 1 to 100MHz

by G. Kalanit, B.Sc., M.I.E.E., Rediffusion Engineering Ltd

Selecting the right type of filter for the particular job at hand from the literature is laborious and time consuming. And little information is provided about design procedure and hardware. These articles provide design procedure and simple formulae by way of examples as well as hardware details. To simplify the description of the examples sufficient formulae and statements are given without theoretical proof; normally theoretical and mathematical development is left to the end of each section. A bibliography accompanies this final part.

THESE ARTICLES concentrate mainly on null-type notch filters derived from a prototype lattice or Wheatstone bridge. At the notch frequency the arms of the bridge are made to resonate into four equal resistances which perform a null of the bridge and no output of the frequency appears at the filter output. At all other frequencies the filter acts as an all-pass network.

The lattice which possesses four resonant arms is a balanced type of network. In most practical applications an unbalanced or grounded form that employs only two resonant arms is preferred, achieved with a hybrid transformer.

There are number of unbalanced configurations, all of which use the same hybrid transformer and the choice depends on the particular application at hand. The notations of the formulae refer always to the prototype lattice; thus the same set of formulae serve all the variations.

Example 5: Helical resonator low-Z notch filter

To avoid confusion in the present example the suffix o is dropped from f_o and ω_o; instead f and ω are used.

A notch filter is required at $f=66$MHz with 3dB bandwidth of $f_3=1$MHz and $R_S=R=75$ohm. From equation 4-7

$$L_b/2=\frac{R/2}{2\pi f_3}=\frac{75/2}{2\pi}=6\mu\text{H}.$$

To have small insertion loss, say of 1dB, $2R_a$ is about $2R_a=20$ohm; hence $R_b/2=2R_a/4=5$ohm. From equation 4-10, extra insertion loss is

$$\frac{75+75}{75+75+20}=0.88\rightarrow 1\text{dB}.$$

From equation 4-1

$$Q_b=\frac{\omega\,.\,(L_b/2)}{R_b/2}=\frac{2\pi 66\times 6}{5}\approx 500.$$

To achieve such a high Q a helical resonator is tried, described in references 15 to 17. In the present example a helical resonator in a square shield is used. From the nomogram, on page 502 of Handbook of Filter Synthesis by A. I. Zverev (reference 3) a Q of 500 is selected on the right hand side vertical scale. A square copper tubing of inside dimension 0.8 was available. Hence from the nomogram a straight horizontal line through $Q=500$, shield size 0.8 gives a resonant frequency of about 100MHz, i.e. at $f_{oc}=100$MHz the helical resonator behaves like a quarter-wave transmission line with the far end short-circuited and the near end open circuit. At lower frequencies the helical resonator is inductive; its reactance is

$$\boxed{X=Z_0\tan\theta} \qquad 5\text{-}1$$

where Z_0 is the characteristic impedance of the helical resonator,

$$\boxed{\theta=\frac{f}{f_{oc}}\,.\,\frac{\pi}{2}\text{ radians}} \qquad 5\text{-}2$$

f is the notch frequency (66MHz), and f_{oc} the open-circuit resonance frequency of the helical resonator (100MHz).

$$\therefore\theta=\frac{66}{100}\,.\,\frac{\pi}{2}=1.037\text{ radians}$$

To simply notation replace $L_b/2$ by L. $L_b/2=L=6\mu$H. The characteristic impedance of the helical resonator is found from

$$\boxed{Z_o=\frac{2\omega L}{\left[\frac{\theta}{\cos^2\theta}+\tan\theta\right]}} \qquad 5\text{-}3$$

Thus

$$Z_o=\frac{2(2\pi 66)\times 6}{\left[\frac{1.037}{\cos^2 1.037}+\tan 1.037\right]}=873\text{ohms}.$$

Joining $Z_o=870$ohms point on the left hand side scale of the nomograph with resonant frequency 100MHz, the result is a coil diameter of 0.6in and number of coil turns is 17. Also the wire gauge is 23 (right hand side scale). A grooved ceramic coil former of diameter 0.6in was available and was wound with 15 turns of 23 s.w.g. tinned copper wire. Coil height was 0.7in. The coil was then fitted inside 1.4in long square copper tubing of inside dimension 0.8in, mentioned above. One end of the coil was soldered to the copper tubing.

The measured f_{oc} of the helical resonator turned out to be $f_{oc}=96$MHz. Re-calculating equations 5-2 and 5-3 with $\theta=1.08$ radians gives $Z_o\approx 750$ohms, which closely agrees with the nomograph 15 turns point. To find the resonating capacitor

$$\boxed{C=\frac{1}{\omega Z_o\tan\theta}} \qquad 5\text{-}4$$

$$C=\frac{1}{2\pi 66\times 750\tan 1.08}=1.72\text{pF}$$

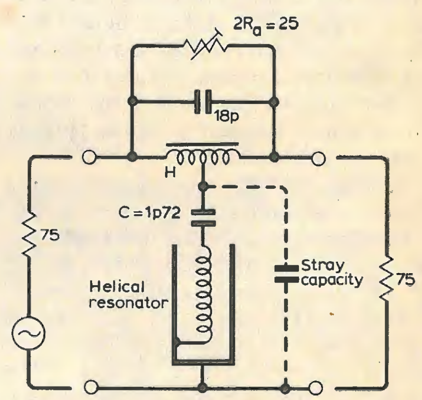


Fig. 5-1

The practical notch is shown in Fig. 5-1, where the 3dB bandwidth is 1.1MHz at 66MHz.

The 18pF capacitor across $2R_a$ was found empirically to give minimum setting of $2R_a=25$ohm and best notch rejection of −76dB. The function of the capacitor may be explained as balancing the stray capacitance appearing across arm 'b' of the notch circuit.

The hybrid transformer was the same as that shown in example 1.

Derivation of foregoing formulae

The helical resonator is a short-circuited transmission line with its reactance given in equation 5-1. When

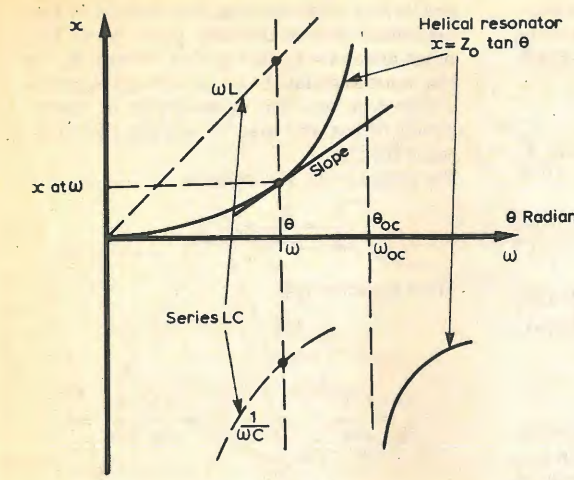


Fig. 5-2

Fig. 5-3

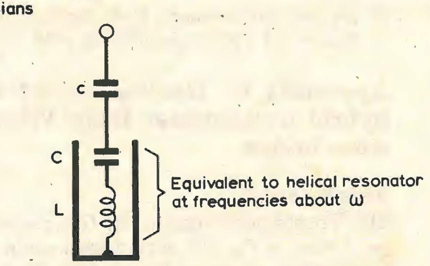
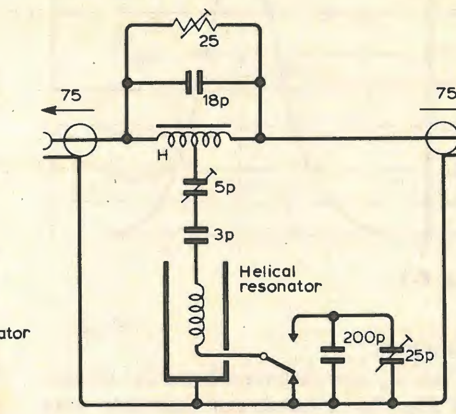


Fig. 5-4



$\theta=\pi/2$ radians, $x=\infty$ and thus $\theta_{oc}=\pi/2$. For $\theta<\pi/2$ the reactance is inductive, shown in reactance graph in Fig. 5-2. From transmission line theory (see reference 7, pp.552/3)

$$\theta=\beta x=\frac{2\pi}{\lambda}\,.\,x=\omega Tx$$

Hence for a transmission line whose length x equals quarter wavelength λ,

$$\theta=\frac{2\pi}{\lambda}\,.\,\frac{\lambda}{4}=\pi/2=\theta_{oc},$$

and

$$\frac{\theta}{\theta_{oc}}=\frac{\pi Tx}{\omega_{oc}Tx}=\frac{f}{f_{oc}}$$

As $\theta_{oc}=\pi/2$

$$\frac{\theta}{\pi/2}=\frac{f}{f_{oc}}\text{ or }\theta=\frac{f}{f_{oc}}\,.\,\pi/2$$

which is equation 5-2.

At ω the helical resonator approximates to reactance of slope S,

$$S=\frac{dx}{d\omega}=\frac{d(Z_o\tan\theta)}{d\theta}\,.\,\frac{d\theta}{d\omega}$$

From equation 5-2,

$$\theta=\frac{\omega}{\omega_{oc}}\,.\,\pi/2$$

$$\therefore\frac{d\theta}{d\omega}=\frac{\pi/2}{\omega_{oc}}$$

Hence $$S=Z_o\sec^2\theta\,.\,\frac{\pi/2}{\omega_{oc}} \qquad 5\text{-}5$$

The slope at ω may also be presented by a series circuit of inductance L in series with capacitance C. Thus $x=\omega L-1/\omega C$ and

$$S=\frac{dx}{d\omega}=L+\frac{1}{\omega^2 C} \qquad 5\text{-}6$$

Hence the helical resonator may be represented, at frequencies near ω, by an equivalent series LC circuit. The equivalent circuit of arm 'b' is shown in Fig. 5-3.

For resonance at ω, two conditions are to be met

- Reactance $x=Z_o\tan\theta$ has to be cancelled by negative reactance of small c, thus

$$1/\omega L=x=Z_o\tan\theta, \qquad 5\text{-}7$$

which proves equation 5-4.

- Resonance at ω also to occur with inductance L in series with capacitors c and C,

$$\omega^2 L=\frac{1}{C}+\frac{1}{c} \qquad 5\text{-}8$$

L is the inductance $L_b/2$ in equation 4-7 for low Z notch.

From equation 5-7

$$\frac{1}{c}=\omega^2\,.\,\frac{Z_o\tan\theta}{\omega}$$

and from equation 5-6

$$\frac{1}{C}=(S-L)\,.\omega^2$$

Substituting both items in equation 5-8

$$\omega^2 L=(S-L)\omega^2+\omega^2\,.\,\frac{Z_o\tan\theta}{\omega}$$

$$\therefore 2L=S+\frac{Z_o\tan\theta}{\omega}$$

Substitute S from equation 5-5

$$2L=Z_o\sec^2\theta\,.\,\frac{\pi/2}{\omega_{oc}}+\frac{Z_o\tan\theta}{\omega}$$

$$2\omega L=Z_o(\sec^2\theta\,.\,\frac{\pi/2\,.\,\omega}{\omega_{oc}}+\tan\theta)$$

$$=Z_o[(\sec^2\theta)\theta+\tan\theta]$$

This proves equation 5-3.

Switched notch filter

The circuit of Fig. 5-1 was required to be switched between two adjacent carriers, the difference in frequencies being about 0.4MHz. A small bistable relay was employed, see Fig. 5-4. The 5pF trimmer was used to tune to the lower frequency first; then the 25pF trimmer used to tune the other frequency (see ref. 6).

Example 6: Crystal low Z notch and bandpass

This example, Figs. 6-1 and 6-2, was not a design effort, but rather an exercise to find out the usefulness of a 3.5MHz crystal, which happened to be available, in a notch circuit (see also ref. 3). The hybrid transformer was similar to the one in Fig. 1-8, but with four bifilar windings (4+4 turns).

To balance the notch $R_a=R_b$ and $C_a=C_b$. From equation 4-7 (see also ref. 13)

$$L_b=\frac{R}{\omega_3}=\frac{2\times 75}{2\pi 100\text{Hz}}=0.24\text{H}$$

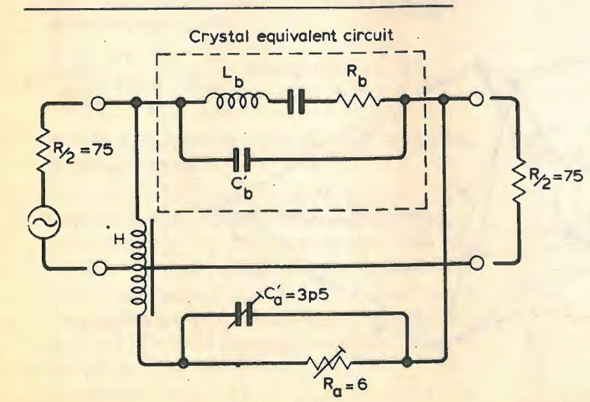


Fig. 6-1

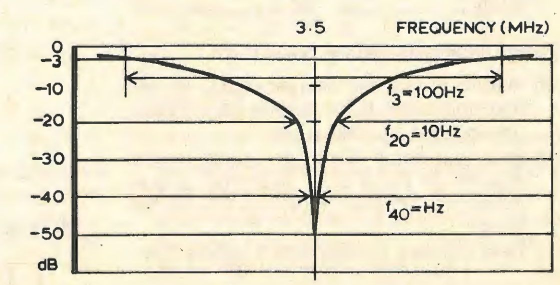


Fig. 6-2 Response of notch

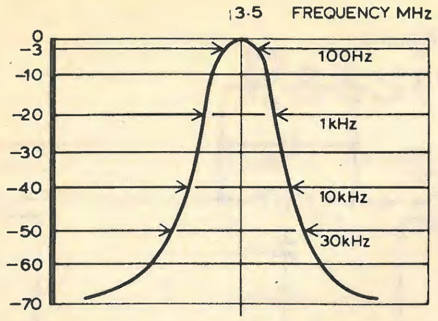


Fig. 6-3

Bandpass

When R_a was removed from the circuit of Fig. 6-1 a bandpass response was obtained.

In the bandstop case with careful adjustment of C'_a, thus balancing the parallel capacitance C'_b of the crystal enabled an attenuation of −7dB to be obtained.

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Hybrid transformer

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Appendix G. Derivation of the hybrid transformer from Wheatstone bridge

Resistive bridge

The Wheatstone bridge in Fig. G-1, re-drawn as a lattice in Fig. G-2, is re-drawn again to a tetrahedron shape in Fig. G-3 to show its three-fold symmetry. Each pair of non-adjacent arms is called a conjugate pair (see reference 1). When the bridge is balanced, an e.m.f. produced in any arm will not induce any power in its conjugate arm.

Thus, for an e.m.f. in arm 's', no voltage drop exists across 'r', i.e. $V_3 = V_4$, and the arms resistance ratio is $m/n = P/q$ or $pn = mq$. G-1

Similarly for the conjugate pair 'n', 'p'; an e.m.f. in 'n' produces no power 'p'. $V_1 = V_3$ when $s/m = q/r$

$\therefore sr = mq$

and from equation G-1

$$\boxed{sr = mq = pn} \qquad \text{G-2}$$

Equation G-2 provides the condition for the three conjugate pairs where each arm is isolated from its conjugate. For an e.m.f., say, in arm 's'; the power will be dissipated in 's' and its four adjacent arms, but none in 'r'. For maximum power transfer from 's' to the other arms; $s = Z_{in}$ in Fig. G-4, where 'Z_{in}' is the input impedance. As no voltage appears across 3, 4, one can open-circuit or short-circuit or put any load 'r' and get the same result for 'Z_{in}'.

For open-circuit 'r' condition,

$$\frac{1}{Z_{in}} = \frac{1}{p+q} + \frac{1}{m+n}$$

From equation G-2

$$p = \frac{mq}{n}$$

$$\frac{1}{Z_{in}} = \frac{1}{\dfrac{mq}{n}+q} + \frac{1}{m+n} = \frac{q+n}{q(m+n)}$$

thus

$$\boxed{s = Z_{in} = \frac{q(m+n)}{q+n}} \qquad \text{G-3}$$

From equations G-2, G-3 and Fig. G-4,

$$\boxed{Z_{out} = r = \frac{mq}{s} = \frac{m(q+n)}{(m+n)}} \qquad \text{G-4}$$

Symmetrical resistive bridge

The tetrahedron is made symmetrical about the vertical plane through nodes 1, 2 and 5 which is the centre of arm 'r', by making $p = m$, and thus $q = n$. It is shown in Fig. G-5, where from equation G-3;

$$s = \frac{n(m+n)}{n+m} = \frac{m+n}{2} \qquad \text{G-5}$$

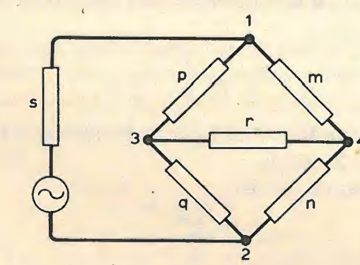


Fig. G-1

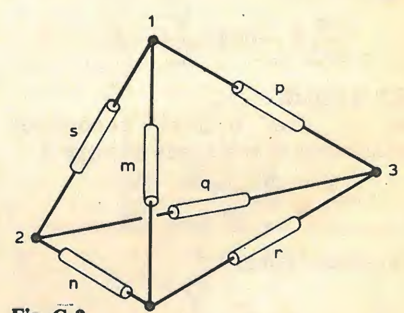


Fig. G-3

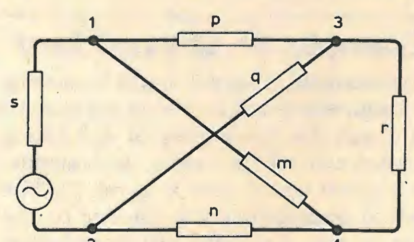


Fig. G-2

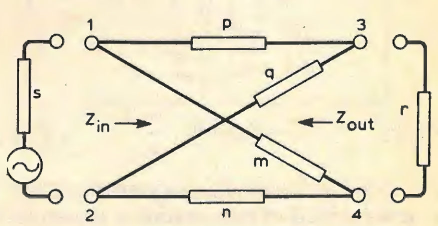


Fig. G-4

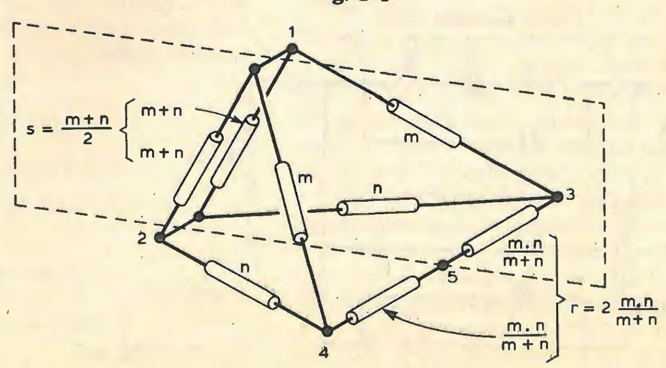


Fig. G-5

and from equation G-4

$$r = \frac{m(n+m)}{m+n} = 2 \cdot \frac{mn}{m+n} \qquad \text{G-6}$$

Resistive hybrid transformer circuit

The tetrahedron can now be divided into two equal halves with the aid of two ideal transformers called hybrid transformers (see also references 20, 21). If the transformers shown in Fig. G-6 have the same ratio as the corresponding arms 'm' and 'n', no voltage drop develops across 4 to 5 and across 5 to 3. Thus, the bridge balance remains, while the number of arms is reduced from total of six to four in each half.

The left-hand side, re-drawn in Fig. G-7, provides the general hybrid network, with two conjugate pairs of arms (see also reference 21).

From equation G-5 and G-6 $2s = m+n \rightarrow$ series combination of m and n, and $r/2 = mn/(m+n) \rightarrow$ parallel combination of m and n. Thus, $2sr/2 = m.n$ are the two conjugate pairs G-7. If, for example; $m/n = 2/1$ and m is 30ohm, then $n = 15$ohm, $2s = 45$ohm and

$$r/2 = \frac{30 \times 15}{30+15} = 10\text{ohm}$$

The hybrid transformer turns ratio is 2:1. The power transmitted by an e.m.f. in any one arm is divided between the source and the other conjugate pair. Half is absorbed by the source while the other half is divided between the arms of the other conjugate pair in the ratio of $m:n$. Other equivalent configurations to Fig. G-7 are shown below.

In Fig. G-8 arm '2s' is transformed by the auto-transformer action of the hybrid from across nodes 1, 2 to

$$2s\left[\frac{m}{m+n}\right]^2 = \frac{m^2}{m+n} \text{ across nodes 1, 5.}$$

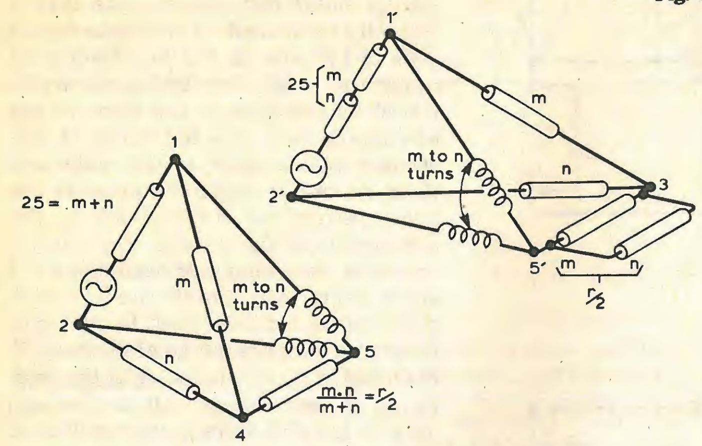
Hybrid transformer circuits with complex impedance arms

When $m = n$ one recognises the hybrid transformers employed in the above notch filters. The foregoing in this section describe the condition at null when the arms are resistive. When the reactive arms are not in resonance the condition of a constant resistive network is $R^2 = a \cdot b$ where the source equals the load equals R. The configuration of Fig. G-1 may be drawn, as in Fig. G-12, with a hybrid transformer of turns ratio 1:1.

This is possible because the voltage at point 5 is a constant at all frequencies due to the symmetrical relation $R^2 = a \cdot b$. By inspection, the voltages across arms 'b' are the inverse of the voltages across arms 'a', thus with variation of frequency, the voltage drop across nodes 3, 4 behaves like a 'see-saw', the fulcrum being node 5. The circuit of Fig. G-12 is divided into two equal halves of Fig. G-13 by the same process as that of Fig. G-5 to Fig. G-6. Thus the notch filters described in the above examples may be realised in any of the hybrid configurations shown in the remainder of the diagrams Figs. G-14 to G-19. Arms 'a' and 'b' may be interchanged. The right hand side of Fig. G-13 is re-drawn in Fig. G-14.

