wireless world

JULY 1975 30p

Digital wristwatch

Active notch filters

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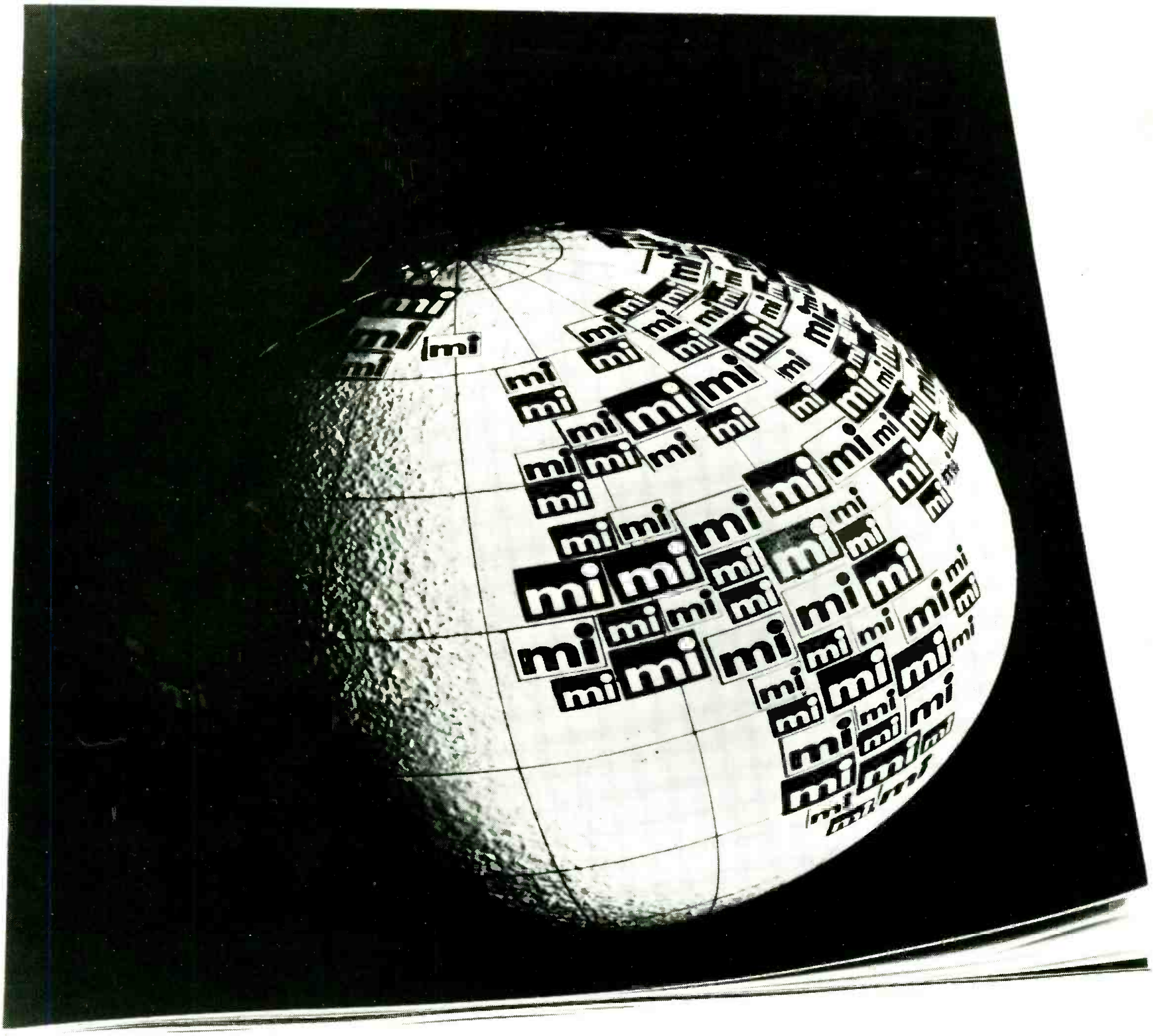
South Africa 95 Cents
Spain Ptas 80.00
Sweden Kr. 6.00 incl. moms
Switzerland Fr. 5.00
U.S.A. $1.50

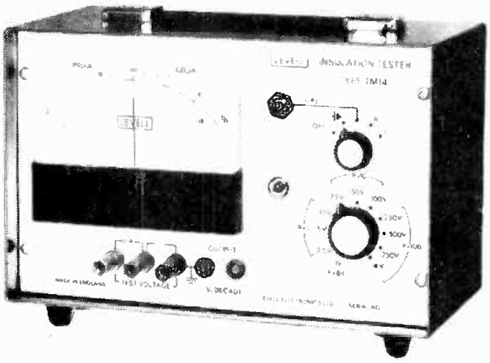


LOW COST TESTERS

LEVELL

PORTABLE INSTRUMENTS

INSULATION TESTER



A logarithmic scale covering 6 decades is used to display either insulation resistance or leakage current at a fixed stabilised test voltage. The current available is limited to a maximum value of 3mA for safety and capacitors are automatically discharged when the instrument is switched off or to the CAL condition. The instrument operates from a 9V internal battery.

RESISTANCE RANGES

10M Ω to 10T Ω (10^{13} Ω) at 250V, 500V, 750V and 1kV.
1 M Ω to 1T Ω at 25V, 50V and 100V.
100k Ω to 100G Ω at 2.5V, 5V and 10V.
10k Ω to 10G Ω at 1V.
Accuracy ±15% +800 Ω on 6 decade logarithmic scale.
Accuracy of test voltages ±3% ±50mV at scale centre.
Fall of test voltages < 2% at 10μA and < 20% at 100μA.
Short circuit current between 500μA and 3mA.

CURRENT RANGE

100pA to 100μA on 6 decade logarithmic scale.
Accuracy of current measurement ±15% of indicated value.
Input voltage drop is approximately 20mV at 100pA, 200mV at 100nA and 400mV at 100μA.
Maximum safe continuous overload is 50mA.

MEASUREMENT TIME

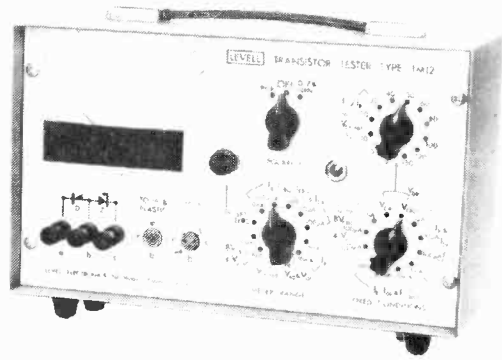
< 3s for resistance on all ranges relative to CAL position.
< 10s for resistance of 10G Ω across 1μF on 50V to 500V.
Discharge time to 1% is 0.1s per μF on CAL position.

RECORDER OUTPUT

1V per decade ±2% with zero output at scale centre.
Maximum output ±3V. Output resistance 1k Ω.

type TM14 **£88**

TRANSISTOR TESTER



Tests bipolar transistors, diodes and zener diodes. Measures leakage down to 0.5 nA at 2V to 150V. Current gains are checked from 1μA to 100mA. Breakdown voltages up to 100V are measured at 10μA, 100μA and 1mA. Collector to emitter saturation voltage is measured at 1mA, 10mA, 30mA and 100mA for I_C/I_B ratios of 10, 20, 30. The instrument is powered by a 9V battery.

TRANSISTOR RANGES (PNP OR NPN)

I_{CBO} & I_{EBO}: 10nA, 100nA, 1μA, 10μA and 100μA f.s.d. acc. ±2% f.s.d. ±1% at voltages of 2V, 5V, 10V, 20V, 30V, 40V, 50V, 60V, 80V, 100V, 120V, and 150V acc. ±3% ±100mV up to 10μA with fall at 100μA < 5%+250mV.

BV_{CBO}: 10V or 100V f.s.d. acc ±2% f.s.d. ±1% at currents of 10μA, 100μA and 1mA ±20%.

I_B: 10nA, 100nA, 1μA . . . 10mA f.s.d. acc. ±2% f.s.d. ±1% at fixed I_E of 1μA, 10μA, 100μA, 1mA, 10mA, 30mA, and 100mA acc. ±1%.

h_{FE}: 3 inverse scales of 2000 to 100, 400 to 30 and 100 to 10 convert I_B into h_{FE} readings.

V_{BE}: 1V f.s.d. acc. ±20mV measured at conditions on h_{FE} test.

$V_{CE(sat)}$: 1V f.s.d. acc. ±20mV at collector currents of 1mA, 10mA, 30mA and 100mA with I_C/I_B selected at 10, 20 or 30 acc. ±20%.

DIODE & ZENER DIODE RANGES

I_{DR}: As I_{EBO} transistor ranges.

V_Z: Breakdown ranges as BV_{CBO} for transistors.

V_{DF}: 1V f.s.d. acc. ±20mV at I_{DF} of 1μA, 10μA, 100μA, 1mA, 10mA, 30mA and 100mA.

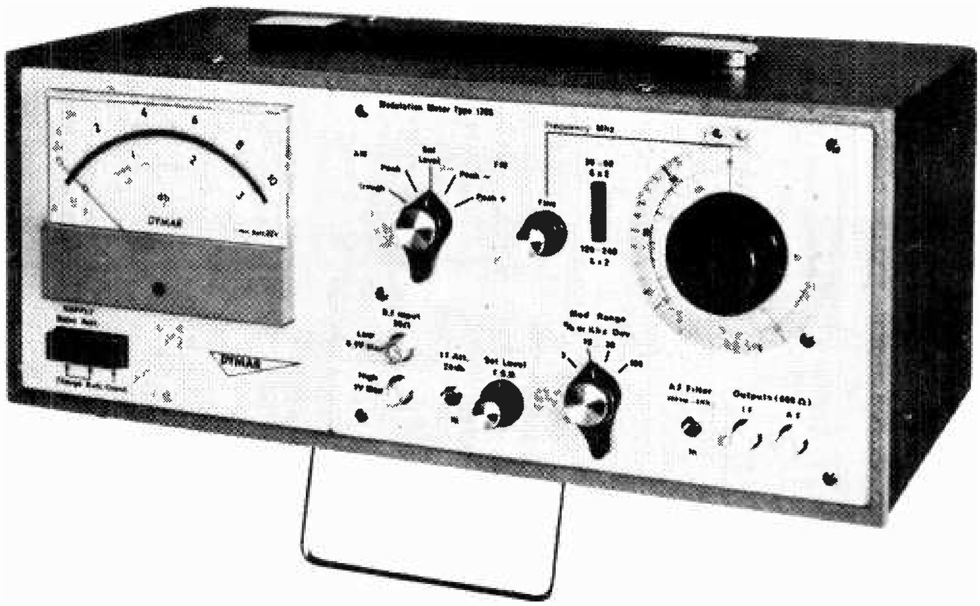
type TM12 **£88**

LEVELL ELECTRONICS LTD.
Moxon Street, High Barnet, Herts. EN5 5SD
Tel: 01-449 5028/440 8686

Prices include batteries and U.K. delivery, V.A.T. extra. Optional extras are leather cases and mains power units. Send for data covering our range of portable instruments.

WW—015 FOR FURTHER DETAILS

The Dymar 1785 portable AM-FM modulation meter.



No need to ask who's in control. It's you!

The Dymar Type 1785 is quickly and easily tuneable anywhere across the entire VHF band and into UHF to encompass the mobile 470MHz band.

Designed to measure the depth of modulation or frequency deviation of today's demanding mobile and portable transmitters, the 1785 offers four ranges of both peak or trough percentage modulation (3% fsd to 100%) and both positive and negative deviation (3kHz to 100kHz).

The sensitivity over the entire frequency range is better than 2.5mV into 50 ohms (–40dbm), which permits loose coupling to the transmitter under test. And internal noise is typically 44db below 3kHz.

Then, like most Dymar instruments, the 1785 is equally at home working from mains supply or in action in the field operating on its own rechargeable NiCd batteries.

With such value-for-money performance, you'll want to drive the 1785 to the limit – and that's why we emphasise that the 1785 is fully tuneable.

Want to know more? Use the Reader Reply Service or contact Dymar direct.

The Dymar range of instruments – designed for the mobile land, marine and air communications industry.

DYMAR

the name in radiotelephones

DYMAR ELECTRONICS LIMITED,
Colonial Way, Radlett Road, Watford,
Herts. WD2 4LA, Telephone Watford 37321.
Telex: 923035. Cables: Dymar Watford.

Again and again and again

Given the time, the patience, and the money, one can connect* fifty 303 amplifiers nose to tail so that the programme goes through one after the other gradually deteriorating along the way.

Deteriorating? The fact is, that apart from a very slight background hiss – akin to a good tape recording – the programme will sound exactly the same at the end as when it started.

*Of course one must fit an attenuator to reduce the signal back to its original level between each amplifier.

Send postcard for illustrated leaflet to Dept.WW Acoustical Manufacturing Co. Ltd., Huntingdon PE18 7DB. Telephone (0480) 52561.

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for the closest approach to the original sound

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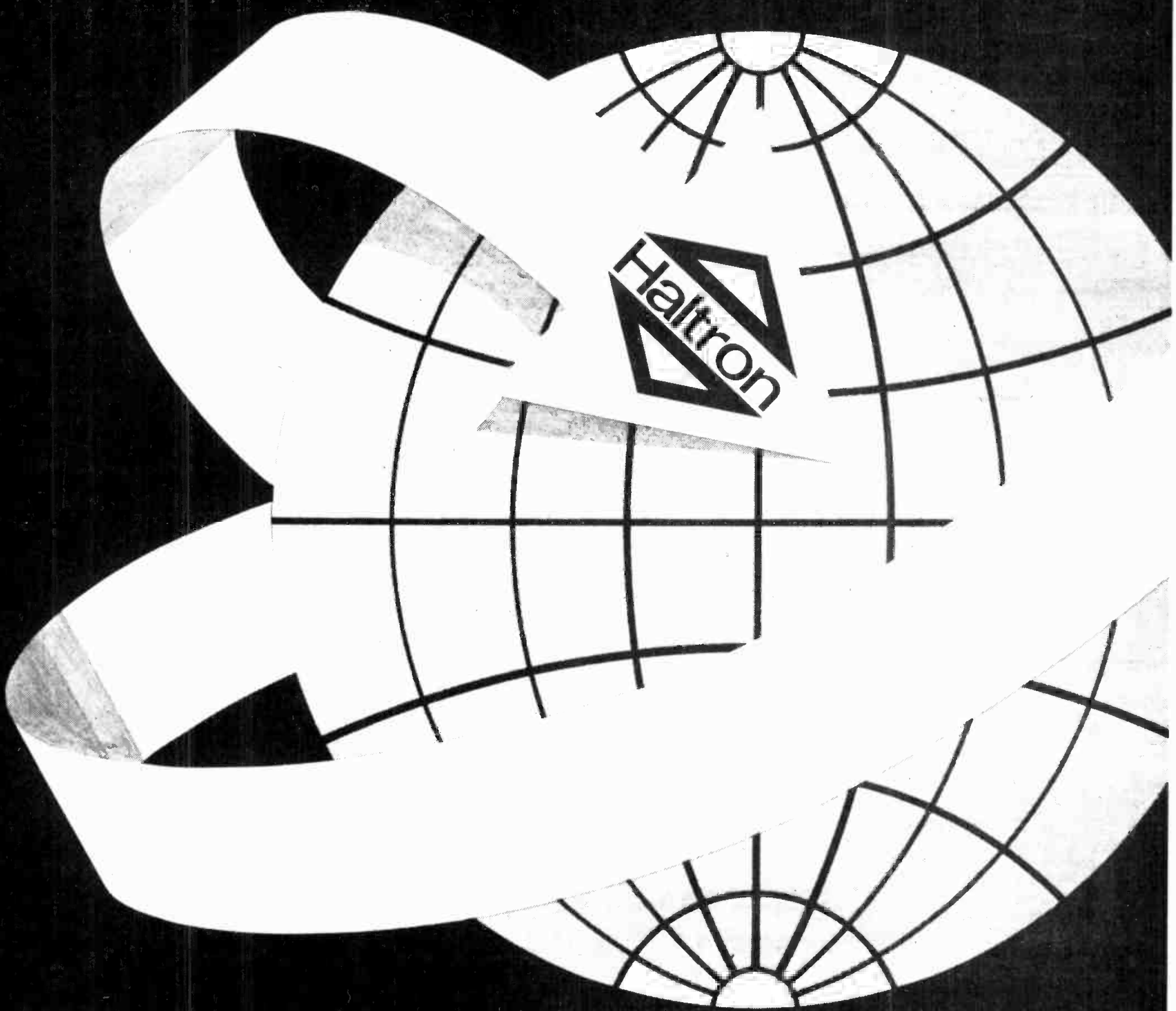
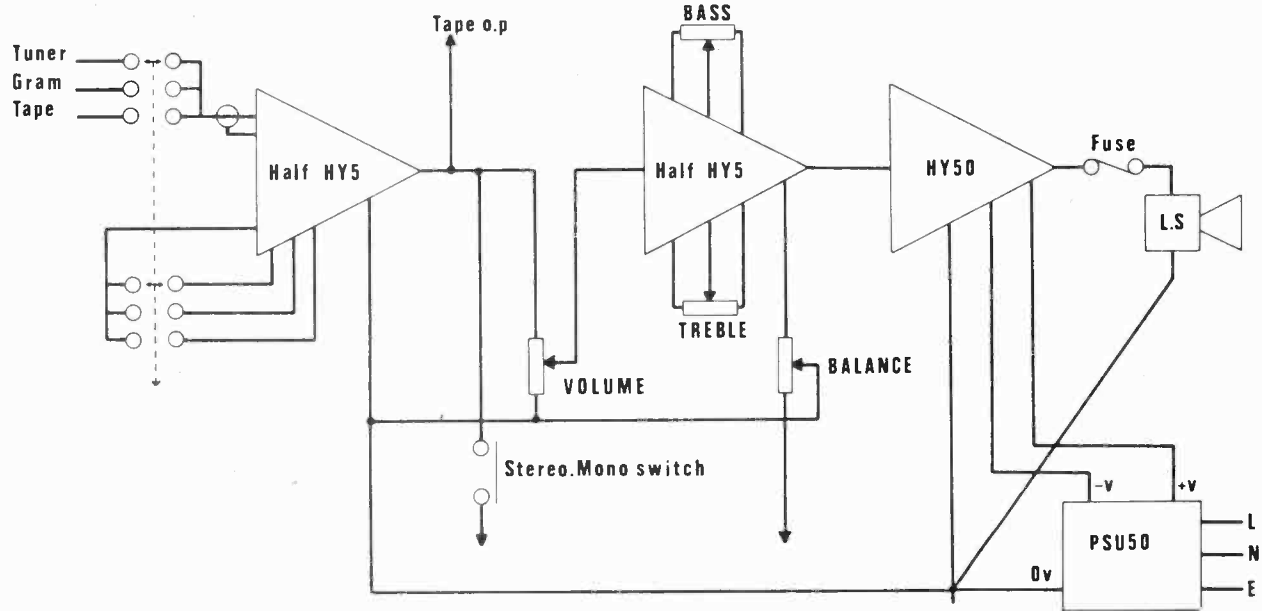
W/W—049 FOR FURTHER DETAILS

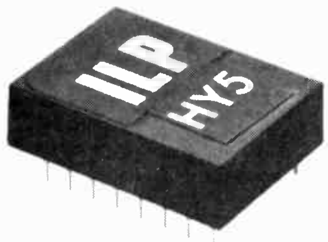

Haltron

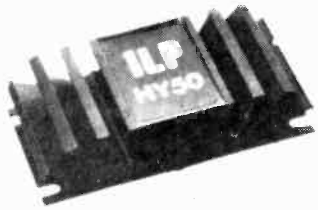
I.L.P. (Electronics) Ltd

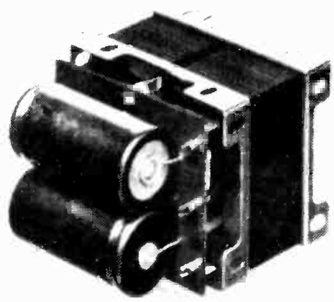
SHEER SIMPLICITY!



Mono electrical circuit diagram with interconnections for stereo shown







The HY5 is a complete mono hybrid preamplifier, ideally suited for both mono and stereo applications. Internally the device consists of two high quality amplifiers – the first contains frequency equalisation and gain correction, while the second caters for tone control and balance.

TECHNICAL SPECIFICATION

Inputs
- Magnetic Pick-up 3mV RIAA
- Ceramic Pick-up 30mV
- Microphone 10mV
- Tuner 100mV
- Auxiliary 3-100mV
- Input impedance 47kΩ at 1kHz

Outputs
- Tape 100mV
- Main output 0db (0.775 volts RMS)

Active Tone Controls
- Treble ±12db at 10kHz
- Bass ±12db at 100Hz

Distortion 0.05% at 1kHz
Signal/Noise Ratio 68db
Overload Capability 40db on most sensitive input
Supply Voltage ±16–25 volts.

PRICE £4.75 + £1.19 V.A.T. P & P free.

The HY50 is a complete solid state hybrid Hi-Fi amplifier incorporating its own high conductivity heatsink hermetically sealed in black epoxy resin. Only five connections are provided: Input, output, power lines and earth.

TECHNICAL SPECIFICATION

Output Power 25 watts RMS into 8Ω
Load Impedance 4–16Ω
Input Sensitivity 0db (0.775 volts RMS)
Input Impedance 47kΩ
Distortion Less than 0.1% at 25 watts typically 0.05%
Signal/Noise Ratio Better than 75db
Frequency Response 10Hz – 50kHz ±3db
Supply Voltage ±25 volts
Size 105 x 50 x 25 mm.

PRICE £6.20 + £1.55 V.A.T. P & P free

The PSU50 incorporated a specially designed transformer and can be used for either mono or stereo systems.

TECHNICAL SPECIFICATIONS

Output voltage 50 volts (25–0–25)
Input voltage 210–240 volts
Size L.70, D.90, H.60 mm.

PRICE £6.25 + £1.56 V.A.T. P & P free

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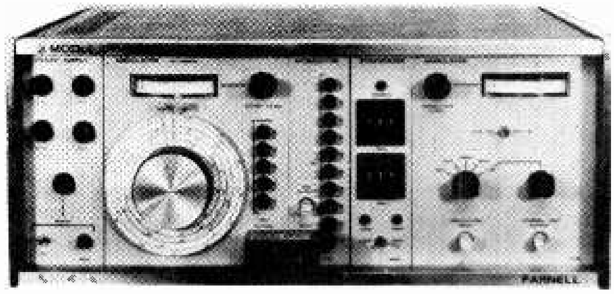
WW—058 FOR FURTHER DETAILS

r.f. test equipment

TM6 R.F. MILLIVOLTMETER
1mV to 300V f.s.d.
50kHz to 1.5GHz
Useful to 3GHz
Near true r.m.s. readings on low ranges

WW—039 FOR FURTHER DETAILS



MODULAR SIGNAL GENERATORS

100kHz to 12MHz
M1A/ABM AM, FM Signal Generator
M1A/ADM Synthesised AM/FM Signal Generator
M1A/ACS Sweep Generator

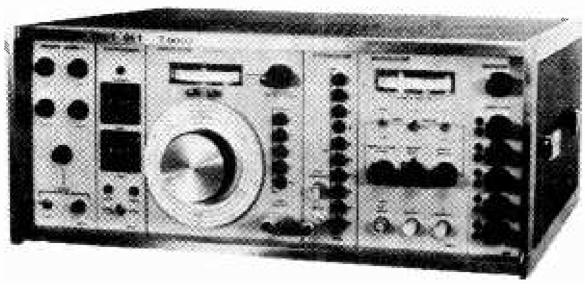
10MHz to 100MHz
M2/ACM AM/FM Signal Generator
M2/ADM Synthesizer AM/FM Signal Generator
M2/ACS Sweep Generator

10MHz to 512MHz
M3A/ABM AM FM Signal Generator
M3A/ACM Synthesized Signal Generator
M3A/ACS Sweep Generator

WW—040 FOR FURTHER DETAILS

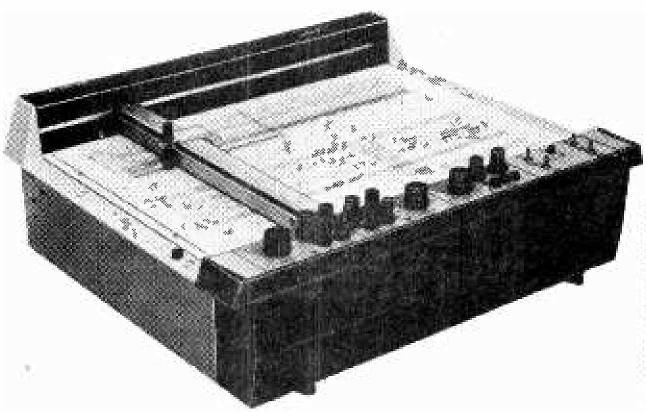
A range of general purpose r.f. signal generators, synthesizers and sweepers is offered covering 100kHz to 512MHz. Specialist instruments include a Marine Test Set covering 0.1 to 12MHz for use with receivers with narrow i.f. filters for S.S.B. reception and u.h.f./v.h.f. Test Sets suitable for work on alerters, pocket pagers and two-way personal radios. All the equipment is programmable and may therefore be used in A.T.E. systems or operated manually.

Complementary r.f. test equipment includes an r.f. millivoltmeter, a programmable attenuator and an x-y recorder.



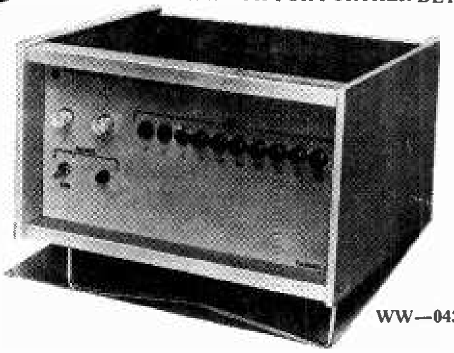
T6003 TEST SET
Synthesized signal generator 0.1 to 12MHz
Accuracy 5PPM. Resolution 100Hz
3 to 50Hz narrowband sweep Five settable markers
A.M./F.M. capabilty Built-in detector

WW—041 FOR FURTHER DETAILS



X-Y RECORDER
A3 Size flatbed Ideal for use with sweepers
Also available with timebase for general use
Electrostatic paper hold Disposable pens

WW—042 FOR FURTHER DETAILS



PA112 ATTENUATOR
Manual or programmable operation
0-122dB in 1dB steps
Uses thick film technnlogy and reed relay switching
Small size
Built-in power supply

WW—043 FOR FURTHER DETAILS

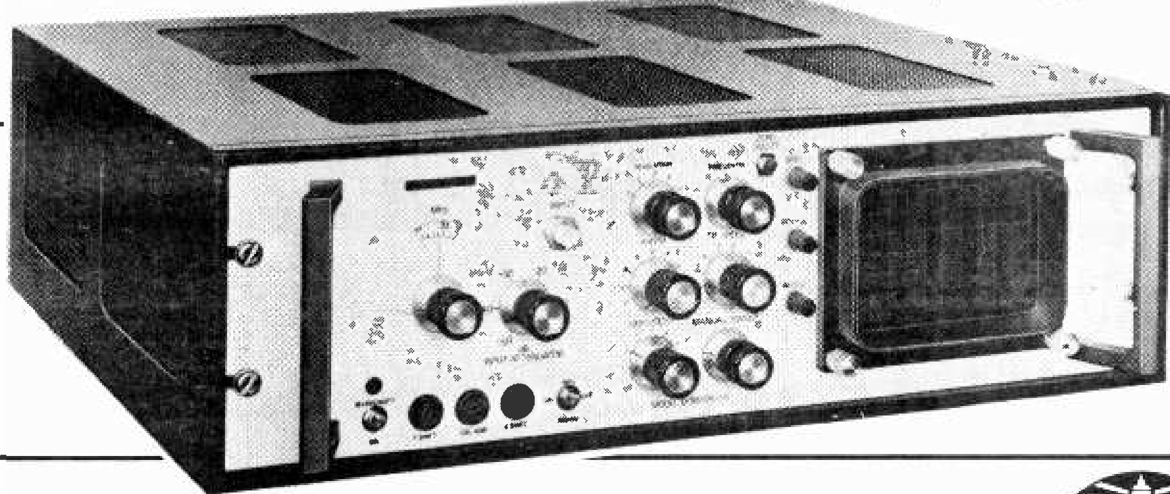
...from Farnell

FARNELL INSTRUMENTS LIMITED · INSTRUMENTS DIVISION · WETHERBY · WEST YORKSHIRE LS22 4DH · TEL 0937 3541

A clear view of the band

Eddystone EP961 MkII Panoramic Display Units provide visual monitoring of all signals in a selected band.
MkII-A is tunable from 50kHz to 800kHz, matching the IFs used in MF and HF communication receivers.

MkII-B covers 500kHz to 36·5MHz. It is ideal for use with VHF and UHF receivers for monitoring FM broadcasts and communication transmissions, and its usefulness extends into the laboratory field.
Both versions can be used with direct aerial input in many applications.



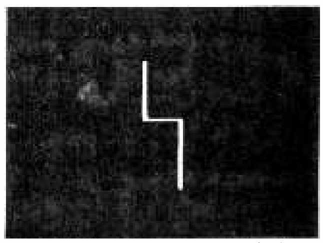
Eddystone Radio Limited
Member of Marconi Communication Systems Limited
Alvechurch Road, Birmingham B31 3PP, England
Telephone: 021-475 2231 Telex: 337081
A GEC-Marconi Electronics Company

Eddystone

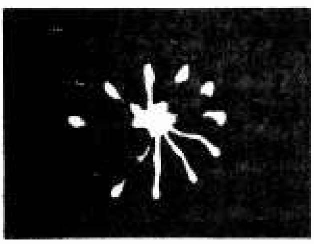
WW—024 FOR FURTHER DETAILS

RCA's new 3-inch scope... an entire servicing system

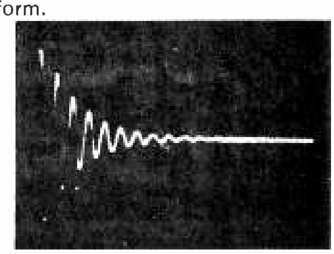
1. It's an 8MHz general purpose scope. Typical composite TV video signal.



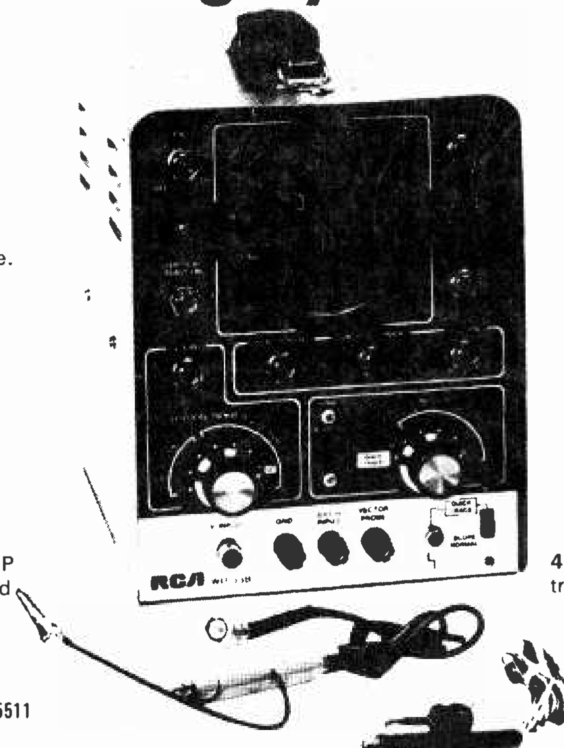
2. It's a "Quicktracer" Transistor/Diode and Component Tester. Typical junction wave form.



3. It's a Vectorscope for colour TV AFPC alignment. Colour bar generator used for test signal.



4. It's a "ringing" tester for coils, yokes, transformers. Typical ringing test pattern.



5. It includes the WG-400A Direct Law-Capacitance Switch Probe and Cable with BNC type connector, and a special "Quicktracer" probe.

For full information on the new WO-33B,
contact RCA Electronic Components
Sunbury-on-Thames, Middlesex Tel: Sunbury 85511
or an appointed RCA (EC) Distributor:
ELECTRONIC COMPONENT SUPPLIES (WINDSOR) Ltd
Thames Avenue, Windsor, Berkshire Tel: Windsor 68101
EDMUNDSON ELECTRONIC COMPONENTS Ltd 30-50 Ossory Road, London SE1 5AN Tel: 01-237 0404
BLACK ARROW ELECTRONICS Ltd Millbrook Road, Yate, Bristol BS17 5NX. Tel: Chipping Sodbury 315824

RCA Electronic Components

WW—033 FOR FURTHER DETAILS

Now suitable for U.K., European and American voltages...

Minimod, the versatile British range of encapsulated power supplies first introduced in 1973, has now been extended to cover European and North American mains voltages (and is interchangeable with most American types). Normally available ex-stock, all units are fully stabilised with fold back current limiting – the 5V models have over voltage crowbar too!

STANDARD MODELS

Type Number	Output Voltage	Output Current Amps	Short Circuit Current mA (Typical)	% Regulation Line and Load (Typical)
PU01	5 ± 0.1	0.5	370	0.3
PU02	5 ± 0.1	1.0	770	0.5
PU03	15 - 0 - 15 ± 0.2	0.10	37	0.1
PU04	15 - 0 - 15 ± 0.2	0.20	84	0.1
PU05	12 - 0 - 12 ± 0.2	0.12	45	0.1
PU06	12 - 0 - 12 ± 0.2	0.24	120	0.2
PU11	18 - 0 - 18 ± 0.2	.15	50	0.1
PU10	15 ± 0.2	.10	37	0.1
PU12	12 ± 0.2	.10	45	0.1
PU13	18 ± 0.2	.065	23	0.1

Input voltage ranges 103 - 126V, 200 - 240V. 210 - 250V. Frequency 50 - 400 Hz all types.

Comprehensive specification given in brochure GT 29b which is available on request.

★SPECIAL DESIGN SERVICE

Custom built units for applications requiring different specifications are produced as part of our standard service. Try us first.

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WW—038 FOR FURTHER DETAILS

NEW!...the decon·dalo 33PC Quick -Dri etch ·resist marker

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Simply draw the desired circuit onto copper laminated board – etch – clean.

The circuit is ready to use

NO MESS – NO MASKING
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Address ....

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Post to: **DECON LABORATORIES LTD.**
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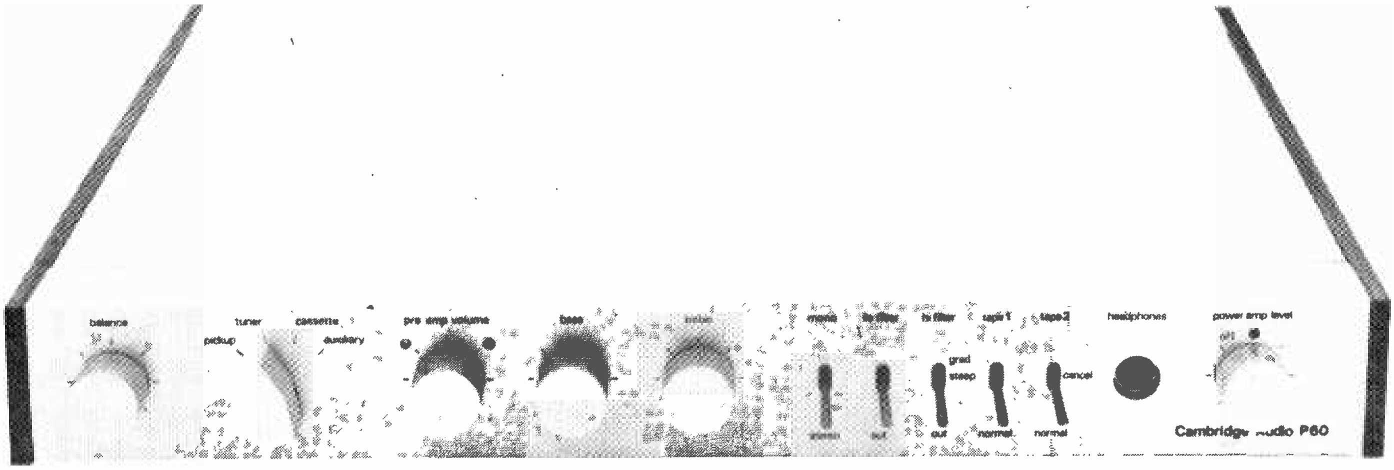
PORTSLADE, BRIGHTON, ENGLAND
(No Stamp Needed) Phone 0273 414371

WW—052 FOR FURTHER DETAILS

A WORLD FIRST* FROM CAMBRIDGE AUDIO



THE NEW P60 INTEGRATED STEREO AMPLIFIER

Low profile design only 2" high.
Recording with or without tone correction.
*Peak level indicator for tape recording.
Suitable for continual high power operation.
Dual independent tape operation.
*Light Emitting Diodes for level monitoring in main and pre-amplifiers.
Toroidal mains transformer.
Facilities for three tape recorders.
*Separate main and pre-amp gain controls.
Fully protected output stages.
RIAA phono correction unaffected by cartridge inductance.
Ultra low distortion circuits.
*New tape monitoring, A-B and A-B-C facilities.
International state-of-the-art circuitry from Cambridge Audio in Britain.

*To the best of our knowledge these features have never been included in a comparable amplifier hitherto.

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Please send me details of the revolutionary New Cambridge P60 Integrated Stereo Amplifier.
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Address
WW 25

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7404	0 13	7444	0 75	7490	0 73	74160	0.85
7405	0.13	7445	0.70	7491	0 71	74162	0.85
7406	0.24	7446	0.85	7492	0.39	74163	0 85
7407	0.24	7447	0 75	7493	0 39	74164	0.25
7408	0.12	7448	0.69	7494	0 42	74165	1 25
7409	0.12	7450	0 11	7495	0.51	74166	1.15
7410	0 11	7451	0 12	7496	0 55	74170	1 65
7411	0.16	7453	0.12	74100	1 25	74175	0.85
7413	0.26	7454	0.12	74107	0 25	74180	0.85
7416	0.25	7460	0 11	74121	0 25	74181	2.95
7417	0.25	7470	0.25	74122	0.35	74182	0.85
7420	0.11	7472	0.21	74123	0.49	74192	0 90
7426	0.22	7473	0 26	74145	0.85	74193	0 90
7430	0 11	7474	0.26	74150	0 75	74194	0.95
7432	0.22	7475	0.37	74151	0.57	74195	0.80
7437	0.24	7476	0 26	74153	0.59	74198	1 70
7438	0.24	7483	0.65	74154	1 15	74199	1 70

HIGH SPEED 74H00

74H00	£ 0 16	74H20	£ 0 16	74H52	£ 0 16	74H72	£ 0 26
74H01	0 16	74H21	0 16	74H53	0 16	74H74	0 28
74H04	0.16	74H22	0 16	74H55	0 16	74H76	0.28
74H08	0.16	74H30	0 16	74H60	0 16		
74H10	0 16	74H40	0.16	74H61	0 16		
74H11	0 16	74H50	0 16	74H62	0 16		

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4000A	£ 0 21	4014	£ 1 10	4028	£ 0 95	4073	£ 0 29
4001	0 21	4015	1 10	4030	0 50	4075	0 29
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4006	0 90	4019	1 10	4049	0 48	4081	0 29
4009	0 29	4020	1 15	4050	0 48	4082	0 29
4008	1 30	4021	1 10	4066	0 75	4528	0 85
4009	0 49	4023	0 21	4068	0 29	4585	1 25
4010	0 49	4024	0 85	4069	0 29		
4011	0 21	4025	0.21	4071	0 29		
4013	0 29	4027	0.75	4072	0.29		

DTL

930	£ 0.10	936	£ 0.10	944	£ 0 10	962	£ 0 10
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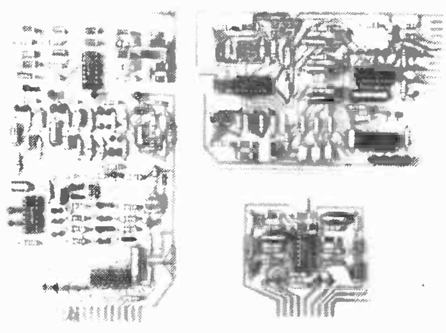

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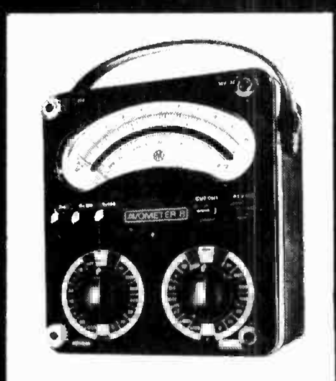

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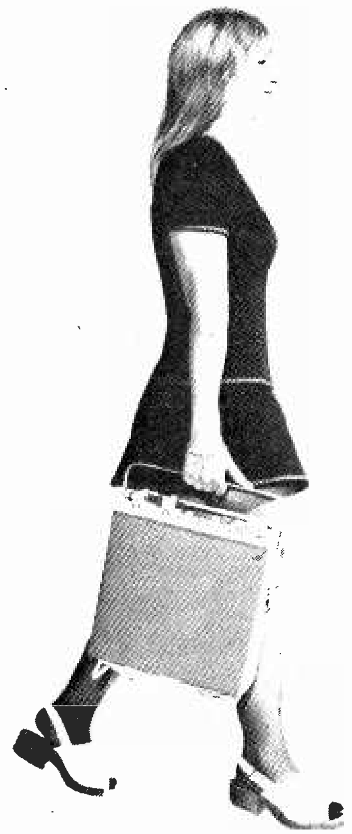

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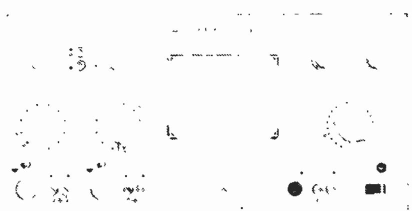

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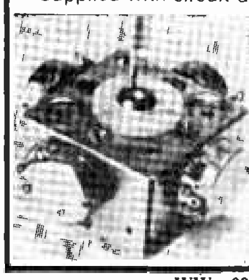

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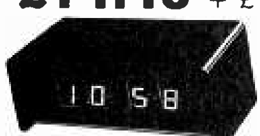

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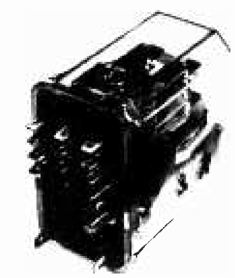	**Miniature Relays AZ 420 . . . 439** International standard relay. 2, 4, or 6 change-overs. Plug-in type saves maintenance costs. Coil voltages: 1.2 to 180 Volts D.C. 6 to 240 Volts A.C. Life expectancy to 100 million operations. Balanced spring-held armature allows operation in any mounting position. Relay extends only ¾" from PC board when used with right-angle socket.

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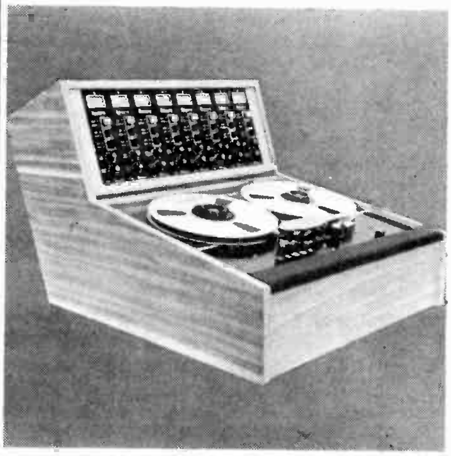

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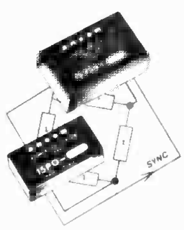

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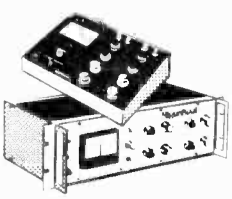

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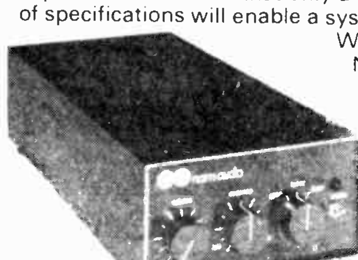

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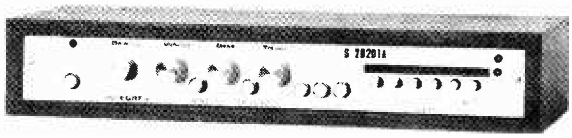

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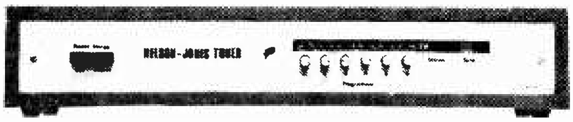

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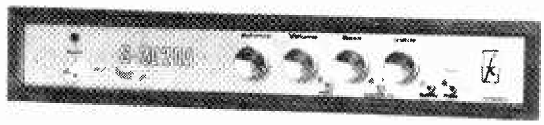

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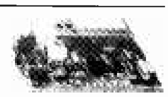

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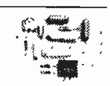

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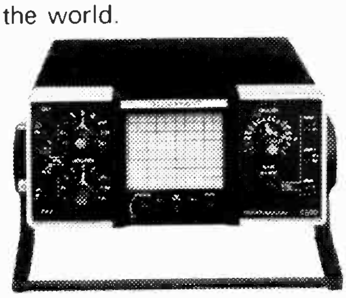

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TQ14

wireless world

Electronics, Television, Radio, Audio

JULY 1975 Vol 81 No 1475

This month's front cover is a composite view of David Clegg's digital watch, a full description of which starts this month.

IN OUR NEXT ISSUE

Electronics and the railways, a survey of past, present and future developments in communications from signalling to fail-safe systems in high-speed travel.

Audio level meter. Constructional design, using columns of l.e.ds for logarithmic display, has characteristics similar to BBC peak programme meter.

Solid-state wristwatch. The second part of this unusual project gives the printed circuit board design and other constructional details.

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Editorial & Advertising offices: Dorset House, Stamford Street, London SE1 9LU.
Telephones: Editorial 01-261 8620; Advertising 01-261 8339.
Telegrams/Telex, Wiworld Bisnespres 25137 London. Cables, "Ethaworld, London SE1."
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Subscriptions: Oakfield House, Perrymount Rd, Haywards Heath, Sussex RH16 3DH. Telephone 0444 53281.
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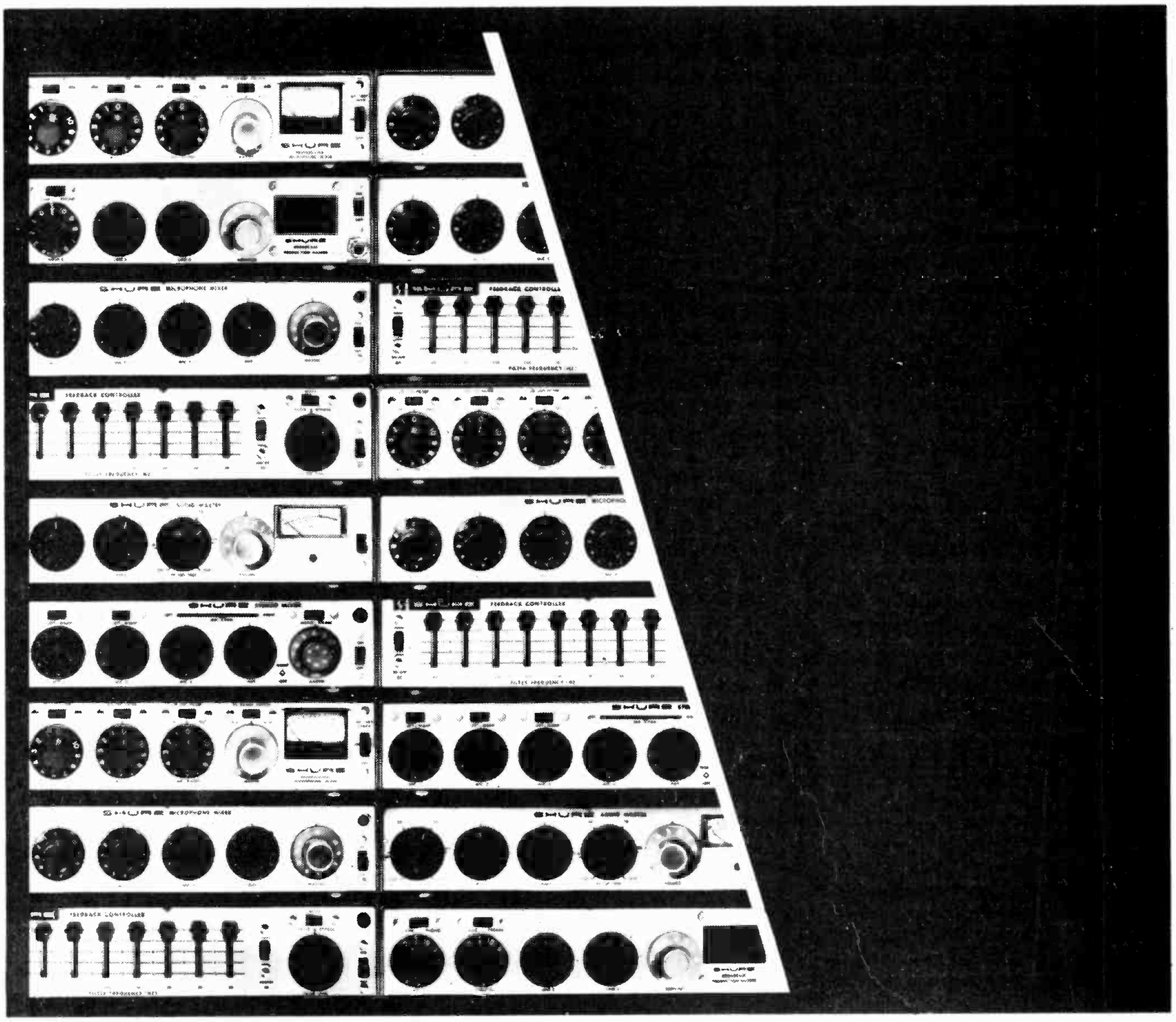

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I.P.C. Electrical-Electronic Press Ltd
Managing Director: George Fowkes
Administration Director: George H. Mansell
Publisher: Gordon Henderson

Until about twenty years ago, the majority of measuring instruments displayed their results in an analogue manner, usually by means of a pointer meter. The accuracy of measuring electronics was such that the precision of this kind of indication was adequate. At this point, frequency measurement using flip-flops and logical gates came into large-scale use, and a numerical indication was the obvious way to display the reading. The numbers did not imply a spurious, mythical accuracy of measurement, because these instruments were capable of a high degree of accuracy.

Since then, measurement capabilities in many fields have improved and digital indication has been adopted to take advantage of this improvement. We have now reached the stage where an instrument is sometimes regarded as not quite "with it" unless a row of numbers appears on the front panel. Digital readout appears, in a sense, to have become a fashion and is sometimes used when the simpler pointer indication may have advantages. It ought to be remembered that the presentation of a measurement in numerical form does not mean that it is necessarily a more accurate measurement. It may give a more precise reading, but that is not to be confused with precision of measurement.

In some instances, a digital display can be a liability. Any slowly-varying quantity or a parameter which is only required to be known roughly is not a suitable case for the digital treatment. In the first instance the display may be a jumble of changing figures and in the second the display must be *read* rather than recognized. Clock faces, for instance, are very rarely read and are sometimes made without numerals: the position of the hands is taken in at a glance. Or again, a speedometer is usually an analogue indicator and one feels that any time spent reading numbers on a car dashboard would be better employed in looking where one is going, particularly while accelerating or decelerating, when the numerals on a digital indicator can be incomprehensible.

This is not, of course, a tirade against the superb digital instruments designed for precision voltage or frequency measurement — there is often no other way to present such readings. But a feeling persists that the humble moving-coil meter on the end of amplifying or impedance-changing electronics (or even displaying the results of measurements made by digital means, such as frequency) can still give a good account of itself.

Doubtless, many engineers who would consider themselves improperly dressed without an array of digital instruments in their equipment will disagree, pointing out that not only have we published a design for a digital speedo, but are now in the digital watch and clock business. We welcome their comments and, if they are sufficiently numerous and interesting to other readers, will publish a selection of them in a future issue.

Solid-state digital wristwatch

C.m.o.s. circuitry and liquid-crystal display give long battery life 1 — Design

by D. D. Clegg

This article describes the design and construction of a wristwatch having a liquid crystal digital display and a quartz crystal time reference. The author was originally tempted to consider the design of a watch with a conventional display, i.e., one with hands driven by a sub-miniature stepping motor. This was later ruled out, however, because it involved a lot of conventional watchmaking expertise quite beyond the limited resources of the author.

Design considerations

As a starting point, the following requirements were set down in order of importance:

(1) The watch should be accurate; at least as accurate as a more conventional watch of equivalent price. The timing reference must, therefore, be a quartz crystal which will result in a stability of better than 1 second per day.

(2) The finished watch should be a reasonably presentable piece of jewellery, i.e. it must not only look good, but also be a sensible size. The author had no intention of wearing a three-inch die-cast box on his wrist!

(3) The display must be easy to read under all reasonable conditions of use.

(4) The batteries must be easily obtainable and must last a sensible length of time. The absolute minimum acceptable battery life would be three months or, preferably, longer.

While compiling this list, the author was tempted to add a fifth requirement — that the watch should be easy to assemble — but later realised that this and requirement (2) are incompatible. It will become obvious during the course of this article that this design is very much a compromise because, in early 1974, there were very few suitable components available: all the major ones being imported from either the USA or Europe. For this reason the watch is quite difficult to construct and is, unfortunately, not suitable for economic manufacture in quantity. The watch described here can be built for around £50.

Logic type. Considerations of size and power consumption ruled out the use of s.s.i. or m.s.i. bipolar logic for the watch: the only alternative was l.s.i./c.m.o.s. and at that time only one manufacturer's product was available in this country. This was the two-chip system designed for wristwatches with digital displays by Solid State Scientific Inc. One of the chips is a silicon gate c.m.o.s. oscillator and divider packaged in a ten-lead flat-pack — the SCL-5425-AF — and the other is an aluminium-gate watch circuit with outputs suitable for driving liquid-crystal displays, packaged in a 30-lead flat-pack — the SCL5424-F.

SPECIFICATION

Time reference: 32.768kHz quartz crystal.

Display: field-effect liquid crystal.

Power supply: three RM312H mercury cells or WH1 watch cells. Typical life 1 year. (Minimum 9 months.)

Stability: better than 1s per day. typically 3 seconds per week.

Size: module diameter 31mm. Depth of main part of module 7.3mm. Depth of front part of module 1.75mm.

Display. After deciding on a digital display, the author's first intention had been to use an l.e.d. display and to provide a "Display" button to reduce power requirements, so that the display would draw power from the battery only when required. The SCL-5424-F watch chip will not drive an l.e.d. display directly and so it was decided to interface it with CD-4009 c.m.o.s. inverters. At that time, however, c.m.o.s. was in short supply, and c.m.o.s. in flat-packs (necessary because of the size) was almost completely unobtainable; delivery times in excess of six months being quoted in some cases.

The alternative was to use a liquid-crystal display which would require no interfacing, since the SCL-5424-F watch chip was designed to drive this type of display directly. Again, at this time there was considerable difficulty in obtaining a liquid-crystal display suitable for a watch. There was quite a lot of literature from various manufacturers, but the only device which was actually obtainable was the LC-201135 from Brown, Boveri and Company. One important advantage gained from using this particular display was its ability to operate from a very low voltage (1.5V to 5V r.m.s.) and still provide a reasonable contrast ratio.

Crystal. The quartz crystal required by the SCL-5425-AF is a 32.768 kHz type. Motorola manufacture a suitable crystal in a sub-miniature vacuum envelope — the MTQ-32. They also make a sub-miniature ceramic trimmer capacitor for wristwatches; this is the MTT-02.

Batteries. It took the author approximately four months to obtain the main components for the watch, these being logic i.cs, display, quartz crystal and trimmer capacitor. Batteries were now the only components outstanding on the shopping list and the author confidently expected this to be very easy since he had obtained the "Designers Guide to Battery Systems" from Mallory. This book describes a very comprehensive range of batteries including no less than six specifically designed for electronic watches.

At this time the author discovered that empty wristwatch cases were available from wholesale watchmakers, so rather than try to make one (the die-cast box effect) it was decided to buy a suitable case ready-made. Before this could be done, however, the type and size of battery or batteries would have to be decided upon.

After visiting a number of large jewellers in central London, it was discovered that watch batteries are not available for sale over the counter; electronic watches requiring new batteries are, apparently, returned to the manufacturers to have their batteries replaced.

To have gone ahead and designed a watch using a battery from the Mallory range, but which proved difficult to obtain in practice, would have broken design rule (4). The author spent some time, therefore, visiting chemists, jewellers and photographic shops in central London to determine which small mercury batteries were easily obtainable. The result of this investigation showed that the best battery for the watch would be the RM-312H mercury battery designed primarily for hearing aids. This is obtainable from most chemists and with a capacity of 36mAh it would appear to fulfil design requirement (4). Three of these batteries are used in the watch and they will have a life in excess of nine months.

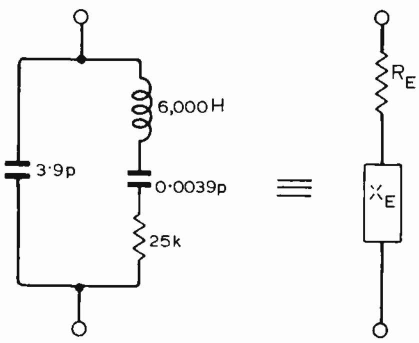


Fig. 1. Equivalent circuit of the MTQ-32 crystal. The values shown are typical and result in a typical Q of 50,000.

Oscillator design

The timing reference in this watch is a quartz crystal oscillating at 32.768kHz. This frequency is popular with i.c. manufacturers because it is an exact power of two, (2^{15} = 32768) thus simplifying frequency divider design. It is also a compromise between power consumption in the oscillator and the physical size of the crystal; lowering the frequency increases the size of the crystal, making it too large for a wristwatch, while increasing the frequency causes an unacceptable increase in power consumption. Future trends in watch design, however, are tending towards much higher frequencies (as high as 4MHz) to increase stability, with the use of silicon-on-sapphire c.m.o.s. integrated circuits to maintain extremely low power consumption.

The equivalent circuit for the Motorola MTQ-32 quartz crystal is shown in Fig. 1 which gives some typical component values. A typical Q of 50,000 would be obtained. The MTQ-32 is an NT-cut crystal and is mounted in an evacuated sub-miniature envelope.

There are two resonance conditions that a quartz crystal can exhibit – parallel resonance and series resonance. If it is assumed, for simplicity, that R_s = 0, then the crystal impedance is given by:

$$Z = \frac{j(1-\omega^2 LC_s)}{\omega^3 LC_sC_p - \omega(C_s+C_p)}.$$

The series resonant frequency f_s is defined at the zero impedance point, where $\omega^2LC_s = 1$, as:

$$f_s = \frac{1}{2\pi\sqrt{LC}}.$$

The parallel resonant frequency f_p is defined as occurring at the infinite-impedance point, where $\omega^3LC_sC_p = \omega(C_s+C_p)$, and is

$$f_p = \frac{1}{2\pi}\sqrt{\frac{1}{L}\left\{\frac{1}{C_s}+\frac{1}{C_p}\right\}}.$$

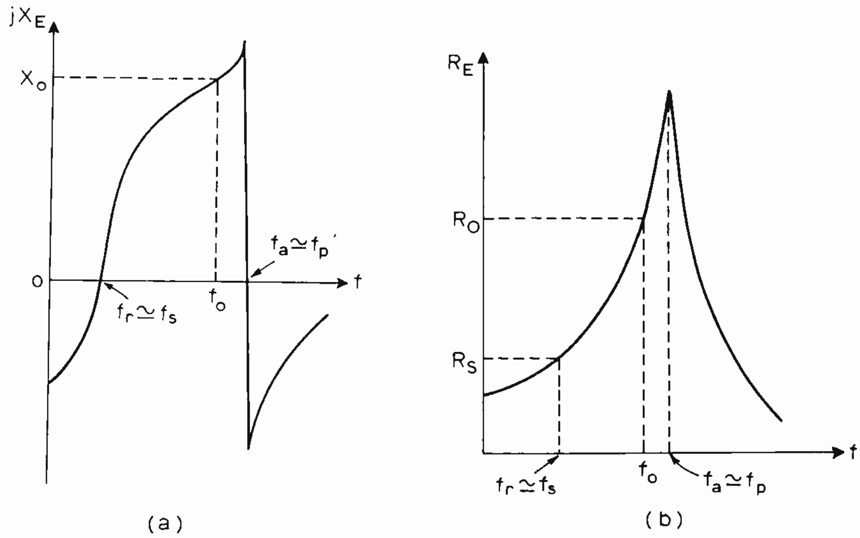


Fig 2. The crystal reactance X_E plotted against frequency is shown at (a), while (b) is the resistance R_E against frequency.

