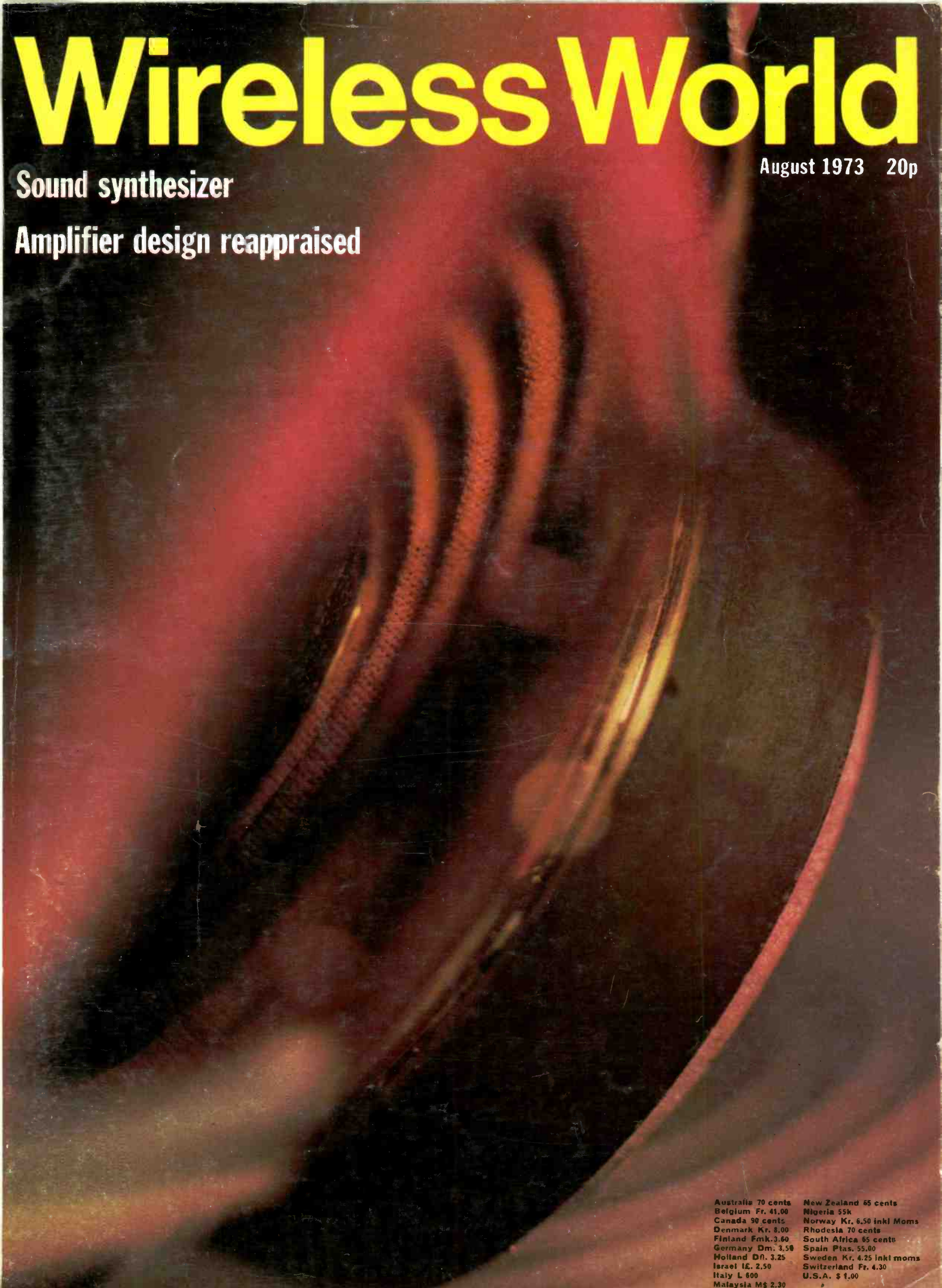
Wireless World

August 1973 20p

Sound synthesizer

Amplifier design reappraised



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It takes a quiet one to know what's going on.

And they don't come any quieter than M.I.'s three low-noise signal generators – TF 2011, 2012, 2013 – for mobile radio wavebands.

These are The Quiet Ones indeed – so quiet that they're the only comparably priced instruments available capable of measuring the adjacent-channel selectivity requirements for narrow-band f.m. specified by the various national authorities. The noise level of TF 2011 and 2012 (— 90 dB) is, in fact, considerably *below* the approved lower limit.

TF 2011 is designed for the v.h.f. band, TF 2012 for u.h.f. And TF 2013 is for the 800–960 MHz band just recently allocated for use for mobile radio. *That's* how forward-looking The Quiet Ones are!

Simple to operate, suitable for a variety of other tests in addition to adjacent-channel rejection measurement, these three M.I. newcomers with their very low noise and frequency drift are a major advance in mobile radio test technology. So get in step with The Quiet Ones . . . and you'll be way, way, ahead!

The full facts are yours for the asking from:

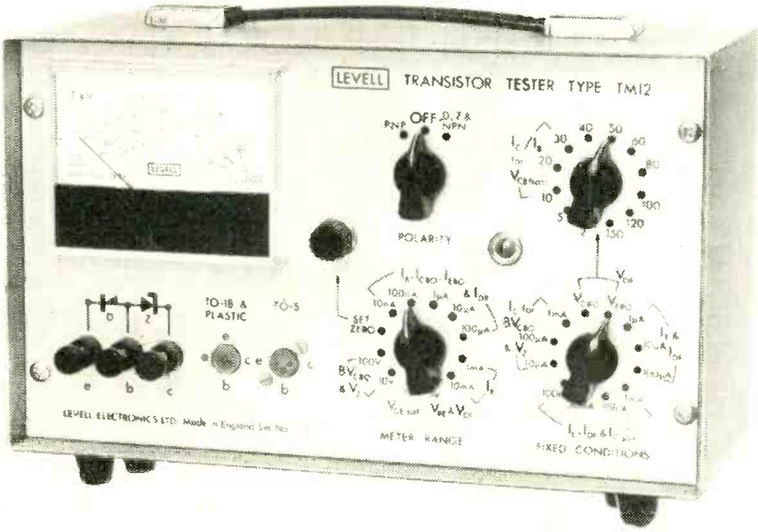
MARCONI INSTRUMENTS LTD.,
Longacres, St. Albans, Herts. AL4 0JN,
England.
Telephone: St. Albans 59292. Telex: 23350.
A GEC – Marconi Electronics Company.

WW—001 FOR FURTHER DETAILS

LOW COST TRANSISTOR TESTERS

LEVELL
PORTABLE INSTRUMENTS

VOLTAGE UP TO 150V. LEAKAGE DOWN TO 0·5nA.



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 and 30. The instrument is powered by a 9V battery and a transistor D.C. to D.C. converter to produce 150V.

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. Short circuit current limit 1mA.
BV_{CBO}:	10V or 100V f.s.d. acc ± 2% f.s.d. ±1% at currents of 10µA, 100µA and 1mA ± 20%. Open circuit voltage limit 150V.
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%. V_{CE}=2V approx.
h_{FE}:	3 inverse scales of 2000 to 100, 400 to 30 and 100 to 10 convert I_B into h_{FE} readings. Acc. is ±(2+200÷% of f.s.d.)% i.e. ±4% at f.s.d.
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 acc. ±1%.

POWER SUPPLY

One type PP9 battery, or A.C. mains when a LEVELL Power Unit is fitted.

SIZE & WEIGHT

7" x 10¼" x 5½". 8 lbs

NOTE: All prices subject to V.A.T.

type TM12 £65

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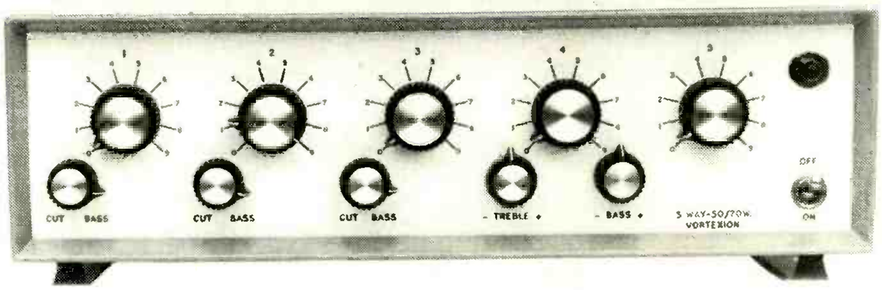
WW—004 FOR FURTHER DETAILS

Vortexion

50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 5-WAY MIXER USING F.E.T.s.



This is a high fidelity amplifier with bass cut controls on each of the three low impedance balanced line microphone stages and a high impedance (1.5 meg.) gram stage with bass and treble controls, plus the usual line or tape input. All the input stages are protected against overload by back to back low self capacity diodes and all use F.E.Ts for low noise, low intermodulation distortion and freedom from radio breakthrough.

A voltage stabilised supply is used for the pre-amplifiers making it independent of mains supply fluctuations and another stabilised supply for the driver stages is arranged to cut off when the output is overloaded or over temperature. The output is 75% efficient and 100V balanced line or 8-16 ohms output are selected by means of a rear panel switch which has a locking plate indicating the output impedance selected. The mixer section has an additional emitter follower output for driving a slave amplifier, phones or tape recorder, output .3V out on 600 ohms upwards.

50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 4-WAY MIXER

(0.3% intermodulation distortion) using the circuit of our 100% reliable 100 Watt Amplifier with its elaborate protection against short and overload, etc. To this is allied our latest development of F.E.T. Mixer Amplifier, again fully protected against overload and completely free from radio break-through. The mixer is arranged for 2-30/60Ω balanced line microphones, 1-HiZ gram input and 1-auxiliary input followed by bass and treble controls. 100 volt balanced line output or 5/15Ω and100 volt line.

100 WATT ALL SILICON AMPLIFIER

A high quality amplifier with 8 ohms-15 ohms or 100 volt line output for A.C. Mains. Protection is given for short and open circuit output over driving and over temperature. Input 0.4 V on 100K ohms.

THE 100 WATT MIXER AMPLIFIER

With specification as above is here combined with a 4 channel F.E.T. Mixer, 2-30/60Ω balanced microphone inputs, 1-HiZ gram input and 1-auxiliary input with tone controls and mounted in a standard robust stove enamelled steel case. A stabilised voltage supply feeds the tone controls and pre amps, compensating for a mains voltage drop of over 25% and the output transistor biasing compensates for a wide range of voltage and temperature. Also available in rack panel form.

CP50 AMPLIFIER

An all silcon transistor 50 watt amplifier for mains and 12 volt battery operation, charging its own battery and automatically going to battery if mains fail. Protected inputs. and overload and short circuit protected outputs for 8 ohms-15 ohms and 100 volt line. Bass and treble controls fitted. Models available with 1 gram and 2 low mic. inputs, 1 gram and 3 low mic. inputs or 4 low mic. inputs.

20/30 WATT MIXER AMPLIFIER

High fidelity all silicon model with F.E.T. input stages to reduce intermodulation distortion to a fraction of normal transistor input circuits. The response is level 20 to 20,000 cps within 2dB and over 30 times damping factor. At 20 watts output there is less than 0.2% intermodulation even over the microphone stage at full gain with the treble and bass controls set level. Standard model 1-low mic. balanced onput and HiZ gram. Outputs available 8/15 ohms OR 100 volt line.

200 WATT AMPLIFIER

Can deliver its full audio power at any frequency in the range of 30 c/s—20 Kc/s ± 1 dB. Less than 0.2% distortion at 1 Kc/s. Can be used to drive mechanical devices for which power is over 120 watt on continuous sine wave. Input 1 mW 600 ohms. Output 100-120 V or 200-240 V. Additional matching transformers for other impedances are available.

F.E.T. MIXERS and PPMs

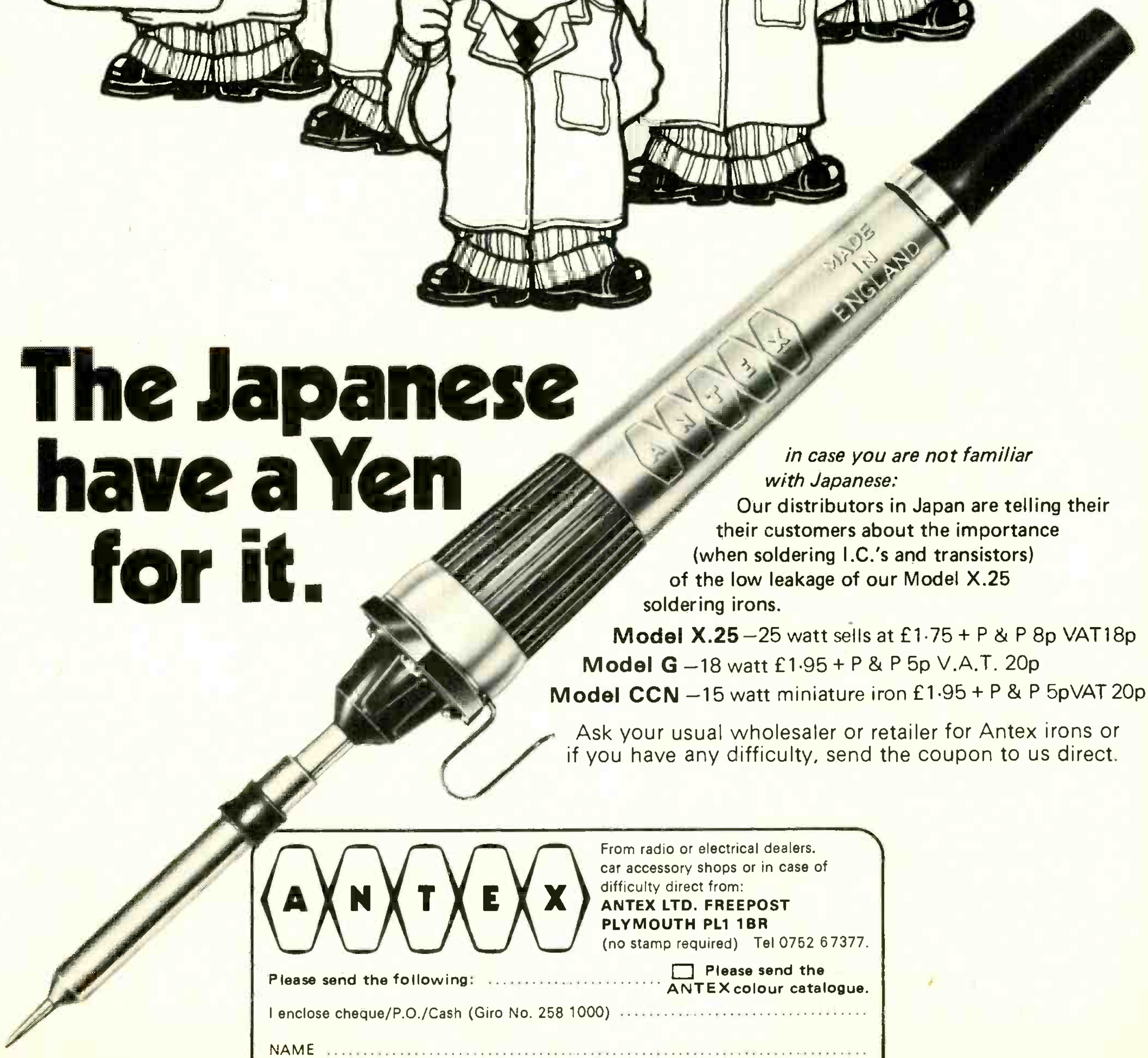
Various types of mixers available. 3, 4, 6 and 8 channel with Peak Programme Meter. 4, 6, 8 and 10 Way Mixers. Twin 3, 4, and 5 channel Stereo, also twin 4 and 5 channel Stereo with 2 PPMs.

VORTEXION LIMITED, **257-263 The Broadway, Wimbledon, S.W.19 1SF**

Telephone: 01-542 2814 and 01-542 6242/3/4 **Telegrams: "Vortexion, London S.W.19"**

WW—005 FOR FURTHER DETAILS

Antex X25



The Japanese have a Yen for it.

in case you are not familiar with Japanese:
Our distributors in Japan are telling their their customers about the importance (when soldering I.C.'s and transistors) of the low leakage of our Model X.25 soldering irons.

Model X.25 –25 watt sells at £1·75 + P & P 8p VAT18p
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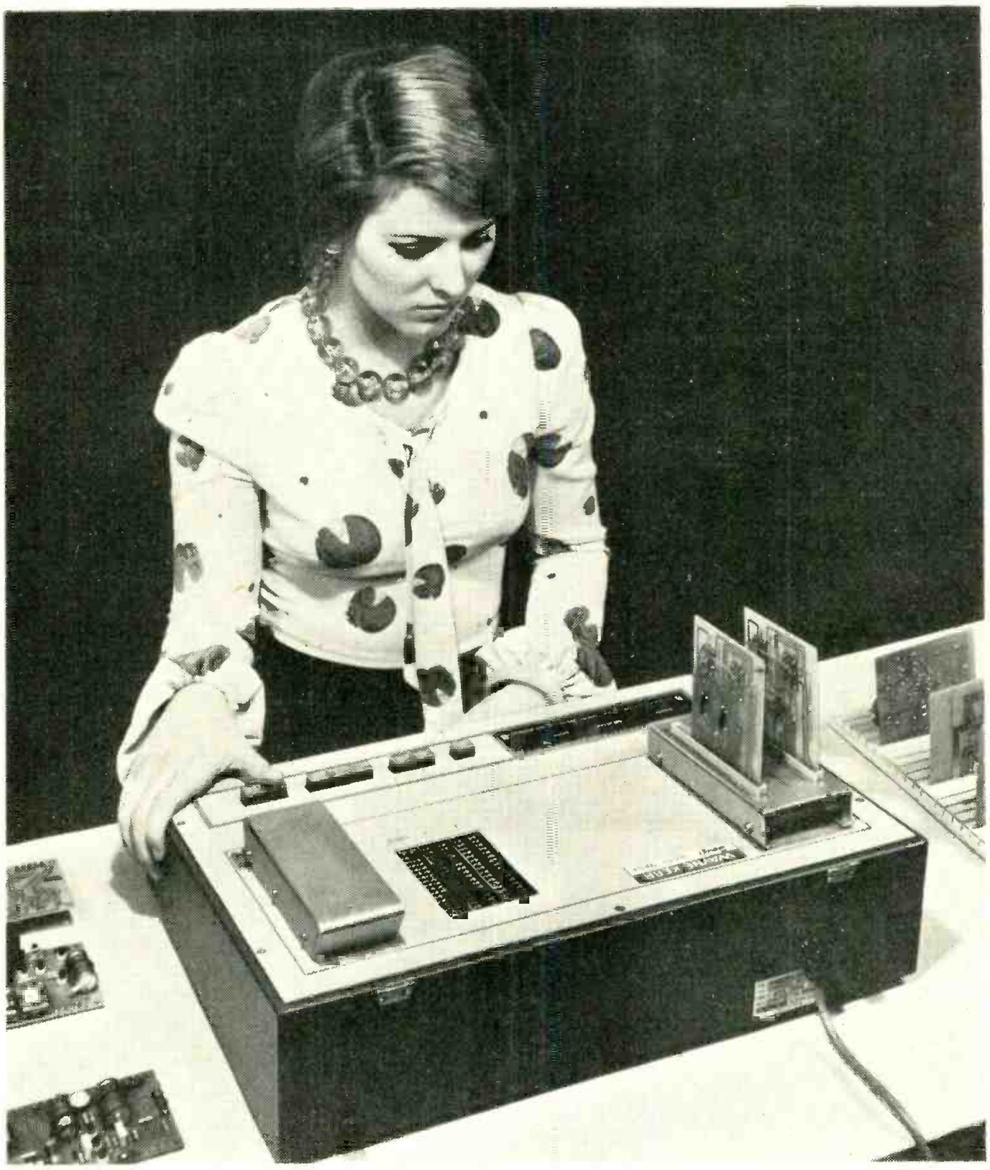
WW—006 FOR FURTHER DETAILS

Wayne Kerr introduce low cost Digital A.T.E.



Easy to set up and operate, the Swift Digital A.T.E. checks digital printed boards containing T.T.L. circuits or T.T.L. compatible functions.

The Swift applies a rapid series of stimuli to the masterboard and, simultaneously, to the board under test.

Lights indicate any non-parity between the outputs of the reference circuit and the circuit under test. These relate to the appropriate outputs. So testing is thorough and time saving. An error light indicates incorrectly inserted boards.

For more information phone Bognor (02433) 4501, or fill in the coupon.

Post to Wayne Kerr,
Durban Road, Bognor Regis, Sussex P022 9RL
Cables: Waynkerr, Bognor. Telex 86120

Please send me details of the Swift Digital A.T.E.

For the attention of Mr ____________________

Company name ____________________

Address ____________________

____

WAYNE KERR
a member of the Wilmot Breeden Group

WW–August

EHPL-

it takes over where MTBF leaves off

While others talk of MTBF, we introduce a new concept—EHPL, Estimated Half-Power Life. Our 400W and 1kW all-solid-state broadband HF linear amplifiers have over five years of it, counted in operational hours. Which, with a remarkably low Mean Time To Repair, means 99.9% up-time.

The multiple p.a. modules of these compact units, arranged in parallel for maximum reliability, ensure that even in the unlikely event of several component failures occurring together, the amplifiers go on working—long after others have stopped.

Moreover, thanks to Redifon's unique Transmit Level Control, they always deliver to any antenna—even to a badly damaged one—the maximum power that is safe, whatever the mismatch.

All of which means that the pair of transmitters in the picture represent the finest and most reliable in the world for civil and military applications, whether in fixed, mobile or containerised stations. And they are in production and service, right now.


400W 1kW

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WW—010 FOR FURTHER DETAILS

Collect Wireless World Circards. And build a valuable dossier on circuit design.

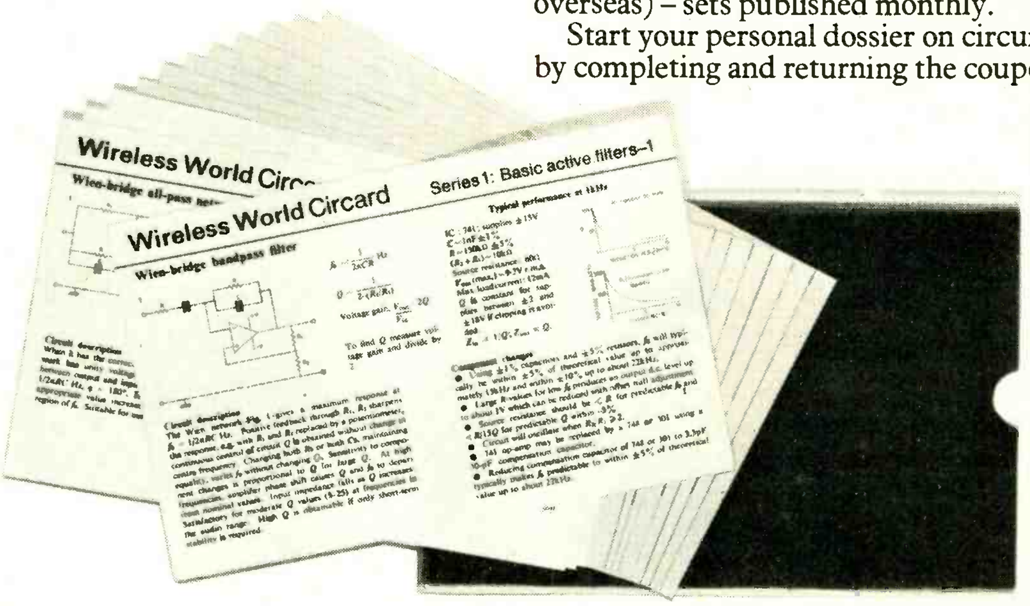
Circards is a new and comprehensive system, launched by Wireless World, to provide professional engineers and enthusiasts with valuable and up-to-the-minute data on circuit design. Data not available from any other single source.

Each Circard is 8″ x 5″ and shows a specific circuit, a description of the circuit operation; component values and ranges; circuit limitations; circuit modifications; tested circuits; performance data and graphs.

The double-sided format enables the Circard to be filed in standard boxes for easy reference. And the plastic wallet provided keeps the cards well-protected.

Each set of circards costs £1 (£1.15 overseas). A subscription to Nos. 6-15 costs £9 (£10.50 overseas) – sets published monthly.

Start your personal dossier on circuit design by completing and returning the coupon below.



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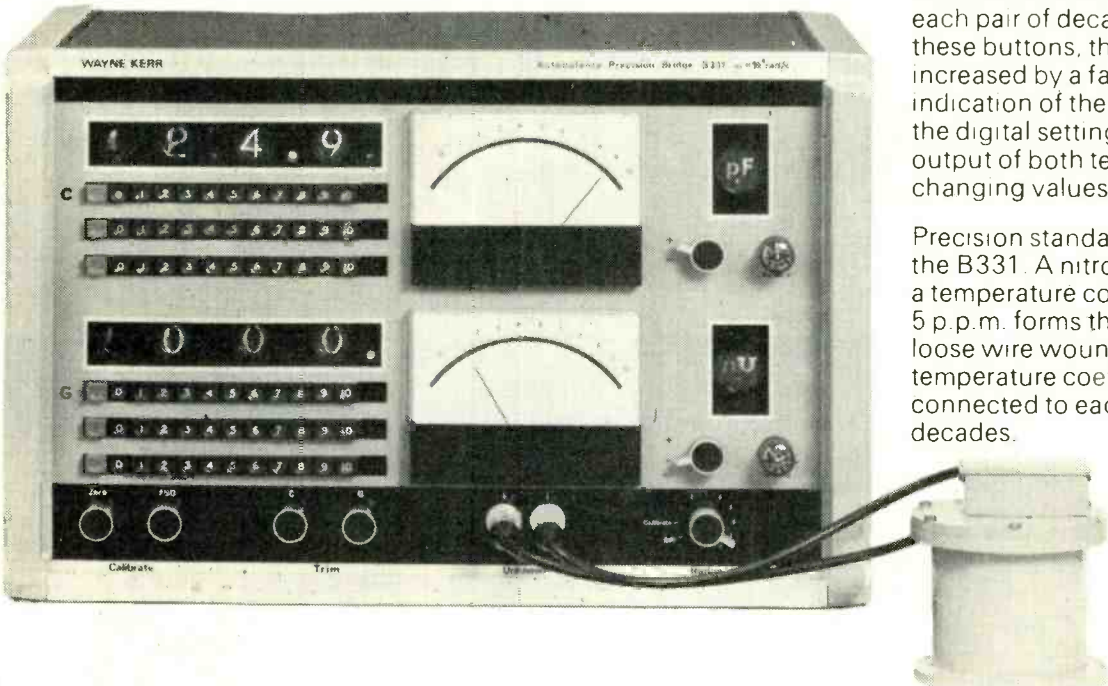
WW—011 FOR FURTHER DETAILS

Six figures in six seconds

A precision bridge that balances itself

the Wayne Kerr B331



This bridge was designed for use in Standards Laboratories, but ease of operation combined with an in-line readout giving up to 6 figure discrimination has enabled many other applications to be covered.

The B331 measures directly a wide range of capacitance and conductance values to 0·01% accuracy. The three terminal facility enables small values of capacitance and high values of resistance to be measured at the end of long cables.

Automatic compensation for the series impedance of the measurement leads is given by an advanced design of Kelvin clip, and a low impedance range directly calibrated in resistance and inductance permits four terminal measurements to be made.

Up to four significant figures can be set on each measurement term with push buttons.

The bridge automatically balances itself, the meters indicating the remainder of the measurement value on linear scales. As each pair of decades is introduced with these buttons, the meter sensitivity is increased by a factor of 10 giving an indication of the next figures required in the digital setting sequence. Analog output of both terms permit recording of changing values.

Precision standards are incorporated in the B331. A nitrogen filled capacitor with a temperature coefficient of less than 5 p.p.m. forms the reactive standard and loose wire wound resistors with temperature coefficients of 5 p.p.m. are connected to each set of conductance decades.

SPECIFICATION

Range (for 0·01% accuracy)	1 pF to 10 μF 10 n℧ to 100 m℧
derived reciprocal values	1 mH to 10 kH 10 Ω to 100 MΩ
Low Impedance Range	100 μΩ to 10 Ω 10 nH to 1 mH
derived reciprocal values	10 μF to 1 F
Frequency	(internal) 1591·55 Hz ± 0·5 Hz (1000 00 Hz to special order) (external) 200Hz to 20kHz.

For more information, either call Bognor (02433) 4501 or write to the address below:

WAYNE KERR

Durban Road, Bognor Regis, Sussex PO22 9RL

A member of the Wilmot Breeden group.

Sinclair Project 60

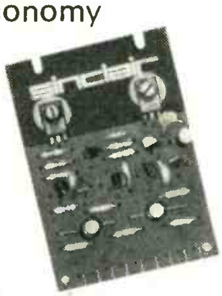
Now–the Z.50 Mk.2

with built-in automatic transient overload protection

When originally introduced, the Sinclair Z.50 proved how it was possible to design and produce a popularly priced modular power amplifier having characteristics to challenge the world's costliest amplifiers. Many thousands of Z.50's are now giving excellent service day in, day out. But we have also learned that constructors do not always use their Z.50's ideally. That is why we have introduced modifications whereby risk of damage through mis-use is greatly reduced and performance further enhanced. The Z.50 Mk.2 has improved thermal stability, more accurately regulated D.C. limiting to ensure more symetrical output voltage swing and clipping and still less distortion at lower power. Z.50 Mk.2 is compatible with all other Project 60 modules, and may be incorporated to advantage in existing systems. Eleven silicon epitaxial planar transistors are now used, two more than in the original Z.50; circuitry has been re-designed, making this versatile high performance amplifier better than ever.

with free manual
£5.48

Z.30 the power amplifier for quality and economy

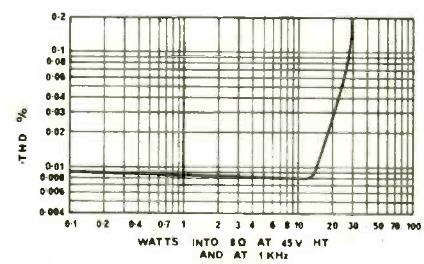


with free manual
£4.48

The Z.30 provides excellent facilities for the constructor requiring a high fidelity audio system of less power than that available from Z.50's. Using a power supply of 35 volts, Z.30 will deliver 15 watts RMS into 8 ohms, or 20 watts RMS into 3 ohms using 30 volts. Total harmonic distortion is a fantastically low 0.02% at 15 watts into 8 ohms with signal to noise ratio better than 70 dB unweighted. Input sensitivity 250mV into 100K ohms. Size 80 x 57 x 13 mm ($3\frac{1}{8}$ x $2\frac{1}{4}$ x $\frac{1}{2}$) Z.30, Z.50 and Z.50 MK.2 modules are compatible and interchangeable.

Brilliant new technical specifications

Input impedance 100 KΩ
Input (for 30w into 8Ω) 400mV
Signal to noise ratio, referred to full o/p at 30v HT 80dB or better
Distortion 0.02% up to 20W at 8Ω. See curve
Frequency response 10Hz to more than 200 KHz ±1dB
Max. supply voltage 45v (4Ω to 8Ω speakers) (50v 15Ω speakers only)
Min. supply voltage 9v
Load impedance – minimum: 4Ω at 45v HT
Load impedance – maximum: safe on open circuit



Typical Project 60 applications

System	The Units to use	together with	Units cost
Simple battery record player	**Z.30**	Crystal P.U., 12V battery volume control, etc.	**£4.48**
Mains powered record player	**Z.30, PZ.5**	Crystal or ceramic P.U. volume control, etc.	**£9.45**
12W. RMS continuous sine wave stereo amp. for average needs	**2 x Z.30s, Stereo 60; PZ.5**	Crystal, ceramic or mag. P.U., F.M. Tuner, etc.	**£23.90**
25W. RMS continuous sine wave stereo amp. using low efficiency (high performance) speakers	**2 x Z.30s, Stereo 60; PZ.6**	High quality ceramic or magnetic P.U., F.M. Tuner, Tape Deck, etc.	**£26.90**
80W. (3 ohms) RMS continuous sine wave de luxe stereo amplifier. (60W. RMS into 8 ohms)	**2 x Z.50s, Stereo 60; PZ.8, mains transformer**	As above	**£34.88**
Indoor P.A.	**Z.50, PZ.8, mains transformer**	Mic., guitar, speakers, etc., controls	**£19.43**

F.M. Stereo Tuner **(£25)** & A.F.U. **(£5.98)** may be added as required.

Guarantee

If, within 3 months of purchasing any product direct from Sinclair Radionics Ltd., you are dissatisfied with it, your money will be refunded at once. Many Sinclair appointed Stockists also offer this same guarantee in co-operation with Sinclair Radionics Ltd.

Each Project 60 module is tested before leaving our factory and is guaranteed to work perfectly. Should any defect arise in normal use, we will service it at once and without any charge to you, if it is returned within two years from the date of purchase. Outside this period of guarantee a small charge (typically £1.00) will be made. No charge is made for postage by surface mail. Air Mail is charged at cost.

sinclair

WW—013 FOR FURTHER DETAILS

model NAUS

R&S

makes a good match easy at 25 to 525 MHz

Frequency Range	25-525 (1000) MHz
Max. forward and reverse power	35 W(Over 525 MHz 6 dB per octave)
Indicating Range	0,3/1/3/10/30 W
Smallest readable value	20 mW
Indicating error	≦ 4%°. rdg. ± 1% of F.s.d.
Variation with temp.	≦ 0,25%/°C
Directivity	≧ 30 dB (< 30 MHz ≧ 26 dB)
VSWR	≦ 1,03
Insertion loss	≦ 0,1 dB (< 525 MHz ≦ 0,25 dB)

Directional Power Meter NAUS

Antenna matching must often be measured when servicing radiotelephone equipment, and, since in many cases the access to built-in radio sets and antennae is difficult, in situ battery-operated instruments which can be easily connected are necessary. To meet this problem, ROHDE & SCHWARZ have developed the DIRECTIONAL POWER METER MODEL NAUS with a separate measuring head which can be connected at any test point between the antenna and transmitter. Whilst the actual measuring instrument is observed by the operator. The new model covers a frequency range from 25 to 525 MHz in one complete band and has two meters for simultaneous indication of incident and reflected power in five ranges (0.3/1/3/10/30 W.). Available with a characteristic impedance of 50, 60 or 75Ω. The NAUS is designed to achieve a high sensitivity and accuracy over the wide temperature range of 20° to +50°C and is considered to be ideal for the servicing of radiotelephone equipment.

For full details and specifications apply to:

AVELEY ELECTRIC LTD.

Roebuck Road, Chessington, Surrey

Tel: 01-397 8771
Telex: Avel London 928479

WW—015 FOR FURTHER DETAILS

What makes you think
that we think
you are thinking
about Terminal Blocks?

WE AREN'T YOU KNOW!

Actually, we *were* thinking that *you* might be thinking of Indicator Lights, Voltage Selectors, Connectors, or perhaps Metal Pressings or Plastic Components. And we were thinking that, even if you only wanted a few of any or each of these, it would be a pleasure to do business with you.

And *you* might find it a pleasure to do business with *us*, especially as we can solve so many of your supply problems.

For instance, suppose you *did* want just a few of these or any other Cinch, Dot or FT components very quickly, we could, as stock holders, have them on the way to you the day we got your order.

Perhaps you'd like to put this promise to the test.

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The single source that simplifies.

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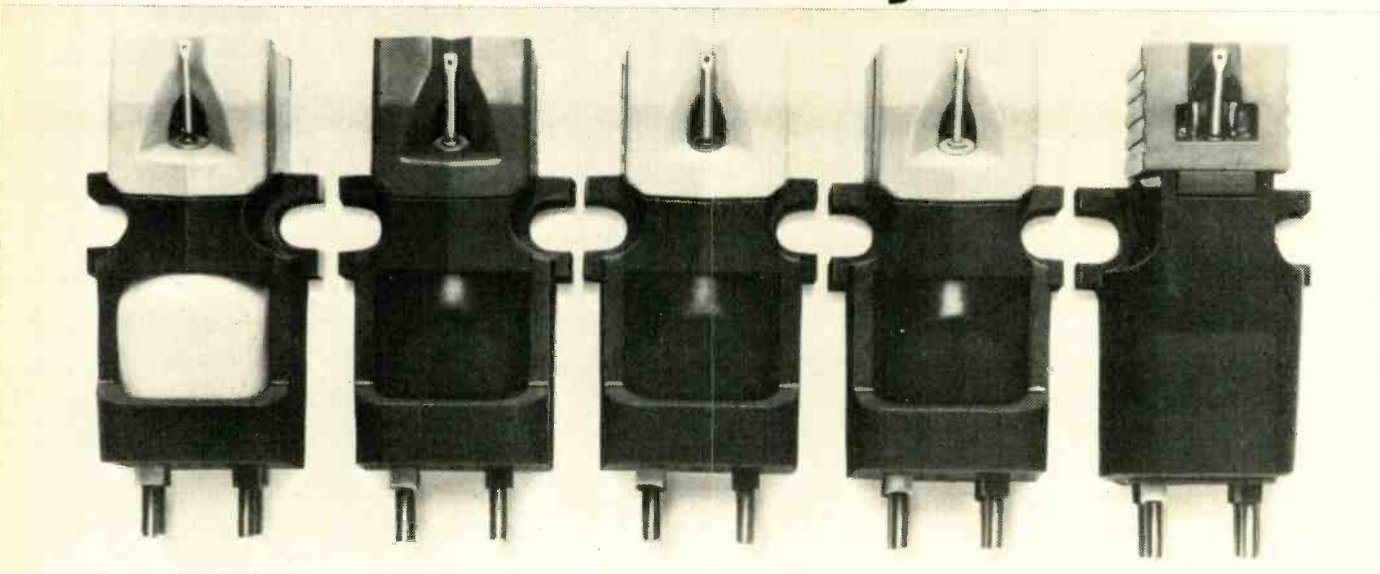
WW—016 FOR FURTHER DETAILS

We're sensitive to everyone's needs.



Different people have very different requirements in Hi-Fi, so Goldring developed a comprehensive range of stereo magnetic cartridges that are superb in performance and realistic in price.

From the G800 Super E for those who seek perfection down to the G850 for systems on a budget, the Goldring range offers unsurpassed quality and value.

Your request will bring full details of these and other Goldring products.
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Goldring Series 800

Stereo Magnetic Cartridges.

WW—020 FOR FURTHER DETAILS

transformers

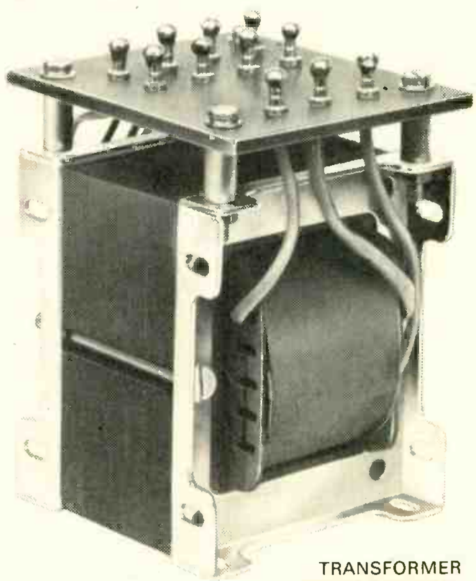
mains, audio, microphone, ferrite core and other wound components

A wide range of transformers manufactured to customers individual requirements.

Prompt Prototype Service available

MICROPHONE TRANSFORMER IN MUMETAL CAN

TRANSFORMER WITH TWO HOLE CLAMP AND SOLDER TAG CONNECTIONS



TRANSFORMER WITH UNIVERSAL END FRAMES AND TURRET LUG CONNECTIONS

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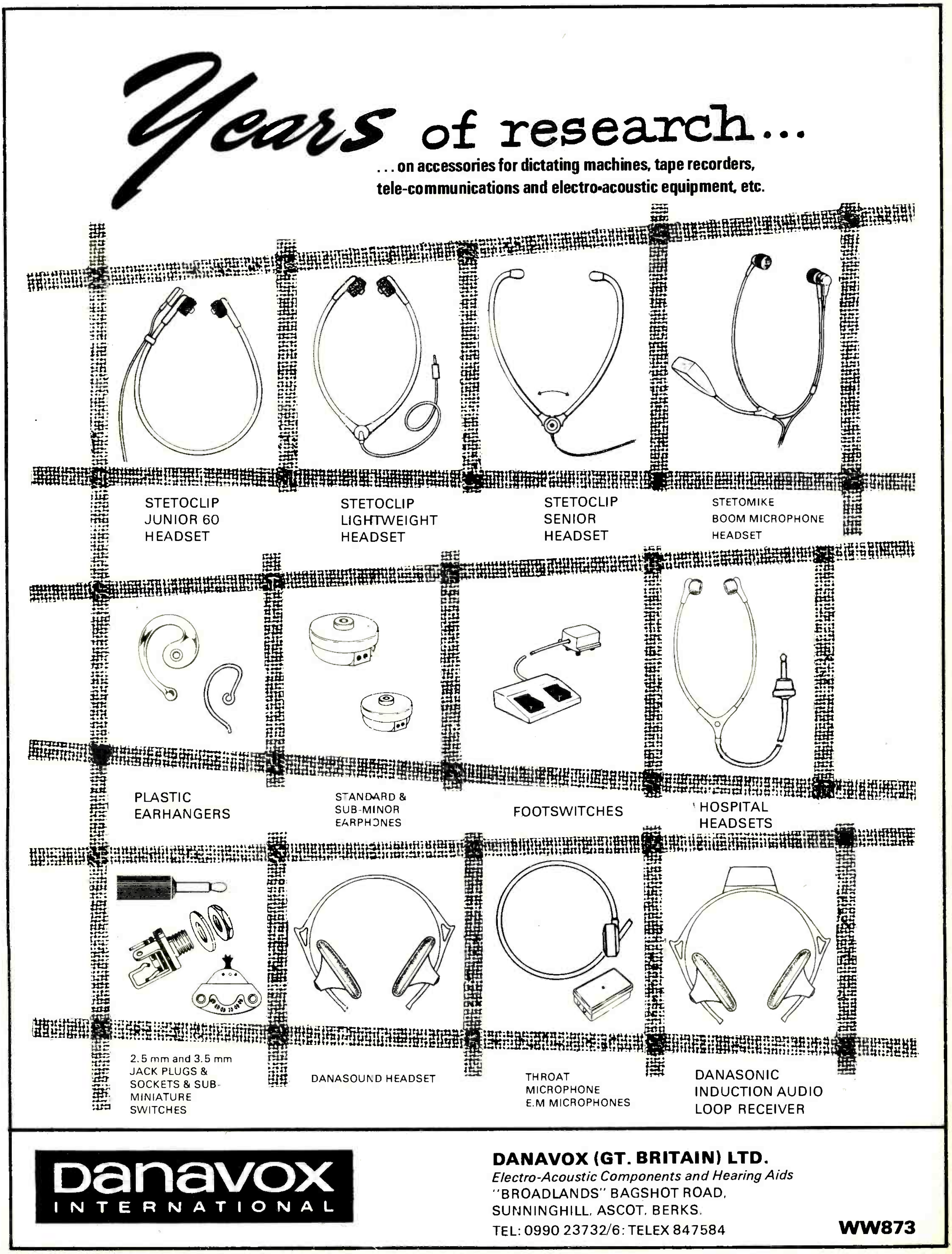
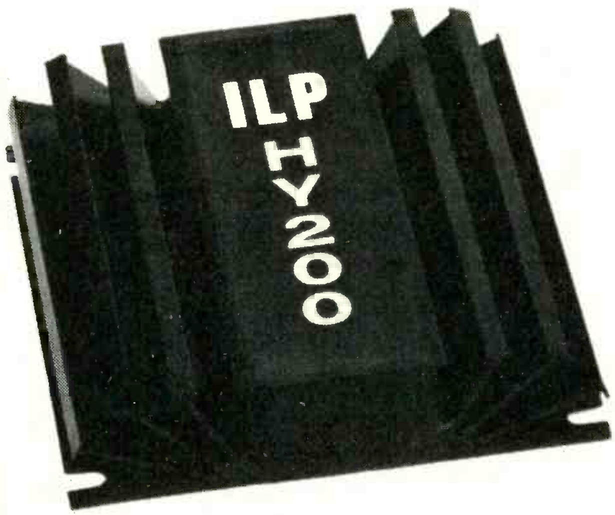
WW—021 FOR FURTHER DETAILS



WW—022 FOR FURTHER DETAILS

I.L.P. (Electronics) Ltd

100 WATTS!



- ★ NO EXTERNAL COMPONENTS
- ★ MECHANICALLY & ELECTRICALLY ROBUST
- ★ INTEGRAL HEATSINK
- ★ HERMETICALLY SEALED UNIT
- ★ ATTRACTIVE APPEARANCE
- ★ LOW COST
- ★ BRITISH BUILT

With the development of the HY200, ILP bring you the first COMPLETE Hybrid Power Amplifier.
COMPLETE: because the HY200 uses no external components!
COMPLETE: because the HY200 is its own heatsink!

By the use of integrated circuit technique, using 27 transistors, the HY200 achieves total component integration. The use of specially developed high thermally conductive alloy and encapsulant is responsible for its compact size and robust nature.

The module is protected by the generous design of the output circuit, incorporating 25amp transistors. A fuse in the speaker line completes protection.

Only 5 connections are provided, input, output, power lines and earth.

Output Power: 100 watts RMS; 200 watts peak music power
Input Impedance: 10KΩ
Input Sensitivity: 0Dbm (0.775volt RMS)
Load Impedance: 4-16Ω
Total Harmonic Distortion: less than 0.1% at 100 watts typically 0.05%
Signal: Noise: Better than 75Db relative to 100 watts
Frequency response: 10Hz-50KHz ±1Db
Supply Voltage: ±45volts
APPLICATIONS: P.A., Disco, Groups, Hi-Fi, Industrial.

PRICE: £14.90 inc. VAT & P & P
Trade applications welcomed

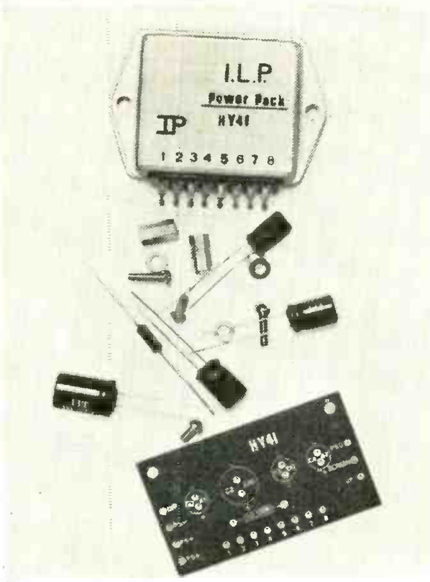
DELIVERY FROM JULY 1st

CROSSLAND HOUSE · NACKINGTON · CANTERBURY · KENT

CANTERBURY 63218

WW—023 FOR FURTHER DETAILS

I.L.P. (Electronics) Ltd



THE HY41

The HY41 supersedes the popular HY40 introduced by ILP last year. This highly improved module achieves true High Fidelity with a dramatic reduction in distortion (typically 0.05% at 1KHz into 8 ohms!) and is electronically and mechanically compatible with the HY40.

With this important improvement the HY41 retains all of the quality characteristics found in the earlier version and P.C. board, Resistor, Capacitors, Hardware Mountings and comprehensive manual are included in the basic kit. No further components are required to construct a complete power amplifier of extremely high performance sufficiently versatile to provide power not merely for Hi-Fi but also for public address systems and industry.

The free manual gives a full circuit diagram of the HY41 and its various applications including a complete stereo amplifier.

Like its predecessor the HY41 is based on conventional and proven circuit techniques developed over recent years.

OUTPUT POWER: British Rating 40 WATTS PEAK, 20 watts R.M.S. continuous.
LOAD IMPEDANCE: 4–16 ohms.
INPUT IMPEDANCE: 30K ohms at 1KHz.
VOLTAGE GAIN: 30db at 1KHz

TOTAL HARMONIC DISTORTION: less than 0.15% (typical 0.05%) at 1KHz.
FREQUENCY RESPONSE: 5Hz–50KHz ± 1db.
SUPPLY VOLTAGE: ± 22.5volts D.C.
SUPPLY CURRENT: 0.8 amps maximum.

PRICE: inc. comprehensive manual, P.C. board, five extra components and P. & P.:–
MONO: £5.39 STEREO: £10.78 This is inclusive of V.A.T. plus P. & P.

UNIQUE HYBRID PRE-AMPLIFIER

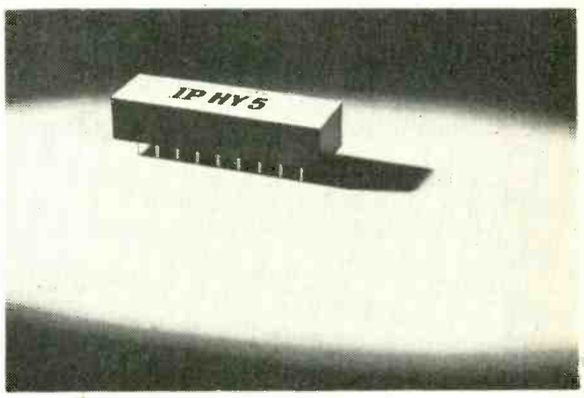
The HY5 has rapidly established a position in the WORLD as the sole hybrid pre-amplifier to contain all feedback and equalization networks within an integrated pre-amplifier circuit.

Supplied with the HY5 are two stabilizing capacitors and by the addition of volume, treble and bass potentiometers it is ready for use.

Internally the HY5 provides equalization for almost every conceivable input, the desired function is achieved by use of a multi-way switch or by direct interconnection.

Two distinctive features of the HY5 are its inbuilt stabilization circuit, allowing it to be run off any unregulated power supply from 16–25 Volts and a balance circuit which, when linked by a balance control to a second HY5, forms a complete stereo pre-amplifier.

Specifically and critically designed to meet exacting Hi-Fi standards, the HY5 combines extremely low noise with a high overload capability. When used in conjunction with the HY41 and PSU45 forms a completely intergrated system.

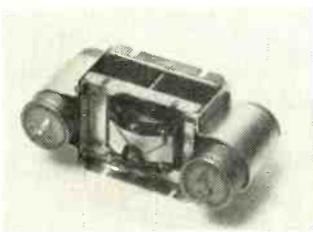


INPUTS
Magnetic Pick-up (within ±1db RIAA curve) 2mV. 47KΩ
Tape Replay (external components to suit head). 4mV. 47KΩ
Microphone (flat) 10mV. 47KΩ
Ceramic Pick-up (equalized and compensatable) 20–2000mV. variable.
Tuner (flat) 250mV. 100KΩ
Auxiliary 1 250mV. 47KΩ
Auxiliary 2 2–20mV. 100KΩ

ACTIVE TONE CONTROLS (Baxendall)
Treble ± 12db.
Bass ± 12db.
INTERNAL STABILIZATION
Enables the HY5 to share an unregulated supply with the Power Amplifier.
SUPPLY VOLTAGE
16–25 volts

SUPPLY CURRENT
6mA approx.
OVERLOAD CAPABILITY
better than 26db on most sensitive input infinite on tuner and auxl.
OUTPUT NOISE VOLTAGE: 0.5mV.

PRICE: MONO: £3.96 STEREO: £7.92 This is inclusive of V.A.T. plus P. & P.



POWER SUPPLY PSU45

The versatile P.S.U.45 is designed to supply your HY41's +HY5's in stereo or mono format.

Specification

Input: 200–240 Volts.
Output: ± 22.5 Volts at 2 amps.
Overall Dimensions: L. 7"; D. 3.8"; H. 3.1"
PRICE: £4.95 This is inclusive of V.A.T. plus P. & P.

Please note we reserve the right to substitute at our discretion updated versions of advertised designs where applicable

CROSSLAND HOUSE · NACKINGTON · CANTERBURY · KENT

CANTERBURY 63218

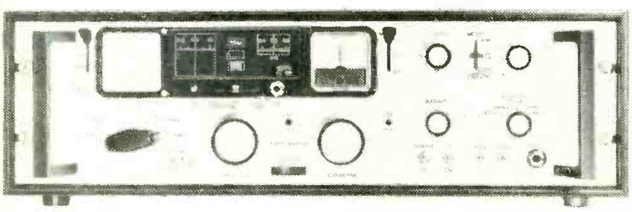
WW—024 FOR FURTHER DETAILS

Eddystone Radio

Eddystone

EC958

series of receivers 10kHz to 30MHz In world-wide use



Professional high-stability receiver series for a wide variety of applications. The standard version can be used as a self-contained F.S.K. terminal, or as a dual-diversity terminal with common oscillator control. Variants are available for Lincompex terminal use, for specialized network monitoring surveillance and for marine applications.

Simplicity Reliability Economy

Your distributor's address and illustrated brochure obtainable from:

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Telephone: 021-475 2231. Telex: 337081

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WW—025 FOR FURTHER DETAILS

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TT 21, THE TUBE THAT GOES ON.

You could design yourself a reputation around this M-OV tube.
- It's the best beam tetrode you can buy.
- Offers lowest possible cost per watt.
- Communications transmitters all over the world depend – and go on depending – on the famous M-OV TT21.

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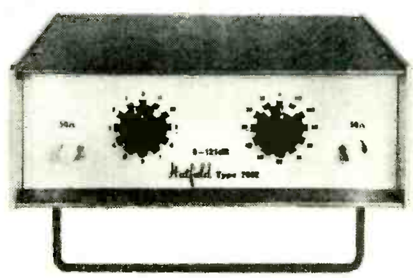
Tel: 01-603 3431. Telex: 23435. Grams: Thermionic London. G.E.C.

WW—026 FOR FURTHER DETAILS

for your Attenuation



With the Hatfield 50 Ω Attenuator model 2002 in your laboratory you can immediately select from 0 to 121 dB in 1 dB steps.
Alternative models for 75 Ω impedance and to cover 0 to 12.1 dB in 0.1 dB steps.

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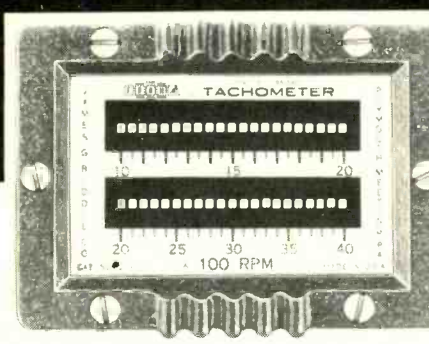
Hatfield Instruments (NZ) Ltd, P.O. Box 561, Napier, New Zealand

WW—027 FOR FURTHER DETAILS

Accurate and direct measurement of speed without coupling to moving parts



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resonant reed TACHOMETERS

for hand use or permanent mounting

Ranges and combinations of ranges from 900 to 100,000 r.p.m.

Descriptive Literature on Frahm Resonant Reed Tachometers and Frequency Meters available from the sole U.K. Distributors. Manufacture and Distribution of Electrical Measuring Instruments and Electronic Equipment. The largest stocks in the U.K. for off-the-shelf delivery.

Anders means meters

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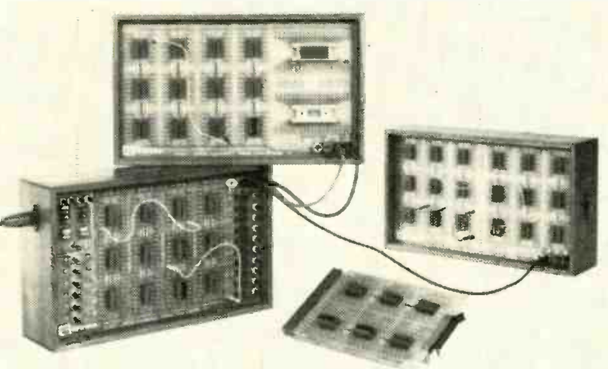
WW—028 FOR FURTHER DETAILS

I C PATCHBOARDS and plug-in cards

low cost, high performance units



Limrose's new family of low-cost universal mounting boards, plug-in cards and breadboarding systems is useful for development work, device testing and circuit evaluation.

Delivery is usually ex-stock. For prices and other information please contact

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limrose Tel. 061 928 8063

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Now! Learn the secrets of radio and electronics by building your own modern transistor radio!

Practical lessons teach you sooner than you would dream possible.

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You get everything you need. Tools. Components. Even a versatile Multimeter that we teach you how to use. All included in the course AT NO EXTRA CHARGE! And this is a course anyone can afford. You can even pay for it in easy payments – in fact you could make extra cash from spare-time work when you've turned yourself into a qualified man through B.I.E.T. training.

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Rapid expansion and a continuous development programme in the field of recording techniques have made a small selection of our good stock redundant.

We are now offering these recording heads at half the normal price.

- ½ track mono R.P.
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- twin stereo erase
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'W.W.' DIGITAL MULTIMETER

(D. E. O'N. Waddington, March 1973)

LIST OF PARTS NOW AVAILABLE

Please send a stamp
We will also include our illustrated lists of other components

CAVERN ELECTRONICS
29 CLAREFIELD ROAD, LEICESTER LE3 6FB
Tel.: Leicester (0533) 857223
(Mail Order only)

WW—038 FOR FURTHER DETAILS

STEREO IC DECODER

HIGH PERFORMANCE PHASE LOCKED LOOP
(as in 'W.W.' July '72)

MOTOROLA MC1310P EX STOCK DELIVERY

SPECIFICATION

Separation: 40dB 50Hz-15kHz. Distortion: 0·3%
I/P level: 560mV rms O/P level: 485mV rms per channel.
Input impedance: 50kΩ. Power requirements: 8-16V at 16mA
Will drive up to 75mA stereo 'on' lamp or LED.

KIT COMPRISES FIBREGLASS PCB (Roller tinned), Resistors, I.C., Capacitors, Preset Potm. & Comprehensive Instructions — ONLY **£3·40** — WHY PAY MORE? post free.

LIGHT EMITTING DIODE (Red) Suitable as stereo 'on' indicator. For above with panel mounting clip and instructions — ONLY **29p** plus p.p.

MC1310P only £2·77 plus p.p. 6p

NOTE
As the supplier of the first MC1310P decoder kit, of which we have sold literally thousands, our customers can benefit from our wide experience.