(See overleaf)

Fig. G-6



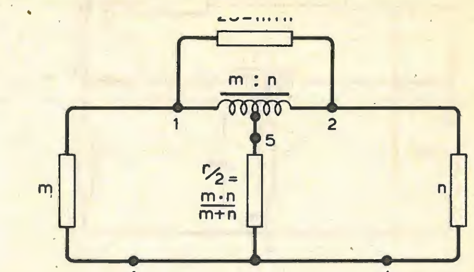


Fig. G-7

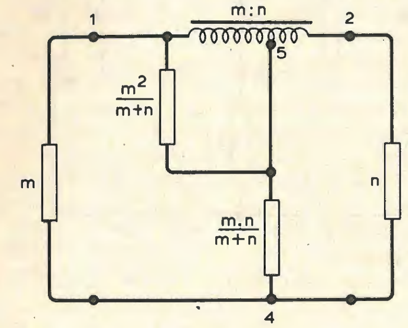


Fig. G-8

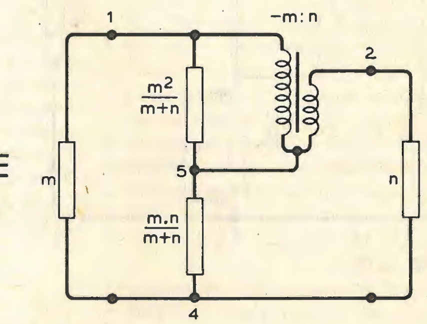


Fig. G-9

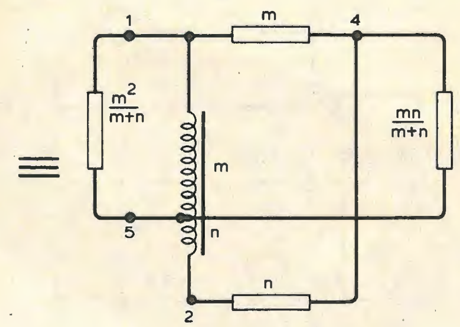


Fig. G-10

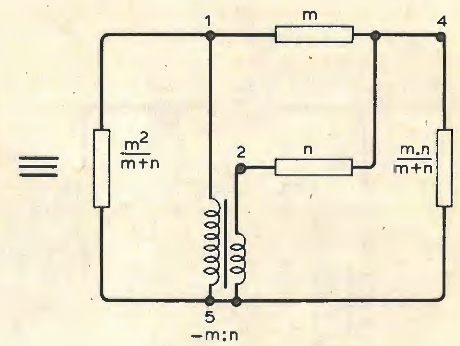


Fig. G-11

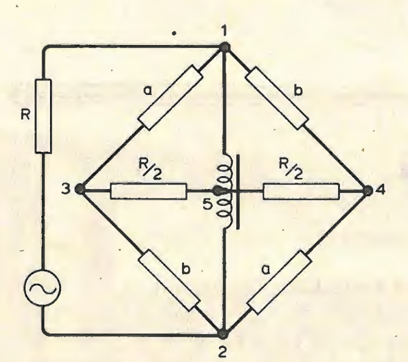


Fig. G-12

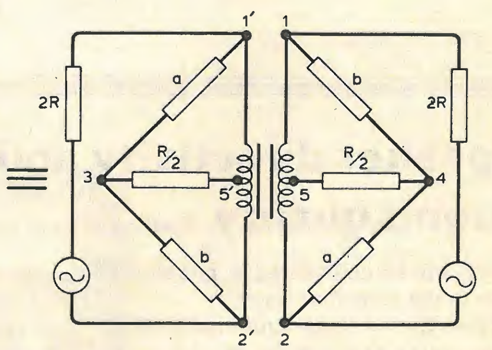


Fig. G-13

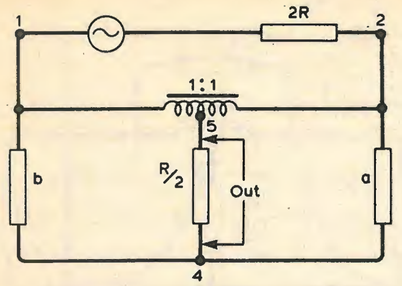


Fig. G-14

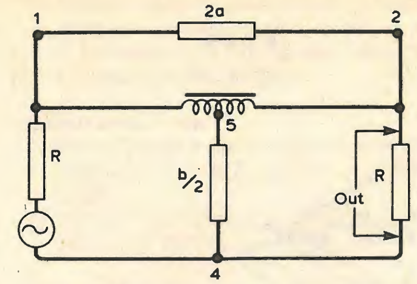


Fig. G-15

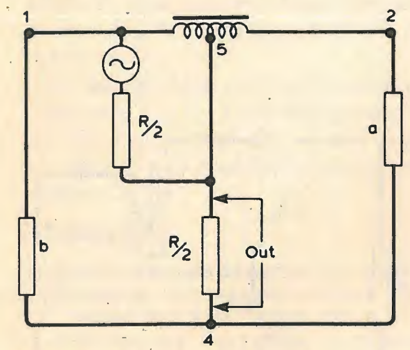


Fig. G-16

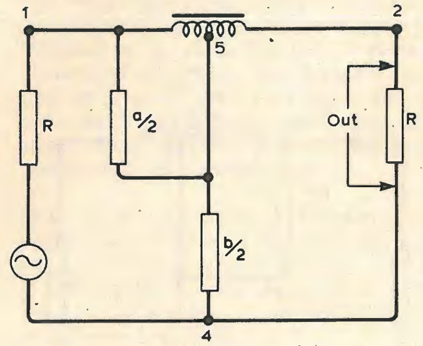


Fig. G-17

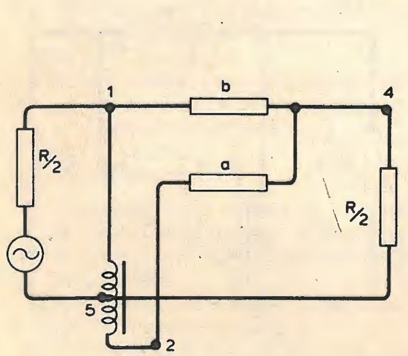


Fig. G-18

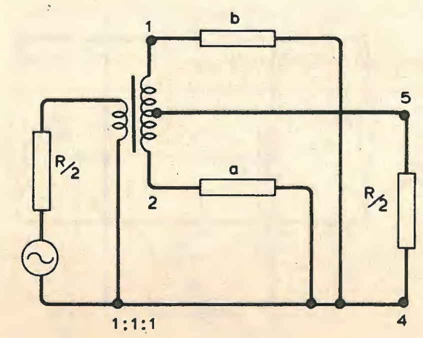


Fig. G-19

Speaker directivity and sound quality *Continued from page 63*

which will be considered in more detail later in the contribution.

There are no single unit loudspeakers that cover the whole of the audio frequency range in a fashion that is acceptable in the hi-fi field, two, three, four or more units being employed to achieve a flat frequency response. The diaphragm diameter of the unit is decreased as the frequency range covered by the unit is increased. Currently a 10in or 12in unit may be used to cover the range up to about 700/1000Hz, a 3in or 4in diameter unit used to deal with the band between 800Hz and perhaps 4000Hz with a 1in or 1½in diameter unit used to radiate the signal in the band above 4000Hz. In some more elaborate systems a super tweeter may be employed to extend the frequency range beyond 18 to 20kHz.

To a first approximation the use of three or four units allows the designer to adjust the "Q"/frequency relation by approximate choice of the frequencies chosen from the crossover points. However the speaker system designer does not have complete freedom to adjust the "Q" in this way for the choice of changeover frequencies is primarily controlled by the usable frequency range of each of the speaker units.

All domestic multiple-unit types of loudspeaker systems have generally similar polar distribution, for this is basically controlled by well established laws of physics. In the low frequency range the polar distribution is determined by the area of the front of the enclosure and the location of the speaker with respect to the walls and floor. At rather higher frequencies the polar distribution is controlled by the dimensions of the woofer cone, an increase in cone diameter decreasing the solid angle into which the acoustic radiation is concentrated. In the mid-frequency range the solid angle is again determined by the diameter of the mid-range speaker cone with the frontal area of the enclosure having influence that decreases with increase in frequency.

In the frequency range radiated by the tweeter cone diameter is the major controlling factor, but some effects are controlled by the enclosure geometry and the contours of the cabinet edges. Thus all multiple unit systems have a "Q"/frequency relation much as outlined in Fig. 3. Changing the cone and cabinet dimensions merely shifts the boundary region up and down the frequency scale without changing the general shape of the curves.

Sound power output

Lack of data on the "Q" of domestic loudspeakers is largely due to the difficulty there is in measuring the parameter. There is a British Standard in preparation that covers the method of measuring "Q" and "DI" but the technique described is really only of academic importance. A measurement of "Q" requires that the sound power output of the loudspeaker is determined, together with a measurement of the sound pressure level at a point one or two metres from the speaker and on its axis. Suitable techniques will be described in a later contribution.

This article can be summarised as suggesting that the polar distribution of sound energy round a loudspeaker has a more important effect on sound quality than a mere absence of top response at points of the axis of the loudspeaker. The ideal polar diagram would appear to confine the sound energy distribution ot something less than ±90 degrees in front of the loudspeaker but it is equally important that the angular distribution should not vary with frequency, particularly at frequencies above about 500Hz. At present this is an ideal that cannot be achieved but there are signs that technical skill may circumvent the apparent limitation imposed by basic physical laws. □

In a later article the author will discuss a new technique for measuring the sound power output from loudspeakers.

NEW PRODUCTS

Viewdata (Prestel) keyboard

Interfacing and editing specifications defined by the Post Office for its Prestel information retrieval service are met by the latest keyboard from Cherry Electrical Products, and the keyboard also fulfils the need for the control keys to deliver two codes rather than one, which is one of Prestel's departures from the norm. The unit is designed to plug into a television display unit directly via a 5 pin DIN plug, and an additional V24 interface socket has been provided at the back of the unit to make possible the transmission and reception of data from the central Prestel computer, using a standard Post Office modem. A nine-key pad provides functions such as normal or double height characters and continuous or single graphics and further keys provide clear, start and end functions. Cursor control is also available as well as the option of flash or steady display. Serial output data is released from the keyboard at a crystal-controlled rate of 75 baud, which means that the fast typing rates which can be achieved can out-pace the rate at which data is assimilated. An internal store of 64 characters prevents any loss of data under these conditions. The keyboard costs £175 without case. Cherry Electrical Products Ltd, St Albans Rd, Sandridge, Herts AL4 9BP.

WW301


WW301

Valve audio amplifiers

With the exception of the preamplifier for magnetic cartridge and the headphone amplifier circuits, which are entirely solid state, the B.A.S. Sound power amplifier model P50 and preamplifier model P500 feature fully valved circuits producing two outputs of 50W (continuous sine wave) into 8Ω loads. The makers point out that, unlike the technique used in many stereo audio systems, where two amplifiers are employed in a single integrated "package", this combination uses two independently-powered identical mono amplifiers, the main aim here being to limit intermodulation distortion to a minimum level. Signal amplifying stages use familiar valves such as the ECC82, the ECC83 and the Z729, while the output stages use KT88 power tetrodes in class AB. The frequency response of both preamplifiers and power amplifiers is 20Hz to 20kHz ±1dB with a phono overload level of +48dB at 1kHz. Switched input capacitance (six values) permits a selection of magnetic cartridges to be used with the preamplifiers. Thermal protection is provided, excessive operating temperature being indicated by a failure lamp and automatic full channel switch-off. An optional moving-coil cartridge preamplifier is also available and a monitoring facility is provided in the form of a power meter for each channel, indicating average output power. The amplifiers can be rack-mounted and presentation is similar to that of many transistor amplifiers. The complete system is claimed to have an unusually high standard of mechanical and electrical engineering. Beard Audio Systems Ltd, 98a Oakland Grove, London W12 0JB.

WW302


WW302

Dual tone bandpass filters

The AF121 and AF122 are dual tone multi-frequency bandpass filters intended for use with digital tone detection circuits, a possible application being tone detection in telephone circuits. These filters are intended to replace discrete designs without requiring additional external components or adjustments. Two bands are covered, the AF121, separating frequencies between 697Hz and 941Hz from other signals, and the AF122, functioning in the same way for frequencies between 1209Hz and 1633Hz. Used together, the filter

separation is 40dB; both filters are 6th order elliptic bandpass filters available in two versions, each with a different ripple level. Items with a "sCJ" suffix have a maximum passband ripple of 2dB peak-to-peak and those with a "iCJ" suffix a 4dB ripple. National Semiconductor (UK) Ltd, 301 Harpur Centre, Horne Lane, Bedford.

WW303

16-bit microprocessor evaluation board

A fully assembled and tested evaluation unit based on the Z8000 microprocessor is available from Advanced Micro Devices. In its basic form the AMC96/4016 incorporates the Z8000 16-bit m.p.u., 8K bytes of r.a.m., 24 parallel i/o lines, two RS232C serial i/o ports, 12K bytes of e.p.r.o.m./r.o.m. sockets in addition to a system clock and

resident monitor. One serial i/o port can be configured as either an RS232C or t.t.y. current loop interface, the other is RS232C only. Two 16-bit counters in an "Am8253" counter/timer provide selectable baud rates, up to 9,600 baud, for each serial i/o port. The third 16-bit counter in the Am8253 is available for user programs. The complete unit will also directly control a standard c.r.t. terminal or a keyboard with a 20 character alphanumeric display; the latter is available as a part of the evaluation board. Optional features are also available including a full decoded keyboard, an e.p.r.o.m.-resident ASCII one-pass, line by line assembler, and a universal prototyping board of the same family form providing positions for up to 95 i.cs. A card enclosure for mounting these additional boards is also available. The basic evaluation board, complete with monitor 4MHz crystal-controlled timebase costs £450. Advanced Micro Devices (UK) Ltd, 16 Grosvenor Place, London SW1X 7HH.
WW304

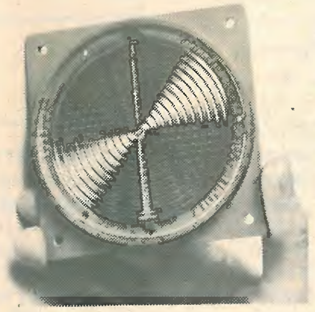
Scanning general coverage receiver

Automatic scanning over the frequency range 50kHz to 29.7MHz at any desired speed is an unusual feature of the DR101 general coverage communications receiver, now in production by the (American) McKay Dymek Co. Scanning occurs in 100Hz tuning increments at rates varying between 100Hz per second and 2MHz per second. When a particular station or frequency is reached, scanning can be stopped and the station monitored. The receiver scans the frequency range in each reception mode, including a.m., s.s.b., c.w. and i.f. filter, the latter mode permitting use with either ceramic or mechanical filters. McKay Dymek Co., 111 So. College Ave., P.O. Box 5000, Claremont, California, CA91711.
WW305


WW305

Instantaneous peak drive indicator

Decreasing efficiencies of high-quality loudspeaker systems means that amplifiers have to work harder to maintain adequate sound levels, with an attendant danger of being operated outside their ratings. Monitoring of excess output, which results in distortion, is difficult without the use of a fast-acting indicator, such as an oscilloscope. John Linsley Hood has produced the JLH peak drive indicator, which surmounts the problem by the use of lamps to show the instantaneous output voltage of the amplifier. It is connected to the amplifier output, which can be 4, 8 or 15Ω depending on the version ordered, and will indicate the drive voltage by one or other of the lamps lighting to indicate 1,3, 10 or 30W. The actual measurement is of peak-to-peak voltage swing, but since this is the limiting factor for transistor amplifiers, the reading is valid. The instruments are available from Robins (Electronics), Greenway, W. Monkton, Taunton, Somerset TA28NQ at £25 for a single item or £30 for the stereo version.
WW306


WW307

Experimenter's solar cell

Under good sunlight conditions the ESC3 solar cell from Ferranti is capable of providing 900mA at 0.5V. This new cell has been introduced with experimental and educational applications in view. To this end, additional protection has been provided in the form of a tough case and a Fresnel lens which also acts as a light "collector". Short-circuiting the output will not damage the cell and it can be arranged in the usual series or parallel lines for higher voltage or current output. The ESC3 cell, which is 3in (76mm) in diameter, costs £12 on a one-off basis, the price falling to between £9 and £10 for quantities over 100. Ferranti Electronics Ltd, Fields New Rd, Chadderton, Oldham, Lancs, L9 8NP.
WW307

LETTER TO THE EDITOR

STILL NO VHF/FM IN NEW ZEALAND

Norman Mcleod's letter in your November 1978 issue regarding a.m. broadcast reception raised a number of interesting points, which have particular relevance in this country, New Zealand, because we still do not have v.h.f./f.m. radio. All sound broadcasting here is restricted to a.m. on the medium wave bands, apart from a very limited short wave service, which carries the internal service programmes anyway. Receivers such as J. W. Herbert's homodyne (which was developed here) and to which Mr McLeod referred, are essential to get any high quality broadcast signals to feed a domestic audio installation. Paradoxically, it has been variously estimated that there are already between 20,000 and 100,000 f.m. receivers in New Zealand. (My household has 5!).

The history of attempts to introduce f.m. radio to New Zealand is a sorry one of difference, procrastination, and excuses, which has not been helped by frequent political interference in broadcasting.

The first event to impede the introduction of f.m. radio was an extremely short-sighted decision of the N.Z. Post Office to allocate most of the international f.m. band to two-way radio/radio-telephone use. Although the Post Office were to have the band cleared by 1980, they have now relaxed this to 1982!

Subsequent events which have contributed to the delays are the introduction of colour television, the establishment and networking of a second government run tv channel throughout the country and, currently, a broadcasting financial crisis.

A 1973 report which recommended the fragmentation of the one government broadcasting organization into four corporations contained an interesting reference to f.m. radio, which admitted its technical advantages, but dismissed it with the statement, and I quote, "but the submissions to the committee did not reveal the existence as yet of any large body of opinion pressing for the change (from a.m. to f.m.)." Thus the public not only has to know about f.m. without having any transmissions to judge it by, it also has to take the initiative in showing the administrators of broadcasting the advantages of high quality transmission methods!

F.m. radio has however always been a useful talking point! Several directors general of government broadcasting in New Zealand have publicly referred to f.m., one director general in 1975 even speaking of "f.m. within five years". The five years are almost up and there is not even a commitment to start f.m. transmission yet! The need for f.m. outlets has become more acute with the present radio corporation's practice of using the one cultural network for sports broadcasts, particularly during the summer months. When cricket commentaries are rebroadcast from Radio Australia, these often pre-empt regular programmes until well into the evening!

Last year a combined government and 'independent broadcasters committee prepared a comprehensive report on f.m. broadcasting, which was presented to the Minister of Broadcasting in October. I believe now that there will be no action on this report because of the financial crisis I mentioned previously. The finances of both government run tv channels are such that cost cutting and pruning is necessary, and even if there was motivation to start f.m. broadcasting, there is no money to do it! Unfortunately, radio seems to have become the poor relation of broadcasting.

Ironically, the government radio corporation, Radio New Zealand, and two of the private stations have stereo studio facilities. Radio New Zealand found that the overseas broadcasting organisations weren't interested in mono recordings of New Zealand programmes, and in order to send them overseas, programmes had to be recorded in stereo. So the tax dollars that support Radio New Zealand are helping overseas broadcasting organizations, not the New Zealand listener who contributed them!

I now realise that rigidly government controlled broadcasting, far from giving me and other users the protection and benefit of certain standards and services, is actually, by its clumsy and ponderous procrastination denying radio listeners any f.m. service at all. This service is available in most developed countries of the world. The introduction of f.m. radio in New Zealand remains where it has been for 15 years, bogged down in a morass of delays, obstruction, and excuses!

Keith Macdonald ZL2AWM
Silverstream
New Zealand

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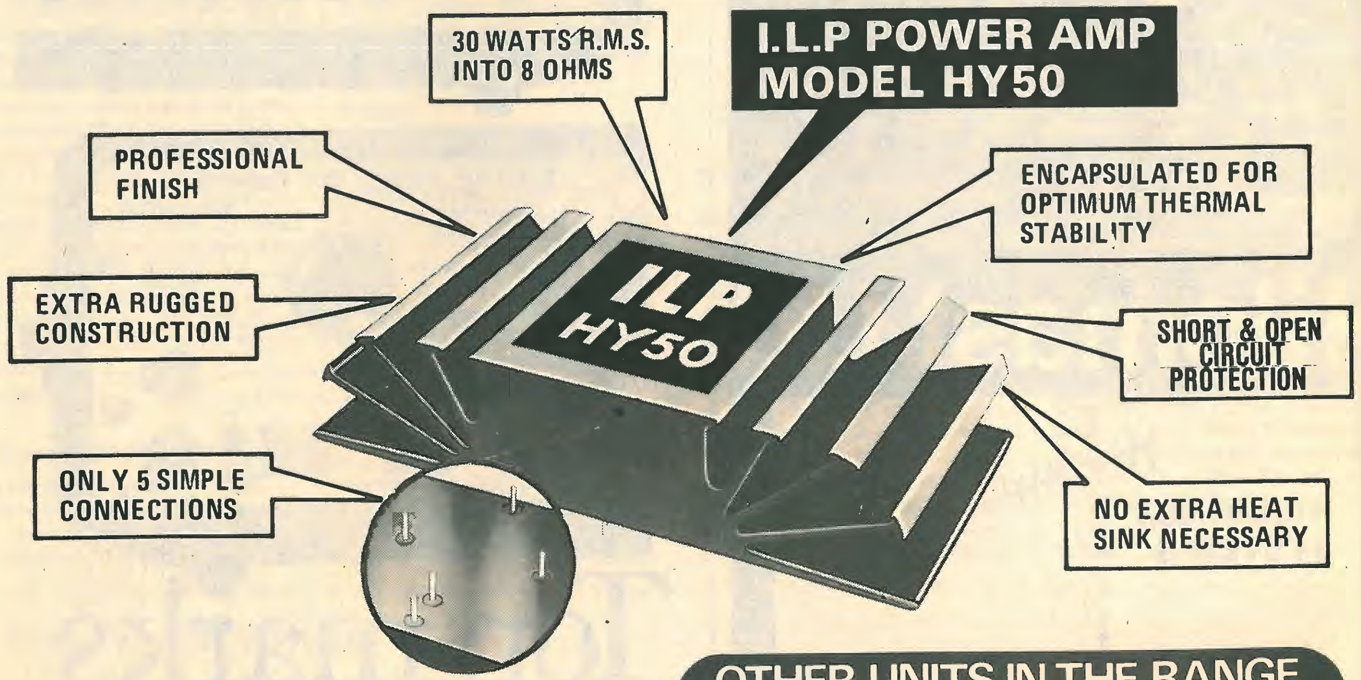

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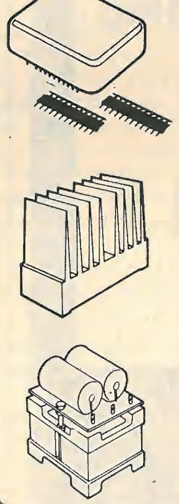

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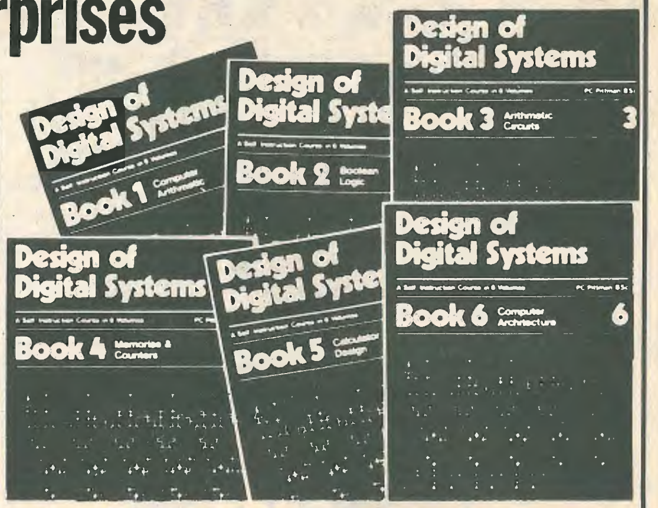
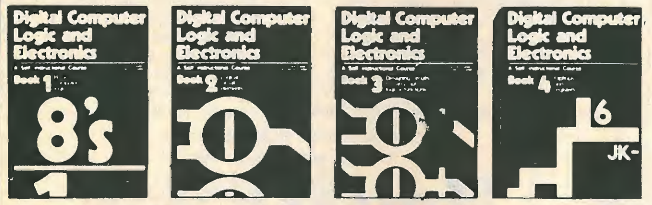


UNDERSTANDING DIGITAL ELECTRONICS

In the years ahead the products of digital electronics technology will play an important part in your life. Calculators and digital watches are already commonplace. Tomorrow a digital display could show your vehicle speed and fuel consumption; you could be 'phoning people by entering their name into a telephone which would automatically look up their number and dial it for you.

These courses were written by experts in electronics and learning systems so that you could teach yourself the theory and application of digital logic. Learning by self-instruction has the advantages of being faster and more thorough than classroom learning. You work at your own pace and must respond by answering questions on each new piece of information before proceeding.

After completing these courses you will have broadened your career prospects and increased your fundamental understanding of the rapidly changing technological world around you.



Digital Computer Logic and Electronics is designed for the beginner. No mathematical knowledge other than simple arithmetic is assumed, though the student should have an aptitude for logical thought. it consists of four volumes - each A4 size - and serves as an introduction to the subject of digital electronics. Everyone can learn from it - designer, executive, scientist, student, engineer.

Contents include: Binary, octal and decimal number systems; conversion betweem number systems, AND, OR, NOR and NAND gates and inverters; Boolean algebra and truth tables; De Morgans Laws; design of logic circuits using NOR gates; R-S and J-K flip flops; binary counters, shift registers and half adders.

Design of Digital Systems is written for the engineer seeking to learn more about digital electronics. Its six volumes - each A4 size are packed with information, diagrams and questions designed to lead you step-by-step through number systems and Boolean algebra to memories, counters and simple arithmetic circuits, and finally to a complete understanding of the design and operation of calculators and computers. Contents include:

Book 1 Octal, hexadecimal and binary number systems; conversion between number systems; representation of negative numbers; complementary systems; binary multiplication and division.