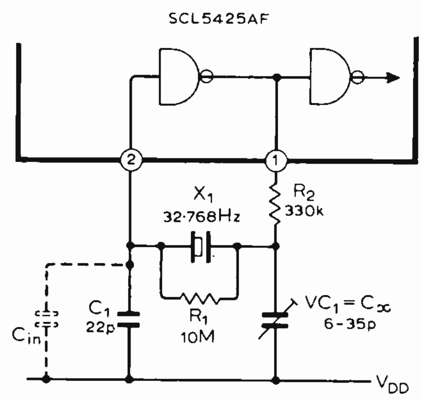


Fig. 3. The practical crystal oscillator circuit, using a logical inverter as the maintaining amplifier. The trimmer is type MTT-02.

Figs. 2(a) and 2(b) respectively show the variations of X_E and R_E with frequency for typical crystal. Unfortunately $R_s \neq 0$ for practical crystals and the real condition frequencies are called resonance (f_r) and antiresonance (f_a). These two frequencies are defined as occurring when the crystal appears purely resistive, i.e. when $X_E = 0$. In practice f_r is very close to f_s and f_a is very close to f_p. Fig. 3 shows the practical oscillator circuit used in the watch – in this circuit the resonant frequency f_0 lies very close to, but below f_a. The MTQ-32 crystal is designed to resonate at the specified frequency of 32.768kHz only when it has an external capacitance C_L of 10-12pF in value in shunt with C_p.

$$C_L = \frac{(C_{in}+C_l)C_x}{C_{in}+C_l+C_x},$$

where C_{in} is the input capacitance of the 5425 inverter, and is probably in the region of 5pF.

The inverter is biased into its linear mode by the series combination of ($R_1 + R_2$) which should have a value of about ten times the crystal impedance at resonance f_0 (typically $Z \gg 10^6$ ohms) but should be lower than the various d.c. leakage impedances – the inverter input impedance, for example. A value of between 10 and 100MΩ for R_1 satisfies these requirements. Unfortunately, however, physically small high value resistors (>10MΩ) are very scarce; indeed, only a very few types of small resistor can be obtained in values above about 330kΩ. The Mullard CR25 range of carbon film resistors extends to 10MΩ and this is the value of R_1.

Resistor R_2 controls the drive level to the crystal and contributes to the feedback network attenuation constant. Its value should be about ten times the crystal series resistance R_s, to give reduced dependence of frequency on the supply voltage.

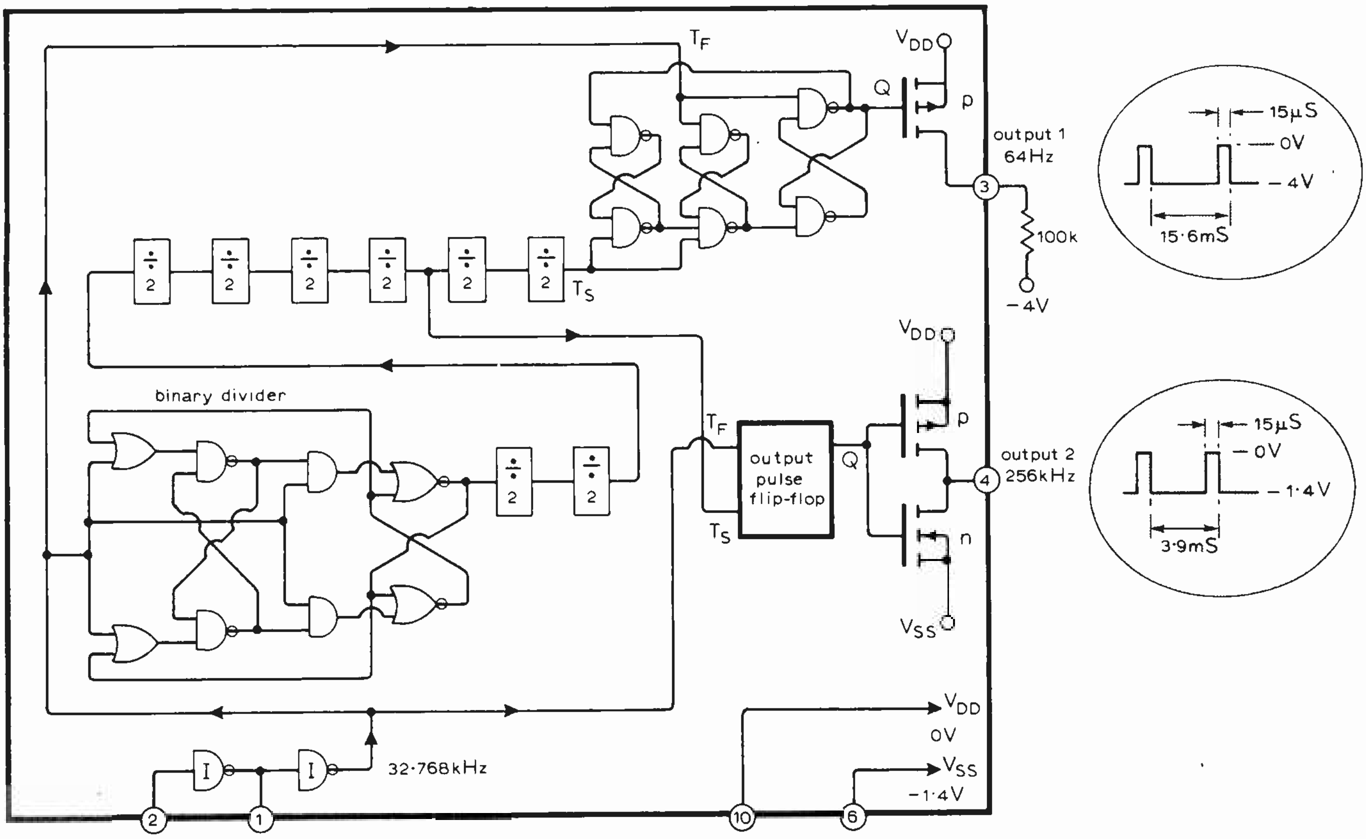


Fig. 4. The logic diagram of the SCL-5425-AF.

The trimmer capacitor VC_1 is adjustable between 6 and 35pF, giving a frequency adjustment of about ±1 Hz from the nominal 32.768kHz. This represents a timing adjustment of about ±2½ seconds per day. VC_1 is a sub-miniature ceramic trimmer, the MTT-02, manufactured by Motorola to complement the MTQ-32 crystal.

Dividers

The main watch integrated circuit (SCL-5424-F) requires an input of 64Hz and this is provided by the oscillator and divider integrated circuit, the SCL-5425-AF.

Fig. 4 is a logical block diagram of the SCL-5425-AF. It consists of an inverter between pins 1 and 2, to which are connected the frequency determining components to form the oscillator, followed by nine binary dividers. There are two outputs, one at the input frequency divided by 2^9 (output 1) and the other at the input frequency divided by 2^7 (output 2). With an input of 32.768kHz, output 1 will be $32768 \div 512 = 64$Hz and output 2 will be $32768 \div 128 = 256$Hz.

The binary dividers used in the 5425 are master/slave toggle flip-flops whose output transitions occur on the rising edge (logic 0 to logic 1 transition) of the input clock. The logical construction of these toggle flip-flops can be seen in Fig. 4. The output from these divers has, of course, a 50% duty cycle (1:1 mark: space ratio). Resistive loads connected to the outputs would, under these conditions, dissipate an unacceptable amount of power, and the output pulse duty cycle is therefore reduced from 50% to 0.1% for output 1 and to 0.4% for output 2. These low duty cycles are generated by the output pulse flip-flops which are set by the first logic 0 to logic 1 transition of T_F when T_S is high and reset by the next logic 1 to logic 0 transition of T_F (Fig. 5). Further changes in T_F have no effect until T_S has gone low and then high again, when another output pulse is generated. The net result of this is that the output pulse flip-flop gates one 15μs pulse of the input frequency at the repetition rate of the output frequency.

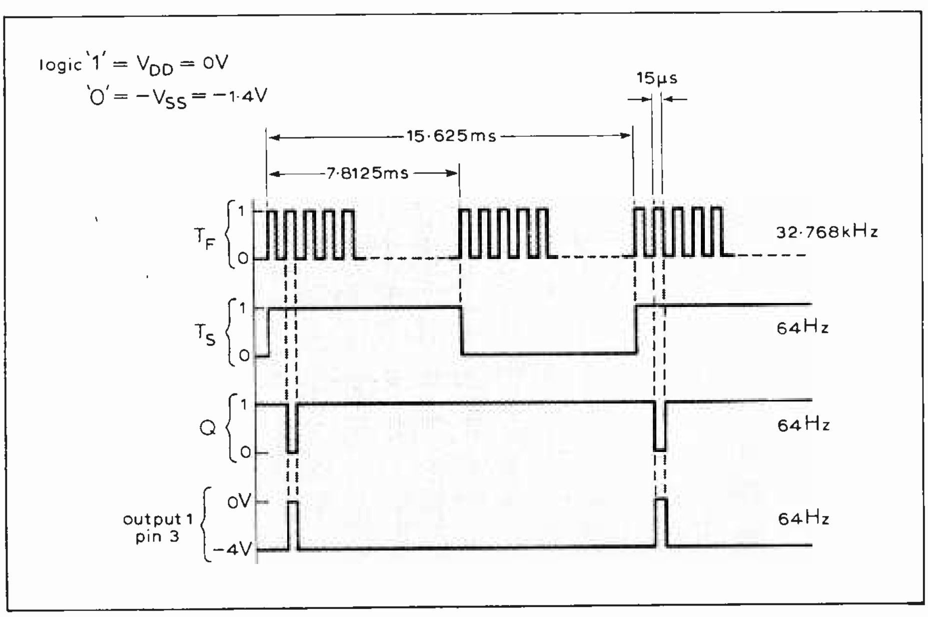


Fig. 5. Generation of low output duty cycles.

Output 1 is an uncommitted p-channel transistor and requires an external drain load of 100kΩ. Output 2 is a conventional c.m.o.s. inverter with an output "on" resistance of 1kΩ at a current of 300μA. This output of 256Hz is primarily intended for driving voltage up-converters to produce the 10 to 15 volts required by many liquid-crystal displays, and it is not used in this design.

Main logic and display

A block diagram of the SCL-5424-F watch is shown in Fig. 6. It accepts an input of 64Hz from the oscillator and divider I.c. and directly drives the liquid crystal display. The 64Hz input (pin 23) has an n-channel transistor connected down to V_{ss} with its gate connected to V_{DD}. It is intended to provide a load for

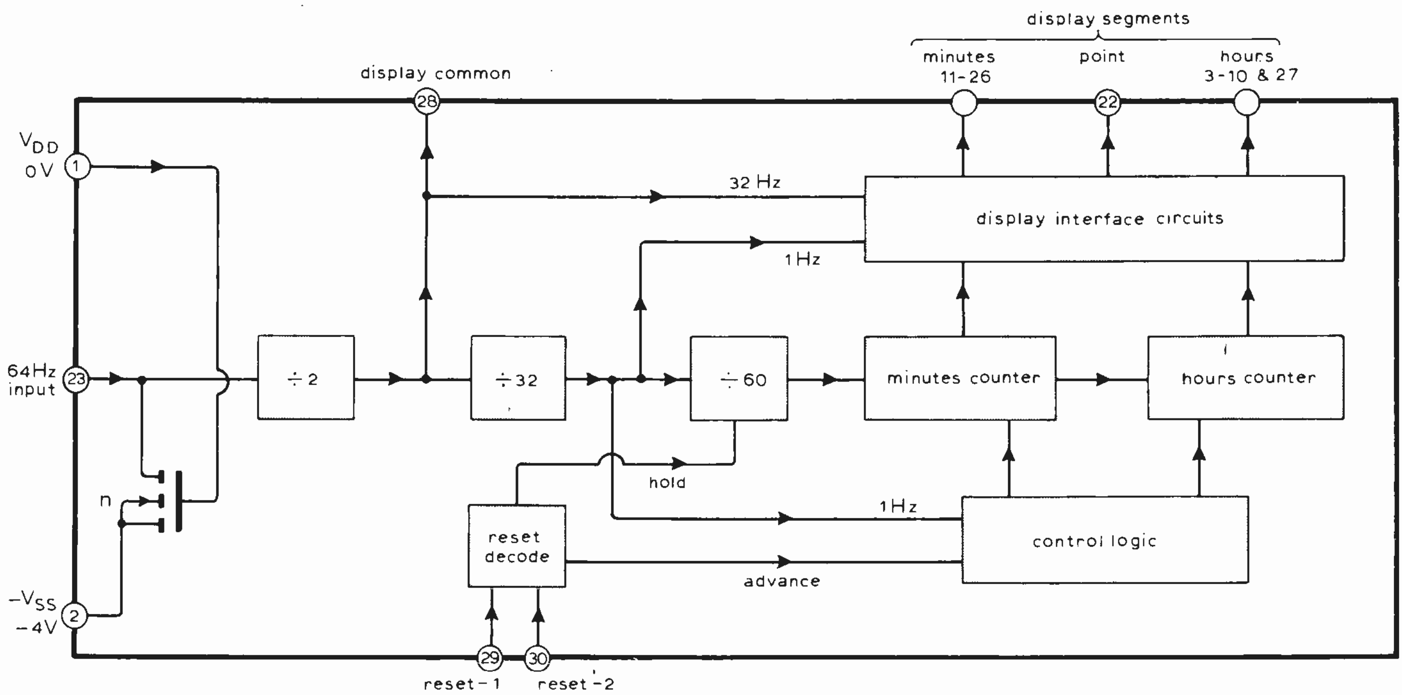


Fig. 6. Block diagram of the SCL-5424-F.

the p-channel current source transistor in the SCL-5425-AF. It is only effective, however, with a supply of 15 volts; with $V_{ss}= -4$ volts an external resistor of 100kΩ is required, since at this voltage the transistor has a very high channel resistance. This value of load resistor might appear to be rather low as it results in a peak current of 40μA ($I = 4 \div 10^5$A) but, since there is only one 15μs pulse every 15ms (duty cycle 0.1%), the mean current is only 40nA. If this resistor is made too large, then the 64Hz input pulse fall time will be too long and may cause incorrect operation of the divider stages following.

There are two "Reset" inputs (pins 29 and 30) which for normal operation are connected to V_{DD} (0V) through two 1MΩ resistors (R_4 and R_5). When reset 2 (pin 30) is taken to $-V_{ss}$ (case potential) the hours increment at a 1Hz rate. Connecting both resets 1 and 2 to $-V_{ss}$ causes the minutes to increment as for the hours. Connecting reset 1 to $-V_{ss}$ by itself, stops the watch and resets the divide-by-60 stage preceding the minutes counters. This is to enable the watch to be synchronized to a reference time source, for example, the Greenwich Time Signal.

Liquid crystal displays require a symmetrical a.c. waveform for correct operation. There must be no d.c. component present in this waveform or electrolytic effects within the cell will seriously damage the display, thus shortening its life. The SCL-5424-F watch chip, therefore, contains interface circuitry which produces the required symmetrical square waveform from the output of the seven-segment decoders: Fig. 7 shows one of these circuits together with the associated waveforms. The interface circuits consists, essentially, of two c.m.o.s. transmission gates connected so that the segment output can be either in phase with the display common output, or 180° out of phase with it.

When all inputs to the segment decoding gate are at logic 1, then its output (a) is logic 0; transmission gate S_1 is on (conducting) and gate S_2 is off. Under these conditions the 32Hz waveforms at pins 28 and 26 are, therefore, out of phase and the net result is that segment E_1 "sees" a symmetrical square wave of 8 volts peak-to-peak, which turns it on. When this segment is

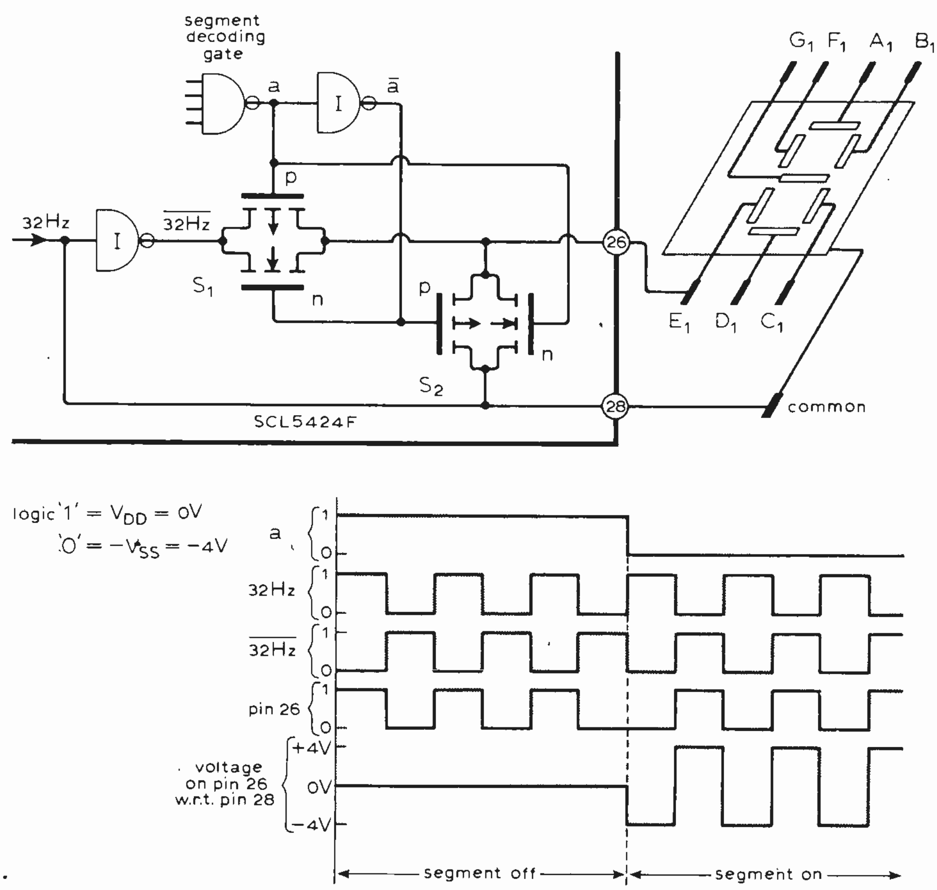


Fig. 7. Display interface circuits.

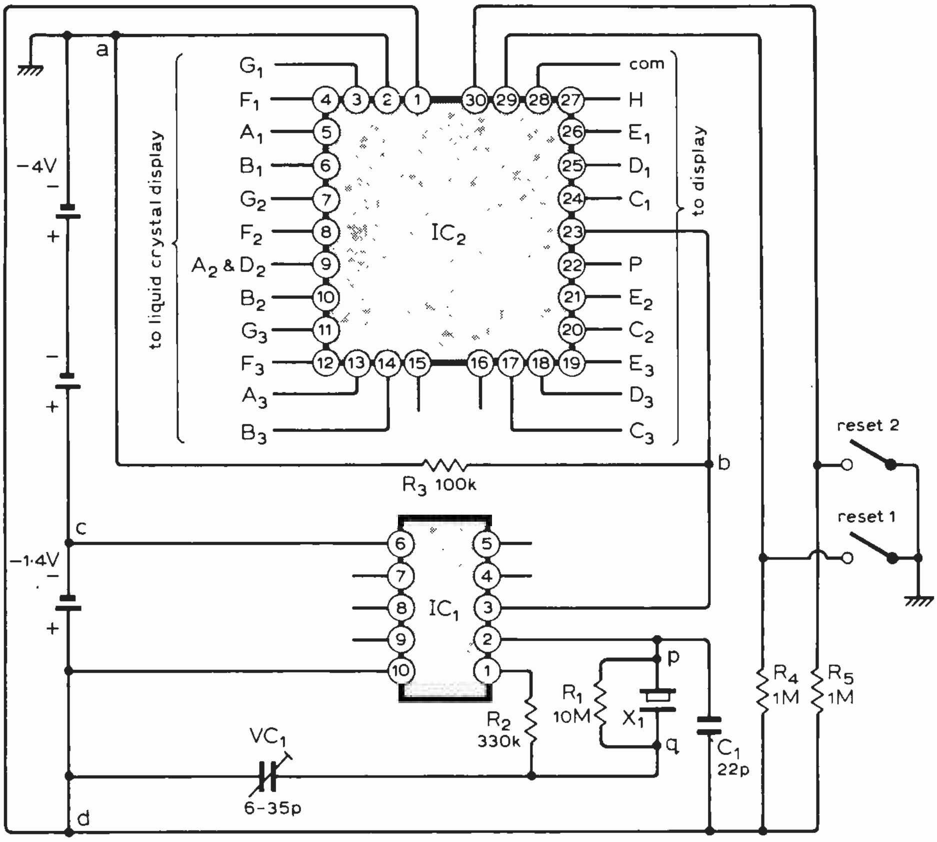


Fig. 8. Complete circuit diagram of the watch.

not required at least one of the inputs to the decoding NAND gate will be at logic 0, its output is logic 1 and transmission gate S_1 will be off, while gate S_2 will be on. There is now no voltage across the cell for this segment, and it is, therefore, off.

Many liquid-crystal displays for wristwatches have a colon between the hours and minutes; the Brown Boveri display used in this design, however, has only a single point. The P output of the watch chip (pin 22) is driven by a 1Hz waveform, through an interface circuit, which results in the display point flashing at a 1Hz rate. This serves two purposes; it gives the wearer confidence that the watch is, in fact, operating, and it can be used as a seconds timer if one is prepared to count the seconds.

Power supply

The SCL-5425-AF oscillator and divider i.c., being a silicon-gate device, will operate with a supply voltage between 1.2 and 10 volts: the main logic i.c. (SCL-5424-F), being an aluminium gate device, operates with a supply of between 3 and 15 volts, while the display requires a voltage of between 1.5 and 10 volts. Three 1.4 volt mercury cells, giving a supply of 4.2 volts, satisfy these requirements. The current consumed by the SCL-5425-AF is typically between 2 and 5μA at 1.4 volts; above this the current rises quite rapidly, until at 4 volts it will be about 15μA. This is far too high for prolonged battery life, so this i.c. is supplied by only one of the three cells. The main logic i.c. and display together consume a maximum current of 300nA (0.3μA) at 4 volts; the total current required by the complete watch will, therefore, lie somewhere between 2.3 and 5.3μA.

The capacity of the RM-312-H mercury cells used in this design is 36mAH or, as it is more usefully quoted in this application, 4μAyears. These cells will therefore last between nine and about eighteen months. For those constructors who would like to try to obtain one of the range of Mallory watch batteries, the WH1 cell is dimensionally the same as the RM312H but it has a slightly higher capacity of 45mAH (5μAyears). (Although the capacity of the RM312H cell is given in the data as 36mAH, this is for a drain of about 2 milliamps and it may in practice have a slightly higher capacity. The capacity of the WH1 is quoted for a current drain of about 50μA.)

Fig. 8 shows the circuit diagram of the complete watch, omitting only the display for clarity. *(Constructional and operational details will be presented in Part 2 of the article.)*

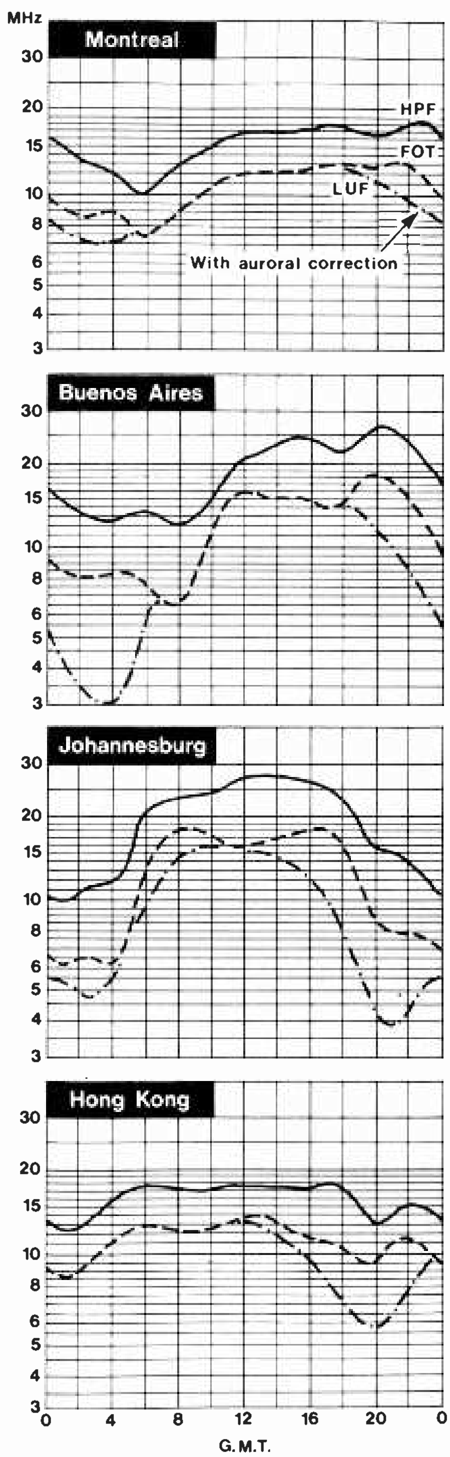
Vision cassette and cartridge recorders

Thorn Electrical Industries have asked us to say that the price of the Radio Rentals Contracts Model 8200 V.C.R. is £335 plus v.a.t., or £132 plus v.a.t. per annum when rented. The firm's address is now APEX House, Twickenham Road, Feltham, Middlesex.

HF predictions

Magnetic activity is still reaching disturbance level on more than fifty per cent of days. This feature developed rapidly in February 1974 and has persisted to date. The same feature was present in 1973 and terminated abruptly in July of that year.

Smoothed sunspot number is now very low with rate of change near zero. It should start increasing in a few months' time.



News of the Month

Josephson faster than transistors

A US patent covering the fabrication of a new type of electronic switch, whose performance far exceeds that of transistors, describes a technique used to grow a thin insulating layer — only 10 to 30 atom layers thick – that is the heart of a device called a Josephson tunnel diode. (The Josephson effect was described in an article by B. D. Josephson in *Wireless World*, October 1966, entitled "New superconducting devices").

It has been recognized for some time that the Josephson effect could provide an extremely fast logic switch that would require very little energy. However, a device based on these effects requires an insulating layer far thinner than has previously been used in electronic devices. The new process, accredited to James H. Greiner of the IBM Thomas J. Watson Research Centre, New York, uses a glow discharge somewhat like that in a fluorescent lamp. When a gas such as oxygen is present in the discharge, an insulating oxide is formed on the surface of the sample up to a certain thickness which is dependent on the oxygen pressure and other factors. As the oxide approaches this thickness, the discharge begins to remove oxide at almost the same rate as it is produced. Thus the oxide layer quickly approaches an equilibrium at the desired thickness.

The Josphenson switch device is based on a phenomenon called electron tunnelling. Because electrons appear to behave as waves as well as particles, they can penetrate or "tunnel" through a barrier such as a thin layer of insulation which would be expected to stop them according to classical physics. The type of tunnelling exploited in the new device occurs only at very low temperatures, where some metals lose all resistance to current flow and become "superconductors." It was discovered in the early 1960s that two different types of tunnelling can occur through a thin insulator separating two superconductors. In one type there is no voltage drop and the insulator acts like a weak superconductor itself. In the other type, there is a slight voltage drop across the insulator. The insulator can be switched from the no voltage drop state by a small magnetic field. (Discovery of these effects was recognised by the 1973 Nobel Prize in physics.)

1975 Spring trade shows

The annual trade shows for the radio and television industry took place in London during May amid an air of surprising confidence and optimism from both retailers and suppliers. Perhaps also, the fact that this was the last show to be held in the London Hotels before the move next year to the Birmingham exhibition centre was the reason for the unusually large number of exhibitors.

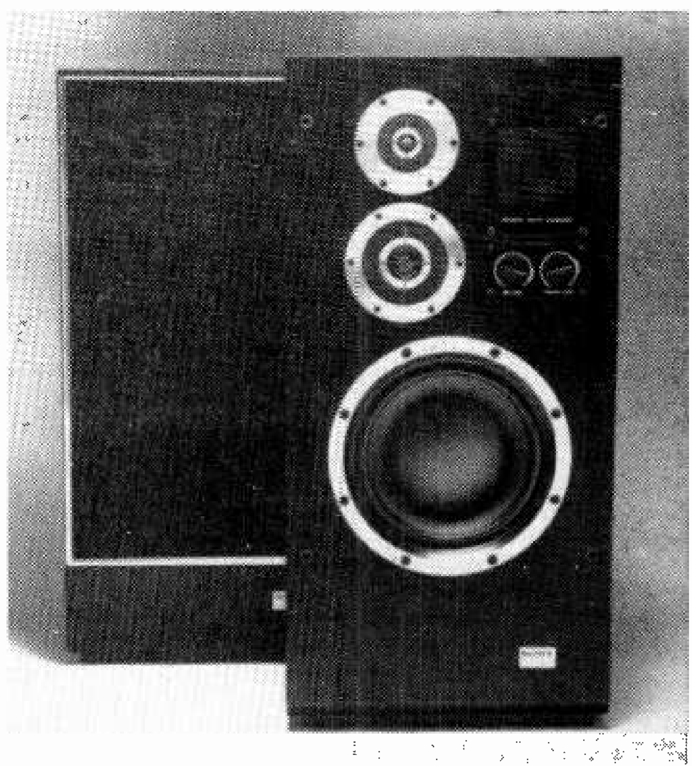
It was very evident, from the range of hi-fi equipment introduced, that many manufacturers believe that one way of ensuring buoyant trade prospects is to move up-market to the very expensive (and very large!) end of the scale. A typical example of this philosophy was to be found at the Cumberland Hotel, where Sony (UK) Ltd were introducing a range of esoteric audio equipment of phenomenally high price. Among these were some loudspeakers priced at about £1,500 a pair and a new reel-to-reel tape recorder priced at around £1,200!

In total contrast, AEG Telefunken were showing some brightly coloured pocket-sized portable radios that were of quite modest price. Significantly, no new developments appeared on show for television, with the exception of an increase in the incidence of slot-mask tubes and the new 20 inch screen size.

Philips were showing a rather battered prototype Teletext decoder incorporated in a large screen television and since it did not seem to be fully functional, little interest was shown by those dealers present at the time.

At the end of the five days, most exhibitors reported a steady trade with dealers buying products, but in many cases, in a cautious way. So much new technology was shown, that this will form the subject of a brief report in the next issue of this journal.

In conclusion, the overall impression gained was of a very high morale and a determination to fight back against the trends of the current decline in consumer sales.



The Sony SS8150 loudspeaker is a typical example of a new technique announced during the show. The drive unit cones are loaded with carbon fibre filaments to give a very high stiffness.

VAT muddle

The introduction of the 25% VAT rate on certain so-called luxury goods appears to have resulted in a good deal of confusion not only among component suppliers and kit companies but also among advertisers using magazines such as *Wireless World* which are aimed at a combined audience of professional engineers and enthusiasts.

As a result we have asked the Customs and Excise for clarification on a number of common questions. The question of VAT liability requires that a distinction be made between those who are VAT registered and those who are not.

For those who are registered, VAT is recoverable, so no change will result in accounting procedures. The changes affect the non-registered purchaser who is either a business with a turn-over less than £5,000 per annum, or is a private purchaser. The types of goods and services subject to the high rate of VAT are defined in Notice 742 from Customs and Excise and are quite clear in all instances except where related to components and borderline products having a possible consumer application.

Taking components first; all those components forming parts of higher rated goods are subject to 25% VAT. Those that have been specifically excluded by the VAT Liability Office may be rated at the higher rate, if they are fitted as a spare part by an engineer performing a service classified at the higher rate. Examples of such components would be those that are rated to a higher specification than that normally used in, say, audio amplifiers. Hence a high power thyristor is excluded and rated at 8% unless it is used by a service engineer as a spare part in a domestic audio amplifier.

A telephone enquiry to the VAT Liability Office elicited the information that there are still many "grey" areas where final decisions on rating have yet to be made. They informed us that local VAT offices are issuing conflicting information and that enquiries concerning electronic and electrical goods not specifically mentioned in Notice 742 should be addressed via the appropriate trade association who will then negotiate with the London VAT Libaility Office. It is only this office that is in the position of making final decisions on specific exclusions.

The VAT officer went on to say that in the intervening period of uncertainty, manufacturers are expected to make their own decisions regarding the rating of their components, in instances where Notice 742 has provided insufficient information.

Finally, two specific examples of liability in relation to advertising. Notice 742 states "Appliances . . . are generally regarded as being for domestic use if they are . . . advertised in those periodicals intended for the public." We are informed by the VAT Liability Office that this is only one of the criteria applied and that where the only advertising outlet for a professional product is through a publicly available journal than this would not result in the high rate being applied. For example, public address equipment is tentatively rated at 8% (subject to discussion with the trade associations resulting in a permanent decision). Advertising in a magazine such as *Wireless World* would not result in the high rate being applied. Similarly professional discotheque equipment may be advertised in the *Melody Maker* and yet be rated at 8%.

All this note serves to show is that in areas of doubt final clarification can only be obtained from the central VAT Liability Office, preferably through a trade association.

Antenna system for AEROSAT

A complete L-band aircraft antenna system of a type suitable for airliners using the projected AEROSAT aircraft/satellite communication system has been developed under contract to the Ministry of Defence in close co-operation with the Royal Aircraft Establishment and completed in time to be installed in one of RAE's Comet 4 aircraft for the AEROSAT system trials. The trials, based on the Azores, are organised by the European Space Research Organisation and started at the end of February. NASA's ATS6 satellite is being used to assess performance of the L-band system, which is of particular significance since in this geographical area the access angle from the aircraft to the satellite is low, resulting in appreciable noise temperature and accentuating possible multi-path problems.

The antenna system consists of two antenna groups with two switching and phasing units with their associated cabling. The antenna groups are virtually flush mounted on each side of the aircraft fuselage at about 40° from the zenith. The switch units are installed in a convenient location inside the fuselage.

An antenna group consists of six slot-dipole elements, three transmitting and three receiving which give the required beam coverage with good multipath signal rejection. The slot-dipole element itself was developed by RAE's Radio and Navigation Department and was selected after detailed examination of a wide range of alternative elements. The L-band system is rated at 200 watts, 50% duty, and has been designed to transmit on 1640-1660MHz and receive on 1540-1560MHz with omni azimuth coverage for elevation angles of 10° and above. After two weeks and nearly 50 hours of flying time the antenna system was working well. There were several days of torrential rain when the Comet 4 remained on the tarmac, during which time the impedance of both the transmitter and receiver were measured several times and no change was observed.

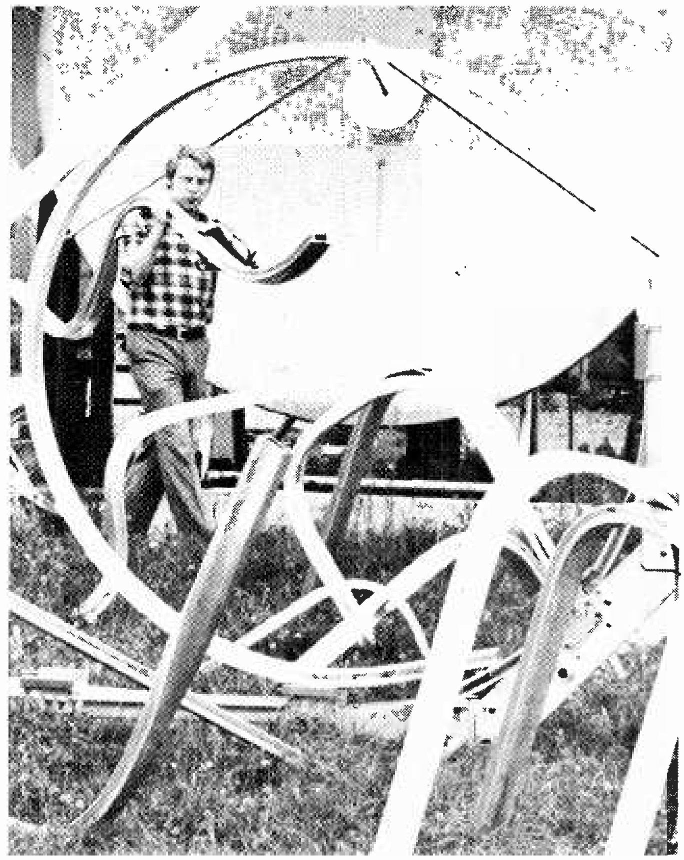
"No madam, this is not Harrods." *Pye Telecommunication's specially adapted "Westminster" mobile radiotelephone in use at the Silverstone Racetrack during recent police trials. The police motorcyclist is using the hand-set for transmitting, and a loudspeaker, mounted on the motorcycle's fairing, for receiving.*

Brema on VAT

The following text of a telegram to Members of Parliament was issued by the British Radio Equipment Manufacturers' Association on 22nd April. "To all members of Parliament from Lord Thorneycroft. President of British Radio Equipment Manufacturers' Association. The recent budgetary proposals to increase VAT to 25 per cent will have the immediate effect of causing serious and permanent redundancies in this industry. At a special meeting of the Association today member companies estimate that permanent and unavoidable lay-offs of staff would exceed 6,000 at least 20 per cent of direct labour employed by the industry. These figures in addition to the 5,000 redundancies which occurred in the calendar year 1974, and exclude serious position which will undoubtedly occur in component and associated industries. Position is grossly aggravated by the retro-active effect of VAT proposals on rental side of industry. We wholeheartedly endorse representations already made by members of the National Television Rental Association. We emphasise that enforced reduction in production capacity now cannot fail to increase the cost of imports when the market next improves, with serious consequences on balance of payments position."

Is circularly polarized TV coming?

The heading to this item was the title of a paper by M. S. Siukola presented in the *IEEE Transactions on Broacasting*, Vol. BC-21, No. 1, March 1975. According to the paper, there is on the horizon a new approach to the way TV signals are radiated. The technique is circular polarization, and while this has been in use for several years in f.m. broadcasting, it is now being viewed for TV as an effective antidote for ghosting, spotty coverage, multipath, poor reception on whips and rabbit ears, misoriented antennas, co-channel and adjacent-channel interference – all ills that have plagued broadcasters and viewers since TV's inception. The conclusions reached in the paper indicate that the principal deterrent would seem to be the cost to the broadcaster, but this may well be completely compensated by the more solid coverage, increased viewer enthusiasm for the enhanced reception and the additional viewer audience that circularly polarized TV is expected to provide within existing coverage areas. Present receiving antennas would not be made obsolescent, but viewers would certainly benefit most by acquiring circularly polarized types. The designs for receiving antennas as well as transmitting types are available and the antennas can be built now.



For radio relay systems using the microwave range above 3GHz Siemens are now developing aluminium waveguides with rectangular cross sections which can be bent and twisted and which simplify the planning and installation of connecting lines between radio relay equipment and antennas.

Association of research contractors formed

The Association of Independent Contract Research Organizations has been formed to represent and promote the resources of seven constituent founder members. Contract research is becoming increasingly important in its scope for serving industrial, commercial, institutional and governmental clients as a world-wide business. The seven major independent organizations based in the UK serve home and overseas markets. Between them they employ 2,250 staff of whom 800 are of professional consultant status. The Association aims to communicate on behalf of its members with international and intergovernmental bodies, with central governments in the UK and overseas, with industry – representational bodies and industry groups – and with commercial organizations able to benefit from contract research services. Further information can be obtained from D. McA. Craig, 7 Catherine Place, London SW1E 6EB.

Queen's awards to electronics

Worthy of note are the following companies who were included in those honoured by the Queen earlier this year for their contribution to Britain's technological development and exports: Beckman Instruments for export achievements during the last three years; Mullard for outstanding export success and development; Micro Consultants for outstanding work in the field of ultra high speed analogue-to-digital conversion; EMI Sound and Vision Equipment for export achievement of the brain diagnostic EMI-Scanner; Marconi-Elliott Avionic Systems for technological innovations in the sophisticated navigation and weapon aiming system NAVWASS, supplied for Jaguar aircraft; KEF Electronics for export achievement of loudspeakers; Sinclair Radionics for outstanding export achievement and for technological innovation in electronic calculators; British Aircraft Corporation for export achievement and for technical innovation in high performance flight radomes by the Reinforced and Microwave Plastics Group. Our congratulations go to all concerned.

Transistor assembly automated

A recently developed transistor assembly system that can assemble a variety of transistor types by means of pattern recognition techniques comprises a minicomputer and image processors and will ultimately have 50 wire-bonding machines with visual functions to determine chip positions of transistors fed into the machines. The system has been installed at Hitachi's Takasaki Works, in Japan.

To recognise the position of transistor chips, an artificial eye is needed to replace the human eye. For this purpose, a microscope and a TV camera are mounted on each wire-bonding machine, so that the image signal from the camera is analyzed by a combination of the image processor and the computer to give a high-speed position recognition rate of 0.2 seconds per chip average. Position data is fed back from the computer to the appropriate wire-bonding machine, whose servomechanism can stretch the gold wire between emitter and base electrodes on the chip and the corresponding outer leads. It is claimed that the production rate has more than doubled since replacement of traditional methods.

World markets decline

An extract from the 1975 first quarter and stockholders meeting report issued by Texas Instruments indicated that the decline in demand for their electronics products experienced in 1974 was generated by the longest, deepest recession since recovery from World War II. The major difference between this and past recessions is the almost concurrent decline of all major economys. In 1970, while the US economy was declining, Japan and Europe continued to grow. In contrast, late 1973 industrial production turned down simultaneously in Japan, Europe and the US.

In the US real growth has dropped for the past five quarters. High unemployment, inventory liquidation and sluggish capital spending suggest they (TI) will not reach the bottom before the third quarter of 1975, with at best a modest upturn this year and a slow recovery in 1976.

Japan appears close to the bottom of its recession, spring wage negotiations influencing the rate of recovery. West Germany probably will have a moderate upturn in the second half of the year. France will have minimal real growth in 1975. In Italy, industrial production is falling still, but the trade balance is improving and inflation is down compared with 1974. The UK economy is expected to remain sluggish well into 1976.

Direct-drive a.c. motor

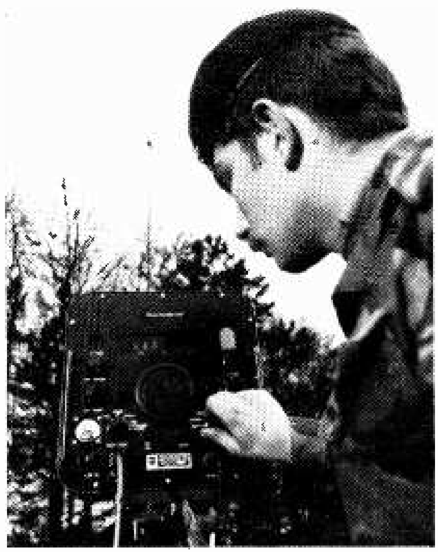
Matsushita, who are represented in the UK by Symot, have announced a direct drive a.c. motor for use in record turntables. The unit, which is called the FF-2000 is basically a linear motor, which drives a light-weight aluminium platter, by eddy currents. Underneath the platter is a geared magnetic speed sensor which forms part of a feedback system for speed regulation. The motor is electronically controlled and requires an a.c. supply of 18V, 40mA. Performance of the FF-2000 is claimed to be equal to or better than the existing d.c. direct-drive motors used in the Technics range (also manufactured by Matsushita). We understand that these motors will cost around £12. in production quantities, and will be available at the end of this year.

Ceefax, Oracle — now Tifax

Texas Instruments announced at a press conference given in May that they have now completed the design of a modular data processor which will decode the Teletext transmissions broadcast by the BBC and IBA. Although no product has yet appeared, samples of the first generation processor will become available later this year, followed by full production in 1976.

What makes the difference in the "Tifax" decoder, from those already designed by such companies as Decca and GEC, is that the Tifax unit is being offered as a p.c.b. module carrying a relatively small number of dedicated l.s.i. circuits.

The projected cost of the "Tifax" module is expected to be around £50, reducing to £10-£15 over a few years. Power consumption is said to be 5W drawn from a regulated +5V ±0.25V supply with a maximum ripple of 10mV pk-pk. Interface to the receiver is by direct connection to the R.G.B. video drive stage from 15V, 20mA current sink open collector outputs. The brightness display can be varied using three integral common base transistors. The video input requires a signal amplitude of 2-3V pk-pk, negative going sync, with an input impedance of typically 10kΩ



New microwave distance measuring equipment, the Tellurometer MRA5, indicates directly in metres and centimetres, operation being either fully automatic or manual at the choice of the operator. Measurement can be accomplished in less than 20 seconds.

Microwave Conference overwhelmed

The organizers of the fifth European Microwave Conference, which takes place September 1-4, 1975, at the Congress Centrum, Hamburg, have announced the list of papers that have been selected by their technical programme Committee and paper review board for this annual event. The response to the conference call for papers has been overwhelming. Over 350 papers from 30 countries were submitted and from those, a total of 112 will be presented at Hamburg. The papers will be grouped into 20 sessions and the morning sessions will be preceded by a total of nine specially invited state-of-the-art survey papers to be given by a number of the world's leading microwave experts. Papers will be presented in English and are limited to 15 minutes duration. A book of abstracts for the conference was published during May. Further information can be obtained from the organizers, Microwave Exhibitions and Publishers Ltd, Temple House, 34-36 High Street, Sevenoaks, Kent TN13 1JG.

TV deliveries down again

Deliveries to UK distributors of UK-made and imported colour television receivers reached 139,000 in March, a 26% decrease over March 1974 (188,000), according to the latest statistics compiled by the British Radio Equipment Manufacturers' Association. This brought the year's total to 475,000, a fall of 23% compared with the same period in 1974 (619,000). Total monochrome television deliveries for March were 63,000, a fall of 22% compared with March 1974. BREMA members delivered 65,000 audio stereo systems in the month, a fall of 10% compared with March 1974 (72,000). This brought the year's total to 192,000, comparable with 202,000 for the same period in 1974. Deliveries of radio receivers reached 351,000 for the month, bringing the year's total to 1,032,000, compared with 1,345,000 in 1974, a fall of 23%.

Briefly

IEA plus Electrex. The International Instruments, Electronics and Automation Exhibition running at Olympia since 1957 and the International Electrical Exhibition (Electrex) organised at Earls Court since 1953 are to be held as a combined event, short title IEA-Electrex, in 1976, at the new National Exhibition Centre, Birmingham.

VAT late extra. An itemized list of components on which specific agreement has been reached between HM Customs & Excise and the Electronic Components Board is now available. It is recognized that there may be some individual products to which the application of these definitions is not entirely straightforward. In such cases, an individual ruling will be given by Customs & Excise, the facts being initially reported to the Electronic Components Board.

Teletext

We plan to publish in the near future a short series of articles on the Teletext television information system, culminating in a design for a decoder for use with domestic receivers. Teletext is a unified version of the BBC's CEEFAX system (*Wireless World*, May 1973, p.222) and the ORACLE system developed by the IBA (July 1973 issue, p.314). Test transmissions were started by the BBC in September 1974 on BBC1, while a group of independent television companies (London Weekend, ITN and Thames) will be starting them in July 1975. The Teletext broadcasting standard was outlined in News of the Month, November 1974 issue.

Active notch filters

Design theory behind the development of discrete frequency rejection circuits

by Yishay Nezer, B.Sc.

We often need to separate a wanted signal from periodic interference. This may happen, for example, when a whistle or a power-line hum is disturbing a radio programme. In simple cases a filter which has zero transmission at one discrete frequency and unity transmission at all other frequencies is sufficient. In contrast to a practical low-pass or high-pass filter, an almost ideal notch filter can be realized with only one section; moreover it can be voltage tuned or even automatically track the interference.

The major class of notch filters, both passive and active, is of the second order and has the following transfer function:

$$G(s) = \frac{s^2 + \omega_0^2}{s^2 + \frac{\omega_0}{Q_0}s + \omega_0^2} \qquad (1)$$

where ω_0 is the rejection frequency and Q_0 is the figure of merit of the filter, which is given by $Q_0 = \frac{\omega_0}{\Delta\omega}$ where $\Delta\omega$ is the rejection bandwidth defined by the 3dB attenuation points. Some typical frequency response curves are plotted in Fig. 1 with Q_0 as the fixed parameter.

Many passive notch networks are known. This article will deal mainly with *RC* networks, since the use of coils is inconvenient, particularly at low frequencies. The best-known *RC* notch network is the symmetric twin-tee illustrated in Fig. 2(a), for this network $\omega_0 = 1/RC$ and $Q_0 = 1/4$. The function is, of course, realized only if the network is fed by a voltage source and subjected to an infinite load.

Another well-known notch network is the Wien bridge. This network is characterized by $\omega_0 = 1/RC$ and $Q_0 = 1/3$. The left side of the bridge shown in Fig. 2(b) is composed of equal resistors and capacitors and, in order to obtain an infinite null, the other two resistors must satisfy the relationship $r_1 = 2r_2$. The notch response, however, can be achieved even if the corresponding components in the reactive side of the bridge are not equal. The rejection frequency will then be $\omega_0 = 1/\sqrt{R_1R_2C_1C_2}$ but the ratio r_1/r_2 will no longer equal two. An important special case occurs when $R_1 = 2R_2$ and $C_1 = C_2/2$; we then have $r_1 = r_2$.

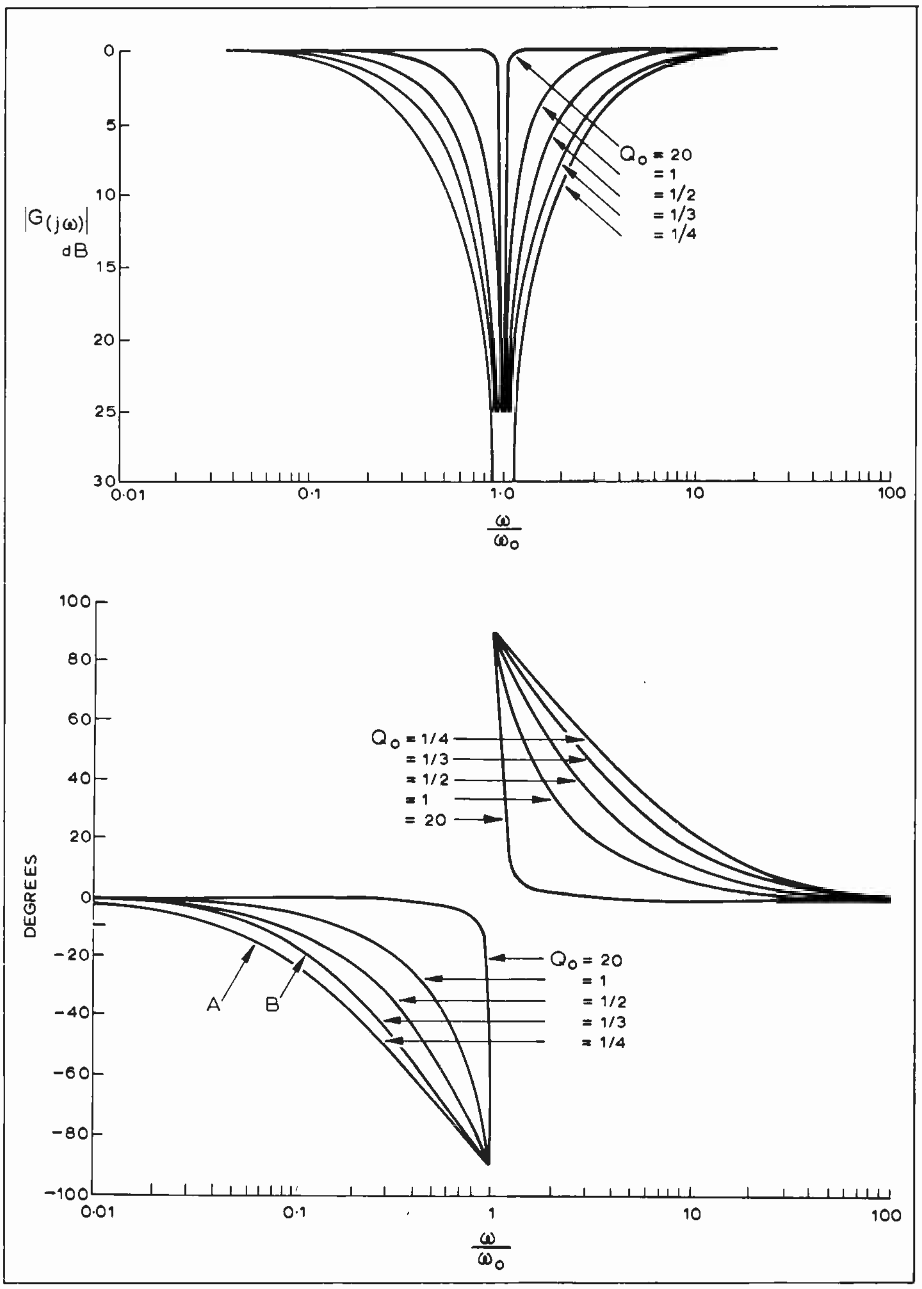


Fig. 1. Normalized phase and magnitude response curves of a notch filter for several values of Q_0.

A drawback of the above two networks is that in order to vary the centre frequency and still maintain the infinite null, two or three closely matching ganged variable components must be used. Several RC bridge networks are known in which a single component is sufficient to control the rejection frequency. However, their practical significance is limited because the frequency response becomes severely asymmetric as the rejection frequency is varied.

A more acceptable variable network was proposed by Hall[1]. It is shown in Fig. 2(c). This network can be tuned by means of a single potentiometer and the tuning law is $\omega_0 = 1/RC\sqrt{\alpha(1-\alpha)}$ which in theory spans the whole frequency range. In practice the tuning range is quite limited due to the extreme non-linear dependence of ω_0 on α. However, this network has unity gain on both sides of the null frequency, irrespective of the tuning.

However, unlike the twin-tee and the Wien bridge it is asymmetric on a logarithmic frequency scale. This follows from the fact that the transfer function of this network is not given by expression (1) but contains an additional real pole and real zero.

A similar potentiometer tuned null network based on the twin-tee was proposed by Andreyev[2].

All the networks discussed so far are characterized by low selectivity. In fact[3], no passive RC notch network, however complex, is capable of achieving Q_0 higher than 0.9. If the notch filter must be passive, a relatively high Q_0 may be achieved by including an inductance as in the bridged-tee network shown in Fig. 3. In order to achieve a complete null this network must satisfy the two conditions:

$$\omega_0^2 = C_1 + C_2/LC_1C_2 \text{ and}$$
$$\omega_0^2 = 1/rRC_1C_2 \qquad (2)$$

The figure of merit will then be $Q_0 = 2\omega_0 L/r$, i.e. proportional to the quality factor of the coil.

Active notch filters

As has been mentioned above, passive RC notch filters suffer from a low selectivity. A theoretically unlimited selectivity can be obtained by the use of active notch filters. These can be built by various active realizations of the transfer function given by expression (1). Simple active circuits are based on passive null networks in which the selectivity is raised by means of negative feedback.

One such scheme is shown in Fig. 4 and the effect of feedback can be explained as follows: When the feedback loop is open the network is simply a passive null network with a passband gain of A_0 represented by curve (a) in Fig. 5. When the feedback loop is closed, the network tends to maintain a voltage gain of $A_0/(1+A_0)$. However, it fails to do so where the forward gain is low, i.e. in the vicinity of ω_0. As a result, the response curve is compressed as shown in curve (b) and the rejection band is narrower. As an additional benefit, the active filter can now be cascaded without being subjected to loading.

The calculated transfer function of the active notch filter is:

$$G(s) = \frac{A_0}{1+A_0}\cdot\frac{s^2+\omega_0^2}{s^2+\omega_0 s/(1+A_0)Q_0+\omega_0^2} \qquad (3)$$

A different realization is shown in Fig. 6 which relies on a single, less-than-unity gain amplifier. It can be seen that there are two feedback paths in the configuration, a positive unity-gain feedback which renders the effective gain of the amplifier equal to $K/(1-K)$ instead of K, and a negative feedback which subtracts the output voltage from the input. If $K/(1-K) = A_0$, this method is equivalent to the former and the transfer function is:

$$G(s) = \frac{s^2+\omega_0^2}{s^2+\omega_0 s(1-K)/Q_0+\omega_0^2} \qquad (4)$$

in which the selectivity is multiplied by $1/(1-K)$.

Practical circuits

The simplest amplifier for the above method is the emitter follower. How-

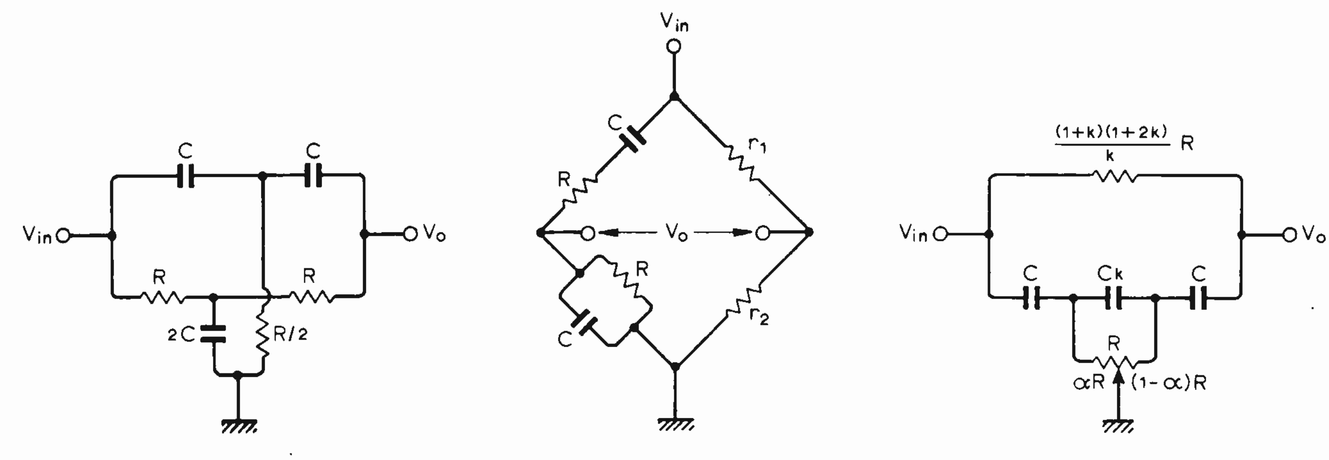


Fig. 2. Three RC null networks: (a) the symmetric twin-tee, (b) the Wien bridge, (c) a potentiometer-tuned network.

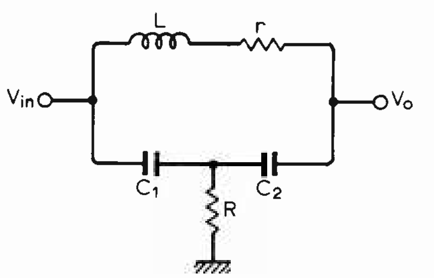


Fig. 3. Bridge-tee RCL null network, the selectivity of which depends on the Q factor of the coil.

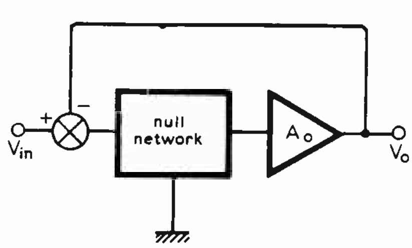


Fig. 4. Basic active configuration for enhancing the selectivity of passive notch filters.

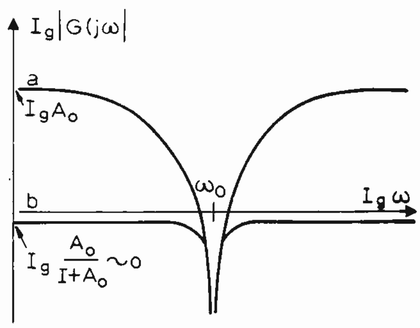


Fig. 5. Frequency characteristics of the network in Fig. 4 (a) open loop, (b) closed loop.

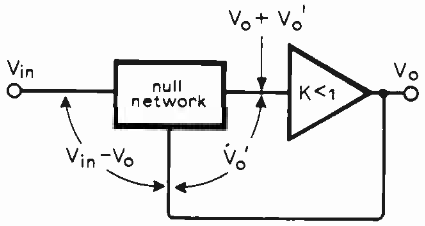


Fig. 6. Practical configuration for enhancing the selectivity of a passive notch network with a single voltage amplifier having a gain of less than unity.

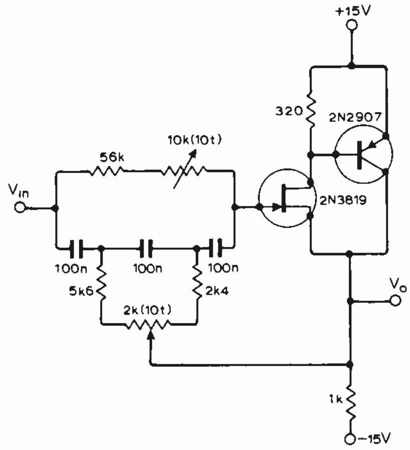
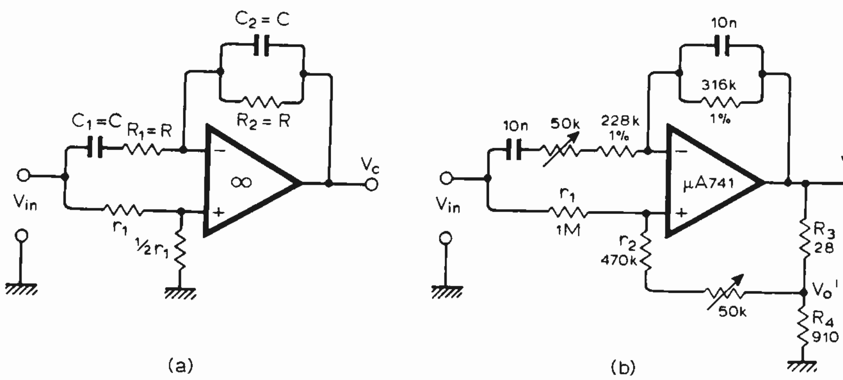


Fig. 7. Simple potentiometer-tuned active notch filter based on the network in Fig. 2(c). Tuning range 200 ± 10Hz; rejection bandwidth 10Hz (3dB).