V.A.T.
From April 1st add V.A.T. at the standard rate to all prices

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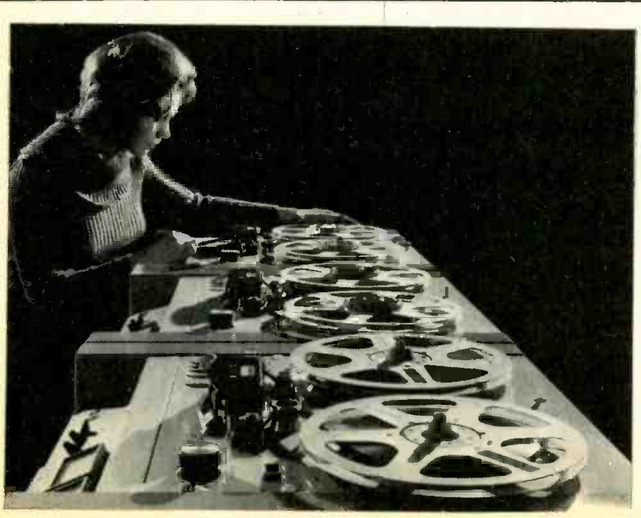

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contact **Derek Owen** at 01-874 9054 or Telex 923455

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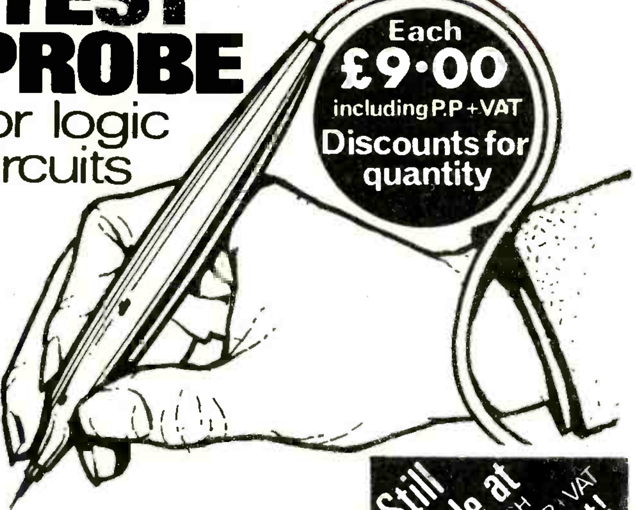
TEST PROBE
for logic circuits



- ★ High-Low Level Probe (2-colour indication)
- ★ Uses L.E.D.
- ★ Reverse Pole Protected
- ★ Very fast response
- ★ 50 nano seconds
- ★ Up to 12 MHz

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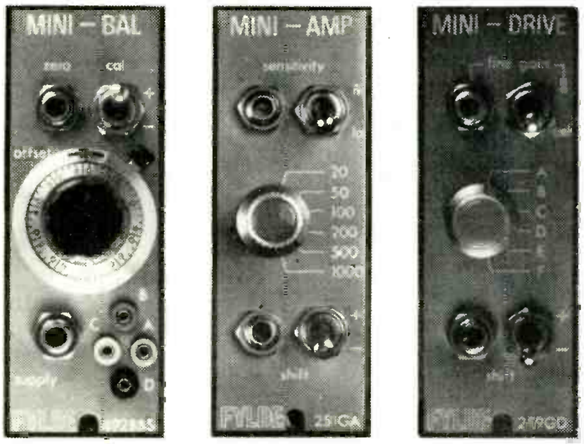
Transducer and Recorder
amplifiers and systems



reliable high performance & practical controls
individually powered modules—mains or dc
option single cases and up to 17 modules
in standard 19" crates small size—low weight
—realistic prices.

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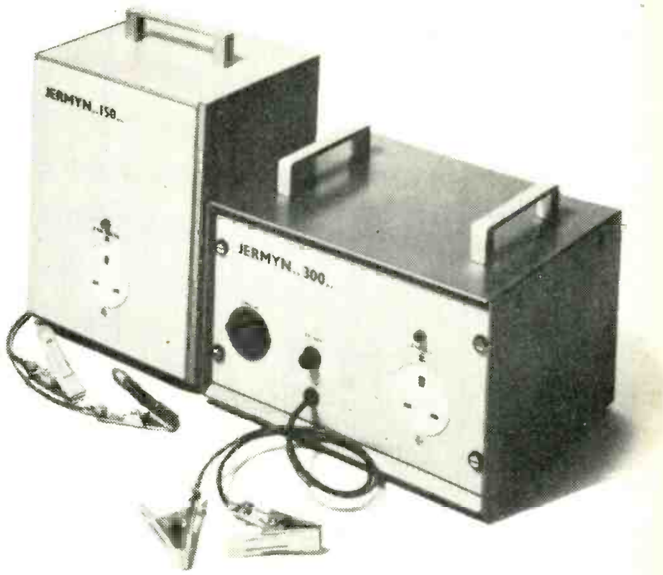
Telephone 0772 57560

WW—048 FOR FURTHER DETAILS

240v AC FROM A CAR BATTERY.



The Jermyn Invertor provides a completely portable source of 240v 50Hz power, working from an ordinary car battery.

No noise. No smell. No fuel oil. No maintenance.

And much cheaper than a 2-stroke generator—150W version (needs 12v battery) £29.00 (+£2.90 VAT). 300W version (needs 24v battery) £39.00 (+£3.90 VAT).

The circuit includes electronic short-circuit prevention and wrong-connection protection.

And you can work it backwards; plug into the mains to recharge the battery.

Ideal for all kinds of field radio equipment, and as a stand-by for the house.

Please send me .... 150W 300W
Jermyn Invertor(s).
I enclose cheque/PO value £..................
Name
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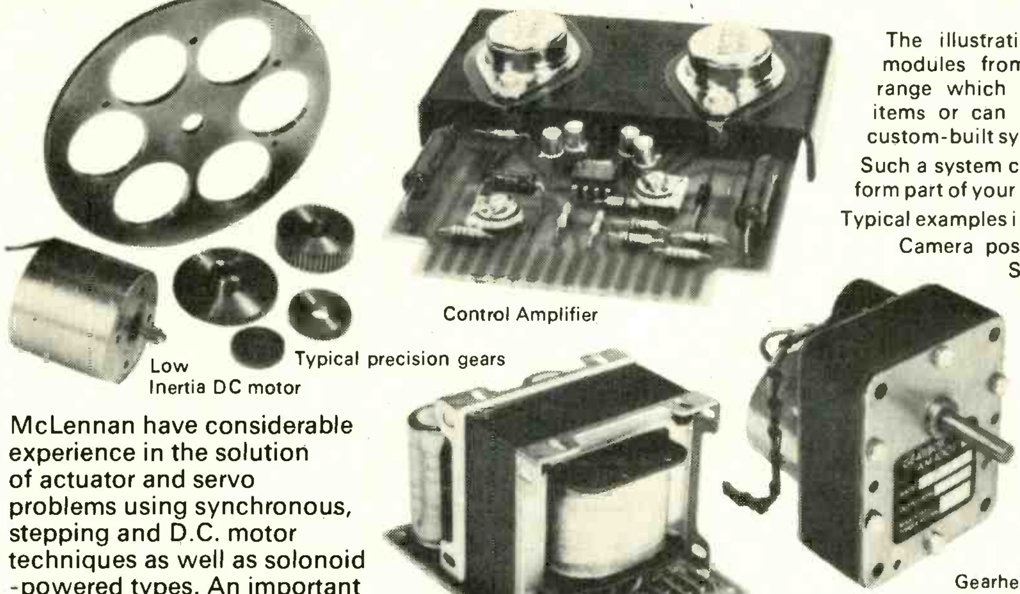
Jermyn

Jermyn Industries 98 Vestry Estate Sevenoaks Kent

WW—049 FOR FURTHER DETAILS

Purpose-built servo and actuator systems using standard components



McLennan have considerable experience in the solution of actuator and servo problems using synchronous, stepping and D.C. motor techniques as well as solonoid -powered types. An important facet of our skill lies in purpose-designing around standard components for speed and economy of building.

The illustration shows a selection of modules from the McLennan standard range which are available as individual items or can be supplied engineered to custom-built systems.

Such a system could be complete in itself or form part of your own design.

Typical examples include:

Camera positioning; Plotting Devices; Self-steering Systems; Signal-seeking Aerial Drives; Professional Tape Drives; Automated Production Lines.

Stimulation of output position or velocity may be by optical, radio, electrical, mechanical, pneumatic or hydraulic signals.

McLennan Engineering Ltd

Control Systems and Components

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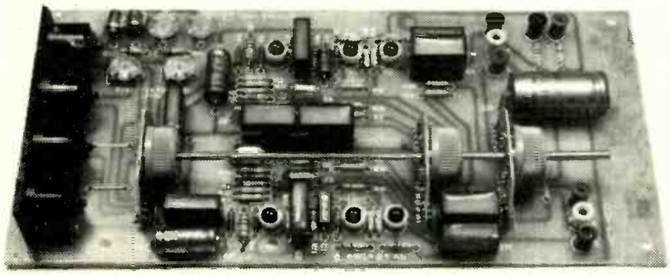
HART ELECTRONICS

Audio Kits



This is our Bailey/Burrows Stereo pre-amp front end. We think it is the best engineered kit of the best pre-amp circuit available, and there is a back end/tone control unit of similar advanced design to go with it which is only 1½" deep so it fits almost anywhere, but of course it's at its best in a Hart universal amplifier metalwork with a couple of Hart Bailey 30 watt power amps to keep it company. That's a recipe for real Hi-Fi with electronics you'll be too proud to cover up.

Also a delight to the connoisseur are our printed circuits and components for the Stuart tape circuits.

This is a most useful high quality circuit with the record, replay and bias functions on separate boards thus giving considerable versatility of use. For instance a stereo replay channel can be built for £6 for single speed use without external components or a switch may be added for multispeed operation.

WE ARE SUPPLYING

Printed Circuit Boards, Components and Kits for the

D. O'N. WADDINGTON DIGITAL MULTIMETER

This most interesting project fulfils the long-felt want for a Digital Multimeter with the added bonus of counter/timer functions, all at a price which makes it extremely attractive to the amateur, educational or commercial user.

Please send 9" x 4" SAE for full details:

Penylan Mill, Oswestry, Salop.

Personal callers are always welcome, but please note we are closed all day Saturday

WW—054 FOR FURTHER DETAILS

THE NEW NELSON-JONES FM TUNER

PUSH-BUTTON VARICAP DIODE TUNING (6 Position)

Exclusive Designer Approved Kits

For the first time the Nelson-Jones Tuner is available as a **complete kit** with all Metalwork, Printed and anodised Front Panel and Teak veneered cabinet. A Six Position push-button unit is used with each pre-selector button fully tuneable with its own scale and pointer and incorporating AFC disable for fine tuning.

Provision is also made for a Stereo LED, Stereo Decoder, Internal PSU and Fine Tuning indication (Meter or LED type). Push-button switches are also used for Stereo Mute and Mains On/Off. All sockets, board standoffs and panel mounting fuse are supplied.

Our attention to detail is such that even our cabinets are veneered inside and out for minimum warp and attractive appearance.

The tuner is available in two gain versions, and our **alignment service** is available to customers without access to a signal generator.

Prices for complete kits start at **£23·75** (mono) plus p.p. 45p., and of course all components are available separately.

Please send large SAE for our latest price lists which detail all of the many options and special low prices for complete kits. All our other products remain available e.g. **The Portus and Haywood Phase Locked Stereo Decoder Kit.**

PLEASE NOTE. Existing tuners are readily convertible and kits/parts are available for this purpose.

TEXAN AMPLIFIER. We have designed the tuner case and metalwork to match the Texan amplifier (see photograph). Complete designer approved Texan kits are available at **£28.50** plus p.p. 45p including a Teak Sleeve.

V.A.T. Please add V.A.T. at 10% to all prices for U.K. orders.

INTEGREX LIMITED, P.O. Box 45, Derby, DE1 1TW **Phone Repton (028389) 3580**

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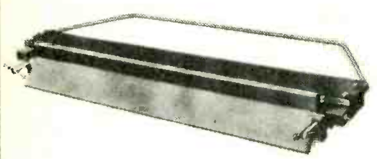
PARKER SHEET METAL FOLDING MACHINES



Forms channels and angles down to 45 degrees which can be flattened to give safe edge. Depth of fold according to height of bench.

BENCH MODEL

36" × 18 gauge capacity	£35.00 carr. 75p
24" × 16 gauge capacity	£32.00 carr. 75p
Also the well-known vice model of	
36" × 18 gauge capacity	£17.00 carr. 50p
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18" × 16 gauge capacity	£12.00 carr. 38p

Add 10% VAT to total price of machine and carriage

One year's guarantee. Money back if not satisfied.

Send for details:

A. B. PARKER

FOLDING MACHINE WORKS, UPPER GEORGE STREET, HECKMONDWIKE, YORKS.

Telephone 3997

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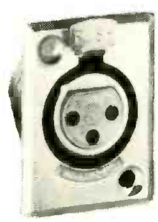
Audio Connectors



Broadcast pattern jackfields, jackcords, plugs and jacks

Quick disconnect microphone connectors

Amphenol (Tuchel) miniature connectors with coupling nut

Hirschmann Banana plugs and test probes

XLR compatible in-line attenuators and reversers

Low cost slider faders by Ruf

Future Film Developments Ltd.
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London W1V 3LE
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WW—057 FOR FURTHER DETAILS

The New Loudspeaker Range...

The sound of music, from the lowest frequency to the highest is now brought to the connoisseur of quality in sound reproduction with the new, Vitavox Power Loudspeaker Range.

The Range blends four superb units into one matchless composite, or each element as a separate unit available for use with other systems. The range gives exceptional quality of sound reproduction and handles up to 100 watts of musical power. The four units are: a High Power, High Frequency Pressure Unit and a High Power Bass Loudspeaker, each designed to give increased power handling capacity without sacrificing either efficiency or frequency response; a High Frequency Dispersive Horn, designed for use with the Pressure Unit – matching accurately the Unit's output characteristics and giving superb sound dispersion; a High Power Dividing Network for use in both high and low power systems and which ensures correct allocation of the frequency spectrum between high and low frequency units.

Carrying the Vitavox stamp of quality, this is the Range which brings you . . .

Please send me further information on your product range V3

Name ______________________

Company ______________________

Address ______________________

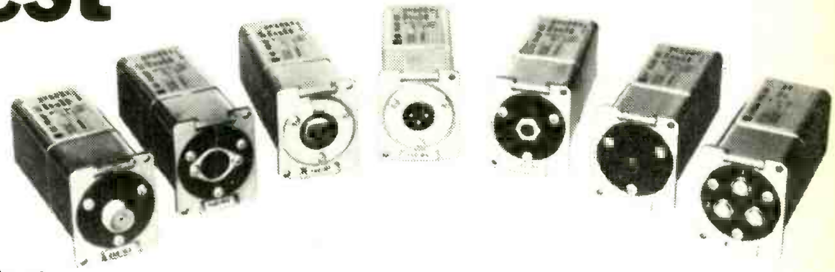
The Great Sound of Vitavox

VITAVOX

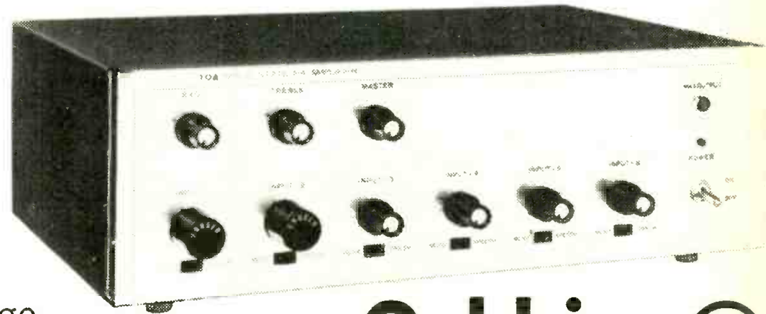
Westmoreland Road, London NW9 9RJ Telephone: 01-204 4234

WW—058 FOR FURTHER DETAILS

NEW! Toa 900 amplifiers have the widest connections.



In fact, the new TOA 900 series of solid-state amplifiers can be fitted with such a wide range of plug-in input modules that they are suitable for almost all signal-sources.
The result is versatility, flexibility and power. And a vast range of applications in offices, schools, sports grounds, industry and everywhere else where TOA's background of experience and skill can make itself felt. Plug into new TOA units – and you'll get the message very clearly indeed.



Goldring

Goldring Ltd., 10 Bayford Street, Hackney, London E8 3SE.

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MODEL U-50DX

SANWA MULTI TESTERS

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6 Months' Guarantee — Excellent Repair Service

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Model U-50DX	£10.89	Model 460-ED	£28.31
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THESE PRICES ARE SUBJECT TO AN ADDITIONAL CHARGE OF 10% FOR V.A.T.

Cases extra, available for most meters, but not sold separately.

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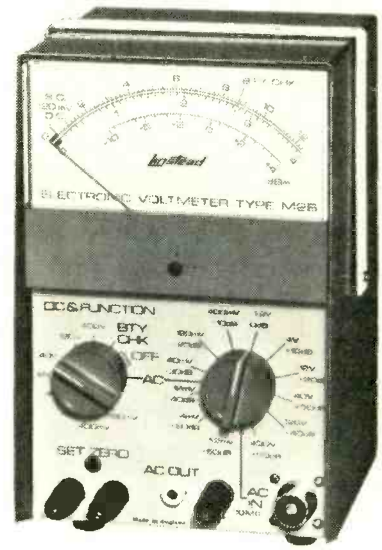

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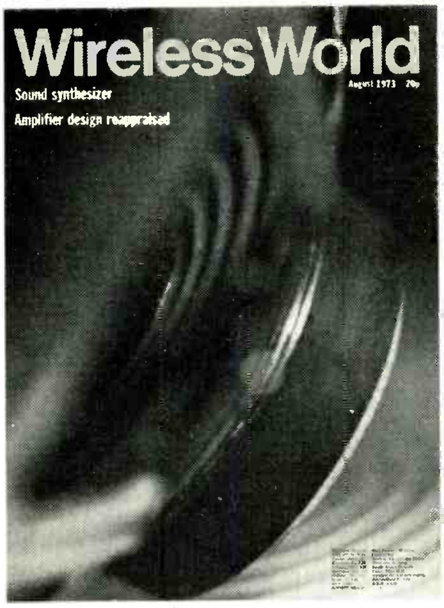

This month's cover picture, showing the centre suspension of a Philips loudspeaker, symbolizes the reproduction and artificial production of sound — the subjects of articles on amplifier design and sound synthesis in this issue.
(Photographer Paul Brierley)

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(publication date August 20)

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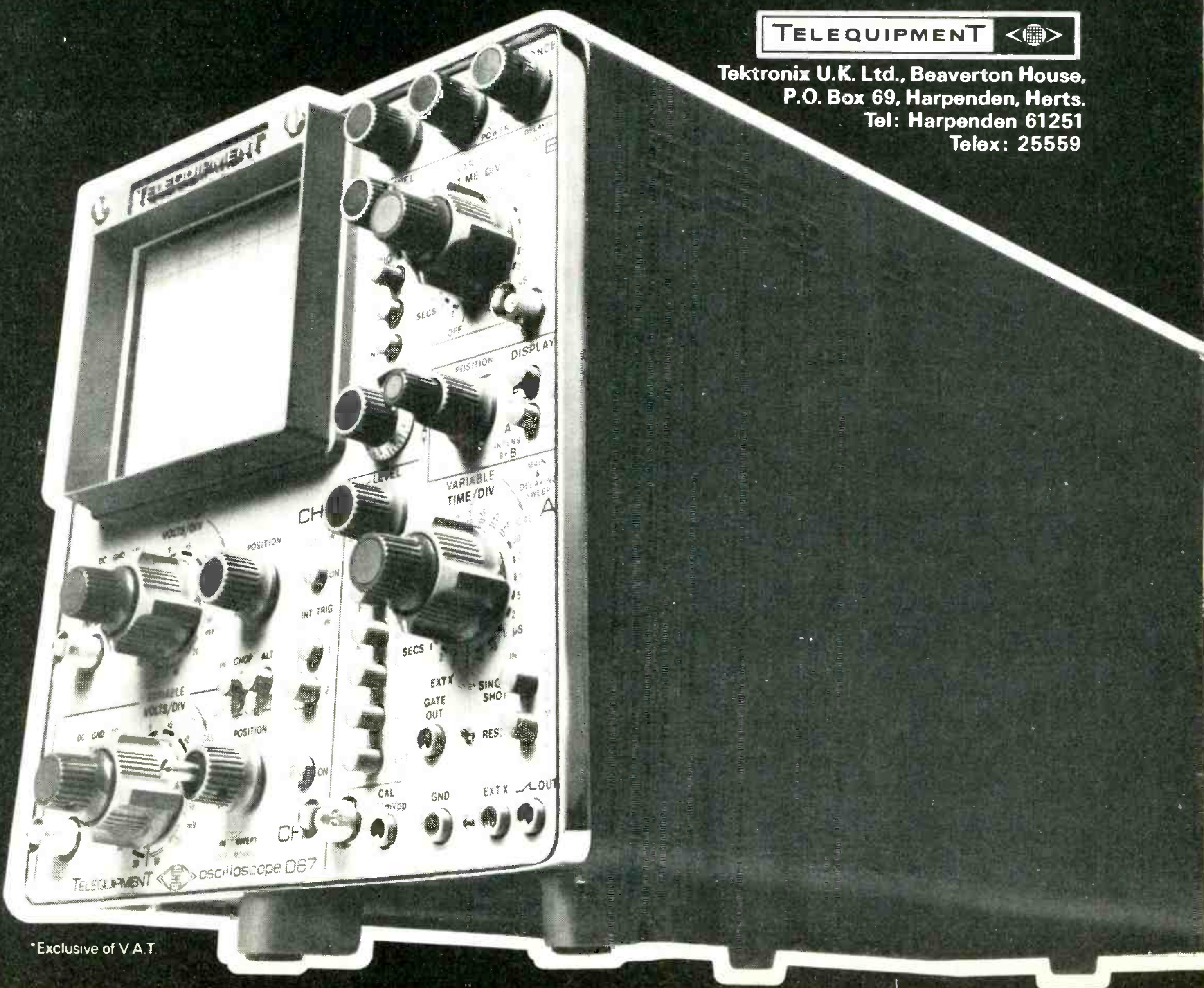

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Cost-effective instruments

It is a natural human trait to want the fastest, biggest (or smallest), widest, brightest or, simply, most. Waste is another, less attractive characteristic of the human animal and the two are inextricably involved.

In the field of electronics it is possible, by the relinquishment of large sums of money, to obtain equipment which is able to perform feats which, if one pauses to think, are little short of miraculous. For example, consider the timebase of an oscilloscope; a sweep speed of 10ns per centimetre (which is often available) will move the spot over one centimetre of screen in the time it takes for a beam of light to travel about ten feet, or at a speed of about two and a quarter million miles per hour. Or take a digital frequency meter with a crystal accuracy of 1 part in 10^{10}. That is about one second in 300 years. These figures mean very little in practice, of course, but they do illustrate the sort of thing that goes on without our giving it a second thought.

The point of all this is that it seems likely that some of this staggering performance is being bought and sold unnecessarily. Time was when an AVO 8 was all the voltage and current measuring equipment considered necessary in the average, workaday, laboratory and 98% was the nearest one wanted to get to the answer. Nowadays, digital voltmeters offering quite incredible accuracies (at quite incredible prices) can sometimes be seen looking at the output of a logic gate to determine whether it is up or down. Digital frequency meters with errors of quite negligible orders are used to plot the frequency/amplitude characteristics of audio amplifiers and we all know of a company who possess a bright, shiny computer which rattles off a payroll in thirty minutes flat and spends the rest of the week gazing into space.

There is some recent evidence that manufacturers of instruments are beginning to realize that not everybody needs the type of equipment which can do eight things at once when not even switched on. One or two oscilloscopes, for instance, have been introduced, designed to perform the majority of work these instruments are required to do and no more, with a very worthwhile saving in cost. One can see the manufacturer's problem; it is common to all makers of "status" equipment — cars being the prime example. How can they produce instruments with reduced specifications when their whole organization is geared to produce the most advanced equipment that it is possible to make?

There is much to be said, however, for the concept of "fitness for the job", and we feel that if some of the bigger companies were to produce instruments at greatly reduced prices, and at reduced specifications, while still possessing the workmanship that made these companies' reputations, they may be surprised by the response.

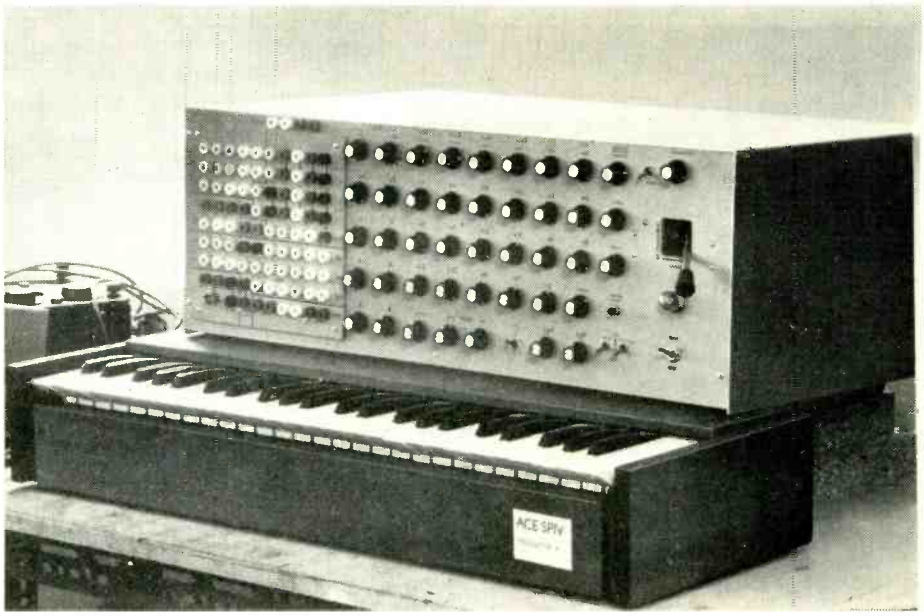
Electronic Sound Synthesizer

First of three articles describing the operation and construction of a modular system with manual or electronic voltage control of synthesized waveforms

by T. Orr †B.Sc. and D. W. Thomas† Ph.D., M.I.E.R.E.*

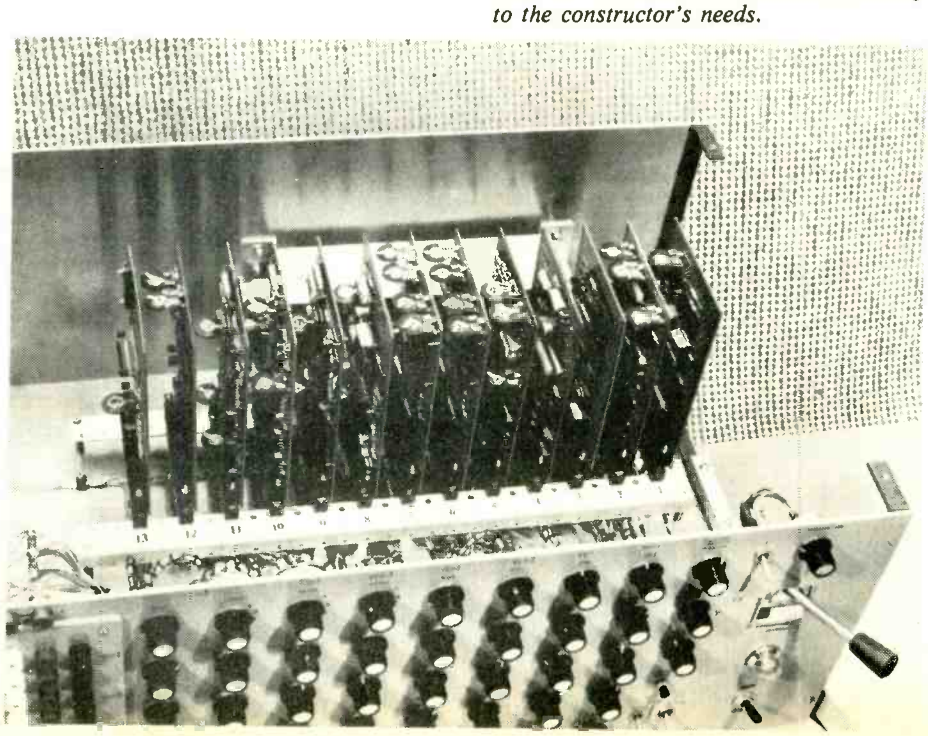
The electronic sound synthesizer is an instrument that can generate a variety of complex outputs, the parameters of which are variable and are controlled by the device itself. In its most common form, the synthesizer is used as an electronic musical instrument, usually being a monophonic keyboard device. It is also to be found in more fixed purpose applications, such as animal "alarm call" generators.

Basically, the synthesizer is capable of generating and processing signals, and by employing such techniques as frequency and amplitude modulation, filtering and mixing, it is usually possible to produce a desirable output. The feature that makes the synthesizer unique from other instruments, such as organs or electric pianos, is its voltage control capability. This enables parameters such as frequency, amplitude, modulation, attack and reverberation, to be not only manually controlled, but also electronically controlled. Couple this voltage control capability to a flexible programming unit and the result is an instrument with an enormous range of possible tone colours. The versatility of the synthesizer can be further extended by the inclusion of more and more functional units, but this approach is over-sophisticated. It is better to try to analyse just what is required and how best to achieve it. For instance, what particular types of sounds should the synthesizer generate; is it for instance, going to be used as a piece of educational equipment or for quantitatively synthesizing known waveforms, for example bird calls, engine noises, spoken words etc? This is the "deep end" of synthesizer technology where a great deal of effort has been expended for few returns. Where reasonable returns have been achieved it has been, generally, with computer back-up.



Manual control of the synthesizer's functions is provided by a control panel, joy-stick and keyboards. The patch panel provides a means, together with voltage summing networks, of linking the internal functions.

(Below) Internal view of the synthesizer, showing the modular construction. Each board is a complete unit — the number of units can be added to or reduced according to the constructor's needs.



Sound synthesis

As a musical instrument the synthesizer is well cast. The world of qualitative descriptions is an ideal environment for a machine that continually defies a quantitative approach. The synthesizer is often used to generate special effects and

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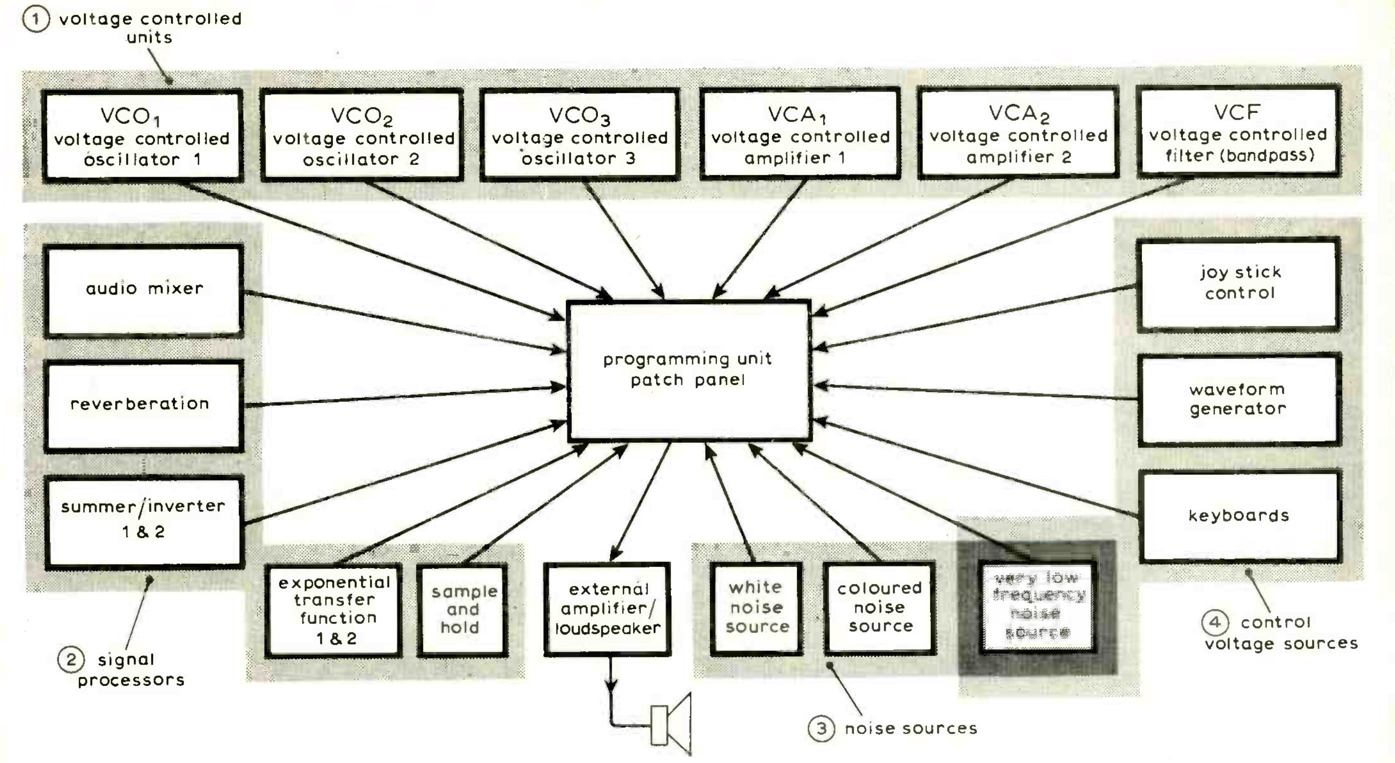


Fig. 1. Block schematic of the total system.

can also be used to produce pseudo-instrumental sounds *via* a keyboard control, or by modifying real instrument sounds. To synthesize implies the process of generating a result by the summation of many parts, and a musical synthesizer should produce a musical output by the summing of a group of semi-musical elements. Musical instruments produce sounds that have a discernible harmonic structure, the perceived sounds being the result of exciting a resonant structure by percussion, bowing, plucking or blowing. The envelope of the signal is modified by various sorts of damping and excitation, and the pitch of the fundamental is either pre-selectable or in some cases continuously variable. To make an electronic synthesis of a "pseudo-instrument", a selection of resonators (oscillators) is required. These resonators should have a variable multi-pitch control (voltage controllable) with a large dynamic range (about 2 x 10_3) and possibly a selection of different harmonic structures (sinewave, square, ramp, etc which have different harmonics; pure tones only have a limited use). Three or four of these resonators can be considered as a basic minimum for any sort of modest synthesizer arrangement. The signal amplitude from the resonators must be controllable and so a means of control (a voltage controlled amplifier, the gain varying with respect to a control voltage) and a source of control (voltage control sources such as other oscillators, joystick, keyboards, potentiometers, waveform generators etc) must be provided. Also, a means is necessary of bringing these units together so that they interact (the patch panel and the voltage summing networks).

When a rapid series of randomly distributed percussions is initiated (for instance, brush drums), the pitch information is low. This group of "pitchless" sounds is characterized by the lack of a significant harmonic structure and can be synthesized by modifying the amplitude and spectrum of a noise source. When a musical instrument is played an amount of reverberation is always introduced, thus a means of adding a controlled amount of reverberation is provided.

The synthesizer is operated to its best advantage using a set of keyboards. However, no dynamic function — i.e. a means of generating a louder note the harder the key is pressed — has been provided as in some other synthesizers. To simulate a percussion envelope, a waveform generator having a variable exponential attack and decay has been included. Other circuit functions are included (described later) and these combine with those units already mentioned to produce a system that is capable of generating a very large range of special effects.

The total collection of units was chosen after monitoring the format of commercially available synthesizers. Such items as oscillators, voltage controlled amplifiers, noise sources, mixer, reverberation, patch panel, keyboard, voltage controlled filter, and waveform generator are common to most devices but unusual items included are a joystick, summer/ inverter, exponential transfer function, and a very low frequency noise source. These units extend the range of special effects that can be generated. Items that appear in other synthesizers, but which had to be left out due to time, space and money limitations are: the internal amplifier, loudspeaker, an input preamplifier for microphone and pickups (these provide some excellent electronic effects), envelope followers (that try to mimic instruments and voices), electronic two-way switches and a programmable memory.

Faced with all the possible combinations of units, the newcomer to sound synthesis will probably be somewhat at a loss to make any decisions as to what units are needed to meet his requirements. Firstly, the system is going to need a power supply. If the synthesizer is likely to be built in modules, which are added when time and money permit, it is advisable to allow a more than sufficient power supply capability to enable an unhindered growth. A current-limited supply would be an improvement over the one given later in this series. The amplifier loudspeaker combination and the patch panel are also essential. The heart of the synthesizer is its oscillators; they generate nearly all of the sound that is produced.

The next most important are the voltage-controlled amplifiers. These are reasonable quality devices, but a cheap f.e.t. modulator could be used if money is tight. Such parameters as linearity and harmonic distortion will suffer from this particular economy. It now becomes more difficult to decide which particular units are most important, so they have been grouped together; the audio mixer, noise sources (coloured), voltage controlled filter, reverberation, waveform generator and keyboards. Lastly, probably the low priority units are the joystick, sample and hold, exponential transfer function, summer/inverter, white and very low frequency noise sources. Even though these last units have the lowest priority, they add considerably to the synthesizer's versatility. As a guide to cost, the synthesizer described in this article was produced for approximately £100. The performance of the machine, as with other synthesizers, is not sufficient for it to be a main instrument for live performances, due mainly to speed considerations in setting up patches and pots. The only way to obtain a versatile performance entirely from the synthesizer is to use multi-track recording techniques.

The system

The synthesizer may be considered as a series of separate units, each with their own respective sub-groupings (see Fig. 1).

Voltage controlled units

This is probably the most important set of units, for it is these devices that have their parameters controlled by external electrical signals.

Voltage controlled oscillators. Each oscillator's fundamental frequency is controlled by the sum of the input control voltages and a bias voltage, there being a fixed relationship between the voltage and frequency. From three oscillators, several waveforms are simultaneously available, these being sinusoidal, square, triangular, sawtooth, variable mark/space ratio, pulse and a sequential signal. The operating ranges extend down to frequencies of a fraction of 1Hz and to frequencies above the audio range. These oscillators perform all the frequency modulation functions of the synthesizer.

Voltage controlled amplifiers. The gain of the unit is linearly controlled by the sum of the input control voltages and a bias voltage. There are two v.c.as and these provide all of the amplitude modulation capacity.

Voltage controlled filter. This unit is a bandpass filter, the value of the resonant frequency being linearly proportional to the sum of the input control voltages and a bias voltage. The Q factor is manually adjustable and increases linearly with frequency.

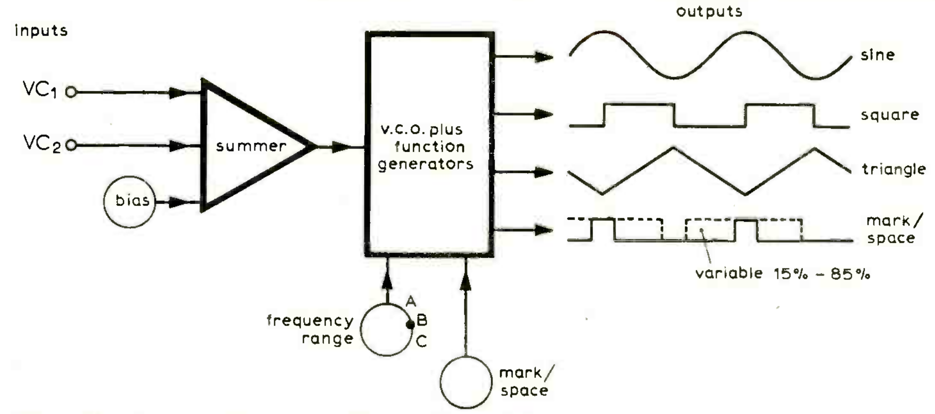


Fig. 2. Functions of voltage controlled oscillator, VCO_1.

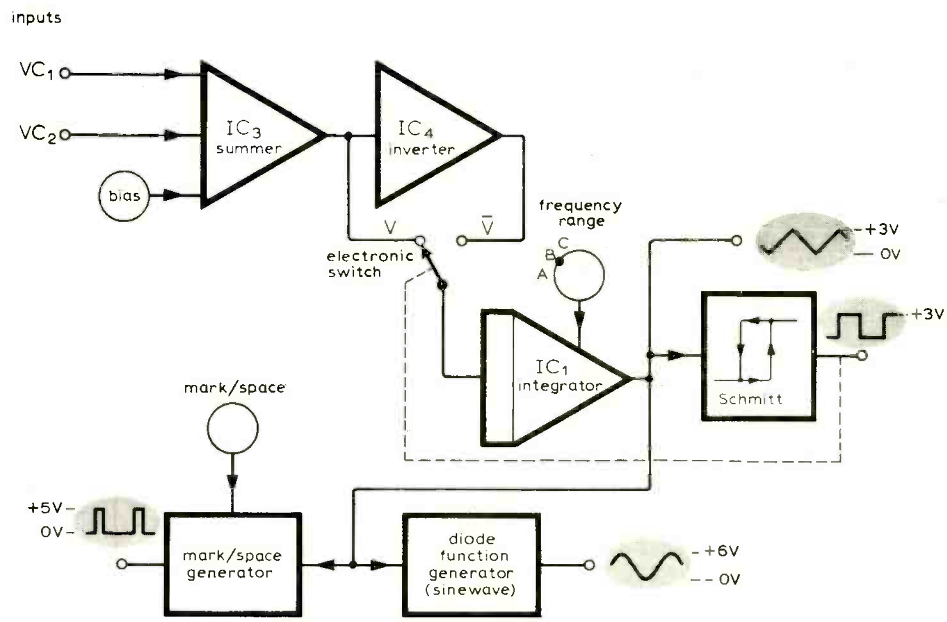


Fig. 3. Oscillator VCO_1 *in block diagram form.*

Signal processors

The voltage controlled units require input control signals and produce either control or audio signals at their outputs. Note that the distinction between control and audio signals is not absolute, but as a generalization, control signals exist from d.c. up to the low frequency end of the audio spectrum. There is no physical reason against control signals extending to high frequencies, except that the effect is rarely a pleasant one! By processing audio and control signals, the range of outputs is considerably enlarged.

Audio mixer and reverberation unit. These two processors are only compatible with audio signals as they are both a.c. coupled. The mixer has three channels, each channel having its own attenuator, and there is also a master gain control. The reverberation unit also has a gain control and provides a source of reverberation up to approximately 4kHz.

Summer/inverter and exponential transfer function. These devices were designed essentially for control signals, but audio signals may also be used. Two of each are used in the synthesizer. The summer/inverter has three inputs, two with a gain of −1, one with a gain of −10.

Sample and hold. This is the only form of analogue memory provided. Sampling is initiated by a positive input pulse that causes the unit to sample the analogue signal for a preset time. This signal is then held for an unspecified period.

Noise sources

Three different outputs are simultaneously available. The noise may be used as a control signal or as an audio signal.

White noise. The noise source provides on average a continuous flat spectrum (within certain limits and tolerances).

Coloured noise source. The output noise spectrum is arbitrarily variable and is controlled by a conventional tone control network.

Very low frequency noise source. One of two v.l.f. outputs may be selected, the signal's function being a random control voltage.

Control voltage sources

The units of this group generate control voltages, and provide the main active link between the operator and the synthesizer.

Joy stick control. Two bias voltages are produced, one associated with each degree of freedom of the device. By physically moving the joystick, the bias voltages change, the modified signals being linearly proportional to the stick's position.

Waveform generator. A "rectangular" waveform with an exponential attack and decay is generated, the process being initiated by a manual or electronic signal. The attack and decay time constant, and the duration are all arbitrarily variable.

Key boards. A standard four-octave keyboard is used to generate a d.c. control voltage, which is linearly proportional to the key position. As the synthesizer is essentially a monophonic instrument, then only one key may be pressed at a time. If two or more are pressed simultaneously, the highest note is automatically selected. Also a pulse is produced at the start of each new note.

Three other units must be introduced to complete the total system. The first is the patch panel which enables the rapid interconnection of units into any desired configuration. Secondly, an external amplifier and loudspeaker is required. The third requirement is an external feedback system with pattern recognition facilities and a versatile complement of servo systems — an operator. The selection of units may be varied to suit one's particular requirements.

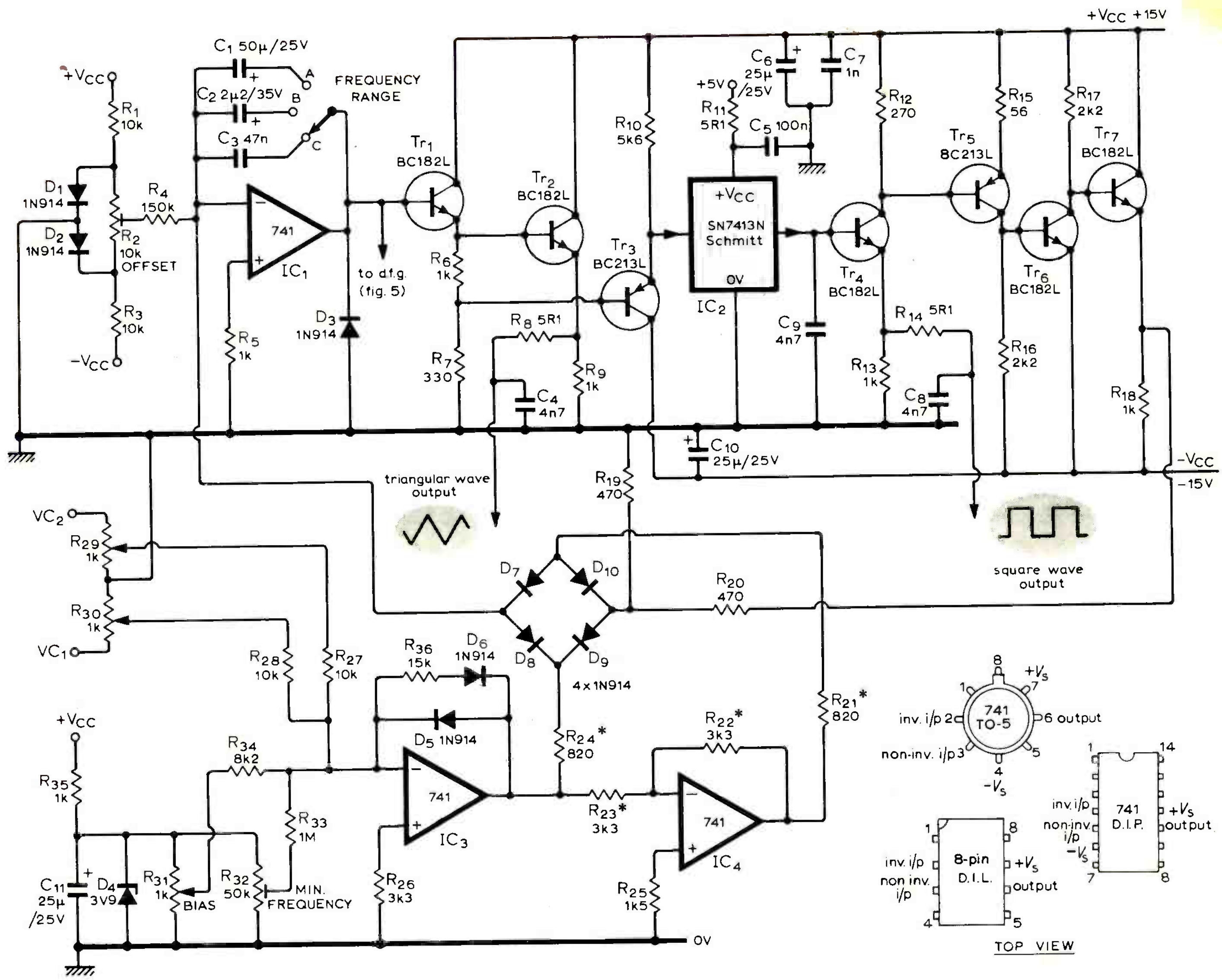


Fig. 4. Circuit of VCO₁. All resistors are 5%, ¼ W unless asterisked — these are 2%.

Design in general

There are certain rules that have to be enforced if the synthesizer is to work satisfactorily. Firstly, it is essential to generate and measure all signals relative to 0V, and this requires a reliable grounding system. A stack of star terminals was employed for this, to which were connected the ground wires from the control pots and all the 0V supply lines from the edge connectors.

A signal level of 3V was selected, this giving ample room for larger signal excursions. Also as there is a considerable amount of wiring between the pots, circuits and patch panel, the input and output impedance of the units was kept low so that unscreened wiring could be used without any serious interference or crosstalk problems occurring. The input impedances are typically 1kΩ and the output impedances must be correspondingly lower to avoid loading. Some control signals are low frequency or even direct voltages and so a.c. coupling between units is not a practical proposition (with the exception of the audio mixer and the reverberation unit). The most significant problem with direct coupling is the fact that control signals are never what they ought to be, but always have an offset voltage added to them. Most of these offset voltages are only a few hundred millivolts (positive), but this is enough to cause disturbing effects. However, the variable bias on the voltage controlled units should be capable of overcoming most offsets.

The general layout of the synthesizer can be seen in the photograph. Most of the circuitry was constructed on plug-in boards and although the connectors increase the cost, they do provide the advantage of making the boards removeable for servicing. Also a spacious layout has been used, enabling clear access to the control pots. Even with a stabilized supply and a reasonable ground system it may prove necessary to decouple the power supply on each board. Minor transients of the supply levels can be disturbing as they can build up into a noticeable background noise, and may even cause the v.c.os to lock on to each other's harmonics.

The synthesizer bears a strong resemblance to an analogue computer, with an array of control pots to vary parameters, a patching system and a selection of functional electronic units. However, whereas the analogue computer makes an attempt at being quantitative and accurate, this synthesizer does not, relying strongly on the qualitative perception of the operator

First voltage controlled oscillator

This oscillator[2] has a linear frequency/voltage characteristic and produces four outputs as shown in Fig. 2. These are square, triangular, sinusoidal and a variable mark/space ratio rectangular waveform. The oscillator has three frequency ranges, the top range covering the audio spectrum, the bottom two extending to subsonic frequencies. The quiescent operating point may be shifted by altering the bias level, and the input control voltages (VC_1, VC_2) may be attenuated by control pots. The final operating frequency is linearly proportional to the sum of the bias voltage and the attenuated control voltages, and should have a dynamic range of at least three decades.

The heart of the oscillator is a triangle-squarewave generator (Fig. 3) where a Schmitt trigger provides positive feedback around an integrator; the integrator's output thus ramps up and down inside the hysteresis window of the Schmitt trigger. The oscillator is both self-starting and stable, having a large dynamic operating range and a defined amplitude. Two outputs are produced, a triangle at the integrator's output and a square wave from the Schmitt trigger. The ramp rate, and hence the operating frequency, may be varied by altering either the integrator's gain and/or the drive voltage.

The two voltages V and $\bar{V}$ (Fig. 3) are alternately switched into the integrator by the electronic switch (a diode ring switch $D_{7, 8, 9, 10}$, Fig 4), which is controlled by the Schmitt trigger. The voltage V is produced at the output of IC_3, where the output is depressed by the forward drop across diode D_6. Ideally D_{6-10} should all be matched and so should resistors $R_{21, 24, 36}$, and $R_{22, 23}$, thus preserving as far as possible the linear voltage/frequency characteristic and signal symmetry. However, as matched diodes are relatively expensive, it was decided to use unmatched unselected diodes.

This had the effect of causing some non-linearities which were only noticeable at low frequencies where the diodes were conducting very low currents. To obtain the required gain from IC_3, resistor R_{36} had to be much larger than $R_{21, 24}$, and this resulted in a loss of voltage/frequency linearity at low frequencies. This effect is not very noticeable, but imbalance in the ring switch may cause a disturbing loss of symmetry (Fig. 7). This can be nulled by preset R_2 (Fig. 4) which is set to cancel the offset caused by the ring switch's imbalance at its minimum operating point. To preserve as much symmetry as possible, R_{21-24} are all 2% tolerance resistors.

Diode D_3 (Fig. 4) is included to protect Tr_1, Tr_2, against emitter-base breakdown; if for any reason the feedback loop is broken, the output of IC_1 may ramp down unhindered, with irreversible results. The Schmitt trigger used is the SN7413N, a t.t.l. integrated circuit. The whole of the circuit operation relies upon the stability of the hysteresis levels; if they alter, then the amplitude and frequency of the output will change. Thus it is particularly essential to have a stabilized and decoupled 5V supply for IC_2 as well as for V_{cc}. If this is not achieved then spikes on the power supplies will cause oscillators VCO_1 and VCO_2 to have a tendency to lock onto one another's harmonics. To reduce the generation of spikes, the output of the Schmitt trigger is capacitively loaded; this however, has little effect on the square wave production at audio frequencies.

It should be pointed out that using the SN7413N for the Schmitt trigger has its drawbacks. The separation between its hysteresis levels is small, making it vulnerable to interference by other v.c.o.s. Its fast rise and fall times can generate significant interference and also it does not like driving long lengths of cable. These difficulties have been largely overcome, but a Schmitt trigger of discrete components would still be an improve-

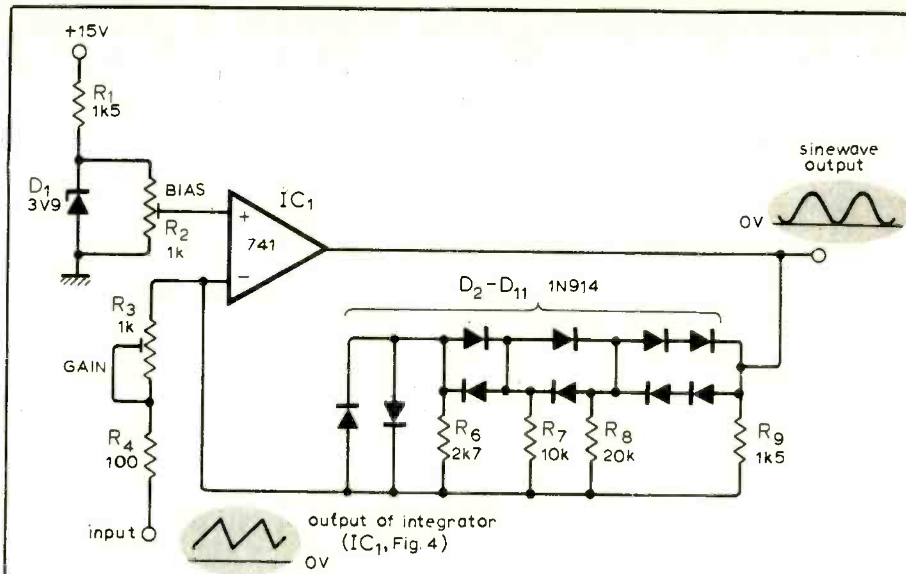


Fig. 5. Diode function generator which produces a sinewave output when fed with the triangular wave output from the integrator IC_1 in Fig. 4. All resistors are $\frac{1}{4}$W, 5%.

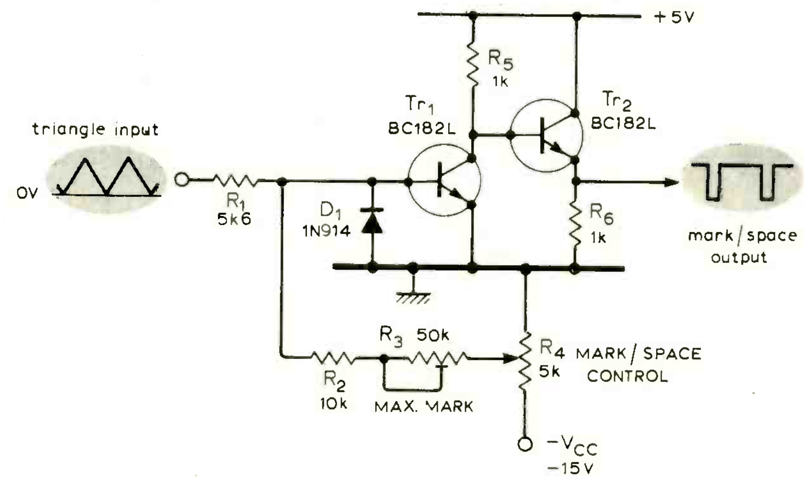


Fig. 6. Mark/space generator whose output mark/space ratio is variable from 15-85%.

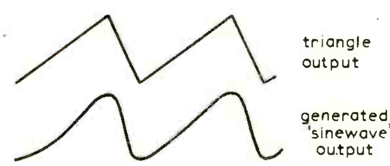


Fig. 7. Asymmetry caused by an imbalance in the diode ring switch.

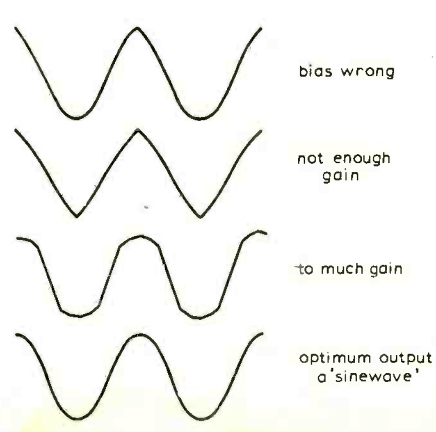


Fig. 8. Output of the diode function generator with cause and effect of incorrect bias and gain adjustment.

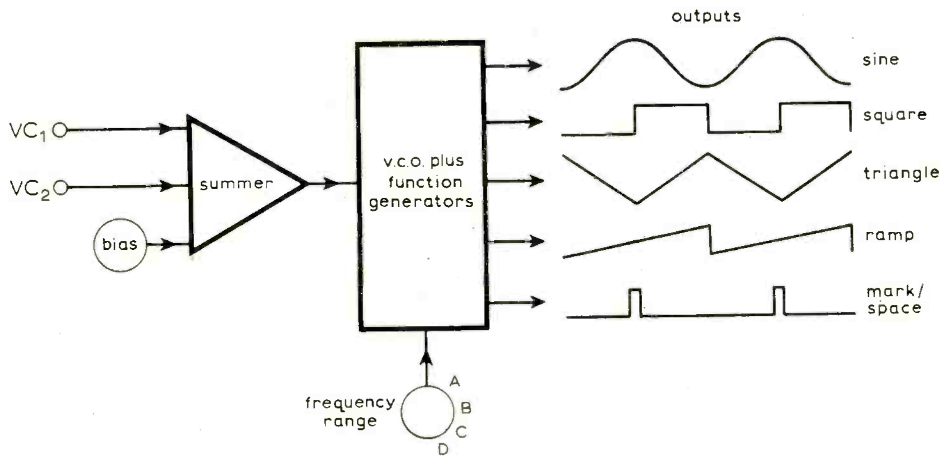


Fig. 9. Functions of voltage controlled oscillator VCO_2.