Book 2 OR and AND functions; logic gates; NOT, exclusive-OR, NAND. NOR and exclusive-NOR functions; multiple input gates; truth tables; De Morgans Laws; canonical forms; logic conventions; Karnaugh mapping; three-state and wired logic.

Book 3 Half adders and full adders; subtractors; serial and parallel adders; processors and arithmetic logic units (ALUs); multiplication and division systems.

Book 4 Flip flops; shift registers; asynchronous and synchronous counters; ring, Johnson and exclusive-OR feedback counters: random access memories (RAMs) and read only memories (ROMs).

Book 5 Structure of calculators; keyboard encoding; decoding display data; register systems; control unit; program ROM; address decoding; instruction sets; instruction decoding; control programe structure.

Book 6 Central processing unit (CPU); memory organization; character representation; program storage; address modes; input/output systems; program interrupts; interrupt priorities; programming; assemblers; computers; executive programs; operating systems and time sharing.

FLOW CHARTS & ALGORITHMS help you present: safety procedures, government legislation, office procedures, teaching materials and computer programs by means of YES and NO anwsers to questions.

The Algorithm Writer's Guide

explains how to: define the questions, put them in the best order and draw the flow chart, with numerous examples shown. All that students require is an aptitude for logical thought. Size: A5, 130 pages. This book is a MUST for those with things to say.

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Complete kit, including licence fee **£49.50** + VAT
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50 watts rms-channel. 0.015% THD. S/N 90 dB, Mags/n 80 dB.
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With Home Office Type approval

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Complete kit £49.50 plus VAT.

Wireless World Dolby noise reducer

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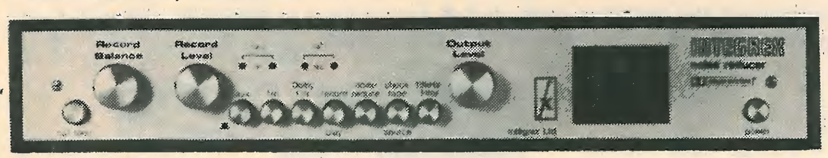

Typical performance
Noise reduction better than 9dB weighted.
Clipping level 16.5dB above Dolby level (measured at 1% third harmonic content)

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

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30mV sensitivity.

Featuring:
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Single channel plug-in Dolby(TM) PROCESSOR BOARDS (92 x 87mm) with gold plated contacts and all components .... **Price £9.00** + VAT

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S-2020TA STEREO TUNER/AMPLIFIER KIT

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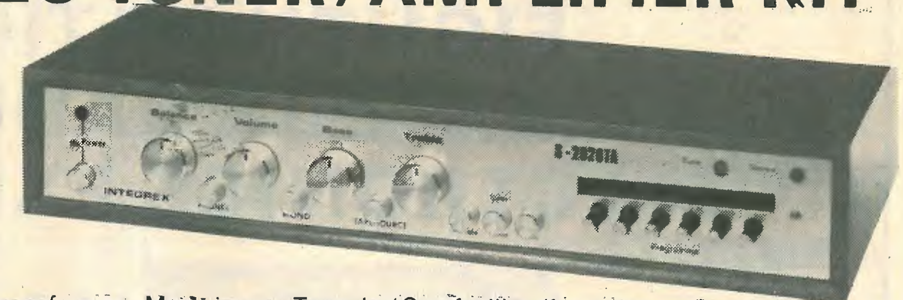
A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.



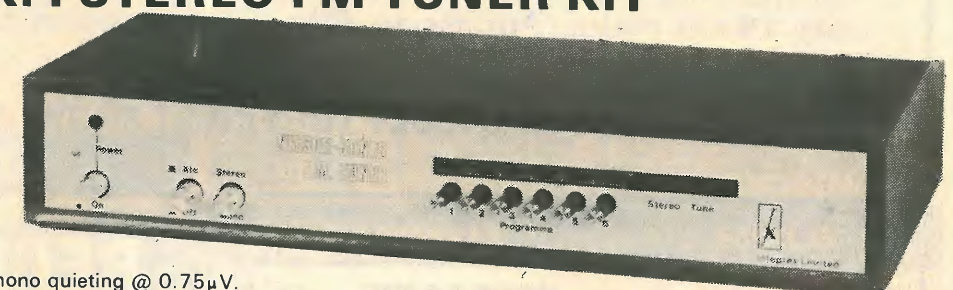
Brief Spec. Amplifier Low field Toroidal transformer, Mag. input, Tape In/Out facility (for noise reduction unit, etc.), THD less than 0.1% at 20W into 8 ohms. Power on/off FET transient protection. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section uses 3302 FET module requiring 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: £59.95** + VAT

NELSON-JONES MK.2 STEREO FM TUNER KIT

Price: **£69.95** + VAT.
Improved performance with linear phase IF and second generation IC decoder.

NELSON-JONES MK. I 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.

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Mono £36.40 + VAT
With ICPL Decoder £40.67 + VAT
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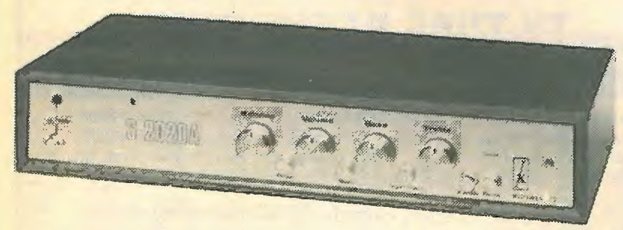
Sens. 30dB S/N mono @ 1.2µV
THD typically 0.3%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

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

PRICE: Stereo £33.95 + VAT



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AAY30	0.31	ASZ16	1.44	BC173	0.14	BD132	0.44	BF258	0.30	GEX66	1.73
AAY32	0.48	ASZ17	1.44	BC177	0.17	BD135	0.39	BF259	0.37	GEX541	2.02
AAZ13	0.21	ASZ20	1.72	BC178	0.16	BD136	0.39	BF336	0.35	GJ3M	0.86
AAZ15	0.39	ASZ21	2.30	BC179	0.18	BD137	0.40	BF337	0.35	GM0378A	2.02
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AC107	0.69	AUY10	2.30	BC183	0.12	BD139	0.49	BFS21	4.55	MJE340	0.92
AC125	0.23	AU110	1.96	BC184	0.13	BD140	0.51	BFS28	2.56	MJE370	1.35
AC126	0.23	BA145	0.15	BC212	0.15	BD144	2.30	BFS61	0.23	MJE371	0.71
AC127	0.23	BA148	0.15	BC213	0.14	BD181	1.26	BFS98	0.23	MJE520	0.60
AC128	0.23	BA154	0.10	BC214	0.17	BD182	1.36	BFW10	0.74	MJE521	0.63
AC141	0.29	BA155	0.12	BC237	0.10	BD237	0.46	BFW11	0.74	MJE2955	1.44
AC141K	0.40	BA156	0.10	BC238	0.14	BD238	0.63	BFX84	0.25	MJE3055	0.86
AC142	0.23	BAW62	0.06	BC301	0.29	BDX10	1.05	BFX85	0.26	MPF102	0.35
AC142K	0.35	BAX13	0.07	BC303	0.28	BDX32	2.30	BFX87	0.24	MPF103	0.35
AC176	0.23	BAX16	0.10	BC307	0.12	BDY20	1.44	BFX88	0.24	MPF104	0.35
AC187	0.23	BC107	0.14	BC308	0.12	BDY60	1.72	BFY50	0.30	MPF105	0.35
AC188	0.23	BC108	0.14	BC327	0.23	BF115	0.29	BFY51	0.30	MPSA06	0.28
ACY17	0.98	BC109	0.15	BC328	0.21	BF152	0.21	BFY52	0.30	MPSA56	0.30
ACY18	0.92	BC113	0.14	BC337	0.21	BF153	0.23	BFY64	0.30	MPSU01	0.41
ACY19	0.86	BC114	0.15	BC338	0.20	BF154	0.20	BFY90	1.44	MPSU06	0.53
ACY20	0.80	BC115	0.16	BCY30	1.15	BF159	0.26	BSX19	0.24	MPSU56	0.56
ACY21	0.86	BC116	0.17	BCY31	1.15	BF160	0.18	BSX20	0.23	NE555	0.52
ACY39	1.72	BC117	0.20	BCY32	1.15	BF167	0.23	BSX21	0.23	NKT401	2.30
AD149	0.80	BC118	0.12	BCY33	1.04	BF173	0.23	BT106	1.44	NKT403	1.99
AD161	0.52	BC125	0.18	BCY34	1.04	BF177	0.28	BTY79/400R	3.67	NKT404	1.99
AD162	0.52	BC126	0.23	BCY39	3.45	BF178	0.28	BU205	2.02	OA5	1.09
AF106	0.52	BC135	0.16	BCY40	1.15	BF179	0.29	BU206	2.59	OA7	0.63
AF114	0.86	BC136	0.17	BCY42	0.29	BF180	0.35	BU208	2.30	OA10	0.74
AF115	0.86	BC137	0.17	BCY43	0.29	BF181	0.35	BY100	0.52	OA47	0.16
AF116	0.86	BC147	0.10	BCY58	0.18	BF182	0.35	BY126	0.16	OA70	0.35
AF117	0.86	BC148	0.09	BCY70	0.17	BF183	0.29	BY127	0.17	OA79	0.35
AF139	0.46	BC149	0.10	BCY71	0.20	BF184	0.29	BZX61 Series	0.21	OA81	0.35
AF186	1.38	BC157	0.10	BCY72	0.15	BF185	0.29	BZY88 Series	0.15	OA85	0.35
AF239	0.52	BC158	0.09	BCZ11	1.72	BF194	0.10	CRS1/40	0.69	OA90	0.09
AFZ11	3.16	BC159	0.12	BD115	0.52	BF195	0.10	CRS3/06	0.52	OA91	0.09
AFZ12	3.16	BC167	0.14	BD121	1.38	BF196	0.12	CRS3/40	0.86	OA95	0.09
ASY26	0.46	BC170	0.13	BD123	1.38	BF197	0.14			OA200	0.10
ASY27	0.46	BC171	0.12	BD124	1.50	BF200	0.31			OA202	0.10
						BF224	0.23			OA211	1.15
						BF244	0.32			OAZ200	1.15

Type	Price	Type	Price	Type	Price	Type	Price	Type	Price
OAZ201	1.15	OC203	2.02	ZTX502	0.18	2N1309	0.63	2N3771	2.02
OAZ206	1.15	OC204	2.88	ZTX503	0.18	2N1613	0.29	2N3772	2.30
OAZ207	1.15	OC205	2.88	ZTX504	0.33	2N1671	1.73	2N3773	3.45
OC16	[illegible]	OC206	2.88	ZTX531	0.23	2N1893	0.29	2N3819	0.41
OC20	[illegible]	OC207	2.02	ZTX550	0.18	2N2147	2.02	2N3820	0.52
OC22	[illegible]	OCP71	1.44	1N914	0.06	2N2148	1.89	2N3823	0.52
OC23	[illegible]	ORP12	1.15	1N916	0.08	2N2218	0.29	2N3866	0.83
OC24	[illegible]	R2008B	2.02	1N4001	0.07	2N2219	0.28	2N3904	0.15
OC25	[illegible]	R2009	2.59	1N4002	0.07	2N2220	0.21	2N3905	0.15
OC26	[illegible]	R2010B	2.02	1N4003	0.08	2N2221	0.21	2N3906	0.15
OC28	[illegible]	TIC44	0.35	1N4004	0.08	2N2222	0.21	2N4059	0.12
OC29	[illegible]	TIC226D	1.38	1N4005	0.09	2N2223	3.16	2N4060	0.14
OC35	[illegible]	TIL209	0.23	1N4006	0.09	2N2368	0.24	2N4061	0.14
OC36	[illegible]	TIP29A	0.47	1N4007	0.10	2N2369A	0.24	2N4062	0.15
OC41	[illegible]	TIP30A	0.48	1N4009	0.07	2N2484	0.23	2N4124	0.17
OC42	[illegible]	TIP31A	0.51	1N4148	0.07	2N2646	0.63	2N4126	0.17
OC43	[illegible]	TIP32A	0.55	1N5400	0.15	2N2904	0.29	2N4286	0.23
OC44	[illegible]	TIP33A	0.79	1N5401	0.15	2N2905	0.29	2N4288	0.25
OC45	[illegible]	TIP34A	0.84	1S44	0.05	2N2906	0.24	2N4289	0.28
OC70	[illegible]	TIP41A	0.72	1S920	0.08	2N2907	0.24	2N5457	0.40
OC71	[illegible]	TIP42A	0.81	1S921	0.08	2N2924	0.24	2N5458	0.40
OC72	[illegible]	TIP2955	0.77	2G301	1.15	2N2925	0.25	2N5459	0.40
OC73	[illegible]	TIP3055	0.64	2G302	1.15	2N2926	0.16	2S017	7.48
OC74	[illegible]	TIS43	0.52	2G306	1.27	2N3053	0.29	2S019	7.48
OC75	[illegible]	ZS140	0.29	2N404	1.15	2N3054	0.58	2S026	13.80
OC76	[illegible]	ZS170	0.24	2N696	0.29	2N3055	0.61	2S103	1.73
OC77	[illegible]	ZS178	0.62	2N697	0.29	2N3440	0.69	2S302	0.86
OC81	[illegible]	ZS271	0.29	2N698	0.35	2N3441	0.92	2S303	0.86
OC81Z	[illegible]	ZS278	0.63	2N705	1.38	2N3442	1.36	2S322	0.92
OC82	[illegible]	ZTX107	0.13	2N706	0.21	2N3614	1.73	2S324	1.44
OC83	[illegible]	ZTX108	0.12	2N708	0.23	2N3702	0.13	2S701	1.73
OC84	[illegible]	ZTX109	0.14	2N930	0.23	2N3703	0.15	2S745A	0.40
OC122	[illegible]	ZTX300	0.14	2N1131	0.30	2N3704	0.15	2S746A	0.40
OC123	[illegible]	ZTX301	0.15	2N1132	0.30	2N3705	0.15		
OC139	[illegible]	ZTX302	0.20	2N1302	0.40	2N3706	0.15		
OC140	[illegible]	ZTX303	0.20	2N1303	0.40	2N3707	0.15		
OC141	[illegible]	ZTX304	0.23	2N1304	0.52	2N3708	0.12		
OC170	[illegible]	ZTX310	0.09	2N1305	0.52	2N3709	0.15		
OC171	[illegible]	ZTX311	0.14	2N1306	0.52	2N3710	0.12		
OC200	[illegible]	ZTX314	0.23	2N1307	0.58	2N3711	0.12		
OC201	[illegible]	ZTX500	0.16	2N1308	0.63				
OC202	2.02	ZTX501	0.16						

VALVES

Type	Price	Type	Price	Type	Price	Type	Price	Type	Price	Type	Price
A1834	10.35	E130L	19.39	EF86	1.74	GXU1	16.10	PC97	1.38	QY5-3000A	82.56
A2087	13.58	E180CC	8.86	EF89	1.84	GXU2	28.43	PC900	1.38	QZ08-20	27.72
A2134	10.06	E180F	7.83	EF91	2.07	GXU3	30.49	PCC84	1.15	R10	5.75
A2293	8.62	E182CC	9.34	EF92	6.03	GXU4	32.77	PCC85	1.38	R17	1.89
A2426	13.50	E186F	11.62	EF93	1.15	GXU50	12.80	PCC88	1.38	R18	4.89
A2521	11.62	E188CC	7.36	EF94	1.24	GY501	2.95	PCC89	1.56	R19	1.38
[illegible]	[illegible]	E280F	25.88	EF95	5.25	GZ32	1.44	PCC189	1.61	R20	1.66
		E283CC	9.02	EF98	1.44	GZ33	4.60	PCC805	1.51		

Type	Price	Type	Price	Type	Price	Type	Price	Type	Price	Type	Price
TY6-5000B	236.90	2AS15	11.50	6AX5GT	3.57	6SN7GT	1.84	150B3	5.06	7025	2.62
TY6-5000W	236.44	2C39A	21.85	6B7	1.73	6SQ7	1.50	150C2	1.73	7551	6.83
TY7-6000A	286.93	2C43	20.70	6B8	2.02	6SR7	1.73	150C4	2.19	7586	13.09
TY7-6000W	232.47	2D21	2.94	6BA6	1.15	6SS7	2.07	211	6.90	7587	22.54
TZ40	17.25	2E26	7.82	6BA7	5.89	6U5G	2.30	723AB	40.25	7609	38.57
U18-20	2.88	2J42	80.70	6BA8A	4.31	6U8	0.92	803	11.50	7868	4.53
U19	10.33	2J55	201.25	6BC4	4.27	6U8A	3.24	805	23.00	7895	14.84
U25	1.33	2J70A	270.25	6BE6	1.24	6V6GT	1.84	807	2.30	8005	34.50
U26	1.66	2J70B	287.50	6BH6	1.75	6X4	1.38	811A	9.78	8068	6.33
U37	10.35	2K25	40.25	6BJ6	1.24	6X5GT	0.97	812A	9.60	6122	48.30
UABC80	1.44	3-400Z	51.75	6BK4	4.84	7B7	1.96	813	36.80	8136	2.81
UAF42	1.44	3-500Z	63.25	6BL6	97.75	7C5	2.02	833A	86.25	8417	6.14
UB41	1.44	3A5	1.55	6BL7GT	4.44	7C6	1.44	866A	6.61	18042	6.92
UBC41	1.73	3B24	9.20	6BM6	97.75	7H7	2.30	872A	15.81	18045	10.66
UBF89	1.38	3B28	5.18	6BN6	1.80	7R7	1.73	922	5.01		
UCC84	1.26	3B29	11.50	6BQ7A	4.14	7S7	2.59	931A	14.08		
UCC85	1.38	3B240M	17.25	6BR7	4.60	7Y4	1.84	1624	2.59	Tested Ex-Equipment	
UCF80	1.32	3B241M	17.25	6BR8	2.02	7Z4	2.13	1625	1.96	4CX250B	5.75
UCH42	1.38	3C23	13.89	6BS7	4.60	11E3	60.82	2050	8.00		
UCH81	2.67	3C45	22.77	6BW6	4.60	12AT6	1.38	4212E	169.90		
UCL82	1.20	3CX100A5	23.00	6BW7	1.75	12AT7	1.01	4212H	207.00		
UCL83	1.66	3E29	29.67	6BX7GT	5.70	12AU6	2.83	5544	62.10		
UF41	1.15	3S4	1.26	6BZ6	2.62	12AU7	0.83	5545	67.85		
UF42	1.44	3V4	1.38	6C4	1.01	12AV6	2.30	5551A	88.44		
UF80	1.66	465A	29.15	6CB6A	2.76	12AV7	3.96	5552A	119.54		
UF85	1.66	4-125A	41.99	6CD6GA	5.64	12AX7	1.01	5553A	259.10		
UF89	1.66	4-250A	41.99	6CG7	2.55	12AY7	5.24	5642	6.05		
UL41	1.84	4-400A	52.05	6CH6	7.48	12B4A	3.50	5654	4.05		
UL84	1.38	4B32	29.16	6CL6	4.12	12BA6	2.42	5651	2.07		
UM80	1.15	4C35	46.00	6CW4	8.33	12BE6	2.55	5670	5.29		
		4CX250B	28.53	6D2	1.91	12BH7	1.29	5675	14.03		
		4CX350A	48.88	6DK6	2.50	12BY7	3.01	5687	7.06		
		4X150A	24.41	6DQ6B	4.49	12E1	8.17	5696	4.53		
		4X150D	28.75	6EA8	3.31	12E11TT	19.26	5718	7.36		

BASES

Type	Price
B7G unskirted	0.17
B7G skirted	0.35
B9A unskirted	0.17
B9A skirted	0.35
Int Octal	0.23
Loctal	0.63
Nuvistor base	0.86
8 pin DIL	0.17
14 pin DIL	0.17
16 pin DIL	0.20
Valve screening cans all sizes	0.35

CRTs

Type	Price	Type	Price	Type	Price
2AP1	9.78	5ADP1	40.25	VCR138A	14.38
2BP1	10.35	5BP1	11.50	VCR139A	9.20
3BP1	9.20	5CP1	11.50	VCR517A	11.50
3DP1	5.75	5ADP1	40.25	VCR517B	11.50
3EG1	8.05	5BP1	11.50	VCR517C	11.50
3FP7	6.90	5CP1	5.75	Tube Bases	0.86
3GP1	6.90	5CP1A	46.00		
3JP1	9.20	5FP15A	17.25		
3JP2	9.20	5UP7	16.10		
3JP7	11.50	DG7-5	28.75		
3KP1	17.25	DG7-32	41.40		
3RP1	40.25	DH3-91	35.65		
3WP1	23.00	DH7-11	78.20		
		VCR97	13.80		
		VCR138	11.50		

INTEGRATED CIRCUITS

Type	Price	Type	Price	Type	Price	Type	Price	Type	Price	Type	Price	Type	Price
7400	0.18	7423	0.37	7460	0.21	7495	0.83	74132	0.81	74173	1.61	TAA570	2.65
7401	0.18	7425	0.35	7470	0.40	7496	0.92	74136	0.63	74174	1.73	TAA630S	4.02
7402	0.18	7427	0.35	7472	0.38	7497	3.45	74141	0.92	74175	1.04	TAA700	4.50
7403	0.18	7428	0.49	7473	0.41	74100	1.73	74142	2.65	74176	1.26	TBA480Q	2.12
7404	0.20	7430	0.20	7474	0.46	74107	0.52	74143	2.88	74178	1.44	TBA520Q	2.65
7405	0.20	7432	0.35	7475	0.62	74109	0.81	74144	2.88	74179	1.44	TBA530	2.28
7406	0.46	7433	0.41	7476	0.46	74110	0.58	74145	1.04	74180	1.32	TBA540Q	2.65
7407	0.46	7437	0.37	7480	0.63	74111	0.81	74147	2.30	74190	1.73	TBA550Q	3.70
7408	0.21	7438	0.37	7482	0.86	74116	2.02	74148	2.02	74191	1.73	TBA560CQ	3.70
7409	0.21	7440	0.21	7483	1.04	74118	1.15	74150	1.84	74192	1.55	TBA673	2.52
7410	0.18	7441	0.97	7484	1.15	74119	1.73	74151	0.97	74193	1.55	TBA700	1.75
7411	0.26	7442	0.83	7486	0.40	74120	0.95	74154	2.02	74194	1.44	TBA720Q	2.65
7412	0.26	7447AN	1.04	7490	0.60	74121	0.46	74155	0.97	74195	1.15	TBA750Q	2.38
7413	0.40	7450	0.21	7491	0.92	74122	0.69	74156	0.97	74196	1.38	TBA800	1.38
7414	0.86	7451	0.21	7492	0.69	74123	1.15	74157	0.86	74197	1.26	TBA920	3.34
7416	0.37	7453	0.21	7493	0.69	74125	0.63	74159	2.42	74198	2.59	TBA920Q	3.34
7417	0.37	7454	0.21	7494	0.92	74126	0.63	74170	2.65	74199	2.59	TBA990Q	3.34
7420	0.21					74128	0.69	74172	5.06	76013N	2.02	TCA270Q	3.34
7422	0.23											TCA760A	1.59

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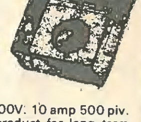

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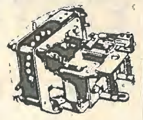

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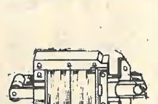
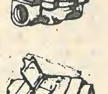
BF lever operated 20A. c/o. mf. Unimax USA. 10 for £4.00 P&P 50p (min. order 10) (£5.18 inc. VAT & P).
D.P. C/O lever m/switch, mfg. by Cherry Co. USA. Precious metal, low resistance contacts. 10 for £2.50. P&P 30p. Total inc. VAT £3.22 (min 10). N.M.S.



HEAVY DUTY SOLENOID
Mfg. by Magnetic Devices. 240V AC. Intermittent operation. Approx. 20lb. pull at 1.25in. Ex. equip. Tested. Price £4.75 + 75p P&P (£6.33 inc. VAT & P). R & T.
PYE EYTHER
240V AC Solenoid. Approx 1lb pull, ¼" travel, intermittant rating. Price £1.00 P&P 20p (£1.38 inc VAT & P) N.M.S.
WESTOOL TYPE MM8 MODEL 2
240V AC. Approx. 1¾ lb pull at ½ inch. Rating 1. Price £1.50 P&P 20p (£1.96 inc. VAT & P). N.M.S.
18-24V DC 70 ohm Coil Solenoid. Push or Pull. Adjustable travel to 3/16in. Fitted with mounting brackets and spark suppressor. Size: 100 × 65 × 25mm. Price: 3 for £2.40 + 30p P&P (min. 3 off) (£3.10 inc. VAT & P)



240V AC 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.
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Test to IEE spec. Rugged metal construction, suitable for bench or field work, constant speed clutch. Size L. 8in, W. 4in, H. 6in, weight 6lb.
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SAE for leaflet.