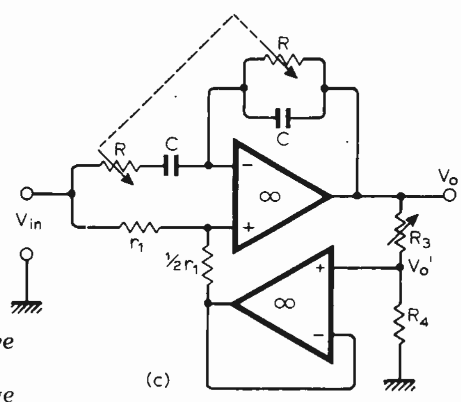


Fig. 8. (a) Wien bridge converted to a three-terminal network; (b) 50Hz active notch filter; (c) variable rejection frequency and bandwidth Wien-bridge active notch filter.

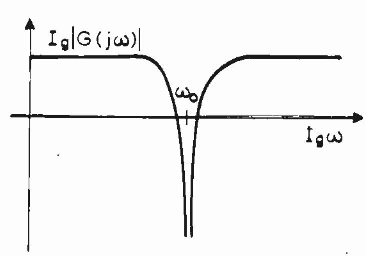


Fig. 9. Wider rejection bandwidth is attained by cascading two notch filters.

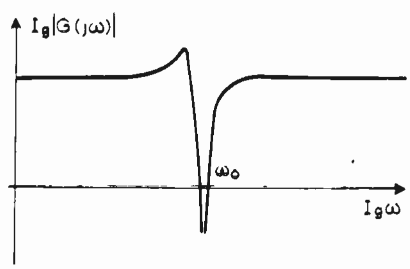


Fig. 10. Asymmetry in the frequency response curve of high Q notch filter as a result of excessive phase shift in the amplifier.

ever, it is not very suitable because in order to prevent the null network from being loaded by the relatively low-input impedance, the resistors must be relatively low and the capacitors must be correspondingly large.

It is obviously possible to replace the transistor by an f.e.t. and use smaller capacitors, but the increase in the selectivity would be limited due to the smaller gain usually associated with the f.e.t. The bootstrapped source follower benefits from high-input impedance and also a gain closer to unity and is shown in Fig. 7 together with the network of Fig. 2(c).

The networks discussed above have ideally an infinite attenuation at the notch frequency. Practically, the attention is limited by the tolerances of the components and is typically 40dB for 1% tolerance. This figure may be exceeded by trimming and is ultimately limited by stray capacitance.

The Wien bridge is attractive owing to its simplicity. However, it is not a three-terminal network, and cannot be activated directly.

The circuit in Fig. 8(a) is a Wien bridge built around an operational amplifier. In spite of being active, the factor of merit is only ½ instead of ⅓ in the passive bridge (it does not belong to either of the schemes shown in Figs. 4 and 6) yet, being a three-terminal network, its selectivity can be improved as shown in Fig. 6. Since the output impedance is already zero an additional buffer amplifier is unnecessary, so that we only have to decrease the gain to below unity by a voltage divider and close the feedback loop at r_2. The network Fig. 8(b) then contains an equivalent amplifier whose gain and output impedance are:

$K = R_4/(R_3 + R_4)$ and $R_3 \| R_4$ respectively. Accordingly, the latter value must be subtracted from r_2 or must be much smaller. Alternatively the voltage divider can be buffered as in Fig. 8(c).

If we use V_0 as the output of the filter instead of V'_0, an advantage results with respect to the network of Fig. 6, in that the passband gain is unity instead of K. However, as the internal amplifier's gain is $K = R_4/R_3 \times R_4$, the factor of merit will be

$$Q = Q_0/(1-K) = (1 + R_4/R_3)/2 \qquad (5)$$

and the rejection bandwidth can be varied by means of either R_3 or R_4. The null frequency can be varied, for example, by R_l and the notch depth can then be adjusted by means of r_2.

If it is desired to vary the rejection frequency over a wide range, it is best to vary simultaneously resistors R_l and R_2. If the tracking is good, the null will be maintained throughout the tuning range without further adjustments.

High Q notch filters

At a frequency $\omega = \omega_0(1 \pm \epsilon)$ close to the resonant frequency, that is $\epsilon \ll 1/2Q$, the response of a notch filter can be approximated by two

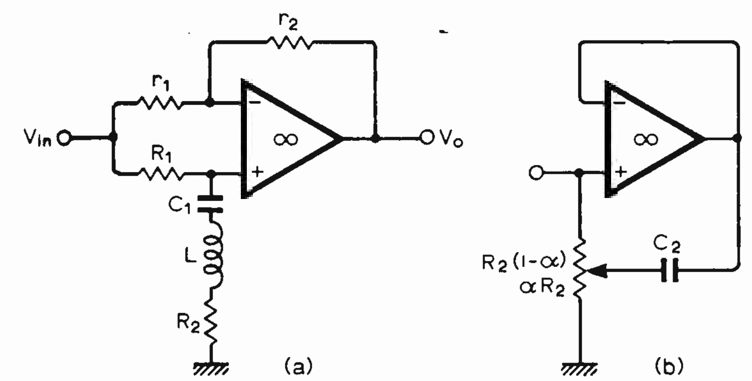
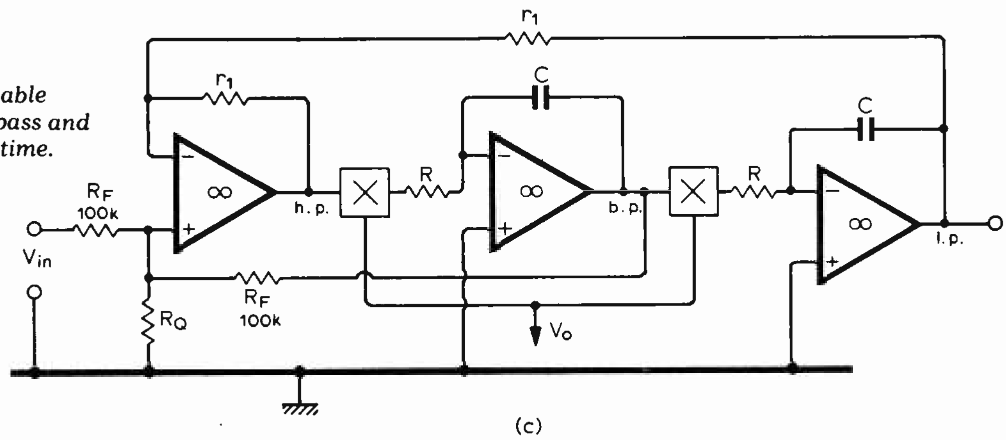


Fig. 11. (a) An active RCL notch filter; (b) a potentiometer-controlled simulated grounded coil.

Fig. 12. Programmed state variable filter provides low-pass, band-pass and high-pass outputs at the same time.



straight lines with slopes ±2Q, and the filter can be used as a frequency discriminator. If Q is large, very small frequency deviations can be observed. On the other hand, if a high Q notch filter is used to reject a power-line hum, for example, a slight deviation of the frequency from its nominal value will suffice to render the attenuation excessively low. In this case a filter with an infinite attenuation over a *band* of frequencies would be desirable. However, such a filter cannot be realized. It is then possible either to lower the Q of the filter or to stagger-tune two or more filters in cascade and obtain a frequency response as in Fig. 9. A more elaborate solution is to use an interference tracking notch filter as suggested in the last paragraph.

When dealing with high Q notch filters, the increasing sensitivity of the notch symmetry and depth to the tolerance of the passive components becomes a serious problem. A practical solution is to use stable capacitors and trim resistors for the required notch frequency and depth. It has been seen that the most suitable network from this standpoint is the Wien bridge, but for ultimate stability the state variable filter (see below) is required owing to its extreme stability.

Another problem in realizing high Q notch filters is the roll-off in the open loop gain of operational amplifiers at high frequencies. It is found that there is a limitation on the maximum possible Q which is inversely proportional to the rejection frequency. This limitation may cause asymmetric frequency response (Fig. 10), even if the values of the passive components are accurate. With the increase in Q, the size of the "the hump" increases to the appearance of oscillations. If the notch frequency is preset this can be rectified by adding an *RC* phase leading section at the input of the amplifier of Fig. 6 and experimentally adjusting the time constant. If the notch frequency must be variable, the only remedy is to use a wide bandwidth amplifier. However, at fairly high frequencies high Q inductors are available, and a passive filter such as the one in Fig. 3 may be preferable.

Simulated inductance

The circuit of Fig. 11(a) is an active bridge similar to that shown in Fig. 8(a), but has a series resonant circuit in one of its arms. If $R_1/R_2 = r_1/r_2$, the circuit will behave as a notch filter whose rejection frequency and factor of merit are

$$\omega_0 = 1/\sqrt{LC_1} \text{ and } Q_0 = \omega_0 L/R_2 \quad (6)$$

In order to avoid using an inductance, the series connection of R_2 and L can be replaced by the circuit of Fig. 11(b)[4] which is equivalent to a coil whose value is $L = C_2R_2\alpha(1-\alpha)$ in series with a resistor R_2. The resulting notch filter has a rejection frequency and factor of merit given by:

$$\omega_0 = 1\sqrt{C_1C_2R_2^2\alpha(1-\alpha)}$$
$$\text{and } Q_0 = \alpha(1-\alpha)\sqrt{C_2/C_1} \quad (7)$$

respectively; the tuning law is thus exactly the same as that of Fig. 2(c).

This network can also be tuned by means of C_1, which may consist of a small trimming capacitor if the simulated inductance is made appropriately large.

State variable filters

A unique active notch filter may be realized by the so-called state variable method[5]. This method is based on a multiple feedback network containing integrators and adders. In spite of the rather large number of operational amplifiers, the number of capacitors needed for the realization of any arbitrary transfer function is minimal.

The basic building block shown in Fig. 12 simultaneously provides three transfer functions of the second order; these are high-pass, band-pass and low-pass function, given by:

$$V_H(s) = Ks^2/(s^2 + (\omega_0/Q_0)s + \omega_0^2) \quad (8)$$

$$V_B(s) = K\frac{-\frac{1}{\tau_1}s}{s^2 + \frac{\omega_0}{Q_0}s + \omega_0^2}$$

$$V_L(s) = K\frac{\omega_0^2}{s^2 + \frac{\omega_0}{Q_0}s + \omega_0^2}$$

The resonant frequency ω_0 is determined by the time constants τ_1, τ_2 of the integrators, and is given by $\omega_0 = 1/\sqrt{\tau_1\tau_2}$. The factor of merit is $Q_0 = 1/K\sqrt{\tau_2/\tau_1}$ where $K = 1/(1 + R_F/2R_Q)$.

This configuration does not provide complex zeroes and in order to obtain the symmetric notch response given by expression (1) we must sum the high-pass and low-pass outputs. The filter obtained contains four operational amplifiers but has the following characteristics: if τ_2 varies, the rejection frequency is varied while the bandwidth $\Delta\omega = \omega_0/Q_0$ remains unchanged; if τ_1 and τ_2 vary simultaneously, the rejection frequency varies linearly while the factor of merit Q_0 remains unchanged; if K is varied with the aid of the resistor R_Q, the rejection frequency remains unchanged and the rejection bandwidth and gain alone will change; the network is quite insensitive both to the values of the passive components and to the gain of the amplifier. Its stability approaches that of passive filters.

The transfer function of a conventional integrator is: $G(s)=1/\tau s=1/RCs$ and the variation of τ can be obtained by varying R or C. If we connect an amplifier with a gain K in series with the integrator, the transfer function changes to $G(s)=K/\tau s$; i.e., τ is decreased without altering R or C. If an analogue multiplier is substituted for the amplifier, an integrator is obtained, in which the time constant τ is dependent on a control voltage. A notch filter with a constant Q and rejection frequency directly proportional to the control voltage can thus be built from two such integrators.

It has already been mentioned that the maximum Q factor which can be obtained in an active filter realization is limited – for a given resonant frequency – by the bandwidth of the operational amplifier. The state variable method is no exception to this rule. Design considerations resulting from these limitations were discussed by Thomas[6].

Bandpass filter synthesis

A common disadvantage which is probably shared by all accepted active bandpass realizations is that the bandwidth is inversely proportional to the midband gain; in other words an increase of Q is accompanied by a proportional rise in gain, which is often undesirable.

A different realization of bandpass filter is given in Fig. 13(a) based on the equation:

$$A\left(1-\frac{s^2+\omega_0^2}{s^2+\frac{\omega_0}{Q}s+\omega_0^2}\right)=A\,\frac{(s/Q).\,\omega_0}{s^2+\frac{\omega_0}{Q}s+\omega_0^2} \qquad (9)$$

which results in a bandpass transfer function whose midband gain is independent of Q. The configuration operates as follows: at frequencies which are remote from ω_0 the notch filter transmission is unity, and the input to the differential amplifier is zero. At frequency ω_0 the notch filter transmission is zero and the input to the amplifier is unity. As equation (9) shows, the resulting bandpass filter has the same Q as the notch filter. Now it is easy to realize notch filters in which the

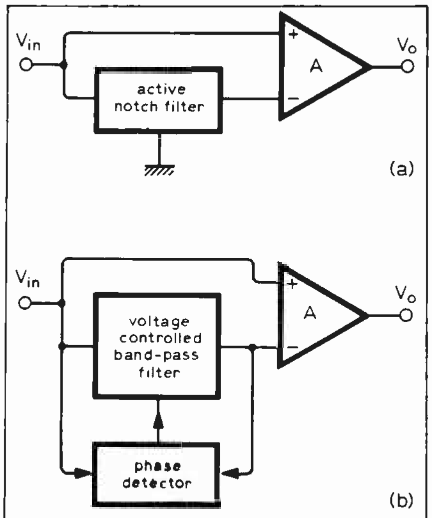


Fig. 13. (a) Realization of constant variable-bandpass filter through the use of notch filter; (b) tracking notch filter, for rejecting a drifting interference.

selectivity is controlled by a single resistor, such as the one shown in Fig. 8. If such a filter is incorporated, a constant-gain variable bandpass filter is obtained.

Interference-tracking notch filter

It has been previously mentioned that a sufficiently narrow-band notch filter may not be effective in rejecting interference which drifts in frequency. Such interference could in principle be tracked by a phase-locked loop, and the output of the loop, which is proportional to the frequency, then applied to a voltage-controlled notch filter. A drawback of such a method is that it is an open-loop system and any residual interference at the output due to imperfect tracking is not corrected for.

In contrast to the phase-locked loop, which is a signal-tracking oscillator, a signal-tracking band-pass filter can be easily built[7]. It is similar to the phase-locked loop and consists of a voltage-controlled band-pass filter, a phase detector and a low-pass filter. The closed loop then centres the band-pass filter on the signal by maintaining an (ideally) zero phase shift between the interference and the output of the filter. This bandpass filter can be converted to a signal-tracking notch filter as shown in Fig. 13(b), in which the filtered interference is subtracted from the original input. However, unlike conventional notch filters, the input to this filter must contain a minimum of interference for locking to occur.

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6. Thomas, Lee C., "The Riquad: Part 1 – Some Practical Design Considerations," *IEEE Transactions – Circuit Theory*, Vol. CT-18, No. 3, May 1971, pp. 350-357.
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Books Received

Dictionary of Data Processing by Jeff Maynard is designed mainly as a source of reference for those interested in, or using computers and data processing equipment. Over 4000 terms are defined, as well as acronyms and abbreviations, in alphabetical order. The final section of the book lists British and American standards relating to data processing. Price £3.90. Pp.269. Butterworth & Co. Ltd, Borough Green, Sevenoaks, Kent TN15 8PH.

Energy and Humanity edited by M. W. Thring and R. J. Crookes. as a former US Secretary of Commerce has pointed out, a finite world with finite energy resources cannot support an exponential growth rate. This book presents the problem as it exists now, with a view to what might be the situation at the turn of the century. An attempt has been made to cover the existing sources of energy along with their associated problems and to assess what might become available in the future. Much of the material has been drawn from an international conference on energy and humanity, held by the SSRS in September 1972. Price £5.50. Pp.195. Peter Peregrinus Ltd, P.O. Box 8, Southgate House, Stevenage, Herts SG1 1HQ.

Recent, updated additions to the **D.A.T.A.** books range cover discontinued thyristors, m.s.i.-l.s.i. memories, diodes, linear i.c.s., microwave tubes, digital integrated circuits, and thyristors. As usual these books provide information on components from most of the producers in the world. Outline diagrams are provided together with pin configurations, and an index of manufacturers is also incorporated making these volumes an invaluable source of information. London Information Ltd, Index House, Ascot, Berks SL5 7EU.

The International VHF-FM Guide by Julian Baldwin and Kris Partridge. This booklet is a useful source of information for the radio amateur who wishes to operate through the VHF repeater networks both at home and abroad. Price 25p + 5p postage and packing. Pp. 38. J. E. C. Baldwin, 50 Aldbourne Road, Burnham, Slough, SL1 7NJ.

Letters to the Editor

"HIGH QUALITY F.M. TUNER"

I was most interested to see that the position of the ceramic filter in Mr J. B. Dance's f.m. tuner (March issue) was after the limiting amplifier. Surely if the filter is to aid tuner selectivity then it must be placed before those parts of the tuner which have non-linear transfer characteristics, i.e. before the limiting amplifier.

Assuming that the input signal level is sufficient to cause limiting (as it should be for any usable signal) then any spurious signal components emerging from the r.f. unit outside the desired i.f. bandwidth will be subjected to intermodulation by the limiting process. Any intermodulation products which appear within the i.f. bandwidth will not be removed by subsequent filtering, but will affect the audio output. Consider, for example the case where one is trying to receive a weak signal in the presence of strong signals in adjacent channels. The output of the r.f. section may contain levels of the adjacent channels of similar or greater amplitude than that of the required signal. In this design the limiter may act on these adjacent channel signals so that these subsequently affect the audio output. Placing the i.f. selectivity before limiting will reduce the levels of unwanted signals entering the limiter, and reduce audible effects due to them.

Intermodulation in the limiter may explain the poor performance observed by the author on an r.f. unit with a high level of local oscillator output.

Note that some filtering after the limiter may be necessary to avoid harmonics of the 10.7MHz i.f. signal affecting the operation of the second mixer.

J. E. Marshall,
Bilborough,
Nottingham.

Mr Dance replies:

I am grateful to Mr Marshall for raising an important point. The NE563 limiter has a bandwidth of 22MHz (typical) and a gain of 60dB. The filter placed between the limiter output and the mixer will reject any noise which lies outside the required passband and will also attenuate any harmonics generated in the limiter.

If one wishes to have a tuner which provides optimum reception of weak signals in a crowded band, then additional filtering is required before the limiter. However, the front-end specified in my article contains a double tuned 10.7MHz circuit before the emitter follower output stage and I felt that the overall selectivity was adequate for normal domestic reception.

I did experiment with an additional FM-4 filter between the front-end and the limiter input. This involved the use of a matching resistor (270 ohm) between the front-end and the filter and a 330 ohm resistor on the output side of the filter. An active circuit is required between the filter output and the limiter, since the input impedance of the latter is quoted as 135 ohms. An active circuit providing gain will also improve the a.m. rejection. However, it seemed that the published circuit was satisfactory for domestic reception and I felt its simplicity would appeal to many readers.

With reference to Mr Marshall's penultimate paragraph, I did try an extra FM-4 filter with the front-end which gave unsatisfactory results, but I still did not obtain audio output of satisfactory quality.

Dr A. Tip of FOM-Instituut Voor Atoom-En Molecuulfysica, Amsterdam, has kindly sent me details of his unpublished work with a more complex system which he uses to receive many UK transmissions. Unfortunately only a few brief details can be mentioned here. Dr Tip employs a BFY90 amplifier by his aerial, and a Valvo FD1A front-end which feeds a 3028A variable gain cascode stage. Four ceramic filters are used, followed by a LM733 stage (set for a gain of 100); the latter feeds the NE563 limiter, The a.g.c. output from the NE563 is fed to a transistor amplifier which provides a.g.c. for the 3028A stage; the amplified a.g.c. also feeds a signal strength meter which is unaffected by the setting of the 563 muting circuit.

In conclusion, may I mention that the NE563 masks are being modified in California? The new NE563 devices will have a different oscillator impedance and should operate more reliably with the Taiyo CR-9.8 ceramic resonators mentioned in my article; the parallel 2.2kilohm resistor and 5pF capacitor should not be required with the new NE 563. In addition, Signetics expect the new device will produce an output with less distortion, but no figures are available at the time of writing. In their current data Signetics suggest a value of 5.1 kilohm for R_6 of my Fig. 1; this will give a slightly improved signal-to-noise ratio and a reduced bandwidth, but the difference is not very noticeable.

J. B. Dance,
Alcester, Warwickshire.

SILENT STEREO SWITCH

Mr Moulana's article in the January 1975 issue, involving the use of f.e.ts for audio switching, prompts me to raise a couple of points:

(1) Using a switching f.e.t at the virtual earth point of an inverting amplifier in series with the input arm (as shown in Fig. 1) ensures low voltage swings at the f.e.t. and takes care of biasing. This configuration is often used in audio equipment.

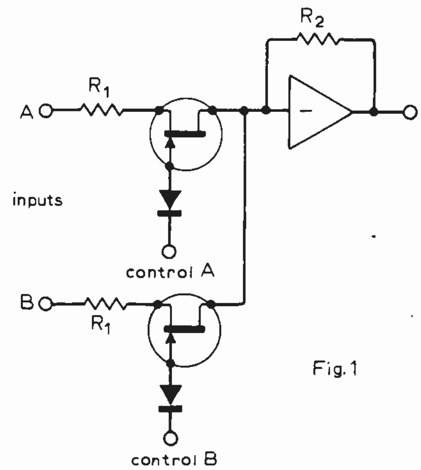


Fig. 1

(2) It seems reasonable that an f.e.t with a low value of r_{ds} *(on)* should have a variation in this resistance with v_{ds} that is also of a low order (in absolute, if not proportional terms). Thus if an f.e.t. such as a TIS73L (Texas) is chosen, which has an r_{ds} *(on)* of 25 ohms maximum, we can see that the variation in r_{ds} *(on)* can be quite small.

Suppose that in the circuit of Fig. 1 we use the TIS73L, and make $R_1 = R_2$ (for unity gain) = 10kΩ, then a variation in r_{ds} *(on)* of 20% (5 ohms) due to changing v_{ds} will give a rise to a distortion of approximately $5/10^4$, or 0.05%. Attenuation of the input signal by 20dB, and making $R_2 = 100k\Omega$ will obviously improve the distortion performance while retaining unity gain. Pinch-off voltage for the TIS73L is a maximum of −11 volts, therefore control voltages in the off mode should be at least −12 volts. Choice of input arm resistance can

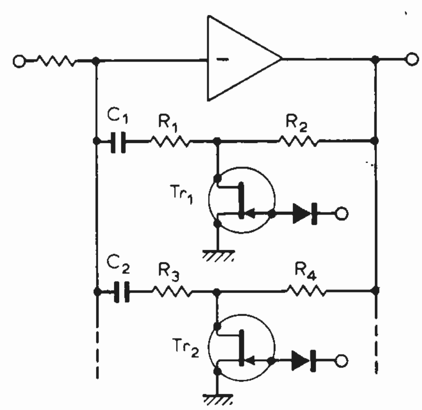


Fig. 2

optimize on/off ratio on the one hand, distortion and input impedance on the other.

As a postscript, a useful configuration when, for example, equalizations are to be switched, is shown in Fig. 2. In this circuit, using low impedance termination of the feedback networks at both ends, the required equalization time constant, $(R_1+R_2)C_1$ or $(R_3+R_4)C_2$ in Fig. 2, is selected by turning the f.e.t (Tr_1 or Tr_2 respectively) off, and all others on. Thus all feedback paths except that required are shunted to ground. If $R_{1, 2, 3, 4}$ are of the order of 100kΩ and Tr_1 and Tr_2 are TIS73L, attenuation of the unwanted f.b. is (25 + 100k)/25, greater than 70dB. Distortion is low because the selected f.b. path uses an f.e.t. in the "off" mode, and contributions from f.e.ts in the "on" mode are at very low level.

S. F. Bywaters,
London, N.W.11.

COMPUTER POWER

It is your privilege as editor to don the mantle of Cassandra from time to time; and we may have cause to be grateful to you for warning us (leader, May issue) of the latent threat of computer power.

Readers of your editorial may however care to join me as I hasten to bury my head in the sand. Or, as it might be, paper; since waste paper is the most obvious product of today's computers. What can be discovered in this mountain of paper is that a computer with remote terminal and interactive conversational language can take all the arithmetical grind out of hitherto laborious calculations in radio and electronics. And this generally involves only a minimal knowledge of computer programming – rather less, I suspect, than is currently mastered by schoolchildren. Indeed, readers who have no direct access to such computing facilities might well bribe sons and daughters to compute for them.

There is of course an additional bonus in speed and accuracy. For example, given the radio frequency range required together with the intermediate frequency, one can calculate component values for superheterodyne tracking to an accuracy much higher than the tolerances of actual components in less than five minutes. A similar time is required to plot the actual tracking error curve. If one then requires information on where the tracking curve moves to at the limits of specified component tolerances, another five minutes will suffice. Most of this total of fifteen minutes is spent by the system in organising itself and in printing — actual computing time may be only two or three minutes.

The story is very similar if one wishes to perform calculations on coupled tuned circuits – the complex arithmetic takes much less time than printing the (unneccessarily accurate) results.

Any reader who has problems with tedious calculations of this kind is welcome to contact me.

D. P. C. Thackeray,
Department of Chemical Physics
University of Surrey,
Guildford, Surrey.

ELECTRODYNAMICALLY INDUCED E.M.F.

"Cathode Ray's" article and Mr Meade's letter (February issue) have prompted some questions concerning a well known problem in school-boy physics:

"If an aeroplane flies a level course through a known vertical component of the earth's magnetic field, then its wings act as a flux cutting conductor and an e.m.f. is induced in them. Can this e.m.f. be measured and, hence, the speed of the aircraft deduced?"

The answer is, of course, no, because as "Cathode Ray" stated, connecting a voltmeter to the ends of the conductor (in this case the wings) would form a closed loop embracing a constant magnetic flux.

Not being well versed in the theory of electromagnetic induction, we would like to ask the following questions:

"Can the induced e.m.f. be measured if the meter leads are screened with a high permeability material?" and, naturally, "If not, why not?"

D. C. E. Todd and
N. G. S. Taylor,
Brunel University,
London.

DIRECTORY OF AUDIO COURSES

The Audio Engineering Society is preparing a Directory of educational facilities and institutions in its field of interest, which embraces sound recording and reproduction, instrumentation, sound reinforcement etc. This information will appear in the *Journal* of the AES and be included in a career booklet eventually to be prepared by the Society.

As the UK representative of the AES Education Committee, I have been asked to act as a focal point for the collection of such information from schools, colleges and universities in the British Isles.

To simplify the listings, I can supply copies of a short questionnaire and I would urge all organisers of courses related to audio engineering to apply to me for copies as soon as possible.

John Borwick,
Senior Lecturer,
Recording Techniques
University of Surrey,
Guildford,
Surrey.

INSTRUMENT READ-OUT IN BRAILLE?

I have recently become interested in the problems of teaching science to blind pupils. Present techniques offer analogue derived information in tactile or audible form. For example in typical science experiments one might wish to indicate the height of a liquid column or the reading of a meter. The liquid level would be located by a light probe whose audio tone would alter on discovering the surface; the meter pointer would be located either by the light probe or feeling the pointer in an instrument made specially for the blind. The actual reading is then taken from an adjacent Braille scale.

Of necessity these procedures are slow, clumsy and very approximate. It occurs to me that in the case of meter readings digital techniques could be exploited with considerable advantage. Many readouts are available in digital form – voltmeters, ammeters, frequency meters, multimeters, balances, calculators – and in many cases the electronics involves binary processing of numbers which in b.c.d. form is decoded for a visual readout such as a seven-segment device. Could not the b.c.d. be decoded direct to Braille format and used to operate a tactile display? It should be possible to devise an electromechanical Braille readout as only four pins are required as shown in the diagram. My guess, based on no direct experience, is that blind pupils would find the reading of electrical quantities more direct and so more meaningful. In the case of balances the accuracy of the weighing would certainly help science teaching. If it proved possible to use this idea with electronic calculator chips, perhaps a new era in teaching maths to the blind might follow also.

Recent progress in artificial vision, reported in your April issue, raises an even more powerful possibility, namely direct excitation of the optic nerve with numerical data. Whether this should be b.c.d., seven-segment, Braille, or some other format is a matter for speculation. Braille has already been used successfully (*WW*, April p.157) for text by this means.

J. M. Osborne,
London, SE5.

	b.c.d. DCBA	denoted by Braille letter	A B / D C	a binary equivalent of Braille
0	0000	J	⠚	0111
1	0001	, A	⠁	1000
2	0010	B	⠃	1001
3	0011	C	⠉	1100
4	0100	D	⠙	1110
5	0101	E	⠑	1010
6	0110	F	⠋	1101
7	0111	G	⠛	1111
8	1000	H	⠓	1011
9	1001	I	⠊	0101

Binary coded decimal compared with numbers in Braille.

Wireless World Dolby noise reducer

3 — Kit alignment and calibration

by Geoffrey Shorter

Intended mainly for hiss reduction in magnetic-tape recording machines, this noise reduction unit can be switched to decode commercially-available Dolby B-encoded cassette tapes, Dolby B-encoded f.m. radio transmissions (current in the USA), or to encode blank tapes from any source. As an alternative it can be used in trading some of the noise improvement for reduced distortion at peak recorded levels. Part 1 in the May issue gave background to the Dolby system and part 2 gave circuit and constructional details together with some suggestions for circuit options and alignment procedure. This part shows how to set-up the kit version design without using additional equipment and gives calibration procedure.

Constructors who build a Dolby-B processor without using the full WW kit have the option of using the power supply included in the circuit of Fig.12 or of using an alternative one, for instance one built into existing equipment. Component values for the circuit of Fig. 12 have been optimized to provide an overload margin of 16dB (equivalent to 1200nWb/m on open-reel) for a 15-volt supply, but voltages between 15 and 24 volts could be used provided component voltage ratings are chosen appropriately. The main requirement is that supply ripple be less than 200μV r.m.s. Current consumption at 15 volts is 20mA per processor; with IC_1 and IC_2 it is 30mA. The voltage regulator IC_2, whose output is 15 volts ±5%, is essential if the meter calibration oscillator of Fig. 14 is used. Input to the regulator should be not greater than 25V and not less than 18.25V.

Kit setting-up procedure

The procedure for setting up the kit design is a little more elaborate than the basic alignment instructions because it is designed to eliminate necessity for additional equipment i.e. a.c. millivoltmeter and variable-frequency a.f. oscillator. It therefore includes a facility for generating a 5kHz circuit alignment tone, as well as a 400Hz calibration tone. Two meter amplifiers, and a 580mV source (1kHz oscillator) to calibrate the meters, are included to obviate the need for an a.c. millivoltmeter.

In using the in-built meter scale in setting up, it is better to use close-tolerance resistors in an attenuator so that all measurements can be made at one meter reading (0dB). Errors in meter reading are minimized by this technique, and errors due to an inaccurate scale eliminated.

Right-channel meter calibration

The unit is aligned using part of IC_1 as a meter calibration oscillator. The amplifier section of IC_1 based on pins 10, 11 and 12 is first used as shown in Fig. 14. In this mode the amplifier is wired as an astable multivibrator switching between the 15V supply rail and 0V, with a mark-to-space ratio of about 1:1 and a frequency of around 1kHz. The real voltage swing is a little less due to saturation voltages, but is highly repeatable from one sample to another.

Typical performance

Noise reduction: better than 9dB weighted

Clipping level: 16.5dB above Dolby level (measured at 1% third harmonic content)

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

Signal-to-noise ratio: 66dB (20Hz to 20kHz, signal at Dolby level)

Approximate voltage readings (AVO 8)

	collector	emitter
Tr_1	9.0	0.6
Tr_2	14.3	1.5
Tr_3	7.6	rail
Tr_5	rail	7.6
Tr_6	—	8.8
Tr_7	8.4	rail
Tr_8	8.0	2.6
IC_1	pin 4	6.8V
	pin 5	7.7V

—Connect resistor R_{59} (3.9MΩ) from the pin at R_{51} to pin 2 or the L_2' position.

—Wire R_{58} (10kΩ) in parallel with R_{47} (1MΩ) across the pins at R_{47} position.

—Form an attenuator with R_{60} (110kΩ 2%) and R_{61} (10kΩ 2%) in series, Fig. 14, earthing the end of R_{61} by connecting to pin 3 of $L_2'$and connecting R_{60} to pin 1.

—Solder one end each of R_{55} (330kΩ 2%) and R_{155} (330kΩ) to their pins. Take the other end of R_{55} to the junction of R_{60}, R_{61} (R_{155} remaining floating). Switch on.

—Adjust RV_8 (Fig. 15) until the r.h. meter reads 0dB. Switch off.

—Remove R_{55}, R_{58}, R_{59}, R_{60}, R_{61} and do not alter the setting of RV_8.

Circuit alignment

The now-calibrated r.h. meter is used to set the gain and f.e.t. bias controls of both left and right processors with the help of a 5-kHz oscillator, Fig. 14, adapted from the 1-kHz oscillator circuit by using arrangement (b).

—Solder C_{30} in position, removing and replacing the p.c.b.

—Solder L_2 on to pins 1 and 2 of the L_2' position. Gently screw in the core.

Right-channel circuit alignment.

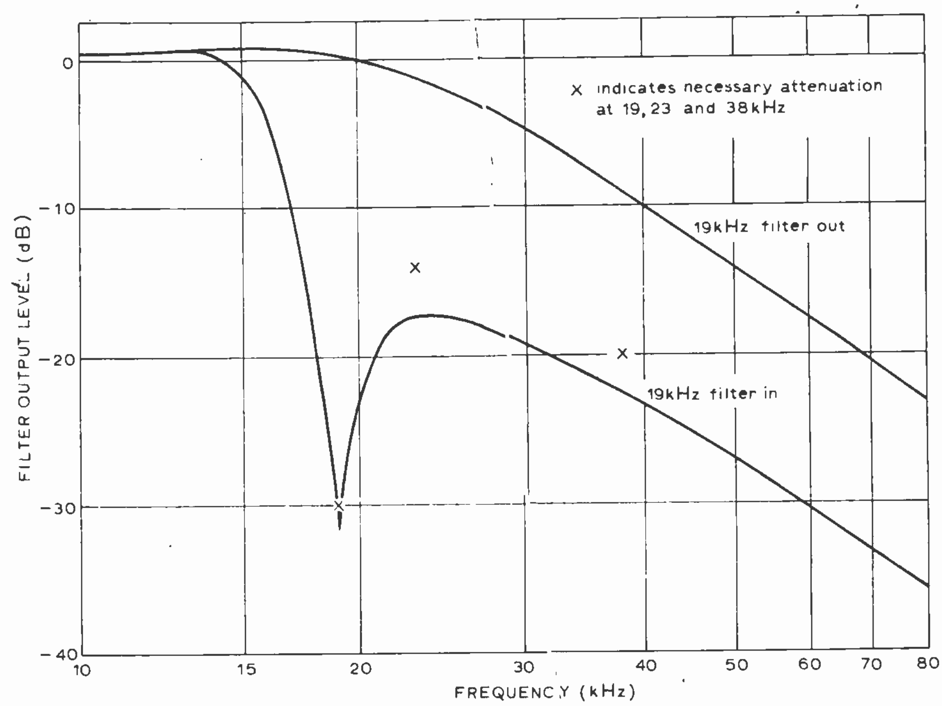
—Connect R_{61} (10kΩ 2%) between the R_{55} pin and test point 1 (TP1) on the sub-board.

—wire the oscillator pin, marked "osc." to the sub-board pin marked R′ (input to processor).

—Set RV_5 (oscillator level) fully anticlockwise. Check that no plugs are connected into the sockets.

Set $RV_{2,102}$ fully anticlockwise. Switch on.

- Select the auxiliary position for Sw_2. Set the balance control RV_9 to mid-position and the input level control RV_{10} fully clockwise.
- Ensure the calibration tone switch Sw_3, the noise reduce switch Sw_4, and the 19-kHz filter switch Sw_6 are in the off position (out), and the check tape switch Sw_5 is in the normal position (out).
- Check that the f.e.t. gates have previously been shorted to ground by two looped links.
- Turn the law control RV_1 fully clockwise to pinch-off f.e.t.
- Switch Sw_1 to record and adjust RV_5 until the meter reads 0dB (equivalent to 17.5mV at TP1). Switch off.
- Transfer the end of R_{61} from TP1 on the sub-board to TP2 and switch on. Meter should read within ±1dB of the previous, 0-dB reading. Note actual reading *. Switch off.
- Solder R_{62} (15kΩ 2%) and R_{63} (6.8kΩ) in series with R_{61} (i.e. between the R_{55} pin and TP2), decreasing meter sensitivity by 10dB. Switch on and check meter reading reduces by roughly two thirds.
- Switch on noise reduction, Sw_4 and adjust RV_2 (gain) to bring back meter reading to that noted above at *. Switch off.
- Cut the f.e.t. gate short for the right-hand channel with wire cutters and short-circuit R_{63} increasing meter sensitivity by 2dB. Switch on.
- Adjust RV_1 (law) until meter reads as noted above, at *. Switch off.
- Re-apply f.e.t. gate short and replace R_{63}. Switch on and check meter still reads as above, at *. Switch off. Remove gate short.



Amplitude response with and without 19kHz filter.

Encode/decode matching check.

- Switch Sw_1 to play and switch noise reduction off, Sw_4.
- Short-circuit R_{63}, leaving R_{61} and R_{62} connected. Set $RV_{4,104}$ fully clockwise. Switch on.
- Adjust 5-kHz oscillator output level control RV_5 until meter reads 0dB (equivalent to 44mV at TP2). Switch off.
- Switch noise reduction on, Sw_4. Short-circuit R_{62} and R_{63} so that only R_{61} is in circuit. Switch on. Meter should read 0dB to within ±1dB. Switch off.

Left-channel circuit alignment. Now repeat this process for the left channel, starting from the point of connecting R_{61} between the R_{55} pin, (not R_{155}) and the test point — now to be TP101 — on the sub-board. Note that the right channel meter, being calibrated, is still used in setting up the left channel, and that TP101 is to be read for TP1, TP102 for TP2, RV_{101} for RV_1, RV_{102} for RV_2, and that the left-channel f.e.t. gate-shorting loop is now implied. The "osc" pin is to be connected to the point L′ on the sub-board at the appropriate time.

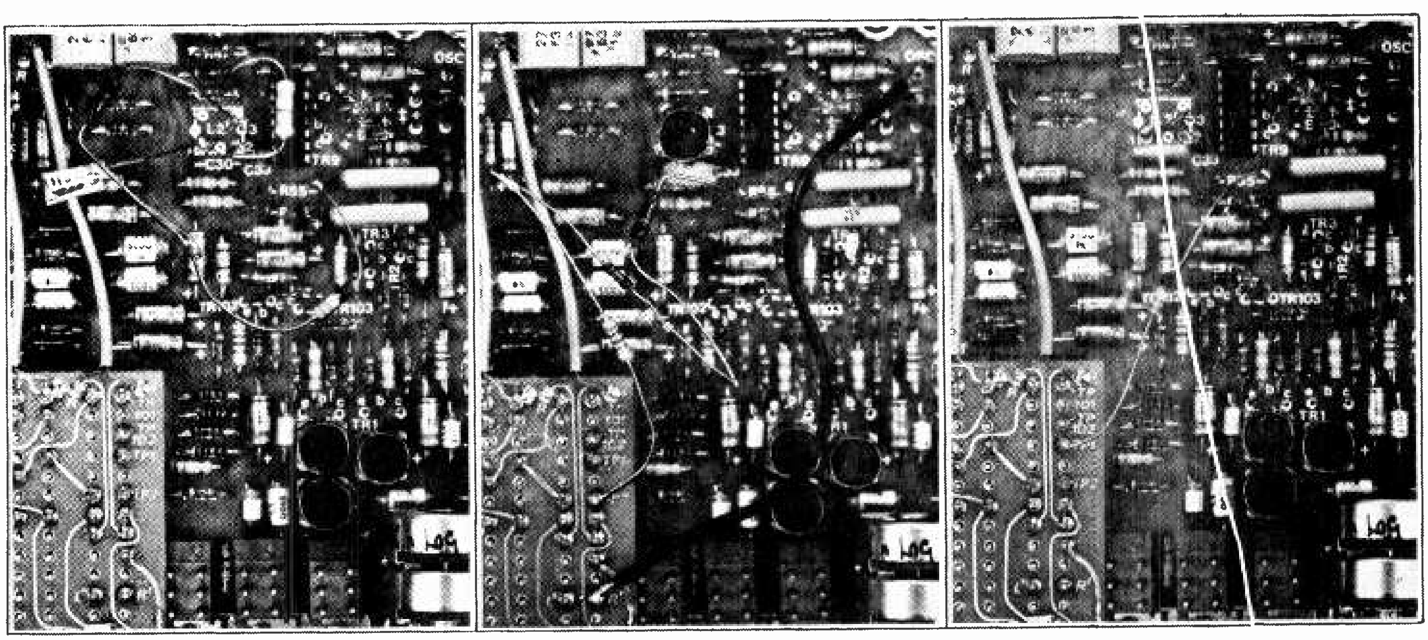


Fig. 18. First part in setting-up procedure for kit version (left) shows arrangement used in calibrating the right-channel meter. For aligning the noise reduction circuit the meter calibration oscillator is changed to a 5kHz oscillator, using L_2 temporarily in the L_2' position (centre). Its output, via the "osc" pin, is taken to the processor input (R′ for the right channel). To calibrate the 400Hz oscillator, L_2 is put in its normal position, the i.c. oscillator disabled, and the oscillator output taken from TP1 or TP101 (right).

After repeating for the left channel, switch off. The gain and law adjustments are now complete.

—Remove the f.e.t. gate shorts, R_{61}, R_{62} and L_2, inserting L_2 into its normal (final) location.

400Hz oscillator calibration

—Solder one end of R_{55} to its pin and connect the other end to TP1.
—Short pins 1 and 3† at the L_2' position, and remove the wire from osc pin to point L′. Switch on.
—Switch Sw_1 to record, press the noise reduce switch Sw_4 off and switch on the 400-Hz calibration tone oscillator, Sw_3.
—Adjust RV_3 (oscillator level) until the right-channel meter reads 0dB. Switch off.
—Transfer the end of R_{55} from TP1 to TP101 and switch on. Adjust RV_{103} until the r.h. meter reads 0dB.
—Repeat this procedure because of a slight interaction between RV_3 and RV_{103}. Switch off.

Left-channel meter calibration

—Disconnect R_{55} from TP101 and connect the free end of R_{155} to TP101 and switch on.
—Adjust RV_{108} to obtain 0dB at the left-channel meter, being careful not to disturb RV_8. Switch off the cal. tone oscillator. Switch off.

†Experience has shown that a better method of disabling the 5kHz oscillator is to remove R_{47}.

19kHz filter adjustment

–Wire R_{155} permanently onto the main board, replace R_{55} with R_{61} and connect free end to TP1.
–Connect an f.m. stereo tuner to the auxiliary input and with the aux-tuner links wired in, switch on and tune to a BBC stereo test transmission.*

Alternatively, if a high accuracy (±50Hz) 19kHz oscillator is available, connect its output to point R′ on the sub-board.

–With zero a.f. modulation,* adjust the record level control RV_{10} to give a 0dB meter reading. Switch the 19kHz filter on, Sw_6.
–Adjust L_2 for minimum reading on the right-channel meter. Do not adjust L_1 or L_{101}. Increase record level for sharper null near tuning point.

Repeat for the left channel starting by transferring end of R_{61} from TP1 to TP101, and adjusting L_{102} for minimum reading. (In using a 19kHz oscillator, connect to point L′ on the sub-board and transfer R_{61} lead from TP1 to TP101 before adjusting L_{102}.)

Calibration

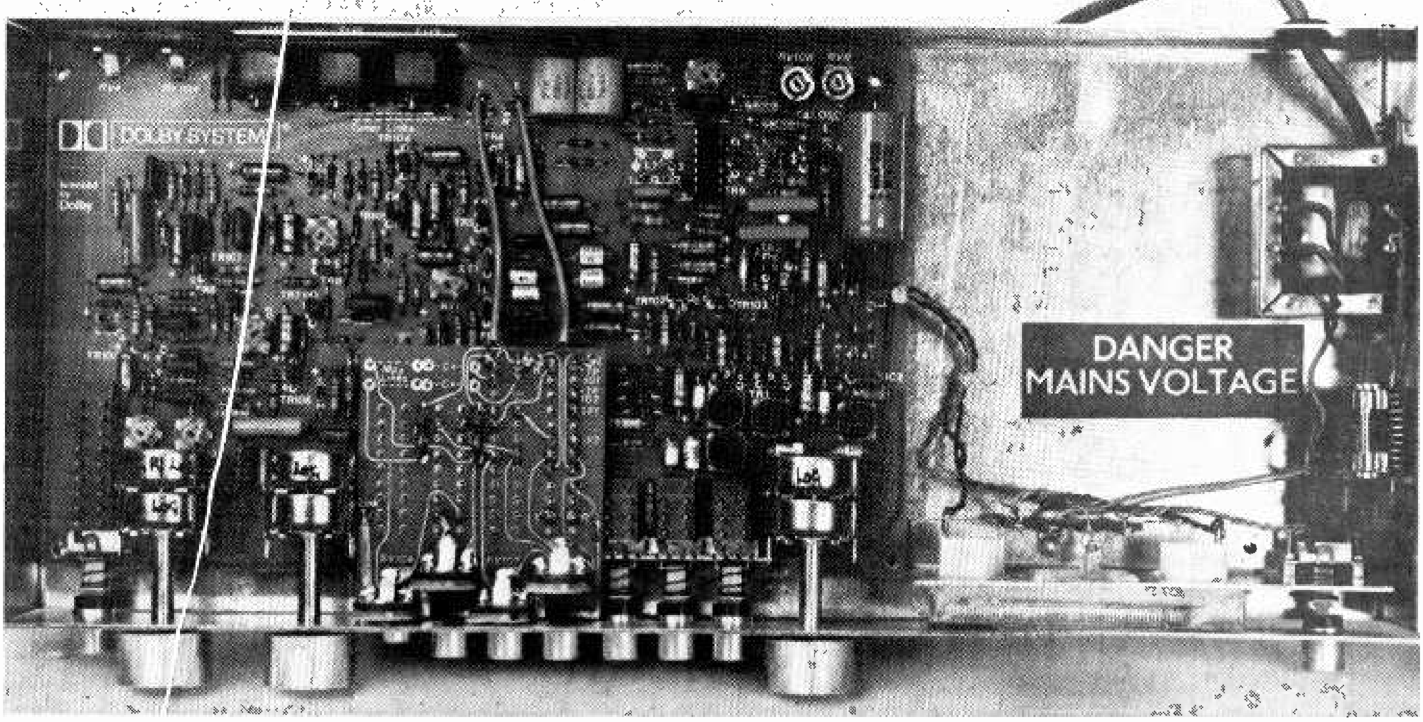
To ensure interchangeability of all Dolby B-encoded tapes and of Dolby B-equipped machines, the voltage levels in the processors must be related to flux levels on the tape. A certain amplitude level is used that bears a fixed relationship to the noise reduction parameters and to conditions between encoder and decoder. The level chosen corresponds with a flux on open-reel tapes and cartridges of 185nWb/m, with 200nWb/m for cassette tapes, with a deviation of 37.5kHz on f.m. transmissions, and with a voltage level at the processor output of 580mV r.m.s.

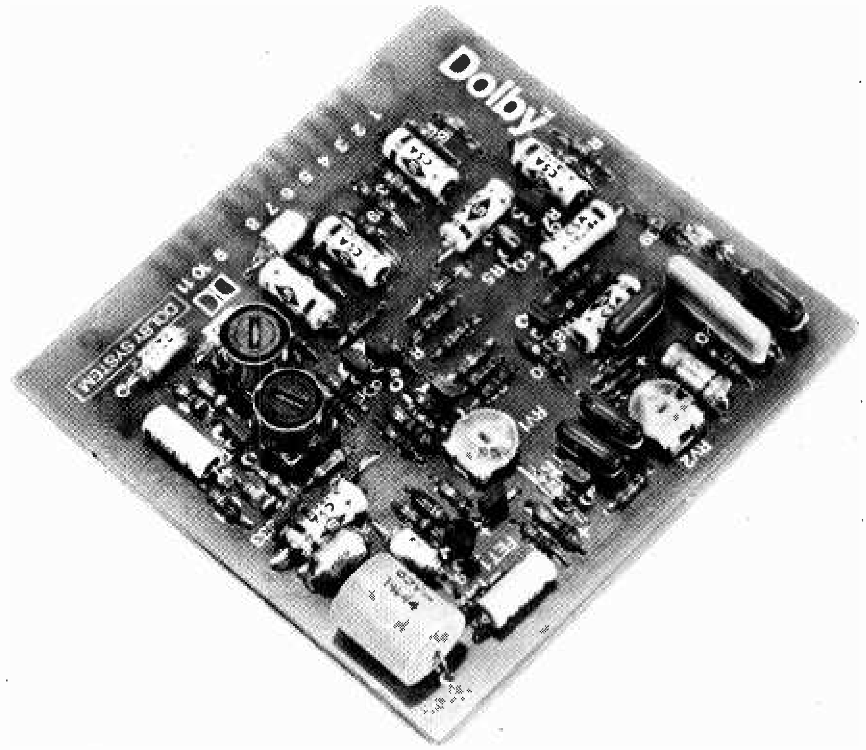
This level, often called Dolby level, should not be taken to imply an operating level. If the level-setting meters in the unit are to be used as modulation-depth meters, a mark may be made on the meter to indicate the reference level. Whilst setting this level equal to 0VU on meters can often lead to reasonable modulation depths, this is not always the case: for cassette recorders it is best set at +3VU.

The 400Hz oscillator and tapes recorded with a 400Hz tone to the above level are used in calibrating units, once the circuitry has been set up. When playing or recording the standard flux level, the 580mV level is set by adjusting the play calibration potentiometers during play, and the record calibration potentiometers during recording.

Playback-only decks and units. As the signal levels on encoded tape cassettes are to be related to those in the decoder during playback only, the 400Hz oscillator is not required and calibration is achieved with a calibration cassette, containing the reference flux.

* Stereophonic test transmissions are broadcast about four minutes after the close of Radio 3 programmes on Mondays and Saturdays. The zero a.f. modulation part occurs about 11 minutes after the start and lasts for nearly two minutes.





An alternative to the kit design is this single-channel processor, using the circuit of Fig. 12 but excluding power supply, alignment and calibration circuitry. (Track diagram will be given in a subsequent issue.)

— Switch noise reduction off.
— Play calibration tape. Set play gain control on tape deck to 0VU on deck meter, if possible, or to mid-position otherwise.
— Adjust play cal. control for 580mV on meter or Dolby level indication, depending on meter used.

Playback gain controls on the recorder in the signal path en route to the processor input should not now be disturbed.

Switchable encode/decode processors.

Playback calibration

— Switch to play and switch off noise reduction. Connect millivoltmeter to point G if meters not built-in.
— Play calibration tape. Set play gain control on tape deck if fitted to 0VU on deck meter, if possible, otherwise to mid-position.
— Adjust play cal. control for 580mV indication.

This completes playback calibration and the play gain controls on the tape deck should not be altered. Adjust listening level with the output level control following the decoder output (as in Fig.13).

Record calibration

Start by setting record gain control on tape deck to mid-position, if fitted. (If combined with playback gain, do not adjust.)

— Switch to record.
— Fit blank tape (as recommended by maker or for which bias is correctly adjusted) and feed in 400Hz at points from external or internal oscillator. (If unit has been built into cassette machine and 400Hz input is via line input socket, adjust record level control so that meter reads 580mV, or Dolby level.)
— Record on tape for a few seconds, rewind and playback, switching to play on the noise reduction circuit as well as on the deck. Note whether meter shows about or below 580mV, or Dolby level.
— Make small adjustment to record cal. controls in appropriate direction and record 400Hz tone again, observing meter reading on playback. Repeat this procedure as many times as necessary to obtain correct reading.

This completes record calibration for tapes. If the circuit of Fig.13 or similar has been adopted, recording level is adjusted with record balance and level controls on the noise reduction unit, the level being judged by the tape deck's normal meters.

When the noise reduction unit is connected to a three-head machine with a simultaneous monitoring facility the tape signal may be monitored in its encoded form by operating the check tape switch.

Simultaneous encode/decode circuits. Constructors with three-head machines having a simultaneous monitoring facility can use single-processor boards permanently wired in the encode and decode modes. If provision for encoded f.m. transmissions is required switching must be arranged so that encoding does not take place during recording. A monitor switch can be provided at the input to the decoder, to switch from tape, via a play cal. potentiometer, to source i.e. a connection to the encoder output via a 580-30mV attenuator, Fig 19.

Playback calibration procedure is as above, but record calibration is simplified.

— Set record level controls on tape recorder to mid-position. Set monitor switch to tape.
— Record on blank tape, operating the calibration tone switch or injecting a 400Hz tone from an external oscillator.
— Adjust record cal. control so that meter reads 580mV, or Dolby level.

FM calibration. If you wish to set the controls for encoded f.m. transmissions, currently being transmitted by stations in the USA, an approximate calibration can be achieved by tuning to a local station, switching to f.m. or Dolby f.m. and setting the f.m. cal. control to give meter readings similar to those obtained when playing pre-recorded tapes. More accurate adjustment can be obtained if a station can be received which transmits the 400Hz calibration tone, identified by a characteristic warbling, or alternatively by using an f.m. generator. In this last-mentioned case, modulation frequency should be set to about 400Hz with a peak deviation of 37.5kHz (not including pilot tone).

Change of time-constant for encoded f.m. transmissions

There are two commonly used pre-emphasis time constants, 50μs and 75μs. Under certain conditions, these values can lead to reduced modulation at low and medium frequencies or severe amplitude distortion at high frequencies. In the USA the FCC has approved Dolby Laboratories' proposal of using 25μs for encoded transmissions, and to receive such broadcasts it is necessary to alter the de-emphasis time constant. In the circuit of Fig.13 this is achieved with components R_x and C_x, values being given in the components list on page 259 (June) for the change from 75 to 25μs and for a change from 50 to 25μs (not yet authorized in 50μs countries). When recording such broadcasts the encoding function of the noise reduction unit is clearly not required and the "Dolby f.m." switch position automatically switches off the encoding function. Application of the Dolby B system to f.m. broadcasting is discussed in two articles in the *Journal of the Audio Engineering Society*, June 1973, pp.351-62, and briefly in the July 1974 issue of *Wireless World*, page 237.

—Tune in to whichever of these signals is available.
—Switch to record, and to either f.m. or Dolby f.m.
—Adjust f.m. cal. control so that meter reads 580mV, or Dolby level.

Using the unit

The calibration procedures described theoretically apply to the one tape speed used during calibration. Whether the calibration will hold for different tape speeds depends on the design of the deck, so check calibration when speed is changed. The calibration tape available can be used at 4.75 and 19cm/s, as well as 9.5cm/s. (For 38cm/s tape speed, where the noise spectrum is wideband, applying the B-type system may result in the remaining mid and low-frequency noise becoming more apparent). When the brand of tape is changed it is usually necessary to readjust the record cal. controls, the play cal. setting remaining unchanged. The characteristics of cassette tapes are more critical, and changing brand will normally require adjustment of bias (and equalization when using CrO_2 tapes).

When the unit is connected to the normal input and output points of a tape recorder, the recorders own input and output controls from part of the calibrated system. The settings used during calibration should not be disturbed, input and output level controls being provided on the noise reduction unit, and it is a good idea to mark the tape recorder control settings.

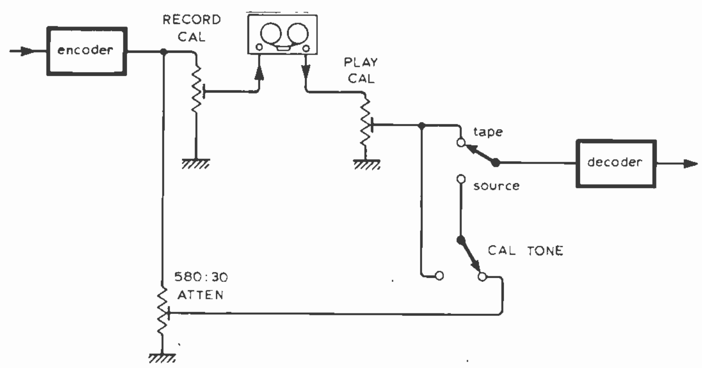


Fig. 19. Monitor switch arrangement for permanently-wired processors in three-head machines.

The amplitude response of the tape recorder must be flat and its gain unity, measured between point G of the processor in record and play, to ensure correct operation, so that the signal voltage in the decoder is the same as that at the encoder (to within 2dB). If there is a bandwidth restriction between encoder and decoder, e.g. if the response of the recorder does not extend up to at least 10kHz, a non-complementary situation arises, unless of course the encoder input bandwidth is similarly limited.

In using the unit don't forget that it will only reduce noise generated after the encoder and before the decoder. If the input signal is noisy in itself or is made noisy by poor circuitry prior to encoding, this noise will be reproduced unaltered along with the signal. In some cassette decks, the line inputs are attenuated prior to amplification by a sometimes noisy microphone pre-amplifier.

As the sensitivity of the processor is of the order of 30mV, a line input amplifier is not required when the circuits are built into a tape recorder, and the input signal should be taken directly to the input gain control via a switch, or socket with switch, to disconnect the microphone pre-amplifier. It's a good idea too to make sure any automatic level limiter operates only in the microphone input and not in the line input.

Complete kits for the *Wireless World* Dolby B noise reducer are available through the address given below. The two-channel design features:
- a weighted noise reduction of 9dB
- switching for both encoding (low-level h.f. compression) and decoding
- a switchable f.m. stereo multiplex and bias filter
- provision for decoding Dolby f.m. radio transmissions (as in USA)
- no equipment needed for alignment
- suitability for both open-reel and cassette tape machines
- check tape switch for encoded monitoring in three-head machines

The kit includes:
—complete set of components for a stereo processor
—regulated power supply components
—board-mounted DIN sockets and push-button switches
—fibreglass board designed for minimum wiring
—solid mahogany cabinet, chassis, two meters, front panel, knobs, mounting screws and nuts.

Price is £43 inclusive.

A single-channel printed-circuit board, with f.e.t. costs £2.50 and £8.63 with all components inclusive (excluding edge connector, £1.37 extra). Selected field-effect transistors cost 68p each inclusive, £1.20 for two and £2.20 for four.

Calibration tapes are available, costing £1.94 inclusive for 9.5cm/s open-reel use and for cassette (specify which).

Send cash with order, making cheques payable to IPC Business Press Ltd, to:
Wireless World noise reducer
General sales department
Room 11, Dorset House,
Stamford Street
London SE1 9LU
Allow three weeks for delivery.

A 50 MHz oscilloscope

3 — E.h.t. oscillator, power supply and tube circuit

by C. M. J. Little, B.A.

Department of Electronics, Southampton University

The requirements of the c.r.t. are a negative supply of 1kV with a current capability of 2mA at maximum brilliance, and a positive supply of 3kV, at a current of 50μA. The e.h.t. supply must be stabilized in order to avoid changes in X and Y plate sensitivities with brilliance. Some oscilloscope designs use mains-derived e.h.t. and rely on the large current capability of the supply to avoid changes in voltage with loading. There are two major disadvantages of this system. First, the need for large-value smoothing capacitors, and second, the danger of lethal electric shock. This design uses the alternative, which is a transistor inverter operating at about 20kHz. Smoothing is easy at this frequency, and feedback stabilization can be used.

E.h.t. generator

The circuit is shown in Fig. 11. Tr_{82} and Tr_{83} form a current-switched class D oscillator. This type of circuit produces a sine wave, but has the high efficiency usually associated with square-wave inverters. The transistors act as switches with, ideally, zero voltage across the transistor for half the cycle. The waveforms are illustrated in Fig. 12. L_7 provides a constant current at the frequency of oscillation, and is uncritical as to exact value. The criterion is that its impedance at the working frequency should be large compared with the static resistance of the oscillator (supply voltage divided by supply current). The output voltage of this type of oscillator is very dependent on load.