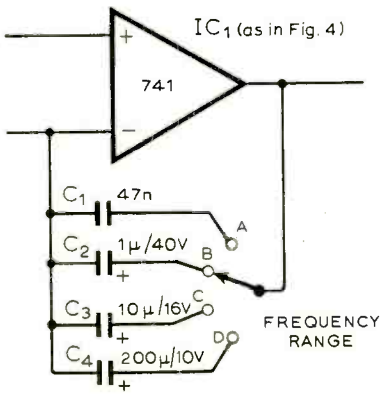


Fig. 10. Different frequency ranges of VCO_2. *The rest of the circuit is the same as in Fig. 4.*

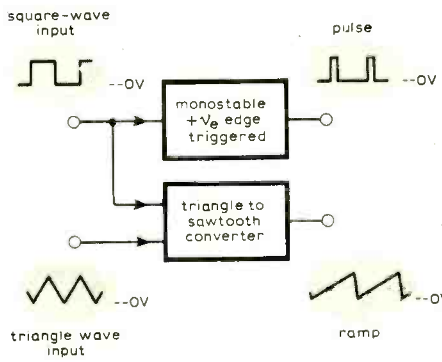


Fig 11. Function generators of VCO_2 *providing a pulse or ramp output.*

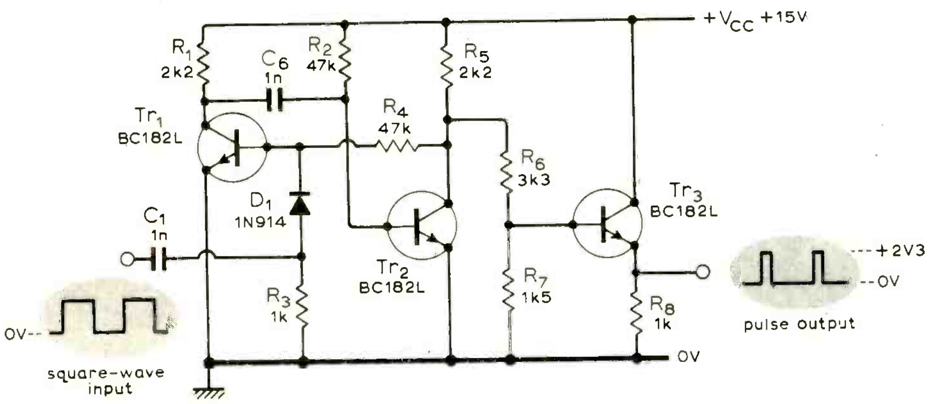


Fig. 12. Circuit of the pulse function generator.

ment. Also, delays in the loop cause some unwanted amplitude modulation. This effect becomes apparent at frequencies above 10kHz, but the change in amplitude and harmonic content (in the case of the piecewise generated sinewave) is not obvious to the observer. The sinewave output is generated by feeding the triangular wave at the output of IC_1 (Fig. 4) into a diode function generator (Fig. 5). Thus, by adjusting the bias, R_2, and the gain, R_3, a sinewave can be produced as shown in Fig. 8.

The mark/space signal is produced by driving the circuit shown in Fig. 6 with the "triangle" waveform. Transistor Tr_1 forms a level sensitive switch, and R_4 effectively shifts the d.c. level of the input signal. The resultant mark/space output is buffered by Tr_2. Preset R_3 is adjusted so that Tr_1 comes on just at the peaks of the input drive with the wiper of R_4 set at $-V_{cc}$. This should provide a mark/space range from about 15 to 85%.

To set up VCO_1, select the highest frequency range, disconnect any inputs, set the bias to mid position and set R_2 and R_{32} (both as in Fig. 4) to mid position. Monitor the triangle output and switch on. Turn the bias level down to zero and if the oscillations stop increase R_{32} until they start again. If the oscillations become badly asymmetric just before stopping, compensate by adjusting the offset control R_2. Thus by adjusting R_2 and R_{32}, optimize the balance between minimum operating frequency and symmetry. Having done this, increase the bias pot setting to give an output frequency of about 1kHz. The triangular wave should now be symmetrical and the diode function generator and mark/space generator presets can now be aligned.

Second voltage controlled oscillator

This oscillator is similar to VCO_1. It produces sine, square and triangular waveforms as before and also pulse and ramp waveforms (Fig. 9). The heart of the oscillator is basically the same as shown in Fig. 4, except that four frequency ranges are employed (see Fig. 10), thus giving an extended low frequency range. The sinewave generator is the same as before (Fig. 5), but two new generators, a pulse and a ramp generator are provided (Fig. 11).

The pulse generator is a monostable; it is triggered on the positive edge of the square-wave output and produces a pulse of approximately 20μs duration (Fig. 12).

The ramp generator is a differential amplifier with a switched gain (Fig. 13). The square-wave is used to control switching transistor Tr_1, so that the differential amplifier has an alternately positive and then negative gain. As the triangle and square-wave are always phase locked, the output of the differential amplifier is a ramp. As the triangular wave will have a d.c. offset voltage associated with it, a step will be produced in the middle of the ramp, but this can be zeroed by cancelling out the offset. For this purpose, preset R_{11} in Fig. 13 has been provided. There will, however, be some distortion generated at the crossover point which cannot be removed, but this is relatively small.

In the article by R. A. Moog[1], the v.c.o. described takes a different approach to the waveform synthesis. It first generates a ramp using a current-driven unijunction relaxation oscillator, and then converts this ramp into a triangle. This type of v.c.o. has a smaller dynamic range than $VCO_{1,2}$, but has a much higher immunity to locking onto harmonics of other oscillators.

The series will be continued with details of a sweep frequency oscillator, VCO_3, voltage controlled amplifiers and filters, mixer and summer/inverter, sample and hold and noise sources. The final part describes the joystick control, waveform generator, keyboards, patch panel and power supply.

to be continued

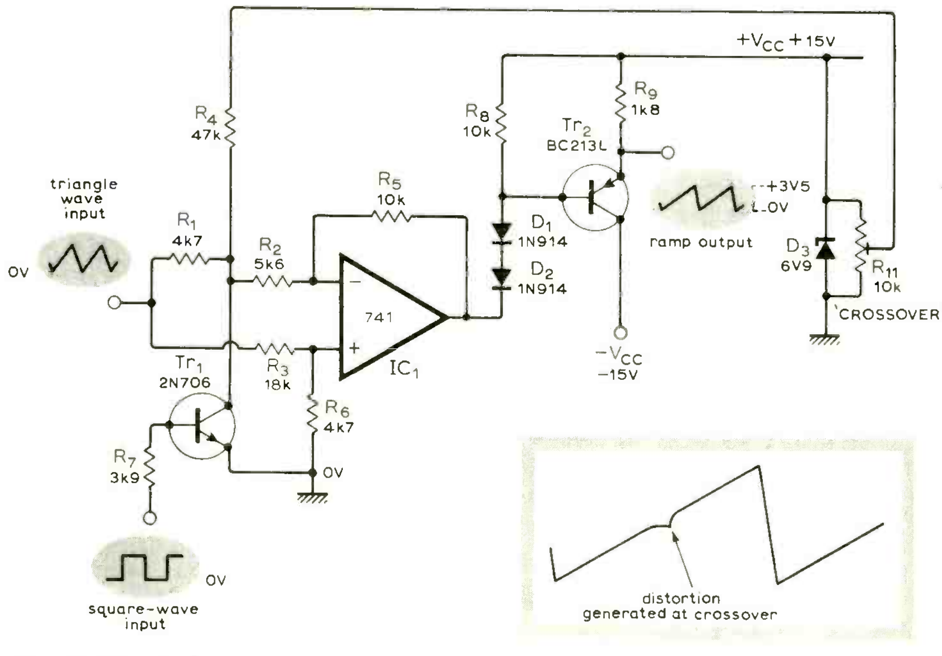


Fig. 13. Circuit of the ramp function generator.

References

1. Moog, R. A., "Voltage Controlled Electronic Music Modules", *Journal of the Audio Engineering Society*, July 1965.
2. Kindlmann and Fuge, "Sound Synthesis", *IEEE Transactions on Audio and Electroacoustics*, Dec. 1968.

Experiments with operational amplifiers

12. Pulse width modulation

by G. B. Clayton, B.Sc., F.Inst.P.*

A pulse width modulator allows the width of a series of pulses, occurring at the fixed frequency of a carrier signal, to be controlled by the amplitude of a modulating signal. An experimental circuit which uses an operational amplifier to perform this function is shown in Fig. 12.1.

The modulating signal (a sinusoid in this case) is applied to one input terminal of the amplifier and a triangular carrier wave is applied to the other. Both the signal sources shown in Fig. 12.1 must contain a d.c. path for amplifier bias currents. The amplifier acts essentially as a comparator. Typical circuit waveforms are illustrated in Fig. 12.2. If a triangular wave source is not available a triangular carrier wave can be generated by integration of a square wave using an operational integrator.

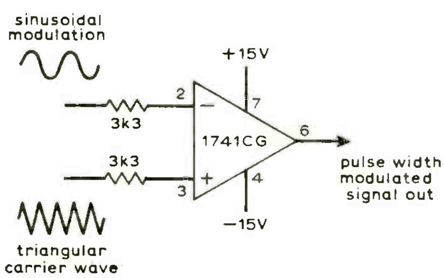


Fig. 12.1 Op-amp used for pulse width modulation.

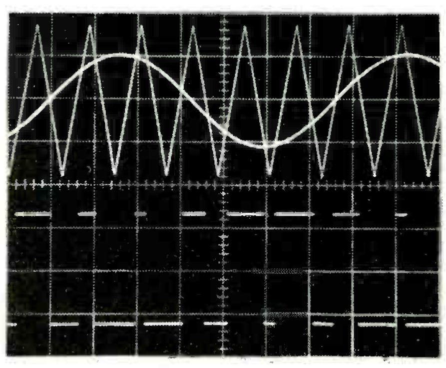


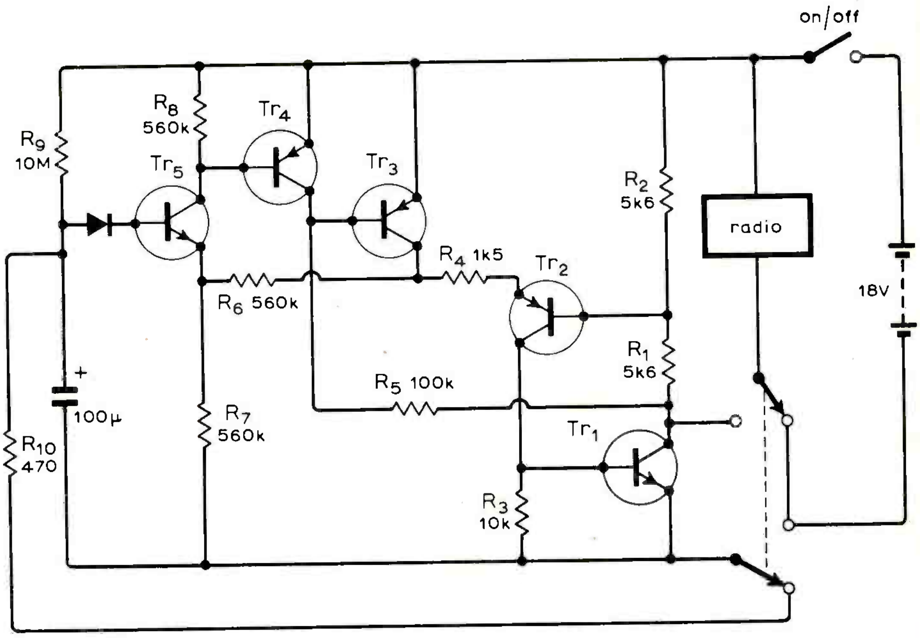
Fig. 12.2 The upper traces show the two input signals to the circuit (2V/div.) and the lower trace the output of width-modulated pulses (10V/div.). Horizontal scale, 10ms/div.

* Department of Physics, Liverpool Polytechnic.

Circuit Ideas

Make your description of a new circuit concise and say how it is an improvement over previously-published circuits, preferably in the first sentence. We pay £5 for published circuits.

Delayed switch off for transistor radios



This circuit switches off a transistor radio after a delay of approximately 30 minutes with a small current consumption while on and negligible consumption when off. The circuit uses Tr_1, Tr_2 as an equivalent but cheaper silicon controlled switch. Resistor R_4 determines Tr_1 base current and Tr_3 is used to cut off this current and hence turn off the radio. The switch is shown in the normal position. When operated the radio supply decoupling capacitor, charged, is connected across R_1, R_2. This turns on Tr_2, Tr_3 which turn on Tr_1. The capacitor charges *via* R_9 until Tr_5 turns on (its emitter is held at half supply voltage by R_6, R_7). This turns Tr_4 on, turning Tr_3 off and hence Tr_2 and Tr_1. The only current flow now is that due to R_7, R_9 and Tr_1, Tr_2 leakage currents, measured as 20μA.

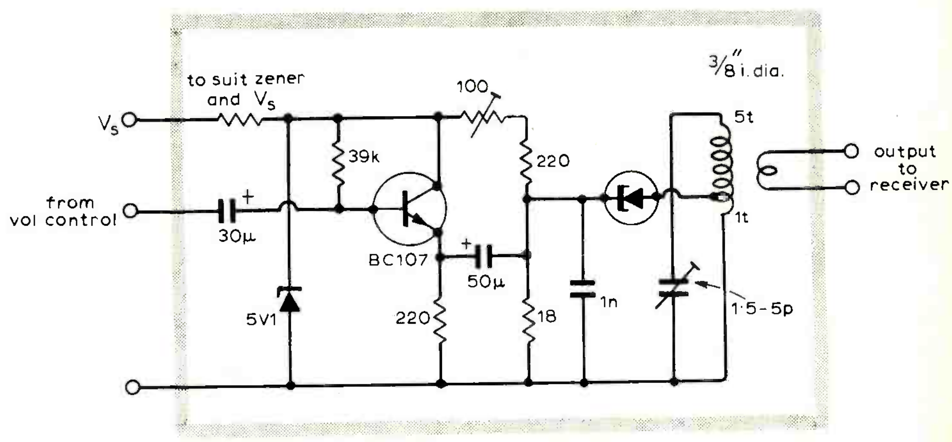
The diode prevents the capacitor charging via Tr_5 base/emitter junction if its reverse voltage rating is exceeded.

All transistors should have low leakage and a current gain greater than 50 at low currents except Tr_1 which need only have a current gain greater than 25 with collector currents from 10 to 100mA. (I used 2N3706 for Tr_1, Tr_5 and 2N3702 for Tr_2, Tr_3, Tr_4.) The capacitor must also have low leakage and some experimentation may be necessary. Resistor R_{10} discharges the capacitor rapidly to permit another operation immediately. The switch requires a good insulation resistance.

Operation of the circuit was between 9 and 18V. To enable operation from 4½ to 9V, halve the values given for R_6, R_7, R_4 and R_5. Also omit the diode as the maximum reverse bias for Tr_5 will then only be 4.5V.

S. Lamb,
Timperley,
Cheshire.

Improving television sound



Most of the distortion in television sound is introduced in the power amplifier and loudspeaker. Coupling the low-level sound signal, available at the detector or soon after, to a hi-fi system is an attractive solution to the problem, but usually founders on the requirement for a large and expensive transformer to isolate the television receiver chassis from the mains neutral. This system dispenses with this requirement.

The tunnel diode oscillator operates at a frequency within the f.m. broadcast band, at a level of a milliwatt or so, and is frequency modulated by the transistor, whose signal is derived from the volume control of the tv set. The oscillator output is inductively coupled to a coaxial line by an air-cored transformer which provides ample power-frequency isolation. At the hi-fi system, the resulting f.m. signal can be capacitatively coupled into the aerial circuit of an f.m. radio. By suitable screening, unwanted f.m. radiation can be kept to an insignificant level.

A. J. Smith,
Aldershot,
Hants.

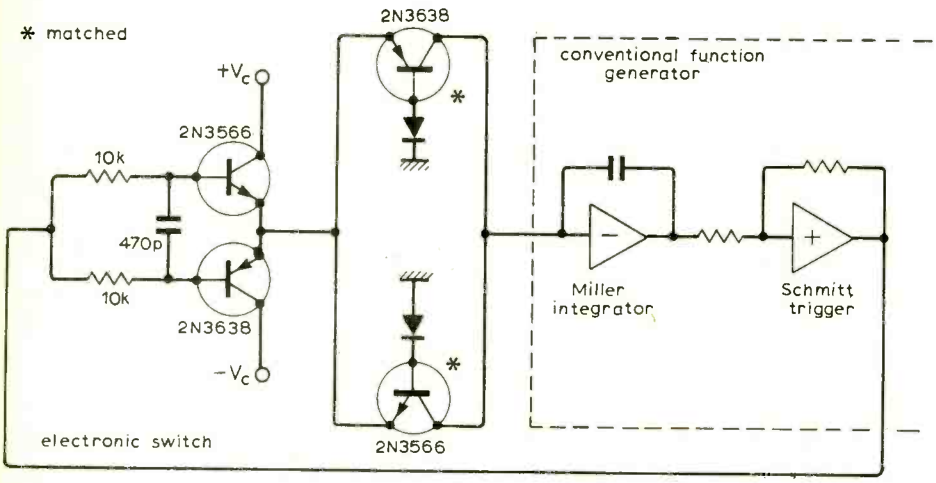
Function generator mod. for wide sweep range

The simple function generator shown in the accompanying diagram may be swept over a 1000:1 frequency range by varying V_C. The network, composed of the two transistors with diodes in their bases, has an exponential output current versus input voltage characteristic, and replaces the usual charging resistor of the Miller integrator. The electronic switch is controlled by the Schmitt trigger alternately connecting $+V_c$ and $-V_c$ to the charging circuit.

In my unit, the control voltages are derived from two operational amplifiers in the unity-gain inverting configuration. Input control voltage is derived from a potentiometer mechanically connected to a strip chart recorder, enabling Bode plots of audio equipment over the entire audio range to be made.

The frequency characteristic was found to be within 6% of a true exponential characteristic.

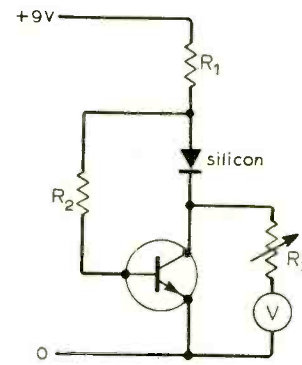
P. D. Hiscocks,
Ryerson Polytechnical Institute,
Toronto.



Measuring transistor gain

This transistor checking device has the advantage of simplicity in checking silicon transistors in which leakage current is negligible and measures gain over a wide range satisfactory as it is indicated on the ohms scale of a multimeter. The meter is set to give full scale reading by adjusting R_3 with a transistor with base and emitter only connected. (The meter is used as a voltmeter, R_3 being such as to bring it to approximately 9V full scale.) When the collector is connected, β will be given by the reading on the ohms scale, provided $R_2 = (R_{mid} - 1)R$, numerically. The value R_{mid} is the mid-range value of the ohms scale and R is the parallel combination of R_1 and the total resistance in the meter circuit.

In my case $R_1 = 1k\Omega$, the meter resistance was $300k\Omega$ and could be neglected and R_{mid} was 18Ω. The use of an $18k\Omega$



resistor for R_2 was sufficiently close for practical purposes.

As an alternative, R_3 may be adjusted with the transistor removed to give a meter indication of "−1 ohm", that is, just beyond the normal full scale reading.

Once the meter is set it does not need readjustment while similar transistors are being checked. If the ohms scale is not of a suitable range, it may, of course, be multiplied by a factor so long as R_2 is calculated using the "scaled" R_{mid}.

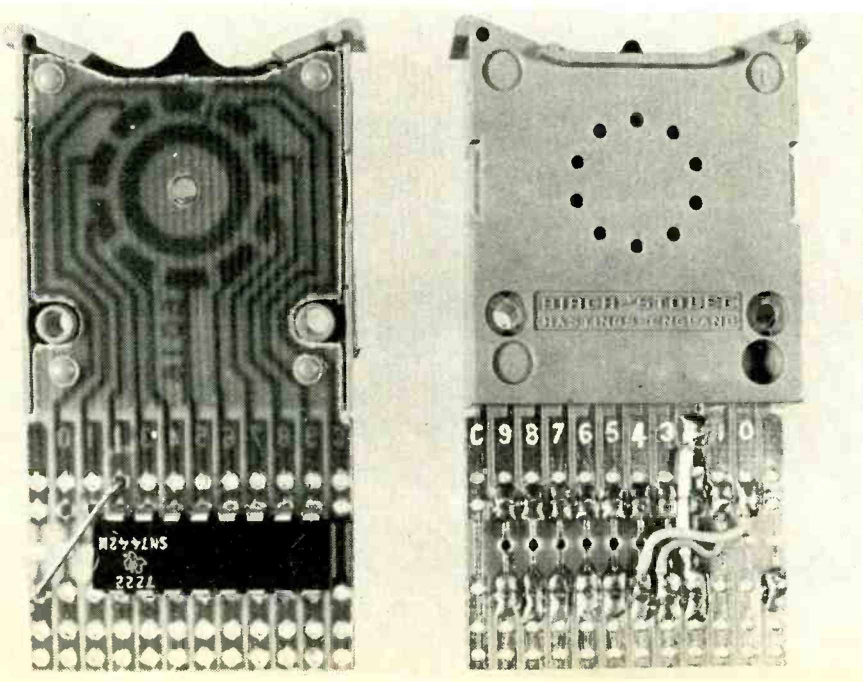
R. G. T. Bennett,
Christchurch, New Zealand.

Inexpensive b-c.d. parity switch

A parity switch can be made for about £2 per decade, using a thumbwheel switch and a b-c.d. to decimal converter such as the 7442. The outputs from up to four such switches could be connected to a four input NOR gate such as 7425, the output from which would go high at parity.

Birch-Stolec of Hastings, Sussex, make a small switch type SM which is available with a reverse numbered drum and extended p.c.b. Cut the copper below the number 2 (see photograph) and connect this to the 7 output of the converter. Numbers 0 and 1 need to be connected to the 9 and 8 outputs of the converter. The spare copper strip adjacent to the 0 can be used for the ground connection.

J. A. L. Fasham,
M.R.C. Laboratories,
Carshalton, Surrey.



New Television Tuner

Reduced cross-modulation using BF479 transistor with p-i-n diodes

*by P. Antoniazzi and A. Mauceri**

With increasing density of television transmitting networks, and especially of the u.h.f. colour stations, the need has emerged for television sets able to withstand larger input signals. Attempts to use dual-gate m.o.s. f.e.ts have so far failed because of severe u.h.f. noise and gain limitations, and because the cross-modulation reduction was not sufficiently great. Our answer is the low-noise, high-current transistor preamplifier, with a p-i-n diode variable attenuator to achieve the required a.g.c. With this approach wide dynamic range is obtained with a noise figure of only 4dB at 800MHz.

*SGS-Ates, Milan.

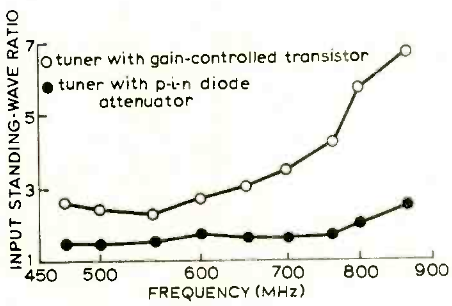


Fig. 1. Better aerial input matching is achieved in tuners using p-i-n diodes instead of gain-controlled transistors for a.g.c.

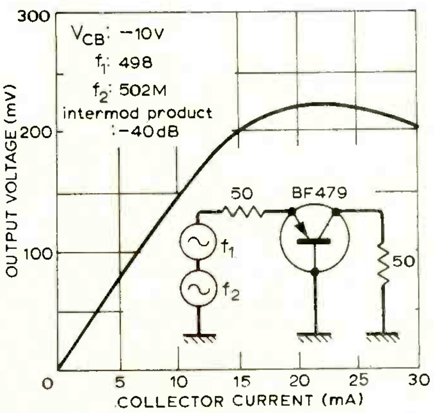


Fig. 2. Linearity of gain up to 15mA or so of BF479 improves cross-modulation performance, the gain control function being taken over by p-i-n diodes.

The introduction of germanium mesa r.f. transistors was undoubtedly revolutionary, and their potential is by no means exhausted, especially as far as noise and gain are concerned. However, a consequence of their mode of operation is poor cross-modulation performance. The a.g.c. front-end transistors are not able to handle very strong signals. Another problem is to achieve good aerial input matching. Input v.s.w.r. in conventional tuners is unsatisfactory at the top end of the u.h.f. band. At the input of this new tuner on the other hand, p-i-n diode attenuation gives very effective matching, a standing-wave ratio smaller than two being obtained without difficulty (Fig. 1).

Cross-modulation performance of a bipolar transistor improves almost linearly with increasing collector current. Standard a.g.c. transistors are unable to take advantage of this because of their limited current-handling characteristics with power gain collapse beyond 3 to 4mA.

In a new transistor, type BF479, a gain curve obtains which remains linear up to 15 to 20mA. This results in a great improvement of cross-modulation performance (Fig. 2). Gain control is provided by p-i-n diodes, handling input signals around 1V with cross-modulation of 1%. Attenuation is negligible with weak signals, which are passed directly to the transistor. As the signal increases, so does the attenuation brought about by the p-i-n diodes and the output is kept constant.

A comparative performance analysis shows that high-frequency gain, as determined by the maximum frequency of oscillation f_{max}, depends mainly on transistor polarity (p-n-p or n-p-n) through the term r_b'. This is because minority carriers flowing through an optimized u.h.f. bipolar transistor experience most of their delay in parts of the structure other than the base quasi-neutral region (e.g. in emitter and collector depletion layers). Moreover, these delays can be reduced and thus f_T increased in a way which is, at a first approximation, independent of transistor polarity. However, r_b', as determined by a certain geometry and certain masking tolerances, is directly affected by the mobility of the base majority carriers, which is more than double for electrons (p-n-ps) than it is for the holes (n-p-ns). Similar considerations hold good for high frequency noise figure.

To reduce r_b' by narrowing the emitter strips is a difficult and expensive task, so it is apparent that the silicon p-n-p transistor is a better choice than n-p-n. Recent progress in h.f. silicon p-n-p manufacture has led to development of the BF479, a planar epitaxial device with very shallow base and emitter diffusions ($w_b = 0.25\mu m$).

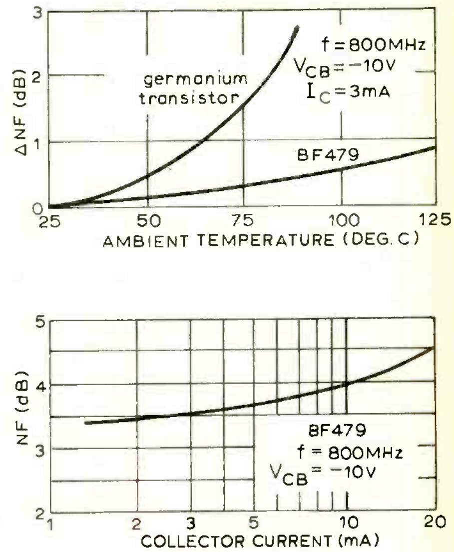


Fig. 3. Lower and more constant noise figure versus temperature and current are features of the BF479 transistor.

Its lower and more constant noise figure versus temperature and current (Fig. 3), and its higher dissipation (working point 10V, 10mA) are essential characteristics for modern television tuner applications.

Reliability considerations have led to an interesting design innovation, illustrated in Fig. 4. This consists in a modification of standard layout to give a "base-grid" geometry, which helps eliminate problems of aluminium migration and metal cracks. Electrical characteristics of the BF479 are summarized in the table.

Characteristics of BF479 transistor

V_{CBO}	30V
V_{CEO}	25V
V_{EBO}	3V
I_{cmax}	50mA
$h_{FE\,min}$	25
P_{tot} at 50°C	125mW
C_{CBO}	0.7pF
f_T	1.6GHz
NF at 800MHz	4dB

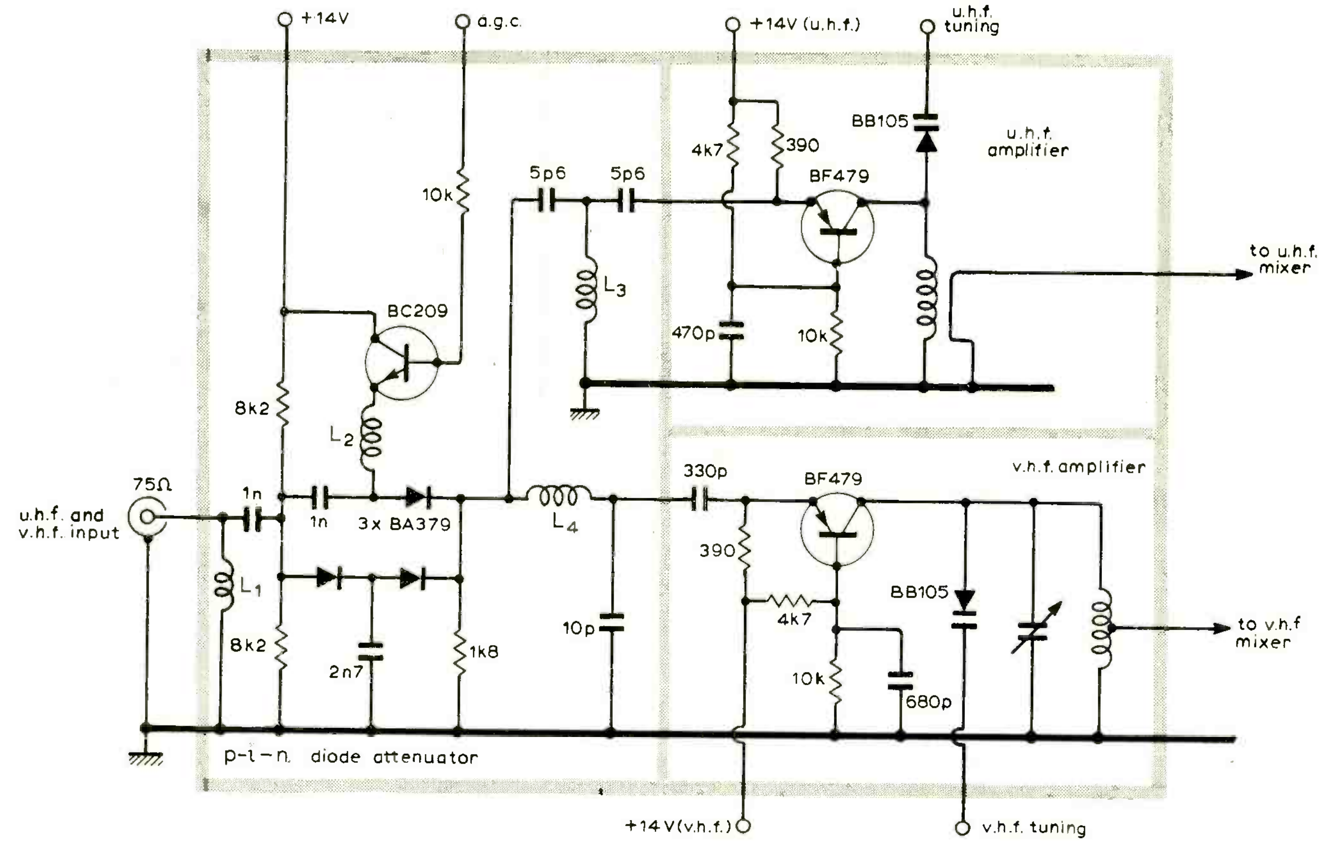


Fig. 5. Combined u.h.f. and v.h.f. television tuner using BF479 for improved cross-modulation and p-i-n diodes for a.g.c.

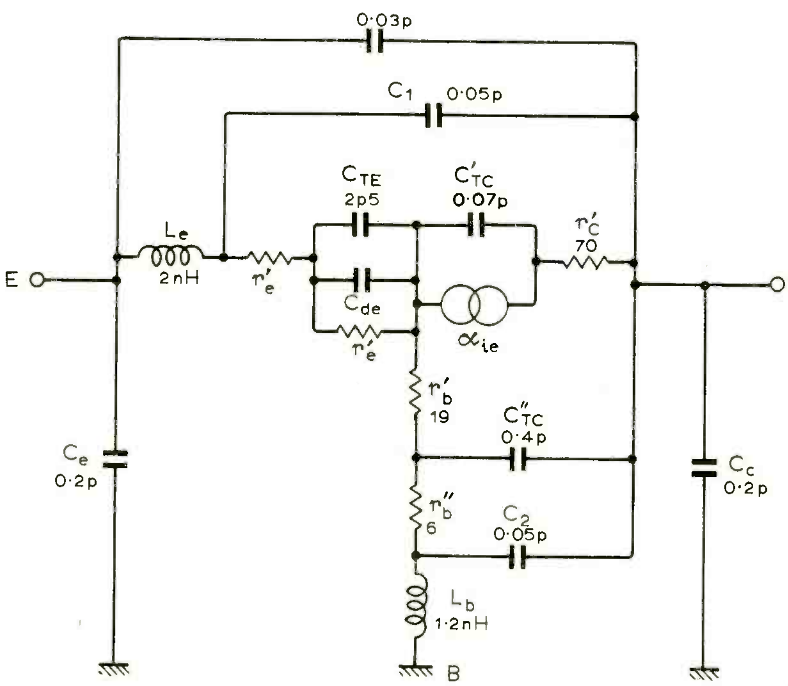
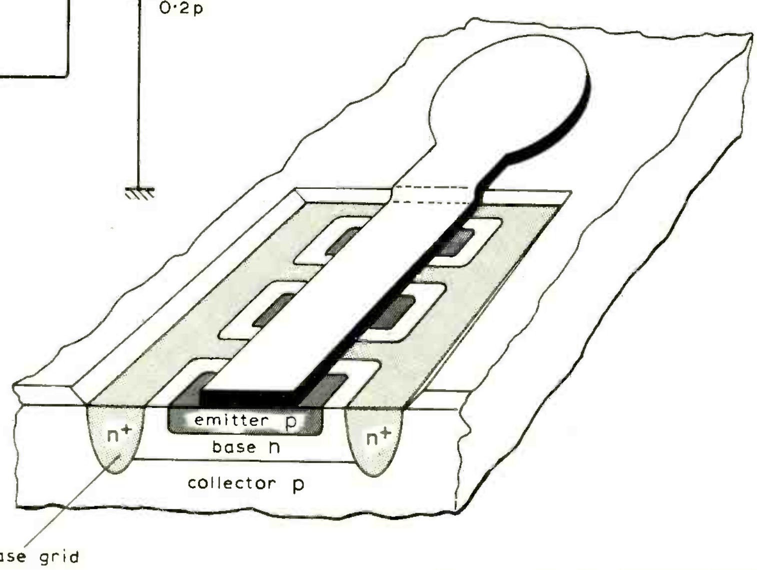


Fig. 4. New base-grid geometry and emitter metallization of BF479, which helps to reduce aluminium migration, and its equivalent circuit.



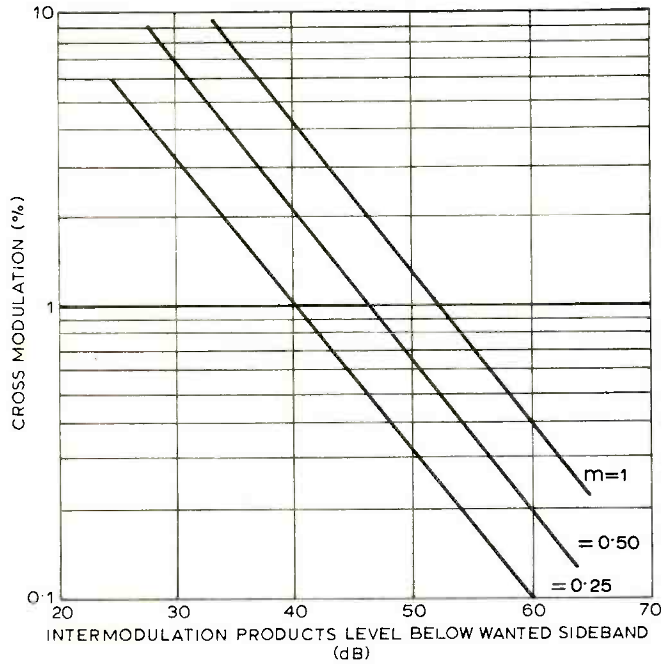


Fig. 6. Theoretical predictions of cross-modulation versus third-order intermodulation products.

Suggested tuner circuit

Fig. 5 shows a television tuner circuit with the BF479 p-n-p silicon transistor used as both u.h.f. and v.h.f. amplifier stage. Remaining parts of the circuit are conventional, except for the a.g.c. function, where p-i-n diodes are used. A further improvement would be obtained by introducing Schottky diodes in the mixer stage, but for the moment this solution is not justified because the overall performance of the new tuners combining p-i-n diodes and high-current silicon p-n-p transistors is more than adequate for present market requirements.

Appendix

Correlation between cross-modulation and third-order distortion

Intermodulation analysis
From the general expression

$$I_{in} = a_0 + a_1 V_b + a_2 V_b{}^2 + a_3 V_b{}^3 + \ldots$$

and with input signal

$$V_b = V_1 \sin \omega_1 t + V_2 \sin \omega_2 t$$

we obtain a third-order current

$$I_{21} = \frac{3}{4} \cdot a_3 V_1^2 V_2$$

where I_{21} is the peak value of third-order intermodulation current at the input ($f = 2f_1 - f_2$). The input voltages and currents are converted to output power by using a transistor model.

For the common-emitter configuration the third-order intermodulation power is

$$P_{21} = 2P_1 + P_2 + K_{21} \quad \text{(dBm)}$$

where P_1 is the output power in dBm at f_1, P_2 the output power in dBm at f_2 and K_{21} a constant in dBm associated with the device. When $P_1 = P_2 = P$ (standard intermodulation tests), $P_{21} = 3P + K_{21}$. Defining distortion as $i.m.d._3 = P_{21} - P$, we have $i.m.d._3 = 2P + K_{21}$. Third-order distortion increases by 2dB per 1dB of fundamental frequency signal.

Cross-modulation
Input signal is

$$V_b = V_s \cos \omega_s t + (V_p \cos \omega_p t)(1 + m_p \cos \Omega_p t)$$

where V_s is the useful signal at f_s, V_p the interference signal at f_p, m_p the mod. signal index V_p and $\Omega_p/2\pi$ the signal modulating frequency V_p. By replacement in the general expression, we obtain input current

$$I_{in} = a_1 V_s \cos \omega_s t \left[1 + \left(\frac{a_3 3 m_p V_p^2}{a_1}\right) \cos \Omega_p t\right]$$

The signal frequency is therefore modulated by Ω_p with cross-modulation index

$$mK = \frac{3a_3 m_p V_p^2}{a_1}.$$

Correlation
A form of intermodulation commonly encountered is cross-modulation, where amplitude modulation from one carrier is transferred to a neighbouring carrier. Considering intermodulation between two signals $V_1 = V_p$ and $V_2 = V_s$,

$$I_{21} = \frac{3}{4} a_3 V_p^2 V_s$$

$$I_2 = a_1 V_s$$

and therefore

$$\left(\frac{P_{21}}{P_2}\right)^{\frac{1}{2}} = \frac{I_{21}}{I_2} = \frac{3a_3 V_p^2}{4a_1}.$$

Substituting in

$$mK = \frac{3a_3 m_p V_p^2}{a_1}$$

we have $\left(\frac{P_{21}}{P_2}\right) = \left(\frac{mK}{4m_p}\right)$

or $$mK = 4m_p \sqrt{\frac{P_{21}}{P_2}},$$

which in logarithmic form is

$$20 \log mK = 20 \log 4 + 20 \log mp + (P_{21})(-P_2) \quad \text{(dBm)}$$

If $m_p = 0.3$ (standard cross measurements)

$$20 \log mK = P_{21} - P_2 + 1.5 \quad \text{(dBm)}$$
$$= 2P_1 + K_{21} + 1.5 \quad \text{(dBm)}.$$

For intermodulation

$$i.m.d._3 = 2P + K_{21} \quad \text{(dBm)}$$

and for cross-modulation

$$i.m.d._{cross} = 2P_1 + K_{21} + 1.5 \quad \text{(dBm)}.$$

The diagram of Fig. 6 makes clear the correlation between cross-modulation and third-order intermodulation.

Sixty Years Ago

The August 1913 edition of *Wireless World* seemed to cater for all tastes from romantic poetry on wireless telegraphy to a historical account of the site selected in Norway for a "Transatlantic Wireless Station". The account included descriptions of the national costume and even a photograph of the Stavanger local church. Anything went to lighten the load of the usual technical and parliamentary reporting. The most unusual bit of light relief was the continuing serial "A Pawn in the Game" whose characters sounded fascinating: "Charles Summers — Inventor and engineer. Son of Vicar of Sotheby, and affianced to Gwen Thrale, daughter of the Squire. Gwen Thrale — Charles Summers' fiancee, a bright, intelligent and original girl, the idolised daughter of the squire, and secretly a member of a Fabian Society. She coaxes Summers to teach her 'wireless' and soon becomes a proficient operator and a bit of an engineer." How on earth the story got past the censors will never be known.

Circards

The next article in the Circards series, No. 9, "opto-electronics", will be published in our September issue.

High quality tone control

A low distortion design

by J. N. Ellis

It is recognized[1,3] that to obtain low noise the usual one-transistor configuration[2] gives generally poor results, and has a distortion level approaching 1% at about 1V r.m.s. output. The signal-to-noise ratio can be greatly improved by using two transistors directly coupled, with the first device operating in common emitter and the second in common collector mode. The first stage current can now be 100μA, giving us a much better signal-to-noise ratio. This two-transistor design is often used, but suffers from latch up on overdrive.

The author's design raises the signal level from 100mV to 1V r.m.s. to drive a power amplifier and uses a cascode circuit to provide a more stable operating point and lower distortion. This is because the instantaneous collector voltage of the common-base transistor does not appreciably affect the current flowing in it. With a similar transistor cascode pair, the bias resistors may be low enough to inject a noise current into the lower device. Use of a complementary cascode configuration allows the selection of reasonable values of bias resistance.

To make full use of the advantages of the design (Fig.1) the tone network is fed from an impedance equal to that presented at the output, essentially R_{16} and R_{17} in parallel. This allows a flat response when the potentiometers R_{19} and R_{20} are mechanically central[1]. The buffer stage (Tr_1) allows the impedance to remain constant, independent of the volume control setting.

Component values of the tone network have been selected so that maximum bass boost or cut occurs at 50Hz, and the treble boost or cut maximum at 10kHz. Inclusion of resistors R_7 and R_8 limits the treble boost or cut to only 12dB beyond 10kHz, as it has been found that the full 20dB (theoretical) at 20kHz is unnecessary, as the sensitivity of the ear is reducing rapidly at that point[1]. Making R_7 and R_8 equal to 1kΩ allows the greater range to be obtained for the impressionist. The frequency response is shown in Fig.2.

Without C_9 the square-wave response showed slight ringing, eliminated by making C_9 = 4.7pF. By increasing C_9 to 10pF the response is made 3dB down at 175kHz and the low frequency 3dB point is 5Hz.

The design has an overall gain of 10 (20dB), and for 1 volt output with R_L = 10kΩ and R_S = 100Ω, the total harmonic distortion (measured) was less than 0.1% at 1kHz. The signal to noise ratio could not be accurately measured on the equipment available at the time, but is estimated to be −110dB and certainly greater than −100dB using low noise transistors — an improvement of 10 to 20dB over other designs.

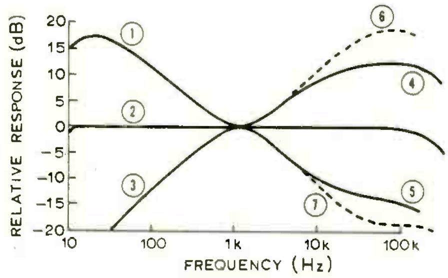


Fig.2. Amplitude/frequency response curves of tone control circuit. 1. Bass boost max. 2. Flat response 3. Bass cut max. 4. Treble boost max. 5. Treble cut max. 6, 7. Treble boost and cut with R_7 $R_8 = 1k\Omega$.

References

1. "Low Distortion Tone Controls", *Wireless World*, April 1971.
2. For example, Mullard "Transistor Audio and Radio Circuits" — Auxiliary high quality tone control.
3. Quad 33 tone control circuit.

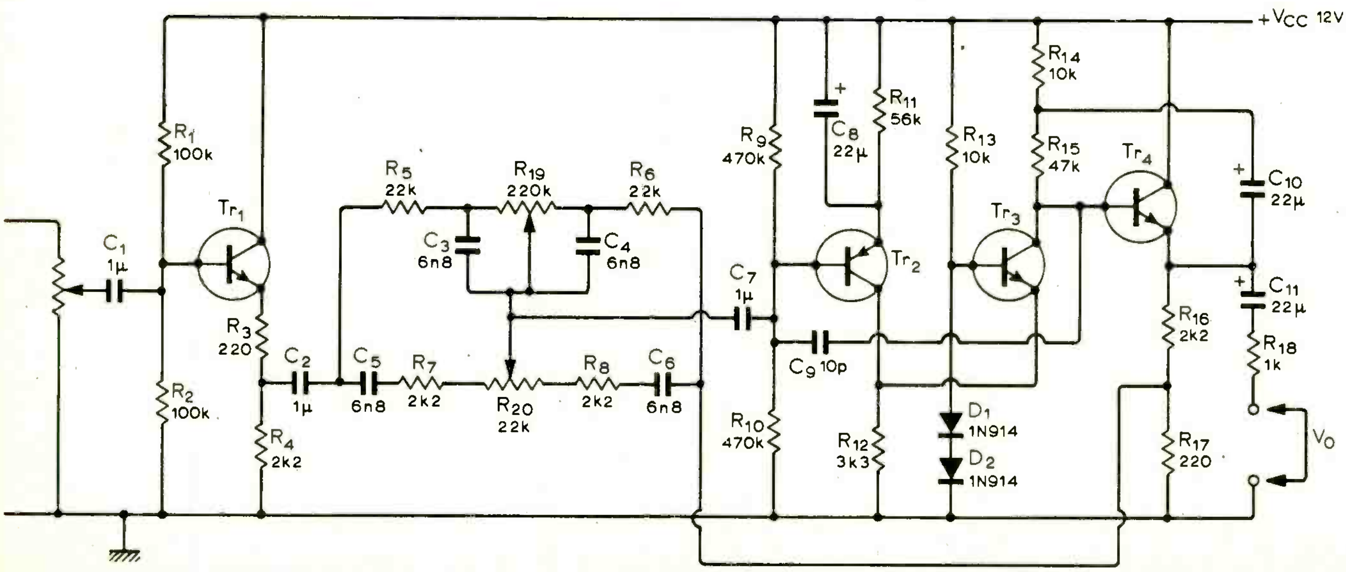


Fig. 1. Circuit diagram of tone control. Transistors Tr_1, Tr_3, Tr_4 = *BC109, BC114, BC184.* Tr_2 = *BC15, BC214, BC309 etc.*

Realm of Microwaves

5. Applications of point-contact, Schottky-barrier, p-i-n and backward diodes

by M. W. Hosking M.Sc.*

It was as a mixer and detector that semiconductor materials found their first microwave application as the point-contact diode, a device still in wide usage. Now it has been joined by numerous other devices, of which the Schottky-barrier or hot carrier diode and the backward diode are the most commonly used. In 1938, Schottky put forward his theory of the metal-semiconductor rectifying junction which did much to explain the action of the point-contact diode and to indicate those areas in which improvements could be made. Present-day devices benefit from the innovation of epitaxial deposition in defining an active layer, but the basic idea has remained unchanged since the days of the cat's whisker.

The rectifying junction is formed by bringing a pointed metal wire into contact with the surface of a semiconductor wafer. In some cases, an electrical discharge is passed through the junction to alloy the metal and semiconductor together. The important properties of the device are controlled by the area of contact metal, which distorts slightly under the contact pressure, the type of metal whisker, and the exact nature of the alloyed-type contact.

Being a metal-semiconductor junction, the point-contact diode is also a Schottky barrier device, but that name is reserved for a much more recent diode which, because of improved fabrication, more closely approaches the ideal Schottky barrier. Instead of a metal whisker, a thin insulating layer of silicon dioxide is formed on top of the epitaxial semiconductor material and a series of windows etched out of it. The diameter of a window might typically be 0.0002in.

Through this hole is deposited a metal film to form the diode junction and a bonded contact to the package is made to this film. A much better defined and controlled junction can be produced in this way, as opposed to the whisker contact and this leads to a device having a lower noise figure, particularly $1/f$ noise, and being more rugged and reliable.

Unlike the point-contact and Schottky-barrier diodes the backward diode is a p-n junction device. As a detector, the negative resistance region of the tunnel diode characteristic is virtually suppressed and the diode is operated on the reverse portion of its I–V characteristic—hence the name backward diode. Materials are n-type Ge or GaAs, with an alloyed junction being formed by the dissolution of a p-type impurity.

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One of the basic parameters of a low-level detector is its rectification efficiency, usually expressed as the output current or voltage obtained for a certain input microwave power. Sensitivity is proportional to the I–V slope at the origin and its value depends on the frequency of operation and the detector load impedance. Clearly then, the backward diode possesses a higher sensitivity than that of the other two types, particularly the Schottky-barrier diode, which is barely conducting at voltage levels which drive the backward diode into saturation. The curves of Fig. 1, however, represent the zero bias case wherein the backward diode comes out as more sensitive.

Applying a small forward bias of typically 10 to 50μA, the small-signal detection property of the point-contact diode becomes comparable with the backward diode, while that of the Schottky-barrier device can be made much better. A widely used method of comparing the low-level detection capabilities of diodes is to measure what is called their tangential signal sensitivity (t.s.s.) which is the ability to detect a signal against a noise background.

The detector is coupled to an oscilloscope through an amplifier. With no input r.f. signal and the amplifier gain turned up, the noise power is visible as "grass". An r.f. pulse is then applied to the detector and its power increased until the detected trace on the oscilloscope has increased in amplitude by an amount equal to the original background noise level. This power is then a measure of the t.s.s. and is usually expressed in dB with reference to one milliwatt (dBm). The t.s.s. is a function of the amplifier bandwidth and noise figure and should always be quoted with reference to these factors.

It is also a subjective measurement, depending on the operator's opinion as to when the pulse trace is at the correct level. In spite of this limitation, t.s.s. is still the most widely used commercial method of characterizing low-level sensitivity. At a frequency of, say, 10,000MHz, with a 1MHz video bandwidth and 2dB amplifier noise figure, the backward diode would typically have a t.s.s. of −56dBm which would not be improved by the use of a d.c. bias. The point-contact diode would have a t.s.s. of

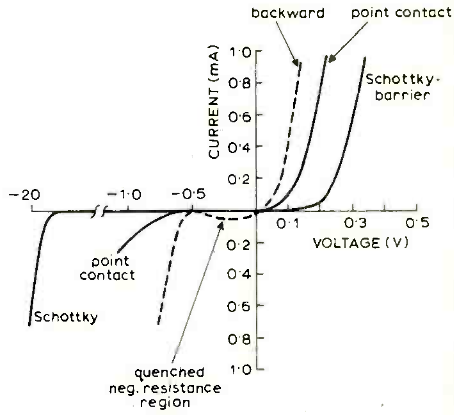


Fig. 1. Large differences in curvature at the origin of the I–V characteristics govern the behaviour of the diodes as detectors.

−52dBm at zero bias and would become comparable with the backward diode at about 50μA of forward bias. The Schottky-barrier diode is not used as a detector at zero bias, being up to 30dB less sensitive, but with about 20μA bias, the t.s.s. would be −58dBm.

Microwave mixing

When greater detection sensitivity is required than can be obtained with the simple diode rectifier, a mixer circuit can be used. The point-contact and Schottky-barrier diodes are most commonly used in microwave mixers as the backward diode suffers from a limited dynamic range and is more susceptible to high-power burnout. However, at low intermediate frequencies, such as might be encountered in a Doppler system, the backward diode has a much lower $1/f$ noise figure than the point-contact type and is often used, but it still faces competition from good-quality Schottky-barrier diodes. The diode requirements for a mixer are different to those for a detector, so that a diode that is best in one application is not necessarily best at the other.

Mixing is a frequency conversion wherein the low-power, high-frequency input signal is converted to a low-power, low-frequency output signal, the amplitude of which is proportional to that of the input. To perform this conversion, a relatively high-power, constant-amplitude local oscillator signal is applied to the mixer diode. The amplitude is sufficiently high to drive the diode into the linear portion of its characteristic shown in Fig. 1, and the effect is to switch the diode's non-linear impedance between a low forward and a high reverse state, at the frequency of the l.o. drive. At the same time, the much lower-power input signal, which must be at a different frequency, amplitude modulates the l.o. signal. The result at the output terminals of the mixer is a d.c. level due to the rectification of the l.o. voltage, which is ignored, and the a.m. component, varying at the beat or difference frequency between the two original input signals.

Unfortunately, however, the process is not quite this simple and other frequencies are generated during the mixing process. In particular one is called the image frequency and can be considered as arising from the i.f. mixing with the l.o. signal to produce another difference signal. These frequencies then beat with each other and with the original two inputs to produce an infinite series with steadily diminishing amplitudes and the effects of these are usually neglected. Thus, if an r.f. signal to be detected, which might contain pulse information, had a frequency of 10,000MHz and the l.o. was allocated a frequency of 9500MHz, then an i.f. containing the pulse information would be generated at 500MHz together with an equal-amplitude image at 9000MHz and a train of harmonics at odd and even multiples of 500MHz apart.

A simple, yet useful, equivalent circuit for a microwave mixer and detector diode is shown in Fig. 2, together with typical X-band (8200–12,400MHz) diode parameters. It is essential to take into account the parasitic reactances of the diode package as well as those of the chip itself as the two sets of parameters are now similar in value and can interact to form unwanted resonances. Values L_p and C_p are the package values and depend on the method of bonding the encapsulated chip and the physical size of the package. Component R_s is the series resistance of the semiconductor material itself and R_j is the resistance of the junction, the capacitance of which is C_j. Both R_j and C_j are functions of the diode current, the former decreasing and the latter increasing with an increase in current.

As it is the junction resistance which provides the non-linear mixing element, the presence of C_j is unwelcome and detracts from the diode performance due to its shunting effect at the higher frequencies. The quality of the diode as a mixer can be expressed in terms of two quantities: noise temperature ratio t_r and conversion loss l_c, the product of which defines a noise figure for the diode. Noise temperature ratio gives a measure of the noise added by the diode in addition to that generated by its series and junction resistance and is defined as the noise power divided by the noise power from an equivalent resistance. At frequencies above about 1MHz, t_r is approximately unity, but below this value t_r increases as the reciprocal of frequency. Ideally, the mixer is required to convert all of the r.f. signal power to i.f. power and the conversion loss is a measure of the efficiency with which this process is carried out. It is simply r.f. input power divided by i.f. output power. Theoretically, this can never be less than 3dB because an equal amount of i.f. power is generated at the image frequency and more is lost in the harmonics. However, in a practical mixer, it is possible to give the circuit a band-pass type of response so that the image frequency lies in the rejection band and "sees" a short or open circuit. In this way, power at the image frequency is reflected back into the mixer where, if given the right phase, it is converted to i.f. power.

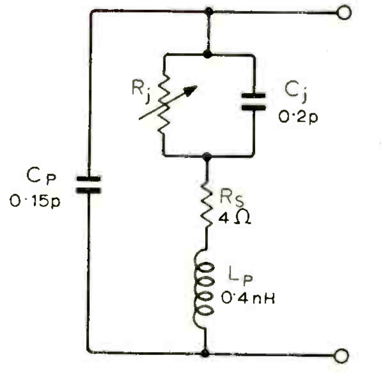


Fig. 2. Most microwave semiconductors are encapsulated and the package reactances must be taken into account when calculating the terminal impedance. Shown is a typical equivalent circuit for an X-band diode.

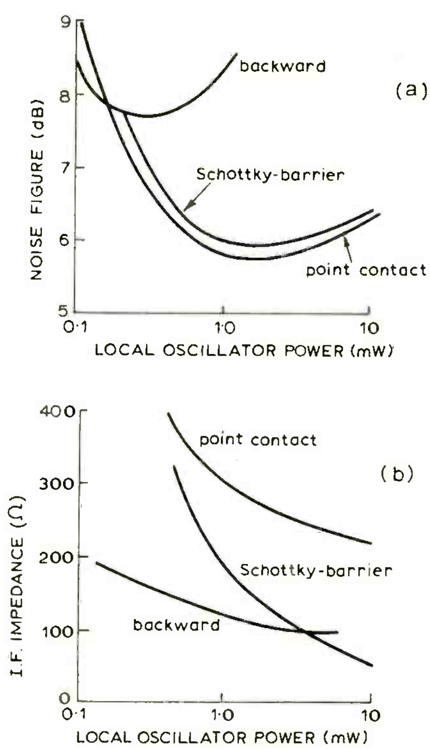


Fig. 3. Increasing oscillator power increases conversion efficiency but also the noise temperature ratio. There is an optimum power level for minimum noise figure.

This is called an image recovery mixer and in practice results in about a 1dB improvement in conversion loss. The conversion loss is the sum of several individual losses, one of which is associated with the conversion efficiency of the diode junction and can be enhanced by image reflection. This loss is a function of the forward and reverse slopes of the diode characteristic and depends on the oscillator power level.

A second loss, which can be made quite small, is due to the mismatch presented by the diode to the r.f. and i.f. signals. Thirdly, the presence of R_s and C_j serves only to impair the diode performance by reducing the power that enters the junction resistance R_j. Because both R_j and C_j are functions of diode current, there is an optimum value of oscillator power to minimize this particular loss and occurs when $R_j = 1/\omega C_j$.

These, then, are the various factors contributing to the noise figure of the mixer diode itself, but to evaluate them, measuring devices must be connected to the i.f. output terminals of the mixer, contributing their own noise to the system. For this reason, quoted noise figures are usually receiver noise figures and include the noise figure of an i.f. amplifier, almost invariably specified as 1.5dB. If the mixer is viewed as the first stage of an amplifier chain and as having a less-than-unity gain equal to $1/l_c$, with an i.f. amplifier of noise figure $F_{i.f.}$ as the second stage, then the receiver noise figure is

$$t_r l_c + \frac{F_{i.f.} - 1}{1/l_c} = l_c(t_r + F_{i.f.} - 1).$$

For optimum oscillator power, an intermediate frequency between 1 and 100MHz and $F_{i.f.}$ of 1.4 (i.e. 1.5dB), typical noise figures at 10,000MHz for commercially available diodes lie between 6 and 7dB for the three types.

Besides biasing the mixer diode onto the linear portion of its characteristic and providing the frequency to mix with, the l.o. also adds its own components of a.m. and f.m. noise and can influence the noise figure of the mixer diode itself by virtue of the incident power level. In addition, the i.f. impedance of the mixer is a function of l.o. power level. At small l.o. power levels, the mixer diode is utilizing the curved portion of its characteristic and the conversion loss is high because efficiency is low. With increasing power, the loss decreases rapidly at first, but then levels off as the operating point on the diode curve moves into the linear region.