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New IMFD 600V Dubilier wire ended capacitors, 10 for £1.50 P&P 50p. (£2.30 inc. VAT + P&P). (Min 10). N.M.S.

VARIABLE VOLTAGE TRANSFORMERS
INPUT 230V AC 50/60
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BRAND NEW. All types.

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0-6V/12V at 10 amp £8.25 P&P £1.25 (inc. VAT £10.93)
0-6V/12V/17V/18V/20V at 20 amp £19.00 P&P £1.50 (£23.58 inc. VAT & P)
0-10V/17V/18V at 10 amp £10.50 P&P £1.50 (inc. VAT £13.80)
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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 (£2.99 inc. VAT & P). **50 WATT** 250 ohm £2.90 Post 25p (£3.62 inc. VAT & P). **100 WATT** 1/5/10/25/50/100/250/300Ω/500/1k/1.5k/2.5k/5k ohm. £5.90 Post 35p (£7.19 inc. VAT & P).
Black Silver Skirted Knob calibrated in Nos. 1-9, 1½ in. dia brass bush. Ideal for above Rheostats, 28p ea.

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3 phase AC motor, 220/250V or 380/440V, 1,425 rpm ⅛ hp cont. Direct coupled to William Allday Alcosa carbon vane blower/vacuum pump. 0.9 cfm 8 hg. Price £22.00 P&P £2.00 (£27.60 inc. VAT & P) N.M.S.

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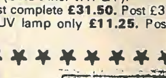

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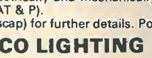
WIDE RANGE OF DISCO LIGHTING EQUIPMENT S.A.E. (Foolscap) for details



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Range of Xenon tubes available from stock. S.A.E. for full details.

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T.E.C. open type 3 c/o. 10 amp £1.10 (£1.50 inc. VAT & P).
DC Relays: Open type 9/12V 3 c/o 7 amp octal base, £1.00 (£1.38 inc. VAT & P). Sealed 12V 1 c/o 7 amp octal base, £1.00 (£1.38 inc. VAT & P). Sealed 12V 2 c/o 7 amp octal base, £1.25 (£1.67 inc. VAT & P). Sealed 12V 3 c/o 7 amp 11-pin, £1.35 (£1.78 inc. VAT & P). 24V. Sealed 3 c/o 7 amp 11-pin £1.35 (£1.78 inc. VAT & P) (amps = contact rating). P&P on any Relay 20p.
Other types available — phone for details. N.M.S.
Very special offer. 9-12V D.C., 2 make contacts, new ITT3 for £1.75 + 25p P&P (inc. VAT £2.30).
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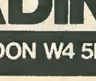

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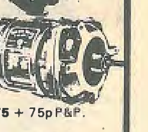

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100 R.P.M. 115 lbs. ins.!!
115 lb. ins., 110 volt, 50Hz, 2.8 amp, single phase, split capacitor motor. Immense power. Continuously rated. Totally enclosed. Fan cooled. In-line gearbox. Length 250mm. Dia. 135mm. Spindle Dia. 15.5mm Length 115mm, ex-equipment tested £12.00 Post £1.50 (£15.53 inc. VAT & P). Suitable transformer 230/240 volt £8.00 Post 75p (£10.06 inc. VAT & P). R&T

GEARED MOTORS
28 r.p.m., 20lb. inch 115V AC Reversible motor.
71 r.p.m. 10 lb. inch. 115V AC Reversible motor.
Both types similar to above drawing. Price either type £4.75 + 75p P&P. (£6.33 inc. VAT + P&P)
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FRACMO MOTOR
56rpm 50lbs inch 240V AC reversible, 0.7 amp. sharplength 35mm, dia. 16mm, weight 6 kilos 600 grams. Price £15.00 P&P £1.50 (£18.98). N.M.S.

FRACMO MOTOR
1400 rpm HP 1-30 continuously rated 115V AC fitted with anti-vibration cradle mounting. Supplied complete with transformer for 230-240V AC op. £10.00 P&P £1.00 (Total £12.65 inc. VAT). N.M.S.

PARVALUX MOTOR TYPE S.D.2
12V DC shunt 1/30th ph motor. Continuously rated 4,000 rpm. **Price £10.00** P&P 75p (£12.36 inc VAT & P). N.M.S.

PARVALUX 230/250V AC MOTOR
Type SD18 240V AC reversible **30 rpm 50lbs** inch. Price £15.00 P&P £1.50 (£18.98 inc. VAT). N.M.S.

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CROUZET — 230/240V AC **2 rpm** synchronous geared motor **£2.90** P&P 30p (Total £3.68 inc VAT). N.M.S
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Precision built miniature motor, 6/12V DC operation. Incredibly powerful for size.
Approx speed at 6V 60 rpm 40 ma
Approx speed at 9V 80 rpm 50 ma
Approx speed at 12V 120 rpm 60 ma
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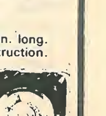
Price: £2.50 post paid (£2.88 inc. VAT).

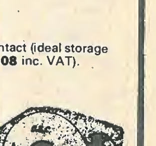
REDUCTION DRIVE GEARBOX
Ratio 72:1. Input spindle ¼ × ½in. Output spindle ⅜ × 3in. long. Overall size approx.: 120 × 98 × 68mm. All metal construction. Ex-equip. tested. Price: £2.00 + 50p P&P (£2.88 inc. VAT)



'VENNER TYPE' ERD TIME SWITCH
200/250V AC 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 £9.00 P&P 75p. (£11.21). R & T.

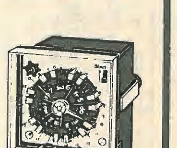
SANGAMO WESTON TIME SWITCH
Type S251 200/250V AC 2 on 2 off every 24 hours. 20 amps contacts with override switch, diameter 4" x 3", price £8.00 P&P 50p (£9.78 inc. VAT & P). Also available with solar dial. R & T.

AEG TIMESWITCH
200/250V AC 1 on/1 off every 24 hours, 80 amp contact (ideal storage heaters). Spring reserve £10.00 P&P 50p (Total £12.08 inc. VAT). N.M.S.



AC 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 £3.05). N.M.S.

2-CAM PROGRAMMER
Crouzet 1 rpm. 115V. A.C Motor operating 2 Roller Micro switches (4 amp). Can be used on 240V AC with either 0.25 mfd 250V Condenser or 5.6K wirewound Resistor 7 watt (not supplied) Price £2.50 + 50p P&P (£3.45 inc VAT & P)



MINIATURE 24-HOUR TIMESWITCH (German mfr.)
240V A.C operation. Spring reserve 10 amp contacts, one on-off every 24 hours. Calibrated in two hour steps. Minimum on-off period 6 hours. **Day Omission.** Unusual feature with these switches is that trips may be removed at will enabling individual days to be programmed as required. Size only 3" x 4". Depth 2¾". Price £6.50 + 50p P&P (£8.05 incl. VAT & P)

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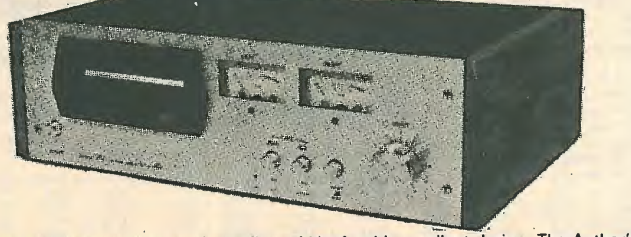

We are the Designer Approved suppliers of kits for this excellent design. The Author's reputation tells all you need to know about the circuitry and Hart expertise and experience guarantees the engineering design of the kit. Advanced features include: High quality separate VU meters with excellent ballistics. Controls, switches and sockets mounted on PCB to eliminate difficult wiring. Proper moulded escutcheon for cassette aperture improves appearance and removes the need for the cassette transport to be set back behind a narrow finger trapping slot. Easy to use, robust Lenco mechanism. Switched bias and equalisation for different tape formulations. All wiring is terminated with plugs and sockets for easy assembly and test. Sophisticated modular PCB system gives a spacious, easily built and tested layout. All these features added to the high quality metalwork make this a most satisfying kit to build. Also included at no extra cost is our new HS15 Sendust Alloy record/play head, available separately at **£7.60** plus VAT, but included FREE as part of the complete kit at **£81.50** plus VAT.

REPRINTS of the 3 articles describing this design **45p** No VAT.

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Special Hart Copyright test tape makes it easy to set up VU level. head azimuth and tape speed, without test instruments. Suitable for any cassette recorder. Complete with instructions **£2.70** inc. VAT.

LINSLEY HOOD CASSETTE RECORDER

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

This latest version has the following extra features. Ultra low wow-and-flutter of .09% — easily meets DIN Hi-fi spec. Deck controls latch in rewind modes and do not have to be held. Full Auto stop on all modes. Tape counter with memory rewind. Oil damped cassette door. Latching record button for level setting. Dual concentric input level controls. Phone output. Microphone input facility if required. Record interlock prevents re-recording on valued cassettes. Frequency generating feedback servo drive motor with built-in speed control for thermal stability. All these desirable and useful features added to the excellent design of the Linsley-Hood circuits and the quality of the components used makes this new kit comparable with built-up units of much higher cost than the modest **£94.90** + VAT we ask for the complete kit.

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LENCO FFR CASSETTE DECK

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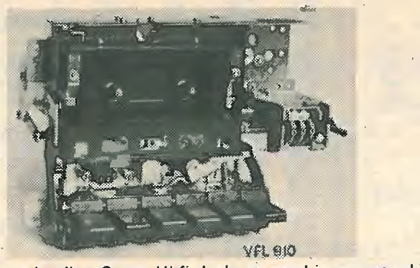
A mono head is fitted but we can supply a stereo head, *bought at the same time,* for only £2 + VAT.

This deck would normally cost about £25, and we are offering it complete with a free escutcheon for the incredibly low price of **£9.99** + VAT.



VFL 910. Vertical front loading Super Hi-fi deck, as used in our new Linsley-Hood Cassette Recorder 2. **£31.99** + VAT. Set of knobs **£1.46** + VAT.

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CD4000	0.15	CD4020	1.11	CD4037	0.85	CD4054	1.04	CD4078	0.20	CD4515	2.82
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CD4008	0.87	CD4025	0.20	CD4042	0.69	CD4063	0.98	CD4089	1.39	CD4532	1.21
CD4009	0.50	CD4026	1.55	CD4043	0.88	CD4066	0.55	CD4093	0.80	CD4555	0.78
CD4010	0.50	CD4027	0.44	CD4044	0.84	CD4067	3.35	CD4094	1.69	CD4556	0.78
CD4011	0.18	CD4028	0.77	CD4045	1.26	CD4068	0.20	CD4095	0.94	MC14528	0.93
CD4012	0.20	CD4029	1.03	CD4046	1.20	CD4069	0.20	CD4096	0.94	MC14553	4.43
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CMOS

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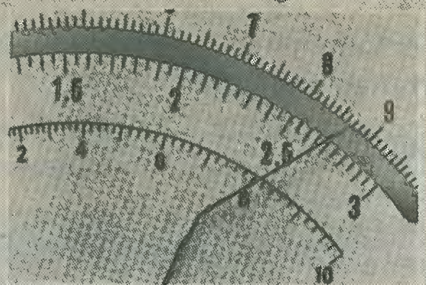

Finally, you can have all the advantages of DMMs and none of the disadvantages of analogues for about the same price.

Our new 169 is a tough, lightweight, battery-powered digital multimeter for use in the field or on the bench. It is a 3½-digit, full 5-function DMM with respectable .25% DC accuracy.

Its low-parts-count, high-efficiency design keeps power consumption to a minimum for longer component life and fewer failures. MTBF is 20,000 hrs. or about 10 years.

Is this the end for Analogue meters?

All 5 functions are fully protected – 1400V peak on DCV and ACV, 300V on Ω, 2A (250V) on DCA and ACA. The fuse is externally accessible for quick replacement. Extensive vibration stress-testing assures the 169 will stand up to all the mechanical shock and abuse normally associated with tough applications.

Cost-conscious ease of maintenance is so thoroughly designed into the 169 that only one calibration adjustment a year is required. That adds up to a cost-of-ownership no other competitive DMM can touch. For example, the 169 needs only one battery change per year at a cost of about £1.50.

When you factor in features like function and range annunciation right on the display, auto-zero, auto polarity, 60% larger display than other DMMs and the easy-to-read, colour coded front panel, we think you'll get the point. No analogue meter or DMM can match the price/performance of the new 169. It costs £99 (plus VAT)

For information on the 169 or any Keithley DMM call (0734) 861287

Telex: 847047

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WW — 121 FOR FURTHER DETAILS

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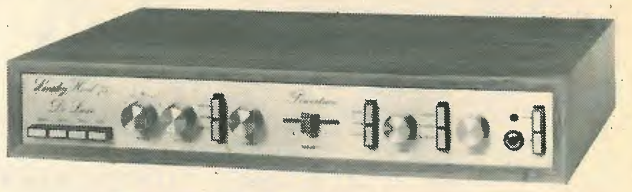
ELECTRONIC KITS OF DISTINCTION FROM POWERTRAN

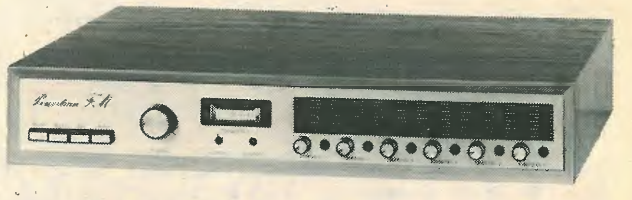
DE LUXE EASY TO BUILD LINSLEY-HOOD 75W STEREO AMPLIFIER £99.30 + VAT

This easy to build version of our world-wide acclaimed 75W amplifier kit based upon circuit boards interconnected with gold plated contacts resulting in minimal wiring and construction delightfully straightforward. The design was published in Hi-Fi News and Record Review and features include rumble filter, variable scratch filter, versatile tone controls and tape monitoring whilst distortion is less than 0.01%.



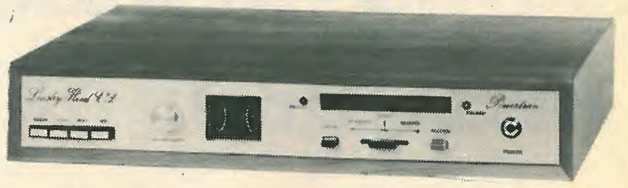
WIRELESS WORLD FM TUNER £70.20 + VAT

A pre-aligned front-end module makes this Wireless World published design very simple to construct and adjust without special instruments. Features include an excellent a.m. rejection push-button station selection as well as infinitely variable tuning and a phase locked loop stereo decoder, incorporating active filters for "birdy" suppression.



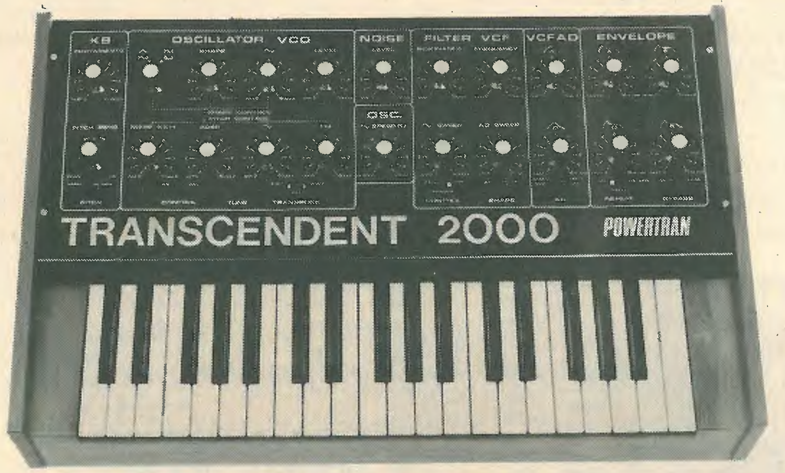
LINSLEY-HOOD CASSETTE DECK £79.60 + VAT

This design, published in Wireless World, although straightforward and relatively low cost provides a very high standard of performance. There are separate record and replay amplifiers and switchable equalisation together with a choice of bias levels are also provided. The mechanism is the Goldring-Lenco CRV with electronic speed control.



TRANSCENDENT 2000 SINGLE BOARD SYNTHESIZER

As featured in Electronics Today International



Cabinet size 24.6"x15.7"x4.8" (rear) 3.4" (front)

The kit includes fully finished metalwork, fully assembled solid teak cabinet, filter sweep pedal, professional quality components (all resistors either 2% metal oxide or ½% metal film!) and it really is complete — right down to the last nut and bolt and last piece of wire! There is even a 13A plug in the kit — you need buy absolutely no more parts before plugging in and making great music! Virtually all the components are on the one professional quality fibre glass PCB printed with component locations. All the controls mount directly on the main board, all connections to the board are made with connector plugs and construction is so simple it can be built easily in a few evenings by almost anyone capable of neat soldering! When finished you will possess a synthesizer comparable in performance and quality with ready built units selling for between £500 and £700!

COMPLETE KIT ONLY £172.00 + VAT!

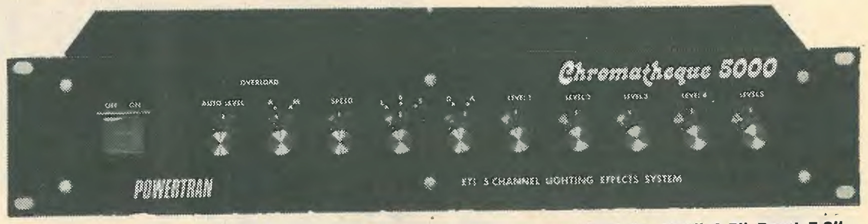
Comprehensive handbook supplied with all complete kits! This fully describes construction and tells you how to set up your synthesizer with nothing more than a multi-meter and a pair of ears!

CHROMATHEQUE 5000 5-CHANNEL LIGHTING EFFECTS SYSTEM

This versatile system featured as a constructional article in ELECTRONICS TODAY INTERNATIONAL has 5 frequency channels with individual level controls on each channel. Control of the lights is comprehensive to say the least. You can run the unit as a straightforward sound-to-light or have it strobe all the lights at a speed dependent upon music level or front panel control setting or use the internal digital circuitry which produces some superb random and sequencing effects. Each channel handles up to 500W and as the kit is a single board design wiring is minimal and construction very straightforward.

Kit includes fully finished metalwork, fibreglass PCB, controls, wire, etc. — Complete right down to the last nut and bolt!

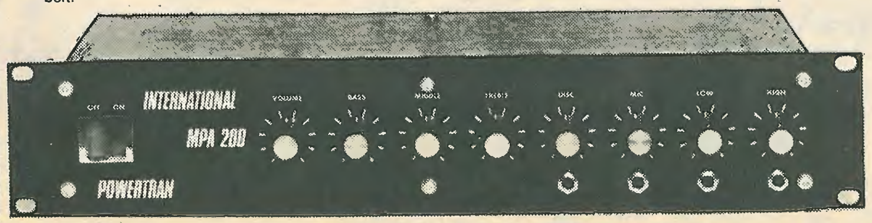
COMPLETE KIT ONLY £49.50 + VAT



Panel size 19.0"x3.5". Depth 7.3"

MPA200 100W MIXER/AMPLIFIER

Featured as a constructional article in Electronics Today International the MPA 200 is an exceptionally low-priced but professionally finished general purpose, rugged, high-power amplifier which has an adaptable range of inputs such as disc, microphone, guitar, etc. There are 3 wide range tone controls and a master volume control. Mechanically the design is simplicity in the extreme with minimal wiring making construction very straightforward. Kit includes fully finished metalwork, fibreglass PCB's, controls, wire, etc. — Complete right down to the last nut and bolt!



Panel size 19.0"x3.5". Depth 7.3"

COMPLETE KIT ONLY £49.90 + VAT

All kits also available as separate packs (e.g. P.C.B. component sets, hardware sets, etc.). Prices in FREE CATALOGUE.

ASCENSION ISLAND YUGOSLAVIA UNITED STATES OF AMERICA JORDAN GREECE INDIA GUYANA PORTUGAL FALKLAND ISLANDS UNITED ARAB EMIRATES JAMAICA HOLLAND KENYA

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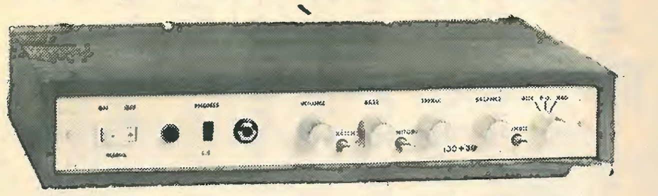
T20+20 AND T30+30 20W, 30W AMPLIFIERS



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.

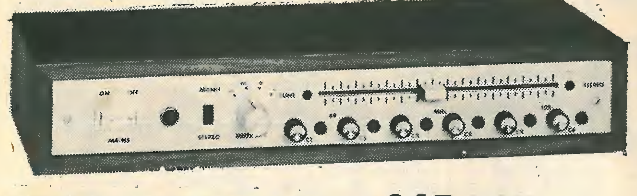
SPECIAL PRICES FOR COMPLETE KITS

T20+20 KIT PRICE **£33.10** + VAT

T30+30 KIT PRICE **£38.40** + VAT

AVAILABLE AS SEPARATE PACKS — PRICES IN OUR FREE CATALOGUE

WWII TUNER

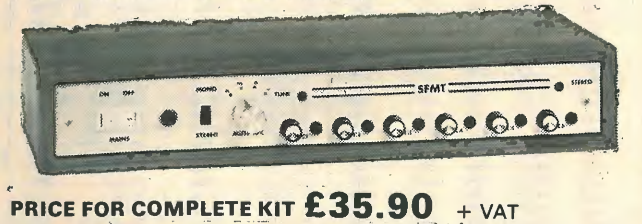


SPECIAL PRICE FOR COMPLETE KIT **£47.70** + VAT

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.

POWERTRAN SFMT TUNER



PRICE FOR COMPLETE KIT **£35.90** + VAT

AVAILABLE AS COMPLETE KIT ONLY

This is a simple, low cost design which can 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. 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.

NEW!

Another superb design by synthesizer expert Tim Orr!

TRANSCENDENT DPX

As featured in Electronics Today International August, September October, 1977 issues

DIGITALLY CONTROLLED, TOUCH SENSITIVE, POLYPHONIC, MULTI-VOICE SYNTHESIZER

The Transcendent PDX is a really versatile new 5 octave keyboard instrument. There are two audio outputs which can be used simultaneously. On the first there is a beautiful harpsichord or reed sound — fully polyphonic i.e. you can play chords with as many notes as you like. On the second output there is a wide range of different voices, still fully polyphonic. It can be a straightforward piano or a honky tonk piano or even a mixture of the two! Alternatively you can play strings over the whole range of the keyboard or brass over the whole range of the keyboard or should you prefer — strings on the top of the keyboard and brass at the lower end (the keyboard is electronically split after the first two octaves) or vice versa or even a combination of strings and brass sounds simultaneously. And on all voices you can switch in circuitry to make the keyboard touch sensitive? The harder you press down a key the louder it sounds — just like an acoustic piano. The digitally controlled multiplexed system makes practical sensitivity with the complex dynamics law necessary for a high degree of realism. There is a master volume and tone control, a separate control for the brass sounds and also a vibrato circuit with variable depth control together with a variable delay control so that the vibrato comes in only after waiting a short time after the note is struck for even more realistic string sounds.

Cabinet size 36.3"x15.0"x5.0" (rear) 3.3" (front)
Also available as separate packs — prices in free catalgoue

COMPLETE KIT ONLY £365.00 + VAT!