The transformer T_2 resonates with its stray capacitance at about 18kHz. The secondary winding steps up the voltage to about 1.5kV peak, which is rectified to give − 1kV d.c. and voltage trebled to give about +3kV d.c. The loading on the negative peaks is much greater than that on the positive so the trebler gives a higher voltage than one would expect. The feed to the stabilizer is taken from C_{128} in order to avoid including the extra

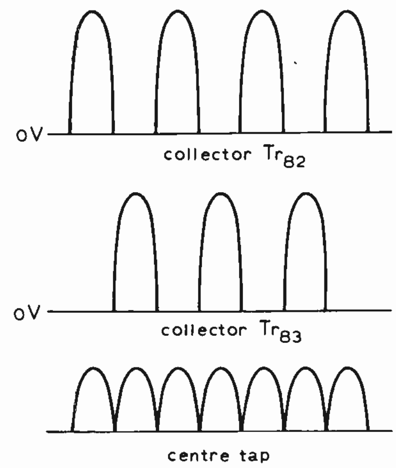
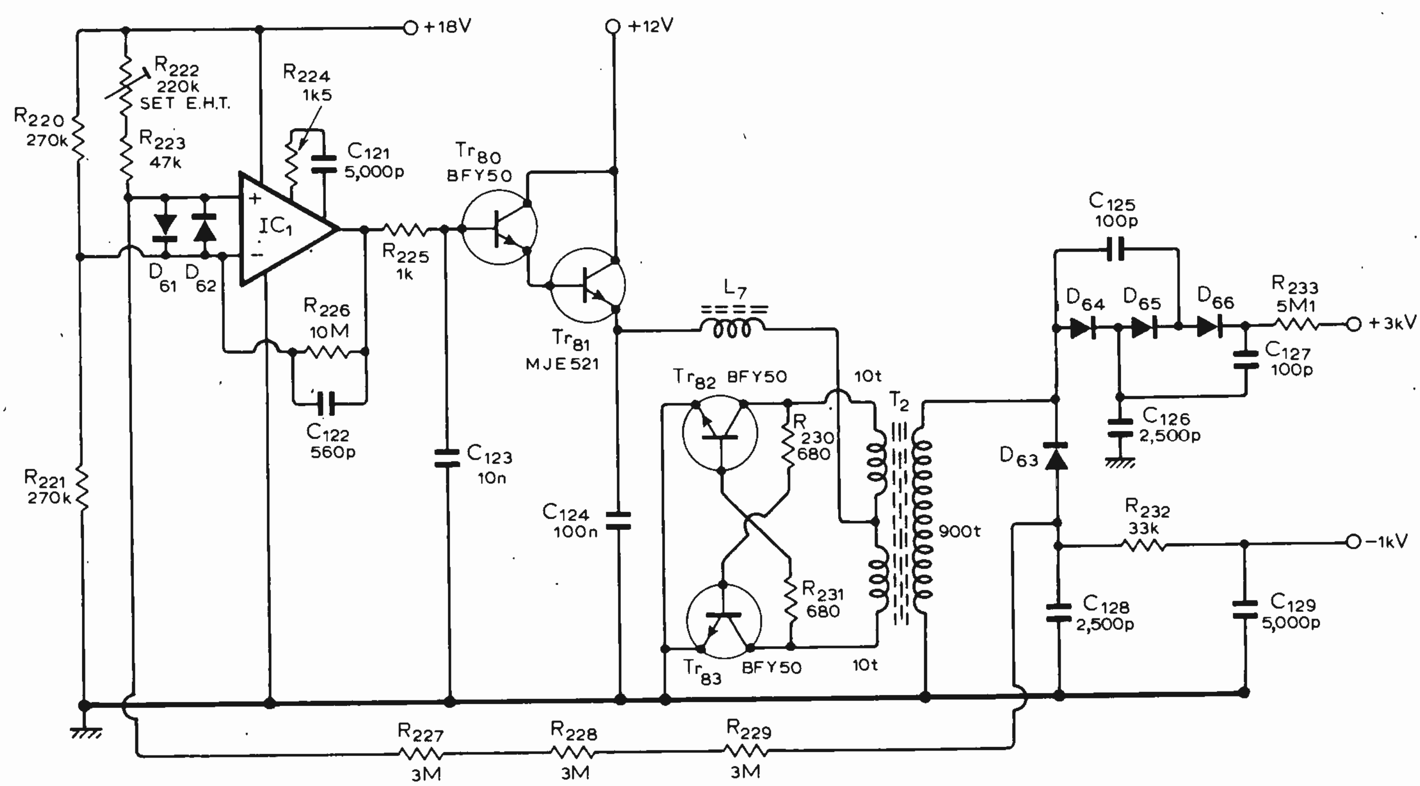


Fig. 12. Waveforms in the e.h.t. class D oscillator.

Fig. 11. The e.h.t. generator.



pole R_{232} and C_{129} in the feedback loop.

The error amplifier is an integrated operational amplifier with current multiplication provided by Tr_{80} and Tr_{81}. The amplifier is used in non-inverting mode and the negative e.h.t. is compared with the 18V rail. R_{226} and C_{122} provide a dominant pole at 30Hz. The gain at 50Hz is high enough to eliminate mains hum from the e.h.t. voltages. If a 741 type of amplifier is used instead of a 709, R_{224} and C_{121} may be left out. C_{124} is probably unnecessary and could be left out, as the effect of C_{123}, Tr_{80} and Tr_{81} will be equivalent to a large capacitor at this point.

C.r.t. and blanking

The circuit associated with the cathode ray tube and the blanking amplifier are shown in Fig. 14. Before considering these, I would like to make some comments regarding the c.r.t. used in the instrument.

Of all the parts in an oscilloscope, the c.r.t. is the most critical, and the choice of tube will affect the performance that it is possible to obtain, and also the circuit techniques used. For these reasons I chose a currently available c.r.t. of modern design, instead of trying to find a surplus tube that might be satisfactory.

The c.r.t. specified has many modern features, such as a flat rectangular screen, built-in parallax-free graticule, spiral p.d.a. (post deflection acceleration) and high deflection sensitivities. It also has a second grid so that retrace blanking may be applied at earth potential. This greatly simplifies the blanking amplifier.

The penalty to be paid for this high performance, of course, is cost. The c.r.t., Mumetal shield, and base will cost about £40. For those readers who would otherwise hurriedly stop reading this article, I will now give some suggestions for possible use of surplus tubes.

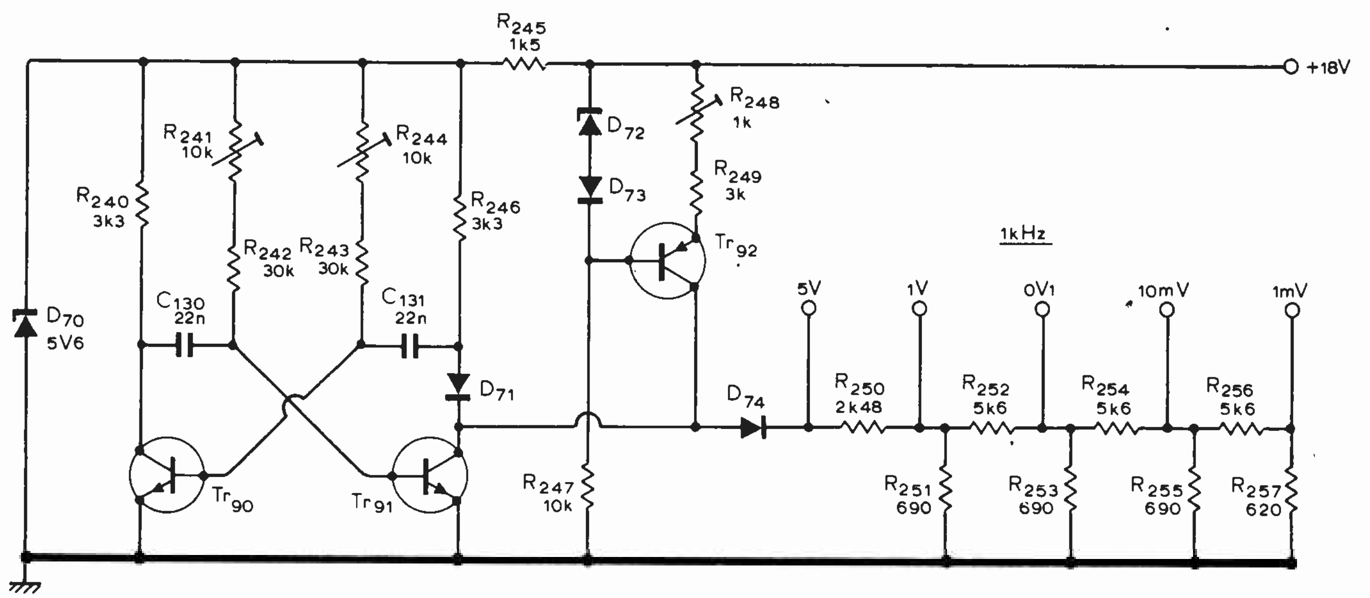


Fig. 13. The square-wave amplitude calibrator.

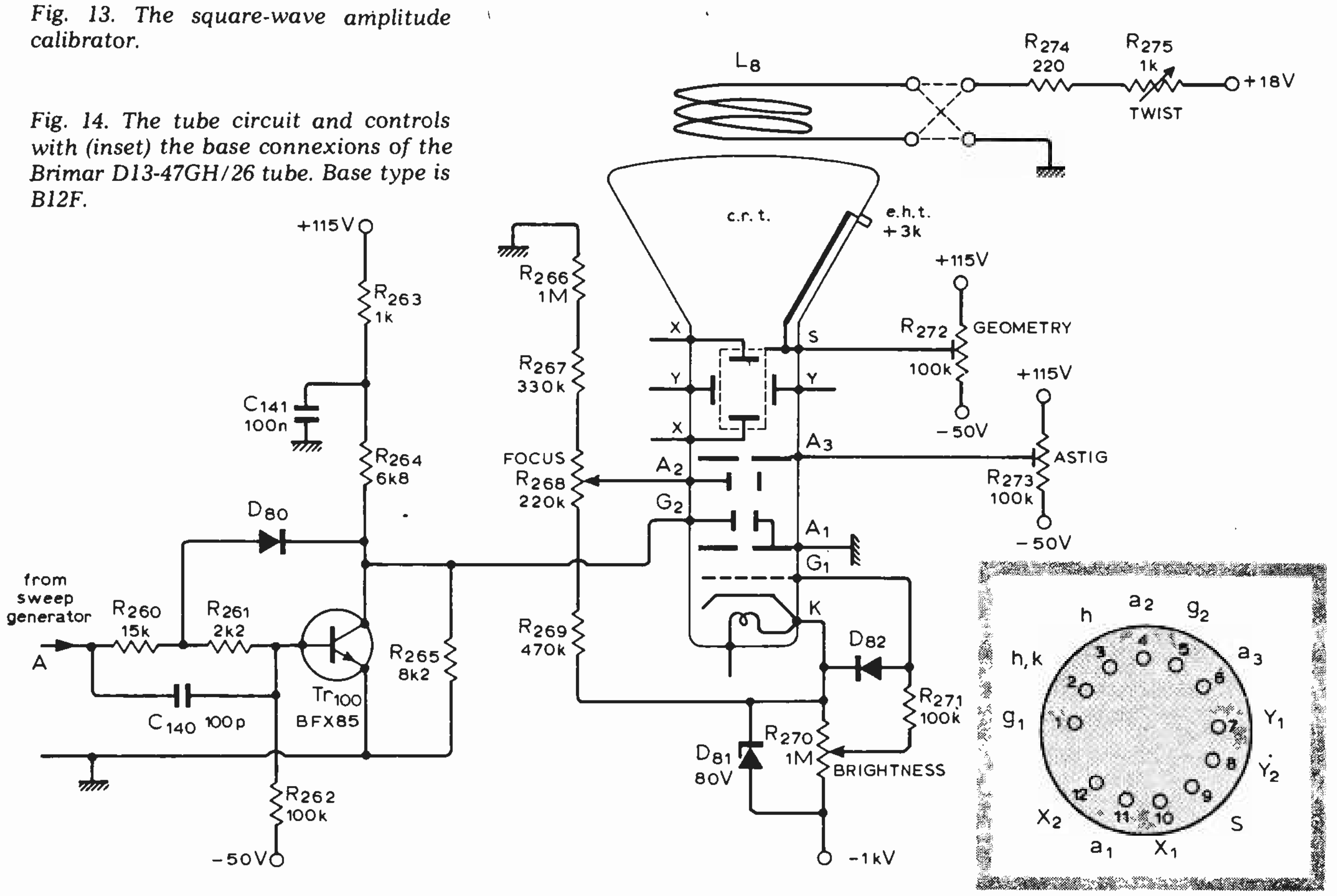


Fig. 14. The tube circuit and controls with (inset) the base connexions of the Brimar D13-47GH/26 tube. Base type is B12F.

Surplus p.d.a. tubes sometimes come on the market, and it is possible that a suitable one may be found. To aid bargain hunters, I have included, in Table 1, extracts from the manufacturers application data giving the main details of the c.r.t. The most important characteristics are the X and Y plate sensitivities, and it is necessary to use a tube with, at worst, sensitivities of 2/3 of these figures. If this is not adhered to, complete redesign of the amplifiers will be necessary. E.h.t. and other voltages are not usually so critical. If a tube is found that does not possess a second grid for blanking, but is otherwise satisfactory, a circuit similar to Fig. 15 may be used.

An additional winding on the e.h.t. transformer is used to provide a floating supply of about 1.2kV. This is used to add a sufficient negative voltage to the output of the blanking amplifier to come within the required range of brilliance control voltages on the grid. The blanking amplifier needs an additional inverting stage to maintain correct polarities. Apart from these ideas I can provide no other information on other c.r.t.s, and any constructor who tries some other tube must make his own decisions.

To return to Fig. 14, D_{81} provides a negative voltage of 80V w.r.t. the cathode for the brilliance control. D_{82} is a safety diode to ensure that the grid cannot go positive with respect to the cathode. L_8 provides an axial magnetic field for alignment of the horizontal trace with the internal graticule. R_{275} adjusts the current in this coil, and the connections are reversed if the correction is in the wrong direction.

Tr_{100} is the blanking amplifier and is an unsaturated switch, with D_{80} preventing saturation. The beam is unblanked when Tr_{100} is on and grid 2 on the c.r.t. is at the same potential as anode 1, i.e. 0 volts. About 60 volts is necessary to fully blank the trace.

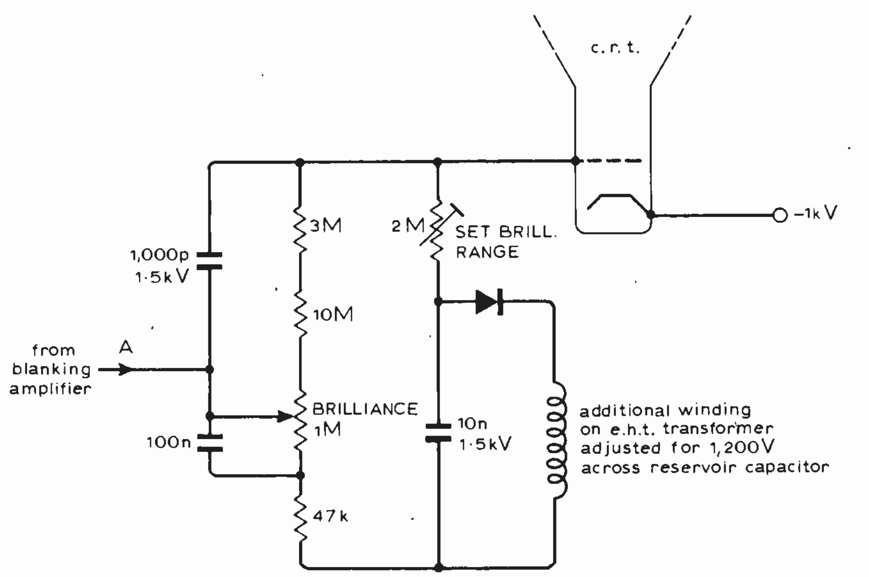


Fig. 15. Alternative grid drive when tube in use does not possess second grid.

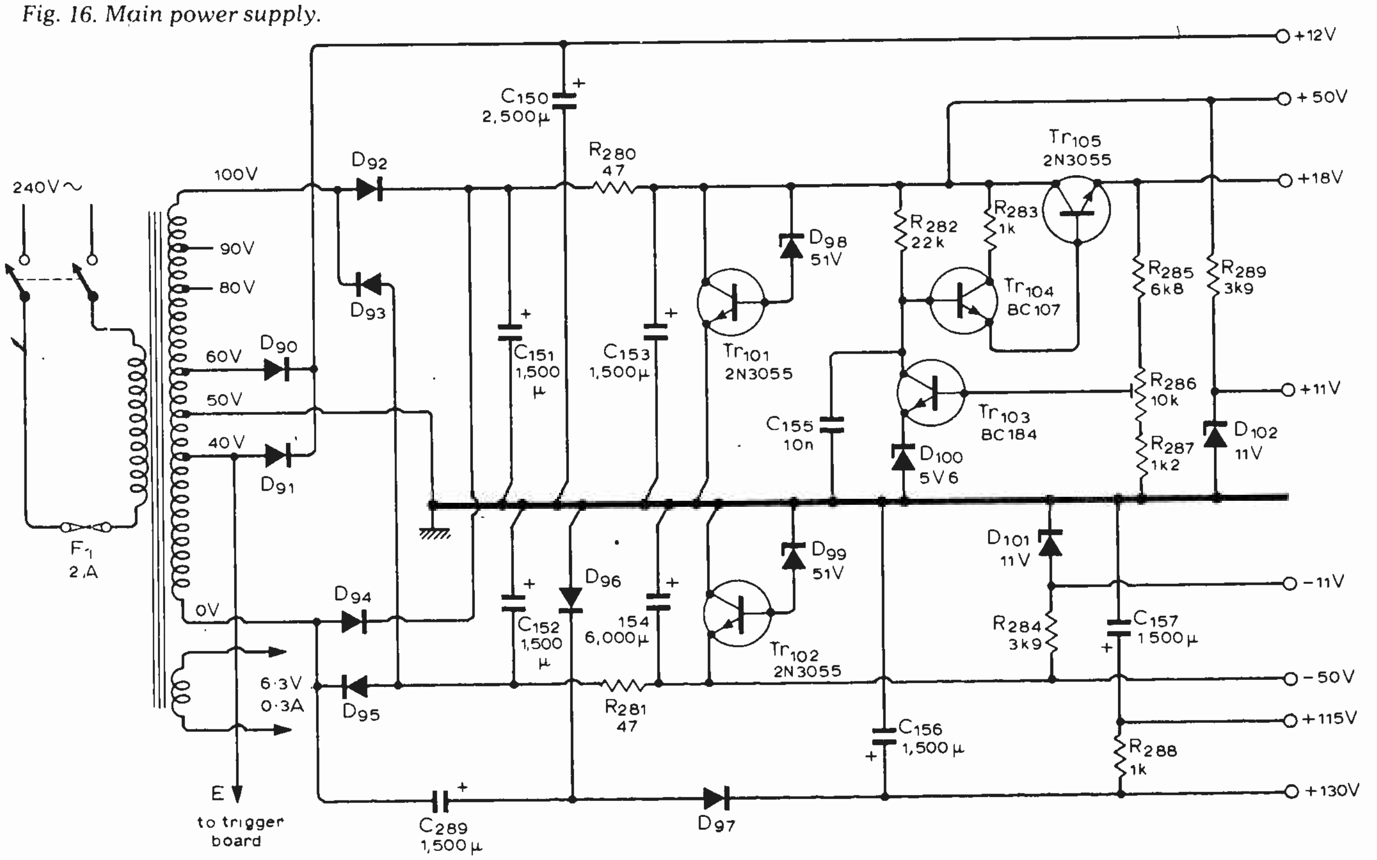
Calibrator

The amplitude and time calibrator is shown in Fig. 13. It is a conventional multivibrator which switches a constant current to and from a ladder attenuator. This provides a square wave of good rise and fall times with an amplitude that is independent of supply voltage variations. R_{241} and R_{244} enable the frequency to be set to 1kHz, and the mark-space ratio to unity. D_{73} provides temperature compensation for Tr_{92}.

Power supply

The mains power supply (Fig. 16) has been kept as simple as possible, consistent with a reasonable degree of stabilization. The main points are the large

Fig. 16. Main power supply.



number of different rail voltages needed, and the provision of a 6.3V, 0.3A a.c. supply for the c.r.t. heater. This winding floats at 1kV from earth. The +50 volt and −50 volt rails are derived from full-wave-rectified 70 volt unstabilized supplies by simple shunt stabilizers, which give adequate regulation and smoothing. The +18V rail is fed from a conventional negative-feedback stabilizer which uses the +50V line as its input. A preset, R_{286}, is used to set the rail voltage. R_{283} provides short circuit protection by limiting the drive current to Tr_{105}.

The X amplifier and the blanking amplifier need a higher voltage than 50V, in fact around 130V. This is obtained from a voltage doubler operating from one side of the 50-0-50 secondary on the transformer. The 130 volt rail is unstabilized. There is a fairly large amount of a.c. ripple on this rail, measured as 700mV peak to peak, and a dropping resistor R_{288} gives a smoothed voltage of +115V which is used in some of the circuits.

An unstabilized 12 volt supply feeds the e.h.t. generator, and finally a highly stable +11V and −11V for the shift controls is obtained from D_{102} and D_{101}.

The mains transformer is available from Osmabet Ltd, and its modification will be described in the section on construction.

Table 1

Some extracts from the manufacturers data on the c.r.t. type D13-47GH

All voltages with respect to anode 1

4th anode (p.d.a.) voltage	+3kV
3rd anode voltage	−50V to +50V (astig)
2nd anode voltage	−600V to −825V (focus)
Cathode voltage	−1000V
Grid 1 volts for cut off	−1065V (brilliance)
Grid 2 volts for blanked trace	65 Volts
X plate sensitivity	14.5 to 17.5 V/cm
Y plate sensitivity	6.7 to 8.3 V/cm
Screen area	10×6cm

Capacitances

X_1 to X_2	2pF
X_1 to all less X_2	6.8pF
X_2 to all less X_1	6.8pF
Y_1 to Y_2	1.5pF
Y_1 to all less Y_2	6.4pF
Y_2 to all less Y_1	6.4pF

Reference circuits — Circards 23

Set 23 of Circards, covering reference circuits, is now available. (Because of space limitations the introductory article has been omitted from this issue.) Titles in the set are

- Reference circuits
- Zener diode characteristics
- Williams ring-of-two reference
- Variable reference diodes
- Bipolar references
- Low temperature coefficient voltage reference
- Voltage & current calibrator
- Compensated reference circuits
- Simple current reference
- Monolithic reference

New circuit book

"Circuit designs — 1, Collected Circards" brings together the first ten sets of Circards, introductory articles to each of the subjects, and ten pages of additional circuits. The hardback A4 book contains 168 pages, in which 120 cards are rearranged so that each is laid out on one page. A brief introduction precedes the articles, which were previously published in *Wireless World*, and each of the ten subjects is followed by an up-dating page. Corrections have been incorporated where appropriate. **"Circuit designs"** is obtainable through leading bookstalls at £10 per copy. In case of difficulty order direct by sending remittance for £10.40 (includes postage and packing) to the address given later, making cheques payable to IPC Business Press Ltd. Advertisement appears on page 27.

Circards are a new method of collating and presenting data about circuits in a compact and easily retrievable way. The sets of 203×127mm (8×5in) double-sided cards are designed for easy filing in standard boxes and for easy access at the desk or at the bench, where transparent plastic wallets keep the cards in good condition.

Each card normally describes operation of a selected circuit, gives *measured* performance data and graphs, component values and ranges, circuit limitations and modifications to alter performance. Suggestions for further reading are included together with cross references to related circuits. The Circard concept was outlined more fully in the October 1972 issue of *Wireless World*, pp.469/70.

How to get Circards

Order a subscription by sending £13.50 for a series of ten sets to:

Circards
IPC Electrical-Electronic Press Ltd
General Sales Department, Room 11
Dorset House
Stamford Street
London SE1 9LU

Specify which set your order should start with, if not the current one. One set costs £1.50, postage included (all countries). Make cheques payable to IPC Business Press Ltd.

Topics covered so far in Circards are:

1 active filters
2 switching circuits (comparator and Schmitt circuits)
3 waveform generators
4 a.c. measurement
5 audio circuits (equalizers, tone controls, filters)
6 constant-current circuits
7 power amplifiers (classes A, B, C & D)
8 astable multivibrator circuits
9 optoelectronics: devices and uses
10 micropower circuits
11 basic logic gates
12 wideband amplifiers
13 alarm circuits
14 digital counters
15 pulse modulators
16 current-differencing amplifiers – signal processing
17 c.d.as—signal generation
18 c.d.as—measurement and detection
19 monostable circuits
20 transistor pairs
21 voltage to frequency converters
22 amplitude modulators.
23 reference circuits

Hermetic plastics i.cs.

A process introduced by RCA is claimed to have overcome the problems of obtaining a hermetic seal in a plastic-packaged integrated circuit at no increase in cost. A high degree of hermeticity has previously been obtainable only with relatively expensive ceramic or glass packages and seals, the package bearing the brunt of atmospheric attack. In the new "trimetal" process, the chip itself is sealed.

At the equivalent of the final oxide step in ordinary i.cs, a silicon nitride layer seals the junctions, a mask being used to gain access to contacts. Platinum is then sputtered over the wafer and sintered locally to provide platinum silicide. Layers of titanium and platinum are now laid down, the platinum layer being etched to provide interconexions, which are then gold-plated. (Titanium is used to provide an easy bond between platinum and silicon nitride.) All this avoids the use of aluminium interconnecting runs, which are prone to attack by moisture. The new process is applied to six RCA linear i.cs, including the CA741G and 747G which take the name of "Gold Chip" devices.

Electronic circuit calculations simplified

2 — Resistive circuits (continued)

by S. W. Amos, B.Sc., M.I.E.E.

Two resistors in parallel. Every experimenter knows that the effective value of a resistor is reduced by connecting another resistor in parallel with it. But by how much is it reduced? To find out we can, of course, use the following well-known expression for the resistance of two resistors (R_1 and R_2) connected in parallel:

$$\text{effective resistance } (R_{eff}) = \frac{R_1R_2}{R_1+R_2}$$

$$= \frac{\text{product of individual resistances}}{\text{sum of individual resistances}}.$$

As an example a 33-kilohm resistor in parallel with a 47-kilohm resistor has an effective value given by:

$$R_{eff} = \frac{33\text{k} \times 47\text{k}}{33\text{k} + 47\text{k}} = 19.4 \text{ kilohms}$$

In practice, however, problems concerning resistors in parallel are usually presented differently. Often we need to know what value of resistor must be connected in parallel with a given resistor to obtain a desired lower value of resistance. It is tedious and unnecessary to repeat the above calculation several times in order to obtain the answer. Instead the above expression can be rearranged as shown below to give the required information directly:

$$\text{resistor to be added } (R_2) = \frac{R_1R_{eff}}{R_1 - R_{eff}}$$

$$= \frac{\text{product of original and effective resistances}}{\text{difference of original and effective resistances}}$$

As an example, if it is desired to reduce a resistor of 27 kilohms effectively to 22 kilohms, the resistance which must be connected in parallel is given by:

$$R_2 = \frac{27\text{k} \times 22\text{k}}{27\text{k} - 22\text{k}} = 120 \text{ kilohms}$$

The above expressions show that the value of a resistor is effectively halved by connecting an equal-value resistor in parallel with it. If the added resistor has twice the value of the original resistor, the net resistance is two thirds that of the original resistor. If the added resistor has three times the resistance of the original, the net resistance is three quarters that of the original. In general if a resistor with n times the resistance of the original resistor is connected across the original, the net resistance is $n/(n + 1)$ that of the original resistor.

Another useful rule which can be deduced from the above expressions is that in order to reduce the effective value of a resistor by 10%, the parallel resistor must have a value 9 times that of the original. For a 5% reduction, the parallel resistance must have 19 times the resistance of the original and for a 1% reduction the parallel resistance must be 99 times the original resistance. These added resistances are respectively approximately 10 times, 20 times and 100 times the original resistance – in each case 100 times the reciprocal of the percentage reduction required. Thus to effect a 2.5% reduction, the added resistance should be 100/2.5 i.e. 40 times the original resistance. In general to reduce the effective value of p% the added resistance should have a value of $(100 - p)/p$ times the original and if p is small compared with 100, it can be neglected in the numerator of the fraction so that the added resistance is approximately $100/p$ as deduced from the numerical examples earlier.

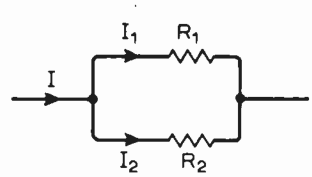


Fig. 16. Current division in a circuit composed of two resistors in parallel.

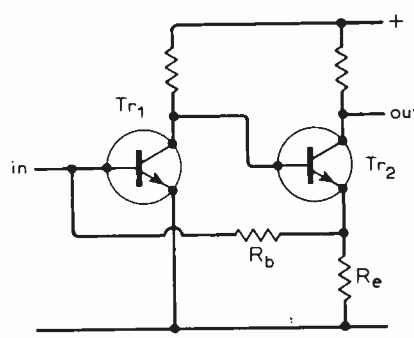


Fig. 17. Simplified diagram of a two-stage current amplifier in which gain is determined by the negative feedback circuit $R_e R_b$.

Current divider. The current I which flows externally to a parallel combination of resistors divides between them in the inverse ratio of their resistances. Thus in Fig. 16 the current (I_1) flowing in R_1 is given by

$$I_1 = \frac{R_2}{R_1+R_2} \cdot I$$

and I_2, the current in R_2, is given by

$$I_2 = \frac{R_2}{R_1+R_2} \cdot I$$

It is useful to regard a parallel resistor combination as a current divider because such a combination is often used as the basic negative feedback circuit in a current amplifier, and this approach enables the resistor values needed to give a wanted value of current gain to be readily calculated. Alternatively it enables the current gain of an amplifier to be deduced from inspection of the resistor values used in the feedback circuit.

For example, in the simplified circuit diagram of Fig. 17, R_e and R_b are effectively in parallel, the current path through R_b being completed by the input resistance of Tr_1 which is normally small compared with R_b. The emitter current of Tr_2 splits at the junction of R_e and R_b and the fraction of it which is returned to Tr_1 base as a negative feedback signal is, as shown by the above expressions, given by $R_e/(R_e + R_b)$. Normally R_b is large compared with R_e and the fraction is thus approximately R_e/R_b. The current gain of the amplifier is equal to the reciprocal of this fraction i.e. R_b/R_e. The values of R_e and R_b should thus be chosen to give the desired value of current gain. Now R_e is one of the components used for biasing Tr_2 and this consideration imposes limitations on its value: a likely value for R_e is 100 ohms. R_b, on the other hand, can be made almost any value and, to give a current gain of 100, should have a value of 100 × 100 ohms i.e. 10 kilohms. Only the essential signal-frequency components are shown in Fig. 17: in a practical circuit additional components may be necessary, e.g. for stabilising the mean emitter currents of the transistors.

Two resistors in series. The effective value of two resistors R_1 and R_2 connected in series is the arithmetical sum of the two thus

$$R_{eff} = R_1 + R_2$$

Thus is a small resistor is connected in series with a large one, the effective resistance is slightly greater than the larger. (If the resistors are connected in parallel, of course, the effective resistance is slightly less than the smaller of the two.)

Two resistors connected in series are often regarded as a potential divider because the voltage V_{out} across R_2 (Fig. 18) is a certain fraction of that (V_{in}) applied to the combination: the fraction is determined by the resistor values according to the expression

$$V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_{in}$$

which is similar to the expression for the current in R_1 in a parallel resistor combination.

Potential dividers are often used for biasing transistors and Fig. 19 shows a typical circuit using an f.e.t. The potential divider R_1R_2 impresses a particular value of voltage on the gate of the f.e.t. and the external source resistance R_s then determines the drain current of the transistor. This bias circuit is preferable to that in Fig. 3 (June) because it gives better d.c. stability i.e. it defines the mean drain current more accurately in spite of manufacturing spreads in transistor parameters and variations in parameters with temperature.

As mentioned earlier one of the features of f.e.ts is that their input resistance is very high. Thus there is virtually no gate current and the resistors R_1 and R_2 are required solely to provide a particular voltage for the gate. The only current in R_1 and R_2 is therefore that which flows through them from the supply (the bleed current) and this can be made any desired value. Normally the bleed current is made very small because this enables the input resistance of the circuit to be kept high. To illustrate this let us assume that there is a 15-V supply and that the transistor is required to take 2mA mean drain (and therefore source) current. For such a current the transistor will be assumed to require a gate-source bias voltage of −1.5V. The gate voltage can be given any desired value up to 15V: 3V is a convenient value. The mean source voltage must then be 4.5V to give the required gate-source bias. Thus the voltage across R_s is 4.5 and the current required in it is 2mA. Ohm's law gives the value of R_s as 2.2 kilohms.

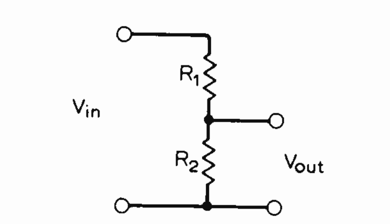


Fig. 18. Potential division in a circuit composed of two resistors in series.

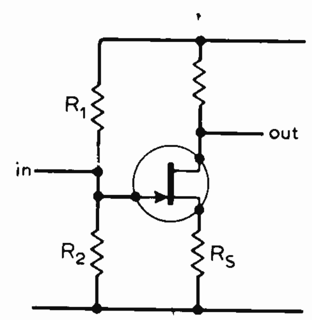


Fig. 19. Potential divider used to bias an f.e.t.

The potential divider must give a gate voltage of 3 and the supply voltage is 15. Let us assume a very low value of bleed current, say 10μA. This is then the current in R_2 and the voltage across R_2 is 3. Thus, from Ohm's law, the value of R_2 is 300 kilohms. The current in R_1 is also 10μA and the voltage across it is 12 so that its value, also from Ohm's law, is 1.2 megohms. R_1 is four times R_2 and provided this ratio is maintained the gate voltage always has the same value of 3: the particular values chosen for R_1 and R_2 determine the bleed current.

In practice we are often concerned about the input resistance of the circuit. The input resistance of the f.e.t. itself is practically infinite but the input resistance of the circuit depends on R_1 and R_2, which are effectively in parallel at signal frequencies. For the values of R_1 and R_2 calculated above the effective input resistance of the circuit is given by:

$$\text{input resistance} = \frac{\text{product of } R_1 \text{ and } R_2}{\text{sum of } R_1 \text{ and } R_2}$$

$$= \frac{1200\text{k} \times 300\text{k}}{1200\text{k} + 300\text{k}} = 240 \text{ kilohms}$$

With f.e.ts it is possible to achieve much higher input resistances than this. For example, suppose we require an input resistance of 5 megohms: such a value might be required to terminate a capacitor or piezo-electric microphone or pickup cartridge. A useful way of calculating the values of R_1 and R_2 to give this value of input resistance as well as the required value of gate voltage is as follows. Let the ratio of the gate voltage to supply voltage be a. This a is also therefore the step-down voltage ratio of the potential divider. Then the resistor values to use in the potential divider are given by:

$$R_1 = \frac{\text{input resistance}}{a}$$

and $$R_2 = \frac{\text{input resistance}}{1-a}$$

For the example in question $a = 3/15 = 0.2$

$$\therefore\ R_1 = \frac{5}{0.2} = 25 \text{ megohms}$$

$$\therefore\ R_2 = \frac{5}{1-0.2} = 6.25 \text{ megohms.}$$

R_1 is four times R_2 which ensures the required gate voltage. A calculation of the resistance R_1 and R_2 in parallel shows that this is 5 megohms as required.

The circuit of Fig.19 is also used to bias bipolar transistors but the design usually proceeds along entirely different lines from those described for f.e.ts. This is primarily because the bipolar transistor has a significant input (base) current: as a result the input resistance is low and, because this shunts both resistors of the potential divider, there is no point in using high-resistance components for R_1 and R_2. Indeed there is a good reason for using low-value resistors, namely that d.c. stability of the circuit is dependent on the value of these resistors, increasing as the resistor value is decreased. The resistors should therefore be made as low as possible subject to keeping the bleed current acceptable: in battery-operated equipment the potential divider should preferably not take as much current as the transistor itself.

A good starting point for the design is thus to decide on a value for the bleed current. Suppose the transistor is to take 1mA mean collector current. Then it is reasonable to let the potential divider take 0.1mA. Let the required base voltage be 3V as before. Then a simple application of Ohm's law tells us that $R_2 = 3/(0.1 \times 10^{-3}) = 30$ kilohms. Now R_1 carries the base current of the transistor in addition to the bleed current of 0.1mA. We can take the base current as $1/\beta$ of the collector current. If β is 100 then the base current is 0.01mA and the total current in R_1 is 0.11mA. If the supply voltage is 12 than there are 9V across R_1 and the value of R_1 is, from Ohm's law, $9/(0.11 \times 10^{-3})$ i.e. 82 kilohms.

Finally we need to calculate the emitter resistor value. If the transistor is a germanium type the emitter potential is very nearly equal to the base potential and there is thus 3V across R_e. Since the current in R_e is 1mA, the value of R_e is given by $3/(1 \times 10^{-3}) = 3$ kilohms. If, however, the transistor is a silicon type there is an offset voltage of approximately 0.7V between base and

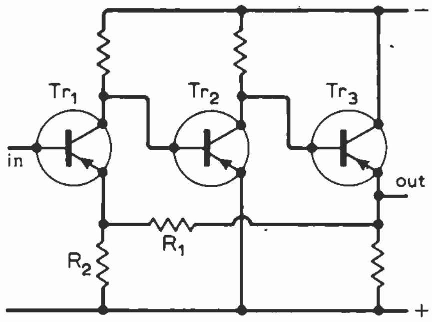


Fig. 20. Simplified diagram of a two-stage voltage amplifier with emitter follower output in which the gain is determined by the negative feedback circuit $R_1 R_2$.

emitter potentials and the voltage across the emitter resistor is only 2.3V, giving R_e as 2.3 kilohms.

If the base current had been ignored R_1 would have been calculated as 90 kilohms instead of 81 kilohms. The difference is not great and to obtain approximate estimates of resistor values it is often permissible to neglect the base current.

A potential divider is often used as the basic element in the negative feedback circuit of a voltage amplifier and the values of the two resistors enable the gain of the amplifier to be set at a particular wanted value. Alternatively the gain of a voltage amplifier can be deduced from the values of the resistors in the negative feedback circuit. For example, in the simplified circuit diagram of Fig. 20 Tr_1 and Tr_2 are common-emitter stages and Tr_3 is an emitter-follower stage which provides the amplifier with a low output resistance. R_1 and R_2 constitute the potential divider which defines the voltage gain of the amplifier. The step-down voltage ratio of the potential divider is $R_2/(R_1+R_2)$ but R_1 is usually large compared with R_2 and the step-down ratio is therefore approximately R_2/R_1. The voltage gain of the amplifier is equal to the reciprocal of this i.e. R_1/R_2. Thus if voltage gain of 200 is required R_1 must equal $200R_2$. R_2 is used to provide bias for Tr_1 and its value is to a large extent determined by this consideration: a likely value for R_2 is 100 ohms. R_1, on the other hand, can be given almost any value and, to give the desired value of voltage gain, should be 200×100 i.e. 20 kilohms.

Only the essential signal-frequency components are shown in this circuit diagram: in a practical circuit additional components are necessary, e.g. for stabilising the mean collector currents of the transistors.

(Next article: capacitive circuits)

Announcements

A one day **conference in Cynernetics** is being organized at Chelsea College, University of London, by the Cybernetics Society on September 1st, 1975. Topics will include artificial intelligence, pattern recognition, cybernetic medicine, systems theory and other topics relating to cybernetics. Further details about the conference or offers of papers can be obtained from the conference organizers: E. Insam, c/o The Cybernetics Society, Chelsea College, University of London, Pulton Place, London S.W.6 or Dr. C. M. Elstob, Cybernetics Dept., Brunel University, Uxbridge, Middlesex. The Society also holds monthly meetings in London with speakers from various fields in cybernetics and other related topics, anyone interested in attending the meetings or becoming a member of the Society should contact Mr Kevin Clifton at the Cybernetics Society address or by telephone. 01-736 1244, ext 229.

Norse Audio Systems Ltd recently launched the Radionette range of audio and television equipment in the UK. The range, which is manufactured in Norway, includes colour television receivers, music centres, tuner-amplifiers, record decks, speakers, and transistor radios. Radionette (a subsidiary of the Tandberg organization) have said that the product range will be backed-up by a first-class after sales service.

Agreement has been reached to house the **Vintage Wireless Museum** of the Wireless Preservation Society in one of the Isle of Wight's "Stately Homes" — Arreton Manor, the home of Count and Countess Slade de Pomeroy. Arreton Manor already houses a Folk Museum, and a unique collection of dolls and dolls' houses.

Dieter Assmann Electronics Ltd, of Watford, manufacturers of a very wide range of components for printed circuit board assembly, have appointed Giltech Components of 22 Portman Road, Reading, as their first distributor in the U.K. Initially, Giltech will hold stocks of the major Assmann lines such as i.c. and transistor sockets, terminals, connectors and heat sinks.

G. A. Stanley Palmer Ltd, Elmbridge Works, Island Farm Avenue, West Molesey Trading Estate, Surrey KT8 OUR, have been appointed exclusive U.K. representatives for the National Wire and Cable Corporation of Los Angeles, California. Products manufactured include connecting wire both screened and unscreened, microminiature low voltage instrument control cable in single or pairs, under water cables, ultra flexible wires, multiple (single and pair) signal and control cables, and digital data transmission cables.

Double R Electronics Ltd., Angus House, 13 Tilehouse Street, Hitchin, Herts SG5 2DU, have been appointed U.K. distributors for Ampower Semi-conductor Corporation in the United Kingdom.

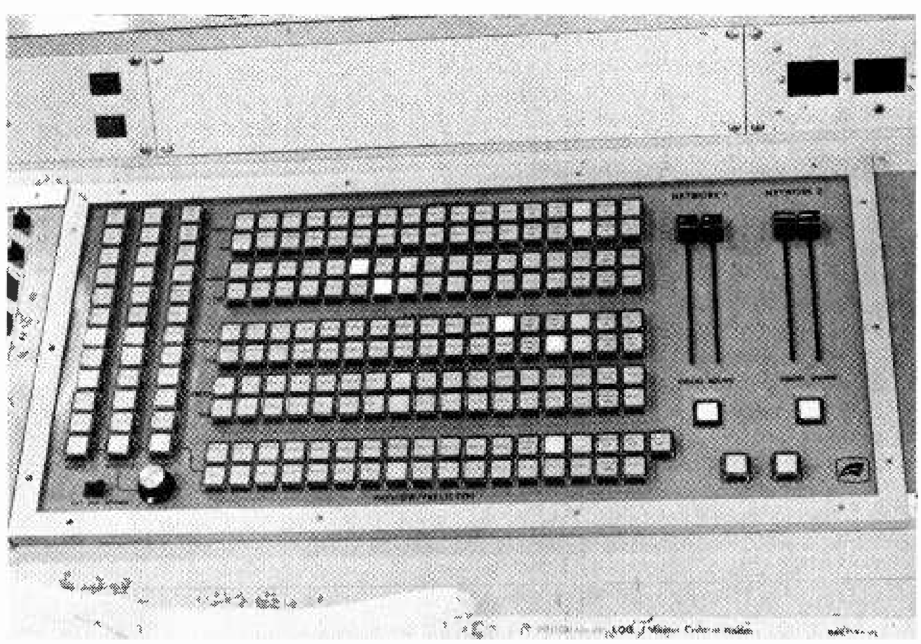
Vision network switcher

Logic-controlled network-switching equipment, recently installed at Yorkshire Television's Leeds studios, provides very simple routeing of signals from 34 inputs (studios, telecine, v.t.r., etc) to three main external outputs and several internal monitoring and recording stations.

The photograph shows the control panel of the switcher, which contains the relevant buttons for two of the external outputs, the other being on another panel. The top two banks (of 68 buttons) each consist of 34 buttons to select signal source, coupled with "on air" lamps. When switching codes, set up in memory by the selector buttons, are activated by output "take" buttons, the "on air" lamps illuminate. Outputs are to the Emley Moor YTV transmitter, the national network and the YTV Belmont transmitter, the selectors for this being on a separate panel. The bottom bank of buttons select inputs for previewing or prelistening and the left-hand set controls feeds to internal monitoring stations, etc.

In essence, the control panel sets up in memory the switching configuration required, resulting logic states being used to control single-f.e.t. cross-point switches (reeds, in the case of audio cross-points).

The equipment was supplied by Crow of Reading, the cross-points originating with Sandar Electronics — a Norwegian company.



Noise — confusion in more ways than one

4—Noise figure and the design of front-ends

by K. L. Smith
University of Kent at Canterbury

The quest for low equipment noise temperature has formed a large part of research and development effort in recent times. The maser, parametric amplifier and other aspects of low-noise technique are covered in this concluding article. Noise figure is still commonly used to characterise performance and this idea, together with the earlier discussion of noise temperature, is considered to show that basically they are saying the same thing.

Getting noise levels down at the front end of modern equipment has been a success story. In this section I will present an outline of some of the strides that have been made, but will not attempt a detailed description of actual front-end hardware, or specific devices and techniques. If you have any special interest requiring a little more detail, I have mentioned a few references for you to follow up.

The basic mechanism of noise generation in active devices is the shot effect, found, of course, in semiconductors as well as in thermionic emission devices. A serious limitation in microwave receivers has been the crystal mixer. Until the advent of low-noise r.f. stages such as the ruby maser and parametric amplifier, the crystal mixer was the front-end component. The crystal has a direct current flowing when operating and therefore shot noise is produced. This makes it appear "hotter" than an equivalent resistor under the same conditions. It also has a conversion loss. If you glance at equation 9 (Part 3), with L now standing for the mixer conversion loss and T_L somewhat above room temperature and related to the crystal noise temperature, then you will see that crystal mixers do not enhance the requirement for low effective input noise temperatures or microwave receivers.

One awkward point arises because of a traditional definition. The crystal noise temperature, T_x, is defined as the effective temperature at the output of the mixer stage when the input is terminated with a matched source resistor at T_0, (290K). So T_x includes the source contribution at T_0. From this, taking care to account for the source contribution, we can write down an analogous equation to (9) for the T_e of the superhet with a crystal mixer front end and an i.f. amplifier whose effective input noise temperature is $T_{i.f.}$.

$$T_e = LT_x - T_0 + LT_{i.f.} \qquad (11)$$

The first term is the crystal noise temperature referred to the front end or input terminals; the second term is the subtraction of the standard source temperature, assumed in the definition of T_x; and the third term is the i.f. amplifier input temperature referred forward to the front-end terminals. For good noise performance, a low T_x and small L is required. A manufacturer's catalogue shows the following for the 1N23C point-contact X-band mixer diode: $t_x(=T_x/290)=2, L=6$dB, which is a loss of four times.

Putting these values into (11) gives

$$T_e = 4\times 2\times 290 - 290 + 4\times 116 \approx 2500K.$$

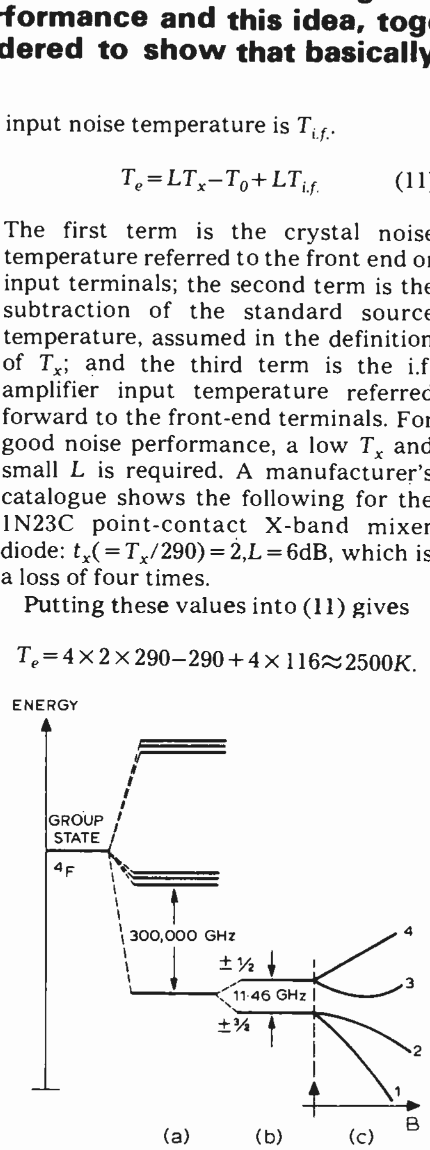


Fig. 16. Quantum mechanics explains the pattern of energy levels obtained in crystal lattice structures (among other things). Example shown is for chromium ions in ruby crystals. Altering value of the magnetic flux B, sets the levels 1, 2, 3 and 4 at convenient energy intervals for maser action.

I have assumed a low-noise i.f. amplifier, a temperature of $T_{i.f.} = 116$K. The noise temperature of 2500K is not a very good performance. From the same catalogue, a modern Schottky-barrier mixer diode type P1906F would given an effective input noise temperature of 740K if used in the same receiver.

Other hazards exist which I have ignored in the above discussion. An important one is the noise generated in the local oscillator. The noise sidebands from the oscillator mix to produce an appreciable output at the i.f. frequency. A balanced mixer should be used to reduce noise from this source. Another dodge is to lock the local oscillator to a low-noise stable frequency generator, such as a crystal oscillator and multiplier chain (which, incidentally, reduces the drift, frequency jumping and the f.m. noise of the local oscillator). The noise performance of the i.f. amplifier is critical with direct conversion receivers. The presence of the loss factor L makes this so, as you can see from (11).

The first stages of the amplifier require transistors specially selected for their good noise performance and the optimum matching conditions between mixer and i.f. input circuit is important. It is possible to obtain optimum performance empirically by switching on and off a gas-tube noise source coupled into the front end, attenuated if necessary, while adjusting the mixer, local oscillator, and i.f. couplings for minimum T_e, as monitored by observing the changes on a power meter at the output of the system. The calculation of the optimum conditions for any given case, including the effects of parasitic reactance, etc, is extremely difficult. If you wish to follow this up, E. G. Nielsen[14] wrote an interesting article on the topic.

You may recall the publicity, about a decade ago, in connection with the Goonhilly station system. The "significant" results that the new maser amplifier was going to make possible were indeed achieved, after the usual teething troubles. We had visions of large Dewar flasks surrounded by liquid-nitrogen-produced vapour clouds and all the other complexities of the cryogenics. The cost and complexity of the maser hardware and cryogenics, and the relatively narrow bandwidth obtainable has meant a decline in their use, and the much more convenient parametric amplifier has taken over. In spite of this, the maser still offers the ultimate in low-noise performance, because not only are the "working bits-n-pieces" cooled to about 4K with liquid helium, you will sometimes see negative temperatures mentioned! Of course, the physical temperature is never below absolute zero, but in some ways the maser acts as if it were.

The action of the solid-state maser depends on materials with paramagnetic ions in a crystal lattice, such as the chromium^{3+} ion in ruby. The spin and orbital motion in these atomic particles are quantized, which means that the only energies allowed them by the laws of quantum physics are very definite values. Any change in energy of particles means a jump from one energy level to another with the absorption or emission of radiation of characteristic frequency. This is pictured in a diagram such as that in Fig. 16; (a) shows some of the chromium ion levels in ruby. The lowest level is the only one of interest for maser work.

In this ion, there are three available electrons which contribute to the paramagnetic splitting. The three electrons give four possible energy levels and the fields of force in the crystal lattice split the levels into two pairs 11.46-GHz apart (the energy difference is measured in "frequency" – this being the frequency of the radiation involved in any jump between the levels), see Fig. 16 (b). A long time ago a fellow named Zeeman in 1896 found that applying an external magnetic field to atoms or molecules with levels which have the same energy (the jargon for this is that they are "degenerate", but this does not mean that they suffer from anything nasty!) separates them, or as we say lifts the degeneracy by an amount depending on how strong the magnetic field is.

Sure enough, this happens with our chromium ions in ruby, see Fig. 16 (c). The low energy levels of the billions of particles in the crystal lattice are occupied according to the quantum laws, and the absolute temperature T. The lowest levels are crowded while higher levels are only sparsely filled. The whole point of maser action is to invert this population distribution – by pumping, so that when dropping back to a low energy level, the electrons involved give energy to the passing signal wave, boosting its amplitude. The waves passing through the crystal (we are discussing a travelling-wave maser) need time to interact with the excited atoms, so a careful design is made of a slow wave structure for this purpose.

The correct populations can only be produced at very low temperatures – hence the liquid helium involved. The magnetic field to split the energy levels to just the right value for the frequency of the signal and pump is often applied by the use of a "persistent current superconducting magnet" – a case of exploiting the very low temperature available and the resulting superconductivity in some materials. Fig. 17 (a) illustrates this and (b) shows diagrammatically the parts of the travelling-wave maser.

We can sum up all of this by noting that the signal wave in a maser extracts energy in phase from the excited ions in the crystal. The presence of the signal stimulates the emission – hence the name of the device, Microwave Amplification by Stimulated Emission of Radiation, as you probably already know. The extremely low effective noise temperature of this amplifying mechanism arises from the requirement to use liquid helium temperature, together with a further reduction of this already low temperature according to $T_{e(maser)} = T_{amb}/I$, where $T_{amb} \approx 4.2$K (liquid helium) and I is the inversion ratio of the maser, usually about three and is the number of times the upper energy level is more densely populated than the lower, as a result of the pumping action.

Naturally, the signal has to be got into the amplifying part of the maser, and out again. Equation 9 shows that the effect of any attenuation in the feeder at the input, will very convincingly degrade the noise performance.

$$T_e = (L-1)T_L + \frac{LT_{amb}}{I} \qquad (12)$$

If T_L is a mean temperature of around 100K and L is a loss of only 0.5dB (1.112 times), then $T_e = (11.2+56)$K. That is, the loss contributes about 11K and the maser itself about 1.5K. Herein lies a big difficulty with such amplifiers: how to get the signal down into the crystal in the Dewar, through the couplings and hardware of the front-end feeder system, without introducing prohibitive losses. Taking the signal out is all right, it has been amplified by the maser gain,

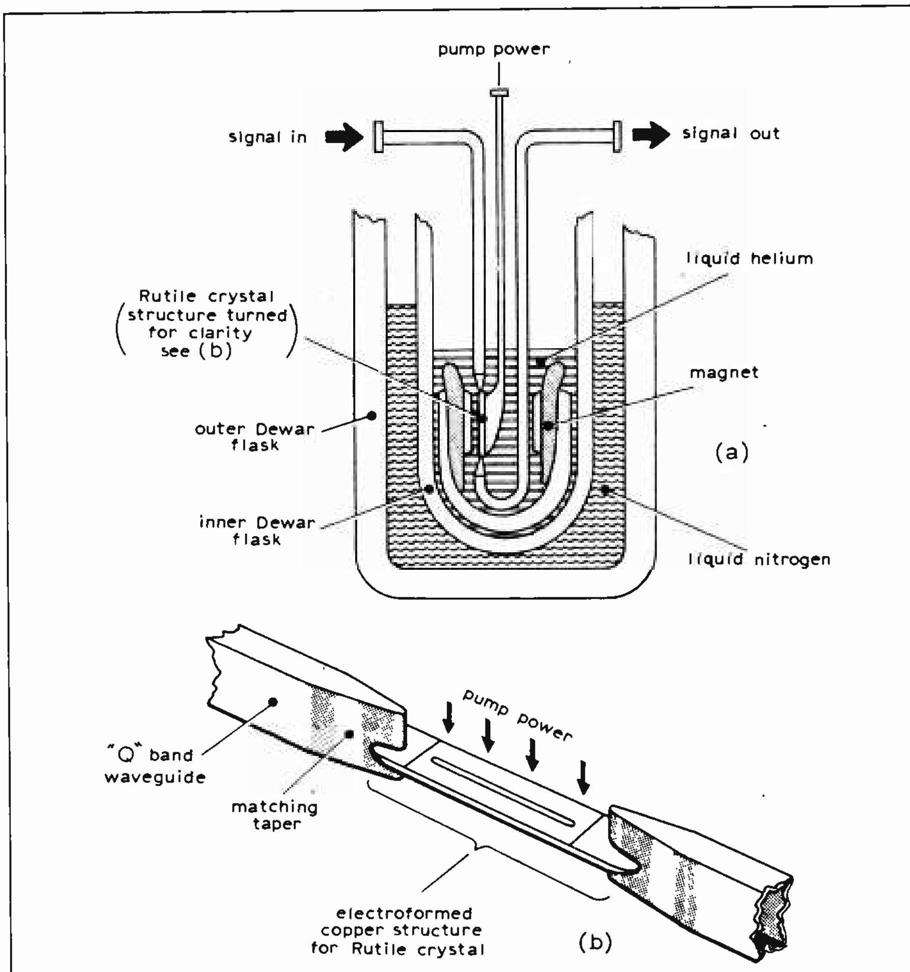


Fig. 17. Inconvenience of maser amplifiers is mainly because of the complex cryogenic system required. Also, getting the signal in and out and the pump power into the crystal is troublesome. Shown here is a typical example of a maser with rutile for the slow-wave structure and interacting element (a). Magnet could be a self-sustaining super-conducting one. Velocity of the wave in rutile is very much less than the velocity in free space, because of the high dielectric constant. One method of feeding in the pump power that has been proposed is to use a side radiating horn, as shown at (b). (A. Fletcher).

perhaps 45dB or so. A good article on masers was presented in *Philips Technical Review* in 1965 if you can get hold of a copy[15]. The practical description of the Goonhilly Down maser is discussed fully.

Parametric amplifier

The source of gain in the parametric amplifier is an entirely different physical mechanism to that in the maser system, although a pump oscillator is again employed. Most of the literature proudly states that Lord Rayleigh, and even Michael Faraday, spoke of the paramp principle way back in the last century. This is so, but the electronic realization of the principle for low-noise amplification is recent (the 1950s). Basically a reactive parameter, such as a capacitance, is varied and this feeds energy into a signal wave. Being a virtually noiseless parameter (reactance), the usual Johnson and current noise contributions are reduced. There is some loss in the active device, which is usually a varactor diode, and in the feeder hardware. Cooling will therefore lower the effective noise temperature. Noise contributions also arrive in the pump frequency oscillations and can degrade the performance.

Three frequencies are usually involved in a paramp; the signal frequency f_s, the pump f_p and the idler frequency f_i. The idler frequency is the mixing product of f_s and f_p, i.e. $f_i = f_p - f_s$. Much of the design work in parametric amplifier projects is involved with the correct design of the resonant structures for f_s and f_i and in ensuring the isolation between them. A circulator is required at the signal front end, because the varactor diode is a two-terminal device. (Tunnel diode amplifiers also have this drawback.) You are correct if you immediately assumed that isolators, circulators, switches or any other such lossy hardware in the input feeder are bad for low-noise performance, equation 9 or 12 operates again.

Fig. 18 gives some idea of the electrical arrangement of a pumped paramp of the "two-tank" variety. The imput signal arriving at port 1 of the circulator is diverted out of port 2 into the signal-tuned circuit CL_s in the paramp. The pump is varying the capacitance of the varactor and energy is fed into the signal oscillations by this action. The amplified signal is passed back to port 2 of the circulator. (You could look upon all this as a signal passing into the paramp on the input transmission line and there reflected with a reflection coefficient greater than unity back down the line.) The circulator passes the amplified signal out of port 3 to the load. The circuit CL_i resonates at the idler frequency and filters F_i and F_s reject the idler and signal frequencies respectively so keeping the various signals and oscillatory powers in their places.

There are various ways in which the realization of the scheme shown in Fig. 18 can be carried out. Fig. 19 shows just one possibility. The pump is much higher in frequency than the signal and is usually supplied via a waveguide, although microstrip techniques are increasingly being employed.

A theoretical analysis of Fig. 18 enables the gain, noise temperature and bandwidth of the amplifier to be derived. If you are interested in some of the theoretical argument, you will find a very good discussion in reference 16. One factor of great importance is γ, which is defined as

$$\frac{C_{max} - C_{min}}{2(C_{max} + C_{min})}$$

This is a kind of goodness factor for the varactor diode and indicates the amount of capacitance variation obtainable by pumping. Another diode parameter is the cut-off frequency, $f_c = 1/2\pi C R_d$, which must be way above the frequencies involved in the amplifier. Noise is contributed directly by the diode loss resistance R_d and also R_i in the idler circuit. It is in cooling these that the improved performance at low frequencies is obtained. Quoting now the noise temperature expression (see reference 16)

$$T_e = T\left[\frac{R_d}{R_g} + A\frac{f_s}{f_i}\left(1 + \frac{R_d}{R_g}\right)\right]$$

where R_g/R_d is often called the over-coupling ratio and T is the physical temperature. A is dependent on the gain, but is normally close to unity, especially at high gain. This means that if we make $R_g \gg R_d$, then the effective noise temperature of the paramp is

$$T_e \approx T.\frac{f_s}{f_i} \qquad (13)$$

Under these conditions, we can see that if the pump frequency is high, so that $f_s \ll f_i$ then the effective input noise temperature of the parametric amplifier can be made less than the physical temperature (i.e. by the fraction f_s/f_i). Lest you think "Ah! let's push up the idler frequency to millions of gigahertz – and get noise temperatures around absolute zero", life is not so kind. Remember f_c for the diode, and other losses limit the possibility of an unlimited rise in the pump and therefore idler frequency. The noise temperature given by (13) is oversimplified and as the gain drops when f_p goes up the noise temperature will start to increase again. This would indicate that there is a minimum noise temperature for an optimized paramp with a given diode, packaging, and so on. It can be shown that

$$T_{e(min)} = \frac{2f_s}{\gamma f_c}$$

As would be expected, a large γ and high f_c for the diode is the best way to a low T_e at any given signal frequency f_s.