At the same time, the noise temperature of the diode steadily increases with power with the result that the overall noise figure of the mixer passes through a minimum at a particular oscillator power level. This minimum varies with diode type as shown in Fig. 3(a) for the Schottky-barrier, point-contact and backward mixers and is an important parameter in microwave receiver design. The corresponding variation in i.f. impedance is shown in Fig. 3(b). (General design of balanced mixers in microstrip form was given in part 3, June issue.)

Uses of the p-i-n diode

The p-i-n diode finds its application mainly in control devices such as switches, modulators, attenuators, limiters and in phase-shifters. All of these components use the prime feature of this diode: the ability to change rapidly from a high impedance to a low impedance on application of bias.

The complete equivalent circuit of a packaged diode is shown in Fig. 4 and it is worth reiterating that the parasitic reactances of the package must be taken into account at microwave frequencies. At microwave frequencies C_I, the intrinsic region capacitance, is constant and is purely a function of the junction geometry. At zero or reverse bias, the intrinsic region of the diode is depleted of charge and thus has a relatively high resistance of typically several thousand ohms. With the application of a forward bias, electron and hole charge carriers are injected into the i-layer with the result that C_I disappears and the layer becomes highly conductive, with a low resistance of usually less than one ohm. This variation of resistance is shown in Fig. 5 and the minimum attainable value for the complete diode is limited by R_S.

When using this property of the p-i-n diode, account must be taken of the operating frequency as this determines the switching efficiency and the signal distortion level. Charge carriers present in the i-region of the diode, that is holes and electrons, have a recombination lifetime τ lying typically between 10 and 300ns.

At frequencies below the value defined by $f = 1/2\pi\tau$, the injection and removal of charge can follow the r.f. waveform and the diode behaves as a p-n junction giving inefficient rectification of the signal. Above this frequency the charge removal process cannot follow the reverse half cycle of the r.f. and the presence of microwave power has the same effect as a steady bias. The result is an impedance state which can be primarily determined by a d.c. bias, but which has a very small modulation component due to the r.f. signal.

A small lifetime enables a fast switching speed to be obtained but limits the lower frequency of useful operation of the diode and so a compromise must be made. Compared with other types of diode, the p-i-n diode has the advantage of a low junction capacitance and high breakdown voltage, enabling it to handle large incident power levels at high frequencies.

An important application of the p-i-n diode is as a microwave switch, for either preventing power from passing between two points or for diverting it to another part of a circuit. The diode can be mounted in series or shunt with the transmission line, as in Fig. 6, and can be classed as broadband or resonant.

Before describing these circuits, it is useful to define terminology used in referring to the two states of the switch. When the switch is on, the diode state is such that power can pass and when off, the power flow is interrupted. Referring to Fig. 6(a) where the p-i-n diode is mounted in series with the main transmission line, a zero or reverse bias to the diode produces a high impedance of about 10kΩ and effectively open-circuits the line. Forward bias short-circuits the diode junction to about 1Ω, a value which is degraded by the series resistance and inductance, but which is sufficient to allow most of the power to pass.

In the shunt-mounted case of Fig. 6(b), the same bias conditions produce opposite results: forward bias tending to produce a short across the transmission line. When designing a switch, low insertion loss and high isolation are required and the degree to which this can be obtained depends on how the magnitude of the diode impedance compares with the characteristic impedance of the transmission line.

A simple design example that is appropriate and is based on the equivalent circuit of Fig. 4 and the graph of Fig. 6, demonstrates practical performance. Transmission line impedance (Z_0) is 50Ω and the diode is series mounted and required to operate at 1000MHz. With the diode impedance expressed as $R+jx$, the transmission loss is $10\log_{10}[R^2+x^2/(4Z_0^2)+(R/Z_0)+1]$(dB). Taking the forward bias case and the circuit given in Fig. 4, then at 50mA bias, R_F is 1Ω, so that $R = R_F + R_S = 2\Omega$. $X_L = 2\pi L_p \times 10^9 = 2.5\Omega$. (Diode reactance is mainly due to L_p at this frequency, so it is easier on the analysis and quite valid to ignore C_p). Thus

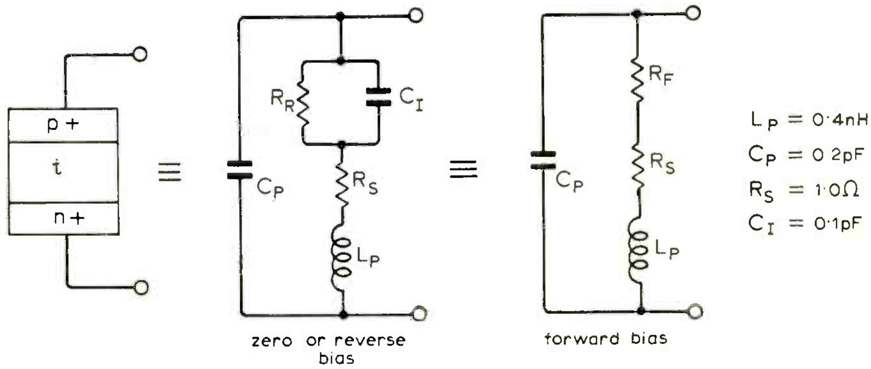


Fig. 4. Equivalent circuits for reverse and forward bias conditions of a silicon p-i-n diode. R_S is the series resistance associated with the contacts to the i-region of the diode and C_i is the intrinsic-region capacitance. Values of L and C_p are typical of devices used up to the end of X-band (8200 to 12,400MHz).

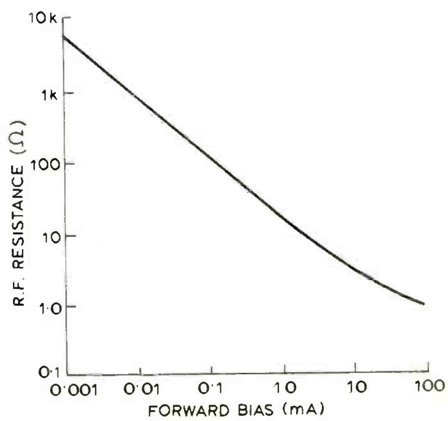
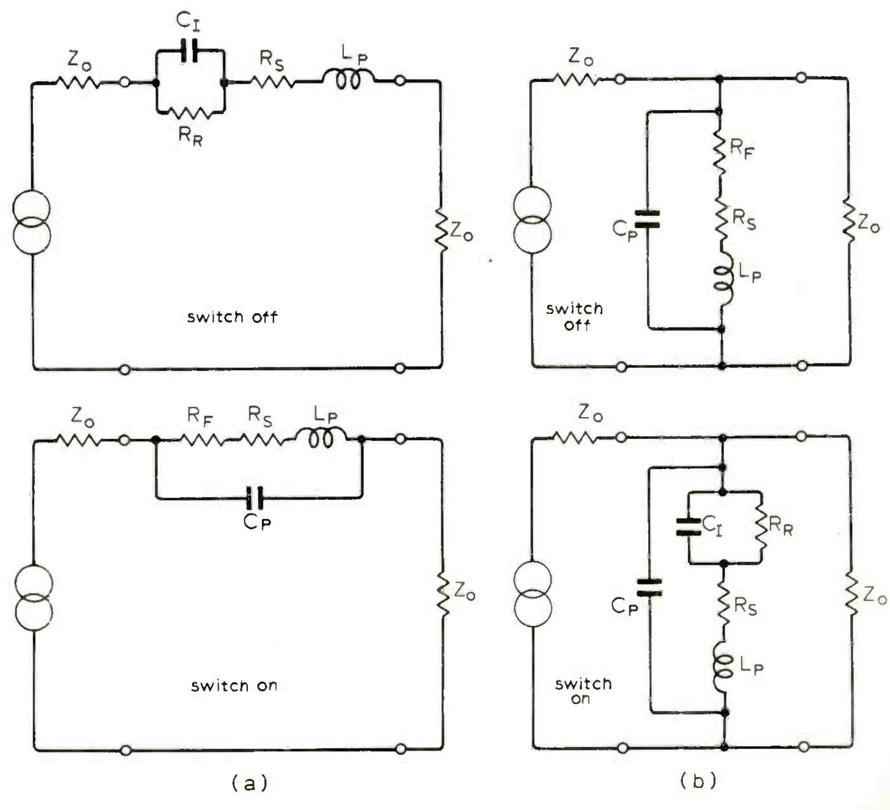


Fig. 5. From zero into reverse bias, junction resistance approaches 10kΩ and in forward bias it approaches the limiting series resistance of less than 1Ω.

Fig. 6. P-i-n diode mountings to control the transmission line impedance and thus microwave power.



insertion loss is $10 \log_{10} [2^2 + 2.5^2/4.5^2 + (2150) + 1] = 0.2$dB. With the switch off under zero bias and again neglecting C_p, $R_F = 10\text{k}\Omega$ and some algebra indicates that the isolation provided is about 24dB.

Junction capacitance degrades isolation by shunting R_F; without it isolation would be 40dB. Ideally, there should be no reactances present and in such a case the diode performance would be independent of frequency. In real life both insertion loss and isolation get worse as the frequency is increased, but the circuits mentioned are termed broadband because the device operates at frequencies well below any circuit resonances. Frequency of operation may be increased and isolation and insertion loss improved by making the p-i-n diode part of a tuned circuit—called a resonant switch.

The idea is to form a high-impedance, parallel resonant circuit when the diode is at zero bias and a low-impedance, series resonant circuit when changing to forward bias. Referring again to Fig. 4, the required conditions are that C_P and L_P be in parallel resonance at forward bias and C_I and L_p be in series resonance at zero bias. Often this can be near enough achieved by proper selection of the diode and package alone, but can also be further tuned by adding some external circuit reactance. The penalty paid for the improved performance is a reduction in bandwidth and there is a direct trade-off between this and isolation.

Typically, resonant switches require bandwidths of less than $\pm 5\%$ and operate at frequencies much higher than their broadband counterparts. The simple circuits of Fig. 6 are single-pole, single-throw switches, but by suitable combinations of shunt and series diodes, it is possible to construct multi-pole, multi-throw devices. If the isolation provided by a single diode is not enough, several diodes can be cascaded, although the bandwidth will be decreased.

As well as their use as switches, p-i-n diodes can be used as attenuators or modulators. If the forward bias is varied at a slower rate than the on/off used for the switch, then the transmission line attenuation can be made to vary accordingly. The power output past the diode can thus be accurately controlled and this attenuator can also be operated on a remote basis, with much saving in complexity over a mechanically varied device.

Not all tube-type r.f. generators like to be supply-voltage modulated with slowly varying waveforms and solid-state devices generally produce large quantities of f.m. noise with anything but a rectangular modulation. The requirement for modulation of some sort in a microwave system is almost always present. Even test gear, for noise and stability reasons, uses a.c. amplifiers at the detection stage with a now-universal 1-kHz bandwidth.

The attenuating or on/off switching is effected mainly by reflecting the incident power back again towards the source, a very small fraction being dissipated within the diode. This is not always acceptable as the reflected power, if allowed to reach the r.f. source, may give rise to instability or even damage. So as a general rule, switches,

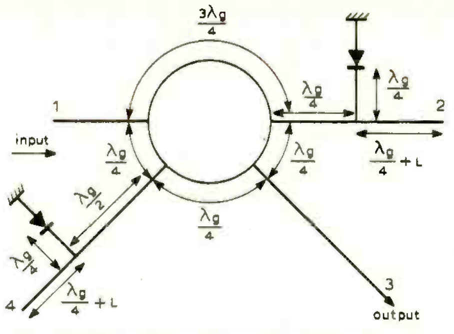


Fig. 7. Hybrid ring phase shifter makes use of directional properties of the coupler and uses p-i-n diodes to switch reactive lengths of line in and out of circuit.

attenuators and modulators are designed into a circuit which presents a constant impedance to the source, regardless of the state of the diode. Such a circuit might consist of a π or T network of diodes, or of diodes connected via a directional coupler or circulator. In these cases, unwanted power is absorbed either within the p-i-n diode or within some terminating load to which it is routed.

Phase shifting with p-i-n diodes

Another important application which makes use of the fast switching ability of the p-i-n diode is that of a phase-shifter. Besides a number of relatively minor applications for which one wishes to shift phase, there is the potential of a large-scale usage for this device in phased-array radar and this has attracted a lot of investigation into the design of low-loss circuits.

Phase shift is produced, not by the diode itself, but by switching additional lengths of transmission line in and out of circuit. If the length of a section of transmission line could be varied at will by a quarter wavelength, for example, the phase of a microwave signal could be correspondingly varied by 90°. The function of the p-i-n diode is to effect this change in line length.

A simple circuit, Fig. 7, illustrates the principle. The d.c. bias lines to the diodes, and the diode details, are omitted. Normally, with no diodes or stub-lines present, an input at arm 1 divides equally at the ring junction; half the power emerging from arm 2, half from arm 4 and none from arm 3. This is evident by summing the different path lengths around the coupler.

To understand the phase-shift circuit, remember that a quarter-wavelength of line acts as an impedance inverter. An impedance measured $\lambda_g/4$ away from its position appears as an admittance. An open-circuit appears as a short-circuit and vice versa.

Referring again to Fig. 7, assume that both p-i-n diodes are forward biased (short-circuit). At the stub junctions with the main lines there appear open-circuits and power flows uninterrupted along these lines.

The half-power travelling clockwise round the ring enters arm 2, where it is reflected back again from the open-circuit at the end of the line and continues round to emerge from arm 3 having travelled a total distance of $2\lambda_g + 2L$. Similarly, the other half of the power in arm 1 combines at arm 3 having traversed arm 4 *en route*, also a distance of $2\lambda_g + 2L$.

If the diodes are zero or reverse biased, the stubs are open-circuited and present short-circuits at their junctions with the main lines. Power will not be reflected back again at these junctions to emerge at arm 3, but after travelling only $1\frac{1}{2}\lambda_g$ in each direction. Thus, switching the diodes between on and off changes the signal phase by $180 + 2L360/\lambda_g^\circ$ and by the appropriate choice of L any phase between 0 and 360° can be produced.

Fig. 8 shows a composite phase shifter in microstrip designed for operation at about 10,000MHz. The two hybrid rings form a 180° and 90° phase shifter and the left-hand circuit is a combined 22.5° and 45° phase shifter. This last-mentioned type of circuit is known as a loaded-line, the amount of phase-shift being a function of the susceptance present at the end of the stubs and the ratio of stub to main line admittance. The diodes are in chip form, mounted on r.f. bypass capacitors and are connected to the 50-ohm lines by 0.001-in bonded wires. Lumped-element r.f. chokes are in the form of spiral inductors.

In a practical circuit such as this, it is essential to take into account the finite size of the diode, the inductance of the bonding wires and the fringing effect from the open-circuit lines. The requirement for dimensional accuracy may be appreciated when one considers that, in this case, a distance along the transmission line of 0.001in corresponds to a phase change of about $\frac{3}{4}°$.

Limiting with p-i-n diodes

The purpose of an r.f. limiter is to attenuate a high-power signal to some safe level and this is generally done automatically, without any d.c. bias. The carrier lifetime of the p-i-n diode is much longer than the period of the microwave signal, so that its impedance cannot follow the r.f. waveform. When mounted in shunt across a transmission line, the forward voltage swing of a high incident power level saturates the i-region with charge, shorting the diode; this charge is not removed on the reverse voltage swing. The average impedance of the diode is thus very low, tending to short the line and thereby reflect most of the power. The response time of the diode before full limiting is several times that of the lifetime so that the diode tends to pass a leading-edge spike of power. On the other hand, the diode can cope with large quantities of power: several kilowatts in L-band (1000–2000MHz).

Varactor diode

As well as a frequency multiplier, varactor diodes can be used to perform the same functions as p-i-n diodes. In the case of the varactor there is no i-region—just a p-n junction. Instead of the junction resistance varying with bias to produce high and low impedance states, it is the junction capacitance which changes to produce the same effect. This capacitance change is not brought about by charge storage as for the p-i-n diode and so the change in state of the

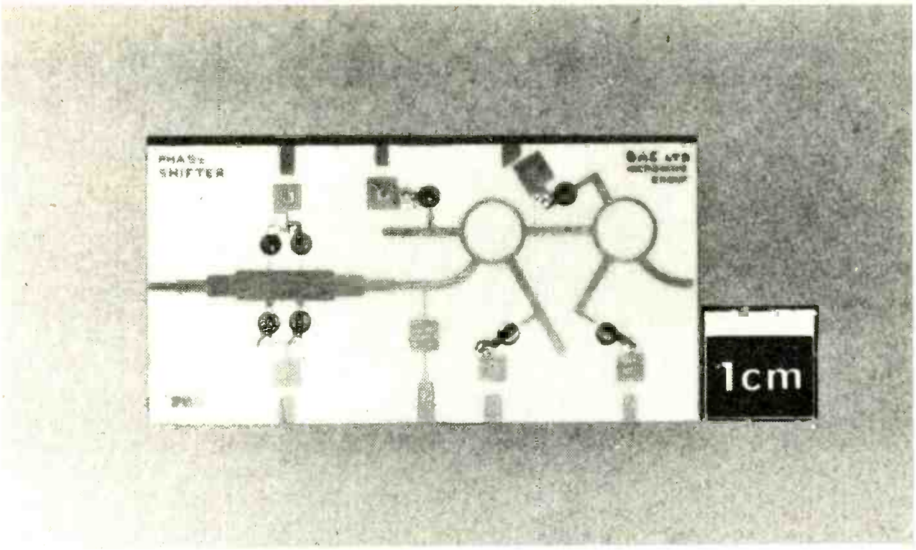


Fig. 8. Four-element phase shifter on 0.025-in alumina consisting of 22.5, 45, 90 and 180° sections which can be switched in any combination. (Thanks to my colleague J. E. Evans for this.)

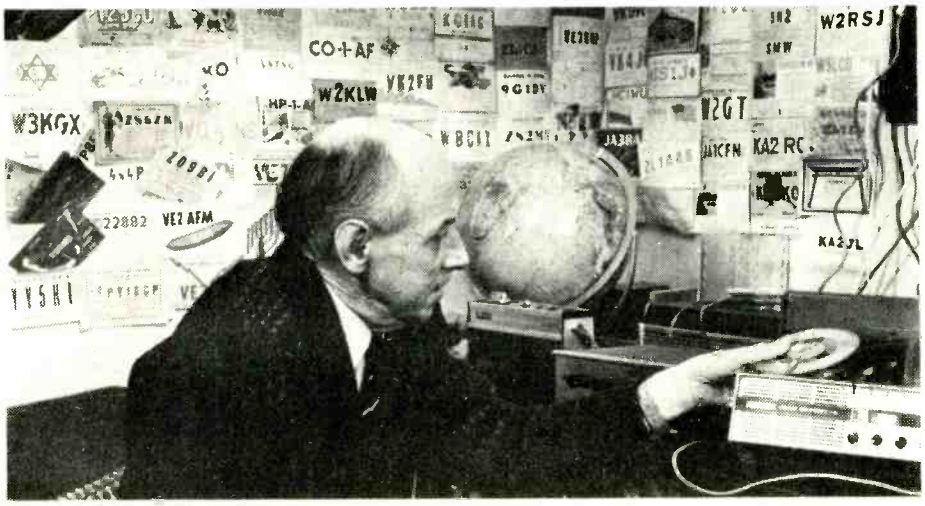
varactor can be made to occur much faster.

In switches, modulators and attenuators, this feature is a disadvantage as the diode impedance is affected by the microwave power level as well as the bias. Power handling is also reduced because of the much smaller junction thickness and the varactor is seldom used in these devices. As a low-power phase shifter the capacitive reactance of the varactor can be used to produce the change in a continuously-varying or analogue fashion, as opposed to the discrete variations with the p-i-n diode.

One of the main applications of the varactor is as a frequency tuner of solid-state oscillators. The diode can either be mounted directly in the resonant circuit of the oscillator or in a separate circuit and reactively coupled to the oscillator. Usually operated in reverse bias, the corresponding increase in capacitance has the effect of making the microwave resonant cavity appear electrically longer than its physical length, thereby decreasing the frequency. Although still restricted to fairly low-power applications, varactor tuning has the advantage of speed over other methods; particularly useful in frequency-agile radar systems where it might provide to local oscillator a.f.c. With careful design, it is possible to tune a 100-mW Gunn-diode oscillator over a 1000MHz range in X band.

Fifty years an amateur

Douglas H. Johnson (G6DW) recently celebrated fifty years of authorized amateur radio transmitting. To mark the occasion, Mr. Johnson gave a party for over 40 people, twenty of them long-established amateurs. Among them was Kenneth Alford (G2DX) who was the holder of a three-letter call sign in 1912 and who was once authorized to use a 2kW spark transmitter!



G6DW in a corner of his "shack", surrounded by a 50-year collection of QSL cards.

Books Received

Guide to Broadcasting Stations, 17th edition, is a guide which covers the subjects of receivers, aerial and earth systems, propagation, signal identification and reception reports. The main body of the book provides information on the long- and medium-wave European broadcasting stations, short-wave stations of the world and European v.h.f. sound broadcasting stations. The information listed is transmission frequency and power, country of origin and programme identification , provided in order of frequency and also geographically. Price 75p. Pp. 201. Butterworth & Co. Ltd, 88 Kingsway, London, WC2B 6AB.

The Radio Amateur's Handbook 1973, is the 50th edition of an American publication which has been revised and updated each year since 1926. In this most recent edition the subjects covering solid-state devices, specialized communication techniques, transmitting and power supplies have been rewritten. Among the revised sections are digital logic devices, toroidal inductors, h.f. aerials, v.h.f. amplifiers and filter networks. Nearly 100 new drawings and charts have been included to help explain all technical facets of communications for the radio amateur. Price $6.00 (limp). $8.00 (hardback). Pp. 692. The American Radio Relay League, Inc., Newington, Connecticut, U.S.A. 06111.

Cybernetic Engineering by John F. Young is aimed particularly at the growing body of people working towards the practical application of cybernetic engineering to the "brain" of robot devices. It presents a critical review of work in this field and considers such problems as conditional probability computers, homeostates, the Lern matrix and the Perceptron. Also considered are the methods of achieving majority logic action, the simulation of nerve cell activity and the importance of such features as probability, inhibition and forgetting in the simulation of animal-like activity. Work on the Astra "associating" machines is reviewed which culminated in the successful Astra Mk 3. After considering future developments of the Astra approach, the theory and practice of information recording, methods of pulse counting in control circuits and applications of this type of work to other fields are discussed. Research and development workers and postgraduate students in the fields of cybernetics, electronics, physics and the behavioural sciences should find this book of great value. Price £4.00. Pp. 153. Butterworth & Co. Ltd, 88 Kingsway, London, WC2B 6AB.

Inter-Noise 72, Proceedings of the International Conference on Noise Control Engineering edited by Malcolm J. Crocker covers the complete papers presented at the conference held in Washington D.C. in October 1972. The subjects covered by the papers range from industrial noise criteria and control to materials for noise control. Price (post paid) $25.00. Pp.565. Editor, Noise/News, P.O. Box 1758, Poughkeepsie, New York 12601, U.S.A.

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

Record equalization

For some time past there has been controversy over what happens at the lower end of the equalization characteristic for records. To humble people such as myself this has caused a good deal of confusion.

Whilst BS1928 calls for a lower time constant of 3180 μsec corresponding to a break point of 50Hz, J. L. Linsley Hood and others advocate the use of a larger l.f. time constant in the belief that some record companies do not provide the requisite boost below 50Hz.

Far be it from me to question these respected people, but surely standards are standards. Everyone I have discussed this with agrees that reproduction with the "extended bass" sounds "nice" and feels cheated when listening to reproduction correct to BS1928. However, does this confirm suspicions that record manufacturers are squeezing the last penny from their budgets through the exclusion of one additional time constant in their equipment, or is it due to an intrinsic liking for bass?

For peace of mind, if nothing else, can someone throw more light on the subject and settle this issue once and for all?

Paul S. Ewer,
Great Bookham,
Surrey.

Audio amplifier design

In his letter in the June issue Mr Linsley Hood asserts that the technique of splitting the h.f. and l.f. negative feedback loops is necessary "to meet the Otala transient intermodulation criterion".

Although a prominent worker in the field, Matti Otala appears never to have published a criterion of transient intermodulation distortion (t.i.d.), and certainly not in the paper referred to. However, this type of intermodulation distortion is of fundamental importance in audio amplifiers.

It must be made clear that t.i.d. in audio amplifiers is an entirely separate subject from that of the overshoot or ringing which may be observed when negative feedback amplifiers are terminated in reactive loads. These effects are solely a function of stability and can, with a good design method, be handled as a totally separate issue.

At no time has it hitherto been suggested that to avoid t.i.d. separate h.f. and l.f. negative feedback loops must be used; in fact this is completely untrue and can lead to t.i.d. being generated.

Mr Linsley Hood does not make clear what he means by h.f. and l.f. feedback loops, but this is of no consequence as the only feedback path which should be considered in an analysis of t.i.d. is the overall negative feedback from the output terminal.

For correct design the only important parameters are the open loop bandwidth (−3dB without feedback), the maximum value of the overall feedback factor and the frequency response of the preceding amplifier section. To minimize the effect of t.i.d. in an audio power amplifier it is necessary that the open-loop bandwidth be as large as possible (greater than 20kHz), to minimize the propagation delay, and that the maximum feedback factor be as low as possible. With current technology this last factor will probably be 10-40dB.

An amplifier with an open loop bandwidth of 10Hz and maximum feedback factor of 76dB will only have, with probable component variations, between 3dB and 8dB of feedback at 20kHz and with usual circuit configurations this can result in comparatively high levels of steady state distortion at high frequencies. Such an amplifier is also likely to generate large amounts of t.i.d.

The lesson is that indiscriminate loop design for feedback need not result in an amplifier which will exhibit low values of steady state and transient distortions.

Turning now to Mr Linsley Hood's reply to my letter in the July issue, I am not satisfied that any of the points have been understood, so for clarity I will summarize:

1. It is shown that the effect of finite input impedance on the closed loop gain (and hence s/n) is not very different in the shunt and series feedback connections. Of course practical amplifiers will have a finite power gain and hence require "input energy", but in both connections this is derived from the input in equal amounts for a given output; anything else conjures up notions of clairvoyant transistors!

2. Of course the *input impedance* of a summing junction can be shown to be $Z_{fb}(s)/A(s)$; however, this is not a "virtual earth impedance capable of generating noise". Otherwise how does the noise rise so much when a 47kΩ resistor is connected in parallel with it?

3. Perhaps I did not make the calculations for the pickup amplifier clear enough; these assume a 600mH + 1kΩ cartridge connected to the amplifier with a 47kΩ input impedance at 300°K and equalized to R.I.A.A. with a closed loop gain of $>>1$ at 1kHz. The results, as are also shown by Mr Walker[2], give s/n of 59dB in the shunt connection and 72dB in the series connection ref. 2mV, 1kHz. Of course the noise is calculated in a 20kHz bandwidth. Who listens to music band limited to 500Hz?

4. Point 3 was stressed because on two occasions Mr Linsley Hood has claimed a s/n of 70dB ref. 2mV for the shunt condition which is below the thermal noise in an audio amplifier of this type, as shown by Mr Craven.

In answer to all this, the discussion can be resolved by two statements:

(i) The s/n ratio of a series feedback amplifier will be larger than that for a shunt feedback amplifier when the source impedance is smaller than the input impedance, and vice versa.

(ii) The problems of distortion in audio amplifiers relate only to good loop design for any configuration and not the feedback connection except in the limit.

J. R. Stuart,
Lecson Audio Ltd,
St. Ives,
Huntingdon.

[1]Otala M. *Trans I.E.E.E.* Sept. 1970.
[2]Walker H. P. *Wireless World*, May 1972.

V.h.f. receiver performance

I was very surprised to read Mr Young's comment on this subject. There are hosts of parameters describing the performance of v.h.f. f.m. receivers, including those by the British Standards Institution "Methods for Expressing the Performance of Radio Receivers — for AM and FM sound broadcast transmissions" No. 4054: 1966; by I.H.F. (Institute of High Fidelity — American) "Methods of Measurements for Tuners" IHFM-T-100, Dec. 1958; by DIN and others.

A v.h.f. receiver cannot be signified in terms of overall performance by a simple "figure of goodness" as there are so many parameters involved in different aspects of the performance. From the sensitivity point of view the I.H.F. usable sensitivity parameter constitutes a searching parameter since it refers the output at 100% modulation to the noise *plus* harmonic distortion of the receiver, the I.H.F. readout (μV p.d.) being for a 30dB ratio. This gives a very good impression of the front-end noise figure, the limiting performance (and hence the i.f. channel design), the symmetry of the f.m. detector, etc. The test also serves to indicate the relative freedom of the tuner from objectional distortion during periods of maximum modulation.

The I.H.F. capture ratio test shows the effect of an interfering signal of the same frequency as the desired signal and thus reveals the performance of the detector, the limiter and a.g.c.

I.H.F. selectivity indicates the inherent "goodness" of the i.f. filters, and takes account of the limiter and a.g.c.

There are other tests, of course, required to appraise the performance of the receiver or tuner in rejecting unwanted signals, such as image rejection ratio, a.m. rejection ratio, etc.

Serious receivers and tuners are fully specified in terms of these (or equivalent) parameters, and it is most certainly possible from these to determine which would be the best receiver under given reception conditions and requirements.

It is agreed that one or two parameters could do with revised attention, one being the input intermodulation/cross-modulation performance, since this is bound to assume greater importance as more v.h.f. stations go on the air, particularly the I.B.A. stations which are not likely to be co-sited with the B.B.C. stations. Thus a high signal field may prevail in a given area due to such a station, while the signal fields from the B.B.C. stations may be insufficiently strong to warrant input attenuation to remove input overloading due to the I.B.A. station!

Clearly, then, it is impossible to say that one receiver is better or worse than another from one parameter alone. Moreover, in certain reception areas, odd reception effects can result from spurious stereo multiplex beats, and these can only be detected conclusively by trying the receiver in the area concerned, so the advice "try it and see" is not as absurd as implied by Mr Young.

Gordon J. King,
Brixham,
Devon.

The Blumlein 4-channel matrix

In three years' time we shall be entitled to celebrate the centenary of the first steps taken on the road to quadraphony. This refers of course to the experiments of Lord Rayleigh in 1876, in which the role of low frequency interaural phase was established.

For matrixing techniques the *locus classicus* (as a colleague insists on calling it) is the November 1971 article in the *Journ. A.E.S.*: "Analyzing Phase-Amplitude Matrices" by Peter Scheiber. In the preamble we read:

"The stereo record or broadcast can be made to carry both left-right and front-rear information by means of matrixing techniques. This *new* possibility. . . ."

The object of the present letter is to demonstrate that not only is this possibility *not* new in principle but that it has an antiquity of some forty years.

The now famous Blumlein stereo patent (394325, 1931) has been an immense source of enlightenment on a wide range of stereo problems. A careful re-reading of the document reveals the following, in connection with a proposal to provide two-directional transmission of a vertical soundplane:

". . . vertical displacement of the source will in this arrangement give phase differences to the outputs while lateral displacements give amplitude differences, and these can be separated, the phase differences converted to intensity differences by modifying networks, as described, and the resulting impulses employed to operate four or more loudspeakers . . . The transmission in such a system occupies *only two channels* up to a point in the system where each of these channels is divided into two parallel channels thus providing four channels in all at this point. Two channels, one from each parallel pair . . . are connected to one modifying network adapted to deal with phase differences, and the other two channels, one from each pair, connected to another modifying network adapted to augment intensity differences. . . .

It will be seen that in such an arrangement the transmission and/or recording may be effected over *only two channels* although directional sensations in two perpendicular directions are subsequently obtained. . . .

The general feature is that two transmitting channels . . . communicate impulses which can be modified and separated to provide two directional senses at right angles to one another . . . by a plurality of loudspeakers."

(page 15 of Complete Specification)

The proposal therefore relies on the possibility of separating amplitude and phase differences to obtain four different signals to feed four (or more) loudspeakers, using appropriate matrixing elements. The basic element for the phase conversion relies on a summing and differencing procedure previously developed in the text, but only for the case of signals of equal amplitude. Consequently, for the arrangement proposed, where both amplitude *and* phase differences may be present, the basic phase conversion circuit described would be effective for only the median vertical axis. Even following the inventor's more general observation that "it may be necessary to employ more complex circuits" we know now that ideally no more than 3 dB of separation would be possible, as is the case with the flanking outputs from an optimum 4-channel matrix.

One must note also Blumlein's tacit assumption that intensity differences are effective as cues for vertical localisation. This assumption could conceivably be circumvented by rotating the soundplane to a horizontal position with the microphone disposed vertically above the centre so as to obtain two mutually perpendicular *horizontal* axes.

Most noteworthy, finally, is the fact that the proposed system is conceived to generate two signals already coded and thus ready for transmission without modification. To this extent, then, it qualifies as a 2-4 system. (Blumlein seems to have been most adept at such devising. In the 2-speaker case his MS system in a similar way produced ready-coded sum and difference signals as an alternative to the AB system with matrixing. And his account of the equivalences between 45/45 and hill-and-dale/lateral is a concise analysis of the coding and decoding potential in stereophonic cutting heads and pickups in relation to an orthogonal groove.)

The more one goes into the matter the greater becomes the conviction that as far as certain basic principles are concerned progress has been more linguistic than material. Thus to say that "our usable matrixing parameters are phase difference and amplitude ratio in the transmission channels both of which may be varied without destroying audible information" is to say very little more than what Blumlein had enunciated. Examples could be multiplied readily. All this leads to the feeling that certain recent claims for novelty are perhaps wider than the circumstances could reasonably warrant, and it would be neither inaccurate nor untimely to say that recent claimants have found the *family* to which Blumlein's lone brainchild belongs.

It is not often that a child is born before its parents!

Is this reason enough for us to deny it?

B. J. Shelley,
Rome,
Italy

Quantity names

Since Mr Baldock (Letters, July 1973) is so modest as to invite criticism of his suggested term "forbiddivity" as the counterpart of permittivity, I would offer two criticisms: forbiddivity is rather anthropomorphic, having more of a connotation of purposive instruction than has the more passive permittivity; it also has a more absolute connotation of total stoppage than the proposed use would justify. Moreover, as a word, it is an abomination!

May I, as a rank outsider, suggest "restrictivity", which has the advantage of being already an accepted English word, and whose restrictiveness appropriately balances the permissiveness of permittivity.

W. B. Broughton,
Animal Acoustics Unit,
City of London Polytechnic,
London, E.C.3.

"Biamplifier" loudspeakers

It is interesting to see how far back the "biamplifier" approach can be traced. The Philco units of 15 years ago, mentioned by Mr. Garland (June issue), are rather young compared to the cinema amplifiers designed in 1934 for use in the B.T.H. sound film equipment. These used two separate output ampliers with an *RC* split at 500Hz before the driver stages to ensure that all the large low frequency signals were handled by a large push-pull stage.

Dual unit loudspeakers were used, the l.f. output from the push-pull stage being handled by a folded horn driven by two 18in. cones. The h.f. output signals above 500Hz were applied to a two-unit straight horn designed to have a cut-off at 200 Hz.

As might be expected there was very little intermodulation of the h.f. signal by the l.f. signals.

Though this design is now almost 40 years old, I believe that it was anticipated by an even earlier design using a split at around 1,000Hz but this was not a B.T.H. product.

James Moir,
Chipperfield,
Herts.

Microphone measurements

It is only necessary to look at a survey of microphones to see the chaotic state of sensitivity measurements.

Sound levels for the measurement vary considerably and are quoted in pressure units. Electrical output may be in mV or odd mixtures based on the decibel. Most of these figures suffer from the severe disadvantage that they vary with the impedance of the microphone.

I would like to suggest a more fundamental approach leading to a much simpler unit of sensitivity.

Sound is a form of energy so, in SI terms, its intensity should presumably be measured in watts metres^{-2} (watts per square metre).

The output of the microphone, being electrical energy, can be measured in watts.

Sensitivity has the dimensions of an area (m^2) which is hardly unexpected. Why then cannot sensitivity or "effective area" be quoted in square metres?

R. V. Hartopp,
Saffron Walden,
Essex.

Current flow symbology

May I say to Mr C. H. Banthorpe (June issue Letters) "more power to your elbow".

As an instructor in radio and television one gets weary of explaining why, if electrons are current and they flow from neg. to pos. in the external circuit, does "this book say current goes from pos. to neg". "Why are there two sorts of current?" "Why is your current different from these notes?" "Why does this book say . . . ?" and so on and so, unnecessarily, blasted well on.

Unnecessary — that is what is so frustrating. If the establishment made the wrong choice in the first place why on earth can it not now be admitted and let's be done with this farce?

Whatever would people think of a jockey and trainer who entered a black horse in a race and described it as "white" so as not to confuse the steward who had got the colours mixed when they first laid down the course rules?

D. V. Ellis,
Waterhouses,
Co. Durham.

I am writing to give wholehearted support to the proposal by Mr C. H. Banthorpe that we drop the use of "conventional" current flow and refer only to electron flow. This has been my practice in both teaching and writing since 1940. I have experienced no difficulties at all in so doing; I am sure that I would have been involved in some horrible tangles had I done otherwise. Those readers who remember the confusion that started with an article in the issue for May 1945 will also probably support Mr Banthorpe.

Roy C. Whitehead,
The Polytechnic of North London.
London N.7.

Since electrical engineering has been using the current flow symbol → (positive to negative) for years, and most text books are written this way it would make students more confused to remove the "conventional" symbol.

What I would recommend is that one should use the following symbol (as I do) for electron flow: ← (negative to positive). There is then no need to write under each ← symbol "electron current" or even "−ve" or "positive current".

The idea will blend in with electrical engineering practice, leaving their → unaltered, and so requiring no alteration to texts; the electron flow ← symbol can then be added for electronic circuits.

A. Parnham,
University of Leeds

Some younger readers may be unaware that C. H. Banthorpe is an editorial invention designed to flush from their holes an aging group of correspondents. When the industry was small, and circuits full of that undoubtedly electronic device, the valve, the change he calls for might, just, have been possible. But now he calls for lots of lovely arrows, depending on whether electrons or holes are the current carriers. Now he calls for a current flow arrow pointing in just the opposite direction to the diode and transistor arrowheads. This dead horse is being flogged up the wrong, over-explored, avenue.

A more satisfactory approach is to give up the electron, which is not a useful concept in passive networks anyway. It has a deplorable habit of sauntering slowly along the wire, and we cannot tell one from t'other. Field is a more realistic concept, and if we use the term "current track" we can forget the nature of the charge carrier altogether. Device makers will need to take it into account, but they are hardly students. Device users can stick to conventional current track symbols.

The most extreme cases I can see for abandoning the electron are the transformer and the gyrator. It is possible to describe gyrator action in terms of electron movement, but I can think of few less rewarding activities.

May I suggest as *Wireless World* policy the setting up of a Libel Defence Fund and the publication of suitably savage reviews of texts which are considered confusing.

Thomas Roddam,
Geriatric Technologists' Home,
London W.8.

Electronics in psychokinesis

I read with interest Dr Stockman's letter "Electronics in psychokinesis" in your June issue as we have been carrying out work on psychokinesis for the last ten years, not only in England but in Russia and Czechoslovakia. Many people have in the past claimed to be able to move compass needles and we have a cine film of a Greek girl apparently accomplishing this feat in 1930.

The most important point is to establish whether the needle has moved because of normal means, e.g. concealed magnets, magnetic dust under fingernails, vibration of table, electrostatics etc. It is more interesting when the entire compass case slides along the table, which I have seen just one month ago in Leningrad. I took a cine film of this which was shown on BBC2 television, in the programme "Leap in the Dark" which also showed my colleague Miss Suzanne Padfield carrying out a psychokinetic experiment on a non-magnetic object.

The compass case in Leningrad was apparently moved at will by a Russian housewife, Madame Kulagina; she has been thoroughly investigated under laboratory conditions, not only by myself but by scientists from the U.S.A., U.S.S.R., Germany, etc., over the last ten years. I myself am a physicist and took with me a variety of equipment to test for the absence of electrostatic and magnetic fields, also any normal means of movement, such as fine invisible fibres. It is of course possible, in principle, to make an entire compass case move by bringing a very strong magnet near to it; the compass needle itself is of course only a small magnet, and if it moves it will carry the case along with it obviously. This is most effectively shown by placing the compass in a plastic dish floating in water, then bringing a strong bar magnet near to the compass. But to make the compass case slide against friction along a rough table top is a much more difficult matter; the field in fact has to be so strong that the needle becomes rigidly fixed in the direction of the field and will not depart from that direction even if the table is kicked. In other words, the presence of such a strong field is immediately betrayed by the behaviour of the needle. Now when I saw the compass case move (in zig-zag fashion) in Leningrad, the compass needle was gently oscillating about 5° on either side of the magnet north, and it was clear to me that only the earth's field was present. Kulagina, as the TV audience saw, is able to move non-magnetic materials under a glass cover, but to my mind this movement of the compass case is the most interesting as the needle gives some indication as to the direction and intensity of the field.

A large s.a.e. to the address below will bring your readers further information free of charge.

B. Herbert,
Paraphysical Laboratory,
Downton, Wilts.

An approach to audio amplifier design

by J. R. Stuart,* B.Sc. (Eng), M.Sc., D.I.C., M.I.E.E.E.

First of a series of three articles in which the fundamentals of audio amplifier design are re-examined, taking account of recent studies in psycho acoustics and circuit techniques. A recent design will be discussed and some experiments related.

In 1883 Lord Kelvin wrote, "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge but you have scarcely in your thoughts advanced to a stage of science whatever the matter may be."

The major difference between a science and any other area of knowledge and thought is that with science, semantic errors can be avoided by reducing all concepts to a numerical form which can give a universally understood meaning, and, most important, allow a value to be predicted which can be experimentally verified.

*Lecson Audio Ltd.

In evolving any theory the investigator is always left with the problem of isolating concepts and parameters, and where there is unusual complexity, as for example in interactions involving human beings, it is made difficult because of the number of ideas that must be involved, and the extreme numerical range that any investigation must produce.

The state of affairs that exists in audio design is that, although certain aspects of performance can be totally described, there is no accepted method which describes the overall performance as judged by the listener.

The ideal situation is one in which the complete audio chain, be it microphone to ear or perhaps record to ear, can be given a figure of merit which relates to its acceptability by a percentage of the population (Fig. 1). However, the problems here are many, not the least that this figure of merit may be time variable due to overall rising standards.

In an earlier article[1] I put forward the idea that subjective sound quality should be considered in terms of things going wrong—that is, a measure of the unpleasantness determined from a weighted sum of critical parameters.

It is fairly well accepted that overall sound quality is not equally disturbed by all the possible shortcomings and it is also accepted that there is a threshold below which a particular shortcoming may not be noticed, at least until one of the others has been improved.

These notions are of fundamental importance to the production of an effective design method, and the implications are that:

1. Linearity and hence superposition cannot be assumed in discussing degrees of aural unpleasantness.

2. The necessity for a compromise of subjective ideals, due to engineering limitations, results in the need to optimize all the parameters in a way that may not coincide with their individual maxima or minima.

In Fig. 2 I have redrawn the simple model which relates sound quality to the mean recording level in a tape recorder; here undesirable effects arise at low levels from noise and at high levels from progressive overloading. The model illustrates intuitively the way in which a trade-off is made and how the best result does not coincide with minima of the dependent variables.

Consider for a moment the record-playing chain of Fig. 3; here some of the variables affecting the final musical impression are isolated. The impression, apart from artistic considerations which can be dominant or destructive, depends on the passing of years t, temperature T, the quality of transduction by the cartridge and its impedance, tracking weight, mass and compliance of stylus. Also included is the amplifier transfer function, loudspeaker transfer function, the absolute level of the signal in the amplifier (e) and loudspeaker (E and P), the room acoustics, sound pressure level, mood m and disposition towards the listening event D. All of this is confused by the fact that the sensitivity to shortcomings in the system or its components is not constant with any individual, or between individuals. Knowing

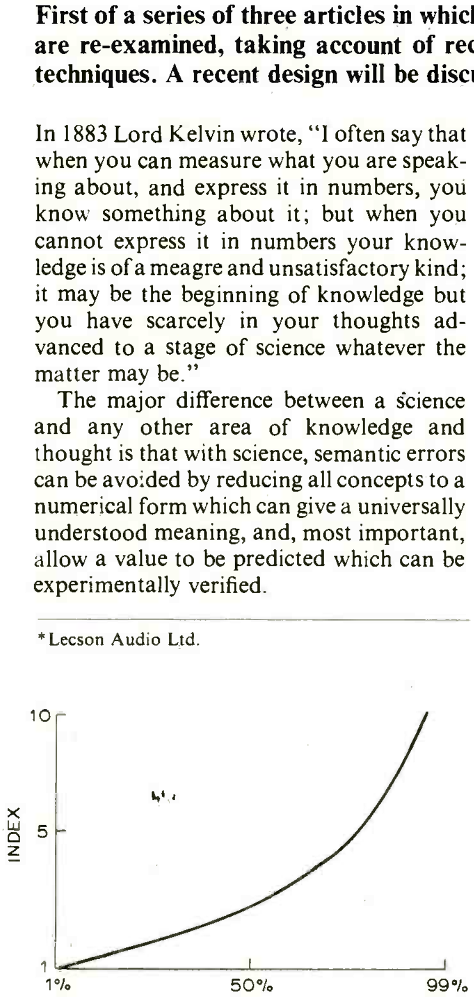


Fig. 1. Percentage population acceptability for more than 95% of the time.

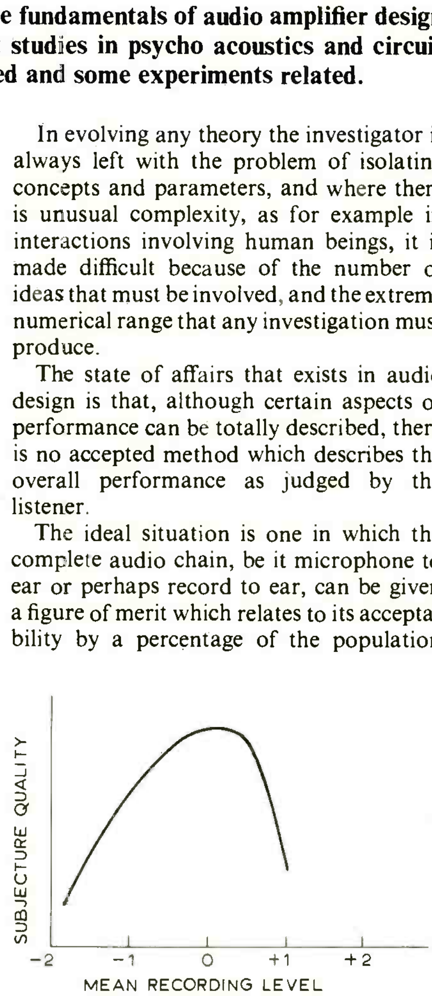


Fig. 2. Subjective quality as a function of mean recording level.

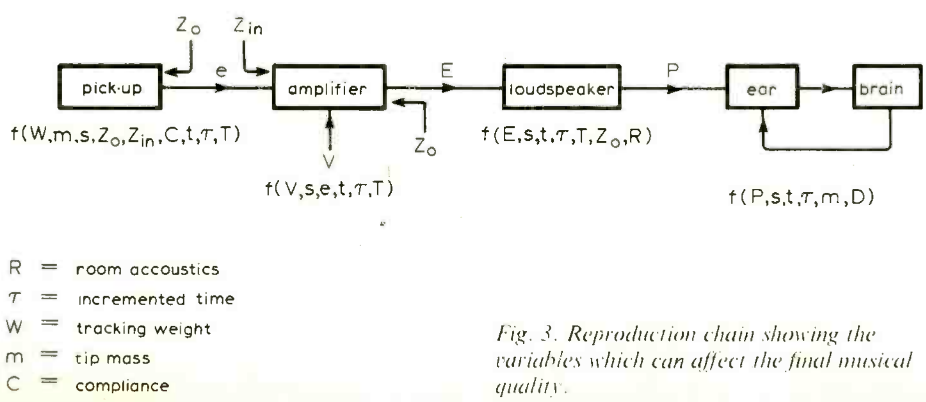


Fig. 3. Reproduction chain showing the variables which can affect the final musical quality.

the techniques of mathematical programming, it is possible to make useful analyses and predictions in problems of just this complexity. In a practical situation there will be a set of constraints which can demonstrate the need for a trade-off between different levels of unpleasant result. Thus a balanced result is obtained from an objective function $O(z)$, which is minimized using the empirical weightings C_α, C_β etc. This is shown in Fig. 4 in a general form. However, it would seem that the real problem is not the availability of tools to produce a design but a serious lack of psychoacoustic data and the consequent agreement on what aspect of it is important.

Constraints	Variables α	β	γ	δ
$A =$	a_{11}	$+ a_{12}$		
$B =$		b_{22}	$+ b_{23}$	$+ b_{24}$
$C =$		c_{32}		$- c_{34}$
etc.				
Min. $O(z) =$	C_α	$+ C_\beta$	$+ C_\gamma$	$+ C_\delta$

Fig. 4 General form of analysis.

When a designer is faced with the problem of producing an amplifier to a price, the most important facts to be established commence with the broad defining specification, and then there is a statement about the trade-off of distortions and other parameters in the chosen configuration. One could perhaps say that total harmonic distortion $D\%$ will reduce according to cost £Z in the following way:

$$Z = a \exp\left[Q \,.\, (D)^{-1}\right] + b \,.\, D^{-2} + c \,.\, D^{-1}$$

where a and Q relate to component cost, b to testing and c to production. Similar relationships could be proposed and tested for all parameters, and interaction analysis will show an overall cost-performance relationship which can in turn be applied to known percentage population preferences. A preference function $p(D)$ representing, for example, the probability that $D\%$ of distortion is detectable by a random population selection could be tested starting out with the form

$$p(D) = \alpha \exp(D - y) \quad D \leqslant y$$

A starting point

So far it has been suggested that a scientific approach is needed to establish for an audio system a figure of merit which can be related to the subjective reaction. Whilst showing that a very complete analysis can be achieved, provided that the correct information is selected and applied, the problems of complexity and variability remain associated with such a project.

It seems that the only road to a useful figure of merit is to accept the concept of "collective subjectivity" as factual and then to attempt to isolate its parameters and effects, assigning, as far as possible, measures of significance.

For example, it would seem reasonable to assume that the first two propositions to establish when discussing any one parameter, e.g. noise, are the level at which it becomes perceptible and the level at which it becomes objectionable—or impossible to neglect. Further work can then substantiate or challenge these results and in addition improve the accuracy of the curve fitting.

In these articles I discuss known parameters relating to amplifier design which can be of significance, attempting to assign to them a degree of importance based on my own work and the work of others. A more complete discussion of the figure of merit concept and a recent design experiment follow. It is not my intention to propose a finalized quality rating, but rather to make a few steps in this direction. At the same time I will point out how such a rating may be derived, in the hope of encouraging new work and discussion on this subject.

System considerations

In contemplating the reproduction of music the ideal is that the sound field, as perceived by the listener, should approach as closely as possible the original event, or at least the balance engineer's version of it.

To recreate a sound field it is necessary to produce all the essential detail of the original acoustic waveform at the appropriate loudness. Now it does seem that an accurate recreation is impossible using loudspeakers, even if they have ideal distribution characteristics. However, it is not possible or necessary in this discussion to consider reverberant sound fields set up by loudspeakers in rooms or the special problems of two or four channel systems.

Consider the problem in its simplest form; the original event is picked up, say, using the dummy-head microphone technique and conveyed through a system to a pair of headphones. In this chain there will be two or four electro-mechanical or electro-acoustic transducers possibly exhibiting non-minimum phase characteristics, resonances etc. It is also possible that the amplifier blocks and other links in this chain will have a historical design approach.

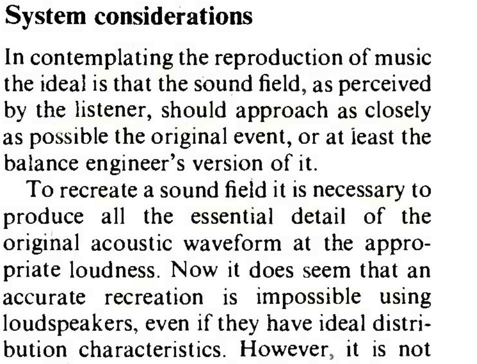


Fig. 5. The energy distribution (in arbitrary units) in an extended musical event.

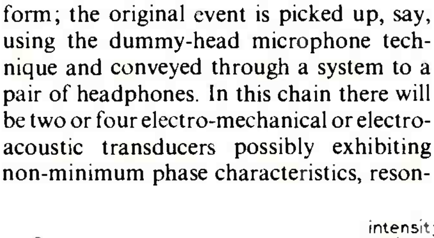


Fig. 6. The effect of frequency range upon the reproduced quality of music.

It seems clear that the criteria will be common for any part of the chain, namely to preserve as far as possible the integrity of the original signal. This implies that the fundamental design criteria be first determined and then applied to every element to ensure success.

Such a conclusion allows a more specific concentration on single elements in the chain, in the knowledge that the general principles derived will be applicable in all instances, provided the correct assumptions are made.

Amplifier design

The current attitude to audio amplifier design is reflected in the DIN 45500 standards, and an amplifier which nowadays would be considered to be very good will have a specification as follows:

1. Output power in excess of 40W each channel.
2. Power bandwidth 20Hz–30kHz ± 1dB.
3. Very low noise and hum, say −80dB.
4. Total harmonic distortion less than 0.1% at all frequencies and power levels in the bandwidth.
5. Intermodulation distortion, however measured less than 0.1%.
6. Low output impedance, say 400mΩ.

The starting point of a truly "scientific" design approach should be to accept the existing requirements, note the areas of weakness and if necessary build up a new design hypothesis.

For me, the practical starting point is that, say, ten amplifiers of different design all with the above specification when compared in a listening test show serious qualitative differences. Given this situation we are now interested in establishing the nature of the differences and from that evolving a figure of merit.

The bandwidth of the ear under the best possible conditions is generally a maximum of 22kHz and since musical events are known to have energy distributions as shown in Fig. 5 it seems reasonable that a system bandwidth of 20Hz–22kHz should be considered sufficient, together with an amplitude response within 0.5dB over this range. Snow[2] described experiments showing how the quality rating he had evolved varied with bandwidth (shown in Fig. 6). From his experimental results, limitation of the bandwidth became objectionable during the whole test cycle when a low frequency cut-off of 1kHz was applied.

It may be that a quality rating based solely on this one parameter is inadequate, but, as I hope to show later, the value of quoting bandwidth as ≈22kHz or >22kHz *per se*, is limited. What can be of overriding importance is the origin of the bandwidth limitation.

A cornerstone of the theory of sound reproduction has been Ohm's Auditory Law which states that the ear tends to analyse the components of a complex sound regardless of their phase relationships. Thus the ear is inclined to operate as an on-line Fourier analyser and this transformation of the waveform is considered to be adequate information.

Twenty years ago the specification for an audio amplifier would suggest that it should amplify all the frequencies of a musical signal equally, without adding any new frequencies. This is, if you like, the credo of the design philosophy based on frequency response and includes the notions of total harmonic distortion (t.h.d.) and intermodulation distortion (i.m.d.).

However, it seems that the "frequency response" viewpoint is very constraining since if one starts out with an idea set in a single frame of reference—in this case the $j\omega$ plane—it is easy to lose sight of the objective. We do not necessarily want to amplify all the frequencies of music equally —especially without regard to phase. What is required is to amplify an audio waveform of acoustic origin in such a way that the ear can detect no degradation.

For many years it has been accepted in audio engineering and psycho-acoustic circles that the ear-brain combination does not perform this frequency analysis in the way Ohm suggested; but rather analyses in terms of the waveform. It has been shown [4,5,6] that the qualitative characteristics of a complex sound depend on the phase relationships of the component harmonics. In fact, more recent work has made it clear that the ear has very specific sensitivities to waveform differences[7,8].

It may be thought that if an amplifier has a response $|F(j\omega)|$ = constant, between 20Hz and 20kHz then it will automatically reproduce all waveforms correctly; however, this is not a sufficient performance description. It is also necessary that the system be minimum phase, making it necessary to eliminate certain all-pass networks in common use. Helmholtz was the first to say that the "quality of musical perception of a complex tone depends solely on the number of partial tones and in no respect on their difference in phase".[9]

As a phase difference must be interpreted as a time delay between the component parts of a signal, it is clear by induction that sufficient phase shift in a system must eventually become audible as a result of moving these components with respect to each other in time. This can be deduced from:

1. The ear's ability to differentiate small time and amplitude differences as confirmed by directional acuity.

2. In practice such large phase shifts as occur in long telephone lines, render speech unintelligible unless phase and delay correction is introduced[10,14].

In addition, recent experimental findings by Madsen[8] are summarized as follows.

1. The ear is sensitive to phase differences between frequency bands.

2. The sensitivity threshold is raised by a factor of three in reverberant surroundings where the sound source is a loudspeaker compared with results obtained using headphones.

3. The ear seems to prefer the frequency content of negative pressure transient wavefronts showing the significance of absolute phase.

4. In listening room conditions using a carefully constructed test signal a 10° phase shift between extreme frequencies was detectable.

Stodolski[7] suggested that an audio system which maintains a 3dB tolerance in amplitude-frequency response should also maintain a 17° tolerance in phase shift; he also showed that a 180° absolute phase error is aurally equivalent to 11.5% intermodulation distortion.

Now whilst it is relatively simple for an amplifier designer to achieve a maximum phase shift of 1° in the audio band with conventional parameters being considered, when I discuss some further aspects of musical realism I will show that it is a more complex problem than that; in addition all sorts of questions are raised about tone controls and filters.

On the basis that it is better to over- rather than under-estimate the acuity of the ear, it seems reasonable in the face of so much experimental evidence to agree that a figure of merit concept should also contain a measure of both phase deviation and phase smoothness. The only remaining problem is to propose the perceptual thresholds.

These arguments tend to convey that the quality of reproduction is principally affected by the accuracy with which the original acoustic waveform is recreated at the ear, but this is a point to return to.

Linear theory shows that in minimum-phase systems the steady-state function $F(j\omega)$ is related to $f(t)$ by the Laplace transform in a specific and simple way. The transfer function of an amplifier is said to be linear when complete correspondence exists between input and output and an important consequence of linearity is that superposition can be held as true.

It is customary and convenient to measure any departure from linearity as the extent to which new frequency components appear in the output of an amplifier, excited by n sinusoids where $n \geqslant 1$. The resulting measurement which is conventionally the r.m.s. sum of these new frequencies will be either t.h.d. for $n = 1$ or i.m.d. $n > 1$.