To add interest to the sounds and make them more natural there is a chorus/ensemble unit which is a complex phasing system using CCD (charge coupled device) analogue delay lines. The overall effect of this is similar to that of several acoustic instruments playing the same piece of music. The ensemble circuitry can be switched in with either strong or mild effects.
As the system is based on digital circuitry data can be easily taken to and from a computer (for storing and playing back accompaniment with or without pitch or key change, computer composing etc., etc.) and an interface socket (25 way D type) is provided for this purpose.
Although the DPX is an advanced design using a very large amount of circuitry, much of it very sophisticated, the kit is mechanically extremely simple with excellent access to all the circuit boards which interconnect with multiway connectors, just four of which are removed to separate the keyboard circuitry and the panel circuitry from the main circuitry in the cabinet.
The kit includes fully finished metalwork, solid teak cabinet, professional quality components (all resistors 2% metal oxide), nuts, bolts, etc., even a 13A plug — you need buy absolutely no more parts before plugging in and making great music! When finished you will possess an instrument comparable in performance and quality with ready-built units selling for over £1200!

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. There is no minimum order charge. Prices same as for U.K. customers but no Value Added Tax charged. Postage charged at actual cost plus 50p documentaton 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.

Value Added Tax not included in prices
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PRICE STABILITY. Order with confidence! Irrespective of any price changes we will honour all prices in this advertisement until October 31st, 1979, if this month's advertisement is mentioned with your order. Errors and VAT rate changes excluded.

U.K. ORDERS. Subject to 15%* surcharge for VAT. 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. 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.

FOR FURTHER INFORMATION PLEASE WRITE OR TELEPHONE FOR OUR FREE CATALOGUE

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MC3360P	120p
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MM57160	620p
NE531	150p
NE555	25p
NE556	70p
NE561B	425p
NE5628	425p
NE565	130p
NE566	155p
NE567	175p
NE571	425p
NE585-6N	300p
RC4151	400p
SAD1024	1250p
SFF96364	1150p
SN76003N	175p
SN76013N	140p
SN76013ND	120p
SN76023N	140p
SN76023ND	120p
SN76477	250p
SP8515	750p
TAA621	275p
TBA641B11	225p
TBA651	200p
TBA800	90p
TBA810	100p
TBA820	90p
TCA940	175p
TDA1004	300p
TDA1008	320p
TDA1010	225p
TDA1022	600p
TDA1024	120p
TDA1034B	250p
TDA1170	250p
TDA2002V	325p
TDA2020	320p
TL072	95p
TL074	150p
TL084	130p
TL170	50p
UDN6118	320p
UDN6184	320p
ULN2003	100p
XR2206	400p
XR2207	400p
XR2211	600p
XR2216	675p
XR2240	400p
ZN414	90p
ZN419C	POA
ZN424E	135p
ZN425E	400p
ZN1034E	200p
95H90	800p
11C90	1400p

VEROBOARDS

(copper clad)	0.1	0.15
2.5×3.75"	48p	43p
2.5×5"	57p	51p
3.75×3.75"	57p	—
3.75×5"	64p	64p
3.75×17"	222p	194p
4.75×17.9"	290p	—
Pkt of 100 pins		50p
Spot face cutter		86p
Pin insertion tool		118p
Vero Wiring Pen + 2 wire spools + combs		370p
Combs		7p

VOLTAGE REGULATORS

Fixed Plastic TO-220

1A	+ve		-ve	
5V	7805	70p	7905	75p
12V	7812	70p	7912	75p
15V	7815	70p	7915	75p
18V	7818	70p	7918	75p
24V	7824	70p	7924	75p
100mA	TO-92			
5V	78L05	30p	79L05	80p
12V	78L12	30p	79L12	80p
15V	78L15	30p	79L15	80p

OTHER REGULATORS

LM309K	135p
LM317T	200p
LM323K	550p
LM723	37p
TBA625B	120p
78HGKC	725p
78HO5KC	625p
78MGT2C	135p
78P05	900p

OPTO-ELECTRONICS

2N5777	45p
OCP71	130p
ORP12	90p
ORP60	90p
ORP61	90p
TIL78	70p

OPTO-ISOLATORS

ILD74	130p
MCT26	100p
MCS2400	190p
TIL111	90p
TIL112	90p
TIL116	90p

LEDS

0.125"	
TIL32	75p
TIL209 Red	13p
TIL211 Gr	20p
TIL212 Ye	25p
TIL216 Red	18p
0.2"	
TIL220 Red	16p
TIL222 Gr	18p
TIL228 Red	22p
MV5491 TS	120p
Clips	3p

DISPLAYS

3015F	200p
DL704	140p
DL707 Red	140p
707 Gr	140p
DL747 Red	225p
747 Gr	225p
FND357	120p
FND500	120p
FND507	120p
MAN3640	175p
MAN4640	250p
NSB5881	570p
TIL311	600p
TIL312/3	110p
TIL321/2	130p
TIL330	140p
7750/60	200p

DRIVERS

9638	200p
9370	200p
UDN6118	320p
UDN6184	320p

TRANSISTORS

AC126	25p
AC127/8	20p
AC176	25p
AC187/8	25p
AF116/7	30p
AD149	70p
AD161/2	45p
AU107	200p
BC107/8	11p
BC109	11p
BC117	20p
BC147/8	9p
BC149	10p
BC157/8	10p
BC159	11p
BC169C	12p
BC172	12p
BC177/8	17p
BC179	18p
BC182/3	10p
BC184	11p
BC187	30p
BC212/3	11p
BC214	12p
BC237	15p
BC327	18p
BC337	18p
BC338	16p
BC461	36p
BC477/8	30p
BC516/7	50p
BC547B	16p
BC548C	9p
BC549C	18p
BC557B	16p
BC559C	18p
BCY70	18p
BCY71/2	22p
BD131/2	50p
BD135/6	54p
BD139	58p
BD140	60p
BD189	60p
BD232	95p
BD233	75p
BD235	85p
BD241	70p
BD242	70p
BDX53B	150p
BDY56	200p
BF200	32p
BF244B	35p
BF256B	70p
BF257/8	32p
BF259	36p
BFR39	25p
BFR40	25p
BFR41	25p
BFR79	25p
BFR80	25p
BFR81	25p
BFX29	30p
BFX30	34p
BFX84/5	40p
BFX86/7	30p
BFX88	30p
BFW10	90p
BFY50	30p
BFY51/2	30p
BFY56	33p
BFY90	90p
BRY39	45p
BSX19/20	20p
BU104	225p
BU105	190p
BU108	250p
BU109	225p
BU205	200p
BU208	200p
BU406	145p
E300	50p
E308	50p
E310	50p
MJ2501	225p
MJ2955	100p
MJ3001	225p
MJE340	65p
MJE2955	100p
MJE3055	70p
MPF102	45p
MPF103/4	40p
MPF105/6	40p
MPS6531	50p
MPS6534	50p
MPSA06	30p
MPSA12	50p
MPSA13	50p
MPSA20	50p
MPSA43	50p
MPSA56	32p
MPSA70	50p
MPSU06	63p
MPSU07	90p
MPSU45	90p
MPSU65	78p
OC28	130p
OC35	130p
R2008B	200p
R20108	200p
TIP29A	40p
TIP29C	55p
TIP30A	48p
TIP30C	60p
TIP31A	58p
TIP31C	62p
TIP32A	68p
TIP32C	82p
TIP33A	90p
TIP33C	114p
TIP34A	115p
TIP34C	160p
TIP35A	225p
TIP35C	290p
TIP36A	270p
TIP36C	340p
TIP41A	65p
TIP41C	78p
TIP42A	70p
TIP42C	82p
TIP54	160p
TIP120	120p
TIP122	130p
TIP2955	78p
TIP4055	70p
TIS43	34p
TIS93	30p
ZTX108	12p
ZTX300	13p
ZTX500	15p
ZTX502	18p
ZTX504	30p
2N457A	250p
2N696	35p
2N697	25p
2N698	45p
2N706A	20p
2N708A	20p
2N918	45p
2N930	18p
2N1131/2	20p
2N1613	25p
2N1711	25p
2N2102	70p
2N2160	350p
2N2219A	22p
2N2222A	22p
2N2369A	16p
2N2484	30p
2N2646	50p
2N2904/5	25p
2N2906A	24p
2N2907A	30p
2N2926	9p
2N3053	27p
2N3054	65p
2N3055	48p
2N3442	140p
2N3553	240p
2N3565	30p
2N3584	250p
2N3643/4	48p
2N3702/3	12p
2N3704/5	12p
2N3706/7	14p
2N3708/9	12p
2N3773	300p
2N3819	25p
2N3820	50p
2N3823	70p
2N3866	90p
2N3902	700p
2N3903/4	18p
2N3905/6	20p
2N4037	65p
2N4058/9	12p
2N4060	12p
2N4061/2	18p
2N4123/4	27p
2N4125/6	27p
2N4401/3	27p
2N4427	90p
2N4871	60p
2N5087	27p
2N5089	27p
2N5172	27p
2N5179	90p
2N5191	83p
2N5194	90p
2N5245	40p
2N5296	55p
2N5401	50p
2N5457/8	40p
2N5459	40p
2N5460	60p
2N5485	44p
2N5875	250p
2N6027	48p
2N6247	190p
2N6254	130p
2N6290	65p
2N6292	65p
2SC1172	150p
3N128	120p
3N140	100p
3N141	110p
3N201	110p
3N204	100p
40290	250p
40360	40p
40361/2	45p
40364	120p
40408	70p
40409	85p
40410	85p
40411	300p
40594	97p
40595	105p
40673	75p
40841	90p
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OA91	9p
OA95	9p
OA200	9p
OA202	10p
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1N916	7p
1N4148	4p
1N4001/2	5p
1N4003/4	6p
1N4005	6p
1N4006/7	7p
1N5401/3	14p
1N5404/7	19p
IS920	9p

HEAT SINKS

For TO220 Voltage Regs. and Transistors	22p
For TO5	12p

BRIDGE RECTIFIERS

1A	50V	19p
1A	100V	20p
1A	400V	25p
1A	600V	30p
2A	50V	30p
2A	100V	35p
2A	400V	45p
3A	200V	60p
3A	600V	72p
4A	100V	95p
4A	400V	100p
6A	50V	80p
6A	100V	100p
6A	400V	120p
10A	400V	200p
25A	400V	400p

ZENERS

2.7V-33V

400mW	9p
1W	15p

TRIACS PLASTIC

3A	400V	60p
3A	500V	65p
6A	400V	70p
6A	500V	88p
8A	400V	75p
8A	500V	95p
12A	400V	85p
12A	500V	105p
16A	400V	110p
16A	500V	130p
T2800D		130p

THYRISTORS

1A	50V	40p
1A	400V	65p
3A	400V	90p
8A	600V	140p
12A	400V	160p
16A	100V	160p
16A	400V	180p
16A	600V	220p
BT106		110p
C106D		45p
MCR101		36p
2N3525		120p
2N4444		140p
2N5060		34p
2N5064		40p

LOUDSPEAKERS

Size		
2½"	64R	70p
2½"	8R	70p
2"	8R	90p
1½"	8R	80p

MEMORIES

2102-2L	120p
2107B	500p
2111-2	225p
2112-2	300p
2114	525p
4027	375p
4044	900p
4116	900p
5101	510p
6810	350p
74S201	325p
82S16	325p

ROM/PROMs

71301	700p
74S188	225p
74S287	350p
74S387	350p
74S470	650p
74S471	650p
74S571	1100p
82S137	750p
93427	400p
93436	650p
93446	650p
93448	1000p

CPUs

1600	£12
2650A	£20
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4002	
6820	500p
6821	500p
6850	500p
8205	320p
8212	225p
8216	225p
8224	400p
8228	525p
8251	700p
8253	1200p
8255	550p
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8259	1400p
Z80P10	650p
Z80CTC	650p
MC14411	1100p
MC14412	1100p

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AY-5-1013P	400p
IM6402	500p
TMS6011NC	400p

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AY-5-2376	£10

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(prim 220/240V)

6-0-6	100mA	88p
9-0-9	75mA	92p
12-0-12	100mA	95p
0-120	12500mA	280p
0-25V (5VA)		250p
9-0-9 1A		270p*
12V 2A		350p*
0-12-15		
20-24-30 1A		340p*
15-0-16 1A		265p*

(Please add 50p p&p charge to all marked * above our normal p&p charge).

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Carbon Track Pots 5K-1M Log or Lin	
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Single with Switch	60p
Dual	72p
SLIDER POTS 60mm Track LIN 5K, 10K, 50K, 100K	50p
LOG 10K	60p

LOW PROFILE DIL SOCKETS BY TEXAS

8 pin	10p	18 pin	22p	24 pin	30p
14 pin	11p	20 pin	25p	28 pin	38p
16 pin	12p	22 pin	28p	40 pin	48p

WIRE WRAP SOCKETS BY TEXAS

8 pin	30p	18 pin	70p	24 pin	90p
14 pin	40p	20 pin	75p	28 pin	110p
16 pin	55p	22 pin	80p	40 pin	140p

SUBMINIATURE SWITCHES

Toggle	
SPST	60p
SPDT	65p
DPDT	70p
DPDT (centre off)	85p
Push to make	15p
break	25p
Push latching SPCO	60p
SLIDE DPDT	18p
ROCKER SPST	28p
WAFER	
1P/12W	45p
3P/4W	45p
4P/3W	45p
2P/6W	45p

ANTEX SOLDERING IRONS

C-15W	380p
CX-17W	400p
CCN-15W	400p
X25	400p
SPARE BITS	
C/CX/CCN	46p
X25	50p
SPARE ELEMENTS	
C/CX/X25	180p
CCN	200p
ADCOLA IRONS	
K1000	550p
K2000	550p

CRYSTALS

100KHz	300p
1MHz	370p
1.008MHz	370p
3.2768MHz	350p
3.579545MHz	200p
4MHz	350p
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10.7MHz	350p
18MHz	300p
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27.145MHz	210p

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DIP Breadboard 4.15 × 6.15 (Suitable for 20 × 14 pin or 16 × 16 pin DIL ICs)	270p
DIP Breadboard as above with tracks for 31 way connector	340p
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31 way Plug	110p
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2 x 18 way	120p		

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ICM7217A	850p
ZN1040E	700p

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10231	350p

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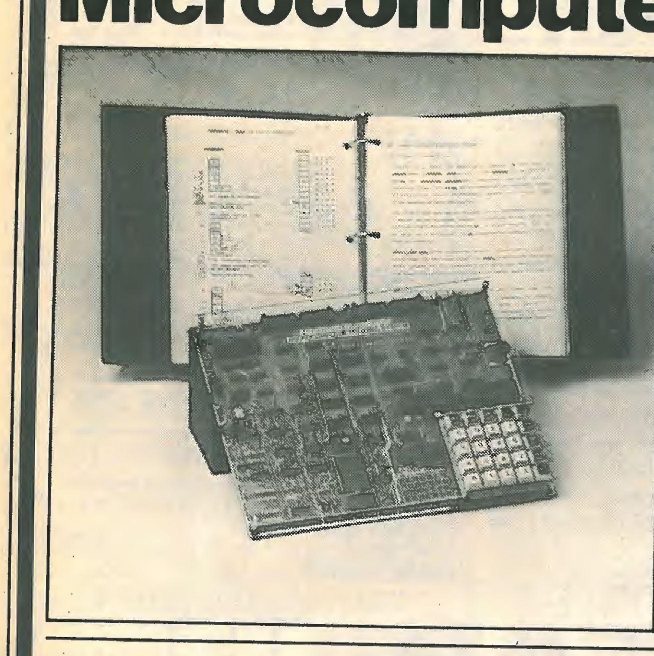

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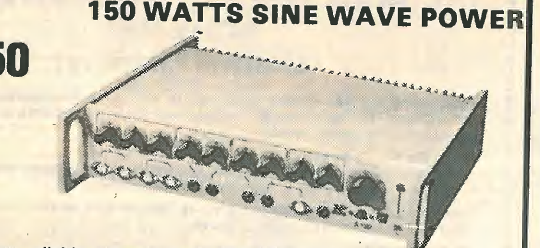

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WW — 109 FOR FURTHER DETAILS

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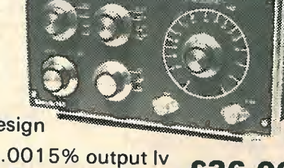

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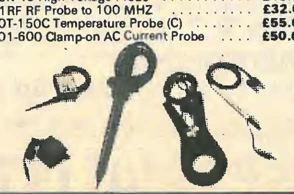

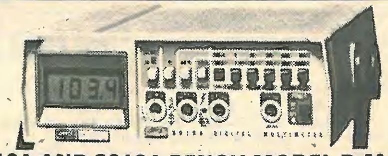

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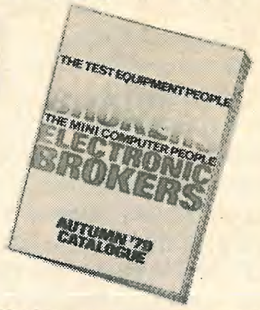

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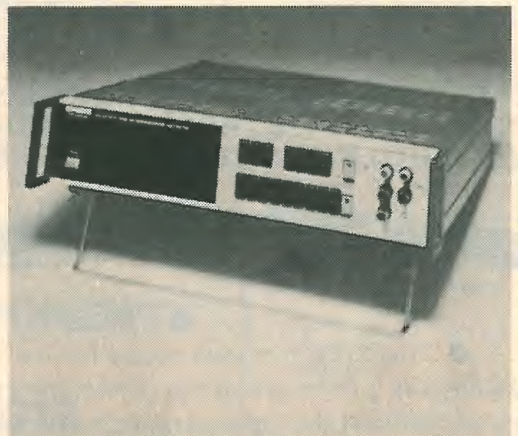

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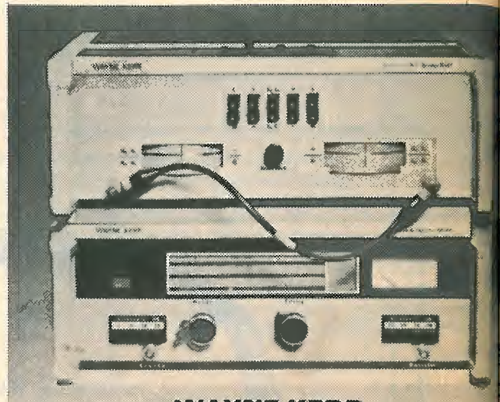

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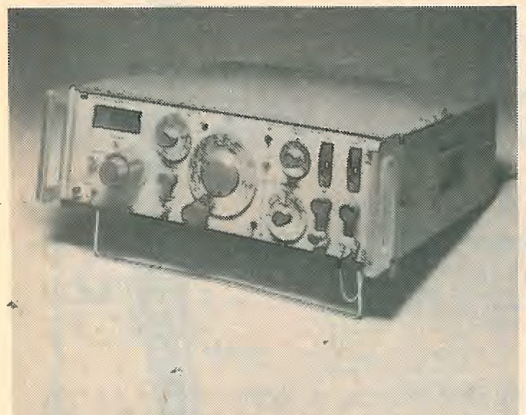

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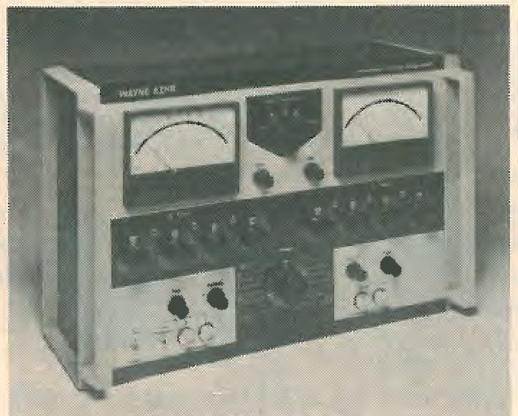

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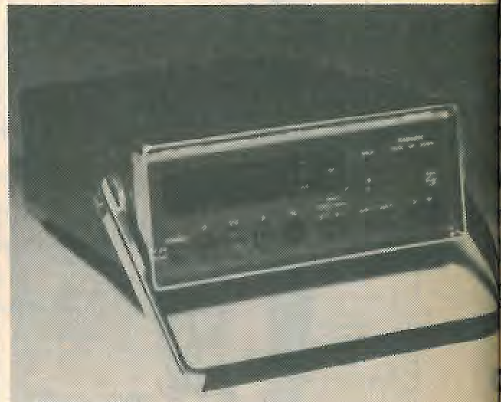

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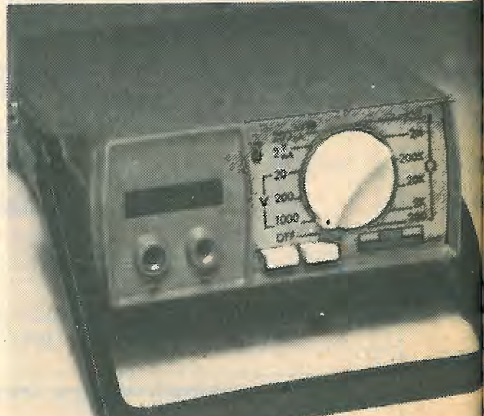

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SUPERB VALUE AT ONLY QUANTITIES AVAILABLE
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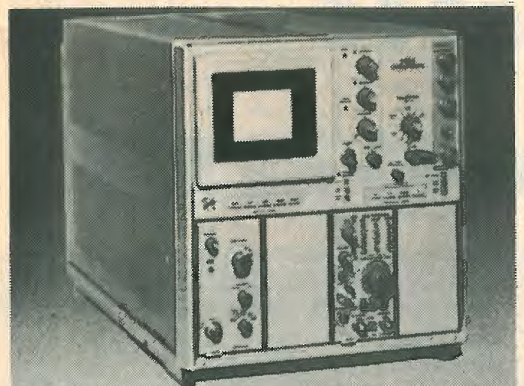

7904 Oscilloscope Main Frame with 7A26 — 7A19 — 7A21 — 7B92
Bandwitch: 350MHz with 7A26
500MHz with 7A19
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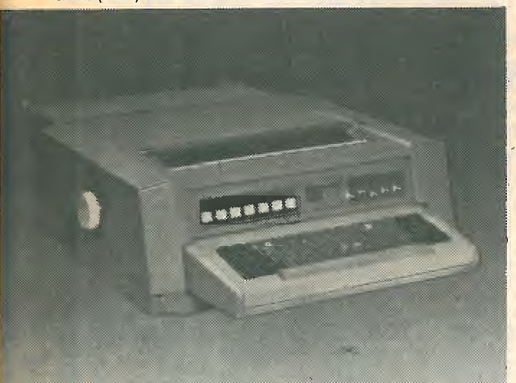

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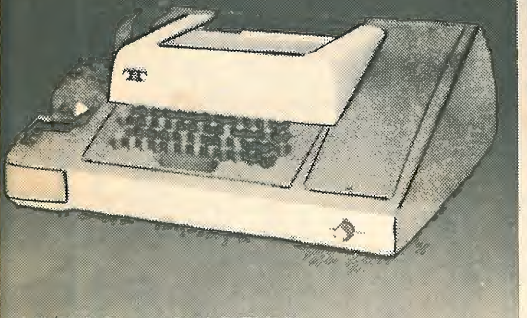

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Input/Output terminals with 64 ASCII character set. 110 baud operation. Paper tape punch and reader (ASR33 only). Choice of interface (20mA or RS232) KSR33 — **£425.00.** ASR33 — **£650.00.** Pedestal **£30.00.**

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WW — 120 FOR FURTHER DETAILS

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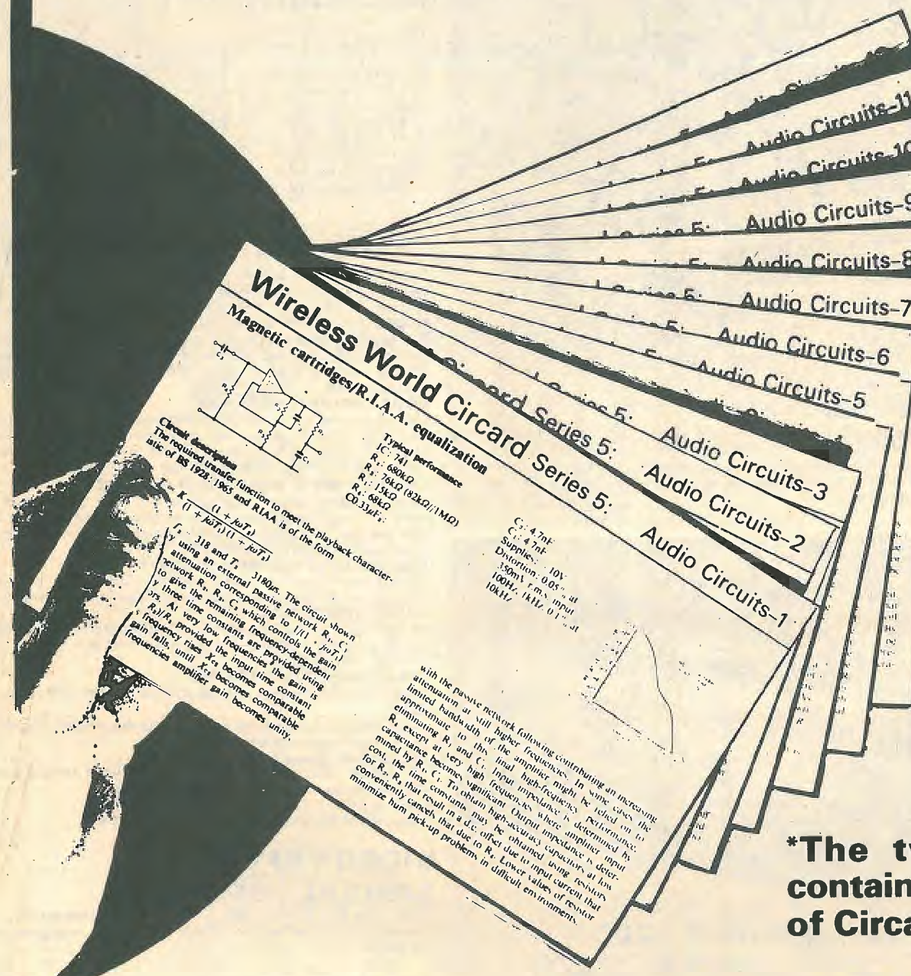