Handling the idea of noise figures

The noise figure, F, has already been mentioned and you may recall from part 1 that H. T. Friis and D. O. North were instrumental in getting the concept off the ground. All the equations to calculate F, are derived from the basic definitions in a similar way to the expressions for T_e. If we went through it all again, it would mean a duplication of effort. The main point now is to derive the relationship between F and T_e so that all the earlier equations can be written in terms of F, if required. Friis defined F as the signals to noise ratio at the input of a network when the source resistance is at 290°K; divided by the signals-to-noise ratio at the output. Because signals-to-noise ratios at the output of amplifiers, receivers and so on, are always smaller than those at the input, then F is always larger than one.

From the above verbal definition you will see that

$F = \dfrac{S_i}{P_{Ni}} \Big/ \dfrac{S_o}{P_{No}}$, and this tidies up to $\dfrac{S_i P_{No}}{P_{Ni} S_o}$

If the network has a power gain of G_A,

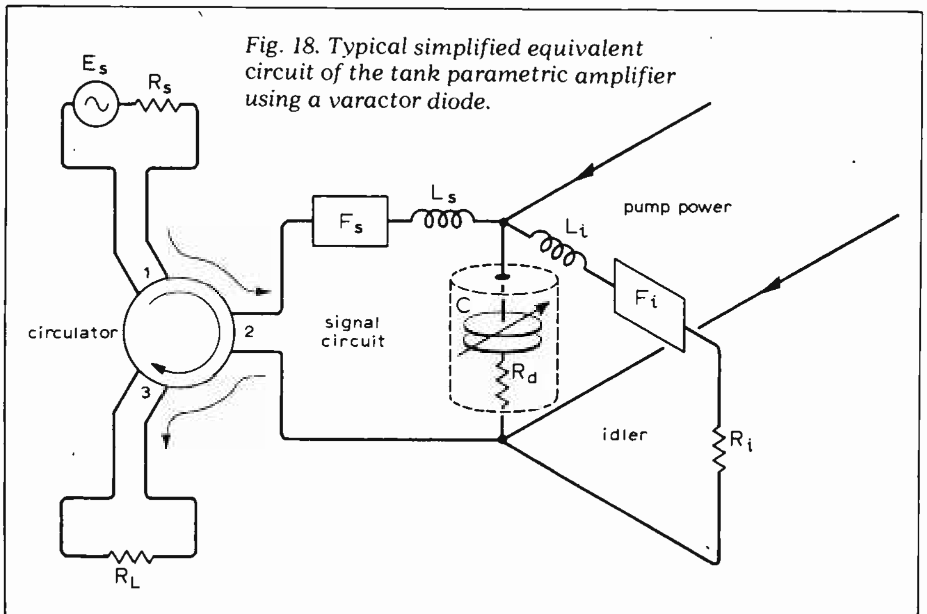


Fig. 18. Typical simplified equivalent circuit of the tank parametric amplifier using a varactor diode.

then $S_o = G_A S_i$ and $P_{No} = G_A P_{Ni} + P_{Na}$, by precisely the same argument that was made in part 2 (first paragraph). This means that

$$F = \frac{S_i(G_A P_{Ni} + P_{Na})}{P_{Ni} G_A S_i} = 1 + \frac{P_{Na}}{G_A P_{Ni}} \quad (14)$$

Immediately from the equation $P_{Na} = G_A k T_e B$, (part 2) and $P_{Ni} = k(290)B$, so that from equation 14

$$F = 1 + \frac{T_e}{290} \quad (15)$$

This is the relationship connecting F and T_e we set out to find.

I indicated at the beginning of this series that D. O. North also defined a noise factor. His definition dispensed with signals right from the start. You may like to see that his definition is just the same as that just given in (15), although North originally suggested 300K for the standard temperature. North's definition went like this: "F is the ratio of the total noise power output from a system when its imput termination is at 290K, to that part of the output which arises from the input termination only".

In symbols, this is

$$F = \frac{P_{No} \text{ (when } T_i \text{ is 290K)}}{G_A k(290)B},$$

but $P_{No} = G_A kB(290 + T_e)$, see part 2, p.169, and therefore

$$F = 1 + \frac{T_e}{290}, \text{ as before.}$$

Some early ideas connected with this topic was discussed in *Wireless World* by L. A. Moxon[17].

We are now in a position to write down any noise expression in terms of F by using the fact that $T_e = 290(F-1)$ by transposing (15). You can see this from the following examples.

Substituting for T_e in the equation on p.171 (part 2) gives

$$F = F_1 \frac{F_2 - 1}{G_i} + \frac{F_3 - 1}{G_1 G_2}$$

From equation 6

$$T_e = \frac{T_{hot} - A T_{cold}}{A - 1} \text{ or}$$

$$290(F-1) = \frac{T_{hot} - A T_{cold}}{A - 1},$$

$$F = \frac{\frac{T_{hot}}{290} - A \frac{T_{cold}}{290}}{A - 1} + 1 \text{ which is}$$

$$F = \frac{\left(\frac{T_{hot}}{290} - 1\right) - A\left(\frac{T_{cold}}{290} - 1\right)}{A - 1}$$

The quantities in the brackets are excess noise ratios. Very often $T_{cold} = 290$K, so that

$$F = \frac{\frac{T_{hot}}{290} - 1}{A - 1}$$

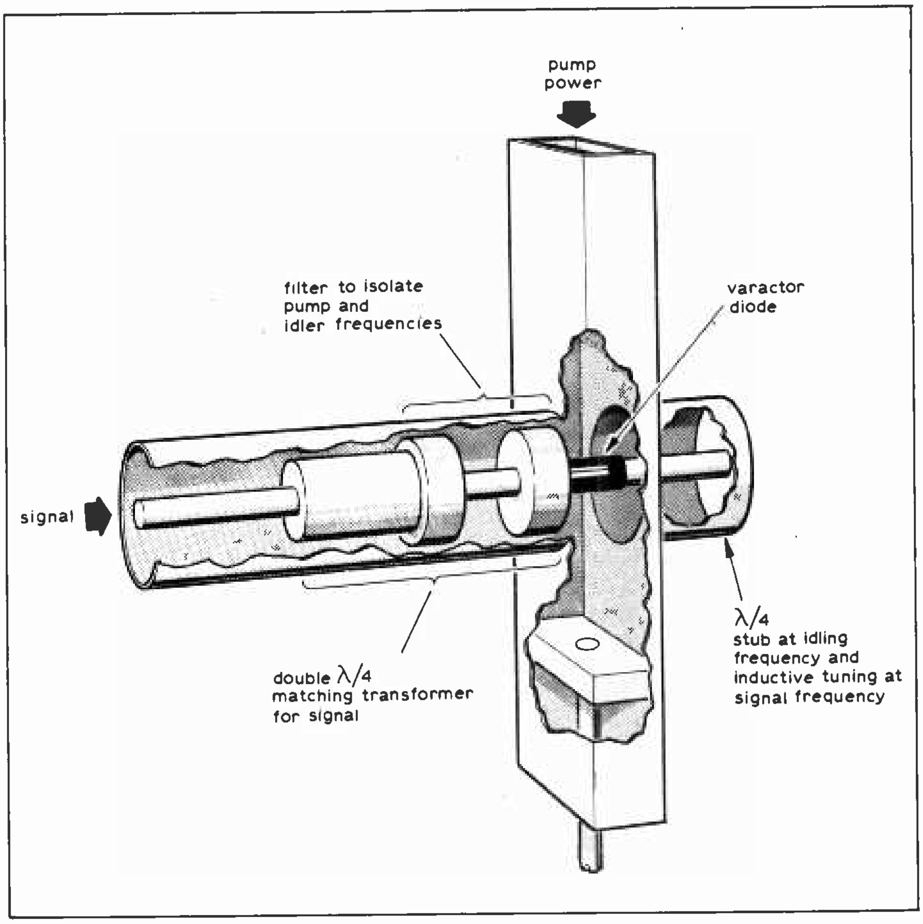
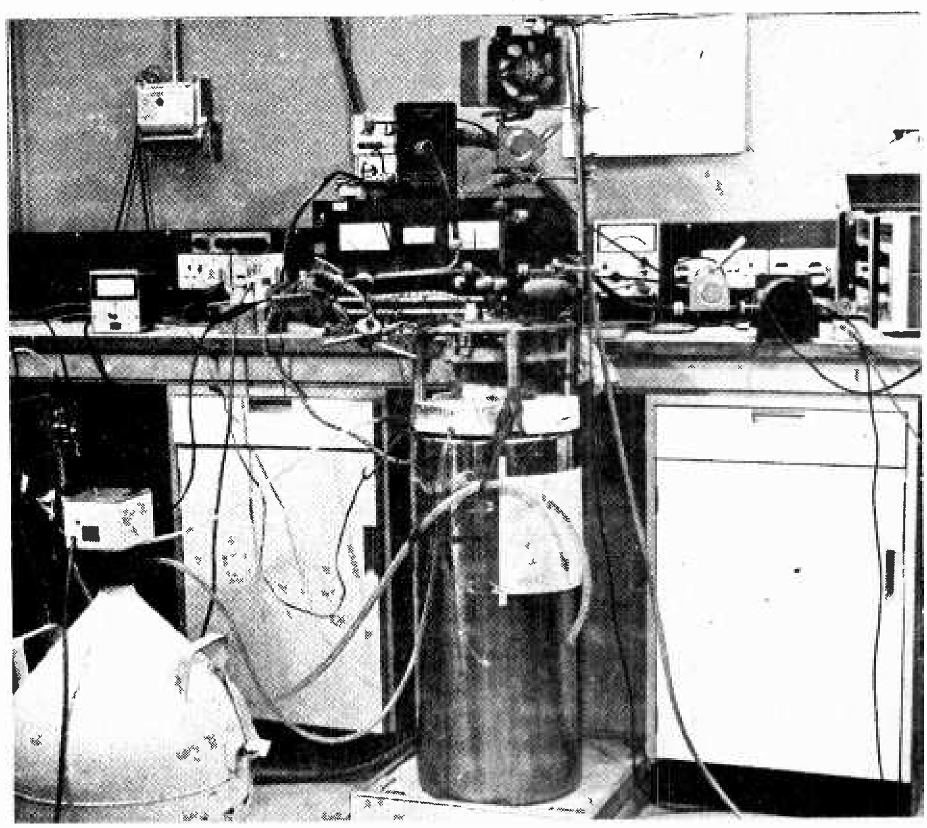


Fig. 19. Hardware of a parametric amplifier for the hundreds of megahertz to lower gigahertz region often consists of a mixture of coaxial and waveguide techniques. This illustration is based on a system described by Aitchison, Davies and Gibson of Mullard Research Labs.

View of Tony Fletcher's 35GHz maser at the University of Kent. Pump power is obtained from a klystron operation at 80GHz. The complexity of the cryogenics is obvious.



If A is made 2 by choosing the value of T_{hot} to make it so, then

$$F=\frac{T_{hot}}{290}-1$$

The last equation in part 2 shows this to be equal to $20I_aR$ for a noise diode, so that we have the interesting result $F=20I_aR$, a well-known expression.

For the next example, we can look at (8), which when substituted gives

$$F=1+\frac{(L-1)T_L}{290}.$$

Similarly from (9)

$$290(F-1)=(L-1)T_L+L(290[F_R-1])$$

$$F=1+(L-1)\frac{T_L}{290}+L(F_R-1).$$

Considering equation (11), we can now see why we had some argument about T_x, because the original derivations were in terms of F. We should expect to see a simplification when "going backwards" to F, to the well-known equation for crystal mixer performance. Now $T_e=290(F-1)$ and $T_{i.f.}=290(F_{i.f.}-1)$, also $T_0=290$K all by definition, so that equation 11 gives

$$290(F-1)=LT_x-290+L290(F_{i.f.}-1)$$

$$\therefore F=L(t_x+F_{i.f.}-1)$$

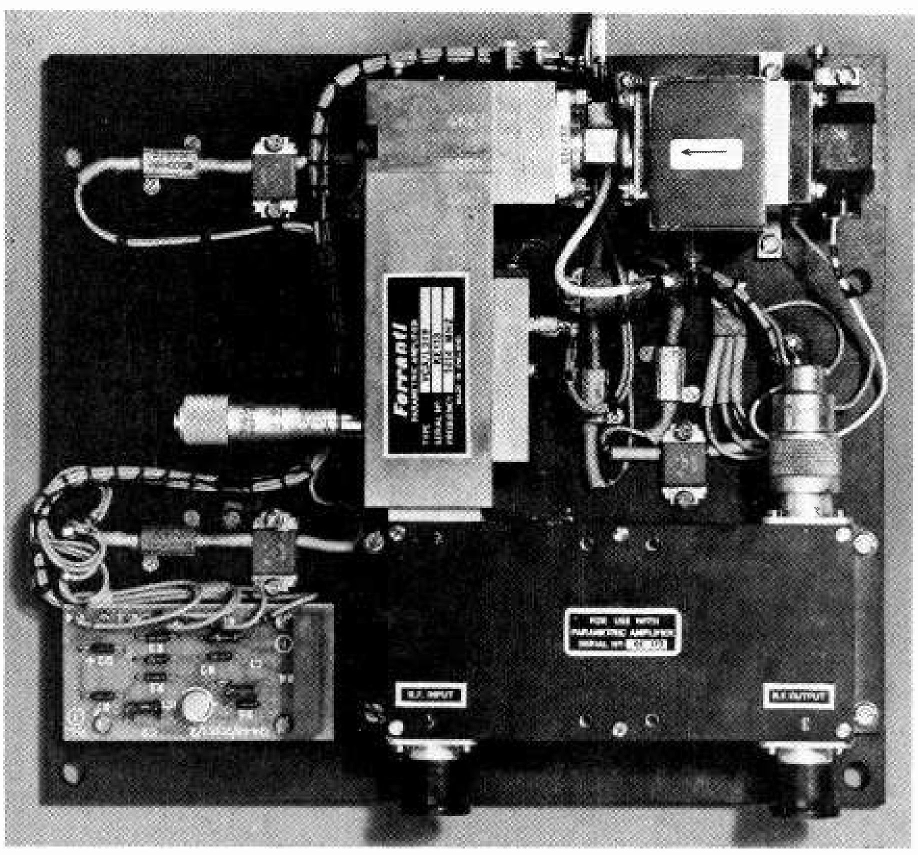
where $t_x=T_x/290$. This is often seen quoted in discussions about crystal mixers.

And so we could go on. Notice that there is often a "1" for the first term on the right-hand side in noise figure equations. This arises because of the contribution of the source at 290K. When the division by 290 is made to obtain the ratio that is F, the first term is "1". This means (by subtracting the "1" from both sides) that the expresion $F-1$ occurs frequently, hence the growth of the term excess noise figure for this. Because I am making a case for a decline in the use of F and an increase in thinking in terms of temperature, I will not labour the point any further.

If you would like to give more prominence to F, and convert all the formulae, for instance, then you can go ahead. But, in this series of articles, I have attempted to show that the mysteries of "temperature" are only imaginary and that so long as care is taken to realise that the term has been extended to mean more than physical hotness, then the idea is valuable in noise discussions.

I suggest that the noise figure is not so clear as temperature, and is tied to "290K", which is sometimes manipulated behind the scenes for the unwary, and this makes a mockery of "F". F has a habit of being what anyone wants it to be (see the satirical article The Art of Noisemanship by J. C. Green[18], also The Noise Figure Muddle by Seymour B. Cohn[19]). As you might see, a lot of confusion can arise. If you have not yet embarked upon a course of advanced study in electronics, perhaps I have been able to give you an inkling of the interesting concepts concerning equipment limitations, meanings of temperature, etc, that you are likely to meet as part of your studies. If you are already doing some work in communications engineering, then a few of the points covered in these articles may show a little of what is "behind the scenes". Mastering the technique of handling T_e, and especially T_{op} or T_{syst} gives you a direct route to the overall signals-to-noise ratio – which when all is said and done, is the vital parameter in modern communications systems.

This is a typical low-noise (50K) commercially-made parametric amplifier. Example illustrated operates at a signal frequency of 1414MHz. Coaxial circulator is seen at the bottom right and the pump power is obtained from the solid state oscillator at the bottom left, which feeds power to the varactor via a ferrite isolator. Amplifier was supplied to Cambridge University for radio astronomical observations around the hydrogen-line frequency. (Courtesy of Ferranti Ltd.)



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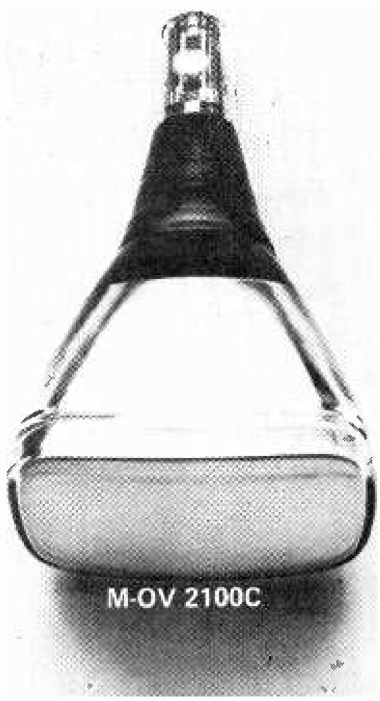
Correction to part 2 (April issue)

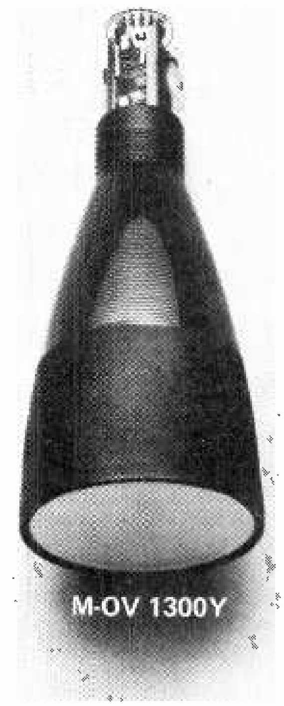
An error occurred in the discussion of noise bandwidths in Appendix B, page 173. The two equations for G_A at the top of the page are correct, but L and C have subsequently become transposed. There is a symmetry about L and C, so the final result is correct, but the statement

$R=\omega C-\frac{1}{\omega L}$ should read $R=\omega L-\frac{1}{\omega C}$

and all Ls and Cs should be interchanged from then on. (The error is obvious if you look at the statement $B_{3dB}=R/2\pi C$, which cannot be true because it is dimensionally incorrect. Replace C with L and it is then alright.)

See more. More to see.





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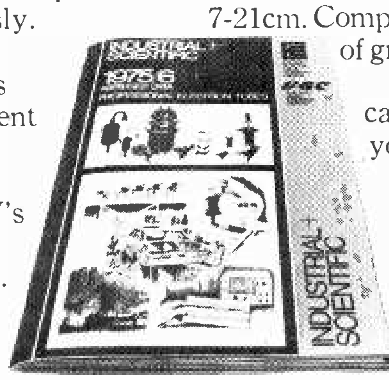

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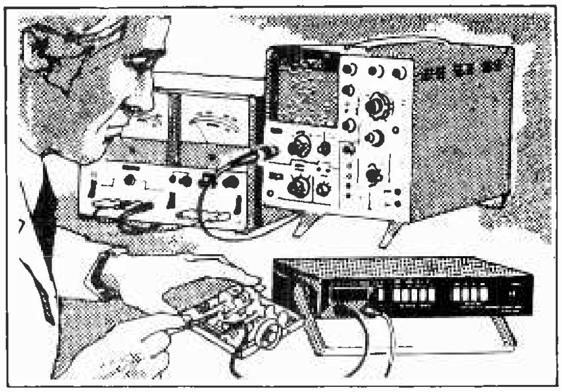

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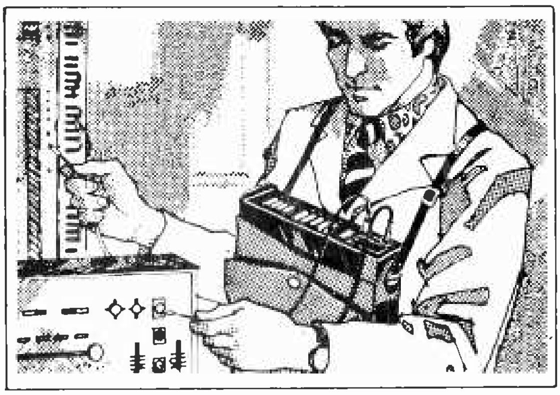

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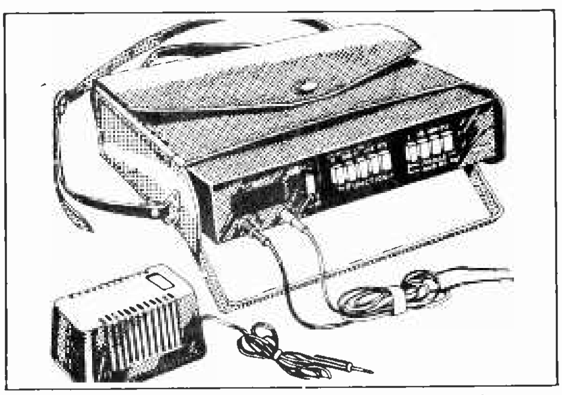

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1000 V	0·5% ± 1 „	10 MΩ	1 V

Maximum overload – 350 V on 1 V range
1000 V on all other ranges.

AC Volts

Range	Accuracy	Input Impedance	Frequency Range
1 V	1·0% ± 2 Digits	10 MΩ/40 pF	20 Hz–3 KHz
10 V	1·0% ± 2 „	10 MΩ/40 pF	20 Hz–3 KHz
100 V	2·0% ± 2 „	10 MΩ/40 pF	20 Hz–3 KHz
1000 V	2·0% ± 2 „	10 MΩ/40 pF	20 Hz–1 KHz

Maximum overload – 300 V on 1 V range
500 V on all other ranges.

DC Current

Range	Accuracy	Input Impedance	Resolution
100 µA	2·0% ± 1 Digit	10 KΩ	100 nA
1 mA	0·8% ± 1 „	1 KΩ	1 µA
10 mA	0·8% ± 1 „	100 Ω	10 µA
100 mA	0·8% ± 1 „	10 Ω	100 µA
1000 mA	2·0% ± 1 „	1 Ω	1 mA

Maximum overload – 1A (fused).

AC Current

Range	Accuracy	Frequency Range
1 mA	1·5% ± 2 Digits	20 Hz–1 KHz
10 mA	1·5% ± 2 „	20 Hz–1 KHz
100 mA	1·5% ± 2 „	20 Hz–1 KHz
1000 mA	2·0% ± 2 „	20 Hz–1 KHz

Maximum overload – 1A (fused).

Resistance

Range	Accuracy	Measuring Current
1 KΩ	1·0% ± 1 Digit	1 mA
10 KΩ	1·0% ± 1 „	100 µA
100 KΩ	1·0% ± 1 „	10 µA
1000 KΩ	1·0% ± 1 „	1 µA
10 MΩ	2·0% ± 1 „	100 nA

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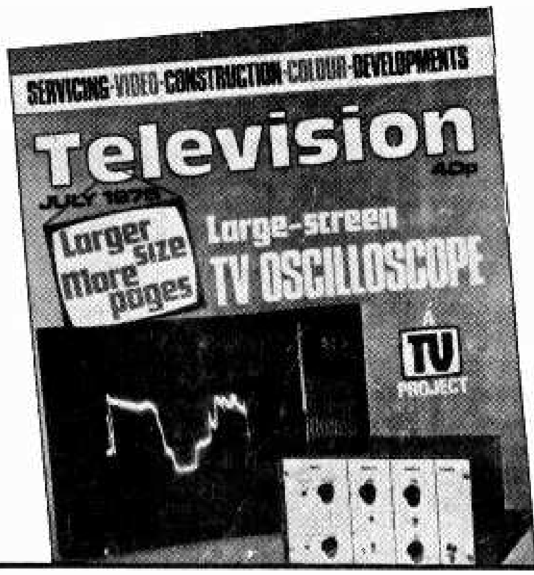

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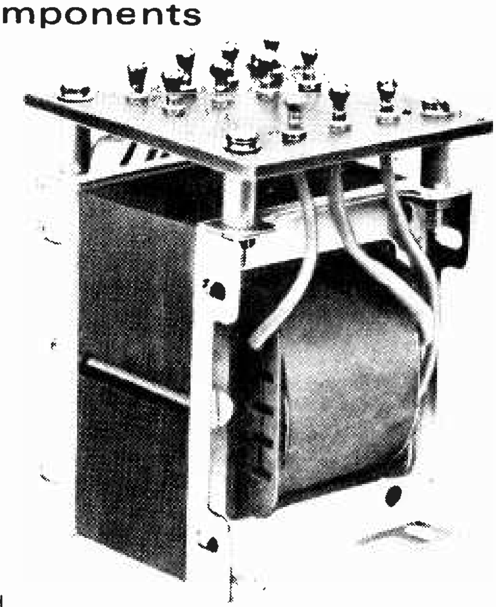

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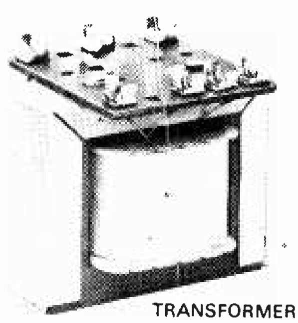

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Resistance comparator

—with linear fractional off-balance indication

by D. Griffiths Ph.D.

Imperial College, London

A simple d.c. op-amp design featuring linear reading of percentage unbalance for any arbitrary value of reference resistor without recalibration in the range 100Ω to 10kΩ.

It was not very clear what the design objectives were at the beginning of this effort; they never seem to be in my experience. It appeared that we needed either (a) to display the variation of the reciprocal of the unknown resistance R_x, about some nominal value R_f, with zero output when $1/R_x = 1/R_f$, or (b) to give a strictly linear output proportional to the fractional deviation of R_x up to 100% above and below R_f, with zero output when $R_x = R_f$. The further proposal that accurately-calibrated percentage deviations should be shown on plugging in any arbitrary value of reference resistor R_f, without recalibration, did not seem to simplify matters.

In the event both requirements (a) and (b) were met in a single circuit design which also gave the proposed constant calibration of the fractional unbalance indication. An accuracy of order 0.1% is achieved with full scale indications of unbalance between 1% and 100% in the range 100Ω to 10kΩ.

The design may be useful on small production runs where resistors have to be hand-trimmed within certain readily-seen percentages of different awkward values; the components used in the original bread-board can then be the master references during trimming. The original application however was with temperature sensors which could be of widely different values although all had similar temperature coefficients of resistance when expressed as a percentage change; this circuit then gave the same loop gain to a process controller when used with different sensors.

As is often the case it was difficult to get away from the first lines of attack that occur to one at the initial doodling stage; I felt that something in the ratio transformer or Wheatstone bridge line would be required. After all, item (a) involved $1/R_x$, i.e. a conductance, and invited a ratio arm transformer technique; but it was not evident how to maintain a calibrated fractional unbalance indication with arbitrary values of R_f, at least with a reasonably simple circuit (watch forthcoming Letters' columns). On the other hand alternative (b), which involved direct display of resistance variations, ruled out a Wheatstone bridge scheme by the wide range of linearity said to be required.

The requirement (b) can be looked at thus: suppose we keep a constant and known voltage across R_f; then if the current through R_f also flows through R_x, the difference in the voltage drops across R_f and R_x will only depend on the fractional relation of R_f and R_x and not on their actual values. It then starts to look like an exercise in op-amp techniques, as indicated in Fig. 1. (Requirements (b) can also be met by interchanging R_f and R_x.

In the prototype the voltage across R_f was set at 1 volt, a higher value bringing power dissipation problems in the test resistors. A proposed system accuracy of order 0.1% implied keeping drifts and computing errors to less than 1mV when referred to this 1-volt level. Past experience suggested that a d.c. technique with type 741 op-amps would just suffice to achieve this, especially in view of the comparatively low values of resistance to be compared. (The use of an a.c. carrier scheme would enable V_f and the power in the test resistors to be set many orders of magnitude smaller but the circuitry would then be a good deal more complex.)

It just remained to convert these ideas into hardware. The functions required are: (1) to hold the voltage V_f across R_f constant at 1 volt; (2) to use a differential amplifier to monitor V_x; and (3) to subtract V_x and V_f, and scale the unbalance appropriately.

Consider first how to hold V_f constant. In an op-amp follower-with-gain circuit, drawn in the usual way in Fig. 2, the ideal action of the negative feedback is to maintain the inverting input terminal (−) at the same voltage as the non-inverting input (+). This will be so, irrespective of the value of R_2, provided R_1 is not so large as to cause the output of the amplifier to saturate at either full positive or negative excursion. Calling

Fig. 1

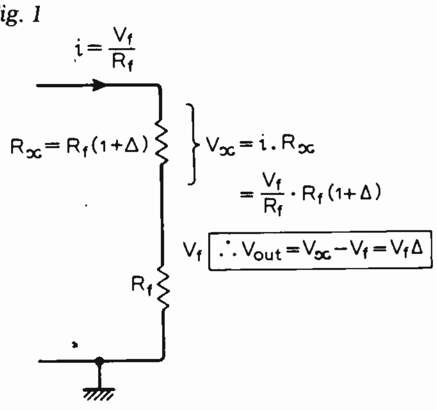


Fig. 2

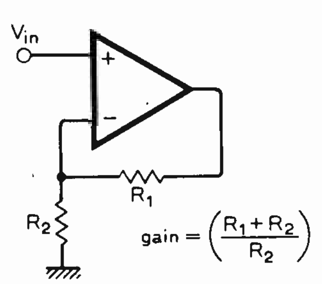
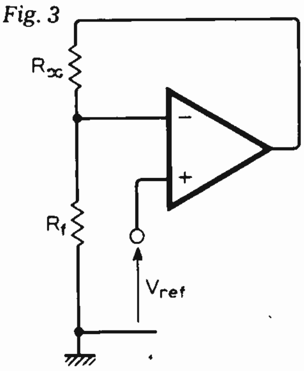


Fig. 3



$R_1 = R_x$ and $R_2 = R_f$, we can redraw Fig. 2 as in Fig. 3, where the voltage across R_f will be held at V_{ref}, for an ideal amplifier. This is the first step in a realization of Fig. 1.

The second function to be achieved is that of causing the voltage across R_x to appear referenced to the common line, so it can be compared subsequently with the voltage appearing across R_f; this is the function of a differential amplifier. Such an amplifier can have its input stage operating in the inverting mode, whereupon the common-mode rejection ratio (c.m.r.r.) of the amplifiers does not limit the achievable c.m.r.r. of the circuit. On the other hand, inverting stages usually have a much lower input resistance than follower stages, though in differential applications the latter are limited by the c.m.r.r. of the op-amps used. The choice is easily made here for R_f has a constant voltage across it which lessens the c.m.r.r. demands on the amplifier and we require a high input resistance to minimize the loading of R_x; if $R_x = 10k\Omega$, an amplifier input resistance of $10M\Omega$ will effectively lower this resistance by 0.1%.

Fig. 4(a) shows a high input resistance differential amplifier, while Fig. 4(b) is intended to show how the common-mode rejection occurs by emphasizing the bridge action through drawing it in a more "Wheatstone" way. If $R_a = R_b = R_c = R_d$, and if in Fig. 4(b) both points A and B move up and down in voltage together (i.e. $V_{AB} = 0$), then points C and D will experience equal voltage excursions of one half of this magnitude if E remains at ground potential. This absence of output from the op-amp is consistent with its zero input, $V_{CD} = 0$ as required.

In Fig. 4(a) the gain to differential input signals is −1 if all the bridge resistors are of equal value. This can perhaps be seen most easily by thinking of the differential input V_{AB} as riding on top of the common-mode signal V_{CM} and remembering that ideally V_{CM} does not affect the voltage at E. Thus one can consider $V_{CM} = 0$ when thinking only of the differential signal and note that this makes point D at ground potential. Resistances R_a and R_c are then evidently seen as a unity-gain see-saw amplifier with phase inversion.

In the prototype circuit the maximum voltage across R_f had to be limited to 1 volt and to reduce the effects of voltage offset drifts the voltage across R_f and R_x was multiplied by three before passing it to the remaining op-amps. The differential amplifier of Fig. 4(a) can give gain by the addition of three resistors as shown in Fig. 5.

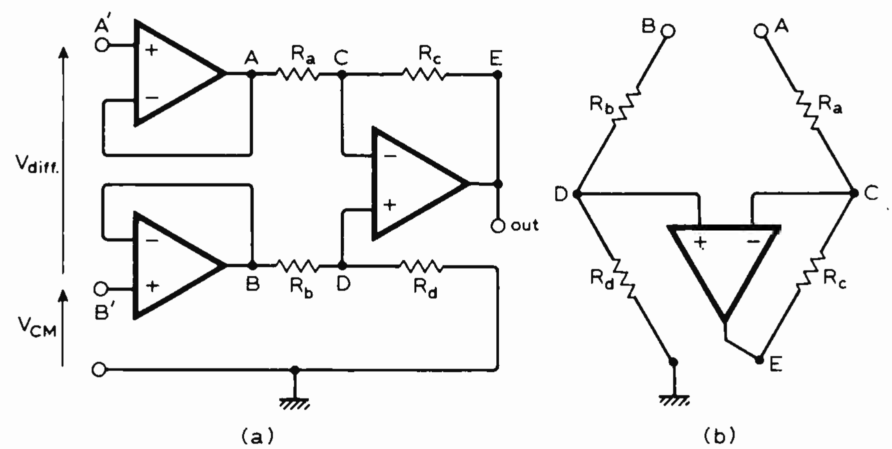


Fig. 4 (a) high input resistance differential amplifier, (b) diagram emphasizing bridge action of (a).

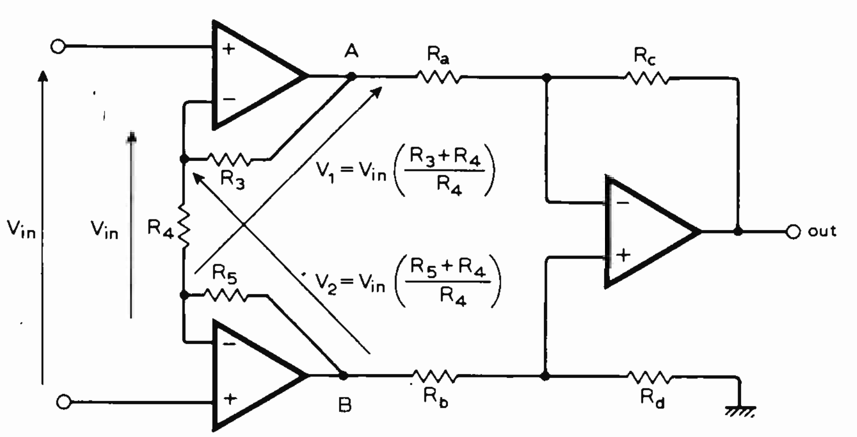


Fig. 5. Comparator with single-resistor gain adjustment.

If $R_3 = R_5$, the voltage gain of the input stage is $+(1 + 2R_3/R_4)$. At first glance one might expect the factor of two to be outside the bracket but inspection of Fig. 5 shows that

$$V_{AB} = V_1 + V_2 - V_{IN} \text{ (across } R_4)$$

$$= V_{IN}\left(\frac{R_3+R_4}{R_4}\right) + V_{IN}\left(\frac{R_4+R_5}{R_4}\right) - V_{IN}$$

$$= V_{IN}\left(1+\frac{2R_3}{R_4}\right), \text{ if } R_3 = R_5.$$

Compared with many other difference amplifiers that of Fig. 5 has two outstanding advantages. First, the gain can be adjusted by varying a single resistor, R_4. Secondly, setting of the gain is quite independent of trimming for best c.m.r.r. It should be noted that if R_3 does not equal R_5 exactly, then this only affects the gain and does not reduce the common mode rejection of the circuit.

The addition of a standard virtual-earth summing amplifier to the circuits of Figs 3 and 5 finishes the design, the complete circuit of which is shown in Fig. 6. A saturated 741 o-amp with ± 15V supplies will have an output of 13 to 14 volts and gives only a modest overload to the meter which requires ± 10V at the output of A_6 for full-scale deflection. The 2.2-μF feedback capacitor reduces needle jitter below the visible limit with a 90-mm scale length meter.

One might imagine at first sight that a 1% change in V_{ref} (and hence V_f) would cause a full-scale change in meter reading when the output stage is on the 1% f.s.d. setting. (If this were so it would place a stringent demand on the stability of V_{ref} and make the circuit rather unattractive.) This misconception can arise by visualizing a 1% change in the voltage across R_f and seeing this as giving rise to a 1% unbalance at the input of the summing amplifier. However, this overlooks the changed voltage across R_x.

It is evident that if R_x exactly equals R_f then the output meter will register zero ideally for any value of V_{ref}. Suppose next that $R_x = (R_f + ½\%)$ with $V_{ref} = 1V$ and the output meter indicates + ½% (i.e. half scale on the 1% range). If now V_{ref} increases by 1% say, then it is the extra voltage drop across the extra ½% of R_x (compared with R_f) that is the unbalanced input to the summing amplifier and will come through to the output; the new output reading would be $(0.5 \times 101/100)\% = 0.505\%$. Thus it is the span of the final meter deflection which is affected in direct proportion to possible changes in V_{ref}.

Fig. 6 shows that V_{ref} is derived here from the integrated power regulator output; the prototype used MVR15 devices from RS Components. These sort of devices have impressive output stability and modest price. Under constant load and in normal laboratory conditions their voltage drift is not

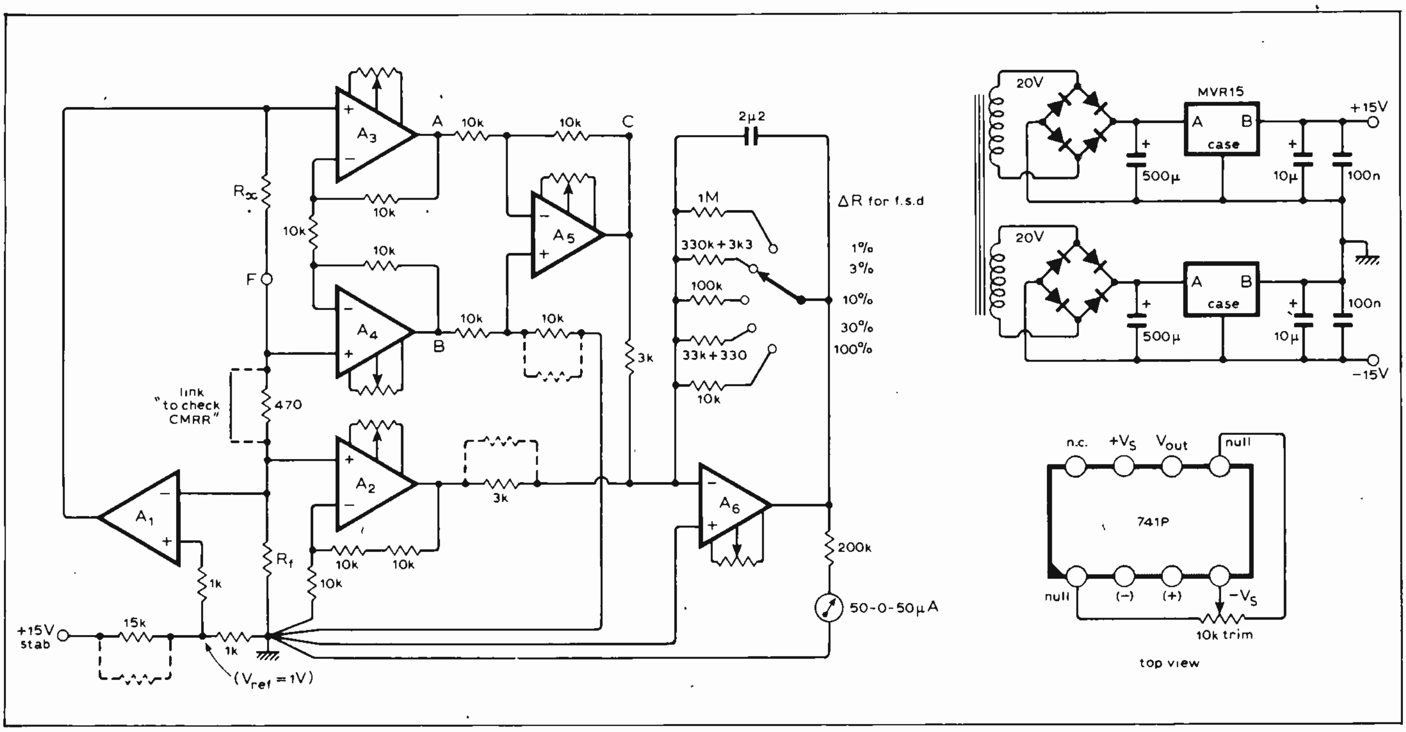


Fig. 6. Complete circuit where V_{ref} is derived from the integrated power regulator having an output stable within 10mV.

visible on a 3½-digit multimeter on its 20-V range after a few minutes from switch-on, i.e. the output is steady to better than 10mV. In view of the insensitivity of this comparator circuit to changes in reference voltage, these regulators are more than adequate for supplying the reference voltage here.

Next we describe the procedure to trim the offsets of the op-amps, balance the differential amplifier and equalize the gains to the summing junction. It may sound a shade long-winded but it is quite straightforward and can be done in a few minutes, at least on the second time round.

Type 741 op-amps were used in all stages and the 10-kΩ offset controls were standard miniature carbon presets. The use of cermet-track elements may give a better temperature stability to the balance of the amplifiers but the extra cost is considerable. When trimming these offset voltages it is necessary to short various resistors; constructors are reminded that (a) the resistance of a "short" can sometimes be significant and (b) the short may be carrying more current than was at first thought. A current of only 10mA flowing through 6 inches (pardon, 15cm) of ordinary 2-amp connecting wire (7/0.2mm, 0.22mm²) produces a voltage drop of 0.1mV. The zero stability of even ordinary unselected 741 amplifiers is sufficiently good that it is worthwhile zeroing them to at least 0.1mV (referred to the input). As indicated in Fig. 6 a single point earthing scheme is a sensible precaution too. However, R_x can be quite distant from the rest of the circuit as the potential drop in the input leads to A_3 and A_4 is only that due to the 0.2μA bias currents of the 741 amplifiers.

A 3½-digit multimeter with least significant digit of 0.1mV was used in setting up the prototype; zeroes were adjusted until the + and − polarity signals were flicking equally. If the 10kΩ preset used with a particular 741 has to be adjusted to more than say 2½kΩ from its mid-track position to balance the offset, it is perhaps prudent to select another 741 in this application.

The trimming procedure is as follows. (1) Short R_x, trim the offset of A_3 and A_4 to give $V_{AF}=V_{BF}=0$, checking $V_{AB}=0$. (2) Keeping R_x shorted also short R_f, measure V_{AB} (ideally zero) and trim A_5 to give $V_{CE}=-V_{AB}$. (3) With R_f and R_x still shorted, trim A_2 for zero output, put A_6 to the 10kΩf.b. setting and trim A_6 to give an output of $-3.3 \times V_{CE}$ (found in step 2). (4) With R_x shorted but restoring R_f to about 500Ω, adjust the balance of the differential 10kΩ bridge until V_{CE} remains constant when opening and closing the link across 470Ω (marked "to check c.m.r.r."). (5) Select R_x and R_f to be exactly the same value (around 2KΩ) and adjust one of the 3kΩ summing resistors to A_6 until the output meter reads zero on the 1% f.s.d. range. (6) See three paragraphs below.

If two resistors of known equality are not available for use in step(5) the comparator can still be used to set up two resistors to the necessary degree of equality. One of the nominally equal pair is made trimmable and adjustment carried out until interchanging these two resistors in the positions R_f and R_x causes no change in the output meter reading; it is of no importance if the reading is non-zero at this point since step (5) has not yet been completed.

The prototype on the 1% range had a zero stability of about 0.005% during a normal day and a drift from cold switch-on of about 0.04%.

The linearity of output was checked on the 100% and 10% ranges with a 3½-digit d.v.m. on the output of A_6 and was found to be better than 0.1% (±1 digit) with R_f of 200Ω, 1kΩ and 5kΩ and full-scale unbalance on either side of equality. This good linearity makes scaling of the output ranges easy and the final item of the trimming procedure, step (6) is: With $R_x=0$ and the output stage on the 100% range, then for any value of R_f (100Ω to 10kΩ) the meter is made to read −100% by trimming the voltage divider giving the nominal 1 volt reference. Accuracy of the scale of the remaining ranges depends almost entirely on the accuracy of the f.h. resistors around A_6 since the open-loop gain of a 741 at zero frequency is typically about 10^5.

And what, you may ask is the fudge which is ill-concealed by the 1-kΩ resistor forlornly stuck between the + terminal of A_1 and the point marked V_{ref} in Fig. 6? Well, it is tied up with the 100-Ωand 10-kΩ limits which were so casually mentioned earlier without explanation. The lower limit is set by A_1 running out of the enthusiasm for supplying current much greater than 10mA, at least to the 0.1% accuracy required here. The prototype was satisfactory of R_f down to 70Ω and lower values could doubtless be accomodated by buffering the output of A_1 with a power transistor. The upper limit arises from errors due to the bias currents in the increasing source resistance presented by A_1 by R_f and R_x in parallel. Making the source resistance of V_{ref} about 2kΩ (as seen by A_1) distributes this offset equally for R_f=100Ω and 10kΩ: on the prototype this error amounted to ±0.07%, causing high values of R_x to read low by this amount. Substituting superbeta or f.e.t.-input op-amps for the 741 would enable the upper resistance limit to be pushed up.

Realm of microwaves

10—Power and frequency measurements

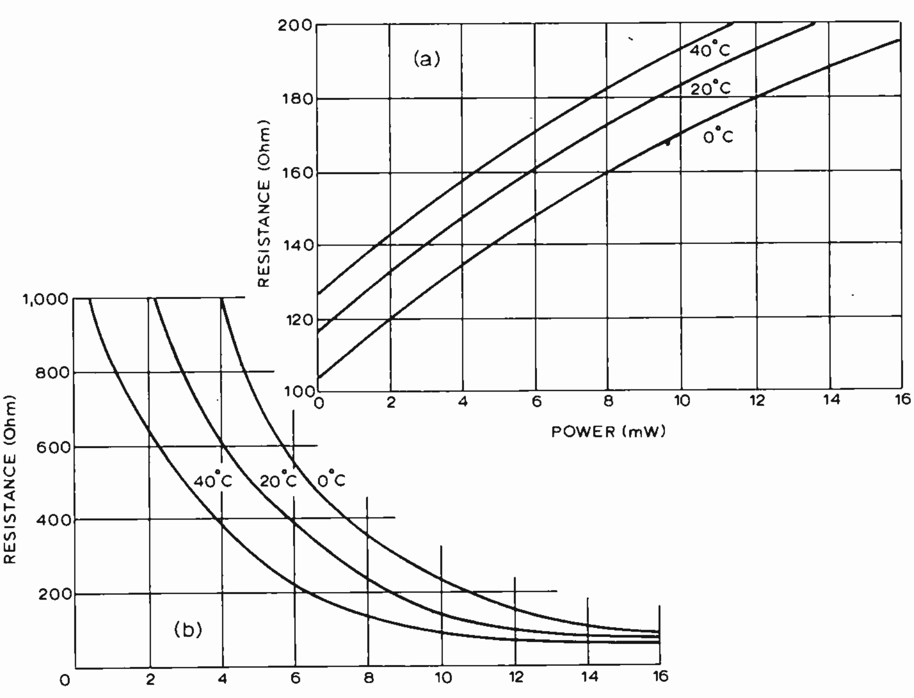
by M. W. Hosking, M.Sc.
British Aircraft Corporation, Filton

At the low frequencies, where a cyclical change of current and voltage can be recorded and where the wavelengths are many orders of magnitude greater than the transverse dimensions of a conductor or component, it is possible to insert a current- or voltage-measuring instrument into the circuit to determine these quantities. The instrument itself has either a negligible or precisely known (internal resistance) effect on the circuit and one knows, say in the case of an ammeter, that it is indicating the total current flowing at that point.

Consider, however, the case of a hollow, metal waveguide: to d.c. this is a single conductor and one has difficulty with the concept of a "potential difference". Furthermore, as shown earlier in this series, the microwave current flows in circulating loops confined closely to the metal surfaces, and even were it possible to measure this current directly one could not say that this was the total current associated with an overall potential. It thus becomes conceptively inconvenient to think in terms of current and voltage as well as impractical to measure, and so these more fundamental quantities are lumped together and it is the total, time-average power which is measured.

Compared with the accuracy to which d.c. or low-frequency power can be measured, the absolute determination of microwave power is rather poor. Typical day-to-day accuracies using standard commercial power meters lie between 5% and 10% and even national standards are only in the region of 0.5% accurate. The fact that high-quality tracking and communication systems have evolved in spite of this limitation demonstrates that it is only on comparatively rare occasions that a highly accurate knowledge of power is necessary. Even then, it is usually required during the development of other instruments. In the majority of cases the important factor is the power difference between one space or time and that in another space or time, i.e. relative power. Using standard laboratory test gear relative microwave can be measured to within a small fraction of 1%.

Fig. 1. Most common bolometric elements consist of either a very thin platinum wire having response curves shown in 1(a) or else a thermistor bead having the opposite type of response shown in 1(b).



As yet there is no practical, absolute method of microwave power measurement; that is, one which will indicate microwave power directly without calibration or transfer from some more primary effect. Although varied priciples and techniques have been proposed and demonstrated over the years, the most practical way of determining microwave power has been by using some element to absorb the power and then observing the resulting heat dissipation. Devices used can conveniently be placed in one of two categories:

- in which the dissipated power produces a change in the electrical resistance of the absorbing element (called a bolometer), or a voltage difference (called a thermocouple);
- in which the rise in temperature of the dissipating element is measured and calibrated to read power (called a calorimeter).

These two groups are by no means exhaustive and there exist both variations and completely different methods of indicating microwave power. However, this series is essentially concerned with the real world of microwave electronics and, in this context, the above categories are the only ones of practical use.

Bolometric devices

Bolometers are temperature-sensitive resistances taking the form of either a thin resistive wire or film, called barreters, or small-bead thermistors. Calibration of these elements is carried out by low-frequency substitution; that is, the change in resistance with microwave power is noted and identified with the d.c. power necessary to produce the same change. Here one starts off with the chain of accumulating errors in the microwave power-measuring system by asking: does the d.c. power represent the total incident microwave power? The answer is that it need not do so and several requirements have to be met before the answer can be changed to "yes" with confidence.

These requirements are that the cross-sectional dimensions of the wire or thermistor should be similar to the skin depth at the operating frequency, so that the d.c. and a.c. densities are similar; and that the physical length of the device should be as small as possible to minimize the very significant inductive reactance.

As a consequence, the barreter is usually constructed from a length of silver-plated platinum wire having a section perhaps 1mm long of the silver etched away, exposing the resistive platinum wire to the microwave field. This wire is very thin, typically 0.002mm in diameter, and is mounted inside a sealed cartridge or on a dielectric support of suitable dimensions for mounting in a waveguide or coaxial monitor. Barreters have a positive temperature coefficient of resistance, and a resistance/power sensitivity shown in Fig. 1(a). They have a very short thermal time constant of several hundred microseconds, useful for fluctuating signals, but this can produce errors when measuring the average power of a pulsed waveform because of the tendency to respond to the signal peaks.

Most popular of the general run of power-sensing elements is the bead thermistor. Composed of semiconducting, sintered metallic oxides, the bead is about ¼mm diameter with two very fine wire contacts and has a negative coefficient of resistance. Its resistance/power sensitivity, shown in Fig. 1(b), is much greater than that of the barreter, operating temperature can be higher, it is more rugged and has a thermal time constant several times longer.

Whichever type of bolometer is used, most power-measuring instruments come in two units. One is the bolometer mount, consisting of the microwave input connection, either waveguide or coaxial, in which the wire or thermistor forms an absorbtive termination, plus a relatively large thermal mass. The second is the meter with associated circuitry, connected to the mount by flexible cable carrying d.c. or low-frequency bias signals.

Within the meter the basic circuit is the balanced bridge with automatic feedback shown in Fig. 2 in which the bolometer element forms one arm. A suitable resistance, usually 100 to 200 ohms, is selected for the element to balance the bridge and is achieved by passing low-frequency current through the element. Audio frequency power is usually chosen for ease of measurement and amplification and, in the case of the thermistor, Fig. 1(b) shows that the current required for a single bead lies between 1 and 15mA.

At this stage, with no microwave power present, the bridge is balanced and the meter reading will be zero. With microwave power present, however, the thermistor will be hotter, its resistance will decrease and, in order to maintain a balance, the audio power must decrease by an amount equal to the microwave power, which can then be identified and displayed. There are many refinements adopted to preserve accuracy and stability in commercial instruments, but the balanced bridge remains the heart of the circuit. The dynamic range of these instruments is generally 40dB with good sensitivity, switchable meter ranges lying between 10 microwatts full scale and 10 milliwatts full scale.

Within the bolometer mount itself lie the sensing elements, usually thermistors, a large thermal mass to help reduce fluctuating external temperatures and also a couple of other thermistors to sense changes in ambient temperature. These latter are not connected to the microwave circuit but form part of another bridge within the power meter and help to distinguish between ambient temperature variations and changes in microwave power. With a large thermal mass, this may appear trivial but, when measuring a few microwatts of power, a 25% meter drift can easily occur with an uncompensated mount.

To be accurate the sensing elements in the microwave circuit must, ideally, form a perfectly matched termination to the transmission line. In the case of standard 50-ohm coaxial line, Fig. 3 shows a mount and method of thermistor attachment. Two beads are used and are mounted between the inner and outer conductors to give the type of electrical circuit shown in Fig. 4. C_1 is a d.c. blocking capacitor to eliminate spurious effects from the source and of the circuit and, with a value of 1 to 2nF, has a very low reactance at the microwave input frequency.

For convenience in biasing and matching, two thermistors are used and are connected in series as far as the audio frequency substitution circuit is

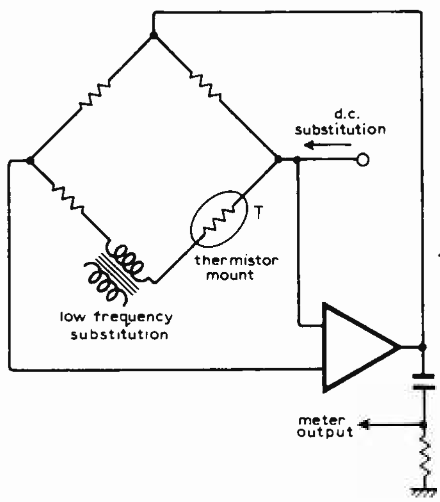


Fig. 2. Variations in bolometer resistance due to incident microwave power are detected by a resistive bridge. The substituted d.c. power to rebalance the bridge is an indication of the microwave power level.

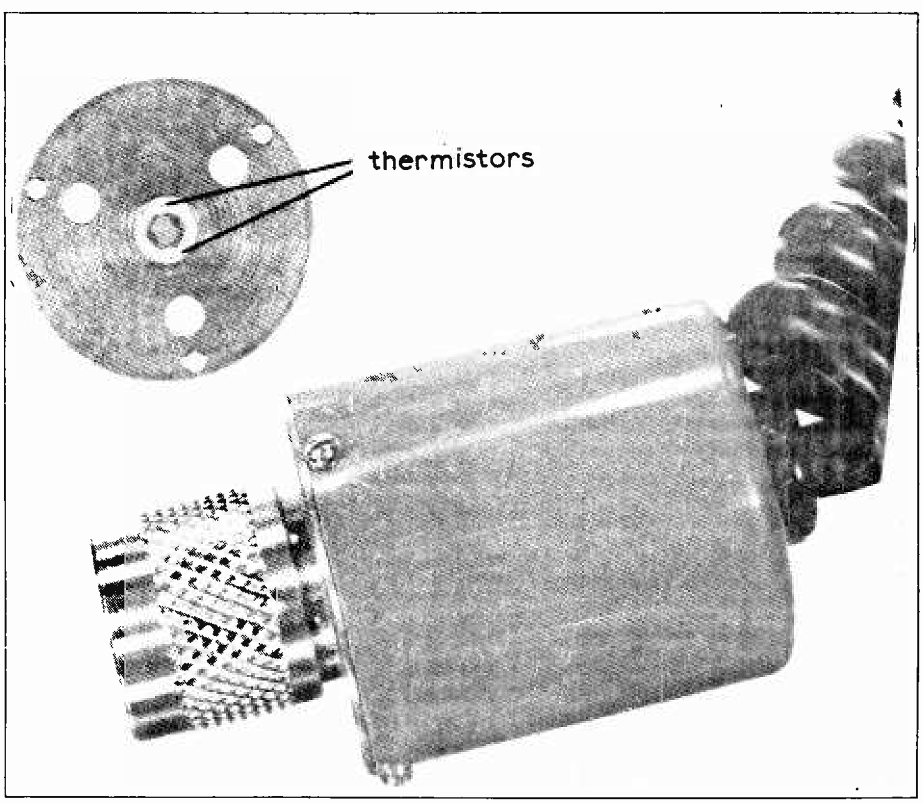


Fig. 3. Coaxial thermistor head in which the thermistor beads terminate the transmission line in a good match and so absorb the microwave power. Head is electrically connected to the power meter bridge, amplifier and display unit.

concerned. They are biased to a value of 100 ohms each. Capacitor C_2 is similar in value to C_1 and thus also presents a low impedance to the input signal, the effect being to cause the thermistors to appear in parallel at r.f. Overall impedance presented to the 50-ohm transmission line is thus 50 ohms and helps towards achieving a good match. The compensating thermistors are electrically isolated from the microwave circuit but are in close enough thermal proximity to experience, identically with the detection thermistors, any variation in ambient temperature.

With a range of waveguide mounts also available, the thermistor power meter is a sufficiently accurate and reliable instrument and, for many years, has been the backbone of engineering power measurements.

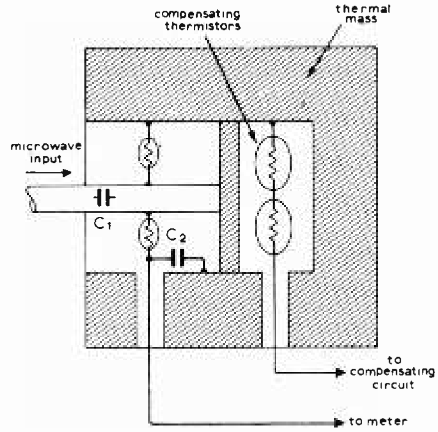


Fig. 4. Thermistors which terminate coaxial line appear in series to the d.c. substitution and bridge circuit but in parallel to the high-frequency microwaves. A large thermal mass together with twin compensating thermistors substantially eliminate ambient temperature fluctuations.

Thermocouple power meter

A strong challenge to the position of the thermistor is being made by the thin-film thermocouple and, with the improvements made in recent years, this device now offers several advantages such as very much greater temperature stability and higher burn-out levels. The coaxial mount construction is very similar to that of the thermistor except that, instead of fine wire supports, the favoured technology is that of thin film deposition on as thin as possible a substrate.

An example is shown in Fig. 5, the thermocouple being formed from evaporated bismuth and antimony with the hot junction lying in the gap between centre and outer conductors; the large semicircular contact pads are of gold.

Thermocouple resistance, and hence match, are controlled by the bismuth and antimony film thickness. Incident microwave power absorbed at these hot junctions raises their temperature, giving rise to a thermoelectric voltage which is then amplified and displayed in terms of microwave power.

The voltage generated in this fashion can be as low as several hundred nanovolts and thus requires careful circuit design to avoid odd thermocouple effects creeping in from dissimilar metal junctions and other sources of noise. Amplification is carried out after first chopping the d.c. signal and the signal is then synchronously detected. Unlike the bolometric power element, instrument calibration is carried out by direct comparison with a national substandard and not by d.c. substitution.

Recently an improved form of thermocouple sensor has appeared on the market* using a silicon p-n diffused region as one arm of the thermocouple with a gold contact to act as the cold junction and a resistive tantalum nitride contact as the hot junction. The complete element is less than 1mm square and 0.005mm thick and offers a better r.f. match because of lower reactance, a faster response time and greater long-term stability than the normal bismuth-antimony element.