In 1947 it was suggested[12] that a good design objective was a maximum of 0.1% harmonic distortion since, first, it represented a readily achievable goal which was better than supposed necessary and, second, it left room for a deterioration of performance in service. (It should be pointed out that this objective referred to class A amplifiers using tetrode valves and having a moderate amount of negative feedback.) This level of performance would appear to be high, and in the light of other published work there is no ground for dismissing it. Olsen[13] showed that for reproduced music in a 15kHz bandwidth the levels of distortion necessary to produce the reactions perceptible, tolerable and objectionable were 0.75%, 1.8% and 2.4% respectively, in a system producing predominantly second-harmonic distortion.

However, no one can now suggest that 0.1% t.h.d. is a criterion by which the goodness of an amplifier can be judged: one only has to listen to a signal containing 0.1% 7th or 9th harmonic to realise that this is definitely audible. More recent investigation has shown that the ear is more sensitive to distortions according to their order, that is, 0.1% third harmonic is more significant than 0.1% second, and so on.

D. E. L. Shorter suggested[14] that the best correlation between objective and subjective tests on the order of harmonic distortions was obtained using the weighting $n^2/4$, thus the fifth harmonic would be 6.25 times as significant as the second harmonic. On the other hand, in a very thorough investigation Wigan[15] suggested that a distortion criterion C_t would be better defined as:

$$C_t = \sum_{2}^{n} n^2(p_n - t) \text{ for } (p_n - t) > 0$$

Here n is the harmonic number, p_n the percentage of the nth harmonic and t the threshold harmonic percentage in the experimental conditions. One of the problems of making use of Wigan's criterion is that it is very sensitive to the value of t, which was thought, in his experiments, to be between 0.1% and 0.5%. The two measures converge for values of $p_n \rightarrow t$; however, I feel that for the purposes of this discussion it will be sufficient to use Wigan's weighting with the arbitrary value for $t = 0.1\%$.

It is easy to be led astray at this point. I have said that the ear is sensitive to defects in waveform reproduction, and it is known that amplitude non-linearities can also degrade the sound. Whilst it is convenient to measure the steady generation of harmonics, it need not necessarily be this particular effect which annoys. For example, other measurements which could be applied to quantify the non-linear amplification of a waveform are

1. The "time rate of departure of the signal from normality" as proposed by Wigan.

2. The percentage of time of deviation.

3. The r.m.s. value of deviation.

4. The peak value of deviation.

5. The measurements used in p.c.m. networks e.g. p.a.r.†

However, as far as possible, existing methods of measurement should be used and a starting point established by proposing values for the two thresholds of perception and total unpleasantness of 0.1% and 2% weighted t.h.d. respectively.

So far, no allowance has been made for transient phenomena, and it is in this parameter, perhaps more than any other, that differences between amplifiers can be detected. In deciding how to demonstrate at a *Wireless World* lecture the inadequacy of the basic specification

1. bandwidth 20Hz – 22kHz ± 2dB
2. weighted t.h.d. 0.1%
3. very low noise and hum

the following system was evolved. Linearity and hence superposition suggest that there is no reason why the audio signal should be handled by one amplifier; therefore it was proposed that the signals should be carried by a triple path amplifier, the parallel sub-amplifiers approximately covering the ranges 20Hz–990Hz, 990Hz–1010Hz, 1010Hz–22Hz.

When comparing this amplifier and another, more conventional, one (both were

†Peak to average ratio.

fed into the same very high quality power amplifier) the difference was very marked. The three-band amplifier was horrendous, with voice reproduction sounding as though it had travelled along a metal tube.

However, both amplifiers met the basic specification; my explanation for the result was that the three-band amplifier exhibited a serious transient fault at around 1kHz, the impulse response of the middle amplifier showing ringing and overhang.

This example was chosen to illustrate the inadequacy of the outline specification and is not as exotic as it may first seem. In any audio chain resonance is inevitable and it is usual that more than one be evident at the extremes of the frequency range, although there are exceptions. It is also usual to find that an amplifier will, under some conditions, exhibit a natural frequency ring when excited by an impulse.

To many, the terms transient response and transient performance are synonymous with square-wave performance and it is necessary at the outset to carefully distinguish the point of discussion. In a linear minimum phase network of first order response the rise time t_r in response to a unit step input is completely related to the bandwidth B by $t_r = \frac{0.35}{B}$.

In general the impulse response $g(t)$ can be related to the frequency domain transfer function $F(s)$ by Laplace transformation; therefore, provided the system performs linearly, the rise time of an amplifier can be deduced.

It has been thought that an audio amplifier should be designed to have as fast a rise time as possible ($<1\mu s$). This implies a frequency response extending to several megahertz. When one is faced with the situation of being told that a response to 1MHz improves the audible quality beyond that given by an amplifier having a response to 25kHz, when it is known that the system reproduces signals like Fig. 5, restricted to 20kHz by a 4th or 5th order roll-off, then it is clear that there are other mechanisms at work.

The value of square-wave testing of equipment is that it can show up

1. Frequency, phase and amplitude performance at a glance.
2. Transient misbehaviour, e.g. ringing or overshoots.
3. Slew-rate limiting.

Ringing and overshoots may excite similar problems in transducers or later amplifier stages and are best minimized. In a system which handles square waves in a linear fashion the best response shape to obtain minimal overshoot is also that which has a maximally flat phase response, i.e. the Bessell.

It is in vogue to measure the performance of a power amplifier when it is delivering square waves into a reactive load which simulates a loudspeaker, and the two most common effects noted are slew-limiting and ringing. The ringing gives an indication of amplifier stability and, although there is no agreement whether or not this has an effect on the reproduced sound, it is probably best to avoid it as much as possible.

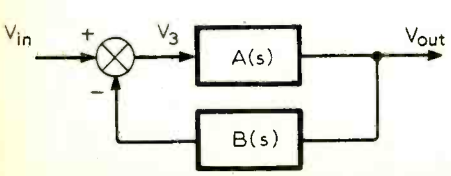


Fig. 7. A feedback amplifier configuration.

Negative feedback

It is a common assumption that all one has to do to produce an audio amplifier is to design any rough old circuit and pull the whole thing straight with negative feedback. In fact this technique could quite possibly permit an achievement of the simple specification which has been evolved so far; although obtaining good distortion figures may not be so easy. Thus to reiterate this specification:

1. Frequency response 20Hz – 22kHz ± 1dB + 10° phase
2. Power 40W
3. Weighted distortion less than 0.1% anywhere
4. Low noise and hum
5. Fast rise-time
6. Low output impedance.

I gain a definite impression that the words hi-fi and negative-feedback are generally accepted as being synonymous, and that enough negative feedback can reduce all undesirable effects. It is well known that using operational amplifier design techniques a t.h.d. of less than 0.002% is quite possible.

Consider the amplifier of Fig. 7. Classical feedback theory states that the gain will be reduced by the feedback factor F, where $F(s) = 1 + A(s)B(s)$. In addition any distortions and noise within the loop will be reduced by the same amount and the bandwidth increased as shown in Fig. 8.

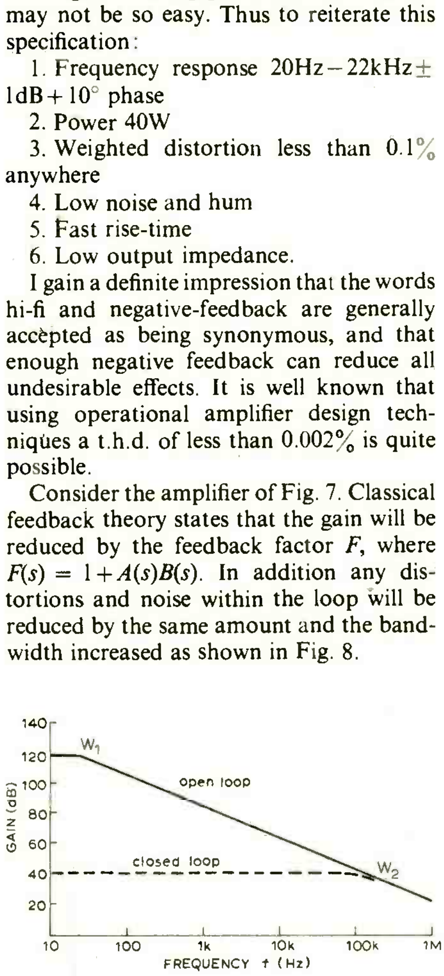


Fig. 8. Bandwidth increase with addition of feedback.

However, as is often forgotten, classical theory makes the following provisos:

1. The transfer function $A(s)$, $B(s)$ must be monotonically continuous and linear, which it is not in the event of clipping or crossover.
2. The feedback must be accurately negative at all times.
3. There must be no forward transfer of signal along the feedback path B.

The immediate implications are that distortion within the loop can only be reduced by the factor $F(s)$ if that distortion is already very small and hence $A(s)$, $B(s)$ does not deviate much from its nominal value.

In addition the theory of stability of negative feedback loops makes it clear that in a practical situation it is not possible for the feedback to be negative at all times, and hence the forward characteristics $A(s)$, $B(s)$ may have a response dictated by stability considerations. We have therefore an indication that negative feedback is not quite the acme first suggested.

Consider, for example, an amplifier of 40dB open loop gain at ω_0 with a 20dB feedback factor. It would be expected that the distortion at ω_0 would be reduced by 20dB or ten times. However, let us consider this statement in more detail. If a distortion occurs on any part of the waveform then v_3, the so-called error signal, will contain frequency components much higher than ω_0, so the effectiveness of the loop in reducing distortion at ω_0 will depend very much on its ability to detect and correct errors at a faster rate than this. Thus an important parameter when designing for low weighted distortion figures would seem to be the open loop frequency response. Two conclusions arise:

1. Negative feedback only reduces distortion by the predicted amount if the feedback is accurately negative and the distortion is very small in the first place.
2. Negative feedback will only reduce distortion at ω_0 by the predicted amount if the open-loop response has not begun to decay by ω_0.

Why do we use negative feedback? The usual reasons are given as a means of accurate calibration and stabilization of gain, to provide an extension of amplitude/frequency response together with linearisation of phase response, a reduction of the effects of open-loop distortion and a way of defining input and output impedances. Admittedly it is a very powerful design tool, but the object of introducing the subject of negative feedback is to discuss its particular shortcomings as judged by the listener.

Scroggie[16] gave a marvellous example of how negative feedback can make matters worse. An amplifier was considered which had a transfer characteristic:

$$V_{out} = 100V_{in} + 100V_{in}^2$$

and with a peak V_{in} of 0.4V this results in 20% 2nd harmonic distortion at a fundamental output of 40V pk. Applying 40dB of feedback reduced the sensitivity, reduced the maximum output to 30V pk and the distortion became 13.2% 2nd, 7.4% 3rd, 3.3% 4th . . . a weighted distortion very much more than 20%! Perhaps the most interesting aspect of amplifier feedback design for audio concerns the performance of the feedback loop under transient signal conditions.

A typical audio amplifier will comprise a pre-amplifier which may have three, four or more stages, of which two will normally have heavy overall feedback in the form of equalisation and tone controls. This is followed by a power amplifier which has a very high open-loop gain; that is, the maximum amount of overall negative feedback to minimize t.h.d.

One consequence of choosing a high overall loop gain is that stability requirements dictate that this gain be rolled off somewhat early in the audio band and it is common for commercial power amplifiers to have the first pole between 100Hz and 4kHz. This is usually effected by lag compensation in the forward path.

Transient intermodulation distortion occurs in amplifiers which employ overall negative feedback over several stages when a large enough signal is presented to the input of the amplifier at a frequency which is above the open-loop break point but is in the audio band. This type of intermodulation distortion occurs because the feedback is not operative during the open-loop rise time of the amplifier. The result is very large overshoots appearing in the error signal and depending on the particular open-loop response and feedback factor. These overshoots can be several hundred times the value of the steady-state error signal. Unless extreme precautions are taken these overshoots will cause clipping or severe overloading of the input at intermediate stages of the amplifier, and the amplifier will produce bursts of 100% intermodulation distortion.

Because the amplifier can be clipped internally, the particular circuit arrangement used can often result in transient intermodulations lasting much longer than the open-loop rise time. This mechanism has been understood for some time[17] and is analysed in some detail by Otala[18]. Figs. 9 and 10 show typical error signals in a power amplifier in response to an input step function. Here the open-loop response is 2kHz and the input is restricted to 20kHz.

It has been shown that the ear is very sensitive to this form of distortion which, in its effects, is very similar to cross-over distortion. The most rapid changes of voltage tend to occur around the zero crossing and both types of distortion produce waveform deviations in this sensitive area[19].

It is interesting that transient distortion has been largely overlooked yet its effects are quite audible. In the third part of this series of articles I will describe some interesting experiments on this problem.

To reduce steady-state distortions to a minimum it has been usual to increase the amount of negative feedback. A consequence of this is that it then becomes necessary to move the open-loop pole to a lower frequency and so inevitably transient intermodulation distortion (t i.d.) becomes more and more likely.

I feel sure that this particular distortion mechanism is as much responsible for the notion of "transistor sound" as any cross-over problems, as it is usual for transistor power amplifiers to have more feedback and lower open-loop bandwidth than the valve counterparts.

The immediate conclusions to be drawn are:

1. Negative feedback has a clearly defined and limited use in audio amplifiers.

2. Attention must be paid to every feedback loop in the system to ensure that it does not produce t.i.d.

3. The power amplifier should have the lowest open-loop bandwidth, so the total system frequency response must be dictated in a controlled way by the pre-amplifier.

4. For ultimate quality, the minimum open-loop bandwidth is 20kHz and only enough negative feedback should be used to reduce steady-state distortions below the psychoacoustic thresholds or until the transient and steady-state distortions achieve the same significance.

In Part 2 I shall continue the discussion of transient distortions and return to discussions of a figure of merit in the context of predictive design.

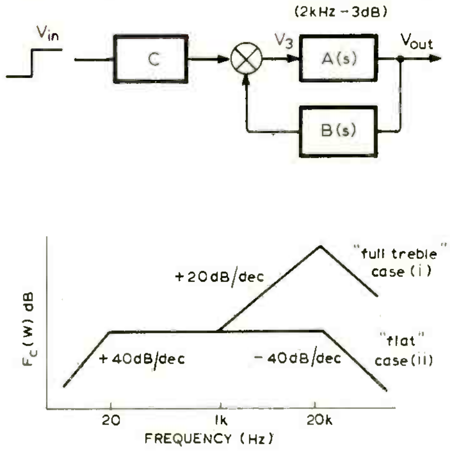


Fig. 9. Block diagram and response of a hypothetical audio amplifier.

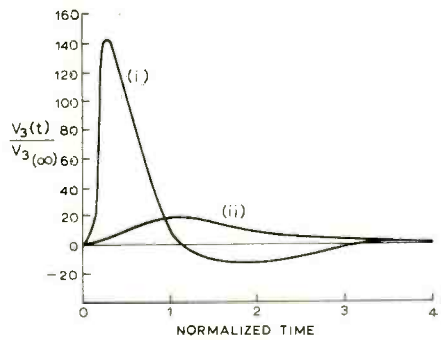


Fig. 10. Error signals produced in the amplifier of Fig. 9 with an input step function.

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Announcements

The first class for the City & Guilds **Radio Amateurs Course** (No. 765) for the 1972-1973 session begins on the 27th September 1973 at the North and West Farnborough Further Education Centre, St. John's Road, Cove, Farnborough, from where course details are available. There is also a Morse proficiency course beginning on 26th September.

The following are **courses for radio and electronics** enthusiasts offered at the Knaresborough Adult Education Centre, King James Road, Knaresborough, during the academic year 1973-74:

Tuesdays, beginning 18th September, "Morse Code For Radio Amateurs"

Wednesdays, beginning 19th September, "Electronics Workshop"

Thursdays, beginning 20th September, "Radio Amateurs Examination Course". All these classes are from 7.30-9.30 p.m. at a fee of £1 per term.

The 1973-74 edition of the annual publication **"A Compendium of Advanced Courses in Technical Colleges"** is available from the London and Home Counties Regional Advisory Council for Technological Education, Tavistock House South, Tavistock Square, London WC1H 9LR, price 70p, by post in the U.K. or from any of the Regional Advisory Councils for Further Education.

QFab Ltd, Milnathort, Kinross, Scotland, sister company to Kepston Ltd, manufacturers of electric resistance atmosphere furnaces, has begun specialization in the production of **magnetic screens** for manufacturers of electronic equipment.

Bosch Ltd, Rhodes Way, Watford, distributors of Uher equipment in the U.K., has announced that **Uher tape recording equipment** purchased in any E.E.C. country and still within the guarantee period offered in the country of original purchase will be accepted for repairs under guarantee.

Datron Electronics Ltd, has announced the appointment of REL Equipment & Components Ltd, Croft House, Bancroft, Hitchin, Herts., as their U.K. sales representatives for the Datron range of instruments, including r.m.s. digital voltmeters and r.m.s. to d.c. converters.

EMI has acquired the **cable television equipment** interests of Thorn Automation Ltd. The Thorn equipment complements the c.a.t.v. product range offered by the Telecommunications Division of EMI Sound & Vision Equipment Ltd., Hayes, Middlesex.

News of the Month

New videotelephone

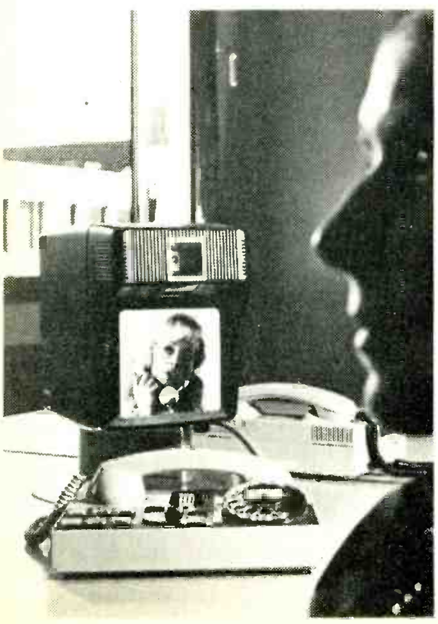
Siemens have introduced a new videotelephone design, "videoset 101", which is now ready for series production. This device is a further development of the first European videotelephone for dial operation, which was presented by Siemens in 1967 and has been in use since 1971 for a trial service between the Deutsche Bundespost in Darmstadt and the manufacturers in Munich. The new videotelephone (see photo) is characterized by a larger screen, improved picture quality and simplified operation. It uses the internationally proposed standard video bandwidth of 1MHz and is fully compatible with the American standard.

Consistent use of the 1MHz bandwidth led to a noticeable improvement of the facilities. The screen, for instance, has been enlarged to 12.8 × 14.1 cm (height × width). The number of lines, 267, gives a resolution at which even small details can be distinguished. For transmission of written texts, for example, a capacity of about 500 characters can be obtained with the enlarged screen area. The field frequency of 60Hz ensures a largely flicker-free picture, even in normal ambient brightness.

The picture unit is rotatable, and its camera section can be tilted by ± 6°. A mechanical scissor aperture permits the use of Plumbicon and silicon-vidicon type camera tubes, as well as the conventional vidicon. With all these types of tubes the automatic aperture control (f = 2.8 to 22), together with the gain control (factor 16), makes it possible to control a wide brightness range with good depth of vision at all stages. An attachment box contains a power supply for the picture unit, as well as a video amplifier, a voice-switched amplifier for hands-free conversation and an associated relay assembly.

The introduction of a videotelephone service in the public telephone network of the Federal Republic of Germany is not expected before 1980. Apart from the audio-visual link between persons and the transmission of graphics, "videoset 101" is also suitable for displaying pictorial information from central microfilm stores. Information services with moving pictures and accompanying sound are an additional possibility.

Siemens' new videotelephone design "videoset 101" which is now ready for series production — see accompanying news item.



Laser communications closer

Bell Laboratories has developed a method for the fabrication of efficient light-carrying glass fibres from a single material. The new, hair-thin fibres are made with the purest known, commercially available glass. Future optical communication systems may use fibres such as these to carry information signals in a manner similar to present-day wires and cables.

The new fibre has shown light loss as low as 5dB per kilometre (50% in 2000 feet). This would allow signal amplifiers to be placed further apart than in land cable systems now in service. Bell scientists expect the new structure to make it possible to take full advantage of the extremely low-loss light-carrying capabilities of ultra-pure glasses.

Today, glass fibres are fabricated with two different materials — one for a very narrow inner region called the core, and the other for a surrounding outer cladding. Light in transit through a glass fibre is kept in the core region by the outer cladding. Until now, fibres made with differing glass materials may have contained undesired impurities that interfered with the passage of light and caused transmission losses.

In one design there are three components to the new fibre: a tube, a solid inner rod, and a supporting plate for the rod. All three are made of the same low-loss glass. The plate bridges the centre of the tube, supporting the glass rod. This configuration is preserved as the assembly is heated and drawn down to the diameter of a human hair.

Background music experiments

The B.B.C. has recently carried out tests on a system for transmitting subsidiary information at the same time as the normal f.m. broadcasts. Tests of the S.C.A. (Subsidiary Communications Authorization) system have been made using a 41kHz subcarrier on the Radio 4 v.h.f. transmission from Wrotham. In order to ensure that any reactions from listeners to the Radio 4 v.h.f. programme should be genuine and not influenced by the knowledge that the tests were taking place, they were not publicized in advance. S.C.A. transmissions, intended chiefly to provide background music in departmental stores and other places, have been broadcast by f.m. stations in the U.S.A. for several years, using a frequency modulated subcarrier in addition to the main mono or stereo programme modulation.

The parameters for the tests were as follows:

Subcarrier frequency — 41kHz

Maximum deviation of subcarrier by subsidiary programme — ± 6kHz pk-to-pk.

Subcarrier programme pre-emphasis time constant — 75μs.

Subcarrier injection (i.e. percentage of total main-carrier deviation allocated to subcarrier) — 7.5% (5.625kHz) later increased to 15% (11.250kHz).

Percentage of total main-carrier deviation allocated to main-channel programme — 85% (with the higher subcarrier injection).

Audio-frequency bandwidth of subcarrier programme — 5kHz.

In the U.S.A., S.C.A. had been established for some time before stereo broadcasting with the Zenith-GE pilot tone system began. The subcarrier, when the main transmission is in stereo, is 67kHz, and from the start of stereo broadcasting in the U.S.A. stereo receivers have been fitted with "storecasting traps" to suppress frequencies around 67kHz emerging from the discriminator. On monophonic v.h.f. transmissions a lower subcarrier frequency can be used, in order to take advantage of the better signal-to-noise ratio which this offers on the S.C.A. programme.

In Europe, stereo receivers have not

generally been equipped with any low-pass filters comparable with the S.C.A. traps in American stereo sets, and it was anticipated that subcarrier broadcasting simultaneously with stereo on the main programme would not be feasible, even on the higher of the subcarrier frequencies used in the U.S.A., because of interference with stereo reception. The tests were therefore carried out using the 41kHz subcarrier. The great majority of listeners to the main channel, including those using stereo receivers, were not affected. The tests did, however, give rise to complaints from some people, using one or other of the stereo receivers having inadequate provision for rendering the decoder circuits inoperative during mono transmissions. The trouble could be removed in most cases by "locking" the receiver to mono.

Reception of the subcarrier programme was found to be rather sensitive to crosstalk under multipath reception conditions. The audio quality was somewhat lacking in treble, but this may have been due to deficiencies in the S.C.A. receivers used for the tests.

When the tests with a 41kHz subcarrier have been fully evaluated, a further series of tests with a higher subcarrier frequency, on or about the 67kHz used in the U.S.A., may be carried out.

Flow-coat mill of Mullard's £10M television picture tube plant at Durham. The equipment in this section of the mill applies a layer of phosphor dots on the face of the tube. The dots provide the blue content of the picture. Similar equipment is used to apply the red and green phosphor dots.

Ceefax tests

The B.B.C. has radiated written information data in a number of out-of-hours test transmissions of the Ceefax TV information data service (see May edition p.222 "TV Information Service"). Subsequently, about 600 questionnaires were distributed and on the results obtained the B.B.C. believe that the experiment should be based on data transmission in television lines 17 and 18 (and the corresponding lines of the other field). In order to minimize any disturbance seen on a conventional receiver, it is proposed to limit the amplitude of the signal to 6dB down on the peak white signal.

Ceramics for control and switching

A new group of ceramic materials employing barium titanate and controlled additives has been developed by the Sprague Electric Co. for use in contactless switching and temperature sensing applications. Some of the new electroceramic devices can control currents as great as 15A at 400V. These switching devices are basically positive temperature coefficient resistors with the special property of switching suddenly from a very low resistance to a very high resistance when the material passes its so-called "Curie point". This may be anywhere from 25° to 125°C and is an inherent characteristic of the specific ceramic composition used.

Future of TV

The establishment of a nation-wide system for the distribution of television programmes by cable would involve a capital expenditure of between £500M and £1,500M (depending upon the system and the number of programmes) according to the Papers of the Technical Sub-Committee of the 1972 Television Advisory Committee. The document states: "There appears to be no physical reason why the project should not be completed in a period of 20 to 25 years, if the public demand for wired services was sufficient to make their provision commercially attractive. The present growth rate of subscribers on cable systems is about 12 per cent per annum." It is unlikely, however, that the growth will continue at this rate because the coverage off-air is of such a high standard in most parts of the country that there are not (or will not be) many places where cable television can offer a worthwhile advantage to the viewer.

The report also covers the subject of future use of the v.h.f. bands for television services. Bands I and III for television services using 625-line definition could be replanned for two programmes, each aimed at maximum coverage (85% of the U.K. population) or one programme could be provided to about 99% of the population using only six channels. The unserved population on the two-programme basis would probably be mainly in the south and east of England. An alternative use would be for local television broadcasting where many choices would be available, ranging from two or three programmes serving the large conurbation to a single programme for a very large number of small population groups. A single national coverage programme serving 99% of the population could be accommodated, together with an additional local service to major conurbations. Alternatively, a single national coverage television programme serving 99% of the population could be coupled with a mobile service using 7MHz of Band I or with an f.m. sound-broadcasting system using 12MHz of Band I.

The report contains the conclusions reached by the technical sub-committee on how far Britain is likely to exploit new broadcasting technology such as cable TV, satellite broadcasting and video-recording in the period after 1976.

Video disc launch at Berlin

The Teldec (Telefunken-Decca) video disc, now called TED for television disc and announced in 1970, will be launched on the market at the 1973 International Radio Exhibition in Berlin. At the last Berlin exhibition (*W.W.* 1971 pages 486–8) the colour version of the disc was announced, but the 21-cm disc only played for five minutes. Now, by increasing groove density to 280 per mm, playing time is brought up to 10 min. A preview of the latest development showed much better colour picture quality than was seen two years ago. Price of the player is expected to be around £170, with discs probably in the region of £1.30.

This year's exhibition, to be held 31 August to 9 September in Berlin, commemorates 50 years of German radio broadcasting, though it now covers entertainment electronics generally. The first broadcast on 15 October 1923 used a transmitter power of 250 watts! (Actually, a fee-charging service started earlier, in September 1922.) The first German Radio Exhibition, held the next year in Berlin, had 250 exhibitors and 114,000 visitors. This year, with the same number of exhibitors, over 600,000 visitors are expected. (Of the 371 firms represented, 147 are foreign.)

A problem with such large exhibitions is finding out who's showing what, and where. To help visitors in this a computer service is provided, with "comptesse"-operated terminals together with viewers and hard-copy printers located at the entrances. The system can say which firms are showing new products (location given), what innovations there are in any of 70 product groups (name, innovation and two features given), where stated firms are (most convenient visiting order given), what innovations there are by a named firm, what historical development of specified product groups was, which events are taking place and where (selected from television and other presentations, concerts, theatre, and others), and which broadcasts provide coverage and programmes about the exhibition. Queries will be analysed to provide information about visitors' interests, needs and motivation. All in all a welcome innovation. But we expect one conclusion will be a need for far more terminals.

Intelsat V satellite

An international team of 17 companies in ten counties has developed and has in operation at the Lockheed Missiles and Space Company plant in Sunnyvale, California, a full scale engineering version of a spacecraft designed as the next generation of communications satellite. The new satellite is privately funded by companies in the team and, if adopted, offers a communications capacity at least five or six times greater than present Intelsat IV satellites (see June News of the Month "New communications satellite").

The added capability will be required during the next ten to fifteen years to keep pace with the rapid growth in international telecommunications. Although growth rates have varied considerably in the past, conservative estimates show that telephone traffic between nations can be expected to increase between 20 and 25% annually during 1975 to 1985.

The major difference between this new satellite and its predecessors is that it will be stabilized in three axes — a technique in which Lockheed have some experience from their military work. This makes it possible to use larger arrays of "solar" cells, similar to the Skylab panels, increasing available power (5 to 7kW) and hence communication capacity. More highly directional aerials can also be used (pointing accuracy 0.16°) and according to Robert Telford, managing director of GEC-Marconi Electronics, one could conceivably get away with 10 to 12ft ground aerials in the 12 to 14GHz band. Existing Intelsat spin-stabilized satellites can only use a third of the solar panels at any one time.

Although the contract, said to be worth $100M, has not yet been awarded — contenders are expected to be TRW, Hughes, Fairchild and possibly General Electric, in addition to Lockheed — the Lockheed consortium are confident enough to have invested $4M so far. Approximately 40% of the contract will be handled by Lockheed, 60% being divided among the remaining members of which GEC-Marconi Electronics — the only U.K. member — has the largest chunk (10%). The Marconi contribution covers horizon sensors (based on the Skylark programme, but new techniques improve positional accuracy to 0.05° in two axes), stripline microwave filters and a computer-controlled automatic check-out system.

Pure metal audio tapes

For a number of years several research establishments have been looking into the possibility of using pure metal micropowders as the magnetic storage element of tape coatings. Indeed there is record of tape having been made using pure iron particles dating back to the earliest days of tape recording.

Modern audio tapes use Fe_2O_3 as the magnetic material in most cases, although two other forms of oxide have been developed for use in the Compact Cassette system. These are cobalt doped Fe_2O_3 and CrO_2. In all these cases a large part of the remanence is derived from shape anisotropy,* although, in the case of the cobalt modified versions, exchange anisotropy** plays a considerable part. Making stable acicular (needle like) particles of suitably small dimensions has not proved too difficult with these oxides. However, the high theoretical values of saturation magnetization possible with pure iron particles cannot be approached in these materials.

The major difficulties in manufacturing suitable pure iron particles lie in their pyrophocity† and chemical instability. These problems appear to have been overcome by Philips Research Laboratories who have just issued a pre-print of a paper describing the properties of a remarkable experimental audio tape based on the use of pure iron particles. This tape, although it requires a bias current about 9dB higher than for Fe_2O_3 has a marked superiority over all other types currently available. At 10kHz signal-to-noise ratio is about 7dB better than CrO_2 tape, using a 70μs equalization. Compared with Fe_2O_3 tapes the improvement is about 11dB when the latter is played via a 120μs equalization.

Apart from the higher coercivity, which requires greater bias and erase currents, the 70μs/3180μs equalization permits the same level of pre-emphasis as for CrO_2, thus ensuring a good compatibility. Even though the experimental tape had a thinner coating than CrO_2, the maximum output level is higher, print-through lower and magnetic stability in humid atmospheres better.

This considerable achievement by the Philips Research Laboratories should be the precursor to some remarkable commercial developments within the next two years.

* Shape anisotropy: Crystalline magnetic particles display a preference for being magnetized in particular directions. In an acicular particle this is usually along the long axis. Such behaviour is called shape anisotropy.

** Exchange anistropy: Occurs in oxide coated metal particles and is an interaction of electron spins at the boundary between oxide and metal causing a lateral displacement of the *B-H* curve.

† Pyrophocity: Property possessed by certain substances or fine particles of spontaneous combustion.

Radar plus laser for landing system

A new laser system that will be teamed with a radar to provide increased precision in evaluating automatic landing systems for aircraft is being designed and built for NASA, the U.S. space agency, by RCA's Missile and Surface Radar Division. The combined laser-radar system will track aircraft at both low altitudes and long ranges. It will be used initially as part of an experimental runway facility at NASA's Wallops Station in Virginia.

Called the Laser Tracking System, the device will provide improved capabilities in detecting and following low flying aircraft and can also be used as an automatic radar calibration aid. The laser system will operate at optical frequencies instead of in the microwave range used by conventional tracking radars. The narrow laser beam will permit the tracking of aircraft flying at very low altitudes since it is not subject to the low altitude microwave tracking problems of distortion and interference from mountains, trees, tall buildings and other obstacles. The system will be able to track aircraft equipped with special reflectors at distances beyond 20 miles under clear atmospheric conditions. The reflectors will be mounted in small, lightweight assemblies attached to the aircraft. The laser system includes its own, separate range tracker, as well as laser angle detectors to provide signals for driving the radar aerial pedestal.

Briefly

A radio service for yachtsmen has begun a six-month trial. The Post Office's 11 coastal radio stations will broadcast any urgent business or personal messages immediately following the morning and evening weather forecasts.

Calculators for Japan. Sinclair Radionics are to export more than 80,000 "Executive" pocket calculators to Japan. The order is valued at £750,000 — a remarkable feat.

Surprise!

You surprised us with the overwhelming demand for our new DM1 digital multimeter—which far exceeded even our optimistic expectation.

An Apology.

The result is that many of you who have placed orders have had to wait an unacceptably long time. For this we apologise.

All present orders will be fulfilled by the end of August and shortly after we hope to supply from stock.

To remind you that the Sinclair DM1 is worth waiting for here are its salient features.

Battery operated from a standard 9v throw away radio battery to give a service life of months—quite independent of mains supply.

Light in weight—only 1lb. 6oz. with battery. A compact transistorised truly portable instrument.

Robust with its tough and practical plastic case designed to put up with rough handling.

Accurate—basic accuracy of 0.4% of reading ± 0.2% of range on 1v DC.

Convenient to use with digital readout shielded within a recess to avoid the reflection of ambient light, brightness adjustment, and two clip probes.

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Guaranteed for twelve months.

All at a price of £49

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WW—067 FOR FURTHER DETAILS

The Sinclair Cambridge... no other calculator is so powerful and so compact.

Complete kit–£29.95!

(INC. VAT)

The Cambridge – new from Sinclair
The Cambridge is a new electronic calculator from Sinclair, Europe's largest calculator manufacturer. It offers the power to handle the most complex calculations, in a compact, reliable package. No other calculator can approach the specification below at anything like the price – and by building it yourself you can save a further £14!

Truly pocket-sized
With all its calculating capability, the Cambridge still measures just $4\frac{1}{2}$" x 2" x $\frac{11}{16}$". That means you can carry the Cambridge wherever you go without inconvenience – it fits in your pocket with barely a bulge. It runs on ordinary U16 batteries and gives months of life before replacement.

Easy to assemble
All parts are supplied – all you need provide is a soldering iron. Complete step-by-step instructions are provided, and our service department will back you throughout if you've any queries or problems.

The cost? Just £29·95!
The Sinclair Cambridge kit is supplied to you direct from the manufacturer – you can't get it anywhere else. Ready assembled, it costs £43·95 – so you're saving £14! Of course we'll be happy to supply you with one ready-assembled if you prefer – it's still far and away the best calculator value on the market.

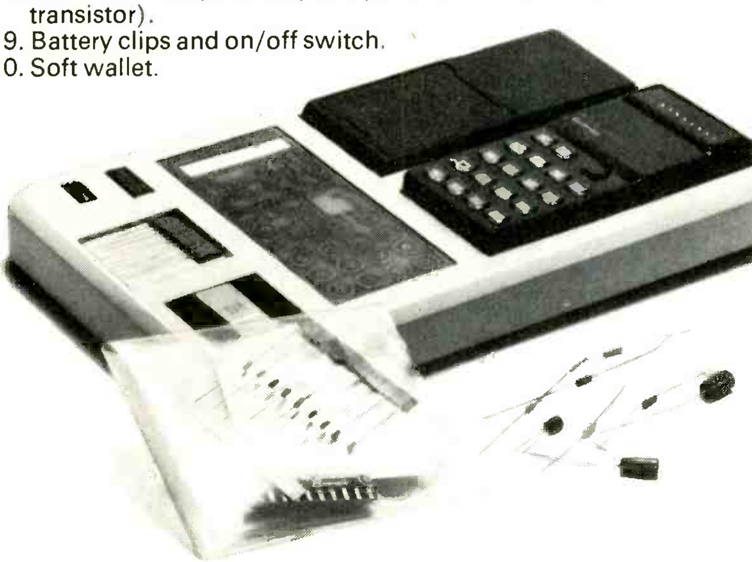
Features of the Sinclair Cambridge

- Uniquely handy package. $4\frac{1}{2}$" x 2" x $\frac{11}{16}$", weight $3\frac{1}{2}$ oz
- Standard keyboard. All you need for complex calculations.
- Clear-last entry feature.
- Fully-floating decimal point.
- Algebraic logic.
- Four operators (+, −, x, ÷), with constant on all four.
- Constant acts as last entry in a calculation.
- Constant and algebraic logic combine to act as a limited memory, allowing complex calculations on a calculator costing less than £30.
- Calculates to 8 significant digits, with exponent range from 10^{-20} to 10^{79}.
- Clear, bright 8-digit display.
- Operates for months on four U16 batteries. (Replacement set costs about 15p.)

A complete kit!

The kit comes to you packaged in a heavy-duty polystyrene container. It contains all you need to assemble your Sinclair Cambridge. Assembly time is about 3 hours.

Contents:
1. Coil.
2. Large-scale integrated circuit.
3. Interface chip.
4. Thick-film resistor pack.
5. Case mouldings, with buttons, window and light-up display in position.
6. Printed circuit board.
7. Keyboard panel.
8. Electronic components pack (diodes, resistors, capacitors, transistor).
9. Battery clips and on/off switch.
10. Soft wallet.



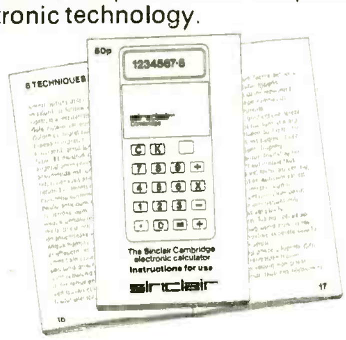
Actual size!

4½in long x 2in wide x $^{11}/_{16}$in deep

This valuable book – free!

If you just use your Sinclair Cambridge for routine arithmetic – for shopping, conversions, percentages, accounting, tallying, and so on – then you'll get more than your money's worth.

But if you want to go even more out of it, you can go one step further and learn how to unlock the full potential of this piece of electronic technology.



How? It's all explained in this unique booklet, written by a leading calculator design consultant. In its fact-packed 32 pages it explains, step by step, how you can use the Sinclair Cambridge to carry out complex calculations like:

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The Sinclair Cambridge is fully guaranteed. Return your kit within 10 days, and we'll refund your money without question. All parts are tested and checked before despatch – and we guarantee a correctly-assembled calculator for one year.

Simply fill in the preferential order form below and slip it in the post today.

Price in kit form: £27·23 + £2·72 VAT. (Total: £29·95)
Price fully built: £39·95 + £4·00 VAT. (Total: £43·95)

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*I enclose cheque for £________, made out to Sinclair Radionics Ltd, and crossed.

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WW—068 FOR FURTHER DETAILS

Complementary m.o.s. Integrated Circuits

Properties, circuits and uses of c.m.o.s. with particular reference to hybrid a. & d. circuits

by P. A. Johnson, M.Sc., Grad.Inst.P.

Complementary m.o.s. logic circuits distinguish themselves from other logic families in their versatility. A standard threshold gate can operate at 10MHz with a power consumption similar to t.t.l., or at 1kHz with a consumption of 1μW. Low threshold versions will operate at 1.5V with 1/30 of the 10-V dissipation and still reach 1MHz —about the same as p-m.o.s. but with 1/100 of its power. Degree of integration is limited only by silicon area, not by power, and major savings are possible in power supplies.

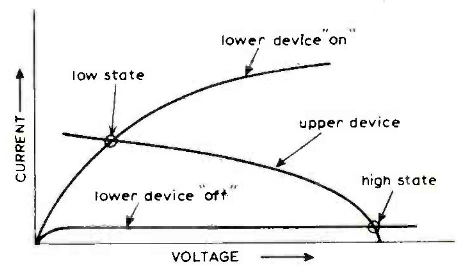


Fig. 1. Load lines of a p-m.o.s. inverter (Fig. C) intersect at a high-current point leading to significant power dissipation, around 10mW, with the lower device on. Complementary m.o.s. devices avoid this.

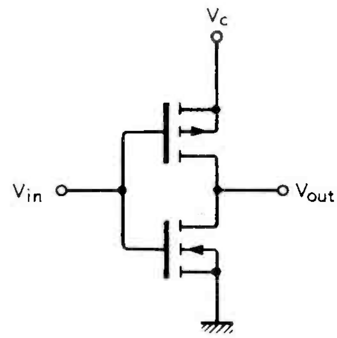


Fig. 2. By using both p- and n-channel devices in a complementary way the high power consumption of the p-m.o.s. inverter is arrived.

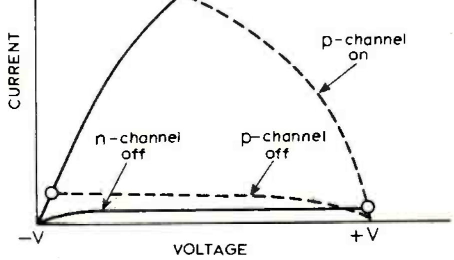


Fig. 3. Load lines of c.m.o.s. device show power dissipation to be low—says 10nW per gate—in both on and off states.

In a p-m.o.s. invertor the upper device presents a fixed non-linear load to the lower device which may be on or off according to the gate potential. (Circuit is shown in Fig. C on page 396 and the corresponding load lines appear in Fig. 1.) With the lower device off, supply consumption is negligible as the off impedance is typically 5000MΩ. With the lower device on, however, the load lines intersect at a high current point leading to a significant steady power consumption. To minimize consumption, a separate supply is often used for the load device gate. The order of power consumption in the on state is 10mW.

Using a complementary load—Fig. 2—allows considerable improvements to be gained. By connecting the n-channel source to the negative supply, the p-channel source to the positive supply, the drains together, and the gates together the c.m.o.s. logic invertor is obtained. The load lines are shown in Fig. 3. When the input is at the negative supply potential, the n-channel device is off, hence appears as 5000MΩ at the drain. The p-channel device is turned on, offering a resistance of typically 1kΩ at its drain. The output point is thus virtually clamped to the positive rail. Similarly, with the input at the positive rail potential, the n-channel device is hard on, and the p-channel device cut off. The power consumption in either state is of the order of 0.01μW per gate i.e. 100,000 gates would idle off 1mW. The fact that one device is fully on, and the other cut off leads to few tolerance problems, and permits a very wide operating temperature range.

The dynamic behaviour of the gate may be understood better by referring to Fig. 4. As the gate potential is raised above the negative rail, no supply current flows until V_t of the lower device is reached. As the gate potential increases the turn-on of the lower device is dominant, causing the output potential to fall, and the supply current to rise. When the output is about midway between the rails, turn-off of the upper device becomes dominant and the current diminishes in a similar pattern until it reaches zero at the threshold V_t of the upper device.

For a low supply voltage, at no point are both the devices well above threshold, hence the peak current for a 5-V supply, Fig. 4(a) is only 13μA. For a 15-V supply on the same gate Fig. 4(b), the peak current is 1.5mA and the range of gate potential over which the output is changing is also considerably widened. The current peak falls to zero height if the supply is set to the sum of the thresholds, but the invertor may still be used with a supply voltage only just greater than the larger threshold of the two, though the speed is very low. In this case with an intermediate gate voltage, both devices would be cut off.

As modern fabrication techniques can result in thresholds well below 2V, standard logic families may be made running off supplies as low as 3V, and special purpose devices will operate from voltages as low as 1.3V. If a complementary invertor is run from a 5-V supply, the off-device behaves as a resistance of 5000MΩ, hence a leakage current of one nanoamp flows. Because the on-device has a resistance of 1kΩ, an offset voltage of the order of μV is generated. When the output state is low, it is clamped to the negative rail, and when high it is clamped to the positive rail. Inspection of Fig. 4(a) shows that the output of a gate only changes significantly for V_{in} = 2 to 2.6V, hence the noise immunity of the gate is 40% of the supply voltage.

Well-regulated power supplies are quite unnecessary, and operation from rectified mains with simple R,C smoothing is satisfactory. The chief effect of varying supply voltages is to modulate the switching speeds of the gates. The input to the basic invertor is insulated from the channels and has a resistance of $10^{12}\Omega$, with a parallel capacitance of 5pF. For low-frequency operations, the number of inputs which may be run from one output, its "fan out", may be regarded as essentially unlimited. For high speed systems it is limited by input capacitance to around 20. To avoid failures due to destructive breakdown of the gate insulation, possible with such high impedances, nearly all gate terminal have protection diodes which are reverse biased during normal operation, but which clamp voltage spikes during handling, installation and operation to safe values.

When the input of an invertor is changed from one state to the other, it swings through the region in which both devices are on, and for a short time current is drawn from the supply. If the output is connected to further logic elements which have input capacitance, the voltage swing requires supply or removal of charge which must pass from the supply through the first invertor. The power consumption of a gate therefore tends to be proportional to the frequency of switching, and proportional to the load capacitance, a typical value being 1μW at 1kHz from 10V.

Logic gates

A section through the complementary transistors required for its implementation is shown in Fig. 5. An inverted tub of p-type material is diffused into an n-type substrate; then diffusions of opposite polarity impurity are used to produce complementary devices.

NAND and NOR gates are simply constructed and are complementary to each other. In the case of the NOR gate, if one input is high, then one of the series transistors in the upper arm is on, hence the output is guaranteed to be low, regardless of the other inputs. If all the inputs are low, the upper arm contains only on transistors in series, the lower arm being a set of parallel off transistors, thus ensuring that the output is high.

The arrangement of transistors may be extended to virtually any number of inputs.

In the case of the invertor, the input was connected to the gates of complementary transistors, resulting in one being on and the other off. If a complementary drive voltage is generated and used as shown in Fig. 6, the transmission gate is achieved. Opposite polarity control signals are applied to the gates, and when the one transistor is on the other is also on. The input and output are connected by two parallel on devices equivalent to about 1kΩ. If the input voltage moves towards the positive rail, the upper

Introducing m.o.s.

The first really important active semiconductor device was the junction bipolar transistor. When the techniques for making discrete transistors was mastered, work was extended to fabricating many transistors on one semiconductor chip. The fruits of this work were firstly diode-transistor logic and subsequently transistor-transistor logic. These families suffer from three of the basic defects of the bipolar transistor.

Firstly, the finite current gain of the transistors requires a steady current consumption even when no information is being processed. Secondly, the maximum useful frequency f_T at which the transistor current gain (common emitter) is unity diminishes rapidly at low currents. Individual logic gates must operate at 2mA to follow rapid input transitions. Dissipation is reduced by lowering the supply voltage as much is practicable, but at 5V, the value often adopted, dissipation is still significant, and complex logic functions executed using many gates on one chip often become dissipation limited. Another defect is that under saturated conditions, charge is stored in the base region of the transistors in excess of the normal value, and switch off is delayed, significantly reducing operation speed, unless special provisions such as the use of Schottky diodes are made.

The junction f.e.t. has the advantages over bipolar transistors of showing no storage effects, being a majority carrier device, and has essentially infinite current gain, giving potentially very low power consumption. It requires negligible power to drive it as long as the gate junction is reverse biased. The main failing of the junction f.e.t. is the gate conduction with forward bias. A logic element may not therefore be easily constructed by using direct coupling because the gate electrode is outside of the range of the source and drain potentials.

Insulated-gate f.e.ts work by the modulation of a conducting channel by means of an insulated gate terminal (Fig. A). Such transistors exist both as depletion types which like j.f.e.ts conduct with zero gate-source bias, requiring reverse bias to cut them off, and also as enhancement devices which are cut off at zero bias, and with low forward bias until a threshold voltage V_t is reached, beyond which current flows.

Gate and drain characteristics for a typical n-channel enhancement insulated gate f.e.t. is shown in Fig. 4. With zero bias the n^+ source is electrically isolated from the n^+ drain by p-type material between. When a voltage greater than V_t is applied to the gate, an inversion layer forms under the gate which behaves as n-type material and provides a conducting path between source and drain. An increase in the forward gate bias extends the inversion layer farther into the p-type substrate, providing a larger crosssection of channel for increased current flow. The typical Z_{in} is 10^{12}ohms.

As such devices were first constructed using a metal gate electrode insulated by a layer of silicon oxide, they have unfortunately come to be known as m.o.s.f.e.t.s, (from Metal Oxide Silicon Field Effect Transistors). Neither the metal gate which now is often replaced by conducting silicon, nor the silicon oxide insulator, which is sometimes replaced by silicon nitride, is an essential part of an i.g.f.e.t. If such are equipped with suitable resistive drain loads, and run from a single d.c. supply greater than V_t they may be directly coupled as shown in Fig. B to perform logic or linear functions.

The simplicity arises from the drain voltage swing being in the same region as the swing required on the gate, a feature not offered by j.f.e.ts. The circuits still suffer from the disadvantage of requiring continuous current consumption in one stage to hold the following one off. The basis of a high proportion of m.o.s. circuits is similar to Fig. B, using p-channel transistors throughout, and using active loads made of further i.g.f.e.ts, rather than resistors (Fig. C).

The final stage of evolution of a new family of circuits exploits the use of complementary devices. The polarity of the i.g.f.e.t. may be reversed by using p^+ source and drain, and an n-type of substrate. The resulting p-channel device requires a negative drain and gate potential.

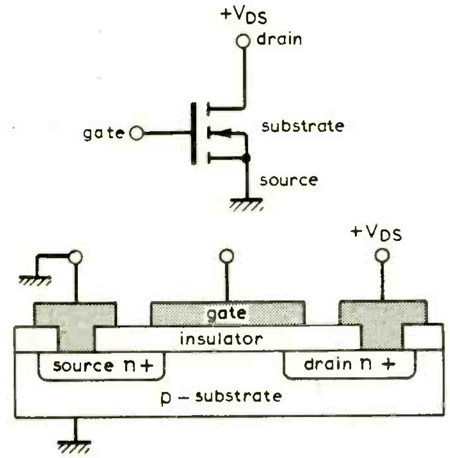


Fig. A. Insulated-gate (m.o.s.) f.e.ts that work by modulation of a conducting channel can be either a depletion type—conducting with zero bias—or an enhancement type—cut off with zero bias. Illustration shows an n-channel enhancement device.

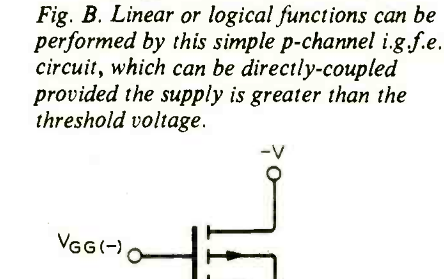


Fig. B. Linear or logical functions can be performed by this simple p-channel i.g.f.e.t. circuit, which can be directly-coupled provided the supply is greater than the threshold voltage.

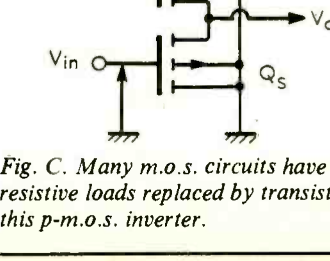


Fig. C. Many m.o.s. circuits have the resistive loads replaced by transistors, as in this p-m.o.s. inverter.

transistor turns on harder because its V_{GS} increases, but the lower one increases in resistance because its V_{GS} decreases. The net effect is to have a low resistance roughly independent of the input voltage. If the control input is raised to the positive rail, both transistors are cut off, behaving as a very high resistance (1000MΩ) in either direction.

This device may be used with a capacitor for dynamic storage within logic elements, or in analogue multiplexing circuits. The invertor may be used as a linear amplifier as opposed to a logic element, though it loses its low standby power consumption. At supplies slightly in excess of the sum of the n- and p-channel transistor thresholds, the voltage gain is very high since the input voltage change required to swing from one device cut off to the opposite one cut off is small, but the output swings by the supply voltage. Output impedance is also very high, hence operation in this area is limited to low frequencies.

The sharpness of the transfer characteristic is evident from Fig. 4(a). An increase of supply voltage from 5 to 15V increases the change of input necessary to change from one transistor threshold point to the other as shown in Fig. 4(a). The gain is therefore significantly lower, but the output impedance is very much lower.

The invertor may be easily biased for linear operation with one resistor, Fig. 7. The use of invertors and gates as linear amplifiers is useful for relaxation oscillators and for low voltage systems such as electronic watches which require crystal oscillators. RCA have introduced a linear circuit element like this, but it is limited in usefulness for the reasons given.

One effect which must be taken into account in some linear and switching circuits is substrate degeneration. The basic characteristics of both types of i.g.f.e.t. are measured with a connection between source and substrate. In most digital gates the on devices have this connection effectively made. If the substrate of an n-channel i.g.f.e.t. is biased one volt negative with respect to the source, the gate threshold increases by nearly a volt. The effect is much less pronounced in p-channel devices due to the differences in material constants. It may become particularly serious for an n-channel device with a normal threshold of, say, +1V. If it is desired to bias the source at +4V, with the substrate at 0V, the threshold voltage on the gate would be approximately +8V. The substrate also may interfere with circuit operation by clipping when the drain-substrate isolating junction becomes forward biased. The choice of substrate bias potential must be made according to these two conflicting requirements.

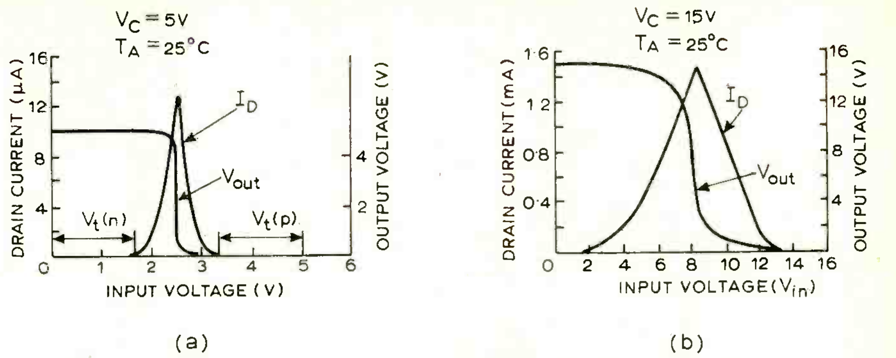


Fig. 4. For a low supply voltage at no point are both devices well above threshold, so peak current is only 13μA (a). But for higher supply voltages peak current can be much higher (b).

Fig. 5. In making a c.m.o.s. device p-type material is diffused into an n-type substrate, followed by diffusions of the opposite polarity.

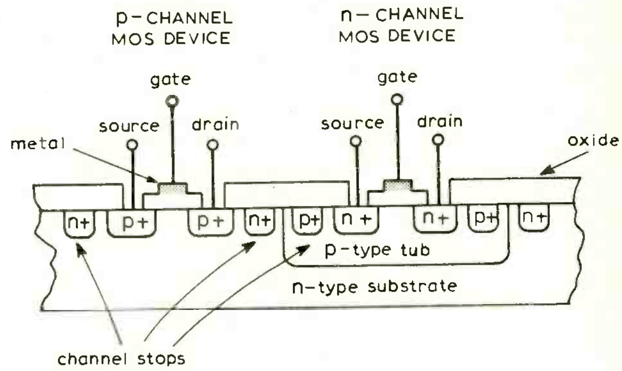
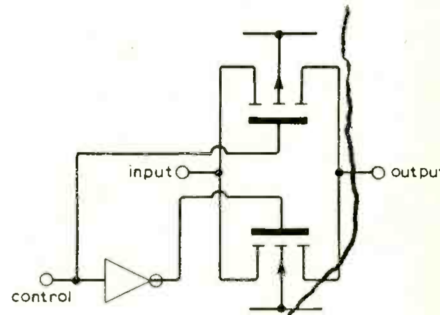
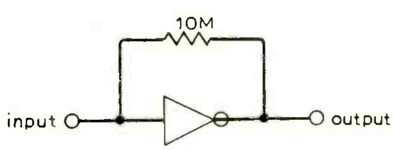


Fig. 6. In the transmission gate an inverter must be used for the drive to one of the devices to get both devices on.



control	$R_{in} - R_{out}$
0	1kΩ
1	>10⁹Ω

Fig. 7. Inverter circuit is biased for linear operation by a single resistor.



Applications for c.m.o.s. elements

The chief characteristic of this family of circuits which distinguishes it from nearly all other logic families is its versatility. It can be run up to more than 10MHz, with t.t.l. levels of power consumption, or at 1kHz with less than 0.1μW. It can run from supply rails as low as 1.3V or as high as 18V, with noise immunity up to 7V. In practical systems, even though the clock frequency may be high, the power requirement is often low enough to permit major savings on power supplies leading to a lower total cost system. Degree of integration is limited only by silicon area and yield, not by power.

A comparison of powers for various logic families is shown in Fig. 8. The standard threshold gate will reach 10MHz for a similar power consumption as t.t.l., and will idle at less than 1μW. The low threshold versions will run at 1.5V with 1/30 the dissipation of standard threshold at 10V, and still reach 1MHz, about the same as p-m.o.s., but with 1/100 of its power.

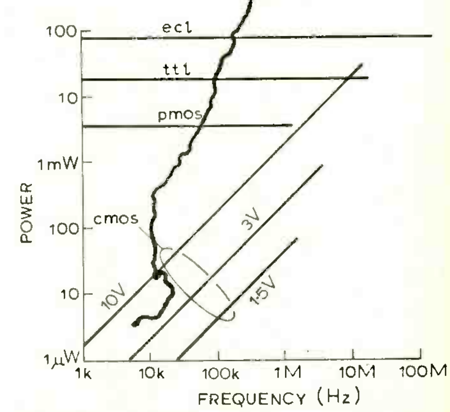


Fig. 8. For c.m.o.s. high speed means high power and low power means low speed.

The range of power supplies which are suitable covers 1.3 to 18V. Standard families cover 3 to 15V operation, thus permitting mixed analogue—digital circuits without additional supplies. Battery operation is simplicity itself from 6 or 12-V lead-acid cells or dry batteries.

The first commercial family of logic elements available used devices with fairly high thresholds—around 2.5V. This led to high impedance devices, and operation only from voltages above 5V. The low threshold "A" versions followed giving thresholds roughly half as high being around 1.2V and giving lower impedances, hence faster switching. The "A" low threshold versions first announced by RCA replaced the standard family at the same price, and offered propagation delays as indicated in the table reduced by a factor of about two to 25ns. Toggle rates for bistables were roughly doubled.

More recently, the commercial availability of a new version from Harris Semiconductor has been announced. It incorporates dielectric isolation which gives propagation delays of 10ns and toggle rates of up to 18MHz typical. Further process improvements are promised from Harris which will give at least a five-fold improvement in speed.