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WW10

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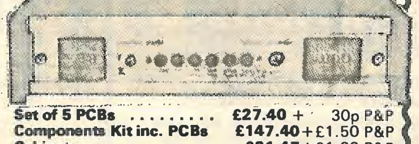

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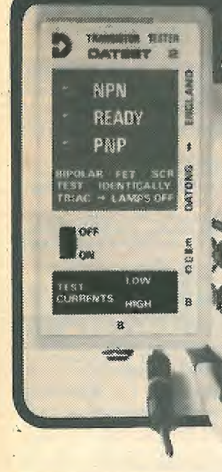

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Please add VAT after P&P

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Centre Tapped and Screened

Ref.	VA (Watts)	£	P&P
07★	20	4.84	.91
149	60	7.37	1.10
150	100	8.38	1.31
151	200	12.28	1.31
152	250	14.61	1.73
153	350	18.07	2.12
154	500	22.52	2.47
155	750	31.97	OA
156	1000	40.92	OA
157	1500	56.52	OA
158	2000	89.99	OA
159	3000	95.33	OA

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Separate 12V windings Pri 220-240V

Ref	Amps 12v	Amps 24v	£	P&P
111	0.5	0.25	2.42	.52
213	1.0	0.5	2.90	.90
71	2	1	3.86	.90
18	4	2	4.43	1.10
85	5	2.5	5.50	1.10
70	6	3	6.99	1.10
108	8	4	8.16	1.31
72	10	5	8.93	1.31
116	12	6	9.89	1.52
17	16	8	11.79	1.52
115	20	10	15.38	2.39
187	30	15	19.72	2.39
226	60	30	40.41	OA

50 VOLT RANGE

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

Ref.	Amps	£	P&P
102	0.5	3.75	.90
103	1.0	5.03	1.10
104	2.0	7.88	1.31
105	3.0	9.15	1.52
106	4.0	12.55	1.73
107	6.0	16.57	1.89
118	8.0	22.29	2.39
119	10.0	27.48	OA
109	12.0	31.79	OA

30 VOLT RANGE

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

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

60 VOLT RANGE

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

Ref.	Amps	£	P&P
124	0.5	4.27	1.10
126	1.0	6.50	1.10
127	2.0	8.36	1.31
125	3.0	12.10	1.39
123	4.0	13.77	2.12
40	5.0	17.42	1.89
120	6.0	19.87	2.12
121	8.0	28.12	OA
122	10.0	32.55	OA
189	12.0	37.47	OA

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

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VA	Ref.	£	P&P
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1000	250	45.94	OA

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Ref.	VA (Watts)	TAPS	£	P&P
113	15	0-115-210-240V	2.73	.81
64	75	0-115-210-240V	4.41	1.10
4	150	0-115-200-220-240V	5.89	1.10
67	500	" "	12.09	1.91
69	250	" "	7.74	1.14
84	1000	" "	20.64	2.39
93	1500	" "	25.61	OA
95	2000	" "	38.30	OA
73	3000	" "	65.13	OA
80s	4000	0-10-115-200-220-240	84.55	OA
57s	5000	" "	98.45	OA

Step Up or Step Down

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200v	4A	65p
400v	4A	80p
400v	6A	£1.40
500v	12A	£2.35

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150VA	£11.01	1.31	4W
200VA	£12.01	1.67	65W
250VA	£12.75	1.67	69W
500VA	£20.13	1.89	67W
1000VA	£30.67	2.65	84W
1500VA	£28.62	OA	93W
2000VA	£54.97	OA	95W

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172	1A	3.26	.78
173	2A	3.95	.78
174	3A	4.13	.86
175	4A	6.30	.96

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Complete 4K x 12 bit memory system on one PCB. This ex computer memory card contains all relevant decoding, read write and control logic for coupling to your M.P.U. or mini computer system. TTL in and out make interfacing a "cinch". We understand that by reading the outputs correctly, the memory can be organised as a 6K x 8! Features include fast 250ns max. access time. Standard +12v, −12v+5v power rails compact construction, non-volatile memory, data remains even when power switched off! Original cost over £800 each, supplied complete with full data and circuit manual, at an unbelievable price of **£39.95** P.P. £1.75

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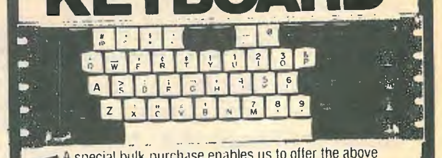

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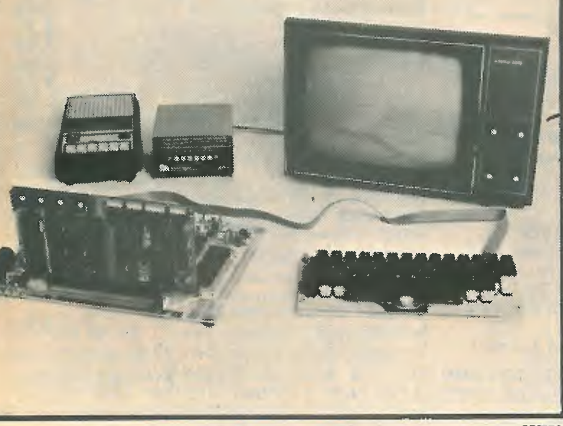

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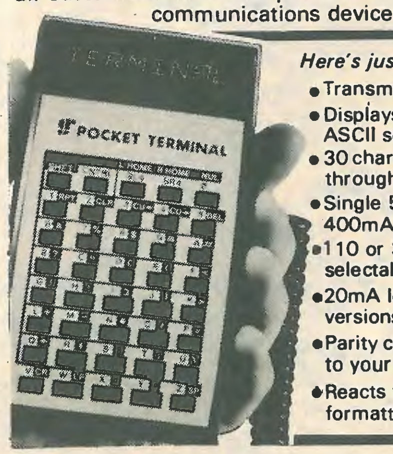

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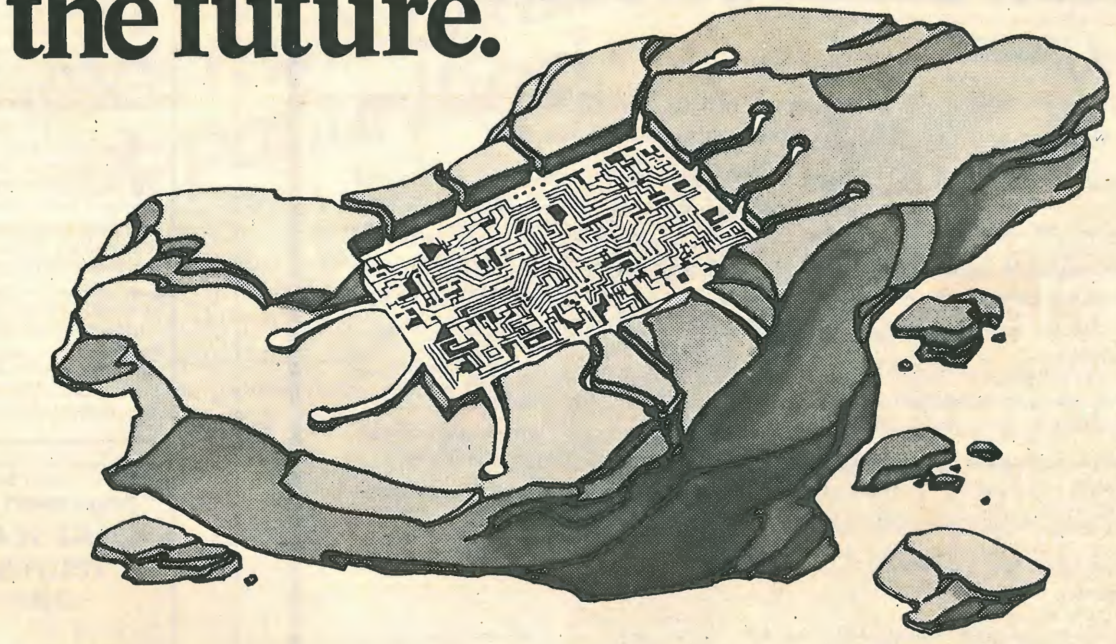

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At Honeywell we are committed to its extension into all areas of potential benefit. The end of 1979 will see the opening of our new facility, devoted exclusively to examining the applicational possibilities within the European market, particularly in the areas of instrument and control.

Based at Newhouse, Lanarkshire, close to our design and development facility, the Solid State Applications Centre therefore represents a major investment, not only for Honeywell, but also for Scotland and the UK as a whole. Our investment amounts to more than £1 million and will provide advanced facilities including computer-aided design.

The Centre's small, highly specialised team will work in close co-operation with the marketing function and the research group in Minneapolis, USA, in investigation and analysis of user-oriented problems, design specification, through prototype development and presentation to the client. In the longer term, the aim of their work will be to enlarge the product range of our Scottish operations.

Commercial awareness – of cost, practical and time factors – will be as important in the engineer as the technical capacity to contribute to this advanced undertaking. Sound relevant R&D experience is necessary; however, since the work is of a very specialist nature, extensive training will be available in USA.

Project Engineers:

These are senior appointments, with responsibility for individual development projects within defined technical and financial goals. Applicants must be fully qualified electronics engineers, who have proven ability to work with multi-discipline engineering teams and with considerable professional experience in at least one of the following: micro-electronics/solid state design; microprocessor software engineering; opto-electronics for object recognition; real-time computer control techniques; advanced electro-mechanical instrument designs.

The work will entail spending periods of up to six months in USA to assist in technology transfer.

Design Engineers:

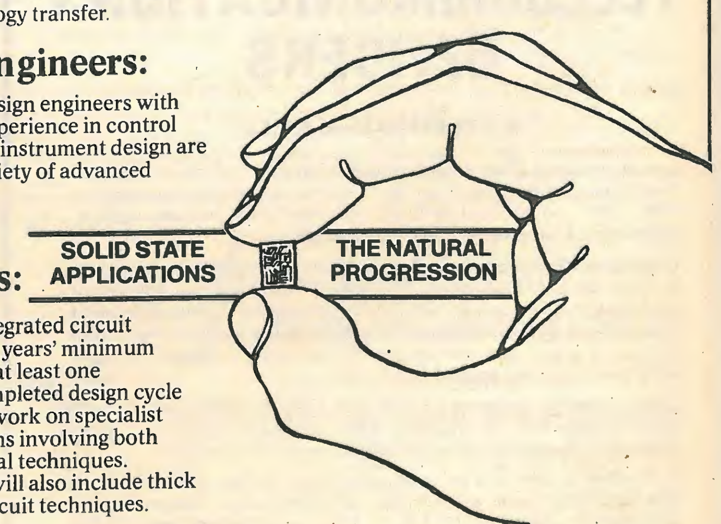
Electronic design engineers with some specific experience in control engineering and instrument design are needed for a variety of advanced design work.

IC Engineers:

Qualified integrated circuit designers with 2 years' minimum experience and at least one successfully completed design cycle are required to work on specialist solid state designs involving both analog and digital techniques. Developments will also include thick and thin film circuit techniques.

The salary and benefits packages attached to these posts will be attractive to the highest calibre of men and women, and career prospects in this stimulating and innovative environment are exceptional.

To apply, please contact:
David Miller, Management Development Manager,
HONEYWELL LIMITED,
Newhouse Industrial Estate,
MOTHERWELL,
Lanarkshire ML1 5SB
Tel. Holytown 732 100
Extension 627



Honeywell

Seek failure and find success

c. £7,000

Correct component choice is a cornerstone of Rank Xerox design philosophy. It has to be right to ensure our continuing world wide commercial success.

We seek a special type of engineer; who has not only a strong background and training in electronics, but also an enquiring mind and the necessary acumen to interact with designers, production engineers, major component suppliers and purchasing staff. Your role will include the establishing of specifications for components, their resourcing, negotiation, overall test, modification and application. We have invested heavily in ATE, and so some software knowledge would be useful.

Male or female, you should have at least HNC level qualifications and electronics experience in an industrial or R & D environment, preferably in component manufacture. Based at our Welwyn Garden City headquarters, you will occasionally be required to travel in both Europe and USA. Thorough specialised training will be provided, and there are excellent prospects for rapid career advancement within this stimulating world wide meritocracy.

Most vacancies are at senior level, but we would also like to hear from those with less experience.

Salaries circa £7,000 are offered. Our benefits package is superb and includes a generous and all embracing re-location package to enable those living outside the area to move to this desirable location within easy reach of London. For an application form and company information package please telephone Jim Collingham on 0908 312870 or write to him at Rank Xerox Engineering Group, 30 Church Street, Welwyn, Herts. AL6 9LX.

(9696)

RANK XEROX
ENGINEERING GROUP

THE THOMSON FOUNDATION TELEVISION COLLEGE

VACANCIES AVAILABLE:

A) SENIOR ENGINEERING LECTURER

B) ENGINEERING LECTURER

Applicants must have had professional broadcast television experience of not less than three years for Lecturer, and seven years for Senior Lecturer. Duties include theoretical and practical training of broadcast engineers and technicians from overseas professional television stations.

These posts are based in a Student Residential College which houses a fully operational television station, and is situated in the rural suburb of Newton Mearns, near Glasgow.

Desirable qualifications: Degree, HND or equivalent. Recent practical broadcast experience essential.

Starting salary negotiable — Engineering Lecturer £7,000+, Senior Engineering Lecturer £8,000+.

Applications in writing to The Principal, Thomson Foundation Television College, Kirkhill House, Broom Road East, Newton Mearns, Glasgow, G77 5RH. (9671)

UNIVERSITY OF LIVERPOOL DEPARTMENT OF PHYSICS

RESEARCH TECHNICIAN GRADE 5

To assist with preparing, commissioning and running apparatus in a Solid State Physics Group. Relevant experience necessary and some knowledge of electronics or workshop practice an advantage. Initiative and ability to work co-operatively important. O.N.C. or equivalent qualification essential. Salary within a range £3700-£4320 p.a. (under review).

Application forms may be obtained from The Register, The University, P.O. Box 147, Liverpool L69 3BX. Quote Ref: RV/766/WW.

(9712)

Foreign and Commonwealth Office

TELECOMMUNICATIONS OFFICERS

£4575-£6100 (from 1.1.80)

. . . .at Hanslope Park, Milton Keynes, for work on the installation, maintenance and operation of HF communication equipment, VHF, UHF and microwave links and associated test equipment, teleprinters and other specialised equipment.

Candidates should normally have ONC in Engineering (with a pass in Electrical Engineering 'A') or Applied Physics, or an equivalent qualification, and have served an apprenticeship or had equivalent training, but ex-Service people who have had suitable training and at least 3 years' appropriate service (as Staff Sergeant or equivalent) will also be considered.

Salary, starting between £3795 and £5015 (according to age), rises to £5415; (to become £4575-£6100 from 1.1.80). Promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 11 October 1979) write to Civil Service Commission, Alencon Link, Basingstoke, Hants RG21 1JB or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). **Please quote ref: T/5221.**

(9707)

OFFLINE EDITING LTD.

REQUIRED:

SENIOR ENGINEER

Salary in accordance with ACTT national agreement plus local incentive.

The engineer required is to join a specialist team engaged in sophisticated video tape post production in the heart of West 1.

The duties will be editing on U-matic, and the operation of all VTR formats. The applicant will be required to become competent in all VTR operations. It is essential that the candidate for this job be familiar with facilities operations and accustomed to dealing with clients.

This job represents a unique opportunity for a VTR engineer or editor with at least two years' experience in Broadcast, or Broadcast Standard TV.

Please contact Barry Stevens on: 01-439 8241

8, Poland Street, London, W1V 3DG.

(9686)

Sony Broadcast success story means more career opportunities!

Yes, having in the last year sold TV equipment and systems to more than 80 organisations in 19 countries, we are already negotiating for additional accommodation at Basingstoke and we plan to double our staff yet again during the next 12 months. This includes the opening of branches in Germany, Scandinavia, Italy and the Middle East, as well as expanding our facilities in Basingstoke itself. In the meantime, we have the following immediate vacancies:-

U.K. Sales Manager
(Salary negotiable around £10K + car)
We're looking for a young, qualified "eager-beaver" who really knows his/her onions when it comes to video tape (and preferably TV cameras, digits and audio as well). Someone who enjoys meeting people, doesn't mind a bit of travel, mostly in the UK, and desirably has some operational experience in TV studios or post-production. Previous sales experience useful, but not essential. Drive, self-motivation, initiative, meticulous attention to detail and perseverance will bring its own rewards. Usual fringe benefits, including free life assurance and free medical insurance.

Senior Proposals Engineer
(Salary negotiable around £7-8.5K depending upon qualifications and experience)
Qualifications similar to above but need not be quite so extrovert, travel so much, or have such hollow legs! Technically, we want a good all-rounder, preferably with Studio and OB planning experience who can ensure that what we propose to customers really meets their requirements and that we have not omitted any vital parts from our quotations. In short, making the system work. Some knowledge of Contract Law and of coping with "Invitation to Tender" small print would be an advantage, but not essential, as would a knowledge of languages. Some opportunities for foreign travel, mostly in Europe, Africa and the Middle East.

Proposals Engineer
(Salary around £6-7.5K depending upon qualifications and experience)
Assistant to the Senior Proposals Engineer. Need not have experience of this kind of work, but must be as keen as mustard and, willing to learn. Would ideally suit a young engineering Graduate, preferably with a couple of years of industrial experience who is interested in developing his/her career on the commercial side. Training provided if necessary. Travel opportunities as above.

Sales Engineers and Senior Sales Engineers
(Salaries negotiable £5-16K depending on qualifications, experience and the selected base (£16K Middle East))
Here we are looking for knowledgeable, resourceful engineers who enjoy travelling and who can be relied upon to maximise any business opportunities which present themselves while assisting customers in every possible way with demonstrations, installation, commissioning and after-sales service. Anyone at present working for one of our competitors would be especially welcome. Must be studio "house-trained". Foreign languages a definite plus particularly if it is your native tongue. We are particularly short of German and Spanish speaking engineers.

Research & Development Engineers
(Salaries negotiable around £7K)
Due to expansion we again have a number of vacancies for experienced engineers to join our small, but growing, R & D team which is involved in the application of high speed digital techniques to video-processing. As the team belongs to an international R & D group these appointments offer many opportunities for both short and long term travel. Ideally, candidates will be qualified to degree level and will have several years R & D experience in video-engineering. However, initiative and ability are the most important characteristics that we are seeking, so candidates with other, relevant experience will also be considered.

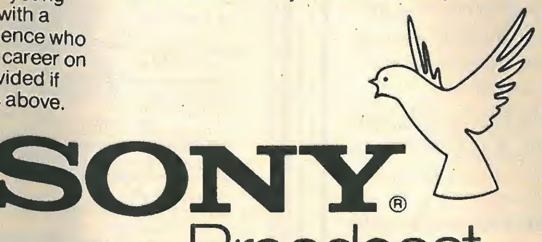
Assistant Product Managers
(Starting salaries circa £7K)
We are looking for either (a) bright young graduates eager to be trained in depth in their chosen product and the needs of the 625 line markets, or (b) engineers or technicians who are already widely experienced with cameras, TBC's, 1" Helical Scan VTR's or High Band U-Matic VTRs (BVU) coupled with an existing comprehensive knowledge of the needs of the EAME market including the strengths and weaknesses of our competitors' products. The various Product development groups in Sony Broadcast rely very heavily on the product planning advice from the Product Managers in the field and these are jobs for those who want to become top experts in their chosen speciality coupled with extensive travel in Europe, Africa and the Middle East; at least one visit to Japan within the first 12 months and thereafter at regular intervals. Four vacancies exist, one for each of the product categories above.

Assistant Marketing Promotions Manager
(Salary negotiable around £7-8K)
This job involves assisting the Marketing Promotions Manager in all aspects of Company promotion (International Exhibitions, preparation of technical sales literature, press liaison, advertising – you name it). A technical background coupled with an ability to write in an effective style are primary requirements. A knowledge of the Broadcast Equipment industry is desirable.

Service Supervisor
(Salary around £7-8K depending upon qualifications and experience)
Here we are looking for a 100% reliable person with some knowledge of administration to be responsible for the day to day running of our Service Department, handling all Sony Broadcast products. Broadcast experience is desirable but not essential if otherwise well qualified and experienced in this kind of work.

Test Engineers/Quality Assurance Technicians
(Salaries £5K upwards)
We anticipate having a number of vacancies in our Quality Assurance team during the next few months as we expand into new premises. HNC, HND or C & G Finals in Telecoms desirable but experience of working on sophisticated Broadcast equipment is more important. Salaries according to qualifications and experience.

All the above posts carry fringe benefits PLUS the advantages of joining a young and already successful company at a relatively early stage. An excellent pensions scheme, a staff purchase scheme, free life assurance and free private health insurance are available to all employees after an initial qualifying period. All posts carry an entitlement to 4 weeks (20 working days) paid holiday per year. Assistance with relocation expenses is given in approved circumstances (usually restricted to the more senior of the more specialised posts). All salaries individually reviewed each year.



Write in strict confidence to the Personnel Manager giving full details of qualifications, experience and present salary.

SONY® Broadcast

Sony Broadcast Ltd.
City Wall House
Basing View, Basingstoke
Hampshire RG21 2LA
Great Britain

RADIO TECHNICIANS

At the Government Communications Headquarters we carry out research and development in radio communications and their security, including related computer applications. Practically every type of system is under investigation, including long-range radio, satellite, microwave and telephony.

Your job as a Radio Technician will concern you in developing, constructing, installing, commissioning, testing, and maintaining our equipment. In performing these tasks you will become familiar with a wide range of processing equipment in the audio to microwave range, involving modern logic techniques, microprocessors, and computer systems. Such work will take you to the frontiers of technology on a broad front and widen your area of expertise — positive career assets whatever the future brings.

Training is comprehensive: special courses, both in-house and with manufacturers, will develop particular aspects of your knowledge and you will be encouraged to take advantage of appropriate day release facilities.

You could travel — we are based in Cheltenham but we have other centres in the UK, most of which, like Cheltenham are situated in environmentally attractive locations. All our centres require resident Radio Technicians and can call for others to make working visits. There will also be some opportunities for short trips abroad, or for longer periods of service overseas.

You should be at least 19 years of age, hold or expect to obtain shortly the City and Guilds Telecommunications Technician Certificate Part I (Intermediate), or its equivalent, and have a sound knowledge of the principles of telecommunications and radio, together with experience of maintenance and the use of test equipment. If you are or have been in HM Forces your Service trade may allow us to dispense with the need for formal qualifications.

WORK IN COMMUNICATIONS R&D AND ADD TO YOUR SKILLS

You start at £3900 rising to £5530, and promotion will put you on the road to posts carrying substantially more. There are also opportunities for overtime and on call work paying good rate.

Get full details from our Recruitment Officer, Robby Robinson, on Cheltenham (0242) 21491, Ext. 2269, or write to him at GCHQ, Oakley, Priors Road, Cheltenham, Glos. GL52 5AJ. If you seem suitable we'll invite you to interview in Cheltenham — at our expense, of course.

(9106)

SCOTTISH HOME AND HEALTH DEPARTMENT

WIRELESS TECHNICIAN

Applications are invited for two posts of Wireless Technician in the Scottish Home and Health Department.