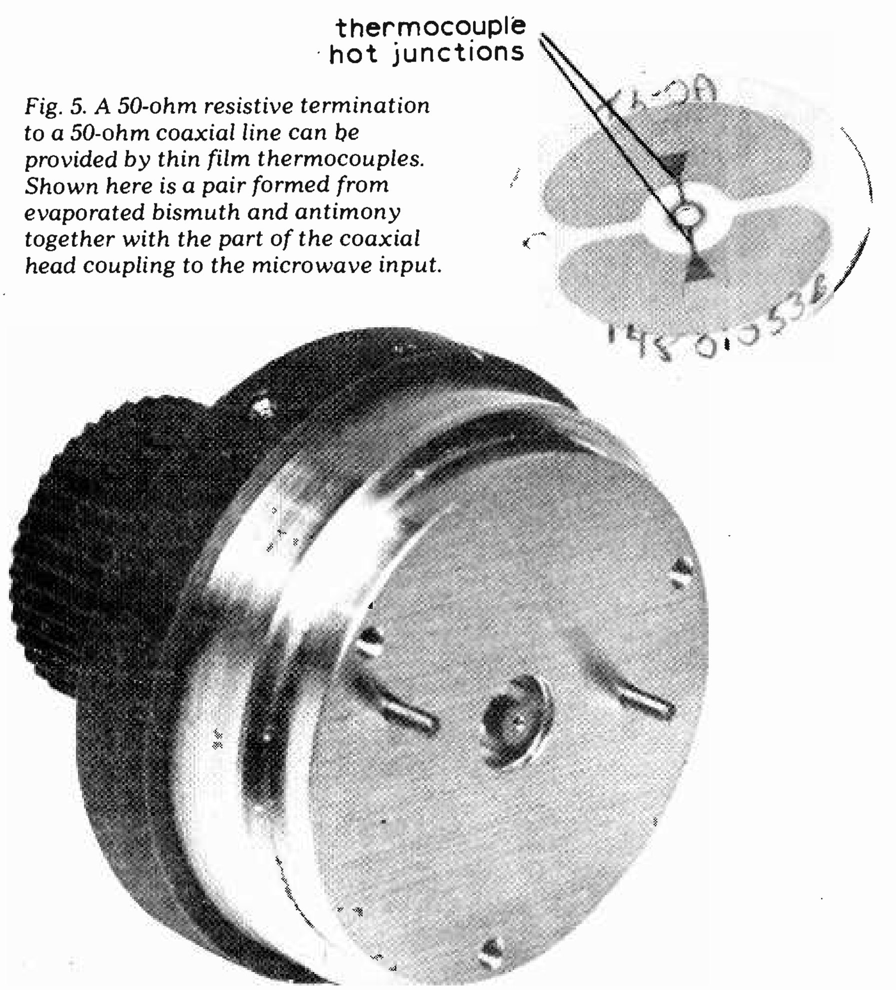


Fig. 5. A 50-ohm resistive termination to a 50-ohm coaxial line can be provided by thin film thermocouples. Shown here is a pair formed from evaporated bismuth and antimony together with the part of the coaxial head coupling to the microwave input.

Calorimeters

In contrast to the devices so far mentioned, in which microwave power is measured by some calibrated change in an electrical property, the calorimeter relies upon dissipating the incident power within some absorbing medium and then measuring the associated rise in temperature. The microwave power can then either be calculated from a knowledge of the temperature rise versus time and the thermal mass, or a calibration can be made against known quantities of d.c. or low-frequency input power.

Commercially available calorimeters are bulky and expensive devices and have measurement rise times of several minutes. Consequently they are usually kept in the standards room of the user as a calibration reference for the more general-purpose bolometric instruments. Higher-order standards tend to be individually designed and vary from country to country and are always being improved. Thus, although the operating principles are the same, there are many different types of calorimeter. Instead of enumerating these, it will probably be of greater interest to describe briefly one of the instruments which has recently been developed at the National Physical Laboratory for use as a national standard.

NPL calorimeter

This device is a twin calorimeter and operates in the system shown in Fig. 6 between d.c. and 6,000MHz and for input power levels of between 10mW

* *Hewlett Packard Journal*, Sept. 1974.

and 100mW. The instrument uses two coaxial transmission lines of 50-ohm characteristic impedance, each terminated in a matched, power-absorbing, resistive load. Microwave power is fed into one of the lines and the resulting rise in temperature difference between the two matched loads is measured by the thermopile. This unit consists of 800 junction pairs of copper-contantan. The loads and thermopile at the end of the calorimeter are shown in Fig. 7. After the heating effect is noted the microwave power level can be determined by measuring the amount of d.c. power which must be applied to the load to produce the same effect. The symmetry of the calorimeter, together with the double-packed thermal insulation, helps to eliminate the effects of room-temperature fluctuations.

An interesting technique used in the development of this NPL calorimeter and in building up a thermal equivalent circuit was the determination of thermal resistances by localized heating with a laser beam. Instead of supplying heat to the calorimeter and noting the temperature response in different areas with thermocouples, these areas were painted black and irradiated with a laser beam, so producing an output from the thermopile. By calculating the local thermal capacities from a knowledge of dimensions and using the laser technique to measure the local resistances, a very comprehensive equivalent was obtained.

In practice, to speed up the reading time the calorimeter is operated in a feedback loop wherein the output from the thermopile is fed via an amplifier and frequency-compensating network back to the second input of the calorimeter. The load at the end of this line is thus heated to the same temperature as that terminating the microwave input and the microwave power can be determined from the substituted d.c. input power necessary to produce the same power in the feedback loop.

With corrections made for losses in the input lines, power lost in heating the thermopile, load mismatch error and d.c. instrumentation errors, the absolute accuracy in measuring the microwave power lies between 0.2% and 0.5% with a measurement time of several minutes.

So, even for a national standard, the accuracy with which microwave power can be measured is not as good as that for d.c. or low-frequency power. The uncertainty of the d.c. calibration power in the calorimeter, for instance, was an order of magnitude loss. Even so the general purpose commercial instruments are many times worse than this in absolute accuracy and it is worthwhile noting the prime causes of error.

Power measurement errors

There are three main sources of error:
—instrumentation error,
—d.c. substitution error,
—mismatch error.

The first is not particular to microwave measurements as it is caused by such things as amplifier non-linearities, range switching and meter display, but might typically lie in the region of 1% of f.s.d. The substitution error has been mentioned previously and is due to the d.c. or low frequency power producing a slightly different heating effect than the microwave power. As such it is a function of the sensing element dimensions compared with the wavelength and is different for the barretter, thermistor and thermo-couple. Usually the error is quoted as an efficiency defined by

$$\frac{\text{d.c. substituted power}}{\text{dissipated microwave power}}$$

and can be quite significant, typically lying between 90% and 99% depending upon frequency. The way round this error is by the instrument manufacturer maintaining a standard microwave power reference source and calibrating each sensing element. An efficiency versus frequency plot is then supplied with each mount and a manual control allows for compensation. By this means the substitution error can be made smaller than the other two main sources.

Finally, the largest single source of error and one which can only be partly controlled by the instrument manufacturer is that due to mismatch. The preceding article in this series pointed out the significance of having an obstacle or load impedance which was different from the characteristic impedance of the transmission line. It was seen that such a difference, or mismatch, caused some of the power to be reflected back again to combine with the incident pattern and produce a standing wave along the line.

Unless the quantity of reflected power is known the power meter will read only the amount actually dissipated in its sensing element and not that incident. Here, though, lies a major problem, in that the actual power reflected depends on two things, one being the impedance of the sensing element and the other the impedance of the microwave source plus any other discontinuities in the line. And, being in general complex quantities, their phase controls the manner in which they combine, a factor which is also influenced by the length of transmission line separating them. This phase relationship is usually an unknown quantity so that, unless elaborate and inconvenient tuning procedures are intro-

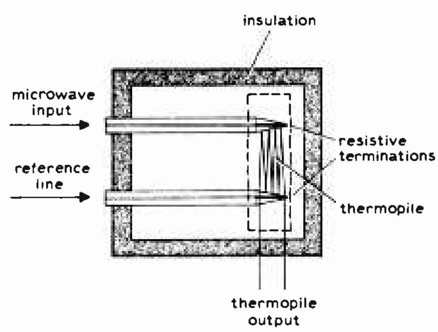
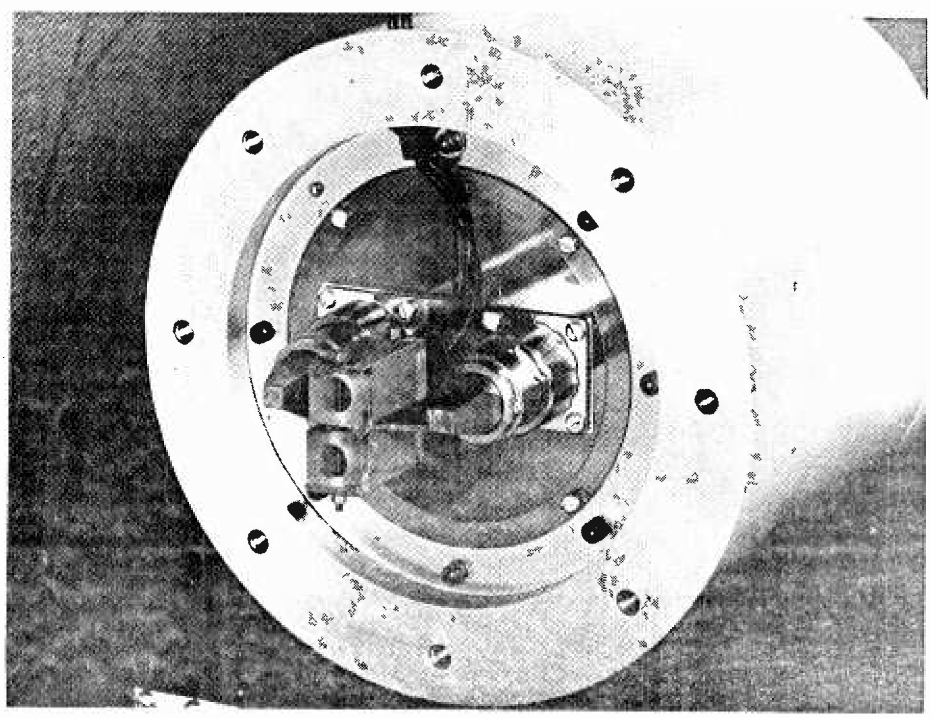


Fig. 6. Schematic of a twin calorimeter wherein the microwave power is absorbed in a resistive load and the resultant rise in temperature measured and calibrated.

Fig. 7. Rear view of the NPL calorimeter showing the resistive load terminations and thermopile coupling. (Courtesy National Physical Laboratory, Crown Copyright reserved.)



duced, the day-to-day practice is for manufacturers to design components to as low a v.s.w.r. as possible and for the user to accept the resultant error.

By way of illustration and to recap on previous subject matter: the ratio of the electric field magnitude reflected from a mismatch to that incident is termed the voltage reflection coefficient (ρ) and this reflected signal gives rise to a transmission-line standing wave pattern as shown in Fig. 1 of Part 9. The ratio of the electric field maximum to minimum of this pattern, which can be directly measured, is termed the voltage standing wave ratio S (v.s.w.r.), and is universally used as an indication of the degree of mismatch of a component. A perfect match is when $S = 1+\rho \ /1 - \rho$ remembering that, in general, ρ is the modulus of a more complete reflection coefficient containing phase information.

Now when two or more sources of mismatch are present the amount of power that is actually reflected from any one of them depends upon the way in which the reflected waves combine, that is, upon their relative phase, and this is the quantity usually unknown. It is, however, possible to define a worst case and a best case limit to the resultant mismatch from just a knowledge of the v.s.w.rs involved. Take the case of a microwave generator having v.s.w.r. S_1 and power monitor of v.s.w.r. S_2 ($S_2 > S_1$), then the worst combination would be if one had a v.s.w.r. of S_1. S_2 and the other unity, and the best case would be if one were S_2/S_1 and the other unity.

Taking some practical values of $S_1 = 1.30$ and $S_2 = 1.50$, which are typical for general test equipment up to J-band (12.4GHz), the worst and best cases result in values of 1.95 and 1.15 corresponding to values of ρ of 0.32 and 0.07 respectively. The power reflected is proportional to ρ^2 and so, in this case, the power meter error will lie between −10.2% and −0.5% depending upon the way in which the mismatches combine. A reduction of the power monitor v.s.w.r. to, say, 1.2 would have a significant effect on the error, reducing the uncertainty range to between −4.8% and 0.2%. The way in which other variations in match can effect the power measurement error is shown in Fig. 8 in which the above two cases are plotted as points A and B. It can readily be seen how easy it is to introduce quite large errors into microwave power measurement and how important it is to minimize the mismatch loss of microwave components.

A final point concerning Fig. 8: the percentage error introduced by combining the v.s.w.rs on this basis is that compared to what would be delivered to a power monitor having an impedance equal to that of the transmission line.

Measurement of frequency

In general the direct measurement of frequency is basically a measurement of time but, because of the manageable size of wavelengths in this region of the spectrum, frequency can also be determined by a measurement of length. An example of this latter method is the slotted line used for v.s.w.r. measurements previously discussed in Part 9. By moving the sliding carriage, the attached probe samples the periodic standing wave pattern in the transmission line which repeats itself every half wavelength. The position of the carriage is indicated by a calibrated venier scale like that used in vernier calipers or sometimes by a clock gauge. In either case position can be measured to about 0.1%, but this accuracy is somewhat degraded when applied to measuring wavelength because of the error in finding the identical probe positions on different cycles of the pattern. This method is comparatively laborious and is only used nowadays either as a teaching aid or in those cases of dire emergency when one's own frequency counting system has broken down and one can't borrow a replacement from someone else.

A second frequency-measuring instrument, and the most widely used of all, is the wavemeter. Many designs exist but all are based on noting the response of a three-dimensional microwave cavity at its point of resonance, this point being adjustable. A popular method is shown in Fig. 9, which illustrates a cylindrical cavity into which slides an adjustable spindle. The cavity is loosely coupled to the main transmission line so that a small amount of microwave power can enter.

With the spindle withdrawn completely from the cavity a waveguide mode can exist, and the cavity will appear as an electrically resonant circuit with a resonant frequency determined by its diameter. As the spindle is inserted the resonant frequency is reduced from this upper limit and becomes a function of the spindle length, L, and the cavity now supports a hybrid mode consisting of the original waveguide one and a TEM mode due to the coaxial section formed by the spindle.

Finally, as the spindle penetration becomes greater, the fringing capacitance between the end of the spindle and the base of the cavity starts to influence the resonant frequency, which starts to decrease quite rapidly. The Q factor of this type of microwave resonant circuit is a function of the ratio of cavity to spindle diameters and can be in the vicinity of 1,000.

A practical realization of the instrument is shown in Fig. 10, in this case for use with miniature coaxial connectors. The right-hand component is inserted in series with the coaxial line carrying the frequency to be measured so that the microwave power enters the left-hand connector, say, and leaves via the right-hand one, which might be terminated in either a crystal detector or a power meter. The hole by which a sample of the power can be coupled out can be clearly seen between the two connectors.

On the left of Fig. 10 is the other part of the wavemeter, which contains the cavity, spindle and frequency readout

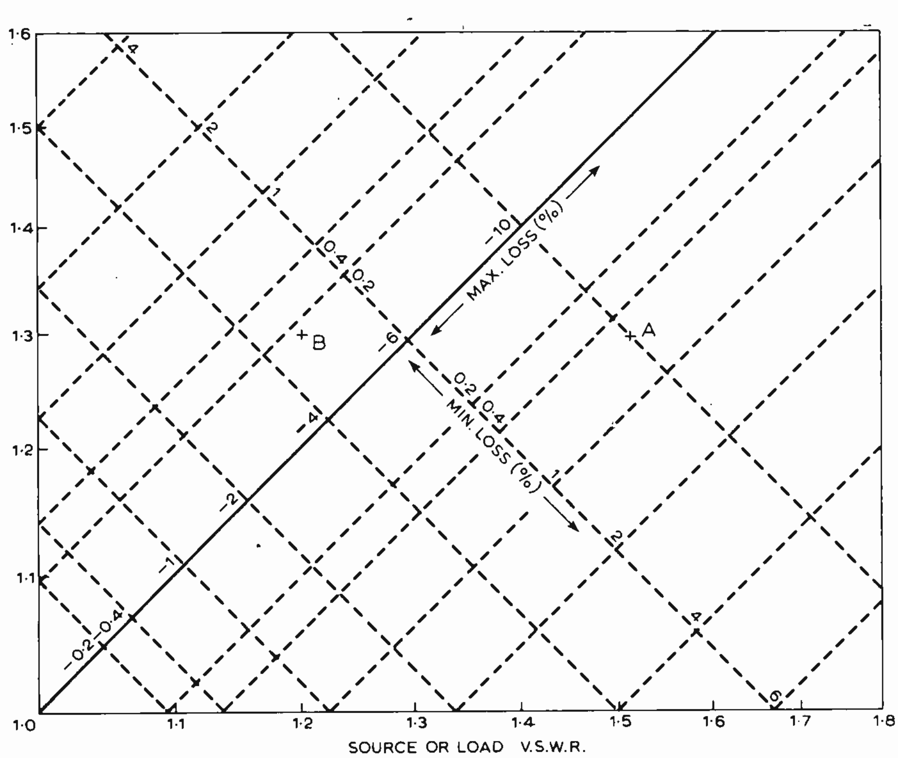
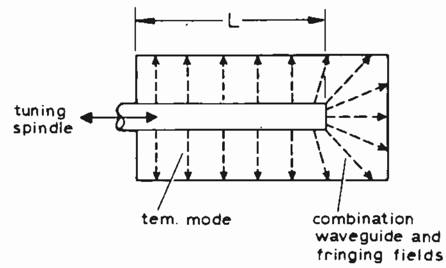


Fig. 8. Effect of the mismatched source and load can be quite serious in terms of measurement error. This graph shows the limits of maximum and minimum loss set by two mismatches; the exact value cannot be determined without phase information, which is usually lacking.

Fig. 9. Popular version of the wavemeter cavity in which the resonant frequency is governed by the spindle penetration. Cavity is coupled electrically to the main transmission line and the frequency is indicated by the point at which the cavity absorbs power at resonance.



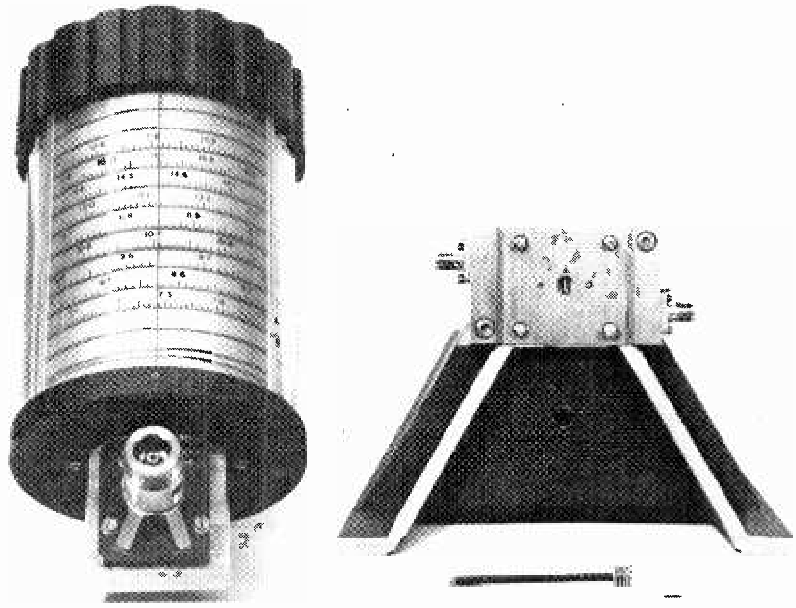


Fig. 10. Commercial wavemeter operating from about 5 to 18GHz, showing the series-mounted section and coupling hole on the right. Bolt-on unit on the left comprises the tunable cavity and frequency readout.

and which bolts onto the other component. Thus, when measuring an unknown frequency, the large drum carrying the scale is slowly rotated, thereby turning also a micrometer thread carrying the spindle and varying its penetration into the cavity. When the point is reached where the cavity is resonant at the transmission line frequency, it will absorb energy from the main line and a sharp dip in output will be observed from the detector or power meter.

The instrument is calibrated from a frequency standard and the advantage of this type of readout is that it enables a large, finely graduated scale to be used. In this case the unwound scale length is about 2m and the measurement accuracy is ±0.1%. The larger type N connector in the photograph is an additional facility and enables the resonant condition to be identified by connecting a detector to monitor the power absorbed into the cavity.

Progressing in complexity (and cost), one comes to the frequency counter type of instrument which is a true frequency meter in that it actually counts the cycles of a periodically varying waveform. For microwave frequencies the counter usually consists of two sections: a low-frequency part containing a crystal-controlled reference oscillator, digital counter and digital display and a high-frequency section containing a transfer oscillator, harmonic selector and r.f. input.

The transfer oscillator consists of a conventional low-frequency oscillator circuit operating at, say, 100MHz and it could either be a highly stabilized one or tunable by several tens of MHz either side of the fundamental, depending upon the approach adopted by the manufacturer. Whichever it is, the output from the oscillator is fed to an harmonic generation circuit producing usable outputs up to, say, the 100th harmonic.

Taking the tunable version as an example, the oscillator output plus harmonics would be fed to a tunable mixer along with the input signal to be measured. Harmonic selection circuitry then allows the harmonic nearest to the unknown frequency to be selected, to producing a low i.f. from the mixer which is displayed on an integral c.r.t. The fundamental oscillator can then be tuned to a frequency which gives a zero beat between the two mixer inputs, at which point the unknown frequency is now a known number of harmonics up on the fundamental and is displayed on a digital readout. In arriving at this correct display it is necessary to know the fundamental oscillator frequency and this is counted directly by shift register in the low-frequency section. Here a reference oscillator accurately times the opening of a sample gate while the number of cycles passing is counted.

Accuracy of these counters is ± one count in the low-frequency section, in this case at a nominal 100MHz plus crystal stability. This latter is typically 1 in 10^7 per week or 2 in 10^{-9} per second with high stability options giving 1 in 10^9 per day. Most instruments also possess a switchable a.f.c. loop which eliminates zero beat error in this case and also enables f.m. signals to be counted.

At present, commercial instruments are available with transfer oscillator plug-ins which enable frequencies of up to 40,000-MHz to be directly measured. But, in principle, the technique can be applied to higher frequencies still.

Acknowledgment Many thanks to my old friends at the Sanders Division of Marconi Instruments Ltd for the photographs used in Figs. 3, 5 and 10 and also to Dr Alan Fanton at the NPL for details of the 6GHz calorimeter.

Sixty Years Ago

ONE of the earliest methods of viewing response curves, now the province of cathode-ray and pen recorder instruments, was described in the issue of *Wireless World* for July 1915. Designed by Dr. J. A. Fleming (Sir Ambrose, of diode fame) the instrument was named the "Campograph" and was reminiscent of the Duddell oscillograph, in that it was "all done by mirrors".

A long, narrow mirror, mounted with its long axis horizontal, was connected by a cord to the spindle of a rotary potentiometer (a new device invented for this instrument) and was tilted as the pot.was turned. The wiper of the pot.derived a voltage which was applied to the device under examination (detector, valve, etc.). A mirror galvanometer, whose light spot was directed on the long mirror, was deflected by the dependent variable signal, such as anode current, the two together forming X and Y axes of the display, projected either onto a screen or photographic plate. Alternatively, the pot. could be replaced by a variable capacitor, when the instrument could be used to plot resonance curves.

Examples of photographs obtained in this way were shown in the article and included valve characteristics, hysteresis curves of iron wire and resonance curves. An instrument which uses a similar principle was described by H. J. N. Riddle in the issue for November, 1971.

World of Amateur Radio

Amateurs and emergencies

From time to time amateur radio finds itself firmly at the centre of the world stage — unfortunately most often in connection with major natural disasters that disrupt normal telecommunications leaving amateur stations as the only or first links with the stricken areas. Magazines from Australia and New Zealand reflect two such events: one last Christmas, the other in 1931.

Electronics Australia describes how when the cyclone struck Darwin on Christmas Day one of the first links to be established was from a mobile station in a car 13km outside Darwin operated by VK2BNN, his wife VK2BYL and VK8JT. They made contact with amateurs in Victoria more than 1,600 miles away, providing one of the few channels for police and emergency traffic. On Boxing Day an emergency s.s.b. net was established on 14.111 MHz with VK3AUP, Melbourne acting as control. VK8CW at Alice Springs acted as a relay station when required. By December 27 the net had become a nationwide system with participating amateurs in Cairns, Townsville, Rockhampton, Mackay, Mt Isa, Brisbane, Lismore, Armidal, Sydney, Canberra, Cooma, Melbourne, Adelaide, Perth and Alice Springs.

The New Zealand journal *Break-in* reports the death of James Mills, ZL2BE of Hastings who for many years was a leading figure of amateur radio in that country and whose activities attracted world interest in February 1931 when a major earthquake shattered the towns of Napier and Hastings. James Mills was one of the few amateurs having a rotary generator that could be run from car batteries and was able to make contact on 3.5 MHz, first with other amateur stations and then with the official New Zealand Government station ZLW at Wellington, handling a very large number of emergency messages. Later a relief expedition to Napier was accompanied by ZL2BO who set up a station there. The events generated enormous goodwill towards amateur radio and the country still maintains an Amateur Radio Emergency Corps which is frequently called upon to help; two recently reported cases involved a search for lost hikers who got into difficulties crossing the Roaring Meg River and a coastal rescue when a trawler went ashore off New Plymouth.

In the United Kingdom the "Raynet" or Radio Amateurs' Emergency Network of the RSGB maintains preparedness for emergency operations through local controllers and groups and by regular exercises in conjunction with the British Red Cross Society, the St John Ambulance Brigade and the police. They are ready and authorised to provide communications assistance on request from the user organisations in conditions where there is a real risk to human life, in the belief that Raynet is a way in which radio amateurs can use their knowledge as a service to the community. Fortunately, the occasions on which Raynet is called upon in earnest are relatively few: most "on air" activity is during simulated emergencies. Nevertheless it is a service that believes in being ready and willing.

Hourly propagation forecasts from WWV

For amateurs and short-wave listeners a source of hourly propagation data is the American standard frequency transmissions from WWV (Colarado) and WWVH (Hawaii) on 2.5, 5, 10, 15, 20 and 25 MHz. These now include at 14 minutes past each hour an indication of solar flux (in the form 72 plus 0.6R) and geomagnetic activity (0 to 9 K scale).

In general for good h.f. conditions the higher the solar flux figure the better (for the next few years this is unlikely very often to exceed 100); conversely a low K figure (preferably 2 or under) is a good sign. High K ratings indicate a significant influx of solar particles, usually resulting in weaker signals, increased fading and noise: over 4 usually indicates a solar storm; 3-4 unstable or unsettled conditions. Unfortunately at the present time the standard frequency transmissions heard most strongly in the UK are seldom those from WWV or WWVH.

There is growing evidence to suggest we are now very close to the end of the present sunspot cycle, with its oddly distorted decay during 1972. Although it is unwise to make long term predictions about future sun-spot activity it looks increasingly as though the next cycle may have a relatively low maximum.

The ZB2VHF beacon station at Gibraltar is now in operation on 144.145 MHz beaming signals towards the UK.

Look no batteries!

The energy crisis has made numbers of amateurs look quite seriously into the question of how radio communication could be maintained completely independently of mains supplies or primary batteries. Some recent experiments have been based on solar batteries, wind generators and pedal- and hand-operated battery chargers. *QST* for example reports that a man on a jacked-up bicycle can generate 100 to 120 watts of power by driving a car generator at over 1,100 r.p.m. using the high gearing provided by a 27-inch wheel (generators for this purpose were dropped by the RAF to the French resistance during World War II).

But for sheer ingenuity a prize must surely go to a Dutch amateur J. M. H. Wagenmans, PA0HWE who claims to have built a milliwatt transmitter powered entirely by the action of the Morse key! He does this by linking the moving arm of a Morse key to the cone of a moving-coil loudspeaker so that the movement produces an electrical output which is rectified and stored in a 40,000μF capacitor to power a transistor crystal oscillator to a d.c. input of 1.5 mW. Brass pounding with a vengeance; although a nagging doubt remains, despite the photographs and circuit details in the April issue of the Dutch journal *Electron:* April issues of amateur journals are notorious for elaborate technical spoofs, though it is difficult to fault this idea!

In brief

The RSGB has stated that it appears that the 25% VAT rating applies to all amateur radio equipment and components . . . The recent use of the callsign GB2IARU at Tonbridge School to mark the 50th anniversary of the formation of the IARU is believed to be the first time a four-letter callsign suffix has been authorised for amateur radio operation in the UK . . . During 1976, the bicentennial year of the constitution of the United States, American amateurs will be able to use callsigns beginning with an "A" instead of "W" or "K": all prefixes will have two letters before the district number, ranging from AA1 to AL7 and including AC4 which was formerly used by amateur stations in Tibet and thus one of the most eagerly sought after prefix of all time . . . American amateurs are concerned that a Dallas consulting firm has filed a proposal with the FCC for a new television channel that would result in the elimination of the 50MHz amateur band . . . A 10GHz beacon station at a temporary site on the Isle of Wight has been heard at distances up to 65km, the beacon uses an 80mW oscillator on 10,100 ± 1MHz with an omnidirectional aerial with a gain of about 11dB. Callsign is GB3IOW . . . Among forthcoming mobile rallies are: Longleat near Warminster on June 29 by Bristol RSGB Group; Upton by Worcester society on July 6; Cornish RAC Rally, Camborne (provisional) on July 20 (details G3NKE); Polegate Steam Engine Rally on July 20 with exhibition station GB2SS.

PAT HAWKER, G3VA

75 Years of magnetic recording

5 — A diversity of applications

by Basil Lane

Assistant Editor, Wireless World

Shortly after the end of World War II, events took an unexpected turn for magnetic recording. Up to that time, although other uses had been suggested for this versatile storage method, the technology had not developed to the stage where they could be practically realized. However, the war effort had resulted in new electronic techniques becoming available and at he same time magnetic recording itself came of age. From that date forward, the number of applications for magnetic recording were to multiply.

Curiously, for the historian, the task of recording events in the recent past becomes more difficult the closer one approaches the present day. There could be many reasons for this, but in the case of magnetic recording it is because technology from 1945 advanced at such a rate that new developments followed one another at an incredible pace. This makes it difficult to say at times who was first in the field with a particular idea. One can only hope to describe from contemporary reports what happened.

A typical example is the computer. Where now we can hardly think of a computer without also thinking of the magnetic storage methods used, the earliest computers were without such an advantage. Suddenly, everyone seemed to be working on the idea of using magnetic tape as a storage medium. In an historical broadsheet put out by 3M a few years ago[68] it was suggested that flexible storage systems were one of the most significant steps taken by computer designers, and in the days just after the war a variety of memory devices were proposed including delay lines filled with gin!

Just about the earliest computer with a magnetic store was the ARC (Automatic Relay Calculator) made at Birkbeck College, London in 1947. Built for the British Rubber Research Association, it had a nickel plated drum store with a capacity for 256 numbers each of 21 binary digits. Shortly after, the experience gained in developing this computer was used to develop the SEC (Simple Electronic Computer), the first all-electronic computer with a drum store.

Also in 1947, Eckert and Mauchly built a machine called BINAC for the Northrop Corporation, this computer using a mercury delay-line memory of 512 words and being the first to use a magnetic tape input and output.

Although magnetic drum and disc scored for short term storage with fast, random access, there was an increasing requirement for long term serial data stores of greater versatility than the punched paper tape and card type. Thus in the early 1950s several machines appeared with a tape storage system, one such machine being the IBM 701. This was the first of the IBM machines to use a combined drum and tape store, supplemented with Williams tubes to give a total memory capacity of 2048 words.

Most of the development from that time on, concentrated on the improvement of the magnetic media, not only to reduce the error rate due to drop-outs but also to increase the capacity of the media to record digital bits. Thus the capability rose from 100 bits per square inch in 1947 to 1500 in 1965[69] and as high as 6500 bits per square inch today — although there are at the moment few, if any, machines that are capable of recording such a bit density. Although plated metal discs had been used from time to time, the real development of this form of recording medium did not start until Zaponi[70] developed a reliable plating technique in 1952. It is interesting to note that 46 years earlier, P. O. Pedersen had patented[71] a plated magnetic carrier though this was of course intended for audio recording.

In modern computers a variety of storage media is used, with magnetic methods still paramount. Disc is used for random access and usually is manufactured as a pack of discs in a standard format. The magnetic layer may be acicular Fe_2O_3, plated nickel-cobalt or other similar magnetic metals and the writing and reading are achieved by flying heads located in the appropriate position in the disc pack by high speed actuators. Magnetic tape is still strongly favoured for long term storage where access time is not so important and will be either ferric oxide, cobalt-doped ferric oxide or chromium dioxide, all of the latter having been developed from the early sixties.

The most popular material used in magnetic tapes is still the leader, this being gamma ferric oxide. Since the

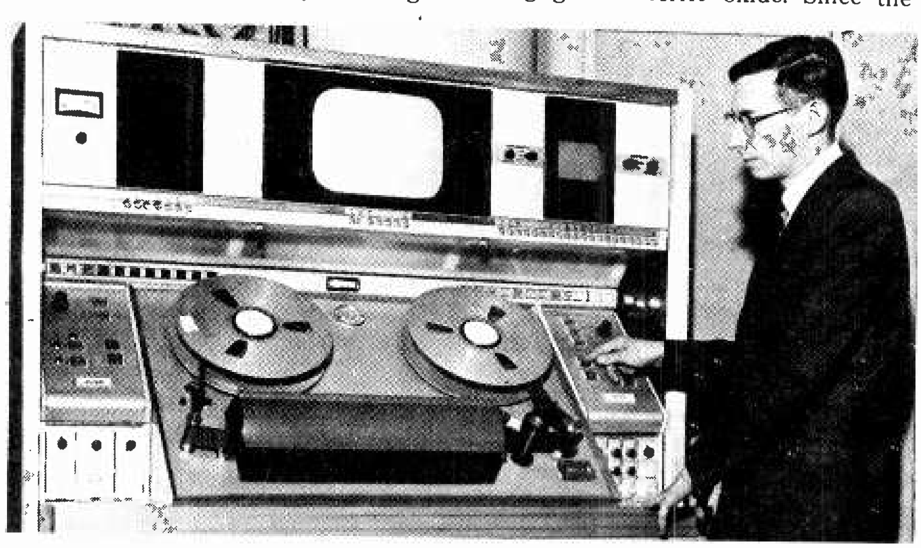


Fig. 2. The TR-22 video recorder by RCA, this was the first transistorized video recorder to enter service, May 7, 1961.

early days of its use as the basis for a coating formulation for magnetic tape, it has been improved and the coating formulation itself developed almost beyond recognition. However, it was inevitable that some challenge to the supremacy of ferric oxide should come from other materials and the demands placed on magnetic tape by the invention of the video recorder and the data recorders for computers provided the impetus for this to happen during the 1960s. From around 1956, cobalt doping of ferric oxide had been studied as a method of improving the short wavelength response of tape and by 1967 an experimental tape had been made. However, the problems associated with this type of magnetic material (e.g. pressure instability of magnetisation) prevented it from becoming as popular as more conventional coatings.

Another line of research had been undertaken by Swoboda[72] who had been concentrating on the problem of synthesizing chromium dioxide, a promising material for tape since it had a high remanence, which offered a very good short wavelength performance. In early 1961 this substance was produced successfully, though it was to be some time before it made its debut as a magnetic tape. As a matter of interest, it took ten years for CrO_2 to appear in a compact cassette, when Crolyn (the Du Pont name for CrO_2) appeared under labels such as Advent and Memorex.

It is interesting to note that, due to a quirk of American Patent law which allows applications to be patented as well as processes, Du Pont held the master patent for the use of CrO_2 as a magnetic recording medium in America. Process patents are held in all the other countries of the world where applications are not patentable, and it was this situation that led to Agfa Gevaert trying to circumvent the Du Pont patent in 1972. They too had invented a process for the manufacture of CrO_2, which differed from the Du Pont method, but were prevented from selling any tape in America because of the patent held by Du Pont. The ridiculous situation of being barred from one of their important markets eventually forced Agfa to take out a licence for the Du Pont process and pay for the privilege of selling CrO_2 tape in America.

Since the date of the appearance of CrO_2 as a magnetic medium for cassette tapes, other manufacturers and those who were licencees have been attempting to either equal the performance of this substance, using cheaper ferric oxide, or have been busy looking at other substances. One development that appeared to result from a parallel, but separate, development project was the dual layer coated tape. These had been proposed as early as 1953, when Kornei[74] suggested that short wavelength performance could be improved if a multi-layer tape was prepared with a high coercivity surface layer, followed with successively deeper layers using oxide of a lower coercivity. Another quite novel idea proposed by Gabor and Bauer[74] was that a dual layer tape should be made with the top layer oriented in a vertical direction.

However, it was Sony and 3M that eventually produced a practical dual layer tape, with Sony marketing its product in Japan in January 1974 and, later that same year, 3M announcing its own product. Again, it would seem that the master patent is probably held in America by 3M,[75] so it is highly likely that Sony have had to come to some cross-licence agreement with 3M in order to sell their tape in the USA.

Developments in heads

No history of magnetic recording would be complete (and this one is far from being so) without a mention of the development of ferrite heads. With the appearance of CrO_2 tape, which is a much more abrasive material, there was a particular requirement for a hard wearing head to be produced which would withstand many hours of use. This was very important in video recording where the head to tape speed is high and the track width is narrow.

Early heads had been made of laminated Mumetal and although experiments had been made with harder materials such as Alfenol, this proved, until recent years, too intractable to be used as a substitute. Permalloy and other harder grades of metal have been used with increasing success, but it was the ferrite head that made the big news when it was first developed. One of the first descriptions of a ferrite head appeared[76] in 1955, to be followed some years later by the classic paper by S. Duinker[77] of Philips, who described the method of using glass as a spacer and as a bonding material in the front gap of the head. This was a significant improvement that reduced the number of rejected heads that had suffered from chipping at the gap edges.

By 1968, Matsushita had developed the hot pressed ferrite head and about this same time Akai appeared with a glass-crystal ferrite head, made from a monocrystalline block of ferrite.

Other important head types used in specialist fields were the flux sensitive heads, either using a saturable limb in the magnetic circuit of the head, or the semiconductor Hall effect types described by Camras in the mid-1950s. It was Camras also that invented the cross-field head[78] for audio use, this being described January 1952.

In recent years there has been an increasing interest in the fabrication of very precisely defined narrow track heads and to this end experiments have been undertaken to produce sputtered film[79] cores in 1967 and later, in 1972, sputtered film heads using Sendust as the magnetic material.[80]

Conclusion

In as brief a series as this has been it is difficult to be as thoroughgoing as perhaps one should be, and I am certain that some important inventions have been left out. Little has been said of the p.c.m. recorders developed by the BBC[81], Nippon Columbia[82] and others[83], nor has anything of note been mentioned of instrumentation recorders, including those used in the space effort. There are also the more exotic types of recorders such as the brilliant invention by Seimens[84] of the slow and stop motion video disc recorder. However, I feel that all of the significant stages in the development of magnetic recording on the broad front have been covered.

It still seems remarkable that only 75 years ago Poulsen and Pedersen could have been responsible for the whole chain of ideas and inventions that resulted in the magnetic recording process that so invades the everyday life of every one of us.

My apologies to Mrs Pedersen who was kind enough to write and point out an error in spelling P. O. Pedersen's name in earlier parts of this series.

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New Products

Thick-film amplifier

A thick-film hybrid amplifier suitable for audio applications will deliver around 15W (average) into an 8Ω load. The class B quasi-complementary circuit has a frequency response from 0 to 80kHz, an input sensitivity of 350mV (typical), and a t.h.d. figure of 0.2%. The device is mounted on an integral heat sink measuring 30 x 30mm which allows full rated output at a temperature of 55°C. Tadiran, 193 Regent Street, London W1.
WW 312 for further details

De-soldering instrument

Adcola Products have introduced an automatic de-soldering instrument for removing d.i.l. i.cs from p.c. boards. The unit, which is called the Removic, consists of an operating gun powered from a control box which adjusts the temperature from 350 to 750°F. In operation the gun is placed over an i.c., a handle is pressed which positions extractor claws and heater blocks on the i.c. When the solder melts the component is extracted by applying steady pressure on the handle. Adcola Products Ltd, Adcola House, Gauden Road, London SW4.
WW308 for further details.

Mini drill

A small power drill manufactured by Expo operates from a 12V 1A supply and has a chuck speed of around 9000 r.p.m. The drill, which is supplied with a range of accessories which include twist drills, cutting, milling, reaming and grinding tools, is priced at £9.17 plus v.a.t. and is available from Electroplan Ltd, P.O. Box 19, Orchard Road, Royston, Herts SG8 5HH.
WW310 for further details

Alarm unit

The Tellit is an audible alarm unit using a continuous loop of tape which may be recorded with any short message or warning specified by the user. Four basic types are available including an uncased playback mechanism for mounting into customers equipment. Highland Electronics Ltd, 33 Dallington Street, London EC1V 0DB.
WW311 for further details

Counter

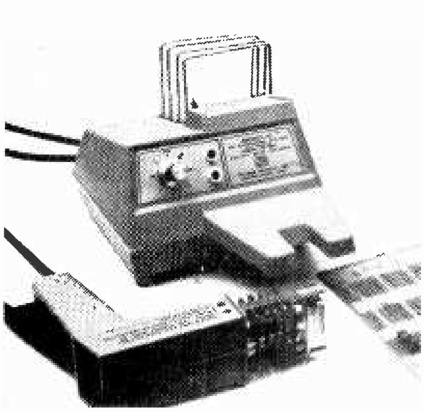
A 75-MHz counter/timer, model 5308A, measures frequency, frequency ratio, period, period average, and time interval. The instrument also offers an auto-range facility which selects the range that will give the best resolution within a measuring time from 0.11 to 1.1s. Measurements are indicated by an eight-digit display housed in a 3½ x 6¼ x 9¾in case. Hewlett-Packard Ltd, King Street Lane, Winnersh, Wokingham, Berks RG11 5AR.
WW303 for further details

Triacs

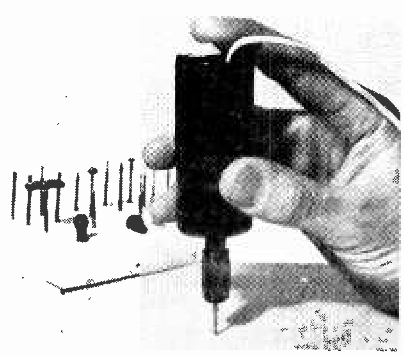
ITT Semiconductors have made their first step into the triac market by announcing the TC range of devices. These components, which have been designed and manufactured in the UK, are available with current ratings of 4, 6, 8, 10, 12 and 16A at voltages of 200, 400, 500 and 600V. The complete range uses a centre-gate construction for improved *di/dt* capability, and has glass passivated chips which improve high-voltage protection. All of the devices are housed in the TO-220AB plastic package and are priced between £0.416 and £1.88 each depending on type and quantity. ITT Semiconductors, Foots Cray, Sidcup, Kent.
WW 335 for further details

Microwave coupler

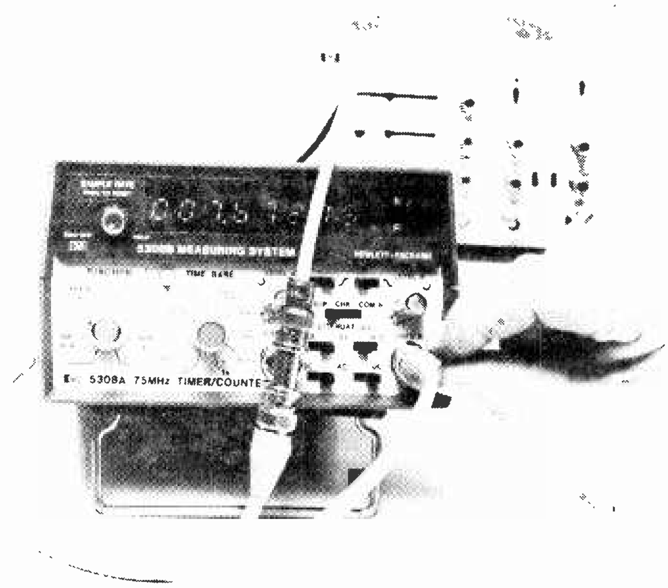
Walmore are now supplying the Norsal 4834 microwave coupler. This device, which is claimed to be the first to cover the range 2 to 12.4GHz, has a v.s.w.r. of 1.4:1, amplitude imbalance of ±0.5dB, and a phase imbalance of ±7°. The coupler is designed to handle input powers of 20W average with a 2kW



WW308



WW310



WW303

WW302

WW313

WW309

peak rating. Microwave Division, Walmore Electronics Ltd, 11 Betterton Street, London WC2H 9BS.
WW307 for further details

Variable-filters

The EF3/03 and EF3/04 are recent additions to the Barr & Stroud range of variable filters. The units are high-pass and low-pass filters respectively which may be switched into several modes including band-pass and band-stop. The cut-off frequency is variable from 0.1Hz to 100kHz with a stop-band attenuation rate of 48dB/octave and a pass-band response from 0 to 700kHz. Barr & Stroud Ltd, Kinnaird House, 1 Pall Mall East, London SW1Y 5AU.
WW302 for further details

Signal generator

The Fluke synthesized signal generator, model 6010A offers a keyboard entry with a manual fine control, and a built-in microprocessor which can store up to nine programmes. Each programme consists of a frequency, a frequency range, an amplitude, and a modulation (c.w., a.m., or f.m.). These programmes can be recalled at any point in a testing sequence. The instrument has a frequency range from 10Hz to 109kHz in 0.1Hz steps and 10Hz to 10MHz in 10Hz steps, an accuracy of ± 3 parts in 10^6 in the temperature range 0 to $+50°C$ and a variable output level from 0.25mV to 5V r.m.s. The selected frequency is indicated on a seven-digit l.e.d. display. Fluke (Nederland) B.V., Ledeboerstraat 27, Tilburg, Netherlands.
WW313 for further details

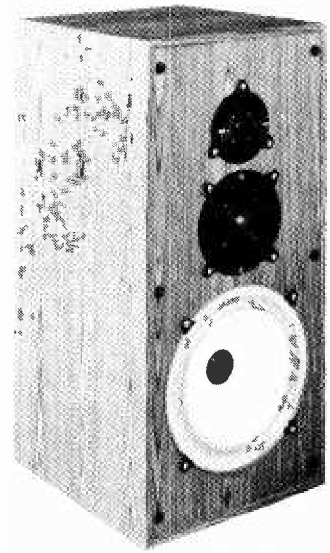
Testing system

The type 8309 test set connects directly to a computer terminal and will transmit to, or receive messages from the terminal for the purpose of checking and/or fault analysis. The 8309 can be operated at data rates between 110 and 9600 bits/sec in a synchronous or asynchronous mode. In the former mode it responds to either the EBCDIC or ASCII SYN character set, while in the latter case the number of stop bits sent by the transmitter may be selected as required. Data Recognition Ltd, Loverock Road, Battle Farm Estate, Reading, Berks.
WW309 for further details

Bezel

A recent addition to the Roxburgh range of switches and accessories is a bezel incorporating a l.e.d. mounting facility. The bezel fits the J50, J60 and 800J switches and accepts a 0.2in l.e.d. Roxburgh Electronics Ltd, 22 Winchelsea Road, Rye, Sussex.
WW301 for further details

Products seen at Hi-Fidelity 75



Sansui tuner

The TU-7700 stereo tuner is one of a series of amplifiers and tuners which Sansui have added to their range. This model will receive f.m. broadcasts within the frequency range 88-108MHz and a.m. broadcasts in the range 535-1605kHz. Containing a high integrated-circuit count, the TU-7700 is to retail at a suggested price of £149.10 plus VAT. Vernitron Ltd, Thornhill, Southampton SO9 5QF.

Four-channel tape deck

Well known on the Continent, but new to the UK, the Dokorder range of reel-to-reel recorders is being distributed by Acoustico Enterprises. The top of the domestic range is the model 7140 which is fully equipped to record and replay up to four tracks on ¼in tape. The head block is interchangeable to offer two track stereo recording and a consequent improvement in signal-to-noise ratio.

A useful facility is offered by the so-called "Multi-Sync" which is a switching arrangement which connects one or more record head tracks to the replay amplifier to permit monitoring of previously recorded tracks, whilst adding in synchronism further recordings to remaining free tracks.

Other facilities include sound-on-sound, echo, bias and record equalisation for two types of tape and A-B monitoring. Acoustico Enterprises Ltd, Unit 7, Space Waye, North Feltham Trading Estate, Feltham, Middx TW14 0TZ.

Eagle range

Eagle International have added considerably to their range of products with the introduction of the 2000 series of equipment. This comprises the A2004 and A2006 amplifiers with a rated output of 20W per channel and having a rather more complex range of tone controls than usual. A matching tuner amplifier, the A2008, provides for reception of the a.m. and f.m. bands and also there is a synchronous motor, belt drive turntable, the D2005. A second turntable, the D2006, is classified by Eagle as a servo-monitor type, though exactly what this means is not quite clear. Finally the 2000 series is completed by a choice of five loudspeakers and two headphones. Eagle International, Heather Park Drive, Wembley, Middx HA0 1SU.

New belt drive turntables

The BDS80 and BDS90 are two turntables added to the series produced by BSR McDonald. Both models are semi-automatic in that when a record has finished playing the arm lifts up, returns to rest, locks and switches off. Both decks are also fitted with a click suppressor and muting switch which prevent an unwanted noise being fed to the amplifier while the automatic set-down and switch off are in operation. A special feature of the BDS90, according to the manufacturers is a new low-resonance tubular aluminium tone-arm, located in a concentric gimbal style mount which carries a calibrated stylus pressure control. The rumble figure for both units is stated to be 55dB. Standard units are available for either 100-125V 60Hz or 200-240V 50Hz. BSR Ltd, Monarch Works, Cradley Heath, Warley, Worcs.

Sansui Tu-7700 stereo tuner

Three new speakers

A new range of loudspeakers from Celestion are the UL6, UL8 and UL10 models. The two smaller models in the range are both two-unit systems, the bass driver being supplemented by a passive auxiliary bass radiator unit. The largest model is the UL10 (see photograph) which houses three in-line drive units. Cabinet dimentions are 673mm height, 317mm width, 380mm depth. Power handling is rated at 50W continuous or 100W peak music power. Sensitivity is sensibly rated using pink noise, an input of 12 volts r.m.s. being required to produce 96dB s.p.l. at 1 metre. Frequency response is stated to be 40Hz to 20kHz ±2dB. Drive units consist of the HF2000 super tweeter, the MD7000 pressure-dome mid range unit and a 254mm bass drive unit. Rola Celestion Ltd, Ditton Works, Foxhall Road, Ipswich, Suffolk IP3 8JP.

New life for Wharfedale

Rank Radio introduced a new XP range of speakers carrying the well-known names of Denton, Linton and Glendale. All have greater power handling capability and are claimed to have improved performance over their predecessors. Taking the smallest in the range, the Denton 2XP, this is a two-way bookshelf enclosure of acoustic suspension design. Main specifications are: power handling 25W (DIN), suitable for use with amplifiers rated from 3 to 30W continuous; frequency response 65-17kHz at —3dB points; crossover frequency 1.4kHz; sensitivity is 96dB at lm for 6W input; impedance is 6Ω nominal; dimensions are 355 × 246 × 22mm. Finish is in teak or white. Rank Radio International Ltd, P.O. Box 596, Power Road, London W4 5PW.

Amplifier with limiter circuit

The new Cambridge Classic One amplifier has several unusual features including l.e.d. monitoring of pre-amplifier signal level in 5dB steps. An l.e.d. indicator is used as a power supply indicator. This also flashes at a regular rate whenever a power amplifier limiter circuit is brought into operation. A circuit in conjunction with the input selector switch is provided to limit the effect of switch-on transients causing 'thumps' through the loudspeakers. Main specifications are: power output at 1kHz, 60W per channel into 8Ω; t.h.d. is less than 0.05% at all audio frequencies, typically 0.005%; signal-to-noise ratio is 65dB ref. 2mV (pickup input), 75dB ref. 250mV (line inputs); input sensitivities are pickup 2mV/47kΩ, tuner 250mV, cassette 100mV and auxiliary 100mV. The pick-up input overload capability is rated at 45dB. Facility for the simultaneous use of three tape recorders is also provided. Cambridge Audio Ltd, Lamb House, Church Street, London W3 2PB.

Solid State Devices

Names of suppliers of devices in this section are given in abbreviation after each entry and in full at the end of the section.

Shift register

A 512-bit dynamic shift register with built-in recirculating and command logic has a maximum operating speed of 4MHz.

WW350 for further details **G.E.**

Diodes

The 501PD series of diodes has an average current rating of 500A at an 84°C case temperature, and are available over the voltage range 2kV to 4kV with non-repetitive ratings up to 4.4kV.

WW351 for further details **I.R.**

R.a.m.

The 1103-1 is a 1k dynamic r.a.m. offering a 340ns full-cycle time and a 150ns read access time. All address inputs are fully decoded and typical power dissipation is 0.4mW/bit.

WW352 for further details **ITT**

Schottky register

A 4-bit register having three-state and standard t.t.l. outputs has been built using Schottky technology. The device is available in three packages and is priced from $3.08 100 up.

WW353 for further details **AMD**

Programmable op-amp

Parameters of the MC3476 op-amp are programmed by an external resistor to suit power supplies from ±6 to ±15V. The device does not require frequency compensation, has offset null capability and is protected against short circuits.

WW354 for further details **Motorola**

Bridge rectifers

A new range of bridge rectifiers has a built-in capacitor in parallel with each diode to absorb reverse voltage transients. The range has repetitive peak-reverse voltage ratings from 50 to 600V and an average direct current rating of 2A.

WW355 for further details **ME**

Memory driver

An n-channel m.o.s. memory driver i.c., type MC3459, contains four identical driver circuits and is capable of maintaining a propagation delay of 20ns when driving a 360pF load.

WW 356 for further details **Motorola**

A-to-d converter

The MC904 is claimed to be the first monolithic i.c. with all the functions necessary for a digital panel meter or multimeter. The device has a resolution of 100μV and an input impedance of 1000MΩ and is housed in a 28-pin d.i.l. package.

WW358 for further details **Macro**

Image sensor

A new 1728-element charge-coupled linear image sensor, suitable for use in optical page scanning systems, has been introduced by Fairchild. The CCD121 is capable of reading a standard 8½ × 11-inch page in less than one second and up to 200 lines per inch can be resolved.

WW 359 for further details **Fairchild**

Count/display i.c.

A t.t.l.-compatible universal count/display i.c., type ZN1040E, offers a count rate of over 5MHz. The device requires a 5V supply and is housed in a 28 pin d.i.l. package.

WW360 for further details **Ferranti**

Low-voltage sensor

An i.c. intended for use with battery operated equipment, is internally set to trigger when a voltage drops to 2.4V ±2%. This value can be increased by adding a resistor.

WW361 for further details **Bowmar**

Sample/hold amp

An adjustment-free sample/hold amplifier called the MN343 provides a droop rate of less than 0.3mV/ms and an acquisition time of better than 10μs.

WW 362 for further details **Tranchant**

F.e.t. input amplifier

The 3670 is a f.e.t.-input i.c. instrumentation amplifier. Gain adjustment, from 1 to 1000V/V, is made with one resistor. Maximum bias current is 10pA, and the input impedance is 10^{13} ohms.

WW363 for further details **Burr Brown**

G.E. Electronics (London) Ltd, 182/4 Campden Hill Road, Kensington, London W8 7AS.
International Rectifier, Hurst Green, Oxted, Surrey RH8 9BB.
ITT Semiconductors, Footscray, Sidcup, Kent.
Advanced Micro Devices Inc., 901 Thompson Place, Sunnyvale, California 94086, U.S.A.
Motorola Ltd, Semiconductor Products Division, York House, Empire Way, Wembley, Middx.
Micro Electronics Ltd, York House, Empire Way, Wembley, Middx.
Macro Marketing Ltd, 396 Bath Road, Slough, Bucks.
Fairchild Camera & Instrument Corporation, Northway House, High Road, Whetstone, London N.20.
Ferranti Ltd, Electronic Components Division, Gem Mill, Chadderton, Oldham, OL9 8NP.
Bowmar Arizona, Inc., 2355 West Williams Field Road, Chandler, Arizona 85224, U.S.A.
Tranchant Electronics (UK) Ltd, Tranchant House, 100a High Street, Hampton. Middx.
Burr-Brown International, 25a King Street, Watford, WD1 8BT.