In the USA a £1 million contract has been placed for a c.m.o.s. logic system to provide a car interlock system which prevents the engine being started until all occupants have fastened their seat belts. The selection of c.m.o.s. is obviously on grounds of negligible power consumption enabling permanent connection to the battery, tolerance to battery voltage which may exceed 7 to 14V range, and ambient temperature tolerance which is particularly good.

The simple interfacing of c.m.o.s. together with its good supply range, power consumption, and noise immunity combines to outperform all other logic families with very few exceptions.

One class of application for c.m.o.s. has been that of remote data systems requiring high reliability and low consumption. One such system achieved a 12-bit code from an analogue input at 100Hz conversion rate for 1mA, 12V. At 5kHz conversion rate the power consumption rose to 20mA, 12V. This is still an order of magnitude below that of a system constructed using low power t.t.l.

Another application which is reaching the consumer sector is the electronic wristwatch. This application demonstrates the many virtues of c.m.o.s. circuitry. A typical system is shown in Fig. 9. An input invertor functions as a linear amplifier with a feedback bias resistor providing negative feedback, and a crystal positive feedback. Crystal frequency is 65,536Hz. The output waveform is squared by a further invertor and then passes into a chain of bistable elements each dividing by two. A consequence of the proportionality between frequency on supply current is that a long binary chain draws less power than twice that of the first element. The output circuit uses combinational logic to generate short-phased drive pulses for a miniature motor driving the watch hands.

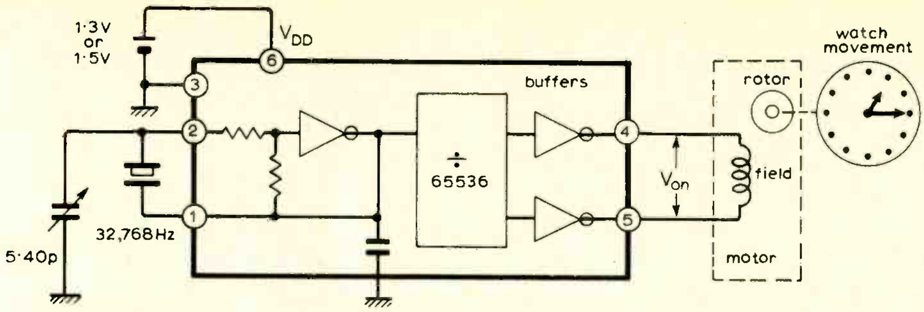


Fig. 9. Electronic watch system features both linear and switching operation of c.m.o.s. This circuit will operate from a 1.3V cell at 6μW.

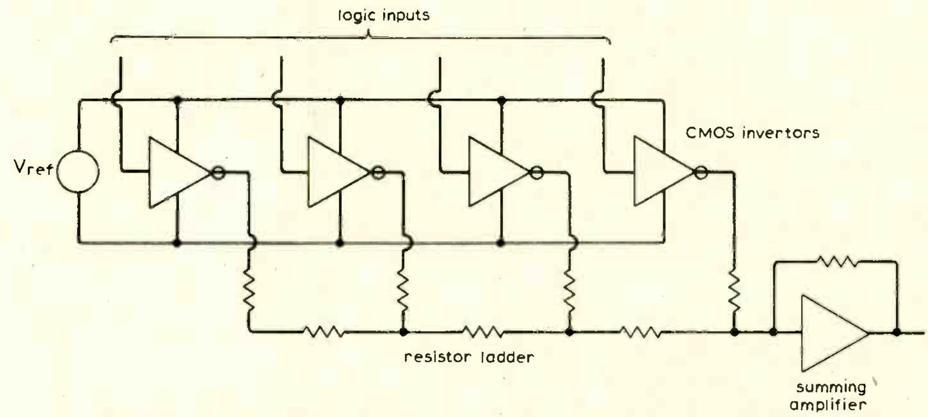


Fig. 10. Technique of digital-to-analogue conversion in which a resistive ladder is switched to generate a linear signal from a digital code.

Table: speed of c.m.o.s. families

Family	Prop. delay (ns)	Toggle freq (MHz)
Standard	100/50	2/5
Low threshold "A"	35/25	4/10
Improved isolation	10	8/18

The whole circuit will run from 1.3 or 1.5-V batteries and consumes a total power of 6 or 8μW respectively. Operation for a year off one tiny inexpensive single-cell battery is assured. Frequency-generation elements are integrated with the exception of the quartz crystal and the trimming capacitor. The performance achieved by the integrated circuit itself led Motorola to set up to design and manufacture crystals and motors to ensure that suitable complete sets of parts were available. Extensions of the design to direct digital readout are relatively trivial.

An application which also exploits the low power consumption is that of the pocket digital calculator. While three logic families are used for the application, c.m.o.s. gives particularly long battery life, especially when using liquid crystal readouts which also have very low power consumption. The main limitation to large logic systems is that the p-tub in the substrate needed for n-channel devices uses a larger silicon area than p-channel m.o.s. systems. In some systems the higher power of p-m.o.s. is acceptable but the extra silicon area of c.m.o.s. is not.

The wide range of supply voltages, from special devices working at 1.3V to standard families working at any supply between 3

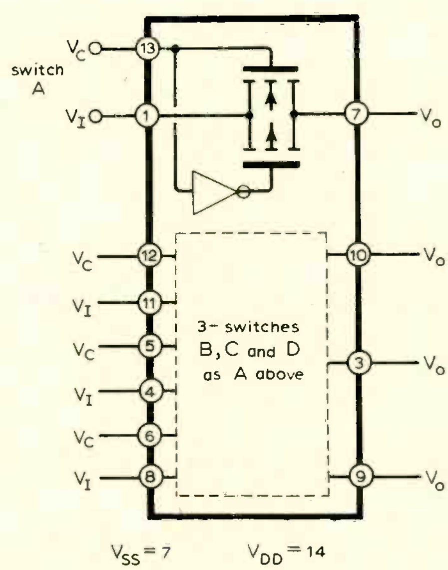


Fig. 11. This quad bilateral switch enables switches to be fully floating.

and 15V simplifies design of hybrid digital-linear circuits. Choice of ±6V rails for an analogue system using operational amplifier permits interfacing by direct connection with c.m.o.s. gates operating from the same supply. Systems for digital to analogue conversion may be made by exploiting the zero offset properties of f.e.ts, and, using a stable precision voltage supply for the circuit, a resistive ladder may be switched to generate a linear signal corresponding to the digital code.

The general scheme is shown in Fig. 10. The resistors would be around 50kΩ to minimize switch resistance errors. Costs of such systems are very low since quad-gate packs are about 50p each. Systems requiring fully floating switches may be executed using the 4016 quad bilateral switch shown in Fig. 11. These are able to handle signals swinging over a range of up to 15V, and offer on-resistances of 300Ω typically, with on-off ratios of 65dB at 10kHz.

The state-of-the-art of commercial devices using both linear and logic sections is indicated by the RCA CD4046 phase-locked loop circuit on one chip in a single 16-lead package. The functions incorporated include an input amplifier, phase comparator, and voltage-controlled oscillator, and operation extends to 500kHz with typical power consumptions of 200μW at 10kHz.

Circuits of the relaxation oscillator class also exist for astable and monostable multivibrators. These i.cs provide solutions to circuit problems at much lower prices than discrete designs, and are expected to become popular on the strength of this alone.

Circuits using c.m.o.s. elements

Straightforward logic systems are not considered here as logic design is not tied to a particular family unless the logic elements are peculiar to it. In the case of c.m.o.s. a large set of standard NAND, NOR, EX-OR, bistable and shift register elements already exist and almost any logic design may be implemented with less difficulty than usual. The explosive growth of logic systems when 74 series became available at low prices led to the system being adopted as standard by many manufacturers, and consequently parts of a 74 series systems may be purchased from many different makers. This situation diminishes supply problems and leads to competitive pricing.

This situation is being repeated with 4000 series c.m.o.s. logic. Devices are now available from RCA, Motorola, and Solidev with identical functions, packages, pin connections, and similar specifications. It is expected that within 12 months, at least 20 manufacturers will be supplying c.m.o.s. devices. Another series, 74C from National Semiconductor, offering pin and functional compatibility with 74-series t.t.l., exists, but interfacing capability from 74C to 74t.t.l. is limited, and 74C has not attracted the support from other makers comparable with 4000A series.

A circuit which exploits many of the properties of the c.m.o.s. invertor both as a logic, and a linear element is the multivibrator circuit shown in Fig. 12. Three invertors each comprising of two i.g.f.e.ts are cascaded. In the logic mode they invert the logic signal and in the linear mode they give a voltage gain of about −10. In the absence of the capacitor the 68-kΩ resistor R_1 provides negative d.c. feedback which results in all inputs and outputs settling at about half the supply. The feedback resistor should be low compared with the r_{in} of 10^{12}ohms, and may be 100MΩ if needed.

The capacitor connects the output of the second invertor to the input of the first, thereby providing broadband positive feedback. The result is that when the gates

Fig. 12. Multivibrator circuit with inverters operating in both linear and logic modes.

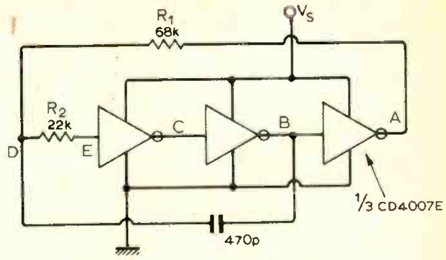
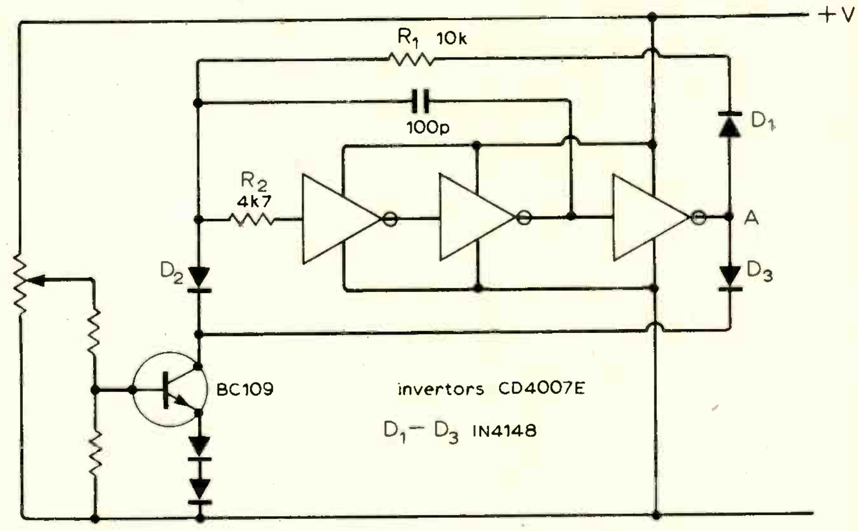


Fig. 13. Voltage-controlled adaptation of Fig. 12. Parts cost £1.00.



approach an equilibrium under the influence of the d.c. feedback the system switches to hard off when the loop gain round the first two invertors reaches unity. The feedback resistor then causes a current from point A to point D into the capacitor to move back toward the equilibrium. This results in a further regenerative switching edge in the reverse direction.

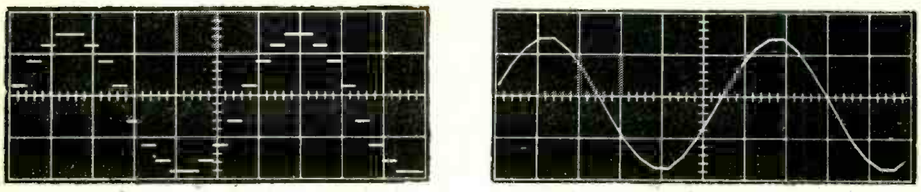
The circuit may be built with only two invertors but the timing resistor must be moved to point C from point A, and the charging current falls rapidly as the switching point approaches giving jitter. The values of components stated gave a frequency of 14kHz with switching edges of approximately 25ns using a high threshold CD4007E device. Current consumption of the circuit is not as low as that of pure c.m.o.s. logic because the first gate spends about 10% of its time in the linear mode, with increasing supply current until the switching point is reached. Consumption of tens of μA would be normal, though fairly strongly dependent on the supply voltage. Frequency is substantially independent of the supply voltage and temperature.

In the multivibrator circuit, the charging current is determined by the supply voltage and the timing resistor. The circuit may be simply adapted to permit control of the frequency as shown in Fig. 13. The half cycle when point A is positive is timed by the resistor in the usual way. After switching however, the series diode D_1 prevents reverse current, hence the recovery of the capacitor voltage is provided by the additional transistor current source through D_2. The additional diode D_3 draws the source current and cuts off D_2 during the fixed half cycle (1μs). The current source is arranged to give an logarithmic input characteristic covering a frequency range of 5.5Hz to 500kHz in five decades. The parts for the circuit costs under £1 in small quantities, making the circuit useful wherever a wide range v.c.o. is needed.

The switching properties of c.m.o.s. gates are exploited in the example of Fig. 14. A three invertor multivibrator provides clock pulses for an eight-stage Johnson or "twisted ring" counter. The outputs each register stages, which are either $+V_s$ or zero through low switching resistances, are connected to a set of resistors. The values are calculated so that the progression of net currents to the output point corresponds to a sine wave function. The oscillogram shows a 7Vpk-pk stepped approximation to a sinewave at 40Hz.

Addition of an integration capacitor to the output shows how good a function may be obtained. It can be shown that the best 16-segment approximation of the sine function is free of all harmonics below the 17th one. Total harmonic content of better than 0.01% may easily be achieved if the function amplitudes are correct, and the output is passed through a simple low-pass filter. Choice of a sinewave output was arbitrary; many periodic functions may be simulated in this way, with very low unwanted harmonic content.

The versatility of separate source and drain connections is exploited in this frequency-to-voltage convertor, Fig. 15. When the invertor input is high, the output is low, and the p-channel f.e.t. discharges the capacitor C fully. When the input is low, the upper f.e.t. is turned off, and the lower one turned on. The drain passes a current until the operator has changed to $+V_s$. The charge, equal to CV_s passes through the source and is extracted by the summing am-



Oscillogram showing a 7-V pk-pk approximation to a 40-Hz sine wave. An harmonic distortion of 0.01% is readily achieved.

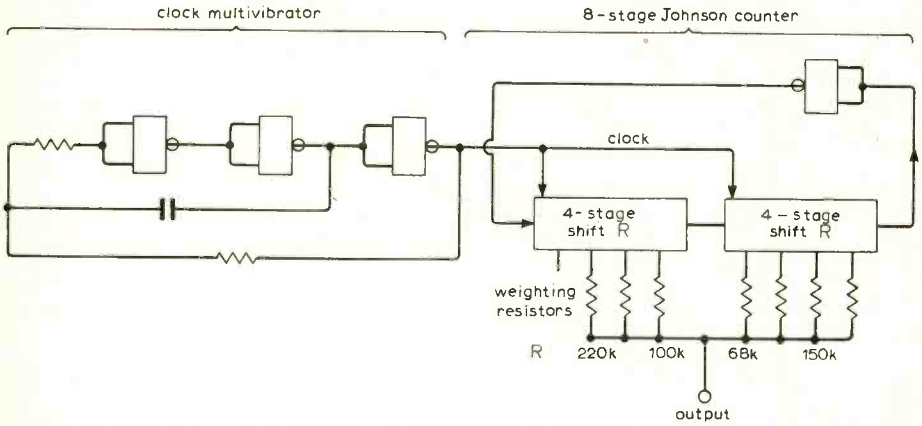


Fig. 14. Function generator using switching approach can provide harmonic content of sine wave of <0.01%.

plifier output going negative and passing the charge through R_f. As a fixed quantum of charge is passed every input cycle, the current in R_f, hence the output voltage is proportional to the input frequency. The circuit usually is fitted with an integration capacitor to reduce the output voltage ripple.

The circuit may of course be implemented using discrete n- and p-channel enhancement i.g.f.e.ts, but the cost of these exceeds the c.m.o.s. package, and provision of an invertor to drive the gates might still be needed. The circuit is capable of very precise operation because the capacitor is switched between precisely determined voltages through the zero offset voltage ohmic f.e.ts. Charge passed must pass into the output circuit unless substrate leakage is significant. The main error is due to incomplete charge and discharge, but such errors may be held below 0.1% of f.s.d.

Future prospects

Prospects for c.m.o.s. integrated circuits are very good. The speed of advance of technology is such that by the time engineers start using new devices or techniques, the break-even cost point has already been passed. The publicity for the last two years on c.m.o.s., and the entry of more of the major manufacturers, is now giving a fast rising application of c.m.o.s. circuits and systems.

Taking pure logic systems, and making fair allowance for the cost of providing power supplies, the total system cost including design and development is less using c.m.o.s. in spite of the 2:1 cost advantage of simple gate packages in favour of t.t.l.

Growth of c.m.o.s. in some special areas is likely to be even faster. This is because the market is new rather than a replacement one, and includes calculator and watch applications.

The other major area is that of the hybrid logic/linear application area where the combination of logic with some linear sections, such as a. to d. conversion, waveform synthesis, and frequency-to-voltage conversion. The growth rate is likely to be less than the other applications but eventual penetration no less great.

Current price levels are around 50p for gate packages (NAND or NOR) in 14-pin d.i.l. packages covering −40 to +85°C, and guaranteed to function over 3 to 15V supply. Complex functions are a few pounds, but are usually economic solutions because of the power of the function executed. System costs using i.cs with a low level of integration are already becoming more dependent on connector and printed circuit cost, so that the high level of integration saves money.

In two years time when we are using our £25 c.m.o.s. pocket calculators, and check the time by a £15 quartz crystal c.m.o.s. watches, we may wonder why t.t.l. ever sold so well when c.m.o.s. logic was available.

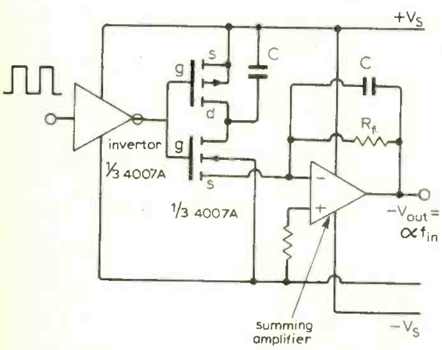
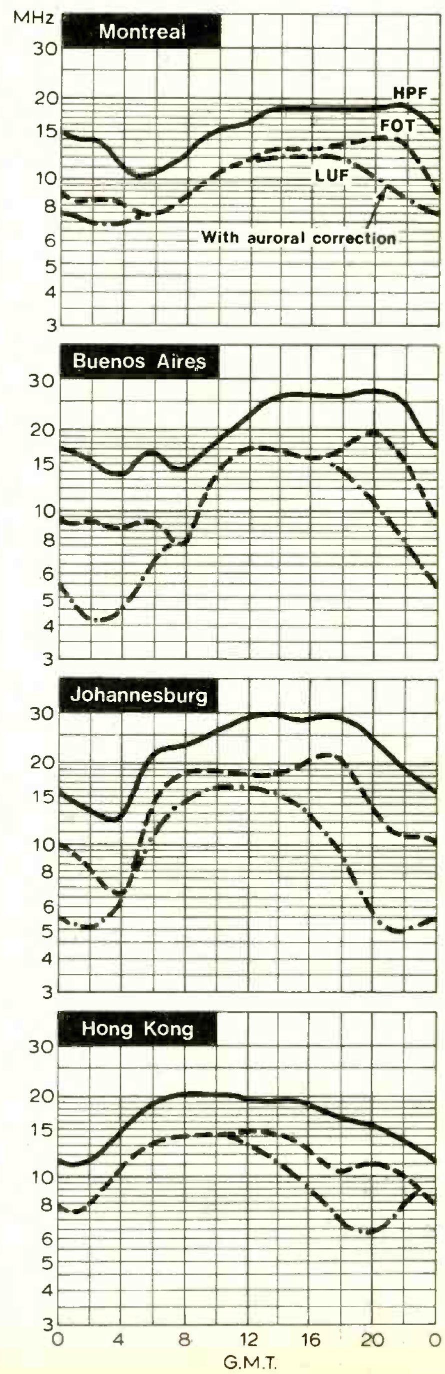


Fig. 15. This precision frequency-to-voltage converter is cheaper using c.m.o.s. package than with discrete i.g.f.e.ts.

H.F. Predictions for August

The charts are based on an ionospheric index value of 30 giving HPFs and FOTs about 2MHz lower than those for August 1972 when the index was 60. Duration and intensity of ionospheric and magnetic disturbances have decreased fairly rapidly since reaching a peak during April/May last. Coupled with the present seasonal trend toward higher frequencies daytime working should show a noticeable improvement.

Most likely disturbed periods are from 5th to 12th and an odd day or so around the 21st.



Electronic Dice

Three circuits for electronic dice using integrated circuits and a seven - segment bar or numeric display

by G.J. Naaijer

This article deals with electronic solutions for that class of dice that have six sides with numerical information. Of the many dice projects already described we recall briefly four essential parts: (1) a push-button operated device which generates a large random number of pulses during the "throw", (2) a divide-by-six counter into which these pulses are fed, (3) a display indicating the state of the counter and therefore the result of the throw after the counter has come to rest, (4) decoding and lamp-control circuitry between counter and display, the most important differences between the various designs concerning in particular this latter part.

A drawback of the dice described hitherto is that, especially if a well-finished product is desired, their practical realisation is time and effort consuming because the total number of electronic components and indicating devices is relatively large.

Retaining, where advantageous, the interesting lines of thought exposed in previous projects and doing some original thinking, we found that, when fully exploiting the possibilities offered by t.t.l. circuits and t.t.l.-compatible devices, a very simple structure is possible. Apart from a single supply (5V), an "on/off" switch, and a "throw" push-button, only three dual-in-line packages are required, including the display. Of the examples to be described only one uses a few additional discrete components.

The low current consumption which, in the first two examples is between 50 and 90mA, depending on the state of the counter, makes the use of four small (size R6 or AA) rechargeable alkaline or nickel-cadmium cells an attractive proposition. The t.t.l. circuits used are relatively cheap and easy to obtain because they are very common types, and no special circuit is required for initial setting of the counter. A small seven-segment display indicator, the 3015F Minitron is used, which is cheap and t.t.l.-compatible, and which gives a brilliant display.

The first example of a simple electronic dice will be described in some detail to permit sufficient understanding of the components used, the principles of operation and the economics of these designs. The majority of design considerations apply also to the other examples which consequently will be treated only briefly; in particular, the pulse generating principle is the same in all examples.

Wireless World, June 1970. p. 268.

N	0	1	2	3	4	9
A	0	1	0	1	0	1
B	0	0	1	1	0	0
C	0	0	0	0	1	0
D	0	0	0	0	0	1
$\bar{A}$	1	0	1	0	1	0
$\overline{B+C}$	1	1	0	0	0	1
$\bar{C}$	1	1	1	1	0	1
D′	0	0	0	0	0	1
N′	2	3	4	5	6	1

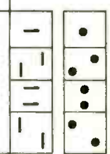


Fig. 1. The states adopted by the decade counter when forced reset is applied. The pattern produced by the 3015F in the "classical" pattern is shown, together with the relevant decoder output states.

Dice with "classical" pattern

The logic employed here is easily understood from Fig. 1, the upper half of which shows the six different states a 4-flip-flop counter is made to adopt successively

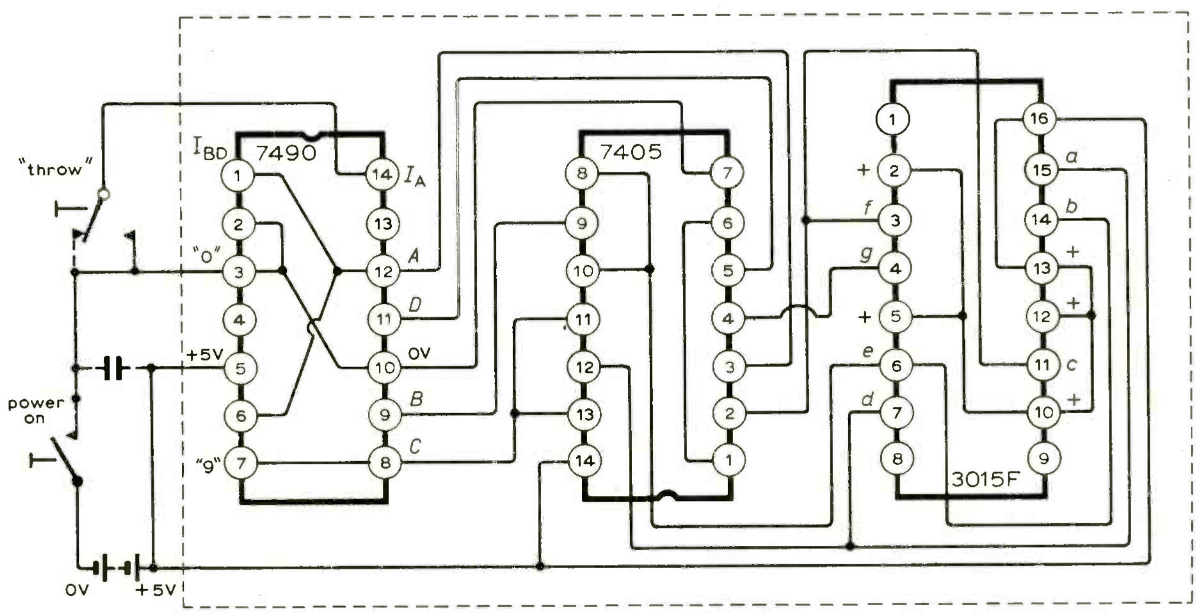


Fig.2. The layout of the circuit, seen from the component side.

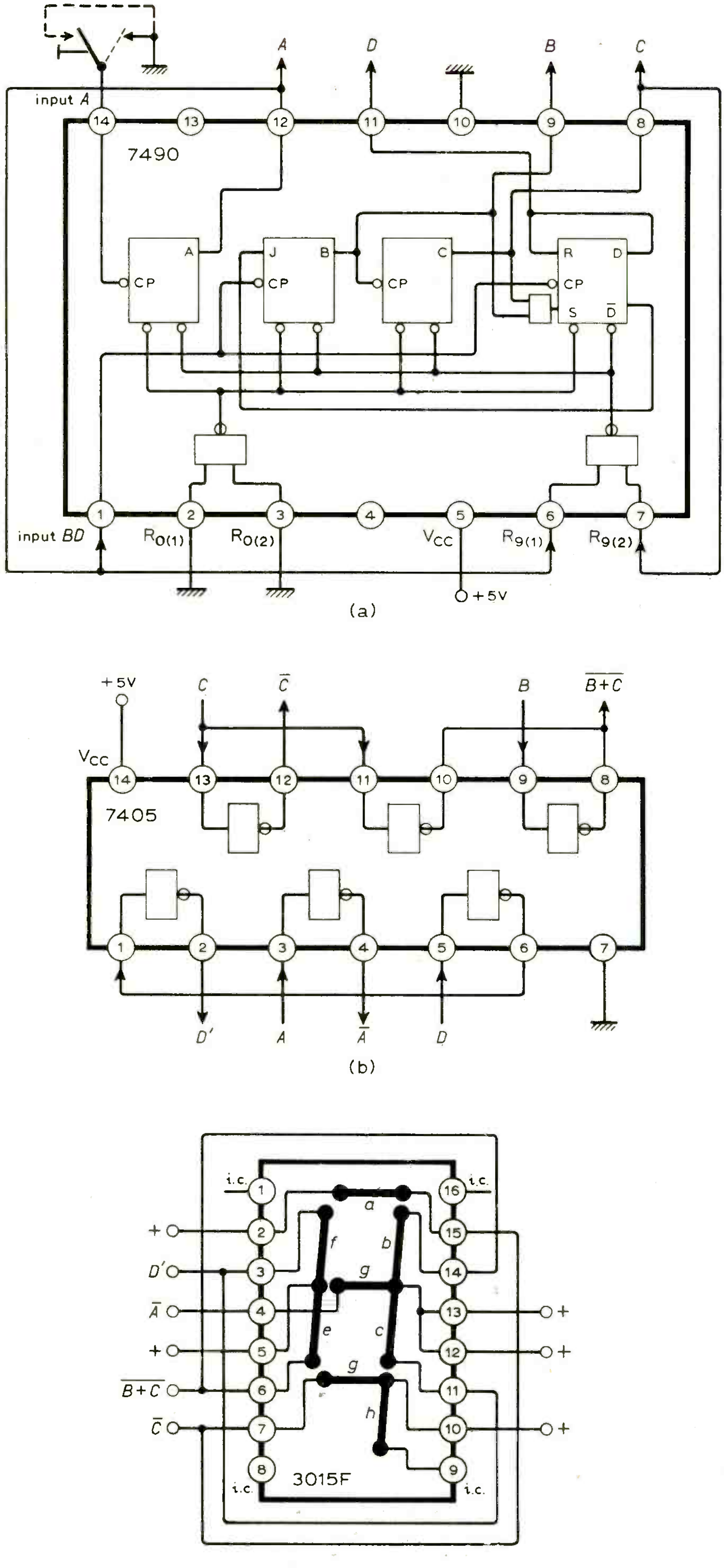


Fig.3. (a) Internal circuit of the 7490 decade counter. The "throw" switch may be earthed at both contacts. (b) Circuit of the 7405 hex. inverter. (c) The 3015F Minitron display.

during a throw, the lower half indicating the six corresponding states obtained at the outputs of the decoding/lamp-drive circuitry. A segment will light up when the output controlling it is in the "0"-state; one will observe that output $\overline{A}$ for instance, controls the central segment of the display. In this way the six different bar patterns shown in the middle of Fig. 1 will be obtained.

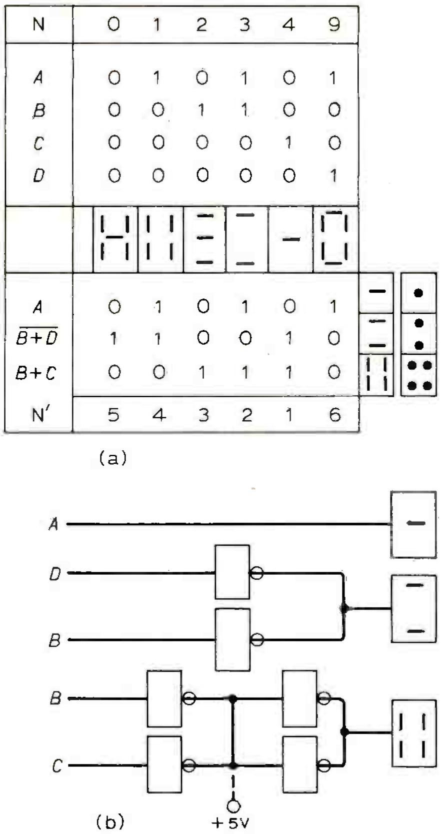
Note that the four functions $\overline{A}$ to D' can also be used to control dots, for example sub-miniature low-current incandescent lamps or even light-emitting diodes, which at 1.7V forward voltage drop and a current of some 8mA (limited by a series resistance of suitable value) give sufficient luminous output. In that case the dot pattern of the "classical" dice is obtained and the final display, although generated by entirely different logic, is the same as the one obtained in reference 1.

Fig. 2 shows the three d.i.l.-packages used, together with a routeing scheme for the printed circuit layout necessitating only two jumpers. The Minitron 3015F has outside dimensions 22mm × 11.5mm and there are 16 pins in d.i.l. configuration; each segment is a filament 5mm long (the eighth filament, partially visible only, provides a decimal point). At its nominal voltage of 5V, compatible with t.t.l. levels, each filament draws only 8mA and life-expectancy is stated to exceed 50,000 hours under these conditions.

The SN7490N is a very economical and flexible high-speed t.t.l. decade counter, the four outputs of which have current-sinking capabilities of 20mA; in this application we found that the counter did not exhibit preferential positions if the A output was loaded by one display segment even though the cold resistance is lower than the value calculated from 5V, 8mA (inrush-current effect).

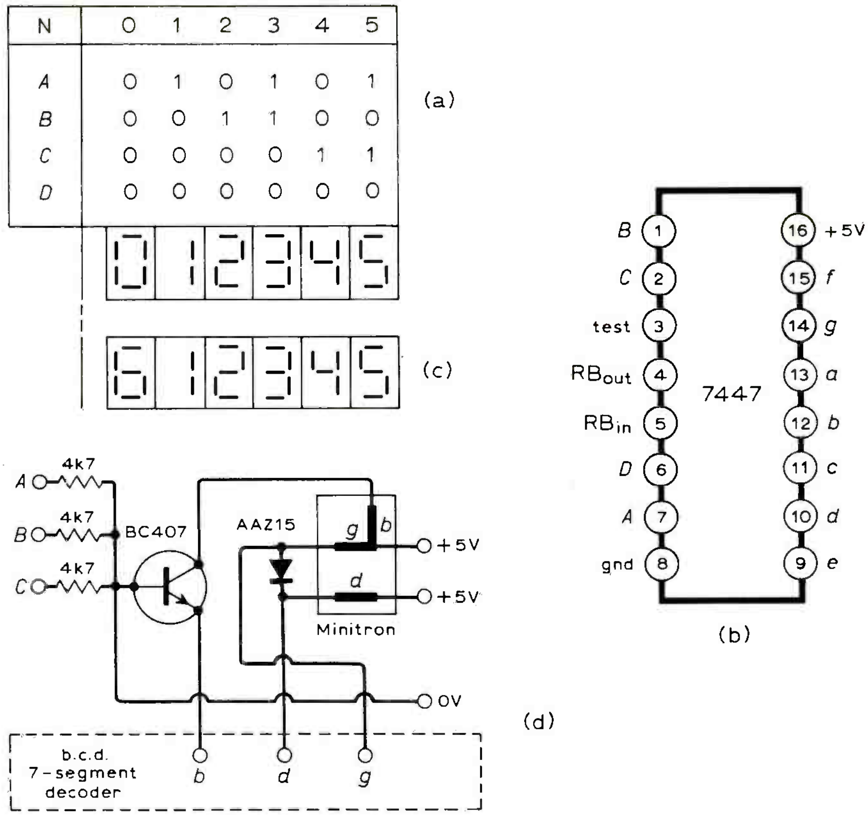
The hex. inverter SN7405 is even cheaper, and its open-collector feature makes it very versatile because wired-OR configurations are possible. Each output has again a current-sinking capability of 20mA and it can readily, without danger of damage, drive two 8mA-segments simultaneously; because of the buffering action the counter operation will not be upset by the inrush-currents.

Fig. 3, showing the inside of the d.i.l.-packages, will be used to explain the principle of operation. The die-projects described so far have used an electronic pulse generator in combination with a push-button in order to feed a large random number of pulses into the counter during a throw. Most mechanical contacts, however, are never bounce- and noise-free, especially when cheap or dirty or self-fabricated. Therefore the electronic pulse generator is entirely superfluous as the push-button contact can easily be made to generate by itself a large random number of negative-going pulses. As the counter input responds to negative current sinking, a pull-up resistor tied to the positive supply is not necessary. At rest the counter input may be at ground (instead of open circuit) so that releasing the push-button creates another



N	0	1	2	3	4	9
A	0	1	0	1	0	1
B	0	0	1	1	0	0
C	0	0	0	0	1	0
D	0	0	0	0	0	1
A	0	1	0	1	0	1
$\overline{B+D}$	1	1	0	0	1	0
$B+C$	0	0	1	1	1	0
N′	5	4	3	2	1	6

Fig.4. (a) Logic states and patterns of the pure binary die. (b) Decoding and drive circuit.



N	0	1	2	3	4	5
A	0	1	0	1	0	1
B	0	0	1	1	0	0
C	0	0	0	0	1	1
D	0	0	0	0	0	0

Fig.5. (a) Logic states and display of the "Arabic" version, using "0" as "6". (b) Decoder connections. (c) Patterns of improved version. (d) Method of converting "0" into "6".

train of pulses, but in its stationary position it should of course make a vibration-proof contact. Incidentally, the small five-pence switch we bought especially for the purpose gave such a clean, almost noise-free signal that it had to be discarded!

The decade counter, with "0"-set and "9"-set inputs at ground will go through 0, 1, 2 . . . . . 8, 9, 0, 1 etc. during counting. In our case however, outputs A and C are fed back to the "9"-set inputs; the "5" will now be an astable state because A and C will then be high simultaneously and therefore force the counter immediately into the "9"-state. The division by six shown in Fig. 5 simplifies the decoding circuitry required. No additional circuitry is necessary to prevent incidental operation in one of the ten forbidden states as this counter will automatically return to one of its six regular states.

The decode-drive circuitry is seen to require six open-collector inverters only: one for each of the functions $\overline{A}$ and $\overline{C}$, two for D' ($= b$) in order to provide the necessary buffer action between b and the two segments to be controlled simultaneously, and two which, with their collectors tied together, produce the function $\overline{B + C}$. It is this latter wired-OR configuration that excludes the use of t.t.l.-inverters with active pull-up such as the SN7404. None of the segments is driven directly by a counter output. The inputs to the Minitron are self-explanatory.

Die with pure binary pattern

The 7-segment configuration of a numerical indicator such as the Minitron is admirably suited to a die display based on a 4-2-1 weighted function. The counter operation, together with the decode/drive logic, requiring again only two d.i.l.-devices, is represented in Fig. 4 (a). Note that the corresponding dot pattern, although obtained by completely different logical operations, is analogous to the one proposed in reference 2. It is also interesting to note that all possible correspondences (they amount to a total of six) between A, $\overline{(B + D)}$ and $(B + C)$ on the one hand and the groups of one, two and four bars on the other hand produce logically correct solutions, but only two of them (A controlling the central bar) give electronically correct solutions: a counter output cannot drive directly more than one filament.

The realisation of the decode/drive logic by means of an open-collector hex. inverter is show in Fig. 4 (b). The logic functions obtained from B, C and D use wired-OR configurations and exclude therefore the use of t.t.l.-inverters with active pull-up.

Dice displaying Arabic numerals

Here we have a display method the Minitron is really intended for, as shown by Fig. 5 (a). The complicated conversion logic required poses no problem: the b.c.d./7-segment decoder SN7447 will do the job and can be directly connected between the four counter outputs and the seven Minitron inputs. The open-collector outputs of the decoder can again sink 20mA each, so that one output may eventually control two 8mA-segments simultaneously. The test-input permits checking of the filaments by turning them all on, while RB_{in} and RB_{out} are ripple-blanking controls (all three signals are normally held high or open). Here the counter should successively count through 0, 1, 2, 3, 4, 5, 0, 1 etc. This mode of operation is obtained if outputs B and C are connected to the "0"-set inputs, the "9"-set inputs being returned to ground; the "6" will now be astable because B and C will then be high simultaneously and therefore force the counter immediately into the "0"-state.

Although this die is very simple it has the obvious drawback that the "0" has to be interpreted as "6". Fortunately it is quite a simple matter to make a "6" appear instead of a "0" as indicated in Fig. 5 (c).

Fig. 5 (d) shows a way of realising this trick. The b-output from the SN7447 is connected to the b-segment via a small, cheap, epoxy-encapsulated n-p-n transistor which at low emitter voltage is only conductive if at least one of the outputs A, B or C is positive (resistor-transistor logic). When and only when the counter is in the "0"-state the b-segment cannot be turned on by a low decoder b-output. Furthermore the diode with low forward voltage drop connected between the d- and g-outputs (instead of a short-circuit) ensures that for "6" the g-segment is turned on by d (which then controls two segments simultaneously) and also prevents the d-segment from being turned on by the g-output in the case of "4". This wired-OR configuration controlling the g-segment is again only possible because the decoder outputs, especially g, have no active pull-up.

World of Amateur Radio

Broadcasts from PAOAA

Listening one Friday evening on 3.6 MHz recently we came across the broadcasts from the Dutch society's headquarters station PAOAA. This station makes official transmissions each Friday evening with an ambitious schedule of news bulletins in English and Dutch, Morse practice sessions and (on the last Friday in each month) the VERON Morse code proficiency speed runs. The transmissions go out simultaneously on 3600kHz, 14100kHz and 145.14MHz, starting at 1900 G.M.T. and also include bulletins transmitted in r.t.t.y. (radio-teleprinting) at 2030 G.M.T. at the 45-baud rate. The code proficiency sessions begin at 21.30 G.M.T. The English news bulletins include mainly DX news.

More evidence on supermodes

The summer propagation conditions this year have generally reflected the falling slope of the sunspot cycle with appreciably shorter "openings" on 21 and 28MHz. Nevertheless the passage of the larger sunspots still tends to result in an initial few days of enhanced conditions quickly followed by disturbed conditions of high attenuation. A noteworthy feature this year has been the prevalence of Sporadic E conditions; although this is often thought of as affecting mainly the 70 MHz v.h.f. band (and indeed has resulted in the reception of the ZB2VHF beacon on Gibraltar in the U.K.) it means also that 21 and 28MHz have been often open for short-skip contacts into Europe.

Interest continues in the most unusual propagation conditions that existed during the summer of 1972 when for some unexplained reason the general level of sunspot activity was much higher than had been predicted. For example an extremely detailed account of the reception at Mzuzu, in the north of Malawi, of the 28MHz beacon transmitter, GB3SX, which is located at Crowborough, Sussex has just been published in *Radio Communication* by A. M. Pomfret, G3LZZ, and A. Taylor, G3DME, covering the period May to August 1972. This shows that this transequatorial path was open for many more hours than expected, even when taking into account the real rather than the predicted level of sunspot activity; certainly significantly longer and more often than can be explained by conventional multihop theory. It would seem likely that some at least of this reception depended on supermode propagation without intermediate ground reflection, over the distance of 4800 miles. In the four months the GB3SX signals were heard during periods extending to 18½ hours out of the 24 hours.

One important factor, not mentioned in the report, was possibly the high site at Mzuzu, 4300 ft a.s.l. Some years ago a paper in *Radio Science* (Vol. 1, 1966, pp. 751-760) showed the advantages of sites up to 1000 ft a.s.l. when compared with those at around 200ft a.s.l. in terms of the time during which long-distance paths stayed open. It is interesting to note that the advantages of high sites for the reception of low-angle supermode signals appears to exist regardless of the height of the aerial above ground: at Mzuzu this was only 33ft.

Amateur radio-teleprinting

The British Amateur Radio Teleprinting Group now has a paid-up membership of just over 300 enthusiasts, of whom about 190 hold British amateur callsigns. At the present time r.t.t.y. operation in the U.K. is predominantly at the 45-baud rate but quite a number of 50-baud machines are also in use. Most h.f. operation in this mode uses frequency shift keying with a carrier shift of either 850Hz or 170Hz, while most v.h.f. operation uses audio f.s.k. with 2125 Hz tone for "mark" and 2975Hz for "space". One of the local r.t.t.y. nets includes a number of amateurs in Northern Ireland and Eire around 3590 kHz on Sunday mornings from 1000 G.M.T.

50 years of amateur licensing in New Zealand

Congratulations to the New Zealand Association of Radio Transmitters for its imaginative and interesting "Amateur Radio Regulation Issue" of its journal *Break-In* marking 50 years of official amateur licences in New Zealand. Not only are many of the happenings since 1923 reproduced fascimile from the original issues, but a number of the pioneers, including Len Spackman, ZL1AC and Tom Clarkson, ZL2AZ and others, have provided their reminiscences of the progression from the famous Ford Model T spark coils and the days of the Radiotron "UV" and Mullard "ORA" valves up to the present transistor era. They recall, for example, the American amateur station 6XAD on Catalina Island off Los Angeles in the early 'twenties using two imported English valves with fixed silica envelopes and with the insides replaced by Western Electric 250-watt electrodes: "Those two valves, immersed in an oil bath, cooled by a copper coil with running water and hopelessly overloaded put down a good signal in New Zealand and Australia". Len Spackman adds rather wistfully: "I am thankful that I was able to take a little part in the heyday of amateur radio when amateurs led the world in radio technology . . . they developed their own circuits and techniques and did not try to ape commercial equipment."

In brief

Professor Sir Martin Ryle, F.R.S., G3CY, The Astronomer Royal, has been made an honorary member of the R.S.G.B., the highest honour the Society can bestow on an individual. Sir Martin joined the Society in 1936. . . . During the first seven months of Oscar 6 at least 1100 different amateurs in 59 countries have put transmissions through the satellite, about half of them in the United States. One American amateur, K7BBO, has made over 3300 contacts through Oscar 6; another, Fred Merry, W2GN, has worked through Oscar 6 from a mobile station using only whip aerials. . . . The French Mirabel and Anjou balloon-carried repeaters have been proving very successful and contacts have included England to Austria (G3LQR to OE3XUA). . . . The R.S.G.B. Liaison Committe has warned amateurs not to condone or co-operate in the operation of illegal broadcasting stations and also to reduce the incidence of bad language and deliberate interference, noting that loss of respect for amateur operation by national administrations could result in loss of frequencies at the next I.T.U. conference. . . . Following investigations a club station entry in the 1973 Affiliated Society Contest has been disqualified and the undisclosed Club barred from entering any R.S.G.B. contest for a year. The event was won by the Cambridge University Wireless Society. . . . The past season's highlights on 1.8MHz have included the completion of "worked all continents" by 12 more stations. . . . Detailed reports on the reception of the GB3LDN 23cm beacon station located at Greenwich would be welcomed by B. W. Godwin, G8AOL, 20 Pembury Road, Bexleyheath, Kent — operation of the station is using up significant numbers of TD03-10 amplifier valves and donations of any spare valves of this type would help keep the beacon running. . . . R.S.G.B. National Mobile Rally is at Woburn Abbey on Sunday, August 5. . . . A consortium of Midlands amateur societies is participating in the "Town and Country Festival" on August 25-27 at the Royal Showground, Stoneleigh, Kenilworth with stations (GB3TCF) on 1.8, 14 and 144MHz (details: Ian Gobbold, G3RPJ; 184 Loxley Road, Stratford-on-Avon).

PAT HAWKER, G3VA.

Efficient Inverter for Fluorescent Tubes

High efficiency circuit for dry battery operation

by K. C. Johnson, M.A.

With modern semiconductor devices and ferrite cores it is easy to drive small fluorescent tubes from low-voltage d.c. power supplies and a variety of commercial circuits are available for this function. Most of these are designed for use in motor vehicles and caravans where an easily recharged accumulator is available and power is no real problem. They use a simple single-transistor single-ferrite core class C oscillator arrangement which is cheap but not particularly efficient. With dry batteries efficiency means longer battery life and a more complicated circuit may be justified if it offers an appreciably better performance.

The essential problem is to generate a source of constant-current a.c. from a direct voltage input. The defined current output characteristic is required because a fluorescent tube is a gas discharge device. It therefore develops an almost constant r.m.s. voltage when operating at any reasonable value of current, once the ionization level has settled down, and the system would tend to be unstable if such a tube were fed with a supply of defined voltage.

The frequency for the a.c. must be high enough to be beyond the range of hearing and to allow simple small transformers and inductors, but low enough to avoid trouble from transistor switching times and capacitances and to avoid the possibility of radio interference. With modern silicon devices a frequency of 25kHz is suitable. At this frequency the standard 8-watt size of fluorescent tube gives an adequate light when fed with 50mA r.m.s. of current. The voltage developed is about 55V r.m.s. and the impedance is very close to a pure resistance as the level of ionization cannot change appreciably within half a cycle.

The first job is to turn the d.c. input, which we shall assume to be at 12V even with dry batteries, into a.c. at the designed frequency. The efficient way to do this with transistors is a class D square-wave generator. Fig. 1 shows two alternative arrangements that might be used. In each of them the two transistors are switched so as to conduct for about 50% of the time each, but in the first the two transistors are directly in series while in the second a transformer is used and the transistors work in push-pull. The first circuit gives a single output swinging through a voltage nearly equal to the supply while the second gives push-pull outputs each swinging through nearly double the supply voltage. Both these arrangements give high efficiency provided that the drives to the bases keep each transistor properly saturated during its conduction half-cycle and that the load current is made to be small at the moments when switching takes place.

The second part of the circuit must then be some arrangement whereby this constant-voltage square-wave is converted efficiently to the constant-current source that we need for driving the tube. This requires a gyrator action, but it can be obtained with nothing more complicated than a simple *LC* network, as shown in Fig. 2, where the two reactors are resonant at the working frequency. If the output of this network is short-circuited then the current flowing in the short is clearly fixed

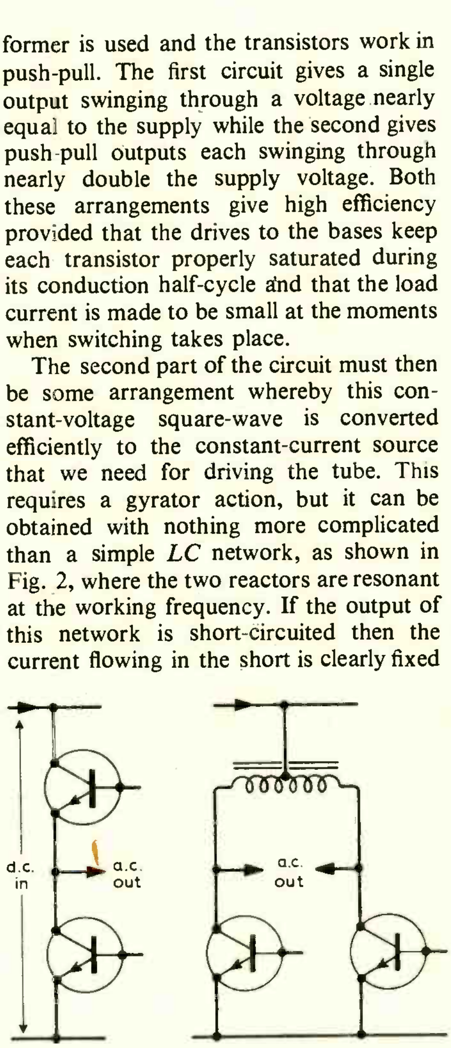


Fig.1. Using the push-pull circuit (b), right, leads to a lower Q requirement for the subsequent gyrator than with the transformerless circuit (a).

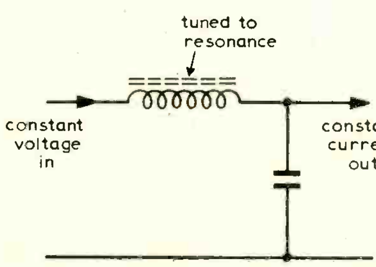


Fig.2. Gyrator network to convert constant-voltage square wave to constant-current tube drive.

by just the voltage of the source and the reactance of the coil. If, however, any other reasonably low impedance is connected at this point the steady current will have just the same value, as the output has the high impedance which is characteristic of resonance. For high efficiency in this arrangement we clearly need good quality reactors and a low value of the Q factor under the working conditions.

This requirement for a low Q leads to the arrangement of Fig. 1(b) for the a.c. generator as the push-pull circuit gives an output of ± 24V and hence allows a working Q of about two for a load which develops 55V r.m.s. With the transformerless layout of Fig. 1(a) a Q of four times the value would have been needed and we would have had to have a transformer for the base drive in any case. With the push-pull circuit the gyrator network must be hung between the transistor collectors. It is convenient to split the inductor winding into halves which can still be wound on a single core and to use two capacitors so that this network is also fully symmetrical.

Doing this avoids having unnecessary voltage swings on the leads to the fluorescent tube and so reduces the risk of interference. The current drawn by the gyrator network from the collectors with the tube alight is almost sinusoidal and has a magnitude of about 105mA r.m.s. Notice that if the tube connection is broken, or the load resistance is otherwise made greater, this current increases and more power is drawn from the input, as would be expected from a current driving system.

Due to the doubling action of the transformer the current at the transistors, considered as a push-pull pair, will be 210mA r.m.s. or 300mA peak in each. There is no great difficulty nowadays in finding transistors able to carry currents as large as this with no more than a few tenths of a volt drop when they are in saturation. Such devices will clearly need no cooling and will help the circuit to be efficient. There is no need either for them to have particularly high values of current gain as it is possible to drive the bases with currents as large as one-tenth of those flowing at the collectors without having to take more than about 1% of the input power.

The devices used must, of course, be rated to stand more than 24V on their collectors, to allow a margin of safety for transients, and they must have a switching speed, defined by the ratio f_T/β, at least as high as the working frequency. Any transistor type, whether of silicon or germanium, n-p-n or p-n-p, that meets these requirements should work well in this circuit. Even the old OC24 will function adequately, while the silicon "core switching" type of device is ideal.

Fig. 3 shows how the drive to the bases is obtained. Many alternative arrangements were considered, including the use of a second transformer, but this simple scheme seems to offer the most satisfactory solution. The two capacitors feeding the bases are each made to be one-quarter of the value of the main capacitors in each half of the gyrator network. They therefore carry currents which are roughly one-fifth of the total gyrator current and hence one-tenth of the collector currents.

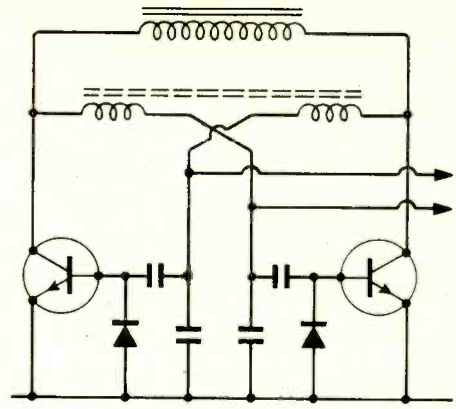
Diodes serve to carry the unwanted reverse flows and must, of course, be connected with reversed polarity if p-n-p transistors are being used. Almost any type of switching diode can be used as the requirements are easily met. Power lost with this system is virtually all in these diodes and in the transistors themselves, and it is easy to see that just 1% of the input is taken if the total voltage swing at each base is about one-tenth of the supply voltage, as it is likely to be in practice.

There is an appreciable power loss at the collectors with this system as the base current is phase advanced by some 25° due to the working of the gyrator network. It thus goes through zero while collector current is still flowing and the volts switch over before this current is stopped. The loss here is again only a few per cent though, and no simple means of reducing it could be found. Attempts to make the transistors switch more quickly led to trouble with spurious modes of oscillation and the grounding of the centre-tap of the gyrator capacitor is also essential for preventing this kind of misbehaviour.

It is a feature of this form of base drive that the circuit draws no power if it is made to stall while the supply voltage is connected. It will not therefore restart automatically but has to be disturbed in some way such as by switching the power off and on again. In practice this is no disadvantage and such harmless stalling occurs if the output is accidentally short-circuited. Notice that the output must never be left open-circuited for long, as the oscillation amplitude builds up and the resulting power is dissipated in the transistors as it can go nowhere else.

The last link in the chain is the fluorescent tube and we must consider the technique that is to be used for starting it off from cold. There is a problem here as these tubes can operate satisfactorily only if the heaters at each end are hot and emitting electrons. Once they are in this

Fig.3. Simple base drive circuit with gyrator inductors wound on same core. Diodes carry reverse current and must be reversed for p-n-p transistors.



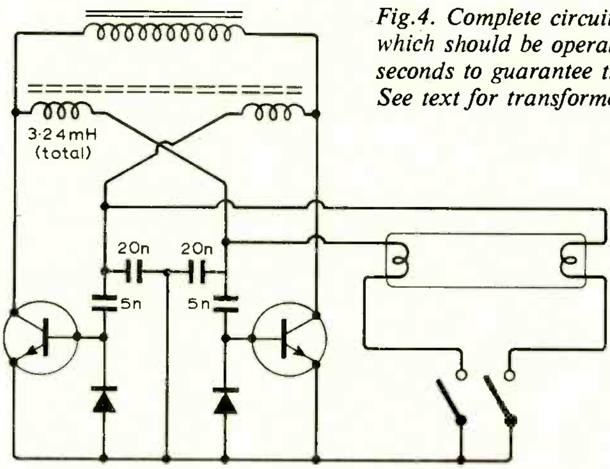


Fig.4. Complete circuit includes starting switch which should be operated for at least ten seconds to guarantee that both filaments heat. See text for transformer winding details.

state the discharge current alone is adequate to maintain the situation, but if either heater is cold no electrons are available to carry the current while it is negative. Thus there is no discharge in that direction, unless a much increased voltage is available which can drive positive mercury ions across the gap. If this occurs there is still no guarantee that the heater will be warmed, as the ion current is not guided towards an emitting area as the electrons are, and the tube will certainly be damaged by the effects of ion bombardment.

To allow the tube to be started up satisfactorily two contacts are thus provided at each end. One only of these is used to carry the working current while the other connects to a heating element which can be energized before the main discharge is started.

Fig. 4 shows how a double-pole switch is arranged so that the 12V is applied to both heaters. Fortunately this is a suitable voltage for direct application to this size of tube. The heavy loading across the output of the oscillator causes it to stall and so waste no current. This switch should, of course, be closed before the main power is turned on and the heaters should be allowed at least ten seconds to warm up.

When the starting switch is opened the oscillator will normally receive a very adequate kick and will run immediately. There will be a brief period in which the ionization in the tube is built up and then the system should operate satisfactorily. There is clearly no problem in arranging a simple relay circuit to make this starting-up procedure automatic, but it is essential that the warming period must be adequate as this circuit can run indefinitely with only one heater lit and a unidirectional current flow in the tube. If this happens the efficiency is reduced and only one of the transistors heats up.

The last figure also shows the values used for the capacitances and for the inductance for working at the frequency and power level that we have assumed. No special ratings are needed for the capacitors, but the inductor should have a Q of 100 or more. This is easily obtained with ferrite material provided that a design with a proper amount of air-gap is used. I used a pair of small E-cores, having a centre-limb cross section of 1.2cm^2, and gapped with 0.2mm in both centre and outside limbs. This gave the required inductance with 48 turns for each half of the winding.

The transformer used another pair of the same cores (Mullard type FX1105) and exactly the same number of turns but with no gap and with the two windings wound together (bifilar) to give low leakage inductance. Wire of 24 s.w.g. is suitable for all these windings on this size of core.

These Fifty Years

Reminiscences of half a century of writing for Wireless World

by M. G. Scroggie

Perhaps it is sufficiently unusual for anyone to have written for *Wireless World* for 50 years to excuse my self-indulgence in calling attention to the fact, and even inflicting on its readers some of my personal reminiscences.