LOCATION. The posts are in Inverness.

QUALIFICATIONS: Candidates must hold an ordinary National Certificate in Electronic or Electrical Engineering or a City and Guilds of London Institute Certificate in an appropriate subject or a qualification of a higher or equivalent standard.

EXPERIENCE. 3 years appropriate experience.

STARTING SALARY: £3,900, scale maximum £5,530.

Applicants should have sound theoretical and practical knowledge of Radio Engineering and Radio Communications Equipment in HF, VHF and UHF bands. The work involves installation and maintenance of equipment located at considerable distance from headquarters. A clean current driving licence and ability to drive private and commercial vehicles are essential.

Appointments are unestablished initially but there are prospects of established (i.e. permanent) appointments after 1 year's satisfactory service.

Application forms and further information are obtainable from Scottish Office Personnel Division, Room 110, 16 Waterloo Place, Edinburgh EH1 3DN (quote Ref. PM(PTS) 2/8/79) (031 556 8400 ext 4317 or 5028).

Closing date for receipt of completed application forms is 25 October 1979.

(9727)

STRIKE IT RICH

WITH ARAMCO IN SAUDI ARABIA

£10,500 – £15,000

per contract year after tax

The Communications Department of Aramco, the world's largest oil producer, urgently requires:—

COMMUNICATIONS ENGINEERS/ DESIGN ENGINEERS

with at least HNC and 10 years experience of one or more of the following fields.—

MICROWAVE RADIO — experience in system design, propagation calculations, CCIR standards, supervisory alarms, broad baseband (1800 channel) voice channel transmission, TV transmission, and protection alternatives.

MULTIPLEX — translation of requirements into detailed MUX plans, forecasts of required equipment, network management and installation standards.

TELEPHONE INSIDE PLANT — small exchanges, ranging 100-15,000 lines.

AE step by step and EAX PABX's.

VHF/UHF LAND MOBILE, MARINE, AIR-GROUND SYSTEMS — network frequency management, touch tone controls and signalling.
Telephone network access by mobile units and remote subscribers, F1/F2 repeaters, duplexing networks, consoles, network planning and familiarity with GE equipment.

- **Renewable contracts, single status**
- **12 days Public Holidays per year**
- **Leave for married men — 14, 14, 25 days after each 4 month period per contract year**
- **Leave for single men — 30 days after 12 months**
- **Free medicare**
- **Air conditioned accommodation**
- **Valid UK driving licence essential**

Please write with career details quoting ref WW/10 to:

(9690)

PMC MANAGEMENT SERVICES LIMITED
INTERNATIONAL RECRUITMENT
5, East Parade, Harrogate, North Yorkshire HG1 5LF.

TEST EQUIPMENT ENGINEERS

Are you seeking an opportunity to work on sophisticated test gear employing the latest analogue and digital techniques?

If so, join Rediffusion and work on a number of exciting projects associated with the design and development of equipment for production line testing of our future colour TV receivers.

Effective testing plays an important part in ensuring that the finished product reaches the high quality levels necessary for success during the 1980's. To increase the scope and flexibility of our testing, new equipment will be microprocessor controlled. Even if you only have limited knowledge of digital techniques this opportunity will enable you to learn the mysteries of microprocessors and their application to testing complex electronic sub-assemblies.

Applications are invited from engineers with a creative ability to work in a congenial and stimulating environment at our Engineering Centre at Chessington, Surrey. We have vacancies at senior and intermediate levels offering opportunities for career advancement. Salaries are obviously commensurate with qualifications and experience, but will be extremely attractive to those engineers whose test equipment background is such that they can make a significant contribution to the performance of our test gear team.

The usual big company benefits, such as pension scheme, free life insurance, 4 weeks holiday with choice of leave period, sports facilities and assistance with relocation expenses are offered for these posts.

If you are interested in these challenging positions and would like more details or wish to discuss the matter in depth, please write or telephone:-

Mr. H. Brearley,
Head of Technical Services,
Rediffusion Consumer Electronics Ltd.,
Fullers Way South,
Chessington, Surrey. KT9 1HJ.
Telephone: 01 397 5411

REDIFFUSION

9677

TEST/QUALITY ASSURANCE ENGINEERS

Test/quality assurance engineers at senior and intermediate level wanted to work on our range of advanced broadcast television studio products including colour and monochrome television studio cameras.

Applicants should have an up to date knowledge of digital and linear circuit techniques gained from experience working on television studio equipment, radar equipment or similar sophisticated products, and qualified to HND, HNC or equivalent level.

Employment benefits include excellent salary, generous holidays, free life and health insurance, pension scheme, staff restaurant and relocation expenses.

Please apply for further details and application forms to Jean Smith at the address given below.

Advanced Broadcasting Equipment

LINK ELECTRONICS

**Link Electronics Limited,
North Way, Andover,
Hants, SP10 5AJ.
Telephone: (0264) 61345**

(9601)

THAMES TELEVISION LTD.

TECHNICAL AND OPERATIONAL TRAINING

Thames Television will be running its Technical Training Scheme beginning November 1979. The course will be of 9 months duration and traineeships will be available in the following areas:

1. Technicians covering VTR, Telecine, and Vision Control operations and maintenance
2. Engineering, covering planning, design and installation
3. Television Camera Operations
4. Television Sound Operations
5. Film covering Camera, Sound, Editing

The course will consist of 5 months broad based training and 4 months specialist training and will take place at the Training Centre, Teddington, with additional experience gained on attachment at each of the Company Sites.

Salary during training will be 1-3 months £3,500 pa, 3-9 months £3,800 pa.

Successful Trainees will then be absorbed into operational departments and go on to a salary structure applicable to the grade.

Candidates should preferably be 20-30 years of age and have academic qualifications, specialist training or experience relevant to their chosen area.

For an application form and full details please write to Pat Evans, Staff Relations Department, Thames Television Limited., Teddington Lock, Teddington, Middlesex, indicating areas of preference.

THAMES
LONDON'S WEEKDAY ITV

(9656)

Radio Technology and the Future

TELECOMMUNICATIONS OPPORTUNITIES

The Home Office Directorate of Radio Technology is responsible for the technical aspects of planning, management and regulation of frequency bands allocated to the broadcasting, fixed, maritime and land mobile, and space services.

The work includes preparing specifications and giving type-approval of equipment for fixed and mobile services, applying information on radio propagation to radio communications services, applying computer techniques to frequency assignment, developing equipment for the detection, location and suppression of radio interference, and giving technical advice on engineering aspects of licensing radio services and in connection with the international radio monitoring service.

The vacancies, which are at two levels, are in Central London and Stanmore, Middlesex.

For the higher level posts (Central London and Stanmore), candidates (aged at least 25) must have had a minimum of 7 years' skilled experience in radio, radar or other electronic work. At the lower level (posts in Central London only), candidates (aged at least 23) should have had experience in the operation of radio receiving equipment and have a knowledge of current operational systems of radio communications.

All candidates must have ONC in Engineering (with a pass in Electrical Engineering 'A') or in Applied Physics or an equivalent qualification.

SALARIES: **Higher Level** £6195-£6690 (to become £6880-£7530 from 1.1.80). **Lower Level** Starting salary between £4955 and £5795 (according to age) rising to £6195 (to become £5355-£6880 from 1.1.80). £455 less at Stanmore. Good promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 11 October 1979) write to Civil Service Commission, Alencon Link, Basingstoke, Hants, RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours).
Please quote ref: T/5215/5.

HOME OFFICE

Electronic Engineers–
What you want, where you want!

TJB Electrotechnical Personnel Services is a specialised appointments service for electrical and electronic engineers. We have clients throughout the UK who urgently need technical staff at all levels from Junior Technician to Senior Management. Vacancies exist in all branches of electronics and allied disciplines - right through from design to marketing - at salary levels from around £4000 to £8000 p.a.

If you wish to make the most of your qualifications and experience and move another rung or two up the ladder we will be pleased to help you.

All applications are treated in strict confidence and there is no danger of your present employer (or other companies you specify) being made aware of your application.

TJB ELECTROTECHNICAL PERSONNEL SERVICES,
12 Mount Ephraim,
Tunbridge Wells,
Kent. TN4 8AS.

Tel: 0892 39388

TJB

Please send me a TJB Appointments Registration form:

Name ....

Address ....

....

(9238)

BRUNEL UNIVERSITY DEPARTMENT OF EDUCATION

GRADE 4 ELECTRONICS/ LABORATORY TECHNICIAN

We are looking for a technician (male or female) to be responsible, under the Chief Technician, for the day-to-day running of a combined Physics/Chemistry laboratory and assist in an Audio/Visual Teaching laboratory. The job includes electronic/electrical maintenance of laboratory equipment, as well as audio and video equipment.
This involves working in close co-operation with both the academic and other technical staff as well as post-graduate students.
The ideal candidate will probably have either an ONC or City and Guilds in electronics (or equivalent), and 3-5 years' relevant experience.
Day release may be given to study for higher qualifications.
21 days' annual leave plus one week at both Christmas and Easter. There are good luncheon, sports and social facilities at hand.
Salary within the scale £3,222-£3,708 (under review) plus £275 London Weighting.
Write for application form to the Establishment Secretary, Brunel University, Uxbridge, Middlesex UB8 3PH, or telephone Uxbridge 37188 extension 49.

(9675)

APPOINTMENTS IN ELECTRONICS
£5 – £10,000

Take your pick of the permanent posts in:

MISSILES — MEDICAL
COMPUTERS
RADAR — COMMS
MICROPROCESSOR
HARDWARE — SOFTWARE

For free expert advice and immediate action on salary and career improvement, 'phone or write to, Mike Gernat BSc.

Technomark
Engineering and Technical Recruitment
11 Westbourne Grove
London W2. 01-229 9239

(9257)

TOP JOBS IN ELECTRONICS

Posts in Computers, Medical, Comms, etc. ONC to Ph.D. Free service.

Phone or write: **BUREAUTECH AGY, 46 SELVAGE LANE, LONDON, NW7. 01-959 3517.**

(8994)

CAPITAL APPTS.
FREE LISTS
101 Design/Development and Test Jobs
Permanent and Contract
To £8,000
29 Windmill St. London W.1.
637 5551 day: 636 9059 eve

(8782)

International Service Engineers

Fly the Flag

. . . with Crosfield Electronics, a worldwide market leader who have achieved success in exporting advanced technology equipment to the graphics arts and printing industries, with over 80% of our products going for export. As an

International Service Engineer up to £7500 + benefits

you'll be part of our growing service support team which provides 'on the spot' service for our equipment, including some installation work. This is a challenging, problem-solving role on complex electronic equipment and you will, therefore, be very much the elite of the service organisation. Travel will be at a moment's notice to the first world industrialised countries and continents, including Europe, Far East, USA, S. America and Australasia, and you can expect to spend approximately 60% of your time overseas.

Candidates, qualified to at least HNC in electronics (ideally graduates in electronics or electrical engineering), should have at least 2 years' experience in Field Service or an associated discipline in the electronics industries in computers, industrial control or complex electronic control equipment.

We offer a salary up to £7500, including overseas allowance plus annual bonus. There are excellent daily allowances when travelling. Career prospects, as a result of the company's growth, are excellent.

Please write, with brief personal and career details, or telephone for an application form to Tony Dewhirst, Personnel Manager, Crosfield Electronics Limited, 766 Holloway Road, London N19 3JG. Tel: 01-272 7766, ext. 229.

Crosfield Electronics
Success in exporting Advanced Technology

A De La Rue Company

(9670)

Electronics & Computer Test
To £7,500

Use your C&G/ONC/HNC/Forces Training and good DIGITAL/ANALOGUE/RF experience to advantage. Working with state-of-the-art MINI/MICRO PROCESSOR; LASER; ATE; COMMUNICATIONS; NUCLEONIC; CCTV and similar equipment. Most UK areas; from Technician to Manager.

For free confidential counselling and practical career advice contact GRANT WILSON ref: GW470.

TECHNOMARK, 11 Westbourne Grove, London W2 4UA.
Tel: 01-229 9239 (01-229 4218—24 hrs).
Engineering Recruitment Consultants.

VIDTRONICS

NEEDS YOU

if you are a video engineer and would like to earn in excess of £6500 p.a. We are adjacent to Heathrow and offer broadcast facilities to Europe. Expansion requires a Senior Engineer and two assistant engineers. Apply to **Barry Blight or Ron Edgerton on 01-759 5432.**

(9710)

SENIOR LABORATORY TECHNICIAN

BBC RESEARCH DEPARTMENT KINGSWOOD WARREN, TADWORTH, SURREY

A vacancy exists in the Transmitters and Propagation Section of the BBC Research Department for a Senior Laboratory Technician. Duties include a variety of work in the field of radio frequency technology under the direction of research engineers. Construction and experimental work is involved on transmitting and receiving systems for a wide selection of frequency bands and includes work on microwaves and optical communications.

Candidates, male or female, must possess an H.N.C. or equivalent qualification and have a good knowledge of radio and electronic technology. An interest in radio and television, and associated radio frequency measuring techniques would be desirable, also experience in basic workshop practice. Good opportunities for promotion to Engineering Technician.

Starting salary according to experience in the range £5170-£5620 rising to £6295 as a Senior Laboratory Technician, and ultimately to £7585 as an Engineering Technician. Pensionable post. Re-location expenses considered.

Write for application form to **Research Executive, BBC Research Department, Kingswood Warren, Tadworth, Surrey KT20 6NP,** quoting reference 696/JME or telephone **Mogador 2361.**

BBC

(9695)

THE ROYAL FREE HOSPITAL, HAMPSTEAD
DEPARTMENT OF MEDICAL PHYSICS

MEDICAL PHYSICS TECHNICIAN II OR III (Electronics)

Salary scale:
£4824-£5964 p.a. MPT II (increase pending)
£4098-£5142 p.a. MPT III (increase pending)

Electronics Technician required to join a small team responsible for maintenance of EMI Brain Scanner, Thermography, Radiotherapy, Ultrasound and other equipment. Qualifications required are HNC or equivalent, with Electronics. Please quote ref. 0763.

BASIC GRADE GRADUATE SCIENTIST

Salary scale £3840-£4269 p.a. (increase pending).

Applications are invited from graduates trained in computing to join this department, with expanding commitments in this field. Duties will be to develop the computer processing of gamma camera data and to assist in the development of a radiotherapy treatment planning scheme, associated with a computer-controlled treatment machine. Please quote ref. 1483.

LOCUM BASIC GRADE PHYSICIST

Required for 6 months to assist in a variety of work, either in Nuclear Medicine or in Radiotherapy Physics. Qualification is an Honours Degree in Science. Please quote ref. 1484.

Applications (to be returned by October 1st) from the Personnel Department, The Royal Free Hospital, Pond Street, N.W.3. Tel. 01-794 0500, ext. 4286.
Camden and Islington Area Health Authority (T).

The Polytechnic of North London

Department of Chemistry

LABORATORY TECHNICIAN (Grade 5)

required for Electronic Instrumentation work in the Laboratories. This will involve maintenance, fault-finding, servicing of amplifiers, servo-systems, analogue and digital circuits as applied to spectroscopic and other scientific equipment. There will also be opportunity for the operation, development, modification and construction of special equipment for research purposes.

Candidates should hold HNC, Advanced City & Guilds or recognised apprenticeship, or an equivalent qualification, preferably in electronics, and have 8 years' experience inclusive of the training period.

Salary Scale: £3999-£4581 inclusive of London Weighting.

Apply for further details and application form to the Head of the Department of Chemistry, The Polytechnic of North London, Holloway Road, London, N7 8DB. (9654)

UNIVERSITY OF WARWICK

Electronics Technician Grade 7

required in the Department of Chemistry and Molecular Sciences to take charge of a well-equipped electronics workshop. The duties include responsibility for maintenance of both electrical and electronic equipment in the Department, design and construction of specialised electronic equipment and modifications to existing equipment and the supervision of a Grade 4 Technician employed primarily on repair and maintenance work. The Department is equipped with a wide range of scientific instrumentation including mass spectrometers, magnetic resonance instruments, spectrophotometers and chromatographic equipment. The successful candidate will probably hold an HNC or equivalent in the field of electronics and have wide experience in the design and maintenance of complex electronic equipment. The University is situated in pleasant rural surroundings within easy commuting distance of Coventry, Kenilworth and Leamington Spa. Salary on the Technican Grade 7 scale: £4,940-£5,500 p.a. (under review), starting point depending on experience and qualifications. Application should be made by letter giving full details and the names and addresses of two referees to the Personnel Office, University of Warwick, Coventry CV4 7AL, quoting Ref. No. 3/5T/79 as soon as possible.

ELECTRONICS/SOFTWARE ENGINEERS

LEISURE INDUSTRY

Due to continued expansion in the development of systems related to coin-operated phonographs, video games and other types of coin-operated amusement machines the Research and Development Department of Associated Leisure Amusement Machines Ltd, is seeking to recruit Electronic Engineers with software experience.

The candidate should have experience in the design and operation of microprocessor systems with a degree of knowledge relative to software programming.

Three weeks' annual holiday, non-contributory pension scheme. Salary negotiable.

Applications in writing to:
Mr. N. Parker
Divisional Research and Development Manager
ASSOCIATED LEISURE AMUSEMENT MACHINES LTD.
The Old Granary, Wetmore Road
Burton-on-Trent, Staffs.

(9697)

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FIELD SERVICE ENGINEERS
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£7,000 + CAR

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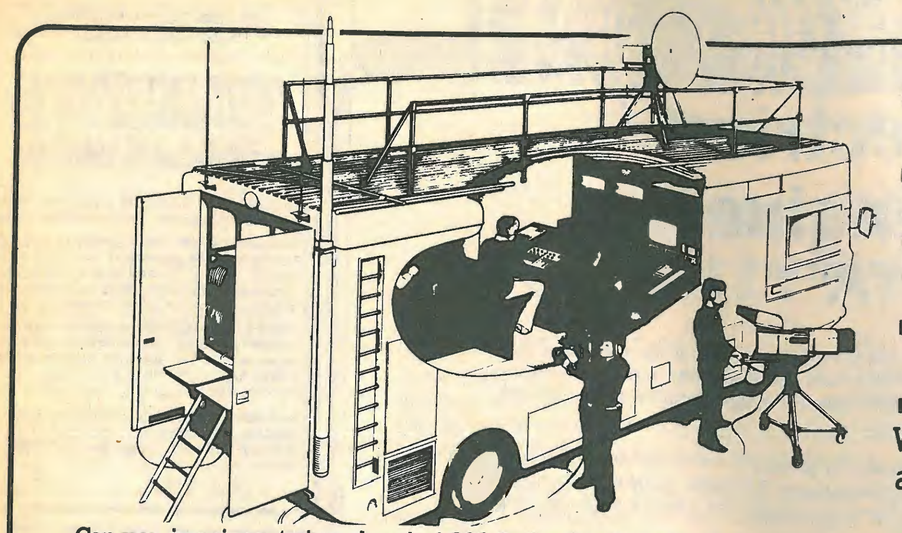

Find the Fault.

We need Test Engineers at all levels.

Can you imagine a 'crime sheet' of 200 faults that have to be cleared? Some of these involve sorting out problems in proprietory equipments, with no time to send them back. Snags range from dry joints leading to complementary colours, to cables that aren't matched in length to within a fraction of an inch.

Systems testing is a very special ability, calling for a cool head, a logical mind and the ability to think 'What kind of thing could possibly cause this fault?' Then the likelihood of each possible cause must be balanced against the time it will take to test as a possibility. It is, in fact, a real intellectual challenge. We are prepared to show you how to do it, provided you have at least an HND in electronics.

Pye TVT is a world leader in the development, production and marketing of professional broadcast equipment. We export 90% of what we make and our sales have grown rapidly in the last five years. We are situated on the outskirts of Cambridge, and have been closely associated with its commercial and cultural activities for many years. There are good schools, historic buildings and large, green, open spaces. We're only 63 minutes away from London and an hour from the coast.

If you are interested in finding out more about the job and its prospects, the possibilities of travel and so on, we have set aside Friday afternoons to talk to you. Why not telephone Alison Millar on **Cambridge (0223) 45115** or write to her at the address below. We can offer generous relocation expenses and other benefits to successful candidates.

PYE

Pye TVT Limited
PO Box 41 Coldhams Lane Cambridge England CB1 3JU
Tel: Cambridge (0223) 45115. Telex: 81103

(9663)

DESIGN AND TEST ENGINEERS

Vacancies exist at both senior and junior levels in the Design Departments and at junior level in the Test Department of the Research Division of Rediffusion Engineering Limited at Kingston-upon-Thames, Surrey.

Rediffusion supply, install and operate Cable Television Distribution Systems in the U.K. and abroad, and Rediffusion Engineering is responsible for the design of equipment to operate and maintain these systems.

Senior Design Engineers are expected to originate and develop through to small scale production analogue and digital equipment solving a variety of problems from D.C. to U.H.F. relating to transmission on cable and via fibre optics. Graduates with at least 5 years' design experience are sought for these positions. Junior positions are also available for graduates or persons qualified to H.N.C. standard to assist in some of these areas.

The Test Department duties will include measuring parameters of components and sub-assemblies at R.F., fault finding and testing of simple circuits, as well as performing other more general duties associated with a test department. Applicants should have a good general education and, through the day release offered, be prepared to study for further technical qualifications.

The company offers excellent working conditions in quiet surroundings, 20 days annual holiday, and a subsidised staff restaurant. There is a contributory pension and Life Assurance Scheme.

Apply to:
H. L. Baker, Esq., or I. R. Budgen, Esq.
Head of Cable Transmission Department, Head of Test.
REDIFFUSION ENGINEERING LTD.,
187 Coombe Lane West,
Kingston-upon-Thames,
Surrey KT2 7DJ.
Telephone: 01-942 8900.

REDIFFUSION

(9718)

Graduate Electrical/ Electronic Engineers

Research and Development in Telecommunications

The Directorate of Telecommunications, London, is responsible for the extensive and sophisticated facilities used by the police, fire, prison and associated services. The role of the Research and Development Section is to ensure that maximum benefit is derived from the use of modern techniques.

The training and experience given to Graduate Engineers — ranging from the initial interpretation of a non-technical statement of requirement through to the management of design, development and contract — is carefully planned by a senior engineer and covers the training requirements of the IEE.

You should preferably be aged under 26 and must have a good honours degree in electronics or electrical engineering or an allied subject.

SALARY (under review)

Your starting salary will be at least £5035. Completion of training (usually one or two years) leads to a salary rising to £7320. Promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 12 October 1979) write to Civil Service Commission, Alencon Link, Basingstoke, Hants RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). **Please quote ref: T/5179/2.**

HOME OFFICE

(9714)

UNIVERSITY OF LIVERPOOL
Department of Physics

SENIOR EXPERIMENTAL OFFICER/ EXPERIMENTAL OFFICER

To assist with developing equipment and systems for collecting and processing data.

An opportunity for recent graduates to gain experience. The successful applicant will work in one of several areas including programme support, logic or analogue circuitry, application of minicomputers, etc.

Degree or equivalent qualification necessary. Salary, according to age and experience on the scale for Experimental Officer (up to £6,108 p.a.) or Senior Experimental Officer (up to £7,145 p.a.)

Application forms may be obtained from The Registrar, the University, P.O. Box 147, Liverpool L69 3BX. Quote Ref: RV/768/WW.

(9713)

BRIGHTON POLYTECHNIC
LEARNING RESOURCES

ELECTRONIC ENGINEER

£4644-£5547 per annum

To work with a team of experienced engineers and technicians developing audio-visual facilities throughout the Polytechnic. The wide range of systems developments include sound and colour TV production, video recording and editing to near broadcast standards. The Electronics Engineer will apply digital and analogue techniques to develop and install new equipment, upgrade existing facilities, and assist with its maintenance. Formal training to degree, HNC or equivalent standard will be expected, and experience with electronic design and construction, preferably including television.

Further details and application form from the Personnel Officer, Brighton Polytechnic, Moulsecoomb, Brighton BN2 4AT. Tel: Brighton 693655 Ext. 2536.

Closing date: 5 October, 1979. (9717)

A MADHOUSE IS MOVING

Those of you who have heard reports of our none too salubrious premises — that you have to fight your way through a surfeit of bodies, fag ends and files — may like to be interviewed in our more spacious offices. The conditions will soon be much the same (Parkinson's Law).

NEW VACANCIES INCLUDE

Senior Project Engineer — overall responsibility for 1-off computer systems. Responsibilities include meeting technical goals, scheduled delivery dates, cost control and customer liaison. Experience in project control plus in-depth knowledge of microcomputer hardware/software. Berks; up to £10,000.