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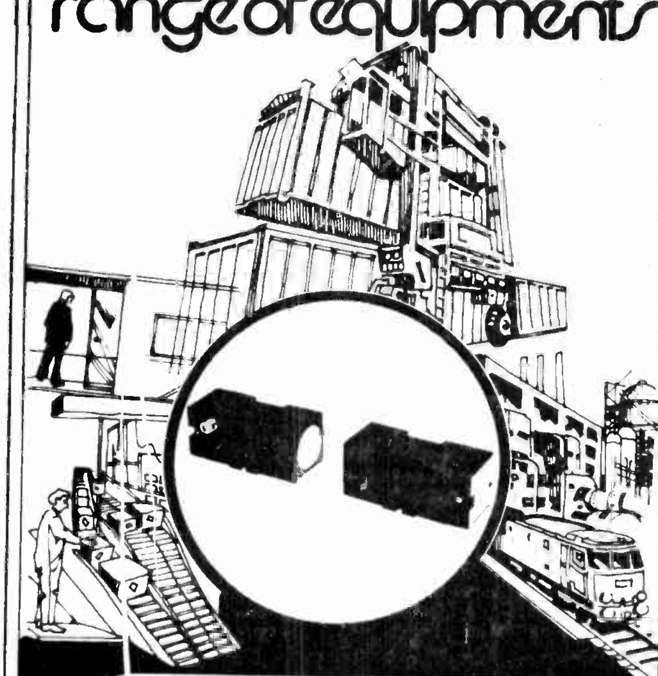

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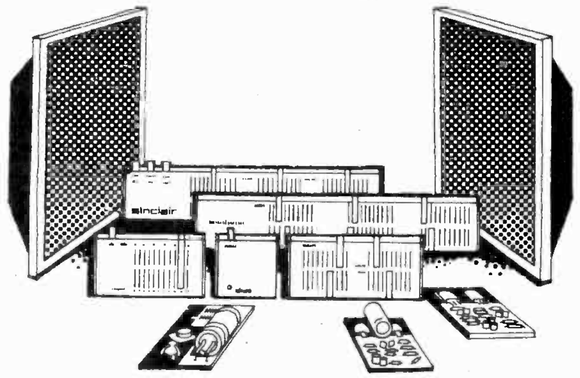

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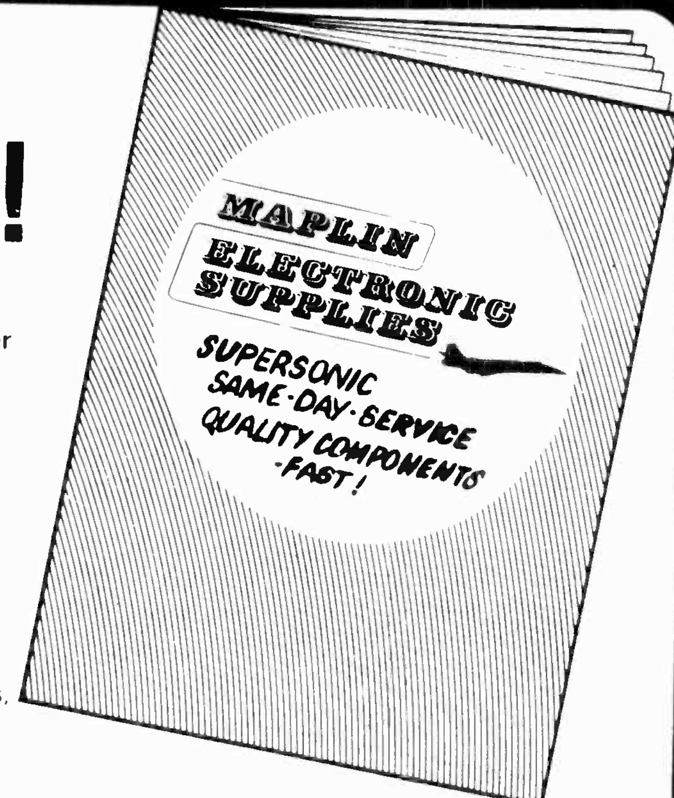

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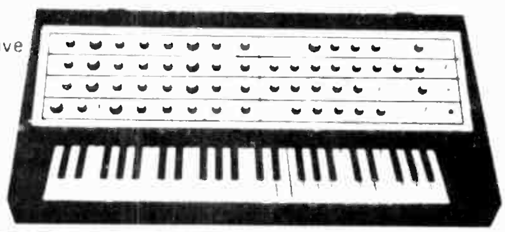

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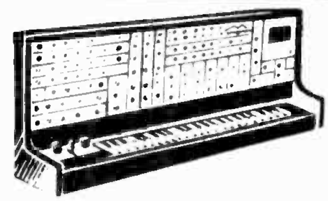

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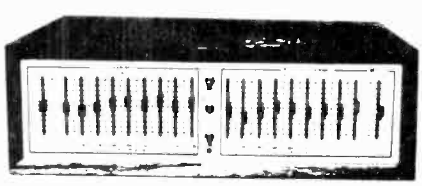

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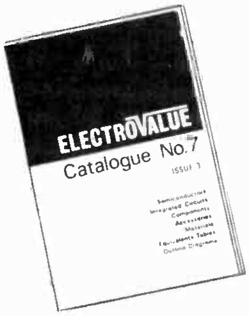

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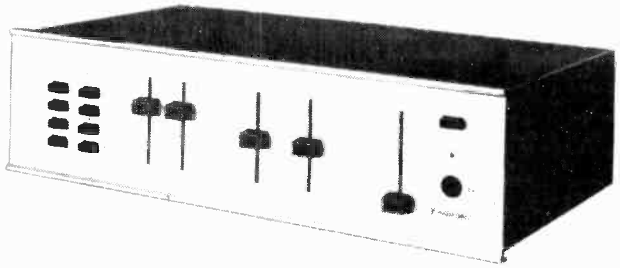

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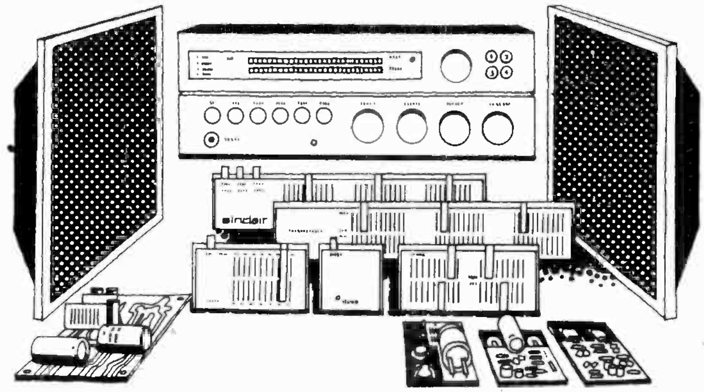

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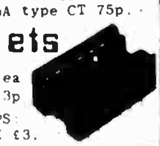

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OC44 0.20, OC45 0.20, OC71 0.18, OC72 0.28, OC76 0.30, OC77 0.54, OC81 0.29, OC81D 0.28, OC81Z 0.45, OC83 0.27, OC140 1.14, OC170 0.30, OC171 0.30, OC200 0.54, OC201 1.00, OC202 0.90, OC203 0.55, OCP71 1.20, ORP12 0.60, ORP60 0.55, TIC44 0.29, TIC226D 1.50, TIL209 0.20, ZTX107 0.12, ZTX108 0.8, ZTX300 0.13, ZTX301 0.14, ZTX302 0.18, ZTX304 0.24, ZTX500 0.13, ZTX501 0.15, ZTX503 0.16, ZTX531 0.25, ZTX550 0.18, IN914 0.06, IN4001 0.06, IN4002 0.7, IN4003 0.8, IN4004 0.8, IN4005 0.10, IN4006 0.12, IN4007 0.12, IN4009 0.06, IN4148 0.06, IS131 0.13, IS921 0.07, IS2033 0.20, IS2051A 0.20, IS2100A 0.20, IS3010 0.25, 2N696 0.15

2N697 0.16, 2N706 0.12, 2N706A 0.12, 2N1131 0.25, 2N1132 0.24, 2N1302 0.18, 2N1303 0.18, 2N1304 0.28, 2N1305 0.22, 2N1306 0.28, 2N1307 0.28, 2N1308 0.28, 2N1309 0.30, 2N1613 0.21, 2N1614 0.45, 2N2147 0.78, 2N2160 0.78, 2N2369A 0.16, 2N2646 0.50, 2N2904 0.20, 2N2904A 0.25, 2N2905 0.32, 2N2905A 0.25, 2N2906 0.20, 2N2926 0.12, 2N3053 0.18, 2N3055 0.45, 2N3525 0.91, 2N3614 0.65, 2N3615 0.65, 2N3702 0.11, 2N3703 0.12, 2N3704 0.14, 2N3705 0.15, 2N3706 0.11, 2N3707 0.13, 2N3708 0.07, 2N3709 0.10, 2N3710 0.11, 2N3711 0.11, 2N3819 0.38, 2N3820 0.50, 2N3823 0.50, 2N3903 0.15, 2N3904 0.20, 2N3905 0.25, 2N3906 0.25, 2N4058 0.15, 2N4059 0.10, 2N4060 0.13, 2N4061 0.13, 2N4062 0.14, 2N4289 0.30

3N141 0.81, 40360 0.40, 40361 0.45, 40362 0.40, 40430 0.85, SN7400 0.16, SN7401 0.16, SN7402 0.16, SN7403 0.16, SN7404 0.26, SN7405 0.22, SN7406 0.42, SN7407 0.42, SN7408 0.28, SN7409 0.28, SN7410 0.16, SN7411 0.25, SN7412 0.30, SN7413 0.36, SN7416 0.36, SN7417 0.36, SN7420 0.16, SN7422 0.25, SN7423 0.37, SN7425 0.37, SN7427 0.37, SN7428 0.40, SN7430 0.16, SN7432 0.37, SN7433 0.37, SN7437 0.37, SN7438 0.37, SN7440 0.22, SN7441AN 0.92, SN7442 0.79, SN7450 0.16, SN7451 0.16, SN7453 0.16, SN7454 0.16, SN7460 0.16, SN7470 0.36, SN7472 0.38, SN7473 0.41, SN7474 0.42, SN7475 0.59

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5B/255M, 5B/256M, 5B/257M, 5C22, 5D21, 5R4GY, 5U4GB, 5Z3, 5Z4G, 6AF4A, 6AK5, 6AM5, 6AM6, 6AN5, 6AN8, 6AR5, 6AS6, 6AU4GTA, 6AU5GT, 6AU6, 6AV5GTA, 6AW8A, 6AX5GT, 6B4G, 6BA8A, 6BK4, 6BK7A, 6BL7GTA, 6BN6, 6BR7, 6BS7, 6BX7GT, 6BZ6, 6CB6, 6CH6, 6CL6, 6CW4, 6DK6, 6DQ6B, 6EA8, 6F33, 6H6(metal), 6K7GT, 6U8A, 6V6GT, 11E3, 11E13, 12AY7, 12B4A, 12BY7A, 12E1, 12E14, 13E1, 28D7, 29C1, 53KU, 75B1, 75C1, 83A1, 85A1, 85A2, 90AG, 90AV, 90C1, 90CG, 90CV, 95A1, 100TH, 150B2, 150B3, 150C1, 150C2, 150C3, 150C4, 250TH, 328, 329

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OD3, OG3, OZ4, OZ4A, PT15, QA2400, QA2403, QA2404, QA2406, QA2407, QB3/300, QB3.5/750, QB4/1100, QF41, QF45, QQV02-6, QQV03/10, QQV03/20, QQV03/20A, QQV04/15, QQV06/40, QQV06/40A, QS70/20, QS75/20, QS75/40, QS75/60, QS83/3, QS92/10, QS95/10, QS105/45, QS150/40, QS150/45, QS150/80, QS1200, QS1202, QS1203, QS1205, QU37, QV03/12, QV04/7, QV05/25, QV06/20, QY3/125A, QY4-250A, QY4/400A, R10, R17, R18, S11E12, S130, S130P, STV280/40, STV280/80, SU41, SU42, TD03/10, TT15, TT21, TTR31MR, TZ40, U17, U19, U27, VLS631, Z300T, Z759, Z803U

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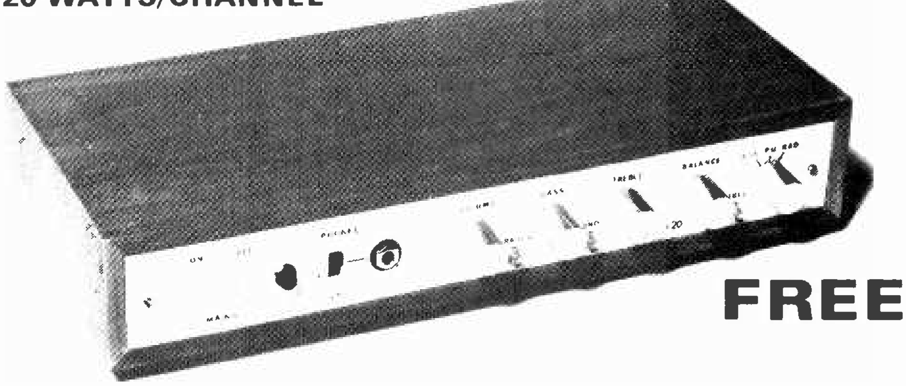
20 WATTS/CHANNEL



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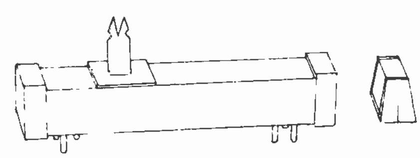

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NOVEL STEREO FM TUNER

In the April and May 1974 issues of *Wireless World* there was published by J. Skingley and N. C. Thompson a novel design for an f.m. tuner which combines consistent high performance with the elimination of the critical setting-up procedure required by too many earlier tuners. The front end is a ready built pre-aligned module which then feeds an amplifier driven screened three section ceramic filter leading to an integrated circuit five-stage limiting amplifier providing excellent a.m. rejection. This is followed by a single coil integrated balanced demodulator from which the audio output may be taken. Temperature compensated varicap tuning allows stations to be selected either by a ten-turn tuning potentiometer or by a choice of six preset push-button controls. Each of the preset controls can be adjusted on the front panel with the settings being indicated by six LED lamps behind an acrylic silk screen printed facia panel insert. Additional circuitry includes temperature compensated AFC restricted to less than station spacing, inter-station muting, a single-lamp LED tuning indicator and a linear scale frequency meter. The stereo decoder, built on a separate board, is based on a well-proven integrated circuit phase-locked-loop to which has been added active filters to remove sub carrier harmonics and 'birdies'. The power supply, to ensure station holding stability, uses an integrated circuit voltage regulator which is powered via a low-hum field specially designed TOROIDAL TRANSFORMER.

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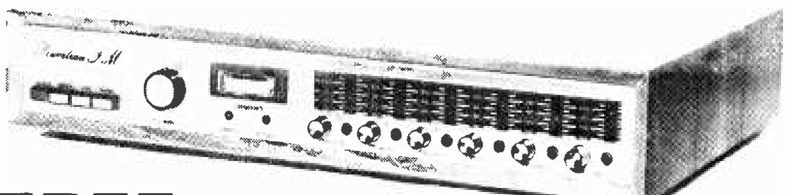

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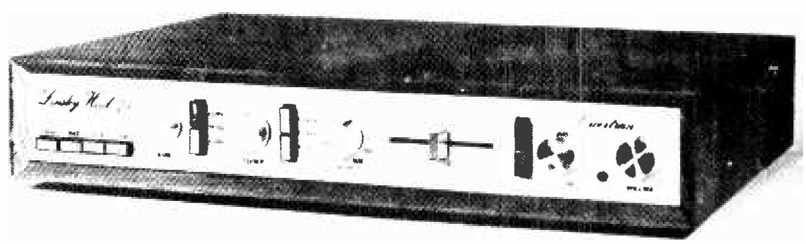
In Hi-Fi News there was published by Mr Linsley-Hood a series of four articles (November 1972–February 1973) and a subsequent follow-up article (April 1974) on a design for an amplifier of exceptional performance which has as its principal feature an ability to supply from a direct coupled fully protected output stage, power in excess of 75 watts whilst maintaining distortion at less than 0.01% even at very low power levels. The power amplifier is complemented by a pre-amplifier based on a discrete component operational amplifier referred to as the Liniac which is employed in the two most critical points of the system, namely the equalization stage and tone control stage, positions where most conventional designs run out of gain at the extremes of the frequency spectrum. Unusual features of the design are the variable transition frequencies of the tone controls and the variable slope of the scratch filter. There is a choice of four inputs, two equalized and two linear, each having independently adjustable signal level. The attractive slimline unit pictured has been made practical by highly compact PCBs and a specially designed Toroidal transformer.

Hi-Fi News Linsley-Hood 75W/Channel Amplifier Mk III Version (modifications as per Hi-Fi News April 1974)



Full circuit description in handbook (pack 15—price 30p)

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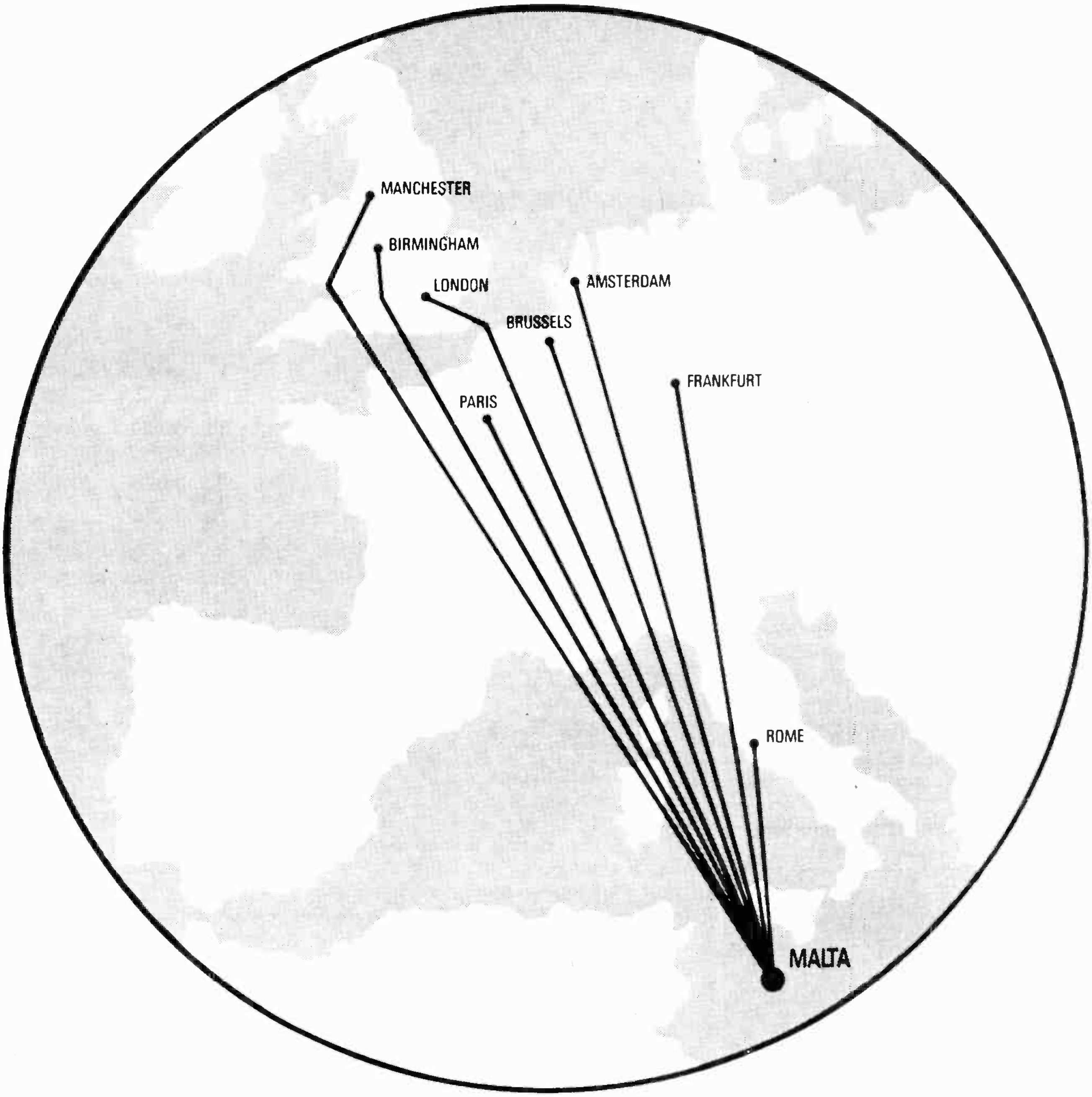

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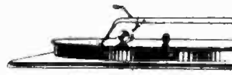

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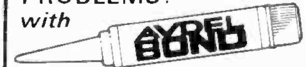

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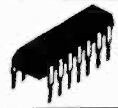

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SN7474	0.41	0.39	0.35
SN7475	0.60	0.58	0.56
SN7476	0.44	0.43	0.42
SN7480	0.60	0.58	0.55
SN7481	£1.10	£1.05	£1.00
SN7482	0.90	0.85	0.80
SN7483	£1.20	£1.15	£1.05
SN7484	£1.00	0.97	0.95
SN7485	£1.60	£1.55	£1.50
SN7486	0.35	0.34	0.33
SN7489	£4.00	£3.75	£3.50
SN7490	0.65	0.63	0.60
SN7491	£1.10	£1.05	£1.00
SN7492	0.74	0.71	0.64
SN7493	0.74	0.71	0.64
SN7494	0.85	0.82	0.75
SN7495	0.85	0.82	0.75
SN7496	0.96	0.93	0.86
SN74100	£1.50	£1.45	£1.40
SN74104	0.60	0.58	0.55
SN74105	0.60	0.58	0.55
SN74107	0.44	0.42	0.40
SN74110	0.60	0.55	0.50
SN74111	0.90	0.88	0.85
SN74118	£1.00	0.95	0.90
SN74119	£1.50	£1.40	£1.30
SN74121	0.50	0.48	0.45
SN74122	0.70	0.68	0.65
SN74123	0.75	0.73	0.70
SN74141	0.85	0.82	0.79
SN74145	£1.30	£1.25	£1.20
SN74150	£1.50	£1.40	£1.30
SN74151	£1.10	£1.05	£1.00

	1	25	100+
SN74153	£1.00	0.95	0.90
SN74154	£1.70	£1.65	£1.60
SN74155	£1.20	£1.15	£1.10
SN74156	£1.20	£1.15	£1.10
SN74157	£1.00	0.95	0.90
SN74160	£1.40	£1.35	£1.30
SN74161	£1.40	£1.35	£1.30
SN74162	£1.40	£1.35	£1.30
SN74163	£1.40	£1.35	£1.30
SN74164	£1.80	£1.75	£1.70
SN74165	£1.80	£1.75	£1.70
SN74166	£1.60	£1.55	£1.50
SN74174	£1.60	£1.55	£1.50
SN74175	£1.10	£1.05	£1.00
SN74176	£1.25	£1.20	£1.15
SN74177	£1.25	£1.20	£1.15
SN74180	£1.25	£1.20	£1.15
SN74181	£3.95	£3.85	£3.75
SN74182	£1.25	£1.20	£1.15
SN74184	£1.80	£1.75	£1.70
SN74190	£1.95	£1.90	£1.85
SN74191	£1.95	£1.90	£1.85
SN74192	£1.95	£1.90	£1.85
SN74193	£1.95	£1.90	£1.85
SN74194	£1.30	£1.25	£1.20
SN74195	£1.10	£1.05	£1.00
SN74196	£1.20	£1.15	£1.10
SN74197	£1.20	£1.15	£1.10
SN74198	£2.75	£2.70	£2.65
SN74199	£2.50	£2.40	£2.30

Devices may be mixed to qualify for quantity price. (TTL 74 Series only) data is available for the above series of I.C.'s in booklet form. Price 35p.

INTEGRATED CIRCUIT PAKS

Manufacturers "Fall Outs" which include Functional and Part-Functional Units. These are classed as 'out-of-spec' from the maker's very rigid specifications, but are ideal for learning about I.C's and experimental work.

Pak No.	Contents	Price
UIC00	= 12 ± 7400	0.54
UIC01	= 12 × 7401	0.54
UIC02	= 12 × 7402	0.54
UIC03	= 12 × 7403	0.54
UIC04	= 12 × 7404	0.54
UIC05	= 12 × 7405	0.54
UIC06	= 8 × 7406	0.54
UIC07	= 8 × 7407	0.54
UIC10	= 12 × 7410	0.54
UIC20	= 12 × 7420	0.54
UIC30	= 12 × 7430	0.54
UIC40	= 12 × 7440	0.54
UIC41	= 5 × 7441	0.54
UIC42	= 5 × 7442	0.54
UIC43	= 5 × 7443	0.54
UIC44	= 5 × 7444	0.54
UIC45	= 5 × 7445	0.54

Pak No.	Contents	Price
UIC46	= 5 × 7446	0.54
UIC48	= 5 × 7448	0.54
UIC50	= 12 × 7450	0.54
U1351	= 12 × 7451	0.54
UIC53	= 12 × 7453	0.54
UIC54	= 12 × 7454	0.54
UIC60	= 12 × 7460	0.54
UIC70	= 8 × 7470	0.54
UIC72	= 8 × 7472	0.54
UIC73	= 8 × 7473	0.54
UIC74	= 8 × 7474	0.54
UIC76	= 8 × 7476	0.54
UIC80	= 5 × 7480	0.54
UIC81	= 5 × 7481	0.54
UIC82	= 5 × 7482	0.54
UIC83	= 5 × 7483	0.54
UIC86	= 5 × 7486	0.54

Pak No.	Contents	Price
UIC90	= 5 × 7490	0.54
UIC91	= 5 × 7491	0.54
UIC92	= 5 × 7492	0.54
UIC93	= 5 × 7493	0.54
UIC94	= 5 × 7494	0.54
UIC95	= 5 × 7495	0.54
UIC96	= 5 × 7496	0.54
UIC100	= 5 × 74100	0.54
UIC121	= 5 × 74121	0.54
UIC141	= 5 × 74141	0.54
UIC151	= 5 × 74151	0.54
UIC154	= 5 × 74154	0.54
UIC193	= 5 × 74193	0.54
UIC199	= 5 × 74199	0.54
UICXI	= 25 Assorted 74's	1.65

Packs cannot be split, but 25 assorted pieces (our mix) is available as PAK UIC X1.

LINEAR I.C.'s—FULL SPEC.

Type No.	1	25	100+
72702	0.50	0.48	0.45
72709	0.25	0.23	0.20
72709P	0.20	0.19	0.18
72710	0.35	0.33	0.30
72741	0.30	0.29	0.28
72741C	0.28	0.27	0.26
72741P	0.30	0.29	0.28
72747	0.85	0.80	0.75
72748P	0.38	0.36	0.34
SL201C	0.59	0.45	0.40
SL701C	0.50	0.45	0.40
SL702C	0.50	0.45	0.40
TAA263	0.80	0.70	0.60
TAA293	£1.00	0.95	0.90
TAA350A	£1.85	£1.80	£1.70
μA703C	0.28	0.26	0.24
μA709C	0.20	0.19	0.18
μA711	0.35	0.33	0.30
μA712	0.35	0.33	0.30
TBA800	£1.50	£1.45	£1.40
76003	£1.50	£1.45	£1.40
76023	£1.50	£1.45	£1.40
76660	0.95	0.93	0.90
LM380	£1.00	0.97	0.95
NE555	0.65	0.63	0.60
NE556	0.95	0.93	0.90

DTL 930 SERIES LOGIC I.C's

Type	1	25	100+
BP930	0·15	0·14	0·13
BP932	0·16	0·15	0·14
BP933	0·16	0·15	0·14
BP935	0·16	0·15	0·14
BP936	0·16	0·15	0·14
BP944	0·16	0·15	0·14
BP945	0·30	0·28	0·25
BP946	0·15	0·14	0·13
BP948	0·30	0·28	0·25
BP951	0·70	0·65	0·60
BP962	0·15	0·14	0·13
BP9093	0·45	0·43	0·40
BP9094	0·45	0·43	0·40
BP9097	0·45	0·43	0·40
BP9099	0·45	0·43	0·40

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Send S.A.E. and 10p

DUAL-IN-LINE SOCKETS

14 & 16 Lead Sockets for use with DUAL-IN-LINE I.C's. TWO Ranges PROFESSIONAL & NEW LOW COST.

PROF. TYPE No.	1–24	25–99	100up
TSO 14 pin type	33p	30p	27p
TSO 16 „ „	38p	35p	32p
TSO 24 „ „	75p	70p	68p
LOW COST No.			
BPS 14 „ „	16p	14p	12p
BPS 16 „ „	17p	15p	13p
BPS 8 pin type	15p	13p	11p

NUMERICAL INDICATOR TUBES

Type	Description	
3015F Minitron	.. .. ..	£1.20
MAN 3M. L.E.D. 7-segment 0·127"	.. .. ..	£1.90

All indicators 0.9 + Decimal point. All side viewing. Full data for all types available on request.

SHP80 STEREO HEADPHONES. 1-16 ohms impedance. Frequency response 20 to 20,000Hz. Stereo/mono switch and volume controls. £4.95

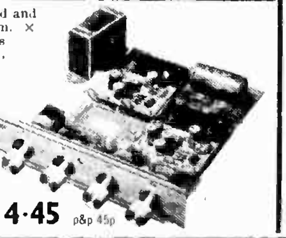
EDSR 3166 TRIPLE 66 BIT DYNAMIC SHIFT REGISTER TTL Compatible. Low Clock Capacitance. High Speed Diode Protected Inputs Wired 'OR' Capability SPECIFICATION SHEET AVAILABLE £1 each

TEAK VENEERED CABINET for: STEREO 20
TC 20. £3.95 p&p 45p

E.M.I. LEK 350 Loudspeaker System Enclosure kit in teak veneer, including speakers. Rec. retail price £45.50 per pr. OUR SPECIAL PRICE £30 per pair P. & P. £3. ONLY WHILE STOCKS LAST!

The STEREO 20

The 'Stereo 20' amplifier is mounted, ready wired and tested on a one-piece chassis measuring 20 cm. × 14 cm. × 5·5 cm. This compact unit comes complete with on/off switch volume control, balance, bass and treble controls, Transformer, Power supply and Power amps. Attractively printed front panel and matching control knobs. The 'Stereo 20 has been designed to fit into most turntable plinths without interfering with the mechanism or, alternatively, into a separate cabinet. Output power 20w peak. Input 1 (Cer.) 300mV into 1M. Freq. res. 25Hz-25kHz. Input 2 (Aux.) 4mV into 30K. Harmonic distortion. Bass control ±12dB at 60Hz typically 0·25% at 1 watt. Treble con. ±14dB at 14kHz.



£14·45 p&p 45p

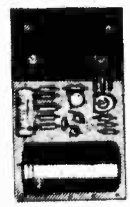
NOW WE GIVE YOU 50w PEAK (25w R.M.S.) *PLUS* THERMAL PROTECTION! The NEW AL60 Hi-Fi Audio Amplifier FOR ONLY £4.25

- Max Heat Sink temp. 90°C.
- Frequency Response 20Hz to 100KHz
- Distortion better than 0.1% at 1KHz
- Supply voltage 15-50 volts
- Thermal Feedback
- Latest Design Improvements
- Load—3, 4, 8 or 16 ohms
- Signal to noise ratio 80dB
- Overall size 63mm × 105mm × 13mm

Especially designed to a strict specification. Only the finest components have been used and the latest solid state circuitry incorporated in this powerful little amplifier which should satisfy the most critical A.F. enthusiast.

FULLY BUILT—TESTED and GUARANTEED

STABILISED POWER MODULE SPM80 £3·25



SPm80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watt (r.m.s.) per channel simultaneously. This module embodies the latest components and circuit techniques incorporating complete short circuit protection. With the addition of the Mains Transformer BmT80, the unit will provide outputs of up to 1·5 amps at 35 volts. Size: 63 mm × 105 mm × 20 mm. These units enable you to build Audio Systems of the highest quality at a hitherto unobtainable price. Also ideal for many other applications including: Disco Systems, Public Address, Intercom Units, etc. Handbook available. 10p.

TRANSFORMER BMT80 £2.75 p. & p. 40p

STEREO PRE-AMPLIFIER TYPE PA100

Built to a specification and NOT a price, and yet still the greatest value on the market, the PA100 stereo pre-amplifier has been conceived from the latest circuit techniques. Designed for use with the AL60 power amplifier system, this quality made unit incorporates no less than eight silicon planar transistors, two of these are specially selected low noise NPN devices for use in the input stages.

Three switched stereo inputs, and rumble and scratch filters are features of the PA100, which also has a STEREO/MONO switch, volume, balance and continuously variable bass and treble controls.

SPECIFICATION:

Frequency response	20Hz—20kHz ±1dB
Harmonic distortion	better than 0·1%
Inputs: 1. Tape head	3·25mV into 50KΩ
2. Radio, Tuner	75mV into 50KΩ
3. Magnetic P.U.	3mV into 50KΩ
Bass control	±15dB at 20Hz
Treble control	±15dB at 20kHz
Filters: Rumble (high pass)	100 Hz
Scratch (low pass)	8kHz
Signal/noise ratio	better than +65dB
Input overload	+26dB
Supply	+35 volts at 20mA
Dimensions	292 × 82 × 35 mm

All input voltages are for an output of 250mV. Tape and P.U. inputs equalised to RIAA curve within ±1dB from 20Hz to 20kHz.

only £14.25

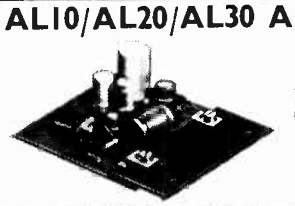
MK 60 AUDIO KIT

Comprising: 2 × AL60. 1 × SPM80. 1 × BTM80. 1 × PA 100. 1 front panel. 1 kit of parts to include on-off switch, neon indicator, stereo headphone sockets plus instruction booklets. Complete Prices: £29.75 plus 45p postage.

TEAK 60 AUDIO KIT

Comprising: Teak veneered cabinet size 16½" × 11¼" × 3¾", other parts include aluminium chassis, heatsink and front panel bracket, plus back panel and appropriate sockets etc. Kit price: £9.95 plus 45p postage.

AL10/AL20/AL30 AUDIO AMPLIFIER MODULES



The AL10, AL20 and AL30 units are similar in their appearance and in their general specification. However, careful selection of the plastic power device has resulted in a range of output powers from 3 to 10 watts R.M.S.

The versatility of their design makes them ideal for use in record players, tape recorders, stereo amplifiers and cassette and cartridge tape players in the car and at home.

Parameter	Conditions	Performance
HARMONIC DISTORTION	Po = 3 WATTS f = 1KHz	0·25%
LOAD IMPEDANCE	—	8–16Ω
INPUT IMPEDANCE	f = 1KHz	100 kΩ
FREQUENCY RESPONSE ± 3dB	Po = 2 WATTS	50 Hz–25KHz
SENSITIVITY for RATED O/P	Vs = 25V. Rl = 8Ω f = 1KHz	75mV. RMS
DIMENSIONS	—	3" × 2¼" × 1"

The above table relates to the AL10, AL20 and AL30 modules. The following table outlines the differences in their working conditions.

Parameter	AL10	AL20	AL30
Maximum Supply Voltage	25	30	30
Power output for 2% T.H.D. (RL = 8Ω f = 1 KHz)	3 watts RMS Min.	5 watts RMS Min.	10 watts RMS Min.
PRICE	£2.50	£2.85	£3.20

3 TERMINAL POSITIVE VOLTAGE REGULATORS

TO.3 Plastic Encapsulation

μA7805/L129 5V (Equiv. to MVR5)	£1.35
μA7812/L130 12V (Equiv. to MVR12V)	£1.35
μA7815/L131 15V (Equiv. to MVR15V)	£1.35
μA7818 18V	£1.35

TRANSFORMERS

T461 (Use with AL10) £1.60 P. & P. 22p.
T538 (Use with AL20 & AL30) £2.30 P. & P. 22p
BMT80 (Use with AL60) £2.75 P. & P. 40p.

POWER SUPPLIES

PS 12. (Use with AL10, AL20 & AL30) 95p
SPM 80. (Use with AL60) £3.25

PA 12. PRE-AMPLIFIER SPECIFICATION

The PA 12 pre-amplifier has been designed to match into most budget stereo systems. It is compatible with the AL 10, AL 20 and AL 30 audio power amplifiers and it can be supplied from their associated power supplies. There are two stereo inputs, one has been designed for use with *Ceramic cartridge while the auxiliary input will suit most †Magnetic cartridges. Full details are given in the specification table. The four controls are, from left to right: Volume and on/off switch, balance, bass and treble. Size 152mm × 84mm × 35mm

PRICE £4·35

Frequency response—
20Hz–50KHz (—3dB
Bass control—
± 12dB at 60H
Treble control—
±14dB at 14KHz
*Input 1. Impedance
1 Meg. ohm
Sensitivity 300mV
†Input 2. Impedance
30 K ohms
Sensitivity 4mV

FRONT PANELS FP12 50p

All prices inclusive of V.A.T. Giro No. 388 - 7006
Please send all orders direct to warehouse and despatch department

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Postage and packing add 20p. Overseas add extra for airmail. Minimum order 55p. Cash with order please.

Guaranteed Satisfaction or Money Back

TRANSISTORS AND DIODES (25%)

Type	Pc	VCBO	FT MHz	
BSY29 (SNPN)	300mw	15	20	17p
BD107 (SNPN)	11 5w	64	100	65p
2N711B/2G106 (SPNP)	150mw	18	120/150 Tot Sw Time 275 nS Tot Sw Time 115 nS	45p
2N985 (GPNP)	300mw	15	6	£1.00
2N1304 (GPNP)	150mw	30	15	17p
2N1309 (GPNP)	150mw	30	20	32p
2N1046 (GPNP)	50w	100	15	£2.60
2N1146A (GPNP)	90w	70	0 35	50p
2N1557 (G)	106w	40	0 2	55p
2N2080 (G)	170w	70	0 2	£1.20
2N2082 (G)	170w	40	120	£1.20
2N2405 (SNPN)	1w	120	1 2	57p
2N3054 (SNPN)	29w	90		45p
2N3055 (SNPN)	115w	100		47p
2N3375 (SNPN)	11 6w	65	500	£3.60
2N4427 (SNPN)	3 5w	40	700	55p
2N5322 (SNPN)	10w	65	325	55p

ASZ18/OC26 25p, OC35 **45p.** OC42 **45p.** OC71 **12p.** CV7006/OC72 **20p.** OC75 **25p.** OC83 **28p.** GET110/NKT303 **25p.** OC702 **10p.** OA10 **25p.** RAS508AF **25p.** RAS310AF **25p.** STC Wire End 400PIV1A 4 for **50p.** IN3193 **13p.** IN3194 **14p.** IN3255 **20p.**

RCA PHOTOMULTIPLIER (8%)
C310058 Caesium and Antimony Cathode Spectral Response Designation RCA 107 or S-11 Incl P/P **£38.00.**

INTEGRATED CIRCUITS (8%)

MC353G Half Adder **£2.20**
MC356G 3 inp OR/NOR GATE **£1.60**
MC358AG AC coupled JK Flipflop **£5.50**
MC365G Line Driver **£5.50**
CA3020 Wideband Pow Amp **£1.00**
CA3021 Low power video **£1.30**
CA3028A RF 1F Amp **£1.00**
CA3038A Operational Amp **£2.30**
CA3055 Pos Volt Regulator **£1.35**
CA3085 Pos Volt Regulator **90p**
CD4035AE 4-stage Serial Register **£2.00**
CD4017AE Decade Counter Divider **£4.00**
CD4047AO Monostable Astable Multivibrator **£4.00**

THYRISTORS (8%)

GE2N1774 200v 5a **£1.20**
CR1-021C 20v 1a **25p**
CR10-101B 100v 10a **£1.00**
CR10 021 10a **£1.00**
CR10-40B 10a **£1.00**
CR10-051 10a **£1.00**
CR10-017 10a **£1.00**
BTX 92 1200R 16a 1200v **£2.85**

RECTIFIER STACKS (8%)

GEX541B1P2 **£6.88** GEX541HP3F **£6.00**
GEX541B1P1 **£3.50** SX751N1B1P1F **£6.00**
GEX541NB1P1F **£6.00**

WESTINGHOUSE (8%)
Westinghouse 3ph bridge rectifier assy type U5028/10 input 35v rms output DC 47v 480 amps. naturally air cooled Inc carr **£56.00**
Type G2 5066 input 38v rms output 47 5v DC 54 amps 30°C. naturally air cooled Inc carr **£25.00**

SWITCHES (8%)

Edward High Vacuum Speedivac model VSK1B range 25-760 torr contact ratings 250v 5a volume 4 2 cu cm max working pressure 15lb/sq in gauge net weight 17 ozs **£6.50**
Belling Delay hand reset L415 **£1.25**
Stackpole min rocker 125v 10a 250v 5a **25p**
Tippalite Rocker 12v **65p**

CIRCUIT BREAKERS 250V AC each £1.35 (8%)

AMP	TRIP	TYPE
2 0	D	Westingh 550
4 0	—	Securex 5000
7 0	Inst	Westingh 550
7 0	4	Heinemann (60c) AM12
8 0	Inst	Westingh 550
8 0	—	Securex 5000
9 0	Inst	Westingh 550
10 0	—	Securex 5000
20 0	—	ETA Magnetic

DIGITAL COUNTERS (8%)

Veeder Root Mech Reset 4 dig **55p**

STABILIZED POWER SUPPLIES (8%)

Gresham Lion GX60/10a—60v 10 amp set to 30v **£65.00** incl carriage
Lambda CC28v—Inp 205-265v output 28v dc /±5% 3 4 amp **£38.50** incl p & p
Power Elect Inp 240v outputs 20v 6 5a 10v 3 4 amp + 10v 300ma **£38.50** inc carr

RELAYS (8%)

Varley ITT Min 700Ω 20v **50p**
Magnetic Dev Type 596E **£2.00**

CONNECTORS (8%)

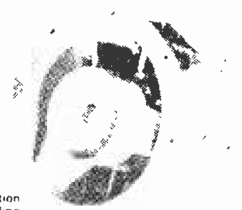
McMurdo Red Range Plug RP24 **56p**
McMurdo Red Range SKT RS32 **90p**
Eng Elect Edge 36 way 0 2 inch pair **£1.00**
Sylvania Edge 48 way 0 125 inch pair **40p**
Amphenol MS3106B-36-10 **£4.50**
Continental microminiature 28 1080IN26 **£1.30**

CAPACITORS (25%)

Daly Electrolytic 9000µF 25v **60p** p/p 15p 500µF 50v **35p** p/p 10p TCC 16µF + 16µF + 8µF 450v **75p** p/p 15p CCL 50µF + 50µF 275v **45p** p/p 10p CCL Suppressor Unit Type SU103/1 comprising capacitor Diode and Resistor **45p** p/p 10p. Dubilier Metalised Paper type 426 100µF 15v **60p** p/p 25p RIC 1 8¼F 440v a c **40p** p/p 10p

FANS (25%), CENTRIFUGAL BLOWERS, VAC. PUMPS & MOTORS (8%)

Airmax Type M1/Y3954 (3 blades) Cast Aluminium alloy impeller & casing (corresponds to current type 3965 7½") 230v 1ph 50c 2900rpm Class A insulation 425 cfm free air weight 9½lbs incl p p **£23.00**



Woods Aerofoil short casing type S Ref HS895/4/66 Cap 2 5fiF Non-reverse 220/240v 1ph 50c 0 19a 2700rpm 6" cast alum impeller 4 blades width casing 2⅝" total 5¼" weight 5¼lbs incl p p **£13.00.** Aerofoil Code 7 5 280K 200/250v 1 0a 1 ph 50c 2700rpm 550cfm free air 7½" impeller 14 blades incl p p **£16.00.**

Service Electric Hi-Velocity Fans suitable for Gas combustion Systems Steam exhausting Pneumatic conveying Cooling Electronic equipment Air blast for Oil burners **Secomak** Model 365 (corresponds to 575) Airblast Fan 440v 3ph 50c 0 75hp 2850rpm continuous 160cfm 12 in w g nett weight 44lb price incl carr **£47.00. Secomak** model 350 250v 1ph 50c 0 166hp 2800rpm continuous 50cfm 2 in w g net weight 34lbs price incl carr **£33.00.** (8%)

Air Controls type VBL4 200/250v 1ph 50c 110cfm free air weight 7½lbs Price incl p p **£16.50.**

Type VBL5 200/250v 1ph 50c 172cfm free air Weight 10¼lbs. price incl p p **£19.50.**

William Allday Alcosa rotary vane oil free Single Stage Vacuum Pump Model HSPOB 8 HG Rpm 1420 E E 3 phase induction motor 1/3hp cont 220/250v 380/440v Class E ins incl carr **£29.00.**

Alcosa blower FAD 3 8cfm at 5psi Rpm 1420 Motor EE 3ph 50c ¼hp 1400rpm incl carr **£29.00.**

Gast MFG. Vacuum pump 0522-P702-R26X Motor 110/120v a c 1ph 60c 1725rpm Class E 10cuft to 10in Mercury in 2 mins maintains vacuum 635mm Mercury Or as compressor 10psi cont or 15psi int incl carr **£29.00.**

3 phase 2HP motor 60/50c 1800/1500 RPM, 208/220/440v **£25 00** incl Carriage

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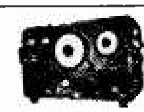

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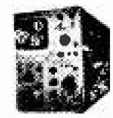

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AF115	13p	BF196	14p	2N698	30p
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AF124	30p	BFR79	30p	2N929	20p
AF125	30p	BFX29	30p	2N930	18p
AF126	30p	BFX30	30p	2N1131	18p
AF127	30p	BFX84	26p	2N1132	18p
AF139	33p	BFX85	25p	2N1302/3	17p
AF181	45p	BFX87	20p	2N1304/5	21p
AF186	48p	BFX88	24p	2N1306/7	28p
AF239	38p	BFY50	16p	2N1308/9	28p
BC107	9p	BFY51	16p	2N1613	20p
BC108	9p	BFY52	16p	2N1711	20p
BC109	10p	BRY39	34p	2N1893	30p
BC115	20p	BSX19	16p	2N2218	21p
BC147	7p	BSX20	16p	2N2219	20p
BC148	7p	BSX21	22p	2N2220	19p
BC149C	8p	MJE340	45p	2N2221	20p
BC157	10p	MJE370	72p	2N2222	20p
BC158	8p	MJE371	84p	2N2369	14p
BC159	9p	MJE520	68p	2N2484	30p
BC169C	12p	MJE521	80p	2N2904	20p
BC171	12p	MJE2955	99p	2N2905	20p
BC177	18p	MJE3055	65p	2N2906	20p
BC178	17p	MPSA12	50p	2N2926RB	7p
BC179	18p	MPSA06	30p	2N29260	8p
BC182	10p	MPSA56	32p	2N2926YG	9p
BC183	10p	MPSU06	62p	2N3053	18p
BC184	11p	MPSU56	78p	2N3054	40p
BC212	11p	OC26	40p	2N3055	50p
BC213	10p	OC28	55p	2N3441	80p
BC214	14p	OC35	48p	2N3442	140p
BCY70	18p	OC36	56p	2N3702/3	11p
BCY71	22p	OC41	15p		
BD123	100p	OC42	15p		
BD124	65p	OC44	11p		
BD131	40p	OC45	11p		
BD132	45p	OC70	11p		
BDY60	75p	OC71	11p		
BDY61	65p	OC72	11p		

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2N3705/6	10p
2N3707	11p
2N3708/9	9p
2N3771	170p
2N3772	180p
2N3773	220p
2N3866	70p
2N3903/4	15p
2N3905/6	15p
2N4058	15p
2N4059	10p
2N4060	13p
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AC128	0.17	BC144	0.25	BCY72	0.14	BF127	0.28	BSV64	0.66
AC141	0.18	BC147	0.11	BD115	0.63	BF157	0.23	BSV68	0.46
AC142	0.21	BC148	0.11	BD130	0.80	BF177	0.28	BSX19	0.16
AC141K	0.32	BC149	0.11	BD131	0.36	BF178	0.29	BSX20	0.17
AC142K	0.30	BC152	0.17	BD132	0.50	BF179	0.34	BSX21	0.23
AC176	0.32	BC153	0.18	BD133	0.66	BF181	0.34	BSX76	0.21
AC187	0.21	BC157	0.13	BD135	0.36	BF185	0.19	BSY41	0.46
AC187K	0.34	BC158	0.13	BD136	0.39	BF194	0.11	BSY52	0.41
AC188	0.21	BC159	0.13	BD137	0.41	BF195	0.12	BSY53	0.39
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AD142	0.52	BC168B	0.11	BD140	0.51	BF219	0.28	BSY56	0.82
AD143	0.46	BC171A	0.11	BD144	2.53	BF220	0.28	BSY65	0.16
AD149	0.55	BC171B	0.11	BD181	0.86	BF224J	0.14	BSY76	0.23
AF114	0.14	BC182	0.14	BD182	0.92	BF240	0.34	BSY78	0.25
AF115	0.14	BC182L	0.14	BD183	0.97	BF244	0.17	BSY95A	0.11
AF116	0.14	BC183	0.10	BD226	0.55	BF245A	0.34	BT101-300R	1.61
AF117	0.14	BC183L	0.10	BD227	0.55	BF257	0.34	BT101-500R	1.72
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AL100	0.78	BC213	0.14	BD233	0.52	BF338	0.44	BT108	1.72
AL102	0.74	BC213L	0.14	BD234	0.54	BFT41	0.40	BT109	1.12
AL103	0.74	BC214	0.16	BD235	0.58	BFT42	0.40	BT116	0.97
BA102	0.18	BC214L	0.16	BD236	0.61	BFT43	0.36	BT119	2.53
BA108	0.41	BC237	0.17	BD237	0.64	BFW30	1.97	BT120	2.53
BA115	0.08	BC238	0.17	BD238	0.67	BFW59	0.18	BTX18-100	0.96
BA130	0.14	BC300	0.34	BD433	0.74	BFW60	0.18	BTX18-200	1.15
BA141	0.31	BC301	0.34	BD434	0.78	BFX29	0.29	BTX18-400	1.61
BA144	0.16	BC303	0.46	BD435	0.86	BFX30	0.29	BTX18-500	1.72
BA145	0.15	BC307	0.11	BD436	0.94	BFX34	0.97	BTY79-100R	2.71
BA148	0.14	BC327	0.18	BD437	0.96	BFX52	0.43	BTY79-200R	3.08
BA154	0.14	BC328	0.17	BD438	1.10	BFX84	0.25	BTY79-300R	3.33
BA155	0.13	BC337	0.17	BDX32	3.04	BFX85	0.29	BTY79-400R	3.80
BA156	0.14	BC338	0.17	BDY10	0.97	BFX86	0.23	BTY79-500R	4.16
BC107	0.16	BC377	0.23	BDY11	1.03	BFX87	0.23	BTY79-600R	4.53
BC108	0.15	BCY30	0.49	BDY20	0.92	BFX88	0.25	BTY79-800R	6.67
BC109	0.16	BCY31	0.57	BDY38	0.69	BFY18	0.34	BTY87-100R	3.22
BC107B	0.18	BCY32	1.23	BDY60	0.80	BFY40	0.55	BTY87-200R	3.56
BC108C	0.18	BCY33	0.40	BDY61	0.69	BFY41	0.57	BTY87-400R	4.14
BC109C	0.23	BCY34	0.52	BDY62	0.66	BFY50	0.23	BTY87-600R	5.06
BC117	0.21	BCY38	0.48	BDY90	3.27	BFY51	0.21	BTY91-200R	4.51
BC125	0.16	BCY39	1.43	BDY91	3.13	BFY52	0.22	BTY91-400R	5.29
BC126	0.21	BCY40	0.78	BDY92	2.53	BFY53	0.23	BTY91-600R	6.39

BU105	1.95	BZX61-C51	0.23	OC140	0.34	1N4149	0.07	2N3233	1.09
BU105-02	2.24	BZX61-C68	0.23	OC170	0.23	1N4454	0.09	2N3415	0.14
BU108	3.33	BZX61-C72	0.23	OC171	0.23	1N4740A	0.19	2N3439	0.69
BU126	1.61	BZX70-C30	0.34	OC172	0.23	1N4742A	0.19	2N3440	0.63
BU133	1.61	BZX83 Series	0.11	OC200	0.63	1N4746A	0.19	2N3442	0.92
BU204	2.30	or		OC206	1.43	1N4749A	0.19	2N3702	0.13
BU205	2.41	BZY88 Series	0.11	OC207	1.61	1N4751A	0.19	2N3703	0.13
BU206	2.76	C106F	0.40	OCP71	1.03	1N5060	0.23	2N3704	0.13
BU208	3.56	C106A	0.46	RAS310AF	0.63	1N5404	0.17	2N3705	0.13
BY100	0.17	C106B	0.57	TAA435	0.52	1N5405	0.21	2N3706	0.11
BY103	0.23	C106D	0.69	TAA550	0.46	1N5406	0.23	2N3707	0.11
BY133	0.23	C111	0.28	TAA611	1.49	1N5837A	0.14	2N3716	1.49
BY142	0.23	CRS1 05	0.28	TAA861	0.57	2N173	2.07	2N3724	0.63
BY184	0.32	CRS1 10	0.28	TBA120S	1.12	2N174	1.72	2N3725	0.69
BY198	0.23	CRS1 20	0.38	TBA530	2.64	2N404	0.23	2N3771	1.43
BY199-400	0.21	CRS1 40	0.46	TBA530Q	2.99	2N457A	1.26	2N3772	1.61
BY201-2	0.23	CRS3/05	0.34	TBA560	3.56	2N525	0.34	2N3773	2.51
BY201-3	0.28	CRS3 10	0.46	TBA570	1.15	2N696	0.17	2N3794	0.23
BY201-4	0.34	CRS3 20	0.52	TBA641	0.92	2N697	0.14	2N3819	0.34
BY201-5	0.36	CRS3 40	0.63	TIC44	0.35	2N706	0.11	2N3904	0.14
BY201-6	0.40	CRS3 60	0.86	TIC45	0.39	2N708	0.17	2N3906	0.14
BY203-12	0.17	D32(DIAC)	0.23	TIC46	0.49	2N718	0.28	2N4032	0.46
BY203-16	0.24	E1222	0.32	TIC47	0.69	2N731	0.64	2N4123	0.14
BY204-4	0.27	FCH101	1.21	TIL209	0.18	2N929	0.17	2N4124	0.14
BY204-8	0.29	FCH141	1.21	TIP29A	0.49	2N930	0.17	2N4235	2.53
BY204-10	0.34	GET885	0.34	TIP30A	0.58	2N986	0.57	2N4248	0.13
BY206	0.17	LM301	0.55	TIP31A	0.62	2N995	1.06	2N4288	0.14
BY207	0.21	LM307	0.55	TIP32A	0.71	2N1131	0.18	2N4290	0.14
BYX10	0.23	LM309K	2.07	TIP41A	0.74	2N1132	0.18	2N4292	0.14
BYX22-200	0.23	MJ480	0.89	TIP42A	0.80	2N1302	0.17	2N4347	1.38
BYX22-800	0.28	MJ481	1.20	TIS26	17.94	2N1303	0.17	2N4348	1.38
BYX36-600	0.17	MJ490	1.01	U235	2.53	2N1304	0.23	2N4918	0.67
BYX38-300	0.50	MJ491	1.32	ZTX109	0.15	2N1305	0.23	2N4919	0.75
BYX38-600	0.57	MJE340	0.46	ZTX313	0.25	2N1306	0.28	2N4920	0.85
BYX38-900	0.62	MJE370	0.57	ZTX504	0.44	2N1307	0.28	2N4921	0.55
BYX38-1200	0.68	MJE371	0.66	1N542	0.07	2N1308	0.30	2N4922	0.63
BYX39-600	0.98	MJE520	0.55	1N645	0.23	2N1309	0.30	2N4923	0.65
BYX39-900	1.12	MJE521	0.66	1N746A	0.14	2N1613	0.21	2N5061	0.25
BYX70-300	0.34	NE555	0.69	1N750A	0.14	2N1711	0.21	2N5062	0.27
BYZ10	0.34	OA5	0.69	1N914	0.04	2N2102	0.52	2N5064	0.28
BYZ11	0.32	OA9	0.23	1N914A	0.07	2N2217	0.34	2N5321	0.60
BYZ12	0.28	OA90	0.08	1N1190A	2.64	2N2219A	0.52	2N5322	0.69
BYZ13	0.23	OA91	0.08	1N1199A	0.46	2N2221A	0.34	2N5323	0.67
BZX61-C15	0.23	OA95	0.08	1N1200A	0.57	2N2222A	0.40	2N5496	0.65
BZX61-C18	0.23	OC41	0.17	1N1201A	0.63	2N2270	0.34	2N5757	1.44
BZX61-C20	0.23	OC42	0.17	1N1202A	0.74	2N2368	0.21	2SC643A	1.49
BZX61-C22	0.23	OC43	0.34	1N1204A	1.03	2N2369	0.17	2SC1172Y	2.96
BZX61-C24	0.23	OC44	0.09	1N1206A	1.35	2N2369A	0.17	2N2894	0.34
BZX61-C30	0.23	OC45	0.09	1N1208A	2.24	2N2401	0.52	2N2894A	0.52
BZX61-C39	0.23	OC46	0.23	1N2069	0.16	2N2405	0.86	2N2904	0.21
BZX61-C43	0.23	OC70	0.09	1N2070	0.17	2N2484	0.23	2N2905	0.19
BZX61-C47	0.23	OC71	0.09	1N4001	0.06	2N2613	0.31	2N2905A	0.25
		OC72	0.11	1N4002	0.07	2N2646	0.46	2N2925	0.13
		OC75	0.09	1N4003	0.074	2N2711	0.11	2N2926R	0.11
		OC81	0.14	1N4004	0.08	2N2712	0.11	2N2926O	0.09
		OC83	0.14	1N4005	0.09	2N2800	3.06	2N2926Y	0.09
		OC84	0.14	1N4006	0.10	2N3055	0.48	2N2926G	0.10
		OC122	0.69	1N4007	0.11	2N3133	0.23	2N3053	0.17
		OC139	0.28	1N4148	0.05	2N3134	0.28	2N3054	0.44

THYRISTORS

	1amp TO5	3amp C106 Type	6 amp TO220	8 amp TO220	10amp TO220
50 V	0.29	0.40	0.41	0.42	0.47
100 V	0.29	0.46	0.47	0.48	0.54
200 V	0.38	0.58	0.58	0.58	0.68
400 V	0.46	0.70	0.87	0.88	0.98
600 V	0.58	0.86	1.09	1.19	1.26

L.E.D's
LIT704 1.03
LIT707 1.03
LIT747 2.01

TRIACS

	1.6amp TO5		4 amp TO220		6.5amp TO220		8.5amp TO220		10amp TO220		16amp TO220	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
100 V	0.32	0.32	0.60	0.60	0.70	0.70	0.78	0.78	0.83	0.83	1.01	1.01
200 V	0.34	0.34	0.64	0.64	0.75	0.75	0.87	0.87	0.87	0.87	1.17	1.17
400 V	0.41	0.44	0.77	0.78	0.80	0.83	0.97	1.01	1.13	1.19	1.70	1.74
600 V	0.51	0.56	0.96	0.99	0.87	1.01	1.21	1.26	1.42	1.50	2.11	2.17

N.B. TRIACS ARE AVAILABLE WITH OR WITHOUT AN INTERNAL TRIGGER DIAC (a) INDICATES PRICES FOR TRIACS WITHOUT AN INTERNAL DIAC (b) INDICATES PRICES OF TRIACS WITH AN INTERNAL TRIGGER DIAC
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RELAYS

SIEMENS PLESSEY, etc. MINIATURE RELAYS

1	2	3	4	1	2	3	4
52	4-8	2c/o	70p	700	16-24	4 M2B	60p
58	5-9	6 c/o	80p	700	16-24	4 c/o	80p
185	8-12	6 M	60p*	1250	18-36	2 c/o	60p*
230	9-18	2 c/o	70p*	2500	36-45	6 M	60p
430	15-24	4 c/o	80p*	2500	31-43	2 c/oHO	60p
700	12-24	2 c/o	60p*	9000	40-70	2 c/o	60p*
				15k	85-110	6 M	60p

(1) Coil ohms; (2) Working d.c. volts; (3) Contacts; (4) Price HD=Heavy Duty. All Post Paid. (*including Base)

OPEN TYPE RELAYS

6 VOLT D.C. 1 make con. **35p** Post 15p

9 VOLT D.C. RELAY
3 c o 5 amp contacts 70 ohm coil **75p** Post 15p

12 VOLT D.C. RELAY
3 c/o 5 amp contacts 120 ohm coil **75p** Post 15p

24 VOLT D.C. 3 c/o 600 ohm coil **75p** Post 15p
2 HD c/o 700 ohm coil **75p** Post 15p
4 c/o 300 ohm coil **85p** Post 15p

ENCLOSED TYPE RELAYS

24V D C 3 c/o **75p**. Post 15p Base 15p

24 VOLT A.C. Mfg ITT 3 h d c/o contacts **55p**. Post 15p Base 15p extra

55 VOLT A.C.
3 heavy duty c o contacts Price **55p**. Post 15p Base 15p

100 VOLT A.C.
2 c o sealed type octal base **75p**. Post 15p. Base 15p

240 VOLT A.C. RELAY
240V A C heavy duty 3 c/o contacts
Price **75p** Post 15p Octal base 15p extra

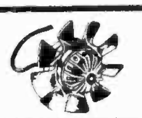
220/240 VOLT AC RELAY
3 c o 5 amp cont Sealed Mfg ISKRA **£1.25**. Post 15p Base 15p extra

ARROW 230/240V AC 2 c/o 15 amp contacts. Amp connectors **£1.00** Post 15p

110 VOLT A.C. 2 c/o 20 amp **£1.25** Post 15p

CLARE-ELLIOT Type RP 7641 G8
Miniature relay 675 ohm coil 24 volt D C 2 c/o **70p** P P

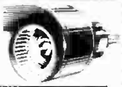
MANY OTHERS FROM STOCK, PHONE FOR DETAILS



BLOWER UNIT

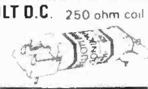
200-240 Volt **A.C. BLOWER UNIT** Precision German built. Dynamically balanced, quiet, continuously rated, reversible motor. Consumption 60mA. Size 120mm. dia. x 60mm. deep. Price £3·00. Post 30o.

PRECISION CENTRIFUGAL BLOWER



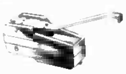
Mfg. Airflow Developments Ltd., continuously rated smooth running 230/240v A.C. motor 80 c f m. **£6.50**. Post 50p.

SUB-MINIATURE REED RELAY 3–9 VOLT D.C. 250 ohm coil



Single make, size 1¼" × ⅜" × ⅜" OUTSTANDING VALUE ONLY **£1 00** for six. **£1.50** for ten Post 15p (Min order six)

VERY SPECIAL OFFER



Honeywell Type N100 10 amp change over micro switch 10 for **£2.50**. Post 25p

Button Micro Switch. 5 amp c/o contacts NEW 20 for **£2.00**. Post 10p (Min order 20) Ditto Press to break 20 for **£1.50**. Post 10p.

LATCHING RELAY

Twin latching relay, flip-flop' 2c/o each relay Mains contacts 115 volts A C or 50 volt D C operation or 240 volts A C with 2 5K resistor **85p**. Post 15p

COIN MECHANISM (Ex-London Transport)

Unit containing selector mechanism for 1p. 2p & 5p coins Micro switches relays solenoid-operated hopper. 24 volt D.C Precision built to high standard Incredible VALUE at only **£2.50**. Post 70p.

230–250 VOLT A.C. SOLENOID

Similar in appearance to illustration. Approximately 1½ lb pull Size of feet 1⅝" × 1 3/16" Price **£1·00** Post 15p.

24 VOLT DC SOLENOIDS

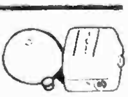
UNIT containing 1 heavy duty solenoid approx 25 lb. pull at 1 in. travel. 2 solenoids of approx. 1 lb. pull at ⅓ in. travel. 6 solenoids of approx. 4 oz. pull at ⅛ in. travel. Plus 1 24V D.C. 1 heavy duty 1 make relay. Price. **£2.50**. Post 75p **ABSOLUTE BARGAIN**.

600 WATT DIMMER SWITCH

Easily fitted. Fully guaranteed by makers. Will control up to 600 watts of all lighting except fluorescent at mains voltage. Complete with simple instructions. **£2·75**. Post 25p

2000 WATT POWER CONTROL
For Power tools. Heating. Lighting etc. incorporating 13 amp. outlet and mains lead **£8·00** Post 27p.

'GENTS' 6" ALARM BELL



200/250 volt AC/DC **Brand New.** Price: **£5·00** Post 60p. (Illustrated)

'STC' 6" RED ALARM BELL

Brand New. Price: **£4·00** Post 50p **24/48V DC**.

VARIABLE VOLTAGE TRANSFORMERS

Carriage extra

INPUT 230 v. A.C. 50/60
OUTPUT VARIABLE 0/260 v. A.C.
BRAND NEW. All types.