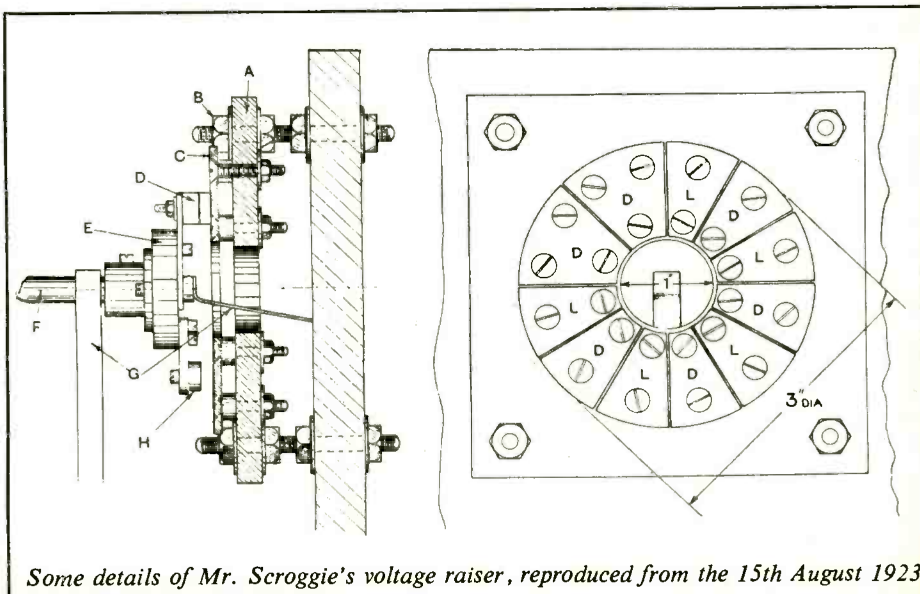
It began in the issue of 15th August 1923 — *W.W.* was weekly in those days and cost four old pence (net). The headline of this, my first excursion into radio journalism, was "Voltage Raiser for Valve Transmitters" and was given the honour of top billing on the front cover, which also informed the reader that *The Wireless World and Radio Review* was registered at the G.P.O. as a newspaper. *Valve* transmitters, note. In those days these were new-fangled contraptions, beginning to take the place of the traditional spark-generating coils and condensers. Nowadays one might suppose that even in 1923 there was nothing very newsworthy about a voltage raiser; surely the transformer had been invented by then? So it had; but it was (and is) inapplicable to d.c., which was then the norm for domestic electricity supplies. The cover and contents versions of my title did in fact say "D.C.". I see too that on this first occasion I revealed my first name, as well as a newly acquired B.Sc. and, in heavy type, my call sign 5JX (in Edinburgh).

In these affluent days one would no doubt have simply bought a motor-generator; but not then. Present-day students, demonstrating their indignation at the total inadequacy of a mere few hundred pounds a year free grant, may hate to be reminded that in 1923 they would have had none at all. We in Scotland were grateful to the late Andrew Carnegie for paying our class fees, at least; and were unconcerned about whether the profits that had been made in Pittsburg to pay for them had or had not been excessive. And there were bursaries to be had by students who studied the small print in the University Year Book. Anyway, for this post-graduate student every penny had to be considered. The machine eventually devised was made of a disused fan motor, a few square inches of copper and ebonite, some screws, and some ex-army Mansbridge condensers (as capacitors were called). Total cost, under £1. It worked by connecting the 230V d.c. mains rapidly in turn across each of four capacitors in series, by means of a pair of brushes rotated by the motor, and in this way provided about 800V. It enabled 5JX to be heard loud and clear 650 miles away on a two-valve receiver. We amateurs were beginning to have to share our working frequencies, such as 680 and 1,500 kHz, with the upstart B.B.C. But we found that the despised "high" frequency of 2,600 kHz was better for DX, and still using the voltage raiser and keeping within the regulation 10 watts input to the transmitting valve I managed in 1923/4 to be heard in Canada.

The financial stringency already referred to was obviously an incentive, though not the only one, towards offering a description of the voltage raiser to *W.W.* The American *Radio News* added to the injury of reprinting the article in full without payment the insult *"English* 5JX". I wrote a fuller, mathematical, account for *W.W.*'s new sister journal, *Experimental Wireless*, which went through several changes of name, finishing up as *Industrial Electronics*.

Incidentally, on the other side of the first page of my *W.W.* article was a picture of a young man, Capt. P. P. Eckersley, gazing proudly at half a dozen little boxes festooned untidily with wires, which comprised the equipment for relaying B.B.C. programmes from London to the regional stations. The following year I saw the inside of the B.B.C. myself, or at least the poky little office in which its General Manager, a Mr J. C. W. Reith, functioned. I had come there to solicit his influence for getting a job. (There was little chance in those days of getting one without.) He was very thin, very tall, very brusque and intimidating, and had a glass of milk and a bar of chocolate brought in for his elevenses. Finally he rang a Mr Frank Phillips, Chief Engineer of Burndept Ltd. (one of the six sponsoring firms of the British Broadcasting Company) and passed me on to him with a far from encouraging assessment. So I was delighted when Mr Phillips received me kindly and made me his Head of Research at £4 10s. a week — 50% up on what I'd been getting at Creed Telegraphs. But that is by the way.

For the next eight years most of my writings appeared in *E.W.* and in the many periodicals that were springing up in response to the home-constructor boom. An exception, in 1927, was a contribution to *W.W.* showing by means of amplitude/frequency graphs the horrific distortion caused by feedback, usually positive, due to impedance in the common



Some details of Mr. Scroggie's voltage raiser, reproduced from the 15th August 1923 issue of Wireless World.

power supply to the amplifier stages. (Negative feedback, as a desirable technique, is usually dated from 1934.)

Among my treasured possessions are copies of the first issues of *Radio Times* and the home constructor period magazines. (I had been too young to take the first issue of *The Marconigraph* or even its first appearance under its new name of *The Wireless World.*) Looking through the home-constructor magazines again I have noted some items that may awaken nostalgia in my contemporaries and astonishment or amusement in my juniors.

In *Wireless Weekly,* dated 11th April 1923 and providing 74 pages for what is now known as $2\frac{1}{2}$p, there was an ad by the celebrated Mrs Raymond of Lisle Street, Soho. In it she offered "sets of parts for assembling 0.0005 mfd condensers, 29 plates" for 4s. 3d, and added "all orders in strict rotation". Whether the condensers themselves could be rotated depended on the skill of the assembler. Other essential components of the period were screwed rod, washers, nuts, switch arms and contact studs. From this it will be gathered that making wireless sets at home was not just assembling components as we now know them; still less, of course, complete circuits; first one had to make the components. High-value resistors were made of blotting paper soaked in indian ink. Even the keen amateur was not expected to make his own headphones however; these could readily be bought complete and were the main cost of a crystal set. The set for the wireless enthusiast, as distinct from the general public who wanted merely to "listen-in" to the B.B.C., was the ex-army Mk III (or III*) Tuner. It had been manufactured at what must have been enormous expense even for those days, in the same way as scientific instruments. The tuning coils were wound with substantial litz wire on ebonite cylinders about 4 in dia. which were helically grooved to receive it. Numerous tappings were made, and selected by instrument-type multi-stud laminated-arm switches. There were two variable capacitors, one of 1,500 pF and the other 500; again, lovely pieces of craftsmanship. I had a pair of them until very recently, when I had to move to a smaller place. The set included a buzzer as well as a crystal detector.

People were by this time beginning to go in for valves, costing about 25s. (£1.25) each and consuming nearly 1 A at 4-6 V from an accumulator, and requiring besides a "high tension" (h.t.) dry battery of usually 120 V. The vastly better performance of valve sets, with much smaller and cheaper coils, was due almost entirely to positive feedback (known as "reaction") which if over-used caused self-oscillation and interference to listeners for miles around. The major part of Captain Eckersley's public relations effort was concentrated into the classic exhortation "Don't do it!"

The first issue of the monthly *Modern Wireless* (also edited by the ubiquitous John Scott-Taggart) contained one of the first expositions by P. G. A. H. Voigt (whose work on sound reproduction was later to be greatly esteemed and who as far as I know is still living in Canada) of "dual" or "reflex" circuits. These made possible major economies by utilizing a single valve to amplify both at r.f. and a.f. Recently the idea has been revived for transistor sets, though why anyone should want to go to the trouble with them I can't imagine.

The same magazine reveals that the G.P.O. had not yet fully adjusted its thinking to anything so unseemly as *entertainment* of the public by wireless telegraphy (*sic*). Until the formation of the B.B.C. a few months earlier, the only receiving licence known to the G.P.O. was one authorizing the holder to install or work apparatus for carrying out experiments in wireless telegraphy. The applicant had to produce evidence of British nationality and two written references as to character, and had to satisfy the Postmaster General that he had in view some object of scientific value or general public utility ("General statements are not sufficient"). The installation, of which full details, including a dimensioned sketch of the aerial, had to be submitted, had to be approved by the P.M.G. and be open to inspection at all reasonable times. If the applicant was under 21, the full names, nationality, etc., of parent or guardian, who would be held personally responsible for observance of the terms, had to be given. One of the many said terms was that the use of reaction on wavelengths between 300 and 500 metres was not permissible between the hours of 5 p.m. and 11 p.m. on weekdays or at all on Sundays.

Obviously broadcasting would not have got off the ground if all listeners had been obliged to go through this sort of hoop. It is perhaps an indication of the reluctance of the G.P.O. to grant alternative licences of a more appropriate kind that it retained half of every ten-shilling fee, the other half being what the B.B.C. had to live on. And this licence was restricted (*de jure,* if not always *de facto*) to the use of apparatus stamped with a circular badge having "B.B.C." in the centre, surrounded by "Type Approved by Postmaster General". A royalty on such apparatus provided supplementary income for the B.B.C.

Technical magazines and journals nowadays almost invariably include one or more postal cards on which to send for further information concerning a selection of the products advertised, and one might suppose this was quite a recent development. It is not. One of my "No. 1" wireless magazines, more than 50 years old, has such a card. The only real difference is that one had to pay postage on it, but as that was only about 0.2p for what was at least as good as present-day first-class mail that was not a major disincentive.

Since my first written contribution to *W.W.,* 750 others have appeared, if book reviews and letters are included. To avoid my Aberdonian name, harsh no doubt to English ears, appearing too often, and to allow me a freedom of expression that might be considered by some to be frivolous or disrespectful coming from a professional engineer, in 1934 by a Jekyll-and-Hyde fission process I appeared alternatively as Cathode Ray; and in 1939 a further subdivision yielded Henry Farrad, who displayed exceptional virtuosity in solving technical problems, having taken care himself to invent the problems beforehand. There were also a few other and more transient emanations. Regretfully, I cannot claim to be Vector, but I would like to pre-empt the name Phasor for possible future use.

I must not end this sonata for solo trumpet without a coda consisting of a grateful tribute to successive editors — H. S. Pocock; H. F. Smith; F. L. Devereux; H. W. Barnard; and now T. E. Ivall — for their tolerance, encouragement and guidance over the half century.

Flat display tube in colour

Display panels are being developed at Philips Research Laboratories in Eindhoven that might overcome the single-colour limitation of existing gas-discharge panels. If successful, such a development would have application in areas of information display where the number of characters to be shown is between the low number used in conventional digital instrument displays and the high number that the cathode ray tube is capable of.

The idea is related to the gas-discharge matrix tubes developed at Mullard Research Laboratories some years ago (*W.W.* 1969, page 228). Since then bigger displays have been developed at Philips. Such panels use a sandwich construction with a glass front having horizontal conductors deposited on one surface, a glass back having vertical conductors, and between them a matrix sheet with gas-filled holes aligning with the wire intersections.

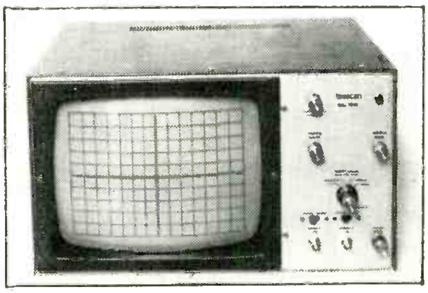
The approach used to get full colour displays differs in that a positive-column discharge is used — as in fluorescent tubes, flash tubes and neon signs — as opposed to the negative glow in small cold-cathode discharge tubes. Adopting this approach opens the way to coloured displays by using different phosphors. The idea is to construct a matrix in a similar way to the glow-discharge matrix panels, but to coat the inside of the hole with a phosphor that will emit on receipt of ultra-violet radiation from the gas discharge. In practice, ignition potentials are high, 700 to 800V with a cold cathode, so an auxiliary anode is used on the other side of the cathode, the effect of which is to reduce ignition potential to 250V. Colour information would of course be provided by using triangles of three primary colours. With this technique a luminous efficiency of 1 to 5 lm/W is achieved, a good improvement on negative-glow discharges.

New Products

Miniature uniselector

"Miniscan", a miniature uniselector, is now available from the Controls Division of Pye TMC Components Ltd. This ratchet-driven three-level uniselector is of unique design which satisfies present-day demands for automatic switching in confined spaces. It can be mounted in any attitude and it occupies little more than half the space of a British Post Office relay type 3000. The mechanism requires no maintenance — even routine lubrication is not required — and it can be replaced simply by unplugging it from its jack.

The Miniscan is a ratchet-driven device of the reverse-drive type, with a minimum of moving parts. There are three main components: the basic mechanism, the bank contact assembly and the jack. The latter is designed for fitting to a mounting-plate or chassis and the Miniscan is plugged into the jack and retained in position with a nut. The design of the Miniscan provides for long life and reliability. It will perform at least 24 million steps without need of adjustment or maintenance and it has therefore been possible to provide complete protection by enclosing it in a metal casing which is spun into place. The switch has three levels each of twelve outlets. Decade counting is possible using twelve outlets. The moving parts of the Miniscan are of low mass and enable much higher speeds to be reached than are possible with conventional switches. They will self-drive at between 85 and 130 steps per second. Pye TMC Components Ltd., Controls Division, Roper Road, Canterbury, Kent.
WW 323 for further details



Large screen display unit

The DU-120 is a large-screen, low-cost display oscilloscope made by Texscan. Stabilized e.h.t. and a dual f.e.t. input give a trace of high stability under all conditions. It is claimed that the bright trace shows up well in high ambient light conditions, even direct sunlight.

A 12in display tube, vertical sensitivity of 1mV per division of 1.5cm, and a marker adder facility make the DU-120 a useful oscilloscope for sweep generator applications. Texscan Instruments Ltd., 1 North Bridge Road, Berkhamsted, Herts.
WW 325 for further details.

Digital phase-angle voltmeter

Aveley Electric Ltd., distributors for North Atlantic Industries Inc. are now introducing a line of digital phase voltmeters which provide an analysis of complex a.c. waveforms at a discrete frequency or frequencies. The parameters measured are total, fundamental, in-phase, and quadrature voltages plus phase angle, which is displayed directly in degrees from 0° to 360° with a resolution of 0.1°. A b.c.d. output is optionally available.

The digital phase-angle voltmeter can be used on the bench or in automatic test applications. Remote programming and auto-ranging allow for operation in automated test consoles. The model 220 operates in phase measurements at a single specified factory-set frequency from 30Hz to greater than 30kHz, whilst the Model 225 has the facility for working at two to four discrete frequencies. Both models can measure voltage over the frequency range 30Hz to 100kHz. A phase-lock loop allows for mid-band angle accuracy of 0.25° with in-phase and quadrature voltage accuracy of 0.1% of full scale. Additional features include greater than 60dB rejection of voltage auto-ranging spikes 1μV resolution on the 10mV scale, and a reference voltage range from 0.2V to 200V without adjustments. Aveley Electric Ltd., Roebuck Road, Chessington, Surrey, KT9 1LP.
WW 326 for further details.

Pocket scientific calculator

A pocket-size scientific calculator has been introduced by Hewlett-Packard. The HP-45 is designed for use in science, engineering, statistics, mathematics, navigation and surveying, and permits the user to solve complex, multi-step problems with greater ease and in less time than previously possible. It has a solid-state (m.o.s.-l.s.i.) memory and is a significantly more powerful version of the HP-35 scientific calculator which has been on the market for more than a year. In addition to increased memory capacity the HP-45 is claimed to be the first pocket-size calculator with polar-rectangular co-ordinate conversion, metric-U.S. unit conversion constants, and the ability to operate in any of three trigonometric modes. Twenty-four of its keys can perform more than one function.

The new calculator offers a number of additional features; one of the most significant is an addressable memory system with nine separate memory registers. These memory locations permit register arithmetic and simultaneous two-dimensional vector accumulation. The user may specify which of the registers he wants to store a number in, recall it at the touch of a button, or combine it with other stored numbers or keyboard functions. Like the HP-35 the new calculator has four operational storage registers that hold intermediate answers and automatically bring them back when needed in a calculation.

The HP-45 operates in any of three trigonometric modes — degrees, radians or grads. It provides trigonometric and logarithmic functions as well as addition, subtraction, multiplication and division. It can raise numbers to powers and calculates reciprocals simply by touching a key. A special feature is its ability to convert decimal angles to degrees, minutes and seconds, or vice versa.

Hewlett-Packard is simultaneously introducing a desk-top version of the HP-45, which is called the HP-46. This unit incorporates an impact printer using standard adding machine paper tape and an optional 15-character solid-state display. Price of the HP-45 will be £208 inclusive of VAT and the HP-46, £389 inclusive of VAT. Discounts for cash with order are available for both models. Hewlett-Packard, Ltd., 224 Bath Road, Slough, Bucks. SL1 4DS.
WW 327 for further details.

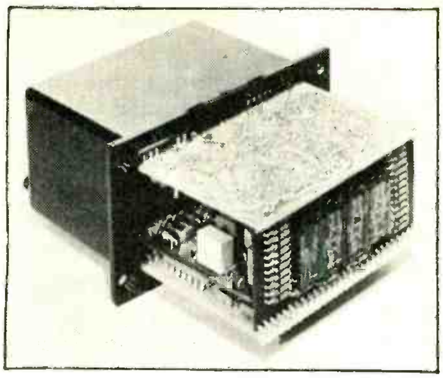
Low-cost portable frequency standards

Frequency standards that are compact enough to be portable, and yet stable enough for applications such as standard frequency broadcasting or laboratory use, are being marketed by Racal Instruments. Known as the Sulzer 2.5B, and manufactured by Tracor, the unit provides outputs at 5MHz, 1MHz and 100KHz which are derived from fail-safe regenerative frequency dividers. The guaranteed frequency stability is 1×10^{-10} per 24 hours, with a short term stability better than 1 times 10^{-10} for one second averaging time. The oscillator when used with a suitable v.l.f. tracking receiver, such as the Tracor 900, will provide accuracies and stabilities to atomic standard performance at much reduced cost.

A standard rack mounting (19×5.25 in.) will mount up to three frequency standards, or one standard and one power supply. Power supply units will provide up to 10, or alternatively 20, hours of self-powered operation at either 115 or 230V, 48-400Hz, automatically maintaining internal batteries in a fully charged condition. Changeover from line to battery supply is accomplished without loss of output or stability. Racal Instruments Ltd., Duke Street, Windsor, Berkshire SL4 1SB.
WW 328 for further details.

Digital panel meter

The model DM-2000 digital panel meter from Tranchant Electronics (U.K.) Ltd. is designed with a true differential input. All inputs can sustain up to ± 2V, common mode with respect to the digital output common. Other input features include a choice of input range, ± 1.999mV or 1.999V full scale, a common mode rejection ratio of 70dB at 60Hz, an input bias current of 20nA and an input impedance of 100MΩ plus automatic polarity switching. The meter has a specified accuracy of ± 0.05% and can resolve to 100μV while operating over a temperature range of 0° to +70°C. Input settling time is 50μs and up to 200 readings can be made asynchronously or synchronously. An

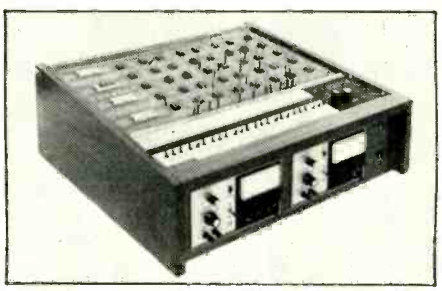


l.e.d. 3½ digit solid state display is provided, together with additional 100% overrange, overflow, decimal point and polarity displays. The DM-2000 is housed in a case measuring $3 \times 1.75 \times 2.25$in and weighs less than 6 oz. All control inputs and digital outputs are t.t.l./d.t.l. compatible. Tranchant Electronics (U.K.) Ltd, Tranchant House, 100a High Street, Hampton, Middlesex.
WW 329 for further details.

I.c. breadboarding system

A breadboarding system for integrated circuits with many unique features has been developed by Limrose Electronics Limited. The new system, PB 100, is a large, sophisticated unit with built-in power supplies for rapidly simulating complex digital, analogue or hybrid systems. It features removable patch panels each of which will accommodate up to 44 dual-in-line integrated circuits. Interconnections between i.cs are made using the Limrose multicoloured solderless patch lead and gold-plated terminal pin system.

Developed in conjunction with the Department of Electrical and Electronic Engineering of Bolton Institute of Technology, the PB 100 System will be used by both undergraduate and post-graduate students on advanced projects using digital



and linear integrated circuits. As a single patch panel can accept up to 44 dual-in-line integrated circuits, this system is claimed to be extremely useful for development work on large industrial control systems, computers, etc. Removable patch panels can be replaced within minutes with other patch panels with different design problems which makes this system invaluable in the multiple-user environment of a teaching establishment or research and development laboratory.

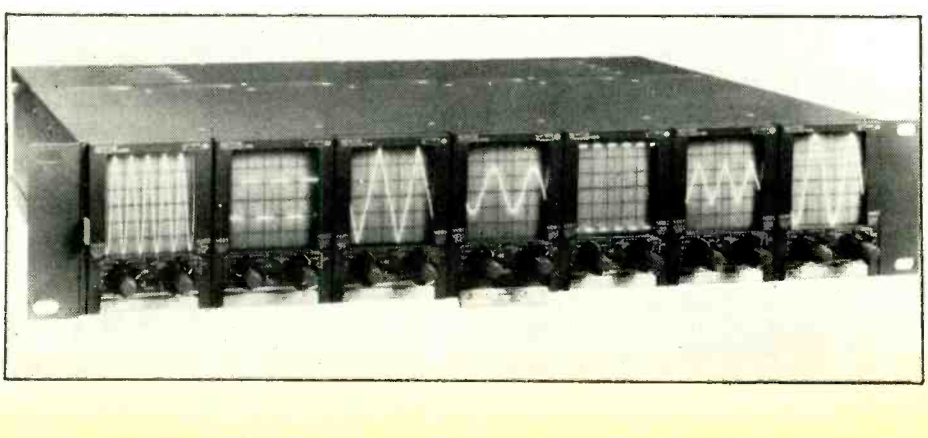
Integrated circuits with 8, 14, 16, 18, 24 or 40 pins in the dual-in-line configuration are simply plugged into sockets on the patch panels. Discrete components and other types of integrated circuits can be used with an inexpensive adaptor. The control panel has 24 input switches with contact-bounce suppression and 24 buffered light-emitting diodes used as logic indicators. A t.t.l.-compatible 1Hz-1MHz clock and a manual pulse generator are also included on the control panel. The PB System can be supplied with or without built-in power supplies to suite customer requirements. Prices from £225. Limrose Electronics Limited, 8-10 Kingsway, Altrincham, Cheshire, WA14 1PJ.
WW314 for further details.

In-line monitor scope

With the introduction of the Series 1200 by Fluke International Corporation, Vu-Data Corporation has brought the monitor oscilloscope to a new functional status. Presentation of seven channels on the same horizontal line is claimed to facilitate greatly comparison between any two channels, with a 2 in. high display.

In the Series 1200 all controls are on the front panel, eliminating the need to slide the instrument out to adjust position, focus, intensity, etc. Controls for these functions are located behind a small "trap door" at the bottom of each module, which also serves as a handle for removal. Absence of rack slides on the 1200A results in smaller size and weight, eliminates cable-tangling at the rear of the instrument, and contributes to its lower price.

Seven separate modules plug into a common power supply/rack adaptor, resulting in an instrument only 3½ inches high. Two different module types are available, which may be used in any combination. The 1210A Module has controls and calibrations designed specifically for tape recorder users, while the



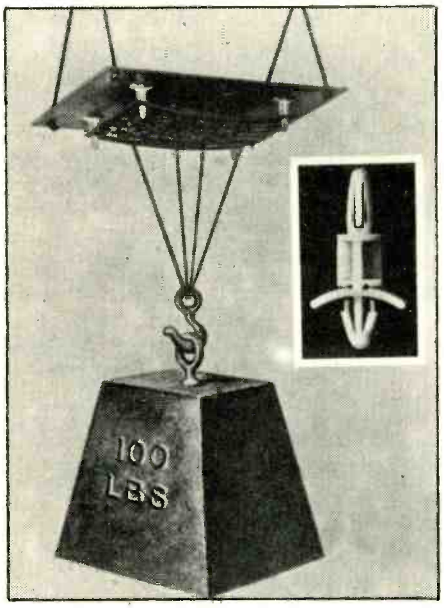
1220A Module has controls identical to those found on laboratory scopes.

Other specifications include: d.c. to 5 MHz bandwidth. 10mV/div. to 50V/div. sensitivity, μ 2 sec/div. to 20msec/div. time base, two selectable inputs for each channel and internal or external triggering. Price: £1,347. Fluke International Corporation, Garnett Close, Watford WD2 4TT.

WW316 for further details.

P.c.b. supports

From PBRA Ltd is a new Series LCBS locking printed circuit board support. Four supports, one at each corner of the board, will resist up to 100lb pull. A new arrow type locking head inserts into a 0.187in. hole in the chassis where it expands to lock permanently into position. The circuit board snaps over the top of the tapered support where it is held firmly in position by a tension flange which, compressed



upon entry, springs back out to lap and secure the board. A squeeze of the fingers permits removal of the board from the support.

Made of natural colour nylon, the LCBS supports are available in seven spacing heights from 0.1875in. to 0.875in. Free samples are available. PBRA Ltd, 33 Holmethorpe Avenue, Holmethorpe Trading Estate, Redhill, Surrey.

WW302 for further details

Dual track slider potentiometers

A large range of dual-track slider potentiometers with an internal screen between the tracks has been introduced by RS Components. The bodies are moulded in glass-filled nylon with snap-on brackets for easy panel mounting. The terminations are suitable for either direct wiring or p.c.b. mounting. Maximum dissipation is 0.4W and 0.2W for linear and logarithmic types respectively, with better than 2dB track matching. The tolerance is 20% or 30% depending on the resistance value. These new pots. are available by return of post at 65p each and there is a knob that matches at 12p. RS Components Ltd., PO Box 427, 13/27 Epworth Street, London, EC2P 2HA.

WW318 for further details

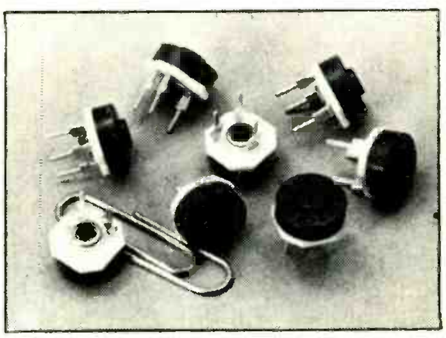
Polycarbonate capacitors

Seatronics (UK) Ltd. has expanded its range of polycarbonate capacitors with the introduction of Type CSM. Housed in flame-resistant nylon cases, this type has similar properties to the earlier polycarbonate capacitors (Type CSK). The difference is in the body size and lead configuration (CSM has axial terminations). The capacitance range is 0.01 to 10μF $\pm$10% with 5%, 2% and 1% tolerance to order, over the working voltage range of 63 to 400V d.c. Tan delta is less than 0.003 at 1kHz and the capacitors will withstand 150% of the working voltage for 30s. Operating over an ambient temperature range of $-55°C$ to $+85°C$, CSM capacitors are suitable for stringent environmental performance, in particular for instrumentation and telecommunication applications. Seatronics (UK) Ltd, 22-25 Finsbury Square, London, EC2A 1DT.

WW319 for further details.

Miniature cermet trimmer

The RGP 10 miniature pre-set cermet potentiometer, now introduced by Guest International Ltd., is claimed to be one of the smallest devices of its kind available. Just 19mm in diameter, the 1000+ price of 14p each also makes it one of the lowest-priced on the market.



The RGP 10 is rated at 0.5W at 40°C, resolution is infinite, and the temperature coefficient is $\pm$ 250p.p.m./°C. Resistance range is 100Ω to 1MΩ. Featuring an integral dust cover, the device also offers standard 0.1in grid pin spacing which, with its low price and technical specification, makes the RGP 10 a practical alternative to carbon devices. Industrial Electronic Components Division, Guest International Ltd., Redlands, Coulsdon, Surrey, CR3 2HT.

WW320 for further details.

R.f.i. filters

A comprehensive range, consisting of approximately 150 varying types of budget priced radio interference filters is now available from Suppression Devices. Certain of these filters are specifically designed to meet varied British and European specifications with current ratings ranging, in the mains filter series, from 300mA, 50Hz to 200A, 50Hz. Also available is a series of military filters with varying ratings up to 120A at 28.5V.d.c. Three phase, 4 line filtering can also be adequately catered for, to a current rating of 40A, 50/60Hz. Filter units can be modified or designed to individual requirements. Included in this range of filters is a series of single line "lead through" filters with current ratings to 200A, 50/60Hz. Varying types of "*XY*" star or delta capacitor suppressor networks are also available, along with more specialized individual single capacitor suppressors, for use at voltages up to 500, 50Hz. Suppression Devices, Woodfield Works, Trafalgar Street, Burnley, Lancs.

WW321 for further details

Vacuum record cleaner

The manufacturers, R.I. Audio, claim that their new "Groovac" record cleaner is the only unit available which removes dust from records by vacuum cleaning. A tracking force of only 0.7g has been achieved by using a lightweight design with lubricated-for-life bearings throughout. This is considerably below the 3 to 6g force of simple brush cleaners. Low tracking force allows fine hairs to be incorporated in the Groovac cleaning nozzle which ensure efficient removal of dust from the bottom of record grooves — most brush cleaners have hairs with a diameter which is larger than the width of the record grooves.

The Groovac consists of a precision lightweight arm, and a suction unit which is acoustically isolated in a special enclosure. The suction unit has been designed to be inaudible at a distance of 2 metres; it has a mains switch and indicator, and is finished in teak. The arm is mounted by means of a magnetic base, and its height is adjustable to suit different turntables. When not in use it is simply rotated outwards and lowered on to its integral rest. Price £6.90 plus VAT. Available from hi-fi retailers or direct from R.I. Audio, Kernick Road, Penryn, Cornwall.

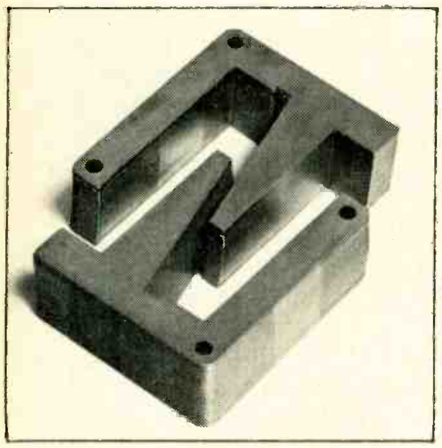
WW322 for further details.

Ingenious transformer core

Our picture shows an unusual type of transformer core now available from Kent Insulations. This design has very real advantage over the traditional 'E' laminations in that it eliminates the time-consuming (and therefore expensive) business of inserting the individual laminations.

Once the coil has been wound, the two halves of the 'Waasner-Ready-Core' are simply pushed together. The wedging action of the centre sections ensures good magnetic continuity right through the core, while built-in clips hold the core securely together. Kent Insulations Limited, Power Road, Chiswick, London, W4 5PZ.

WW301 for further details.



Miniature rotary switch

A ten-position miniature rotary switch, 0.3in. diameter, has just been added to the Highland/Grayhill range of electrical components. Two styles are available, the 75AP, a screwdriver-operated switch 0.3in. diameter, 0.6in. long, and the 75BP, shaft-operated 0.3in. diameter, 1.125in. long switch.

These have terminals suitable for mounting on printed circuit boards and are available with 1 pole 10 positions or 2 poles 5 positions per pole configurations. The electrical rating are 100mA at 115V a.c. or 30V d.c. resistive load, for a life of 10,000 cycles. The 100 off price is £1.50 each. Highland Electronics Ltd., 33-41 Dallington Street, London EC1V 0BD.

WW304 for further details.

Low cost power unit

A low cost, regulated d.c. power supply, made by Zauie Industries Ltd, is available from PBRA Ltd. Designated Type 2005, the unit has an output range of 0-20V d.c. at 0 to 0.5A. Both line and load regulation is within 0.01% + 1mV. Ripple and noise at full load is less than 1mV peak to peak and resolution is within 50mV. The unit has a 20μs transient recovery time and a total drift figure of less than 0.1% + 4mV over an eight hour period. Measuring only 3 × 6 × 8in., the 2005 has its own voltmeter and separate ammeter built in, and is priced at £25. PBRA Ltd, 33 Holmethorpe Avenue, Holmethorpe Trading Estate, Redhill, Surrey.

WW305 for further details.

Frequency-agile magnetron

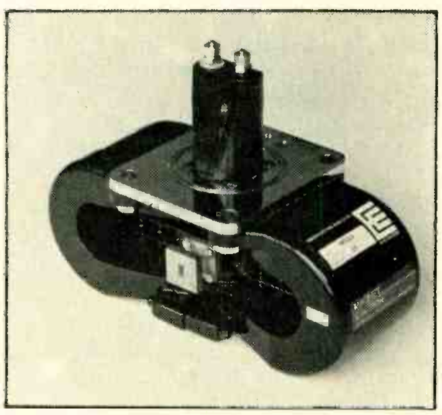
Rapid tuning, a claimed long life and reliability are provided by a completely new method of frequency-agile tuning used in the latest Q(Ka)-Band magnetron, type M5059, made by English Electric Valve Co. Ltd.

Tuning is obtained by applying a voltage waveform to the input of a piezo-electric transducer which, because of its high impedance, requires only a very low drive power. The agile range can be swept at frequencies up to 1kHz. The life of the tuner is not impaired by moving surfaces in contact with each other. By mounting the tuner mechanism within the vacuum envelope, potentially unreliable mechanical bearings and vacuum bellows are eliminated.

The M5059 is designed to meet the full requirements of a modern frequency-agile Q(Ka)-Band radar. It has a peak output power of 50kW and can be operated with short pulses and high rates of rise of voltage. Each tube is tested at more than 400kV/μs.

Life tests have shown this tube to have an exceptionally high degree of stability from the moment full pulse voltage is applied. English Electric Valve Co. Ltd., Chelmsford, Essex.

WW306 for further details.



Colour monitors

The Tektronix 670 Series colour television picture monitor uses a 17in. 114° Trinton (470DLB22) c.r. tube. Screen size is approximately 138sq. in. (890sq. cm) with an aspect ratio of 3:4. Two inputs are provided for encoded video signals and these can be isolated from the chassis to prevent ground current induced hum and also isolated from all others. Hum is at least 50dB down with up to 4V r.m.s. mains frequency common-mode signal.

Two external composite sync inputs are provided which automatically switch between sync sources as the video input is switched. The sync inputs may be isolated from the chassis in the same manner as the encoded video inputs. Chrominance gain and phase (N.T.S.C. only), video gain and brightness controls are provided with presettable detented positions. These positions allow the monitor to be reset to its standard calibration at any time. A front panel lamp indicates non-calibrated operation. Chromaticity of the c.r. tube in the 670 Series Monitors falls within the ranges specified by C.C.I.R. recommendations for PAL and by the Canadian Television Practices Committee.

The c.r. tube is operated from a fully regulated e.h.t. supply providing 24kV. This supply is interlocked with the horizontal and vertical deflection circuits to prevent damage to the c.r. tube in the event of deflection failure. The e.h.t. is also protected against current overload. When the current limiter is in operation, certain characteristics of the monitor are necessarily altered, therefore a front-panel "OVERLOAD" indicator lamp is provided.

Note:- Colour matrix correction in N.T.S.C.

PAL 1 display phosphors in common use today, including those in the Tektronix 650 and 670 Monitors, differ in chromaticity from those which were used as the basis for the N.T.S.C. standards. Changes were made to secure advantages in brightness, producibility and hue stability. American receivers have compensation for the resulting shifts in hue and saturation and produce a picture very much in accord with the N.T.S.C. standards. Studio monitors, and colour bar generators on the other hand, have maintained the original N.T.S.C. coding and matrixing, resulting in chrominance errors in the display which are due to the difference between the N.T.S.C. camera primaries and the present display primaries. Tektronix Limited, P.O. Box 36, St. Peter Port, Guernsey, Channel Islands.

WW307 for further details.

Millimetre wavelength mixers

Many countries are developing low-loss trunk waveguide systems which are being designed to operate at gigabit rates with attendant high intermediate frequencies. For this purpose, and any other systems with gigahertz intermediate frequencies, EMI-Varian Ltd. has introduced the

MMC 10 series of millimetric mixers.

The mixers in this new range use a gallium arsenide Schottky barrier diode incorporated in a waveguide wafer. No sliding of this wafer is required for matching, only tuning of the short circuit being necessary. They are available in all waveguide sizes to cover the frequency range 20GHz, to 170GHz, and extension of the range to 300GHz is in progress.

The typical conversion loss (including all mismatch losses and mount losses) varies from 4.5dB at 30GHz to 11.5dB at 135GHz.

Intermediate frequencies up to 14GHz may be used for devices designed to separate above 40GHz and up to 8GHz for those designed to work below 40GHz. Excellent broadband mixing is achieved with low v.s.w.r. at both r.f. and i.f. ports. Both single and balanced versions are available from EMI-Varian. In addition, there is a range of single mixers with two r.f. ports for upconverter application, and up to 1mW may be generated in this mode at frequencies up to 90GHz.

Tests have shown these devices are also sensitive detectors with low flicker noise characteristics. The full benefit of these low noise characteristics can be obtained in systems with extremely low intermediate frequencies, such as doppler radars.

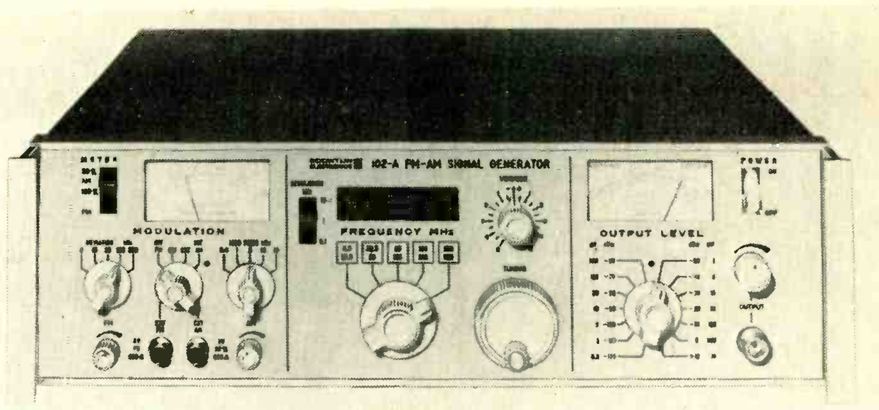
For mixers at lower frequencies (below 20GHz) the local oscillator level is in many cases sufficient to bring the diode into conduction. At higher frequencies this is not always the case due to the lower powers available. Thus it is advisable to apply a d.c. forward bias voltage to the diode for maximum efficiency in the mixing mode. EMI-Varian Limited, Hayes, Middlesex, England.
WW 310 for further details.

Magnetic switch

A magnetic switch, claimed to be of a totally new form and designed to handle high inductive loads without any contact protection, has just been launched in the U.K. by B & R Relays. Called the ATS-6000 (Axial Travel Switch), the new Gordos-manufactured switch complements the company's existing range of dry reed, mercury wetted and mercury tilt switches.

Initially, the switch is available in two standard lengths — 24mm and 17mm with a maximum diameter of 3.55mm. Contact rating is 15VA/watts, one amp resistive at a maximum of 50V, d.c. Operating temperature is between 12°C and 125°C.

Hermetically sealed and strongly built (the terminals are designed for fuse-clip mounting), the normally closed version meets all the normally open switch specifications with the exception of the contact rating which is 0.5A resistive maximum — unlike its reed switch counterpart, however, it does not require any magnetic biasing. B & R Relays, Temple Fields, Harlow, Essex.
WW311 for further details.



F.m.-a.m. signal generator

Boonton Electronics Corporation have introduced a high performance f.m.-a.m. signal generator — the Model 102A — which covers the frequency range 4.3MHz to 520MHz.

Using a combination of fundamental only, mixing, multiplying and dividing techniques for frequency generation, the Model 102A is claimed to avoid problems inherent in systems using single generating techniques. Readout of frequency is by a 6-digit display giving 100Hz resolution, and stability after a 2-hour warm-up period is typically 10 p.p.m./10 min. Internal or external modulation modes can be selected by a front panel switch with f.m. variable from 0 to 300kHz peak calibrated, or to greater than 1MHz uncalibrated, and a.m. variable from 0 to 100% at modulation frequencies of 400Hz, 1kHz, 3kHz, 10kHz and 19kHz. Modulation monitoring is by a panel meter.

Output levels from −130dBm to +13dBm can be selected by a 13-step attenuator giving 10dB step plus variable 13dB calibrated on the output meter. Output levelling is better than ±0.5dB across each of the five bands and output impedance is 50 ohms. Euro Electronic Instruments Ltd, Shirley House, 27 Camden Road, London N.W.1.
WW308 for further details

Strobing meter

The Strobovolt produced by Physical & Electronic Laboratories Ltd includes two completely independent multirange meters which cover a wide range of voltage and current measurement. The voltage selector switches from 0.5V through ten ranges to 500V and the meters have an input impedance of 1MΩ/V on all ranges. The eleven current ranges on each instrument extend from 1μA full scale deflection to 0.5A.

The type of measurement, however, differs from previous multimeters by using a strobing action which samples a repetitive waveform applied to the input for less than 0.5μs, once per cycle. By means of this narrow sampling pulse, the frequency of which is adjustable from the panel controls, it is possible to minutely examine any part of the waveform. Thus peaks, troughs, and other discontinuities on the input waveform may be accurately measured. Moreover, as the instruments are synchronized to sample their respective input waveforms simultaneously the two meters will always indicate the relative instanteous voltages or currents applied, and will therefore accurately indicate the relative phase.

By adjusting the sampling frequency to be slightly different from the input frequency the sampling pulse will slowly progress through the waveform applied to the input and will produce an accurate copy of the input waveform but at a frequency which is equal to the difference between the input and sampling frequencies. Thus a low frequency copy of the input waveform is produced in the same way as a stroboscope. This low frequency waveform which is produced at the output of the integrator amplifier in the strobovolt is available at the output sockets and may be used, for instance, to drive an *x-y* plotter which will then record accurately waveforms which occur at many thousands of times the speed at which the *x-y* plotter could normally respond. For this use, it is convenient to use one meter for the *x* direction and the other for the *y* direction.

Uses for the Strobovolt include harmonic analysis, phase and distortion measurement, etc. and by means of the synchronizing pulse input, the device can measure voltage or current at a specific instant as required in time-division multiplex systems. Physical & Electronic Laboratories Ltd, 28 Athenaeum Road, Whetstone, London N.20.
WW315 for further details

Two-channel recorder

Elcomatic have recently announced their new EM 700 two-channel direct writing recorder which accepts inputs of ±500mV for the 5cm full deflection. Rectilinear write-out is by means of hot styli on heat sensitive paper. The temperature of each stylus can be adjusted independently to give a trace density suitable to the waveform being recorded and is automatically compensated for change in paper speed. The standard chart speeds are 30mm/min and 25mm/sec, although alternative speeds are available. The recorder is available as free standing or rack mounted, and costs £395. Elcomatic Ltd, Kirktonfield Road, Neilston, Glasgow, G78 3PL.
WW324 for further details

Real and Imaginary

by "Vector"

'. . . Not a Horse, Not a Bus, but a Tram'

In a journal of the technical standing of *Wireless World* it's only natural that a considerable proportion of its articles and correspondence columns should be concerned with the problems of minimizing distortion in amplifiers and sound reproducers. But I sometimes wonder whether we tend to stick too closely to the conventional tram-lines of transistors (in terms of amplification) and the various woofer-tweeter combinations which serve as transducers.

"So what else is there?" comes the question from the back of the hall. That's something I haven't got the space to deal with fully here and so all I can suggest is that my inquisitors should beg, borrow or steal a copy of Blake's "History of Wireless Telegraphy and Telephony" (Chapman and Hall, 1928), and he will find enough off-beat ideas for loudspeakers to keep him going construction-wise for quite a while.

Flame reproducers, for instance. (No — this isn't a misprint for "flare" — I really do mean "flame"!) It isn't exactly a new idea; the accord which exists between sound and flame was noted by J. Leconte in 1858 and a number of distinguished names have worked on it over the years, including Lord Rayleigh and Professor Andrade. Some five years ago a letter to *Nature* resurrected the topic* and I'm indebted to this for what follows: —

The simplest device described is one in which a flow of oxygen is arranged to pass over a diaphragm attached to a conventional moving-coil unit (N.B. in the authors' diagram, air is given as the medium but the text says "oxygen"). After passing over the diaphragm the air/oxygen is concentrated into a jet which blows at right angles into a natural-gas flame of the Bunsen burner type. Given a tape-recorded input into the moving-coil unit, the authors state that the flame will provide a rendering which is limited in quality only by the recording and the modulation unit.

This, of course (as our hi-fi enthusiasts will quickly point out if I don't get in first), makes no significant contribution to quality as all the conventional distortion-introducers still remain in the chain. What it does do, however (claim the authors), is to provide amplification "of the order of several hundred", and that's most interesting.

But the flame can also be modulated electrically. For this approach, two tungsten electrodes are introduced into it, one at the base of its visible region and the other at the top end. The other ends of the electrodes connect to the secondary windings of an a.f. transformer, one directly and the other via a biasing supply. The recommended flame is in this instance derived from an oxy-acetylene welding torch and to assist ionisation an asbestos wick feeds an alkaline salt solution (potassium nitrate) into the flame. With audio applied via the transformer primary, the arrangement, say the authors, will fill a large room with speech or music.

So there you are, all you hi-fi enthusiasts athirst for fresh woods and pastures new. Abolish the tyranny of the cone! Mystify your friends and achieve the ultimate in one-upmanship! There may, of course, be minor obstacles; the distaff side could conceivably become a shade unreasonable about harbouring an oxy-acetylene welding plant in the lounge, but don't let that discourage you. Trade her in for an arson-orientated model and press on regardless. Seriously, though, it's an interesting project and I'd be glad to hear from anybody who's actually tried it.

Coming now to less far-out amplifiers, does anybody know what became of the solid-state triode of about ten years ago? (No, I don't mean the various types of transistor.) One form of the device consisted, as I recall, of two slices of cadmium sulphide crystal with a conducting layer between them. A silver contact at the top formed the anode, the conducting layer the gate or grid, while a deposit of indium at the bottom end of the other slice was the cathode (no heater needed). The valve had a high input resistance and allegedly held promise of useful amplification at microwave frequencies.

I seem to remember that one of the bugs in the experimental device hatched from imperfections in the crystal structure of the cadmium sulphide. That problem, like the poor, is always with us, so perhaps this is what prevented the solid-state triode from getting off the ground. Or did the f.e.t. and m.o.s.t. devices (also of high input resistance), which were being developed concurrently, kill the dielectric valve stone dead?

And, speaking of solid-state, I wonder how long the electron will remain as undisputed master in the realms of amplification and control?

Doesn't it strike you as odd that old Mother Nature doesn't use electronics for control and message-carrying? If you think that it's simply that she wasn't clever enough, I suggest you think again. Remember the human brain with its physical volume of only a relatively few cubic centimetres. If we were daft enough to build a microcircuit-based computer that would do everything a brain can do we should be lumbered with hardware that occupied the area of a fair-sized town. Furthermore, it would never be in 100% working order; the mean-time-between-failures situation would see to that. At any given moment, within the complex, there would be a component breaking down.

Nature has avoided solid-state electronics like the plague and opted instead for liquid-state devices of molecular size and operating at ion level. This, on the face of it, is sheer stupidity because the ion is about 10^3 times heavier than the electron which streaks around about 10^7 times faster. So what was the point?

If you consider even the tiniest microcircuit objectively you will see an enormous involvement of electrons in every simple operation — for instance, about 10^9 electrons are deployed in an on-off switching application. But that's only a drop in the ocean; vastly greater numbers are merely loafing around to provide mechanical support. Think also of the relatively enormous distances over which the electron has to travel (or, more properly, over which electron-pattern disruption has to take place) in order to achieve a desired end. By contrast, Nature's liquid-state devices use under a million ions to do a similar job and these only have to diffuse across the minutest distance, so the reaction time is not nearly so sluggish as you'd think. And it's all done at low noise and power levels.

Perhaps even more important is the way Nature builds monumental redundancy and self-repairing elements into her liquid-state systems. As we're all only too well aware, when a microcircuit goes phut it stays phut; not so in biological engineering, where molecule-sized amplifiers can not only move around but also, to a large extent, repair themselves.

So don't let's ever fall into the error of supposing that the development of amplifiers, digital data transmission systems, computers and what-have-you is forever going to remain a monopoly of the electronics engineer. As long ago as 1958, liquid-state amplifiers were being devised; true, their practical value was limited because of the extremely slow transit times; but then, did Faraday's first generator show any great promise of being able to light and heat a city? The engineers of tomorrow, or the day after, may well be electro-chemists.

**Nature*, Vol 216, 18.11.67, Babcock W. R., Baker K. L., Cattaneo A. G., Physical Sciences Laboratory, United Technology Center, Sunnyvale, California.

BOOKS ON ELECTRONICS

Basic Engineering Craft Studies— General (01)

Edited by
P. H. M. Bourbousson, CIMarE, and
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Written for students studying for the City and Guilds of London Institute 500 Courses on Basic Engineering Craft Studies (Part I), this book together with a companion volume covers all the topics required for each of the courses. The General 01 volume contains basic material and should be used in conjunction with the appropriate complementary volume covering the syllabus relating to the required craft or trade bias.
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Semiconductors: Basic Theory and Devices

Ian Kampel

Although this book covers a wider range of devices than is usually dealt with on any one course, it nevertheless provides a useful introductory text for students. All topics are explained in straightforward graphical terms without complicated formulae. It begins with an explanation of elementary atomic theory and gradually progresses through diodes, transistors and the more sophisticated devices that are available today.
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Gordon J. King, RTechEng, MIPRE, FSRE, MRTS, FISTC

This comprehensive book deals straightforwardly with the servicing of PAL receivers, using a minimum of mathematics. It is divided into three sections: the first surveys the colour TV system as a whole, the second studies the elements involved (e.g. picture tubes, conveyance systems, chroma channels) and the third is devoted exclusively to servicing.
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J. Wilson, BSc, PhD, AInstP

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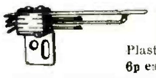

Very slight pressure closes both contacts. **8p** each. 10 for **72p** Plastic push-rod suitable for operating. **6p** each, **54p** for 10

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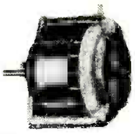
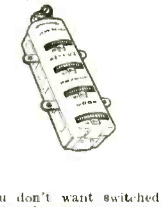


Est. 1/20th h.p. Made for 110-120 volt working, but two of these work ideally together off our standard 240 volt mains. A really beautiful motor, extremely quiet running and reversible. **£1·65** each. Postage one 23p, two 33p. 230 V. model **£3·30**

MINIATURE SEALED RELAY

American made. Our Ref. No. REL A1. Measures only ⅞" wide × 1" thick and ⅞" high and it's a double change over, we don't know the contact rating but estimate this at 3/5 amps. The coil resistance is 600 ohms and 9-12 volt will close it. Ideal for models and miniaturised equipment. It's a plug in relay but we supply complete with base. Price **28p** including base.

COMBINATION SWITCH



This comprises of 12 miniature micro switches. Joined in banks of 3 and mounted on frame with four digital numbered thumb wheels and a removable lever for locking the thumb wheel—the thumb wheel operates 3 banks. Over 4,000 combinations are possible but by rewiring the switch connections underneath then thousands more variations are possible. If you are making equipment which you don't want switched on accidentally or without authority then this is a switch to consider—this can also be used as a coding switch for many other operations. Very neat and compact and measuring approx. 4" × 1¾" × 1¾" deep. Priced at **£2·75**.

MAGNETIC CLUTCH

XEROX 121̶5494—J/N 10-1110 PN866-10. We have no information on this but it appears that the main section with coil fits to the spindle of the machine and there is a contact plate to fit on a stationary part. It appears also that the clutch can be used as a partial break by putting reduced voltage into it, as a normal brake with normal voltage or as emergency stop by putting increased voltage into it. American made and very well made at that. Price **£1·65**.

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New 1kW model.

Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by finger-tip control. Kit includes all parts, case, everything and full instructions **£1·65**, plus 13p post and insurance. Made up model also available **£2·97** plus 13p p. & p.

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Size approx. 6½"×3¾"×2" deep with brass inserts in four corners and bakelite panel. This is a very strong case suitable to house instruments and special rigs, etc. Price **50p** each. Paxlids **11p** extra.

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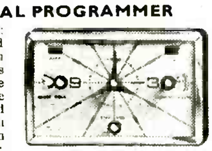

Learn in your sleep! Have radio playing and kettle boiling as you awake—switch on lights to ward off intruders—have warm house to come home to. All these and many other things you can do if you invest in an electrical programmer. Clock by famous maker with 15 amp. on/off switch. Switch on time can be set anywhere to stay on up to 6 hours. Independent 60 minute memory jogger. A beautiful unit. Price **£2·15** + 20p p. & p. or with glass front chrome bezel **83p** extra.

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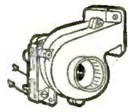
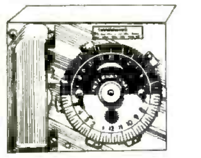


Miniature mains driven blower centrifugal type blower unit by Woods, powerful but specially built for quiet running—driven by cushioned induction motor with specially built low noise bearings. Overall size of blower is approx. 4½" × 4½" × 4". When mounted by its flange air is blown into the equipment but to suck air out mount it from the centre using a clamp, ideal for cooling electrical equipment, or fitting into a cooker hood, film drying cabinet or for removing flux smoke when soldering etc., etc. A real bargain at **£2·05**.



ELECTRIC TIME SWITCH

Made by Smiths these are A.C. mains operated. NOT CLOCKWORK. Ideal for mounting on rack or shelf or can be built into box with 13A socket. 2 completely adjustable time periods per 24 hours, 5 amp changeover contacts will switch circuit on or off during these periods. **£2·75** post and ins., 23p. Additional time contacts **50p** pair.

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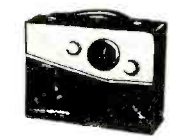
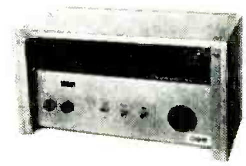
¼" Scotch tape. Brand new. Suits many video recorders. **£3·30** for 3,600ft.



GOOD COMPANION I.C. MODEL

We can now offer this fine receiver but in I.C. version using Ferranti ZN414 and Mullard AF Module 1172. Cabinet size approx. 11in. wide × 8in. high × 3in. deep. Complete with excellent 2 tone cabinet with assembly instructions **£5·75**.

ERGOTROL UNITS



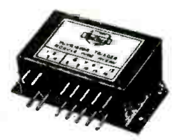
These units made by the Mullard Group are for operating and controlling d.c. Motors and equipment from A.C. mains.

Thyristors are used and these supply a variable d.c. resulting in motor speed control and operating efficiency far superior to most other methods.

The units are contained in wall mounting cabinets with front control panel on which are fuses—push buttons for on/off and the variable thyristor firing control.

4 models are available—all are brand new in makers cases:
Model 2410 for up to 5 amps **£19·25**
Model 2411 for up to 10 amps **£30·25**

MULLARD THYRISTOR TRIGGER MODULE

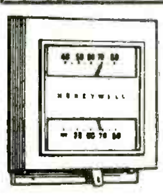


This produces pulses for phase control triggering, it has two isolated out-puts, so one thyristor or two thyristors (in separate arms of bridge) may be controlled by one module. The timing circuit is synchronised to the mains frequency and control is by an external variable resistor or from a voltage or current source. Provision is made for feedback where automatic control is required. Price **£4·95** each or 10 for **£45·00**.

THIS MONTH'S SNIP

30KV EHT UNIT

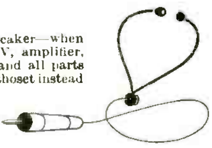
This unit is self contained and on wheels. It stands approx. 6 ft high and 3 ft square. On the front panel is a Variac, Voltmeter, a 60 second Timer as well as the normal overload trip on/off switch and cut outs, etc. The transformer itself is oil filled and rated at 7 KVA 30KV. The variac is in the primary so all voltages up to 35 KV are available. We believe the normal use for such a unit would be as a break down and flash tester. 1 only—not new but in good order. Price **£99**.



THERMOSTAT WITH THERMOMETER

Made by Honeywell for normal air temperatures 40°-80°F. (5-25°C.). This is a precision instrument with a differential which can be adjusted to better than 1·5°F. A mercury switch breaks on temp. rise—the switch is operated by coiled bi-metal element and an adjustable heater is incorporated for heat anticipation. Elegantly styled and encased in an ivory plastic case with clear plastic windows, thermometer above and switch setting scale below. Size approx. 3·8" × 3·2" × 1·4" deep. Can be mounted on conduit box or directly on wall. Price **£1·38** each or 10 for **£12·52**.

RADIO STETHOSCOPE



Easiest way to fault find—traces signal from aerial to speaker—when signal stops you've found the fault. Use it on Radio, TV, amplifier, anything—complete kit comprises two special transistors and all parts including probe tube and crystal earpiece, **£2·20**—twin stethoset instead of earpiece **83p** extra—post and ins. 20p.

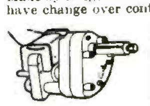
HORSTMANN "TIME & SET" SWITCH

(A 30 Amp Switch.) Just the thing if you want to come home to a warm house without it costing you a fortune. You can delay the switch on time of your electric fires, etc., up to 14 hours from setting time or you can use the switch to give a boost on period of up to 3 hours. Equally suitable to control processing. Regular price probably around £5. Special snip price **£1·65**. Post and ins. 23p.

SUB. MINIATURE MICROSWITCH

Made by Burgess, their Ref. V4T6—our ref. MS. A1. These measure only ⅞" × ⅜" × ¼" thick—have change over contacts and tag connection. Price **16p** each or 10 for **£1·44**.

SPIT MOTOR



200-250v. Induction Motor, driving a carter gear box with 1¼in. of output drive shaft running at 5 revs. per minute. Intended for roasting chickens, also suitable for driving models, windmills, coloured disc lighting effect, etc., etc. **£2·05** plus 20p post and insurance.

DISTRIBUTION PANELS

Just what you need for work bench or lab. 4 × 13 amp sockets in metal box to take standard 13 amp fused plugs and on/off switch with neon warning light. Supplied complete with 6 feet of heavy cable. Wired up ready to work, **£2·50** plus 25p P. & P.