Project Managers and **Circuit designers** — alarm and shutdown equipment for off-shore oil platforms — a microprocessor based system with colour visual display — very high reliability design techniques. To £8,000. To £10,000 for project managers.

Design development engineers for the latest generation of intelligent terminals used in Viewdata and Prestel. Varied techniques including microprocessor controls and audio telephone. Essex; to £7,500.

Young Communications Systems Engineer: experienced in VHF/UHF 2 way mobile, portable and paging systems. Plenty of technical and sales liaison. Will train. Hants.

Exceptional opportunities for young graduates in medical instrumentation. Very high technology employing both analogue and digital techniques. Cambs; to £5,500.

Young engineers with experience or wishing to gain experience in microprocessor hardware/software — join a new team engineering — the ultimate? — in automatic test equipment. High level and low level languages employed. London; to £7,000

ALWAYS IN DEMAND

Electronic Blokes — all shapes and sizes — anyone with experience and/or qualifications in electronics.

For further details, please contact:

Charles Airey Associates

"PROBABLY THE BEST KNOWN SUPPLIER OF ELECTRONICS ENGINEERS IN THE COUNTRY" FINANCIAL TIMES

155 KNIGHTSBRIDGE, LONDON, SW1. TEL: 01-581 0286

(9708)

TECHNICAL LIAISON EXECUTIVE
Dusseldorf

Maxell Europe are International leaders in the field of quality magnetic tapes which include audio and video cassettes. As a result of their European expansion programme they require a young and energetic person, ideally aged 25-35 to work closely with their European distributors and dealers and to supervise the Maxell tape clinics.

Based in Dusseldorf but with extensive European travel, a working knowledge of German would be useful, though not essential. Salary will be negotiable, commensurate with the position.

Please write to the address below.

CHR Recruitment

11 Hanover Street, London W1R 9HF.
Telephone: 01-629 3727. Telex: 261254 CHRINT (9672)

RUFFLER & DEITH LTD.
Leaders in leisure, require the following staff:

ELECTRONICS ENGINEERS

ONC/HND or relevant experience preferably with digital and video background to work on amusement machines and logic boards.

TV ENGINEERS

with mono and colour experience.

Details on application to J. Emerson at: 127 Wandsworth High Street, London, S.W.18. 01-870 5224/5238. (9665)

UNIVERSITY OF LIVERPOOL
DEPARTMENT OF PHYSICS

ELECTRONICS TECHNICIAN GRADE 6

To assist in developing and commissioning digital and analogue electronic equipment. Good opportunity to gain experience of complex systems for data acquisition and processing using micro- and minicomputers linked to powerful mainframes. Recognised qualification (H.N.C. or equivalent) and previous experience essential. Salary within a range £4243-£5068 p.a. (under review).
Application forms may be obtained from The Registrar, The University, P.O. Box 147, Liverpool L69 3BX. Quote Ref: RV/765/WW.

(9711)

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MANAGER QUALITY ASSURANCE

ROHDE & SCHWARZ are one of the worlds leading manufacturers of communication equipment and instrumentation for the radio frequency market. A career opportunity exists at AVELEY/ROHDE & SCHWARZ UK LTD for a quality assurance manager with the aptitude for the demanding and fascinating business of controlling quality in a DEF STAN 05.24 MOD approved organisation.

We operate at the forefront of technology. The prospects are excellent and the successful candidate will be encouraged to develop to their full potential. An HNC or equivalent experience will be required in order to understand the technology and test methods. Training is given in Germany and the United States.

If you consider you are qualified to manage our quality assurance department please telephone 01-397 8771 for an application form or contact direct our General Manager D. H. Meyer.

We offer attractive reward packages to our successful managers and provide pleasant working conditions at our Chessington office.

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Electronic Instruments & Communications Equipment

aveley electric LTD

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Surrey KT9 1LP
01-397 8771

(9629)

Service Engineer

ITT Consumer Products is one of the leading manufacturers of colour T.V.'s, with Teletext and Viewdata, also radios and hi-fi equipment. We now need an engineer to service our wide range of colour T.V.'s at our main service centre in Paddock Wood.

The ideal candidate, male or female, will have City and Guilds 222, plus a colour endorsement, and at least 3 years' practical experience. Experience of ITT products is preferred but not essential, as training will be given.

We offer an excellent starting salary, and the opportunity to work with some of the latest television technology including Teletext.

Please write or telephone for an application form to:
Mr. S. Cousins, Personnel Officer, ITT Consumer Products (UK) Ltd., Eldon Way, Paddock Wood, Nr. Tonbridge, Kent. Tel: Paddock Wood 4422.

(9706)

ITT
World-wide Technology

Technician/ Engineer
TV Broadcasting

We have a vacancy for a skilled Technician/Engineer in the central technical area at our Birmingham studio centre: the job involves the operation and maintenance of electronic film projection equipment (telecine) during programme transmission hours.

Applicants must have a thorough knowledge of modern colour TV engineering principles and practices, and good practical maintenance ability. Education to C&G (Full Tech. Cert.), TEC Dip. or HNC would be appropriate.

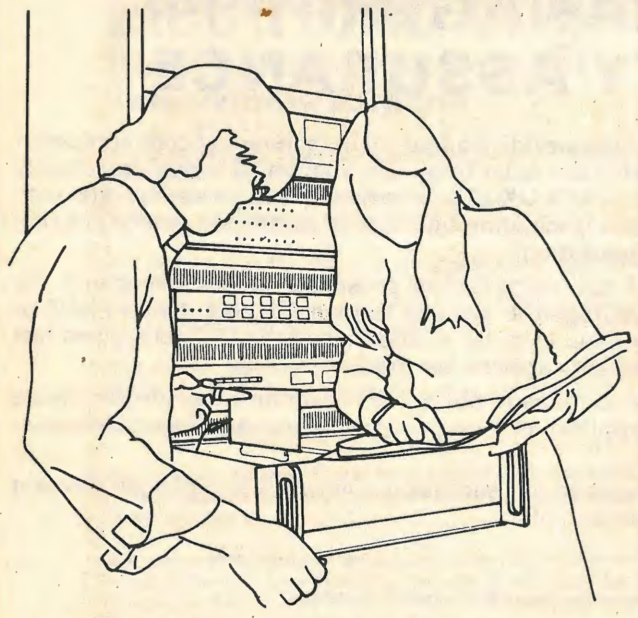
The appointment will be made on an automatic annual salary scale from £4442 p.a. to £6323 p.a., according to qualifications and experience. (ACTT Agreement, rates under review).

Application forms are available from:-

The Head of Staff Relations,
ATV Network Limited
ATV Centre, Birmingham. B1 2JP
021 643 9898 Ext. 369
Please quote Vacancy Number 66 (W)

(9662)

Professional Careers in Electronics



All the others are measured by us...

At Marconi Instruments we ensure that the very best of innovative design is used on our range of communications test instruments and A.T.E. We have a number of interesting opportunities in our Design, Production and Service Departments and we can offer attractive salaries, productivity bonus, pension and sick pay schemes together with help over relocation.
If you are interested to hear more, please fill in the following details:-

Name ______ Age ______

Address ______

______

Telephone Work/Home (if convenient) ______

Years of experience	0-1	1-3	3-6	Over 6
	□	□	□	□
Present salary	£2,500-3,500	£3,500-4,500	£4,500-5,500	over £5,500
	□	□	□	□
Qualifications	None	C & G	HNC	Degree
	□	□	□	□

Present job ______

______

Return this coupon to John Prodger, Marconi Instruments Limited, FREEPOST, St. Albans, Herts, AL4 0BR. Tel: St Albans 59292

Marconi Instruments A GEC MARCONI ELECTRONICS COMPANY

(9200)

INSTRUMENT TECHNICIANS

Help to ensure a safer environment

These posts, at Cricklewood in London, are in the Instrument Maintenance Unit, which undertakes acceptance testing of new equipment, and provides a maintenance and repair service for an extensive range of portable environmental monitoring instruments used by the Inspectorate. This work is expanding to cover both the development of new instruments and the design of specialised test facilities. It is possible that the Laboratories will be dispersed to SW Lancashire in the 1980s.

There are two posts available:

The successful candidate for the senior post will be expected to handle the more demanding work and will supervise and train other members of the team. He will design new equipment, modify existing instruments and may be involved in the automation of the routine testing and calibration facilities.

The successful candidate for the junior post will be expected to assist the senior officer and will be concerned with the constructing, setting-up and checking calibration test rigs as well as the routine diagnosis of instrument failures.

Candidates for either post must hold O.N.C. or equivalent in an appropriate subject, and have an aggregate of at least 4 years' training (e.g. apprenticeships and/or full-time study) and relevant experience; at least eight years required for the senior post.

Salary for the senior post will start at £5305 and rise to £5875. For the second post, salary starts between £3965 and £4680 according to age, and rises to £5305. **Salaries under review.** Promotion prospects at both levels. Non-contributory pension scheme.

For further details and an application form (to be returned by October 19, 1979) write to Civil Service Commission, Alencon Link, Basingstoke, Hants, RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). **Please quote ref: T(J)648.**

(9669)

Health & Safety Executive

DEVELOPMENT MANAGER/ENGINEER

A leading Scientific Instrument Manufacturer require an experienced Development Manager/Engineer to control a small development department in their U.K. Office in the South of England.

Applicants should have wide experience in project management within the scientific instrument field and a highly innovative approach to instrumentation design.

The post requires a possible base in Holland for training during the first six months.

Applicants should apply in writing with full career details to **Box No. 9692.**

(9692)

EDITOR

An Editor is required for a new technical journal aimed at Communications engineers in all disciplines from telephony to data comms.

Applicants need not have experience in journalism but must be literate and thoroughly conversant with the communications industry.

The successful applicant will be capable of controlling the editorial policy of the journal and ensuring its development as one of the most exciting and respected international publications in the communications business.

This independent publishing house already produces one of the top UK electronics journals and is able to respond quickly and flexibly to individual initiative.

This responsible position will justify a high salary and offer considerable potential for personal development.

Please contact Mike Dance at 375 Upper Richmond Road West, London SW14 7NX (Tel. 01-878 4852) and explain why you think you might be suitable for this position.

UNIVERSITY OF YORK
Department of Chemistry

CHIEF ELECTRONICS TECHNICIAN (GRADE 6)

A vacancy has occurred for the post of Chief Electronics Technician. The person appointed will be responsible for the day-to-day servicing of all electronic and electrical equipment, ranging from simple electrical apparatus to sophisticated computer-controlled equipment. He will also be responsible, in consultation with the academic and other technical staff, for the development and construction of new equipment and for liaison with service engineers when necessary. A background in laboratory instrumentation will be an advantage but not essential.

Salary on Grade 6 (£3,984-£4,758 p.a., under review).

Applications including curriculum vitae and the names of two professional referees should be sent as soon as possible for the attention of The Laboratory Superintendent, Department of Chemistry, University of York, Heslington, York YO1 5DD (Tel. 0904 59861, Ext. 310), from whom further details are available.

(9676)

SENIOR ELECTRONICS TECHNICIAN

Salary £3744-£4788

Electronics Technician required to form part of a department responsible for the maintenance and servicing of medical and electronic equipment throughout the district. Candidates should have a wide experience of electronic equipment with an understanding of its safety aspects.

Qualifications — HNC Electronics preferred — ONC Electronics considered. Job description and application form from District Works Officer, Hastings Health District, 9 White Rock Road, Hastings. Closing date 5th October, 1979.

(9726)

TELEVISION TECHNICIAN required in Educational Services Unit, Medical School, for interesting and varied work including maintenance and operation of a small studio, black and white/colour equipment. Previous experience with television desirable but not essential. Candidates should have appropriate qualifications and background. Salary scale £3474-£4056 p.a. — Application form from Assistant Secretary, Personnel Office, University of Birmingham, P.O. Box 363, Birmingham B15 2TT. Ref. 496/C/339. Closing date 9th October. (9664)

TELEVISION RETAIL BUSINESS of the highest standing requires Trainee. Good opportunity for capable applicant with technical aptitude. — Write only, stating age and details of background and career, Drazin Ltd., 57 Heath Street, Hampstead, N.W.3. (9659

ELECTRONICS ENGINEERS to £14,000, Microwave/RF design to £250 pw, Microwave/RF test to £220 pw, Digital, Analogue, Communication and Computer Engineers, Design/Test/Service to £230 pw, for long (2 years) lucrative contracts at many sites throughout Southern England. — Roger Howard, C.Eng, MIEE, Cliveden Consultants (CRC), 99 St Leonards Road, Windsor (07535) 57818, answerphone. (9646

SHELL U.K. EXPLORATION & PRODUCTION

Telecommunications Maintenance Technician

This position provides an excellent opportunity for a senior telecommunications technician to work with a broad range of equipment covering internal and external communications facilities on our North Sea Oil and Gas Production platforms. The range covers public address, P.A.B.X., A.M. and F.M. radios, line of sight and tropospheric scatter systems.

The Job

The successful applicant will be required to:
* Co-ordinate and supervise a planned maintenance system
* Prepare defect reports for the telecommunications engineers.
* Ensure that adequate stocks of spare parts are maintained.
* Ensure the documentation system are updated as required.

Qualifications and Experience

Applicants should be aged 25-40 with an appropriate O.N.C or full City and Guilds Technological certificate in telecommunications, or have an equivalent services background.
Some experience on microwave equipment maintenance, with at least one year at a supervisory grade would be advantageous.

The Rewards

A competitive salary package will be offered which will include allowances for offshore visits. The position is based in Aberdeen, so relocation expenses will be paid where appropriate.
Please write for an application form to:
Recruitment and Development Supervisor, UEPA/113, Shell U.K. Exploration and Production, 1 Altens Farm Road, Nigg, Aberdeen. or telephone 0224 - 882149

(9685)

ARTICLES WANTED

SPOT CASH for all types test equipment, receivers, transmitters, valves, components, cable and surplus electronic scrap. M. & B. Radio, 86 Bishopgate Street, Leeds LS1 4BB. 0532 35649. (8789

STORAGE SPACE is expensive, why store redundant and obsolete equipment? For fast and efficient clearance of all test gear, power supplies, PC boards, components, etc., regardless of condition or quantities. Call 01-771 9413. (8209

TURN YOUR SURPLUS Capacitors, transistors, etc, into cash. Contact COLES-HARDING & Co., 103 South Brink, Wisbech, Cambs. 0945-4188. Immediate settlement. We also welcome the opportunity to quote for complete factory clearance. (9509

SITUATIONS VACANT

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Independent concern represented in 80 countries

MANAGER
TECHNICAL SERVICES DEPARTMENT

ROHDE & SCHWARZ are one of the worlds leading manufacturers of communication equipment and instrumentation for the radio frequency market. A management career opportunity exists at AVELEY / ROHDE & SCHWARZ UK LTD for an electronic engineer with the aptitude for the demanding and fascinating business of technical services management. A technical services manager in addition to leading a team of service engineers playing a major role in the liaison at engineering level with our parent in Germany and the company's customers.

We operate at the forefront of technology. The prospects are excellent and the successful candidate will be encouraged to develop to their full potential. An HNC / BNC or equivalent experience will be required in order to understand the technology. Training is given in Germany and USA.

If you consider you are qualified to manage our technical services department please telephone 01-397 8771 for an application form or contact direct our General Manager D. H. Meyer.

We offer attractive reward packages to successful managers and provide pleasant working conditions at our Chessington office.

Company car, Bonus scheme, Other Fringe Benefits.

Ring now!

Electronic Instruments & Communications Equipment

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Roebuck Road
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Surrey KT9 1LP
01-397 8771

(9630)

ELECTRONIC TECHNICIAN

Communication Systems

Applications are invited for an Electronic Technician, Communication Systems. A range of projects are on-going, primarily concerned with mobile radio systems. These cover work on equipment and sub-systems operating at frequencies ranging from audio v.h.f. In addition, a significant activity now exists in digital transmission systems so that a knowledge of the latest digital techniques, particularly those involving microprocessor elements, would be an asset.

Candidates should possess as a minimum the City and Guilds Electrical / Electronic Engineering Craft Advanced Certificate and have at least 3 years' experience in research, development or experimental work. Preference will, however, be given to those who possess a full Technological Certificate or equivalent.

Conditions of service are excellent.

Starting salary will be within an incremental scale from £3,540 to £4,332 (under review), plus a current self-financing productivity deal. Initial placing according to age, qualifications and experience.

Application forms may be obtained from:

British Gas Corporation
Engineering Research Station
Killingworth
Newcastle upon Tyne NE99 1LH
Telephone: Newcastle 684828, Extension 348.

BRITISH GAS (9701)

Engineering Research Station

BRIGHTON POLYTECHNIC

LEARNING RESOURCES

VIDEO RECORDING & STUDIO ENGINEER

£4644-£5547 per annum

To supervise work in newly equipped 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 in the two adjoining studios, containing systems with 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 further details from the Personnel Officer, Brighton Polytechnic, Moulsecombe, Brighton BN2 4AT. Tel: Brighton 693655 Ext. 2536.

Closing date: 17 October, 1979. (9716)

ELECTRONICS. We are creating a new dept to provide a leasing service for Prestel View-data, Teletext and micro-computers. Good opportunity for keen young applicants with technical and commercial ability. — Write only, stating age and details of background and career, DRAZIN Ltd., 59 Heath Street, Hampstead, N.W.3. (9660

ARTICLES FOR SALE

SPEAKER KITS

Two great new kits from KEF — the Speaker Engineers respected by HiFi enthusiasts all over the world.
One is based on the Model 104aB and the other on the larger, free standing Cantata.
We'll give you helpful advice and full instructions.
And you can hear how good the speakers are before you build.

Nottingham Hi-Fi Centre
156 Alfreton Road
Nottingham
Tel: 0602 786919

(9657)

ANTIQUE MACHINES + CURIOSITIES

The world's first high quality glossy magazine devoted to mechanical and other collectables and curiosities of all types. Fifty-six page first issue out now price 95p including 16 pages in full colour and the unique collectors card index. Obtainable from your newsagent or direct from AM+C, 3 Heathcock Court, Strand WC2R OPA. Telephone: 01-379 6025.

(9357)

ELECTRONIC IGNITION P.C. boards (capacitor discharge) manufactures surplus, tested, less box £2.75 each. — 01-643 6111, evenings. (9689

HP608F AM laboratory signal generator, 10-450 MHz, calibrated, excellent condition, £420. — Tel. 04555 4356 (Leics.) (9682

OSCILLOSCOPES — SOLARTRON CD1400 D/trace with £20 manual DC-15 MHz £125. Heathkit 10-18U professionally built 4.5 MHz £28. Both good condition. 39 Horsebrook Lane, Brewood, Staffs. Tel. 850 760. (9680

ARTICLES FOR SALE

ENCAPSULATING, coils, transformers, components, degassing, silicone rubber, resin, epoxy. Lost wax casting for brass, bronze, silver, etc. Impregnating coils, transformers, components. Vacuum equipment low cost, used and new. Also for CRT regunning metallising. Research & Development. Barratts, Mayo Road, Croydon, CR0 2QP. 01-684 9917. (9678

WIRELESS WORLD design teletext decoder, fully operational with keypad accessory. Quick sale £50. — Phone 01-250 0626. (9688

WIRELESS WORLD, May, 1970, to Aug., 1978. — Offers to M. V. Pedersen, 19 Belgrave Street, Brighton. (9703

VISION ENGINEERING COMPARASCOPE enabling rapid comparison of two objects up to 12 inches square, e.g. circuit boards, diagrams, etc. The optics highlight differences between two items for the purpose of inspection and/or error detection. A pair of X 7 binoculars is included which enables viewing smaller detail. — Phone Guernsey (0481) 37701. (9653

SITUATIONS VACANT

Hewlett-Packard Limited designs and manufactures electronic test and measuring instruments and systems for a world-wide telecommunications market. New projects now under way demonstrate considerable technical innovation in analogue and digital design, and many use microprocessors.

As a result of continuing growth we now have vacancies for people qualified to Degree, H.N.C., or equivalent level and with at least one year's relevant experience, in the following positions:

Product Support Engineers

To work with our R & D teams and ensure that serviceability is designed into products currently under development, plan and implement service support programmes for new products, train service personnel and customers, and provide support and repair advice to our world-wide service organization.

Technical Authors

To work with our Product Support Engineers, and the R & D and Marketing teams, to produce high-quality Operating and Service manuals—coordinating the manuals through illustration and photography into print.

The successful applicants will combine a good knowledge of analogue and digital techniques with the ability to get on well with people and communicate both the written and spoken word.

We can offer attractive salaries, and the Company's conditions of employment are excellent—including profit sharing, bonus, stock purchase scheme, non-contributory pension and life assurance plans, prolonged disability scheme and flexible working hours.

Please write or telephone for an application form to:

Liz Stenhouse,
Personnel Administrator,
Hewlett-Packard Limited,
South Queensferry,
EH30 9TG.
Tel. 031-331 1000.

HEWLETT hp PACKARD

THORN CONSUMER ELECTRONICS LTD.

Advance Study Engineer

Thorn Consumer Electronics Limited, leading manufacturers of television and audio equipment in the U.K. wish to appoint an experienced Engineer for their Advance Study Group situated in the Research and Engineering Centre at Enfield.

The successful applicant will join a team investigating new ideas and systems including digital techniques and microprocessors as well as modern analogue methods.

He/she should preferably be under 35 years of age with a degree or H.N.C. or relevant experience, recent graduates will be considered.

Please apply in writing to:

The Personnel Manager, (ASE/WW),
Thorn Consumer Electronics Limited,
Great Cambridge Road, Enfield, Middlesex EN1 1UL
or telephone 363 5353 extension 2201 for an application form.

(9699)

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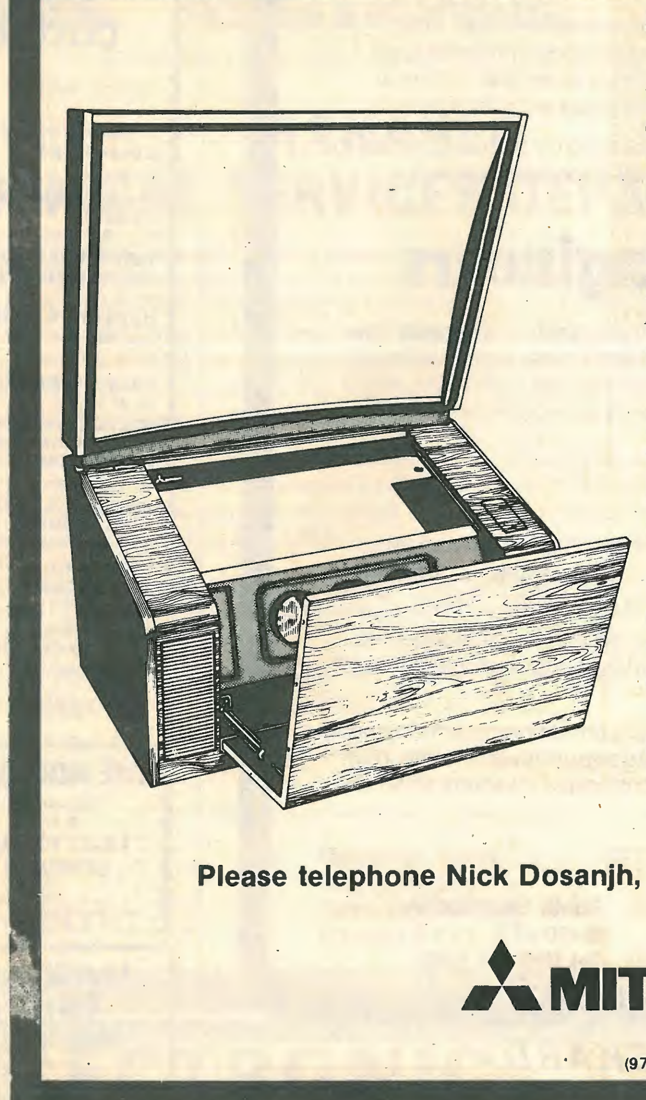

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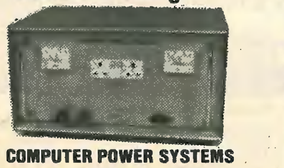

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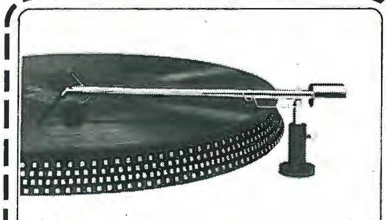

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