200W (1 Amp)	£10.00
0.5 KVA (Max. 2½ Amp)	£11.50
1 KVA (Max. 5 Amp)	£16.50
2 KVA (Max. 10 Amp)	£30.00
3 KVA (Max. 15 Amp)	£33.00
4 KVA (Max. 20 Amp)	£60.00
(max. 37.5 Amp)	£102.50
1 Amp OPEN TYPE (Panel Mounting)	£10.00

300 VA ISOLATING TRANSFORMER

115/230–230/230 volts Screened Primary two separate 0–115 volts for 115 or 230 volts. Secondary two 115 volts at 150 VA each for 115 or 230 volts output. Can be used in series or parallel connections Fully tropicalised Length 13 5 cm Width 11 cm Height 13.5 cm Weight 15 lb SPECIAL OFFER PRICE Only **£5.00** Carr 80p

LT TRANSFORMERS

0, 6, 12 volt @ 10 amp	**£5.60** Post 70p
0, 10, 17, 18 volt @ 10 amp	**£7.90** Post 70p
0, 6, 12 volt @ 20 amp	**£9.00** Post 70p
0, 12, 24 volt @ 10 amp	**£9.20** Post 70p
0, 4, 6, 24, 32 volt @ 12 amp	**£9.90** Post 70p
0, 6, 12, 17, 18, 20 volt @ 20 amp	**£10.40** Post 70p

Other types to order at short notice Phone your enquiries.

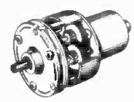
AUTO TRANSFORMERS

Step up step down 0 115 200 220 240 volts
At 75 watt **£2.64** Post 40p. 150 watt **£3.50** Post 50p. 300 watt **£6.20** Post 60p. 500 watt **£9.20** Post 75p. 1000 watt **£12.00** Post 90p.

20 r.p.m. GEARED MOTOR

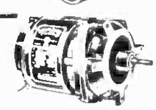
230/240 volt 20 r.p.m. motor **£1.00** Post 15p.

9/12 VOLT DC GOVERNED REVERSIBLE MOTOR



Machine-cut gear train giving final speed of 2 r p m with cam driving 3 sub miniature micro-switches (removable). Spindle 12mm long 6mm dia. Built to PO spec in heavy metal hinged case. **£3.75** Post 40p

BODINE TYPE N.C.I. GEARED MOTOR

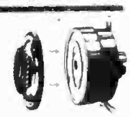


(Type 1) 71 r.p.m. torque 10 lb. in. **Reversible** 1/70th h.p. cycle 38 amp. **(Type 2) 28 r.p.m.** torque 20 lb. in. **Reversible** 1 80th h.p. 50 cycle ·28 amp. The above two precision made U.S.A. motors are offered in 'as new' condition. Input voltage of motor 115v **A.C.** Supplied complete with transformer for **230/240v A.C. input**.

Price either type **£6.25** Post 65p. or less transformer **£3.75** Post 50p.

These motors are ideal for rotating aerials, drawing curtains, display stands, vending machines, etc. etc.

BENDIX MAGNETIC CLUTCH



A superb example of Electro-mechanics! The main body is in two sections. The coil section is fixed and has a ⅜in. sleeve. The drive section rotating on the outer perimeters. The uniting plate has ⅜in. ID bearing concentric with main section and 18-tooth cog wheel.
When energized transmission is extremely powerful. 24V d.c. at 240 MA. **OUR PRICE JUST £2.50.** Post 30p

NICKEL CADMIUM BATTERY

1 5 Volt 15 Amp Size 154mm high, 76mm wide, 29mm deep Price £1 50 post 50p.

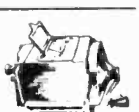
POWER RHEOSTATS

New ceramic construction, vitreous enamel embedded winding, heavy duty brush assembly, continuously rated.
25 WATT 10 25 100 150 250 500 1k 1·5k 2 5k ohm **£1.70** Post 15p **50 WATT** 1 5 10 25 50 100 500 1k ohm **£2.10** Post 20p. **100 WATT** 1 10 25/50/100 250/500/1k 1·5k 2·5k/5k ohm **£3.30** Post 25p
Black Silver Skirted knob calibrated in Nos. 1-9. 1¼ in. dia brass bush. Ideal for above Rheostats, 22p ea.

TRIAC

Raytheon Tag symmetrical Triac. Type TAG 250/500V. 10 amp. 500 p.i.v. Glass passivated plastic triac. Swiss precision product for long term reliability **£1.00** Post 10p. Incl data and application sheet Suitable Diac **18p**

INSULATION TESTERS (NEW)



Test to I.E.E. Spec. Rugged metal construction, suitable for bench or field work, constant speed clutch. Size L. 8 in., W. 4 in., H. 6 in., weight 6 lb.
500 VOLTS 500 megohms **£30.00**. Post 80p.

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FOUR EASY TO BUILD KITS USING XENON WHITE LIGHT FLASH TUBES, SOLID STATE TIMING + TRIGGERING CIRCUITS, PROVISION FOR EXTERNAL TRIGGERING. 230-250v. A.C. OPERATION.

RANGE OF 4 STROBE KITS FROM STOCK. PRICES FROM £6.30–£22.00. SAE FOR DETAILS.

BIG BLACK LIGHT
400 Watt Mercury vapour ultra violet lamp. Extremely compact and powerful source of u.v. Innumerable industrial applications also ideal for stage, display, discos etc. P.F. ballast is essential with these bulbs. Price of matched ballast and bulb **£21.00.** Post £1 Spare bulb **£8.00.** Post 40p

BLACK LIGHT FLUORESCENT U.V. TUBES
4ft. 40 watt £5.50 (callers only) **2ft. 20 watt £4.25.** Post 40p (For use in stan bi-pin fittings) MINI **12in. 8 watt £1.60.** Post 25p **9in. 6 watt £1.30.** Post 25p Complete ballast unit and holders for either 9" or 12" tube **£1.70.** Post 25p (9in × 12in measures approx.)

METERS NEW

90mm Diameter.
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Type 62T2 1A A C M/I 20A A C M/I 300V A C M/I ALL ABOVE **£2.50.** Post 20p

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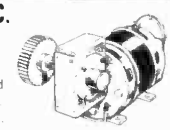
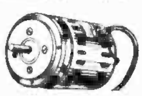
'FRACMO' 240 VOLT A.C. 50 cycle SINGLE PHASE GEARED MOTOR



33 r.p.m 30 lb ins Reversible fitted with mounting feet. Brand New. **£14.00** Post £1 00. (Total price incl. VAT £16.20.)

REVERSIBLE MOTOR



A.E.I 1 10th h.p. reversible motor 100/120V A C., 50/60 cycle. 1400/1680 r.p.m Flange fixing. Dia. 4", length 6½" shaft 1" × 5/16". Price **£2.50** Post 50p. Brand new Suitable 110/240V 150 watt Auto Transformer **£3.50** Post 50p. (Post for both items together 75p.)

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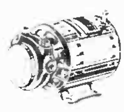

Carbon vane, oil-less 100 115V A.C 1/12 h.p. motor 50/60 cycle 2875 3450 r.p.m 20" vacuum 1.25 c f.m 10 p s i (approx figures). New unused surplus stock with elect. connection data. Fraction of maker's price **£12.00** Post 50p. Suitable transformer as above.

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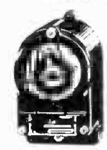
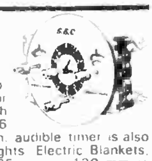
TIME SWITCH



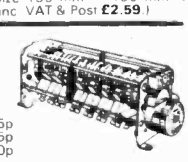
'Horstmann' Type V Mk II Time Switch. 200/250 volt A.C Two on/two off every 24 hours, at any manually pre-set time. 30 amp contacts 36-hour spring reserve in case of power failure Day omitting device. Fitted in heavy high impact case, with glass observation window Built to highest Electricity Board spec individually tested. Price **£7.75**. Post 50p. (Total inc VAT £8 91)

A.C. MAINS TIMER UNIT



Based on an electric clock with 25 amp single pole switch, which can be preset for any period up to 12 hrs. ahead to switch on for any length of time from 10 mins. to 6 hrs. then switch off. An additional 60 min. audible timer is also incorporated. Ideal for Tape Recorders Lights Electric Blankets, etc Attractive satin copper finish Size 135 mm × 130 mm × 60 mm Price **£2.00** Post 40p (Total inc VAT & Post **£2.59**.)

PROGRAMME TIMERS



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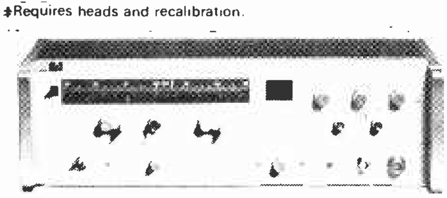

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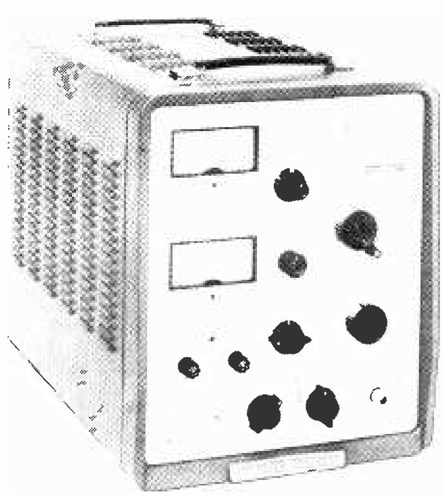

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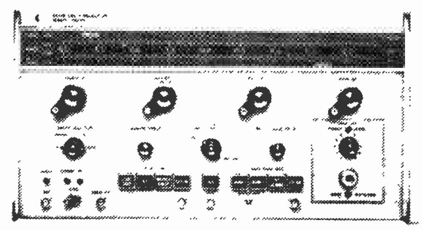

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SN7403	0.14	0.13	0.12
SN7404	0.15	0.14	0.13
SN7405	0.15	0.14	0.13
SN7406	0.30	0.29	0.28
SN7407	0.30	0.29	0.28
SN7408	0.15	0.13	0.12
SN7409	0.15	0.13	0.12
SN7410	0.14	0.13	0.12
SN7411	0.23	0.22	0.21
SN7412	0.19	0.18	0.17
SN7413	0.30	0.29	0.28
SN7414	0.71	0.70	0.69
SN7415	0.30	0.29	0.27
SN7416	0.28	0.27	0.26
SN7417	0.28	0.27	0.26
SN7420	0.14	0.13	0.12
SN7421	0.95	0.94	0.93
SN7422	0.25	0.24	0.23
SN7423	0.26	0.25	0.22
SN7425	0.26	0.25	0.22
SN7426	0.26	0.25	0.22
SN7427	0.26	0.25	0.22
SN7428	0.39	0.38	0.37
SN7430	0.14	0.13	0.12
SN7432	0.25	0.24	0.22
SN7433	0.36	0.35	0.34
SN7437	0.27	0.26	0.22
SN7438	0.27	0.26	0.22
SN7439	1.10	1.08	1.06
SN7440	0.14	0.13	0.12
SN7441	0.70	0.69	0.66
SN7442	0.63	0.60	0.53
SN7443	1.00	0.99	0.90
SN7444	1.08	1.07	1.05
SN7445	0.85	0.83	0.70
SN7446	1.03	1.00	0.85
SN7447	1.03	1.00	0.85
SN7448	0.85	0.83	0.70
SN7450	0.14	0.13	0.12
SN7451	0.14	0.13	0.12
SN7453	0.14	0.13	0.12
SN7454	0.14	0.13	0.12
SN7455	0.40	0.39	0.38
SN7460	0.14	0.13	0.12
SN7462	0.45	0.44	0.42
SN7464	0.45	0.44	0.42
SN7465	0.45	0.44	0.42
SN7470	0.30	0.27	0.25
SN7471	0.60	0.59	0.58
SN7472	0.25	0.24	0.21
SN7473	0.30	0.27	0.26
SN7474	0.31	0.29	0.26
SN7475	0.40	0.39	0.38
SN7476	0.31	0.29	0.26
SN7478	0.65	0.63	0.61
SN7480	0.43	0.41	0.36
SN7481	1.00	0.95	0.90
SN7482	0.75	0.70	0.62
SN7483	0.81	0.80	0.68
SN7484	0.90	0.86	0.85
SN7485	1.25	1.15	1.00
SN7486	0.31	0.28	0.25
SN7489	3.50	3.20	3.00
SN7490	0.45	0.42	0.35
SN7491	1.00	0.95	0.90
SN7492	0.45	0.42	0.35
SN7493	0.45	0.42	0.35
SN7494	0.48	0.45	0.40

	1	25	100+
SN7495	0.60	0.56	0.50
SN7496	0.70	0.67	0.60
SN7497	0.70	0.69	0.68
SN74100	1.35	1.30	1.25
SN74104	0.31	0.29	0.26
SN74105	0.31	0.29	0.26
SN74107	0.31	0.29	0.26
SN74109	1.00	0.97	0.95
SN74110	0.55	0.50	0.45
SN74111	0.81	0.80	0.76
SN74114	1.00	0.97	0.95
SN74115	1.00	0.97	0.95
SN74118	1.00	0.95	0.90
SN74121	0.31	0.29	0.25
SN74122	0.44	0.41	0.37
SN74123	0.62	0.58	0.50
SN74125	0.70	0.65	0.60
SN74126	0.75	0.70	0.65
SN74128	1.40	1.35	1.30
SN74132	2.10	2.05	2.00
SN74136	0.95	0.90	0.85
SN74140	2.50	2.45	2.40
SN74141	0.75	0.70	0.62
SN74145	1.15	1.10	1.05
SN74147	2.95	2.90	2.85
SN74148	2.30	2.25	2.20
SN74150	1.35	1.30	1.25
SN74151	0.68	0.62	0.55
SN74152	1.55	1.50	1.45
SN74153	0.68	0.62	0.55
SN74154	1.55	1.50	1.45
SN74155	0.68	0.62	0.55
SN74156	0.68	0.62	0.55
SN74157	0.90	0.85	0.80
SN74158	1.50	1.45	1.40
SN74160	0.95	0.90	0.80
SN74161	0.95	0.90	0.80
SN74162	0.95	0.90	0.80
SN74163	0.95	0.90	0.80
SN74164	1.60	1.55	1.50
SN74165	1.60	1.55	1.50
SN74166	1.40	1.30	1.15
SN74170	2.40	2.30	2.20
SN74173	1.65	1.60	1.55
SN74174	1.15	1.10	1.00
SN74175	0.97	0.90	0.80
SN74176	1.10	1.05	1.00
SN74177	1.10	1.05	1.00
SN74180	1.10	1.05	1.00
SN74181	3.50	3.45	3.35
SN74182	1.10	1.05	1.00
SN74184	1.60	1.55	1.50
SN74185	2.30	2.25	2.20
SN74188	4.90	4.85	4.80
SN74190	1.75	1.70	1.65
SN74191	1.70	1.65	1.60
SN74192	1.25	1.05	1.00
SN74193	1.25	1.05	1.00
SN74194	1.10	1.05	1.00
SN74195	0.90	0.85	0.80
SN74196	1.05	1.00	0.95
SN74197	1.05	1.00	0.95
SN74198	2.05	2.00	1.70
SN74199	2.05	2.00	1.70
SN74200	6.00	5.95	5.80
SN74221	1.80	1.75	1.70
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4001AE	0.24	0.19	0.16
4002AE	0.24	0.19	0.16
4004AE	4.90	4.80	4.70
4006AE	1.55	1.50	1.45
4007AE	0.24	0.19	0.16
4008AE	1.60	1.55	1.50
4009AE	0.35	0.34	0.30
4010AE	0.50	0.48	0.46
4011AE	0.24	0.19	0.16
4012AE	0.24	0.19	0.16
4013AE	0.59	0.47	0.39
4014AE	1.65	1.33	1.10
4015AE	1.65	1.33	1.10
4016AE	0.62	0.50	0.41
4017AE	1.62	1.31	1.08
4018AE	2.45	2.40	2.30
4019AE	0.62	0.50	0.41
4020AE	1.82	1.46	1.21
4021AE	1.65	1.33	1.10
4022AE	1.65	1.33	1.10
4023AE	0.24	0.19	0.16
4024AE	1.13	0.91	0.75
4025AE	0.24	0.19	0.16
4026AE	6.50	6.40	6.30
4027AE	0.42	0.41	0.40
4028AE	1.41	1.14	0.94
4029AE	1.95	1.57	1.30
4030AE	0.62	0.50	0.41
4033AE	2.80	2.70	2.60
4035AE	1.71	1.38	1.14
4040AE	1.82	1.46	1.21
4041AE	0.90	0.85	0.80
4042AE	1.00	0.90	0.80
4043AE	1.00	0.90	0.80
4044AE	1.00	0.90	0.80
4047AE	1.50	1.45	1.40
4048AE	1.30	1.25	1.20
4049AE	0.54	0.44	0.36
4050AE	0.54	0.44	0.36
4051AE	1.77	1.43	1.18
4052AE	2.00	1.90	1.80
4053AE	2.70	2.60	2.50
4055AE	2.60	2.50	2.40
4056AE	1.35	1.09	0.90
4060AE	2.25	1.82	1.50
4066AE	0.95	0.90	0.85
4069AE	0.38	0.30	0.25
4071AE	0.34	0.27	0.23
4076AE	1.45	1.40	1.35
4081AE	0.34	0.27	0.23
4510AE	1.75	1.70	1.65
4516AE	1.76	1.42	1.18
4518AE	2.17	1.75	1.45
4520AE	1.65	1.60	1.50
4901AE	0.37	0.35	0.33
4911AE	0.37	0.35	0.33

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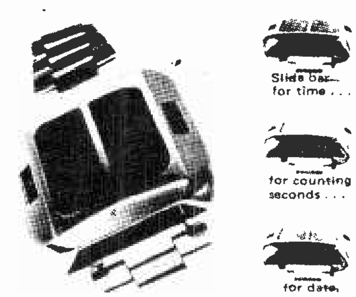
Comm. Anode. 14-pin DIL. Red LED

SOLID-STATE ACCURACY

SOLAR POWERED
100-Year Calendar Watch



SP-1

This is the world's first solar-powered timepiece. Solar cells (similar to those used in the Skylab program) draw power from the sun (10 to 15 minutes per day) or from ambient light (slightly longer) to keep batteries fully charged. Batteries operate up to 10 years without replacement. A true calendar watch — LSI circuitry is programmed to provide a calendar to the year 2100, automatically adjusting for 30 and 31 day months, even leap years. Automatic brightness control adjusts LED for perfect viewing even in outdoors. Shows minutes and hours, counts out seconds or shows the date. Easily adjusts to reset hour or date without affecting calendar. Shock and water resistant. Accurate to 5 seconds per month. **£298.50.**

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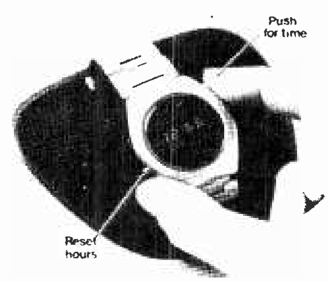

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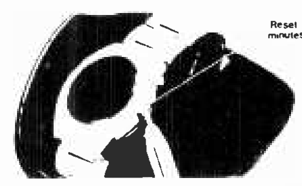

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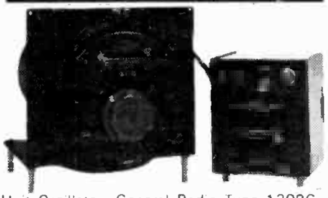

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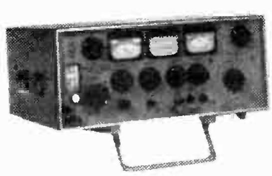

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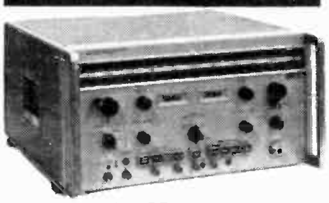

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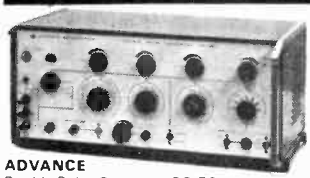

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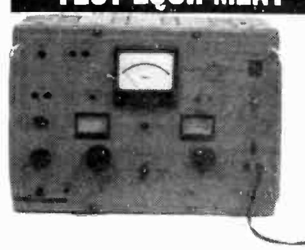

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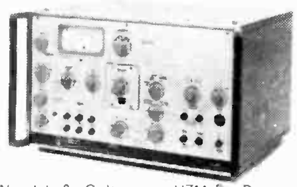

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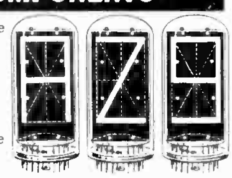

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7409	16p	13p	11p
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7420	16p	13p	11p
7427	27p	22½p	18p
7430	16p	13p	11p
7432	27p	22½p	18p
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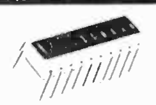

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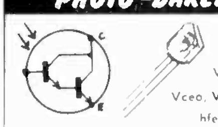

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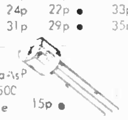

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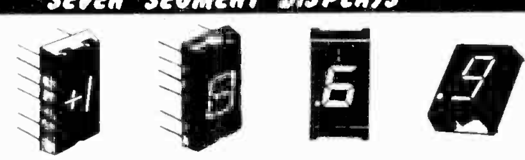

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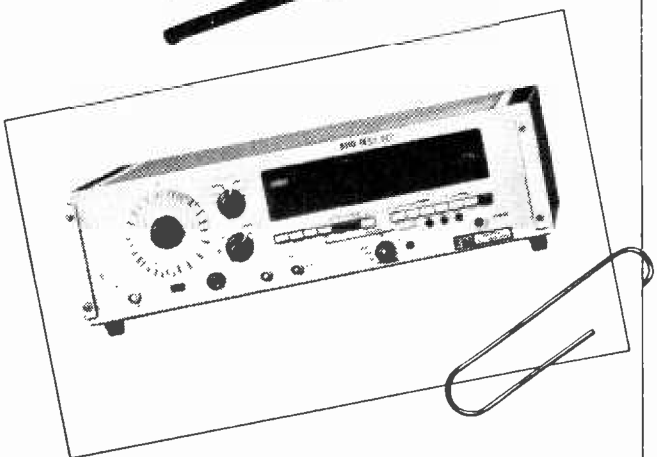

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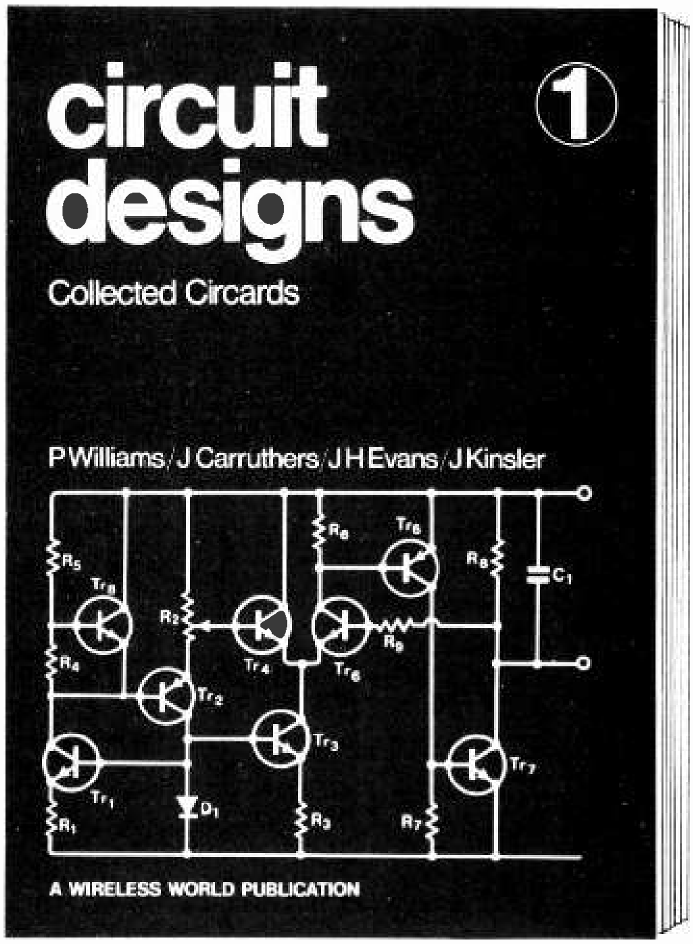

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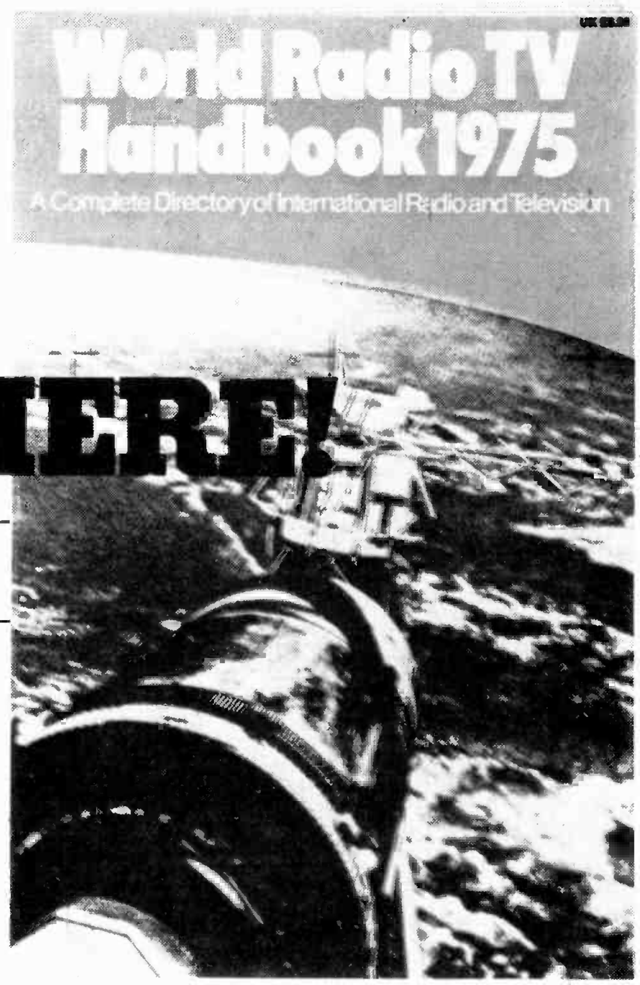

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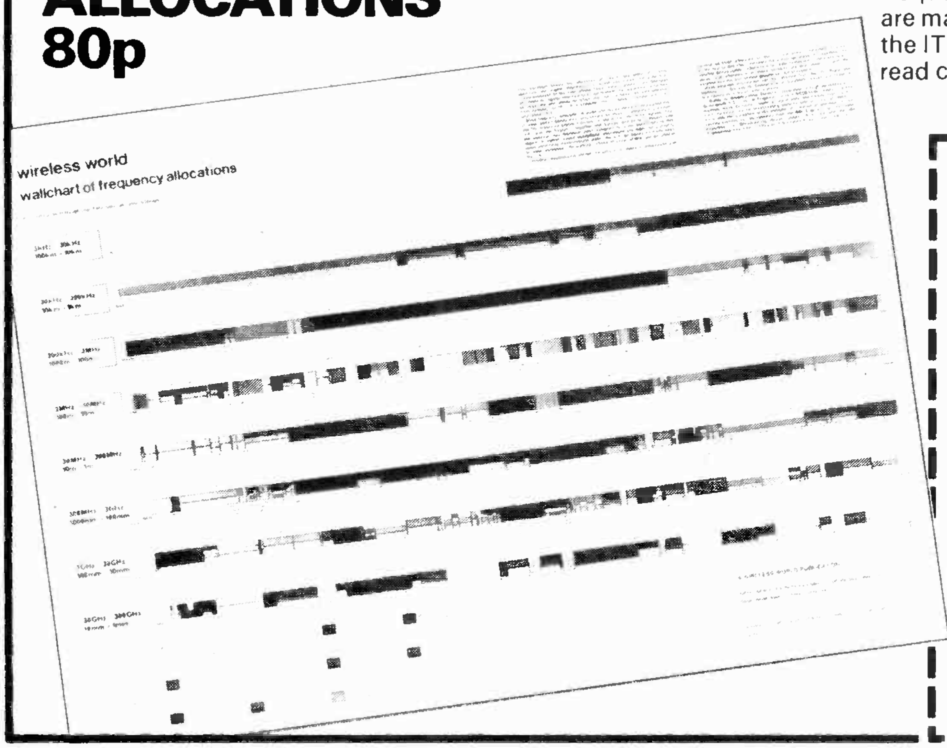

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Engineers! If you are interested in electronics, data transmission, digital systems, this could mean a lot more to you than you imagine – both now and in the future.

What are the tangible results of this declared policy by Neville Cooper, STC Director with responsibility for personnel policies? What does it mean in terms of salaries and benefits, working conditions, prospects of promotion and development within the company? What does it leave unsaid about STC's attitude to its people and their needs as individuals?

STC – one of the world's leading companies in telecommunications and a pioneer of the new British Telephone Switching System, TXE4 – is looking for professional and technical engineers at all levels of experience for Advanced Systems Development, Application Engineering, Systems Design and Integration, and Circuit and Logic Design.

STC – on record!

To answer some of the questions you might be expected to ask about us, Ken Corfield, STC's Managing Director, and three of his colleagues – Neville Cooper, Jock Marsh and Jeoff Samson – have chosen to make a record, each explaining the thinking behind the tasks and challenges of his own specific area of responsibility, and outlining the opportunities within STC. In this way, you can build up a positive picture of the company as a whole: its attitudes, approach to business, present and long-term views.

You can have a free copy of this record now. Send for it. Play it. Listen to it. Consider whether you like the sound of us. It could mean a lot to you, your future – and ours!

Neville Cooper, Standard Telephones and Cables Limited, 190 Strand, London WC2R 1DU
Please send me a free copy of your record "Just for the record," and the illustrated brochure that goes with it.

Name

Address

Present job title

WW206

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(4716

Opportunities in Electronics

Train to be an Electronics Technician

If you are 16-18 years old and would like a career in Electronics, our special 3 year training scheme provides the opportunity you are looking for.

We are offering you the opportunity to become an Electronics Technician in a fast expanding industry with an ever increasing demand for those with the ability to understand the practical workings of complex electronic equipment.

Our scheme includes well paid employment whilst training and day release to attend college to study for the City and Guilds Electronics Technician Certificate.

In addition to a practical interest in electronics you will require 'O' levels or CSE grades in Maths, Physics and English.

Telephone or write to
R. F. Honnor,
Personnel Manager,
G & E BRADLEY LTD.,
Electral House,
Neasden Lane, N.W.10.
Tel. 01-450 7811.

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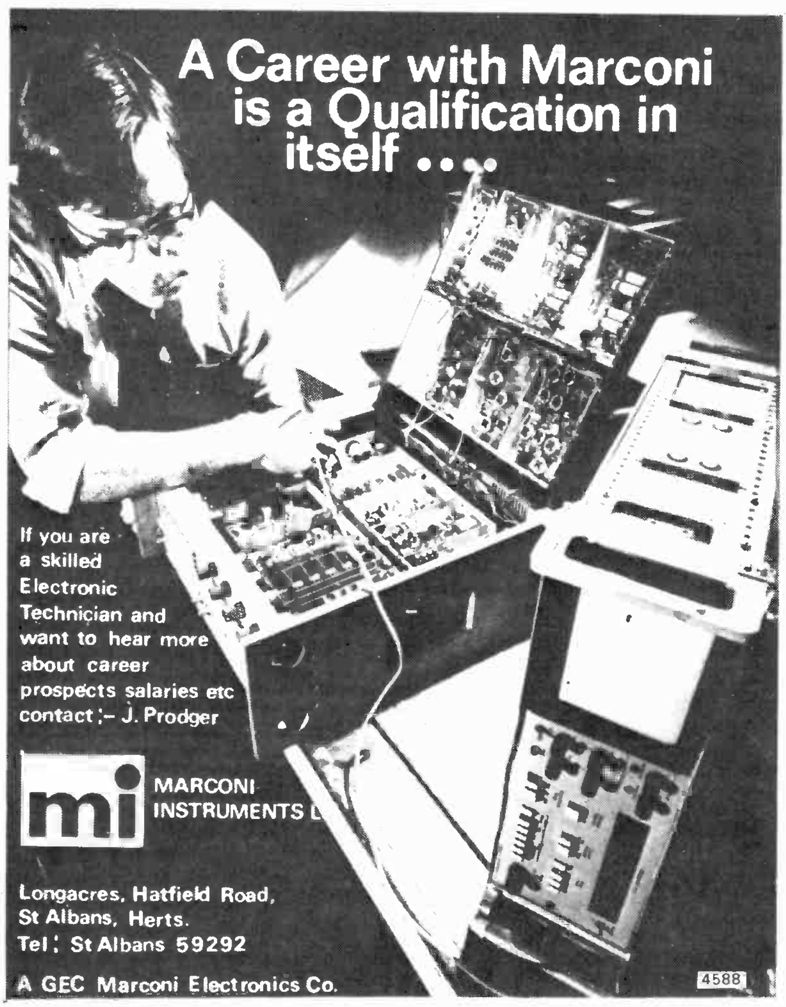
4738



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Many locations

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4678

UNIVERSITY OF GLASGOW

ELECTRONIC RESEARCH ASSISTANT

Applications are invited for an Electronic Research Assistant in the Department of Physiology to join team working on electrical properties of nerve muscle and heart cells. No previous biological experience required. Applicants of degree standard may register for a postgraduate degree on a part-time basis.

Salary according to qualifications and experience in electronics within national salary structure for research staff (Range 1B £1809-£2757 or Range 1A £2118-£3990).

Applications to: Professor O. F. Hutter, Department of Physiology, University of Glasgow, G12 8QQ, from whom further particulars may be obtained.

In reply please quote Ref. No. 3681 FH.

4756

Find your place in British Gas

Training in Engineering

CONTROL AND INSTRUMENTATION

British Gas has vacancies from time to time for control and instrumentation engineers at graduate level, technician engineer level and technician level. The posts concerned demand good standards of ability and a high sense of responsibility. To help fill them, we are prepared to train small numbers of selected men of suitable educational and technical ability who have previously worked in a related technological field, such as light current electrical engineering, or electronic control engineering. The courses are designed to train suitable men quickly to a standard which will enable them to contribute effectively to the Industry's work at the earliest possible stage, following which expertise will be developed through more advanced training.

If you are thinking of a change of career and would like to be involved in an undertaking which gives scope for personal development, and at the same time contributes to the wellbeing of the country, write in confidence, giving full details of your age, educational and technical qualifications and experience, and indicating the area of the country in which you would prefer to work, to:-

Mr. T. A. Lucas,
Communications and Instrumentation Dept. (WW),
British Gas, National Westminster House,
326 High Holborn, London WC1V 7PT.

BRITISH GAS

4729

C.C.T.V. SYSTEMS

Teletape Video, U.K.'s most progressive video systems company, are seeking a top man to organise and run a new division formed to actively develop the C.C.T.V. security surveillance activities of the company. Existing international contracts run into six figures, and we hold distribution rights on all good agencies so the opportunities are unlimited.

We are looking for a man fully experienced in all aspects of this business with good product knowledge and capable of dealing at Government level on large contracts. He should be capable of working entirely on his own initiative and will report directly to the Managing Director.

We envisage a good basic salary plus a sensible incentive participation on sales, with a company vehicle, etc.

This is a unique opportunity.

Please apply in confidence to:
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Managing Director
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76 Brewer Street, W1R 3PH
Telephone 734 1319 or 434 1267

(4758)

Opportunities in the
ELECTRONICS FIELD

Men with analogue or digital qualifications / experience seeking higher paid posts in: TEST - SERVICE - DESIGN SALES.

Phone: Mike Gernat, Ref. W.W.

NEWMAN APPOINTMENTS
360 Oxford Street, W.1,
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LINK

DEVELOPMENT ENGINEER

to work in our audio group on the development of studio talkback and communications equipment used in TV studio broadcasting systems.

You should be 21-25, have HNC or equivalent plus 1-2 years' experience in the use and/or design of audio products.

As an independent and well established Company we have kept a young and flexible outlook and attach great importance to people fitting in. Apart from an above average salary we also offer free life and health insurance, pension scheme of course and a subsidised canteen, as well as a congenial environment which we think is very important. We will help with relocation expenses where necessary. Andover is a growing town in an attractive part of rural Hampshire, close to Salisbury and Winchester and within easy reach of London and the south coast.

Either telephone Mic Comber at Andover 61345 (reverse charge if you wish) or write with brief details so that we can send you an application form.

4745

LINK ELECTRONICS
Walworth Industrial Estate, Andover, Hampshire, England — Telephone: Andover (0264) 61345

Applied Physicist
or
Electronics Engineer

required by the Institute of Cancer Research at Sutton, Surrey, to join an active R and D programme on ultrasonic diagnosis of cancer. The work will be varied and responsible, in a joint hospital/research institute environment and will call for a range of practical abilities in the development and application of novel instrumentation. Previous experience in ultrasonics would be useful but is not essential.

Appointment will be on the MRC Technical Officer/JTO scale at a salary in the range £2,688 — £3,792 (TO) or £1,494 — £2,592 (JTO) plus Threshold award of £229 plus London allowance of £312. Scales under review.

Applicants should normally hold an appropriate degree or equivalent qualification and preferably have some R & D or industrial experience. Exceptionally possession of two appropriate "A" levels can be accepted for appointment to a junior post.

Applications with curriculum vitae in duplicate and naming two referees to: The Secretary, Institute of Cancer Research, 34 Sumner Place, London SW7 3NU, quoting ref. 300/G/85.

4742

How do you value your electronics testing ability?

All the benefits of the world's largest radio-telephone exporters, could soon be yours. If you value your expertise highly, this is where to get most mileage from it.

Career progression paths are long and wide – the Company's expansion rate has been unaffected by the present economic situation. Equally significant is the importance Pye Telecom rightly attaches to fault-finding and testing to exacting specifications their VHF/UHF advanced design communications equipment. Reasons are obvious – not only is reliability crucial in furthering the Company's progress, but frequently lives depend on the performance of the equipment, because fire, police and ambulance services use it extensively.

So if you have practical experience of this work, maybe in the armed forces, it will pay you handsomely to get full information about the conditions, the relocation assistance and other attractions. Work and live in the attractive university city of Cambridge: alternatively in the nearby expanding town of Haverhill where there are excellent possibilities for private and rented housing.

Phone or write today to

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Pye Telecommunications Ltd
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Elizabeth Way, Cambridge CB4 1DW
Tel: Cambridge 58985

or

Mrs Cath Dawe
Pye Telecommunications Ltd
Colne Valley Road
Haverhill, Suffolk CB9 8DU
Tel: Haverhill 4422

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(4717

Kensington and Chelsea and Westminster Area Health Authority
North East District

MEDICAL PHYSICS TECHNICIAN

Applications are invited for the post of Medical Physics Technician Grade IV at the Middlesex Hospital. Salary according to Whitley Council 'B' Scales. Duties will involve a wide variety of work in Physiological measurement including work in the Department of Cardiology. Day release facilities for study at approved Colleges can be arranged.

Applications with full details of career to date and quoting two referees should be sent to Establishment Officer, The Middlesex Hospital, London W1N 8AA. Closing date for applications 2nd June 1975.

4650

RADIO ENGINEER

Telerenters (London & Provincial) Limited have vacancy for Senior Engineer at Watford.

The Engineer should have detailed knowledge of RF and audio measurements and be familiar with European specifications to enable him to implement and manage a test laboratory for the type approval of domestic radio, audio and recording equipment. Factory experience essential.

Salary: £4,000-£5,000.

Write giving brief details to: The Director, Telerenters (London & Provincial) Limited, 155/159 Queen's Road, Watford, Herts WD1 2QH.

(4724

RADIO TECHNICIANS

Are you a Radio Technician with a City and Guilds Intermediate Telecommunications Certificate or equivalent, plus 1 year's practical work-shop experience? If so, then why not join the Home Office. We have a vacancy at Baldock, Hertfordshire to carry out installation, maintenance, modification and construction of complex specialised radio communications equipment and systems.

Pay

£2010 at 17, £2230 at 19, rising to £3385 a year.

A Secure Future

with a non-contributory pension scheme, good prospects of promotion and a generous leave allowance. 5-day week of 42 hours.

Interested?

Then telephone or write for an application form to: Mr J J Willis, Directorate of Radio Technology, Room 514, Waterloo Bridge House, Waterloo Road, London, SE1 8UA. Telephone 01-275 3006.

4722

Home Office

SERVICE ENGINEER

Required to service our range of scientific and laboratory instruments, which include Fraction Collectors, U.V. Monitering, Ultromicrotomy equipment. The applicant should be resident in an area North of the Thames to Luton or prepared to move. A good working knowledge of modern electronics and a scientific background is desirable.

The Company offers excellent working conditions including pension scheme, profit sharing bonus scheme, BUPA membership and Company car.

Write or telephone for an application form.

The Service Manager
LKB Instruments Limited
232 Addington Road
Selsdon, South Croydon, Surrey
01-657 8822

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Openings for research in amplifier, passives, converter, aerial designing — your choice
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Electronics person strong in leadership, Methods and Mechanical Acumen required for capacity of **PRODUCTION MANAGER.**
Good salaries, generous benefits.
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(4759)

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UNIVERSITY OF LONDON

ELECTRONICS TECHNICIAN

GRADE 5

required for interesting design and development work in an Electronics Workshop, catering for the prototype requirements for teaching and research in the Departments of Electronics and Physics.

Salary £2,849-£3,305 per annum, including London Allowance.

Five-day, 37½-hour week.

Generous holidays.

Application forms and further details from Mr. M. E. Cane (5EW), Chelsea College, Pulton Place, London SW6 5PR.

4753

CHELSEA COLLEGE
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ELECTRONICS ENGINEER

required to take charge of Electronics Workshop for the design and production of prototype electronic equipment for electronics and physics research and teaching, and also for the servicing and maintenance of a wide range of commercial electronic equipment.

A wide practical experience and a sound theoretical knowledge of electronics is essential. Experience in microwave instrumentation would be an advantage, five-day, 37½-hour week. Salary (Technical Staff Grade 6) £3,254-£3,860 per annum, including London Allowance.

Further details and application form from Mr. M. E. Cane (EW7), Chelsea College (University of London), Departments of Electronics and Physics, Pulton Place, Fulham, London SW6 5PR.

4754

Colour CCTV Engineer

We are looking for a first-class electro-mechanical service engineer to maintain television, film, electronic and other equipment including Shibaden 1212 colour cameras, IVC colour VTRs, Sony U-matic recorders, etc. This equipment is sited in our theatre, studio, cinema and boardrooms in Shell Centre and at our Conference Centre at Teddington.

The job also involves production of programmes, organisation of staff, design and building of prototypes of mechanical, optical and electronic units in our busy AV Centre.

Starting salary would be negotiable, dependent upon qualification/experience. 5 day week, contributory Pension Fund, free 3-course lunches, 4 weeks annual holiday. Sports and social facilities in the building, including squash, badminton, swimming.

Telephone or write for an application form to: Shell International Petroleum Company Limited, LP/112, Shell Centre, London SE1 7NA. 01-934 2828.

4767

GLASGOW COLLEGE OF TECHNOLOGY

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IN

ELECTRICAL ENGINEERING

with choices in Power or Electronic subjects

Holders of a good HNC or HND in Electrical/Electronic Engineering or related disciplines may be eligible to enter the above course commencing 18th August, 1975. If you are interested in the above course, write or telephone now for application form and further details to:
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(4765)

BRITISH MEDICAL ASSOCIATION

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Up to £3008 (increase is currently being negotiated) + £410 London Weighting

With lively interest in Audio/Visual aids for education.

Duties will include liaising with medical teachers and providing information and advice on a wide range of equipment; supervising a workshop for repair and maintenance of closed circuit television and audio equipment for research purposes; supervising the design and construction of prototype equipment and an audio cassette duplication service; undertaking sound and television recordings in a small studio.

Applicants should have at least 5 years' experience in the educational uses of audio/visual aids.

Starting salary according to qualifications and experience.

Applications, with a full curriculum vitae and the names of two referees, to the Director, BMA House, Tavistock Square, London WC1H 9JP, not later than 11th July.

(4719

THE ROYAL NATIONAL THROAT, NOSE & EAR HOSPITAL
Gray's Inn Road, London WC1X 8DA

PHYSICIST

(BASIC GRADE)

Applications are invited for a newly established post of Physicist (Basic Grade) for work in the field of hearing disorders and the applications of hearing aids. Suitable candidates will have a degree in Physics and should have experience in electronics and acoustics. He/she will be based in a new electronic-acoustics laboratory and in the Hearing Aid Centre.

Salary scale £2046-£2562+ £312 London Weighting + current Threshold payments.

Applications giving details and names of two referees to Senior Administrative Assistant.

ELECTRONICS TECHNICIAN

Grade 5

required for the Chemistry Department. Duties include the servicing and repair of a wide range of optical and electronic instrumentation, the design, construction and modification of electronic units concerned with instruments. Minimum qualification O.N.C. or equivalent. Salary on scale £2849 p.a.-£3305 p.a. (including London weighting) according to experience. Apply in writing giving full details to the Head Clerk (WW), University of London King's College, Strand WC2R 2LS.

4749

CITY OF LONDON POLYTECHNIC

TV ENGINEER

(MAINTENANCE) REQUIRED to join a small team working on the installation and maintenance of a wide range of equipment from CCTV equipment to slide projectors.

Applicants must have a sound practical knowledge of electronics and mechanics; relevant qualifications an advantage.

Salary Technician Grade 3 scale £2,424-£2,754 including London Weighting. Entry point according to qualifications and experience.

Application forms and further details from The Assistant Secretary, City of London Polytechnic, 117/119 Houndsditch, London EC3A 7BU.

(4737

ELECTRONICS TECHNICIAN

(Grade 5)

required in the Department of Physiology to be responsible for the servicing of a wide range of sophisticated electronic instruments for both research and teaching and the design and construction of prototype apparatus. Good electronic background and qualifications essential. Some experience in medical or biological field preferable. Salary on scale £2849 per annum-£3305 per annum (including London weighting) according to age and qualifications, four weeks' annual holiday. Contributory Pension Scheme. Apply in writing with full details to the **Head Clerk (WW), King's College, London, Strand WC2R 2LS.**

4740

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S. LONDON
UP TO £2,800 p.a.

Dolby Laboratories is a young, go-ahead company with a world wide reputation for their audio noise reduction system. Test Engineers with a good understanding of basic circuits are required to test and trouble shoot professional audio P.C.B.s and equipment. This is interesting and well paid work. We give over four weeks' holiday per annum.

Write or phone:

Mr. C. Keys
Dolby Laboratories Inc.
346 Clapham Road
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Tel. 01-720 1111

(4764)

Opportunities for Electronics Engineers

To change to wider fields of electronics – join the EMI Service Team at Hayes.

Vacancies exist on repair and calibration of a wide range of electronic test gear including oscilloscopes, DVMs, pulse generators, power supplies etc.

Also

Servicing and commissioning closed circuit television equipment including cameras, VTRs, Monitors etc.

Applicants should have at least 5 years practical experience.

These positions offer varied and interesting work. Attractive starting salaries, subsidised lunches, 4 weeks holiday and excellent sick pay and pension schemes.

For further details telephone or write to:- M. Ford, 01-573 3888, Ext. 2167, EMI Service, 254 Blyth Road, Hayes, Middlesex.

EMI

The international music, electronics and leisure Group.

4741

VIDEO ENGINEER

Good all-rounder required by London's liveliest video dealers.

Due to continuing expansion in all departments we need another good engineer. Our team is small but very good so we are seeking someone with sound practical knowledge and wide product experience.

In return we are prepared to pay a more than generous wage with fringe benefits.

Please contact in confidence:

Peter Ellis, Technical Manager
TELETAPE VIDEO
76 Brewer Street
London, W1R 3PH
Telephone 743 1319 or 434 1267

(4757)

Directorate of Radio Technology

Telecommunications Officers (£4,190-£4,620)

. . . to be responsible for the study of radio propagation matters over the whole of the radio frequency spectrum (10kHz-275 GHz) and for the forward planning, management and regulation of frequency bands allocated to broadcasting, fixed, maritime and land mobile, and space services.

Duties also include: preparing specifications and type-approval of equipment for fixed and mobile services; application of computer techniques to frequency assignment problems; development of equipment for the location and suppression of radio interference; technical advice on all aspects of licensing of radio services and advice in connection with the international radio monitoring service.

Candidates (aged at least 25) must have ONC in Engineering (with a pass in Electrical Engineering 'A') or in Applied Physics *or* an equivalent qualification. In addition they must have had at least 7 years' experience of skilled work on radio, radar or other electronic work.

Salary, starting at £4,190, rises to £4,625. Good promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 10 July, 1975) write to Civil Service Commission, Alencon Link, Basingstoke, Hants. RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours) or London 01-839 1992 (24 hour answering service). Please quote ref. T/9017.

HOME OFFICE, London

4720

UNIVERSITY OF SOUTHAMPTON

Research Fellow in Optical Communications

Applications are invited for a Research Fellow or Assistant to join an active group working on Optical Fibre Communications in the Department of Electronics. The work involves the use of fibres in multi-access communication systems including the development of couplers and junctions. The normal qualifications required are a Ph.D. or equivalent research experience although applicants with other qualifications will be considered. Some knowledge of electronics, communications or opto-electronics is desirable. Salary will depend on experience and qualifications and will be within the range £1 809 to £3,813 (under review) plus Threshold payments.

Applications, including curriculum vitae and the names of two referees, should be sent to Mr. D. A. S. Copland, The University, Southampton SO9 5NH, quoting reference 383/R/WW.

(4744)

UNIVERSITY OF SURREY

ELECTRONIC ENGINEER

Applications are invited for the above position in the Electronic Workshop of the Psychics Department. The person appointed will work, together with two other members of the technical staff, under the general direction of a Chief Technician.

Applicants should have a good electronics background, a sound theoretical knowledge and should have experience in the development and construction of computer interfacing and be familiar with nucleonic instrumentation Qualification: HNC or equivalent. Salary scale: £2,844 - £3,450.

For further details and application forms please apply to the Staff Officer, University of Surrey, Guildford, Surrey GU2 5XH or Tel: Guildford 71281, Ext. 452.

(4654)

NORTHAMPTON COLLEGE OF TECHNOLOGY

DEPARTMENT OF ENGINEERING

Lecturer Grade I in Electrical Engineering

Applicants should have had previous experience of light current/electronic work and hold an H.N.C. or a final C.G.L.I. certificate with electronic subjects. Previous teaching is not essential, although desirable.

Duties will commence on 1st September 1975. Salary scale (under review) £1869-£3633 per annum plus threshold payment.

On 1st September 1975 the Northampton Colleges of Technology, Art and Education will amalgamate to form a new College of Higher Education (Nene College).

Further particulars and application forms can be obtained from the Chief Administrative Officer, Northampton College of Technology, St. George's Avenue, Northampton NN2 6JB. Telephone (0604) 713505.

4769

PRODUCTION MANAGER

for small quartz crystal manufacturing plant

in

NEW ZEALAND

An opportunity exists for a Production Manager familiar with all aspects of quartz crystal manufacturing for the communications market. Past experience should encompass grinding, vacuum plating and finishing to frequency.

The company, Hatfield Crystals Ltd., has recently entered the field of quartz crystal filter manufacture thus, although not an essential, it would be useful if the applicant has knowledge of quartz crystal design, particularly monolithic crystal filters in the 10.7 MHz band.

The successful applicant must be prepared to reside permanently in New Zealand and will be sponsored through the Migration Department of the New Zealand High Commission. The company is located at Napier, North Island, in a temperate climate not unlike the South of France. An attractive salary together with the usual fringe benefits will be offered.

Applicants to write in the first instance to:

The Managing Director
HATFIELD INSTRUMENTS LTD.
Burrington Way
Plymouth, PL5 3LZ
Devon

4646

TEST ENGINEERS

We have vacancies for Test Engineers to fault find and test a wide variety of quality control equipment, with experience of working on chemical, gas and oil analysis essential.

These positions would be ideal for ex-service personnel with relevant experience.

Good rates of pay, 4 weeks holiday, pension and sick pay schemes.

Ring Sylvia Borra 01-692 1271 Ext 393
or write to her at
The Personnel Department

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CAPACITY AVAILABLE

DESIGN, development, repair, test and small production of electronic equipment. Specialist in production of printed circuit assemblies. YOUNG ELECTRONICS LTD., 184 Royal College Street, London NW1 9NN. 01-267 0201. (29

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SITUATIONS VACANT

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ELECTRONICS TECHNICIAN required in Department of Psychology, University of Reading. Should have or be completing final C & G in Electronic Servicing or equivalent. Salary in scale £2439-£2895 p.a. (Grade 5). Apply with names of 2 referees and full details, quoting Ref. TZZ.23A to Assistant Bursar (Personnel). Universoty of Reading. Whiteknights, Reading RG6 2AH. (4725

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We are a research establishment and our craftsmen are engaged on a wide variety of work in the fields of prototype and small batch wiring and assembly, test and inspection, maintenance fault finding and repair. Why not join us and enjoy working in first-class conditions in the country?

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Applicants who should have served a recognised apprenticeship or have had equivalent training together with experience in one of the fields detailed should 'phone Tadley 4111 (STD 073-56 4111) Ext. 5230, or write to:

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RG7 4PR

(4718

SONY®

Trainee V.T.R. Service Engineer

Due to the continued growth in the sales of our products we have a vacancy for a qualified V.T.R. Engineer in our Central Service Division, Ascot Road, Bedfont, Middlesex. Ideally we require an engineer with previous experience of servicing Video products, but we are prepared to train engineers who have experience of televisions and tape-recorders.

The duties will involve the servicing of our wide range of Video products, including recorders, cameras and microphones.

We are offering an attractive salary which will be based on qualifications and experience and generous staff discounts on all of our products.

Please apply to: The Personnel Officer, Sony (UK) Ltd., Pyrene House, Sunbury-on-Thames, Middlesex. Tel: Sunbury 87644.

4739

MINISTRY OF DEFENCE (ARMY DEPARTMENT)

A vacancy exists for a

CIVILIAN INSTRUCTIONAL OFFICER

Grade III (Telecommunications), TV Servicing at 2 Resettlement Centre, Aldershot.

The post is open to men and women fully skilled and experienced in Television Servicing.

Appropriate ONC, C & G Certificate or equivalent qualification desirable.

Selection is by test and interview.

Starting salary £2825 to £3209 (at age 28 or over), rising to £3925.

Non-contributory pensionable employment.

Write for application forms to:

Commandant, 2 Resettlement Centre, Gallway Road
Aldershot, Hants. GU11 2DG

Closing date: 16th July, 1975.

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DY87	30.0
DY802	30.0
ECC82	28.0
EF80	29.5
EF183	34.5
EF184	34.5
EH90	35.5
PC900	24.5
PCC89	40.0
PCC189	41.0
PCF80	31.5
PCF86	39.0
PCF801	42.0
PCF802	40.0
PCL82	39.0
PCL84	39.0
PCL85	44.5
PCL86	41.0
PFL200	59.5
PL36	55.5
PL84	25.0
PL504	64.5
PL508	67.0
PL519	£1.50
PY88	35.5
PY800	33.0
PY500A	85.0

SEMI CONDUCTORS

Type	Price Each (p)	Type	Price Each (p)	Type	Price Each (p)
AC127	17	AD149	40	BD124	75
AC128	13	AD161	38	BD131	45
AC141K	25	AD162	38	BD132	39
AC142K	25	AF114	24	BD160	£1.39
AC151	20	AF115	21	BD235	49
AC154	18	AF116	22	BD237	52
AC155	18	AF117	19	BDX32	£2.40
AC156	20	AF118	50	BF115	20
AC176	22	AF139	35	BF160	15
AC187	19	AF178	45	BF167	20
AC187K	24	AF180	45	BF173	20
AC188	17	AF181	45	BF178	35
AC188K	26	AF239	40	BF179	40
AD142	45	AF240	60	BF180	31
		BC107	11	BF181	32
		BC108	10	BF184	25
		BC109	14	BF185	25
		BC109C	14	BF194	9
		BC113	13	BF195	8
		BC116A	19	BF196	10
		BC117	14	BF197	12
		BC125B	15	BF198	23
		BC132	25	BF200	25
		BC135	15	BF218	30
		BC137	19	BF224	23
		BC138	26	BF258	34
		BC142	23	BF336	28
		BC143	25	BF337	35
		BC147	11	BF355	54
		BC147A	11	BFX86	28
		BC148	10	BFY50	19
		BC149	10	BFY52	20
		BC153	15	BSY52	35
		BC154	15	BT106	£1.20
		BC157	14	BU105/02	£1.95
		BC158	10	BU108	£2.10
		BC159	11	BU208	£2.95
		BC173	18	E1222	30
		BC178B	20	MJE340	45
		BC182L	12	OC71	15
		BC183L	12	OC72	16
		BC187	25	R2008B	£2.00
		BC214L	15	R2010B	£2.00
		BC328	28	RCA16334	80
		BC337	19	RCA16335	80

DIODES

Type	Each (p)
BA115	7
BA145	14
BA148	19
BA154/201	11
BY126	11
BY127	12
BY199	27
BY206	21
BY238	25
OA90	6
OA202	7.5
IN60/OA91	5

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TBA540Q	£1.75
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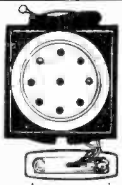

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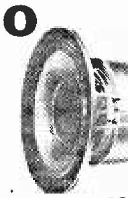

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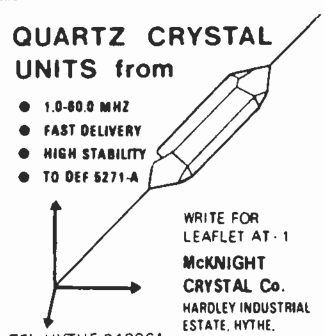

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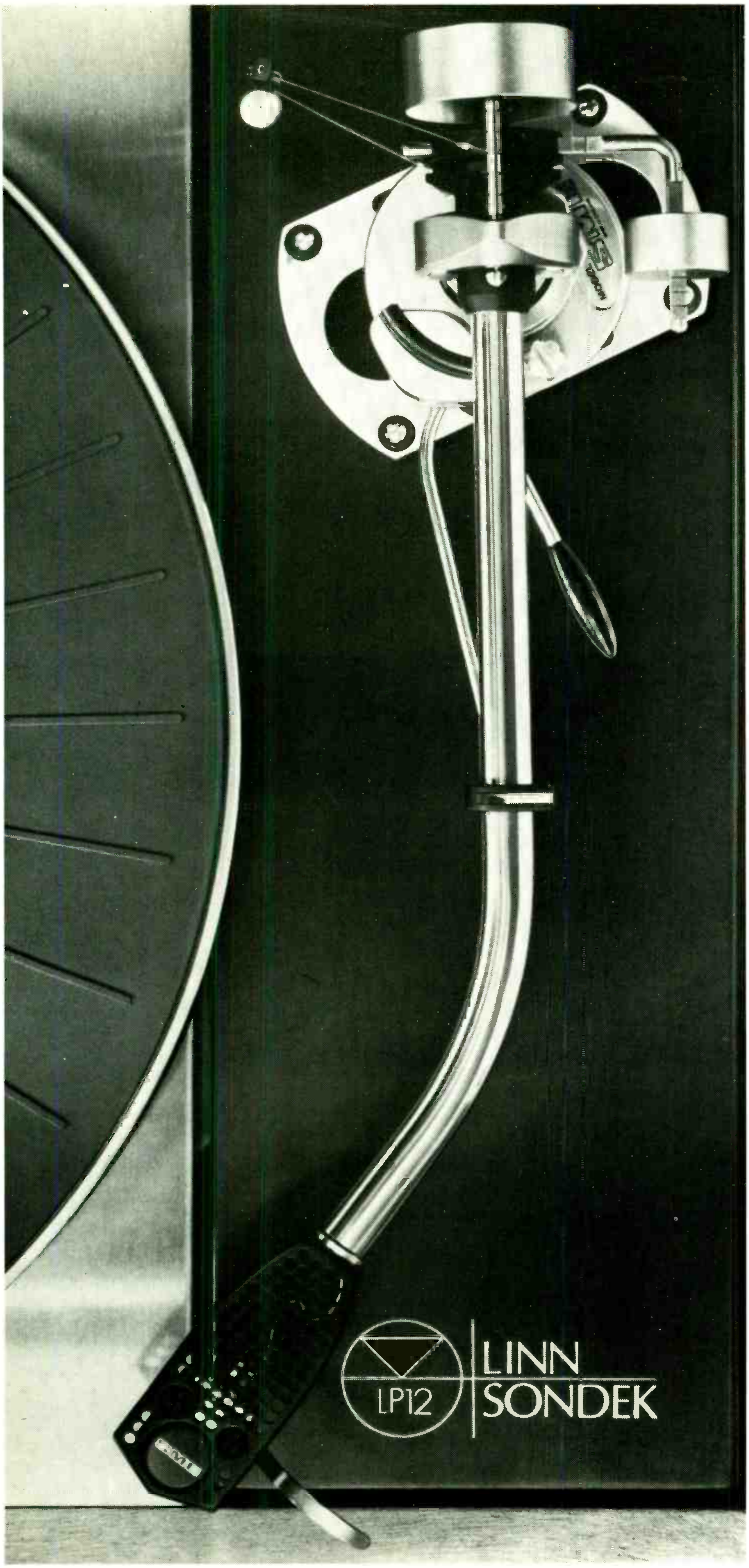
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