MULLARD AUDIO AMPLIFIERS

All in module form, each ready built complete with heat sinks and connection tags, data supplied.
Model 1153 500mW power output **72p**.
Model 1172 750mW power output **94p**.
Model EP9000 4 watt power output **£1·60**.
EP9001 twin channel or stereo pre amp. **£1·99**.
10% discount if 10 or more ordered.

INSTRUMENT RACKS WITH DRAWERS

These extremely well made racks measure 6ft. high, 22in. wide, 23in. deep, they comprise four drawers each of which is on ball bearings for easy withdrawal, but is of very solid construction to hold equipment in a rigid mode. Originally, these held computer equipment and must have cost £50-£60 each. We have only 10 and offer these at **£11** per rack with drawers. You must collect.

SATCHWELL DUOTRONIC CONTROLLER

These are big wall mounting panels containing transformers, relays, valves etc. Used for the control of ducting (through ZPM modulation motor which we can supply). Their primary use of course is in air conditioning, but no doubt other applications are available. These panels cost £50-£60 each. Our price **£16** each. Quantity price by negotiation.

6V D.C. POWER MOTOR MADE BY REDMUND

For driving a bilge pump and similar applications. This motor we understand develops on ⅛ H.P. It is extremely powerful and although rated at 6v, this operates up to 12v. for short periods with very much increased power, (probably at least ½ H.P.) We understand that from the makers they cost over £5. At **£2·20** each plus 25p post on one and then 15p each.

TRANSMITTER FOR BLEEPERS

Mains operated, simply needs a single copper conductor to surround the bleeped area then any bleep receiver may be called at will. 2 only of these. Price **£15** each. Now new but believed to be in good order.

RACK AND CHARGER FOR BLEEPERS

Receivers are stored in this over night and charged at the same time. 2 only available. Not new but believed in good order. **£10** each.

8 AMP VARIACS

These are variable voltage transformers. British made by the famous Zenith Co. Fully enclosed for bench use and fitted with calibrated scale and control knob. Zenith model No. 100 LM. 220-240v. A.C., output 0-240v. up to 8 amps. This model is listed at over £20. We have a limited quantity only, absolutely brand new, still in maker's cartons, offered to you at **£13·75** each plus £1 carriage and insurance up to 400 miles.

MOTOR GENERATOR

Made for Admiralty. 24 volt D.C. input, 240v. 50 cps. output. Admiralty rating 80 watts but we have tested this to 50% overload voltage regulated so suitable to operate TV or instrument. In case with metal cover controls on front include voltmeter. Unused. Probably cost £200 each to make. Our price only **£25** each plus carriage £2 up to 200 miles, £4 up to 400 miles.

150 WATT PEARL LAMPS

230v. Best makes, Mazda etc. Balance of G.P.O. contract **£1·20** per box of 25. Plus 25p post. 5 boxes post free.

POWER RHEOSTAT

61 ohms at 11·5 amps. This is a large rheostat. 1 only. Good order, ex equipment. **£6·60** plus £2 carriage.

POWER RHEOSTAT

·78 amps. 399 ohms. Price **£3·50** plus 75p carriage.

9 V GRAMOPHONE UNIT

Battery operated with pick-up on unit plate 2 Speed auto-stop, crystal cartridge. Price **£2·50** plus 40p post and insurance.

BUY TIME SLOT METER

Made by Sangamo Weston. 3 types, one for each coin, 2½p, 5p, or 10p. Price **£1·75** each plus 25p post and ins.

4 STATION TRANSISTORISED INTERCOM

Solid State three transistor printed cct. mater and tree sub station push button/press talk system. 200mW output, complete with installation accessories and 9v. Ever-ready power pack approx. 3 × 1¾ × 4in. Price **£8·50** plus 20p.

PHOTO ELECTRIC KIT

Contains photo cell, relay, transistor and all parts to make light operated switch. **£1·75** plus 20p post and ins.

AC/DC MILLIAMETERS 3 RANGE

Moving iron mirror scale laboratory instalate. Ranges 52 and 50 and 100mA by selection switch (coil resistance marked) size 7¼ × 5 × 3½in. type 35999/I. Price **£6·60**.

GALVOMETER 7—0—7 UA F.S.D.

Moving coil precision laboratory instrument of extremely high sensitivity (3×10-7 A per division), size approx. 6¼ × 2¼ × 2in. Price **£7·50**.

ACOS. 'G' METERS

For use with transducers and accelerometers. These are precision instruments they measure "g" in three steps 0-10, 0-100 and 0-1000 directly on a large clear meter scale 0-1. Two models available:— Standard model (IDOOL) price **£T2** and Auto cutout model (IDOOL) which has and inbuilt circuit with relay to trip the external circuit (trip level is adjustable by a control which is virtually linear with the meter scale). The trip load may be up to 2a. Once the circuit has been tripped it can be restored by a reset button. Price of this model is **£18**.

PARMEKO NEPTUNE SERIES C CORE TRANSFORMERS

These transformers are beautifully made, steel encased stove enamelled black, upright mounting. All have normal 50cps. primary 230/240v. with primary screen and are new and unused. Small quantities only of each type available as follows:

Model 6000/79 275-0-275v. at 330mA. and 6·3v. at 4·6a. Price **£6·60**. 50p post.
Model 6000/71, 290-215-0-215-290 at 125mA. and 2 at 6·3v. 6a. Price **£5·50**, 40p post.
Model 49 250v. at 10mA. 6·3v. at 3a., 5v. at 0·75a. Price **£2** plus 30p post.
Model 600/39 standard primary 25-0-25 VAT 50mA Price **77p**
Parmeko Neptune C Core Chokes. These are encased and match the transformer above.
Model 6000/73 4H at 560mA.. **£2·75** plus 40p post.
Model 55 10H at 1mA. **£2·75** plus post 40p.
Model 49 10H at 70mA. **£1·75** plus 30p post.
Model 69 10H at 110mA. **£2·20** plus 40p.

ELECTRIC CAR IGNITION

In addition to the kits for 12v. cars we can also supply systems for 6v. cars. These are not kits but made up and ready to work. Price **£5·50** plus 30p post.

VARIABLE INDUCTANCE CHOKE

Has three windings. Two of them rated to carry 8A. AC. The third a control winding needs current of up to 75mA DC. In an unsaturated state that is with no or very low control current flowing the volts dropped across the AC windings will be high but as the control current increases the reactance of the main windings decreases and the voltage dropped by them would become less and less. Uses of his inductor are for voltage regulation, current control, lamp dimming etc. Weighs approx. 60 lbs. Price **£12** each plus £2 carriage up to 200 miles, £3, 300 miles, £4 400 miles.

Where postage is not stated then orders over £5 are post free. Below £5 add 20p. S.A.E. with enquiries please.

J. BULL (ELECTRICAL) LTD.

(Dept. W.W.) 7, Park Street, Croydon, CR0 1YD
Callers to 102/3, Tamworth Road, Croydon

FOR THE STOCKS, THE DISCOUNTS AND THE SERVICE YOU NEED

ELECTROVALUE
Electronic Component Specialists

RESISTORS—10%, 5%, 2%

Code	Power	Tolerance	Range	Values available	1 to 9	10 to 99	100 up
					(see note below)		
C	1/20W	5%	82Ω–220KΩ	E12	9	8	7·5
C	1/8W	5%	4·7Ω–470KΩ	E24	1	0·9	0·75 nett
C	1/4W	5%	4·7Ω–10MΩ	E12	1	0·9	0·75 nett
C	1/2W	5%	4·7Ω–10MΩ	E24	1·2	1	0·9 nett
C	1W	5%	4·7Ω–10MΩ	E12	2·5	2	1·6 nett
MO	1/2W	2%	10Ω–1MΩ	E24	4	3	2 nett
WW	1W	10%±1/20Ω	0·22Ω–3·9Ω	E12	7	7	6
WW	3W	5%	1Ω–10KΩ	E12	7	7	6
WW	7W	5%	1Ω–10KΩ	E12	9	9	8

Codes: C = carbon film, high stability, low noise.
MO = metal oxide, Electrosil TR5, ultra low noise.
WW = wire wound, Plessey.

Values:
E12 denotes series: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and their decades.
E24 denotes series, as E12 plus 11, 13, 16, 20, 24, 30, 36, 43, 51, 62, 75, 91 and their decades.

Prices are in pence each for quantities of the same ohmic value and power rating. NOT mixed values. (Ignore fractions of one penny on total value of resistor order.)

TRANSISTORS BY SIEMENS AND NEWMARKET

2N3055 npn silicon power **60p**
AC153K pnp germanium low power **32p**
AC176K npn germanium low power **32p**
AD161 npn germanium medium power **42p**
AD162 pnp germanium medium power **40p**
AF139 pnp germanium UHF **33p**
BC107—13p; BC108—12p; BC109—13p
BC167—11p; BC168—10p; BC169—11p] npn
BC177—21p; BC178—19p; BC179—22p
BC257—12p; BC258—11p; BC259—13p] pnp
Standard groupings available.

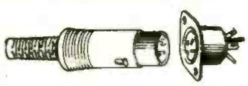
BD135 npn medium power **37p**
BD136 pnp medium power **38p**

DIODES
OA90, OA91, OA95 each **6p**
OA200—**9p**; OA202—**10p**

Other semi-conductors
AC128—**21p** AF117—**32p**
BFY51—**19p**

Very many other types listed, described and illustrated in catalogue.

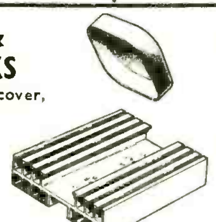
DIN CONNECTORS by Hirshmann 4A rating



2 way loudspeaker	Socket	**10p**	Plug	**12p**
3 way audio	Socket	**10p**	Plug	**12p**
5 way audio 180°	Socket	**12p**	Plug	**15p**
5 way audio 240°	Socket	**12p**	Plug	**15p**
6 way audio	Socket	**13p**	Plug	**15p**

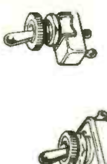
Lockable types, phono connectors, etc.

COVERS & HEATSINKS



T03 Transistor cover, clip-on **7p**
HEATSINK
Type 6WI Extruded aluminium 1°C/W, undrilled **60p**

TOGGLE SWITCHES

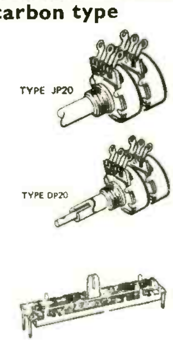


1011C SPST toggle **19p**; **409** DPDT toggle **28p.** (These are chrome plated, 2.5A rating). **7201** Sub-miniature DPDT 250V a.c./2A **48p**

TTL ICs

	Nett Price
7400	20p
7401	20p
7402	20p
7403	20p
7404	25p
7405	20p
7408	25p
7409	25p
7410	20p
7413	35p
7420	20p
7430	20p
7440	20p
74141 (16)	99p
7442 (16)	87p
7443 (16)	£1·00
7444 (16)	£1·00
7447	£1·36
7450	20p
7451	20p
7453	20p
7454	20p
7466	20p
7470	33p
7472	30p
7473	36p
7474	36p
7475 (16)	60p
7476 (16)	45p
7480	68p
7482	87p
7483 (16)	£1·32
7485	£1·70
7486	35p
7490	60p
7491AN	£1·00
7492	70p
7493	65p
7495	87p
7496 (16)	£1·00
74100 (24)	£1·64
74104	65p
74107	52p
74121	48p
74190 (16)	£1·80
74191 (16)	£1·80
74192 (16)	£1·74
74193 (16)	£1·74

POTENTIOMETER carbon type



long spindles. Double wipers for low noise.
SINGLE GANG P20 linear 100Ω to 2·2MΩ, **12p**, JP20 Log, 4·7KΩ, to 2·2MΩ **12p.**
DUAL GANG linear 4·7KΩ to 2·2MΩ, **42p**; Dual gang log, 4·7KΩ to 2·2MΩ, **42p**; Log/antilog, 10K, 22K, 47K, 1MΩ only **42p**; Dual antilog, 10K only, **42p.** Any type with 2A D.P. mains switch, **12p** extra.
Only decades of 10, 22 & 47 available in ranges quoted.
DUAL CONCENTRIC DP20 in any combination of P20 values, **60p**; with switch, **72p.**
SLIDER POTS. In values from 4K7Ω to 1MΩ, linear or log, **26p.** Escutcheon, white, grey, black, **10p.** Knobs, flat, grip type, in 7 colours, **5p each.**
SKELETON PRE-SETS. Small high quality, type PR linear only: 100Ω, 220Ω, 470Ω, 1K, 2K2, 4K7, 10K, 22K, 47K, 100K, 470K, 1M, 2M2, 5M, 10MΩ. Vertical or horizontal mounting, **5p each.**

NUTS, SCREWS, ETC. In lots of 100.
Nuts 2BA—**41p**; 4BA—**28p**; 6BA—**26p.**
Screws 1″—2BA—**67p**; 4BA—**35p**; 6BA—**26p.** 0·5″—2BA—**50p**; 4BA—**23p**; 6BA—**19p.**
Screws roundheaded, cheese headed or countersunk. Other sizes available. Also tags, washers, spacers, etc.

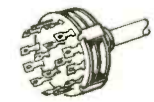
ELECTROLYTICS

Prices in pennies

μF	3V	6.3V	10V	16V	25V	40V	63V	100V
0.47							10	7
1.0						10		7
2.2					10		7	8
4.7				10		7	8	7
10					7	8	7	8
22			7		8	7	7	9
47	7		8	7	7	7	9	12
100	8	7	7	7	7	9	11	19
220	7	8	8	8	9	10	17	27
470	8	9	9	10	12	17	24	43
1000	10	12	12	17	20	24	40	
2200	14	17	22	25	36	40		
4700	25	28	37	41	54			
10,000	40	43						

Smallest size 3·7mm x 12mm. Largest size 25·5mm x 41mm. Full ranges of many other types of capacitors stocked.

ROTARY SWITCHES

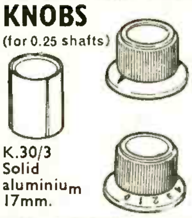


Radiospares Miniature Maka-switch (in assembly kit form). Shaft **48p.** Wafers, MBB—2P5W, 1P11W; BBM1P12W, 2P6W, 3P4W, 4P3W, 6P2W, each **32p.**

Wavechange switches 1P12W, 2P6W, 3P4W, 4P3W. each **24p.**

KNOBS

(for 0.25 shafts)



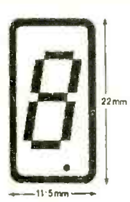
K.30/3 Solid aluminium 17mm.

F.14 skirt dia. 20mm.	pack of 2	**32p**
F.13 skirt dia. 26mm.	pack of 2	**38p**
F.12 skirt dia. 33mm.	pack of 2	**40p**
F.19 engraved	20mm.—two	**32p**
F.18 engraved.	26mm.—two	**38p**
F.17 engraved:	33mm.—two	**40p**

KB.4 Ribbed Skirt dia. 20mm. 4 in pack. **40p**

Very many other types in stock—see Catalogue.

Minitron DIGITAL INDICATOR



TYPE 3015F Seven segment indicator compatible with standard logic modules and power supplies. Figs. 0 9 from well illuminated filament segments to give character of 9mm height plus decimal point. Power requirement 8mA from 5V D.C. per segment. A limited number of alphabetical symbols also available. In 16 lead DIL case .. .. nett **£2·00**
Suitable BCD decoder driver type FLL121T nett **£1·36**
DIL Socket; 16 lead 30p. No. 3015G showing + or — and fig. 1 and decimal poin £2·00. nett

DISCOUNTS

Available on all items except those shown with NETT PRICES. 10% on orders from £5 to £15. 15% on orders £15 and over.

TERMS OF BUSINESS
All items are offered for sale in accordance with our standard terms of business, a copy of which is available on request. Prices subject to alteration without notice. Enquiries from quantity users invited.

PACKING & POSTAGE FREE in U.K. For mail orders for £2 list value and under, there is an additional handling charge of 10p.

As prices shown here **DO NOT INCLUDE V.A.T.**
Please add 10% to nett value of order to meet tax requirements.
Overseas orders are exempt.

ZENER DIODES

Full range E24 values: 400m W: 2·7V to 36V, **14p each**; 1W: 6·8V to 82V, **21p each**; 1·5W: 4·7V to 75V, **48p each. Clip** to increase 1·5 W rating to 3 watts (type) 266F) **4p.**

SIEMENS THYRISTORS

0·8A 400V, **56p**; 600V **70p.** 3A 400V, **60p**; 600V, **88p.**

DE-SOLDER BRAID

6ft. nett **50p**

S-DEC

Unsurpassed for "breadboard work" can be used indefinitely without deterioration. Components just push into plug holes and connect automatically. Slot for control panel. 70 holes, **£1·44.**

T-DEC

For more advanced work with 208 contacts in 38 rows. Will take one 16 lead carrier. **£2·88.** (Carriers supplied separately.)

BAXANDALL SPEAKER

As described originally in "Wireless World" and still one of the most brilliant designs in high quality low priced speakers. You save by assembling it yourself. 10 watts/15Ω.
Complete kit **£14·90**+**60p** part carr.
Equaliser components **£2·00.**
Speaker unit **£2·45.**

No. 6 CATALOGUE SUPPLEMENT
of latest price adjustments and new items. S.A.E. for your copy.

MAINS TRANSFORMERS

MT3 30V/2A plus 4 taps **£2·85**
MT103 50V/1A+4 taps **£2·55**
MT104 50V/2A+4 taps **£3·50**
MT127 60V/2A+4 taps **£3·80**
13T05 13V/½A, CT **£1·25**
28T05 12+12; 2-0-2V/½A **£1·60**

U.S.A. CUSTOMERS should contact **Electrovalue America, P.O. Box 27, Swarthmore, PA.**

ELECTROVALUE LTD

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Hours: 9-5.30, 1.0 p.m. Saturdays. ***Phone: Egham 3603 Telex 264475***
Reg. offices at above address Business Reg. No. 1047769

COMPONENTS FOR W.W. AMPLIFIER DESIGNS

100W AMPLIFIER (FEB. 1972)
Designer approved kit.

Semiconductor set	15·60
Resistors, capacitors, pots	2·50
F/Glass PCB	1·30

POWER SUPPLY (For 100W Amp.)
Designer approved kit.

Semiconductors, Resistors, capacitors, pots, transformers, F/Glass PCB	14·70

30W BLOMLEY (New approach to class B)

Semiconductor set	5·60
Resistors, capacitors, pots	1·85
F/Glass PCB	0·70

30W BAILEY (Single power rail)

Transistor set	4·60
Resistors, capacitors, pots	1·45
F/Glass PCB	0·65

LINSLEY-HOOD CLASS A (Dec., 1970, circuit)
Designer approved kit.

2N3055 pair, BC212L, 2N1711	1·20
Resistors, capacitors, pot	1·80
F/Glass PCB	0·60

LINSLEY-HOOD 20W CLASS AB
Designer approved kit.

MJ481/491, MJE521, BC182L, BC212L, zener	3·35
Resistors, capacitors, pots	2·20
F/Glass PCB	0·70

Please state 8Ω or 15Ω

REGULATED 60V POWER SUPPLY
A 5 transistor series stabiliser, suitable for a pair of Bailey or Blomley amplifiers, featuring very effective S/C protection. All Semi/C's, R's, C's, F/Glass PCB .. 4·85
Power supplies for other amplifiers also available

BAILEY/BURROWS PRE-AMP (Aug., 1971)

Component Set: Mono	2·75
Component set: Stereo	6·35

Each component set comprises of all specified resistors, capacitors. transistors pots, including special balance control for stereo sets.

Stereo F/Glass PCB	1·60

STUART TAPE RECORDER

Set of stereo f/glass PCBs	2·70

Components sets on price ist.

'TEXAN' TEXAS INSTRUMENTS DESIGNED & APPROVED FULL KIT

£28·50 INCLUDES TEAK CASE

20 Watt per channel stereo amplifier designed by Richard Mann of Texas Instruments and published in Practical Wireless May-July 1972.
This low distortion (0.09% at 20W into 8 ohm), wide bandwidth (—3dB 5Hz-35KHz) design is offered as a Texas Instruments approved full kit (including all metalwork and Teak case for a total of **£28.50** post paid. Full details in price list.

METALWORK SYSTEM

Designed to house Bailey, Blomley or Linsley Hood Class AB amplifiers with simple or regulated power supplies and Bailey Burrows pre-amp. Options of standard or hum reducing toroidal mains transformer.

TOROIDAL TRANSFORMER 60 volt 2 amp.

Max. height 2in. Suitable for our regulated power supply	£7.40
Simple clamp	£0.20
Magnetically screening clamp	£0.75

SEMICONDUCTORS

2N699	0·25	BC184L	0·11
2N1613	0·20	BC212L	0·12
2N1711	0·25	BC214L	0·14
2N2926G	0·10	BCY72	0.13
2N3053	0·15	BF257	0·40
2N3055	0·45	BF259	0·47
2N3442	1·20	BFR39	0.25
2N3702	0.11	BFR79	0.25
2N3703	0.10	BFY50	0·20
2N3704	0.10	BFY51	0.20
2N3705	0.10	BFY52	0.20
2N3706	0.09	MJ481	1·20
		MJ491	1·30
2N3707	0.10	MJE521	0·60
2N3708	0.07	MPSA05	0·30
2N3709	0.09	MPSA12	0·55
2N3710	0.09	MPSA14	0·35
2N3711	0.09	MPSA55	0·35
2N3819	0·23	MPSA65	0·35
		MPSA66	0·40
2N3904	0·17	MPSU05	0·60
2N3906	0·20	MPSU55	0·70
2N4058	0·12	SN72741P	0·58
2N4062	0·11	SN72748P	0·58
2N4302	0·60	THB11	1·10
		TIP29A	0·50
2N5087	0.42	TIP30A	0·60
2N5210	0.54	TIP31A	0·60
2N5457	0·30	TIP32A	0·70
2N5830	0·30	TIP33A	1·00
40361	0·40	TIP34A	1·50
		TIP41A	0·74
40362	0·45	TIP42A	0·90
BC107	0·08	TIP3055	0·60
BC108	0·08	1B08T20	0·50
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BC12S	0·15	1N914	0·07
BC126	0·15	1N916	0·07
		1S44	0·05
BC182K	0·10	1S920	0·10
BC212K	0·12	1S3062	0·25
BC182L	0·10	5B05	1·20

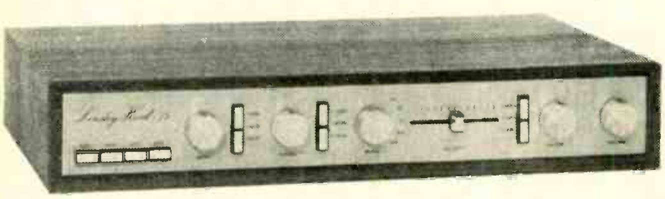
HI-FI NEWS 75 WATT AMPLIFIER

BY J. L. LINSLEY-HOOD

Published Nov. 1972 to Feb. 1973

DESIGNER APPROVED KIT

★ **75 WATTS PER CHANNEL**
★ **BANDWIDTH (3dB) 3HZ-40KHZ**
★ **DISTORTION LESS THAN 0.01%**
★ **UNCONDITIONAL STABILITY**



SLIMLINE STYLE CHASSIS DIMENSIONS: 17.0in. x 2.0in. x 12.0in.
This slimline unit has been made practical by the use of a specially designed TOROIDAL TRANSFORMER and highly compact printed circuit boards which have been fully tested and approved by Mr. Linsley-Hood.

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Pack		
1	Fibre glass printed circuit board for power amp.	£0.75
2	Set of resistors, capacitors, pre-sets for power amp.	£1.50
3	Set of semi-conductors for power amp. (highest voltage version)	£5.50
4	Pair of 2 drilled, finned heat sinks	£0.80
5	Fibre glass printed circuit board for pre-amp.	£1.10
6	Set of low noise resistors, capacitors, pre-sets for pre-amp	£2.70
7	Set of low noise, high gain semi-conductors for pre-amp	£2.10
8	Set of potentiometers (including mains switch)	£1.55
9	Set of 4 push button switches, rotary mode switch	£3.10
10	Toroidal transformer complete with magnetic screen/housing primary: 0-117-234 V. secondaries: 33-0-33 V. 24-0-24 V., electrostatic screen	£9.15
11	Fibre glass printed circuit board for power supply	£0.55
12	Set of resistors, capacitors, secondary fuses, semi-conductors for power supply	£3.50
13	Set of miscellaneous parts including DIN skts., mains input skt. fuse holder, interconnecting cable, control knobs	£3.25
14	Set of metal workparts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£6.30
15	Handbook, based on Hi-Fi News articles	£0.30
16	Teak cabinet	£7.35

2 each of packs 1-7 inclusive are required for complete stereo system.

FREE
TEAK CASE
WITH 75 WATT PER CHANNEL COMPLETE AMPLIFIER KITS

Total cost of individually purchased packs:
£63.95

Cost of complete kit:
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TRADE ENQUIRIES WELCOME

P.S. Full circuit description in handbook **30p**

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Set of semi-conductors, resistors, capacitors, printed circuit boards for stereo power amp, pre-amp. and power supply.

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Handbook Included

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(As featured in "Practical Wireless" May to August 1972)

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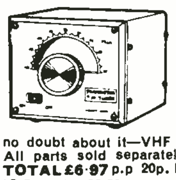

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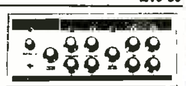

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SC45B	200	£1·00
SC45D	400	£1·25
SC45E	500	£1·45
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B1/10	100	25p
B1/20	200	30p
B1/60	600	35p
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W005	50	30p
W01	100	35p
W02	200	40p
W06	600	45p
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B2/100	100	40p
B2/200	200	45p
B2/600	600	50p
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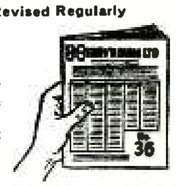

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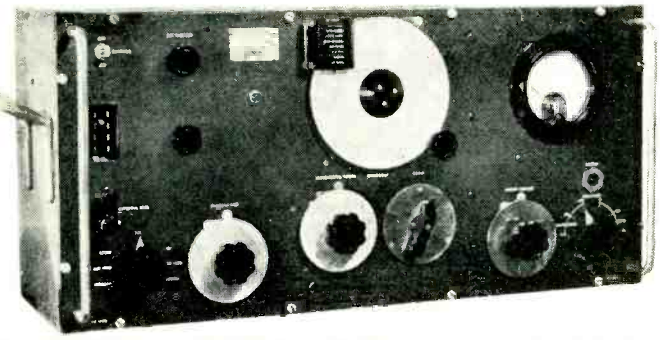

MARCONI SIGNAL GENERATOR TYPE TF-144G: Freq. 85 Kc/s-25 Mc/s in 8 ranges. Incremental: ±1% at 1 Mc/s. Output: continuously variable 1 microvolt to 1 volt. Output Impedance: 1 microvolt to 100 millivolts, 10 ohms 100mV - 1 volt - 52·5 ohms. Internal Modulation: 400 c/s sinewave 75% depth. External Modulation: Direct or via internal amplifier. A.C. mains 200/250V, 40-100 c/s. Consumption approx. 40 watts. Measurements 29 × 12¼ × 10 in. Secondhand condition. **£27·50** each, Carr. £1·50.

T.1509 TRANSMITTERS (FOR EXPORT ONLY): General-purpose HF communications transmitter for use in fixed or mobile ground stations. Hand or high-speed keying. Crystal or MO control, with temperature compensated MO circuit.CW, MCW and R/T. Frequency: 1.5 to 20 Mc/s. Modulation: 100% O/put impedance: 50 ohms. Audio input: 600 ohms. Valves: Power Amplifier 2 × 813 and Modulator 2 × 813. Power requirements 200-250 volts a.c., 50 cycles. Power out put 300 watts. Dimensions 2ft. 6in. W. × 2ft. D. × 5ft. H. Weight: 800 lbs. Excellent condition, price **£225.00** each.

AN/ARC-27 TRANSMITTER/RECEIVER (FOR EXPORT ONLY): Frequency 225-400 mc. 1750 channels 100 Kc apart with 18 preset channels. Modulation: am. Power output 9 watts. Receiver is superheterodyne. Max. output 2 watts. Antenna: 50 ohm impedance. Power requirements 24v d.c. Complete transmitter with operating cables, control box, headphones, microphone. Price **£250.00** each secondhand, excellent condition.

POWER SUPPLY suitable for AN/ARC-27: 100 volts to 250 volts a.c. input. 24v d.c. output @ 41 amps fully smoothed. **£45.00** each.

TEST SET TS-147C: Combined signal generator, frequency meter and power meter for 8500-9600 Mc/s. CW or FM signals of known freq. and power or measurement of same. *Signal Generator:* O/put −7 to −85 dbm. Transmission—FM, PM, CW. Sweep Rate—0-6 Mc/s per microsec. Deviation—0-40 Mc/s per sec. Phase Range—3-50 microsec. Pulse Repetition Rate—to 4000 pulses per sec. RF Trigger for Sawtooth Sweep—5-500 watts peak. 0.2-6 microsec. duration, 0.5 microsec pulse rise time. Video Trigger for Sawtooth Sweep—Positive polarity, 10-50V peak. 0.5-20 microsec duration at 10% max. amplitude, less than 0.5 microsec rise time between 90% and 10% max. amplitude points. *Frequency Meter:* Freq. 8470-9360 Mc/s. Accuracy—+2.5 Mc/s per sec. absolute, +1.0 Mc/s per sec. for freq. increments of less than 60 Mc/s relative, ±1.0 Mc/s per sec. a 9310 Mc/s per sec. calibration point. Accuracy measured at 25° C and 60 humidity. *Power Meter:* Input: +7 to +30 dbm. Output −7 to −85 dbm. Price: **£75** each + £1 carr.

SIGNAL GENERATOR TS-403B/U (or URM-61A): (Hewlett Packard). A portable, self-contained, general-purpose test equipment designed for use with radio and radar receivers and for other applications requiring small amounts of RF power such as measuring standing-wave ratios, antenna and transmission line characteristics, conversion gain, etc. Both the output freq. and power are indicated on direct-reading dials. 115V, AC, 50 c/s. Freq.—1800-4000 Mc/s. CW, FM, Modulated Pulse—40-4000 pulses per sec. Pulse Width—0.5-10 microsecs. Timing —Undelayed or delayed from 3-300 microsecs from external or internal pulse. O/put—1 milliwatt max., 0 to −127 db variable. O/put Impedance—50Ω. Price **£120** used, excellent condition. Unused as new condition **£150** + carr. £2.

TS-382/U AUDIO OSCILLATOR: 20 to 200,000 c/s. in four ranges. Freq. meter check 60 c/s. and 400 c/s. Emission CW. O/put voltage: 1 uv to 10V ±3% in seven ranges. Power req. 115V AC single phase. Price **£20** each, used good condition. Unused condition **£30** + carr. £1.50.

FREQUENCY METER BC-221: 125-20,000 Kc/s, complete with original calibration charts. Checked out, working order. **£18·50** + £1·00 carr. BC-221 Unused as new condition complete with headset, spare valves, charts. **£35·00** + £2·00 carr.

TS-452 F.M. SWEEP GENERATOR: Power supply 115V, 50c/s, 5-100MHz in 6 bands (rf o/put); 5-102MHz in 4 bands (freq. meter). Emission: F.M. R.F. Voltage o/put ·25V. Input impedance 470 ohms. O/put impedance 73 ohms. Displays band pass characteristics on 3in. C.R.T. S/hand good condition **£95·00** + £2·00 carr.

TS-419/URM 64 SIGNAL GENERATOR: Freq. 900-2100MHz. CW or pulse emission. Power o/put Zero dbm-120dbm continuously adjustable to ·2uv into 50. O/put impedance 50 ohms with VSWR of 2:1. 115V a.c. 50 c/s. As new condition **£150·00** + £2·00 carr.

TS-622/URM 44 SIGNAL GENERATOR: Freq. range —7 to 11 GHz Power o/put —10 to 127 dbm; Emission CW, FM, Pulse. Direct reading dials for both frequency and power. Operates on 115 volts, 50-1000Hz. As new condition **£175·00** + £2·00 carr.

CT.52 MINIATURE OSCILLOSCOPE: Portable. Operates from 115V or 250V 50-60c/s; or 180V 500c/s. A small compact tropicalised instrument designed to meet requirements of radar and communication engineers and general electronic service. Measures 9 in. × 8 in. × 6½in. Time base 10c/s-40Kc/s. Y plate sensitivity 40V per cm. Tube 2¾in. Frequency compensated amplifier up to 38dB gain. Bandwidth up to 1 Mc/s. Single sweep facilities. Complete with test leads, metal transit case. As new **£27·50** each. Carr. £1.

TRANSFORMER HV: 228V input 19,500–0–19,500 4.5KVA, Wt. 220 lbs. **£30** each. Carr. £4.

TUNING UNIT: 24V geared motor driving double 25pf double spaced variable capacitor. One m/c relay and 2 other relays. **£2·50** each 30p post, good condition.

UHF ASSEMBLY: (suitable for 1,000MHz conversion) including UHF valves: 2C42, 2C46, 1B40 (complete with associated capacitors and screening), 3 manual counters 0-999. Valves 6AL5 and 8 × 6AK5. **£10·00** plus 60p post, good condition.

MODULATOR UNIT: complete with transformer and 2 × 807 valves mounted in 19 in. chassis × 8 in. high × 8 in. deep. **£4·50** secondhand cond., or **£6·50** new cond. Carriage £1.

RF UNIT: suitable for use with the above unit. Complete with 2 × 3E29 valves. Ideal for conversion to 4 metres. **£5** secondhand cond., or **£7·50** new cond. Carriage £1.

POWER SUPPLY UNIT PN-12A: 230V a.c. input 50-60 c/s. 513V and 1025V @ 420 mA output. With 2 smoothing chokes 9H, 2 Capacitors, 10Mfd 1500V and 10Mfd 600V. Filament Transformer 230V a.c. input. 4 Rectifying Valves type 5Z3. 2 × 5V windings @ 3 Amps each, and 5V @ 6 Amp and 4V @ 0.25 Amp. Mounted on steel base 19"Wx11"Hx14"D. (All connections at the rear.) Excellent condition **£6·50** each, carr. £1.

AUTO TRANSFORMER: 230-115V, 50-60c/s, 1000 watts, mounted in a strong steel case 5" × 6½" × 7". Bitumen impregnated. **£7** each, Carr. 75p. 230-115V, 50-60c/s, 500 watts. 7" × 5" × 5". Mounted in steel ventilated case. **£4·00** each, Carr. 75p.

MODULATOR UNIT: 50 watt, part of BC-640, complete with 2 × 811 valves, microphone and modulator transformers etc. **£7·50** each, 75p carr.

CATHODE RAY TUBE UNIT: With 3in. tube, Type 3EG1 (CV1526) colour green, medium persistence complete with nu-metal screen, **£3·50** each, post 50p.

APN-1 INDICATOR METER, 270° Movement. Ideal for making rev. counter. **£1·25**, post 30p.

AIRCRAFT SOLENOID UNIT S.P.S.T.: 24V, 200 Amps, **£2** each, 30p post.

DECADE RESISTOR SWITCH: 0.1 ohm per step. 10 positions. 3 Gang, each, 0·9 ohms. Tolerance ± 1% **£3** each, 25p post. 90 ohms per step. 10 positions, total value 900 ohms. 3 Gang. Tolerance ± 1% **£3·50** each, post 30p.

TF-1041B VALVE VOLTMETER: Measures 25mV to 300V, 20 c/s to 1500 Mc/s a.c. Also 10mV to 1000V d.c. Resistance 0.02 ohms to 500 Meg. ohms. Power requirements 200-250 volts a.c. Secondhand, excellent con. **£35·00.** Carr. £1.

VARIAC TRANSFORMERS: Input 115V, output 0-135V at 2 Amps. **£3** each 75p post.

RACK CABINETS: (totally enclosed) for Std. 19 in. Panels. Size 6 ft. high × 21 in. wide × 16 in. deep, with rear door. **£12** each, £2·50 Carr. OR 4 ft. high × 23 in. wide × 19 in. deep, with rear door.**£8·50**, each, £2 Carr.

INSTRUMENT CABINETS: 19"W. × 16"H. × 16"D. **£5·00** + £1·25 carr. 19"W. × 10"D. × 5"H. **£2·50** + £1·00 carr.

FUEL INDICATOR Type 113R: 24V complete with 2 magnetic counters 0-9999, with locking and reset controls mounted in 3in. diameter case. Price **£2** each, 30p post.

TS-418/URM49 SIGNAL GENERATOR: Covers 400-1000MHz range. CW Pulse or AM emission. Power Range 0-120 dbm. **£125** each. Carr. £1·50.

TN/130/APR.9 UHF TUNING UNIT: Freq. 4300-7350MHz. IF Output 160MHz with bandwidth of 20MHz and is electrically tuned by a d.c. reversible motor. **£27·50** each. Carr. £1.

APR-4 AM RADIO RECEIVER: 90-1000MHz. This receiver is suitable for monitoring and measuring frequencies as well as relative signal strength. Power Supply 115V 50c/s. **£100** each. Carr. £2.

SIGNAL GENERATOR TS-497B/URR: (Boonton). Freq. 2-400 Mc/s in 6 bands. Internal Mod. 400 or 1000 c/s per sec. External Mod. 50 to 10,000 c/s per sec. External PM. Percent Mod. 0-30 for sine wave. Am or Pulse Carrier. O/put Voltage 0·1-100,000 microvolts cont. variable. Impedance 50Ω. Price: **£85** each + £1·50 carr.

CLASS "D" WAVEMETER NO. 2: Crystal controlled heterodyne frequency meter covering 2-8MHz. Power supply 6V d.c. Good secondhand cond. **£7·50 each.** Post 60p.

RCA TE-149 HETERODYNE WAVEMETER: V-cut, 1MHz crystal (0·005%). Accuracy better than 0·02%. Dial directly calibrated every 1KHz from 2·5-5MHz. Useful harmonics up to 20MHz. Provision for fitting internal dry batteries. "As new" complete with Manual and Spares. **£14** each. Carr. 75p.

POWER UNIT TYPE 24: (for R.216 Receiver) A.C. operated 100-125V or 200-250V, 50c/s. "As new" **£10** each. Carr. 75p.

ROTARY INVERTERS: TYPE PE.218E—input 24-28V d.c., 80 Amps. 4,800 rpm. Output 115V a.c. 13 Amp 400 c/s. 1 Ph. P.F.9. **£17·50** each. Carr. £1·50.

POWER SUPPLY: 230V a.c. input; 3000V @ 2·5mA; 4v @ 1 Amp, 300-0-300 200mA; 6V @ 7 Amp; 6V @ 3 Amp. With smoothing capacitors etc. **£10·00** each. £1·50 carr.

GEARED MOTOR: 24V D.C., current 150mA, output 1 rpm, **£1·50** each, 30p post. **ASSEMBLY UNIT** with Letcherbar Tuning Mechanism and potentiometer, 3 rpm, **£2** each 30p post. **SYNCHROS:** and other special purpose motors available. List 3p.

ACTUATOR UNIT: With 115V d.c. geared motor; o/put 12·5 rpm; torque 16 ins. oz; reversible; microswitches and potentiometer. **£3·50** ea. + 40p post.

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MOTOR: 240V single phase, 2,400 rpm. 1/40 H.P. approx. Price **£1·75** each, 30p post.

CONDENSERS: 30 mfd 600 v wkg. d.c., **£3·50** each, post 50p. 15 mfd 330 v a.c., wkg., **75p** each, post 25p. 10 mfd 600 v. **43p** each, 25p post. 8 mfd 2500 v. **£5** each, carr. 63p. 8 mfd 600 v. **43p** each, post 15p. 8 mfd. 1% 300 v. D.C. **£1·25**, post 25p, 4 mfd 3000 v. wkg. **£3** each, post 37p. 4 mfd 2000 v. **£2** each, post 25p. 4 mfd 600 v., 2 for **£1.** 0·01 mfd MICA 2·5Kv, **£1** for 5, post 10p. Capacitor 0·125 mfd, 27,000 v. wkg. **£3·75** each, 50p post. 2·25 mfd 25 Kv. wkg. **£20** each, £3 carr. 2 mfd 12·5 Kv wkg. TCC RL 7002-97 **£8·50** each, carr. £1. 10 mfd 3 Kv wkg. 55°C. TCC oil filled **£7·50** each, £1 carr. 5 x 1 mfd 3 Kv wkg. 55°C. **£6·50** each, £1 carr. 12 mfd 1500v d.c. wkg. **£3·50** each, 50p post.

CONTROL PANEL: 230 v. A.C., 24 v. D.C. @ 2 amps, **£2·50** each, carr. 75p.

OHMITE VARIABLE RESISTOR: 5 ohms, 5½ amps; or 40 ohms at 2·6 amps; 500 ohms, 0·55 amps. Price (either type) **£2** each, 30p post each.

TX DRIVER UNIT: Freq. 100-156 Mc/s. Valves 3 × 3C24's; complete with filament transformer 230 v. A.C. Mounted in 19in. panel, **£4·50** each, carr. 75p.

AR88 RECEIVER: List of spares, **5p.**

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REDIFON TELEPRINTER RELAY UNIT NO. 12: ZA-41196 and power supply 200-250V a.c. Polarised relay type 3SEITR. 80-0-80V 25mA. Two stabilised valves CV 286. Centre Zero Meter 10-0-10. Size 8in. × 8in. × 8in. New condition **£7.50,** Carr. 75p.

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071 15472	16	4700	3·9 amps	1oz	17p
071 15682	16	6800	5·8 amps	1½oz	22p
071 15103	16	10000	7·9 amps	2½oz	27p
071 18222	63	2200	5·8 amps	3oz	30p
072 14113	10	11000 + 11000	10·6 amps	3oz	37p
072 14173	10	16500 + 16500	13·4 amps	4oz	49p
072 15752	16	7500 + 7500	10·5 amps	3oz	37p
072 15113	16	11000 + 11000	13·8 amps	4½oz	49p
071 16222	25	2200	2·2 amps	1oz	15p
072 16502	25	5000 + 5000	9·6 amps	3½oz	37p
072 16752	25	7500 + 7500	12·6 amps	4½oz	49p
072 17342	40	3400 + 3400	9·1 amps	3½oz	37p
072 17502	40	5000 + 5000	12·0 amps	4½oz	49p
071 18681	63	680	2·1 amps	1oz	15p
072 18172	63	1650 + 1650	7·8 amps	3oz	37p

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106 15103	16	10000	7 amps	2½oz	65p
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106 17103	40	10000	12 amps	7½oz	94p
106 18153	63	15000	28 amps	18oz	£1·79
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H8/3	3µf	50v	4p
H8/3A	4µf	50v	4p
H8/4	4·7µf	25v	4p
H8/4A	5µf	64v	4p
H8/5	5µf	10v	4p
H8/5A	5µf	150v	4p
H8/6A	10µf	10v	4p
H8/7	10µf	70v	4p
H8/8	16µf	35v	4p
H8/8A	16µf	16v	4p
H8/9	20µf	6v	2p
H8/9A	20µf	70v	4p
H8/10	22µf	50v	4p
H8/10A	22µf	100v	4p
H8/11	25µf	12v	4p
H8/11A	24µf	275v	4p
H8/12	32µf	15v	4p
H8/12A	30µf	10v	4p
H8/13A	32µf	50v	4p
H8/14	40µf	25v	5p
H8/14A	40µf	16v	4p
H8/15	47µf	50v	4p
H8/15A	40µf	35v	4p
H7/1	50µf	6v	3p
H7/1A	50µf	10v	4p
H7/2	50µf	50v	4p
H7/2A	64µf	2·5v	2p
H7/3A	64µf	25v	4p
H7/4	64µf	15v	4p
H7/4A	64µf	35v	5p
H7/5	80µf	16v	4p
H7/6	100µf	25v	5p
H7/6A	100µf	15v	4p
H7/7	100µf	25v	4p
H7/8	125µf	16v	5p
H7/8A	100µf	35v	6p
H7/9	100µf	63v	6p
H7/9A	125µf	4v	4p
H7/10	125µf	25v	6p
H7/10A	160µf	2·5v	3p
H7/11	160µf	25v	6p
H7/11A	150µf	16v	5p
H7/13A	200µf	25v	8p
H7/14	220µf	50v	10p
H7/14A	220µf	16v	6p
H7/15	220µf	25v	5p
H7/15A	220µf	35v	10p
H6/1A	250µf	4v	3p
H6/2			
H6/3A	320µf	2·5v	3p
H6/4	320µf	10v	4p
H6/4A	330µf	16v	5p
H6/5	330µf	25v	10p
H6/5A	330µf	35v	15p
H6/7	400µf	15v	5p
H6/8	470µf	25v	10p
H6/8A	470µf	35v	20p
H6/9			
H6/9A	400µf	40v	20p
H6/10	750µf	12v	5p
H6/13A	1000µf	25v	16p
H5/2A	2200µf	16v	15p

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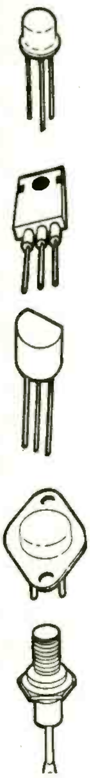

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AC128	25p	BCY34	30p	MJE520	59p	OC44	20p	TIP34C	£1·90	2N2646	50p
AC176	25p	BCY55	60p	MJE521	73p	OC45	20p	TIP35C	£3·20	2N2846	£1·50
ACY17	25p	BCY70	20p	MJE2955	£1·95	OC70	15p	TIP36C	£4·10	2N2904	20p
ACY18	25p	BCY71	20p	MJE3055	65p	OC71	17p	TIP41C	95p	2N2905	25p
ACY19	25p	BCY72	20p	MM1613	43p	OC72	20p	TIP42C	£1·10	2N2906	22p
ACY20	25p	BD121	75p	MM1712	60p	OC75	25p	TIS50	40p	2N2907	25p
ACY39	50p	BD123	75p	MPF102	45p	OC76	25p	ZTX107	15p	2N2962	10p
ACY21	25p	BD131	75p	MPF103		OC77	40p	ZTX300	15p	2N3053	30p
AD140	55p	BD153	75p	(2N5457)	35p	OC81	23p	ZTX500	15p	2N3054	46p
AD149	65p	BD156	75p	MPF104		OC82	25p	ZTX531	27p	2N3055	50p
AD161	37p	BDY11	£1·40	(2N5458)	35p	OC83	22p	1N659	7p	2N3232	98p
AD162	37p	BF152	20p	MPF105		OC84	25p	1N914	8p	2N3702	10p
ADZ11	£1·50	BF194	14p	(2N5459)	40p	OC139	30p	1N916	8p	2N3703	10p
AF114	25p	BF195	15p	MPSA06	35p	OC140	30p	1N4001	8p	2N3704	10p
AF115	25p	BFX29	30p	MPSA16	30p	OC170	25p	1N4002	9p	2N3705	10p
AF116	25p	BFX84	25p	MPSA56	35p	OC171	30p	1N4003	9p	2N3706	10p
AF117	25p	BFX85	30p	MPSU06	75p	OC200	50p	1N4004	10p	2N3707	10p
AF118	50p	BFX86	25p	MPSU56	70p	OC201	60p	1N4005	12p	2N3708	10p
AF172	25p	BFX88	25p	NKT135	35p	OC202	65p	1N4006	15p	2N3709	10p
ASY28	30p	BFY44	50p	NKT222	25p	TIP29A	49p	1N4007	18p	2N3771	£2·70
ASZ21	55p	BFY50	25p	NKT401	85p	TIP30A	58p	1N4148	7p	2N3772	£2·75
BA102	30p	BFY51	20p	NKT404	80p	TIP31A	62p	2N696	25p	2N3773	£2·90
BA112	60p	BFY52	22p	NKT773	25p	TIP32A	74p	2N697	20p	2N3819	35p
BA114	16p	BFY53	19p	NKT774	25p	TIP33A	£1·05	2N698	25p	2N3820	55p
BA156	15p	BFY90	60p	OA5	20p	TIP34A	£1·55	2N706	12p	2N3904	22p
BC107	10p	BSW63	60p	OA10	20p	TIP35A	£2·65	2N706A	15p	2N3905	25p
BC108	10p	BSW68	75p	OA47	10p	TIP36A	£3·35	2N708	15p	2N4058	12p
BC109	10p	BSY95A	12p	OA70	12p	TIP41A	75p	2N930	20p	2N4059	12p
BC147	12p	C111	40p	OA79	12p	TIP42A	90p	2N1132	25p	2N4060	12p
BC148	12p	C426	30p	OA81	10p	TIP29B	58p	2N1302	16p	2N4061	12p
BC149	12p	BY100	15p	OA90	10p	TIP30B	66p	2N1303	16p	2N4062	12p
BC157	13p	BY122	65p	OA91	10p	TIP31B	70p	2N1304	20p	2N4286	15p
BC158	13p	BY126	20p	OA200	10p	TIP32B	82p	2N1305	20p	2N4287	15p
BC159	13p	BY127	20p	OA202	10p	TIP33B	£1·12	2N1306	25p	2N4288	15p
BC169C	13p	BY164	65p	OA210	35p	TIP34B	£1·68	2N1307	25p	2N4289	15p
BC182	10p	IS100	15p	OA211	35p	TIP35B	£2·81	2N1308	25p	2N4290	15p
BC183	10p	IS103	20p	OC19	85p	TIP36B	£3·64	2N1309	25p	2N4444	£1·90
BC184	10p	MJ340	50p	OC22	50p	TIP41B	83p	2N1613	20p	40361	50p
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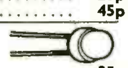

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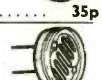

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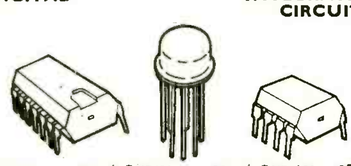

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AC113	0·22	AD161 & AD162 (MP)	0·61	BC149	0·13	BD137	0·50	BF188	0·44
AC115	0·26	ADT140	0·55	BC150	0·20	BD138	0·55	BF194	0·13
AC117K	0·22	AF114	0·27	BC151	0·22	BD139	0·61	BF195	0·13
AC122	0·13	AF115	0·27	BC152	0·19	BD140	0·66	BF196	0·16
AC125	0·19	AF116	0·27	BC153	0·31	BD155	0·88	BF197	0·16
AC126	0·19	AF117	0·27	BC154	0·33	BD175	0·66	BF200	0·50
AC127	0·19	AF118	0·39	BC157	0·20	BD176	0·66	BF222	1·05
AC128	0·19	AF124	0·33	BC158	0·13	BD177	0·72	BF257	0·50
AC132	0·16	AF125	0·28	BC159	0·13	BD178	0·72	BF258	0·66
AC134	0·16	AF126	0·31	BC160	0·50	BD179	0·77	BF259	0·94
AC137	0·16	AF127	0·31	BC161	0·55	BD180	0·77	BF292	0·61
AC141	0·16	AF139	0·33	BC167	0·13	BD185	0·83	BF263	0·61
AC141K	0·19	AF178	0·33	BC168	0·13	BD186	0·72	BF270	0·39
AC142	0·16	AF179	0·55	BC169	0·13	BD187	0·77	BF271	0·33
AC142K	0·19	AF180	0·55	BC170	0·13	BD188	0·77	BF272	0·38
AC151	0·17	AF181	0·50	BC171	0·16	BD189	0·99	BF273	0·39
AC154	0·22	AF186	0·50	BC172	0·16	BD190	0·83	BF274	0·39
AC155	0·22	AF239	0·41	BC173	0·16	BD195	0·94	BFW10	0·66
AC156	0·22	AL102	0·72	BC174	0·16	BD196	0·94	BFX29	0·30
AC157	0·27	AL103	0·72	BC175	0·24	BD197	0·99	BFX84	0·24
AC165	0·22	ASY26	0·28	BC177	0·21	BD198	0·99	BFX85	0·33
AC166	0·22	ASY27	0·33	BC178	0·21	BD199	1·05	BFX86	0·24
AC167	0·22	ASY28	0·28	BC179	0·21	BD200	1·05	BFX87	0·27
AC168	0·27	ASY29	0·28	BC180	0·27	BD205	0·88	BFX88	0·24
AC169	0·16	ASY50	0·28	BC181	0·27	BD206	0·88	BFY50	0·22
AC176	0·22	ASY51	0·28	BC182	0·11	BD207	1·05	BFY51	0·22
AC177	0·27	ASY52	0·28	BC182L	0·11	BD208	1·05	BFY52	0·22
AC178	0·31	ASY54	0·28	BC183	0·11	BDY20	1·10	BFY53	0·19
AC179	0·31	ASY55	0·28	BC183L	0·11	BF115	0·27	BPX25	0·94
AC180	0·19	ASY56	0·28	BC184	0·13	BF117	0·50	BSX19	0·17
AC180K	0·22	ASY57	0·28	BC184L	0·13	BF118	0·77	BSX20	0·17
AC181	0·19	ASY58	0·28	BC186	0·31	BF119	0·77	BSY25	0·17
AC181K	0·22	ASZ21	0·44	BC187	0·31	BF121	0·50	BSY26	0·17
AC187	0·24	BC107	0·10	BC207	0·12	BF123	0·55	BSY27	0·17
AC187K	0·22	BC108	0·10	BC208	0·12	BF125	0·50	BSY28	0·17
AC188	0·24	BC109	0·11	BC209	0·13	BF127	0·55	BSY29	0·17
AC188K	0·22	BC113	0·11	BC212L	0·12	BF152	0·61	BSY38	0·20
ACY17	0·28	BC114	0·17	BC213L	0·12	BF153	0·50	BSY39	0·20
ACY18	0·22	BC115	0·17	BC214L	0·16	BF154	0·50	BSY40	0·31
ACY19	0·22	BC116	0·17	BC225	0·28	BF155	0·77	BSY41	0·31
ACY20	0·22	BC117	0·17	BC226	0·39	BF156	0·53	BSY95	0·14
ACY21	0·22	BC118	0·11	BCY30	0·27	BF157	0·61	BSY95A	0·14
ACY22	0·18	BC119	0·33	BCY30	0·27	BF158	0·61	Bu105	2·20
ACY27	0·20	BC120	0·88	BCY31	0·29	BF159	0·66	C111E	0·55
ACY28	0·21	BC125	0·13	BCY32	0·33	BF160	0·44	C400	0·33
ACY29	0·39	BC126	0·20	BCY33	0·24	BF162	0·44	C407	0·28
ACY30	0·31	BC132	0·13	BCY34	0·28	BF163	0·44	C424	0·22
ACY31	0·31	BC134	0·20	BCY70	0·16	BF164	0·44	C425	0·55
ACY34	0·23	BC135	0·13	BCY71	0·20	BF165	0·44	C426	0·39
ACY35	0·23	BC136	0·17	BCY72	0·16	BF167	0·24	C428	0·22
ACY36	0·31	BC137	0·17	BCZ10	0·22	BF173	0·24	C441	0·33
ACY40	0·19	BC139	0·44	BCZ11	0·28	BF176	0·34	C442	0·33
ACY41	0·20	BC140	0·33	BCX12	0·28	BF177	0·39	C444	0·39
ACY44	0·39	BC141	0·33	BD121	0·66	BF178	0·33	C450	0·24
AD130	0·42	BC142	0·33	BD123	0·72	BF179	0·33	MAT00	10·21
AD140	0·53	BC143	0·33	BD124	0·66	BF180	0·33	MAT101	0·22
AD142	0·53	BC145	0·50	BD131	0·55	BF181	0·33	MAT120	0·21
AD143	0·43	BC147	0·11	BD132	0·66	BF182	0·44	MAT121	0·20
AD149	0·55			BD133	0·72	BF183	0·44	MPF102	0·46
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OC19	0·39	2G345	0·18	2N2218	0·22	2N3054	0·51	2N4060	0·13
OC20	0·70	2G371	0·18	2N2219	0·22	2N3055	0·55	2N4061	0·13
OC22	0·42	2G371B	0·13	2N2220	0·24	2N3391	0·16	2N4062	0·13
OC23	0·46	2G373	0·19	2N2221	0·22	2N3391A	0·18	2N4284	0·19
OC24	0·62	2G374	0·19	2N2222	0·22	2N3392	0·16	2N4285	0·19
OC25	0·42	2G377	0·33	2N2368	0·19	2N3393	0·16	2N4286	0·19
OC26	0·28	2G378	0·18	2N2369	0·16	2N3394	0·16	2N4287	0·19
OC28	0·55	2G381	0·18	2N2369A	0·16	2N3395	0·19	2N4288	0·19
OC29	0·55	2G382	0·18	2N2411	0·27	2N3402	0·23	2N4289	0·19
OC35	0·46	2G401	0·33	2N2412	0·27	2N3403	0·23	2N4290	0·19
OC36	0·55	2G414	0·33	2N2646	0·52	2N3404	0·31	2N4291	0·19
OC41	0·22	2G417	0·28	2N2711	0·23	2N3405	0·46	2N4292	0·19
OC42	0·27	2N388	0·28	2N2712	0·23	2N3414	0·17	2N4293	0·19
OC44	0·17	2N388A	0·61	2N2714	0·23	2N3415	0·17	2N5172	0·13
OC45	0·14	2N404	0·22	2M2904	0·19	2N3416	0·31	2N5457	0·35
OC70	0·11	2N404A	0·31	2N2904A	0·23	2N3417	0·31	2N5458	0·35
OC71	0·11	2N524	0·46	2N2905	0·23	2N3525	0·83	2N5459	0·44
OC72	0·16	2N527	0·54	2N2905A	0·23	2N3646	0·10	2S301	0·55
OC74	0·16	2N598	0·46	2N2906	0·17	2N3702	0·11	2S302A	0·46
OC75	0·17	2N599	0·50	2N2906A	0·20	2N3703	0·11	2S302	0·46
OC76	0·17	2N696	0·14	2N2907	0·22	2N3704	0·12	2S303	0·61
OC77	0·28	2N697	0·15	2N2907A	0·24	2N3705	0·11	2S304	0·77
OC81	0·17	2N698	0·27	2N2923	0·16	2N3706	0·10	2S305	0·93
OC81D	0·17	2N699	0·39	2N2924	0·16	2N3707	0·12	2S306	0·93
OC82	0·17	2N706	0·09	2N2925	0·16	2N3708	0·08	2S307	0·93
OC82D	0·17	2N706A	0·10	2N2926(G)	0·14	2N3709	0·10	2S321	0·62
OC83	0·22	2N708	0·13			2N3710	0·10	2S322	0·46
OC84	0·22	2N711	0·33	2N2926(Y)	0·12	2N3711	0·10	2S322A	0·46
OC139	0·22	2N717	0·39			2N3819	0·31	2S323	0·62
OC140	0·22	2N718	0·27	2N2926(O)	0·11	2N3820	0·55	2S324	0·77
OC169	0·28	2N718A	0·55			2N3821	0·39	2S325	0·77
OC170	0·28	2N726	0·31	2N2926(R)	0·11	2N3823	0·31	2S326	0·77
OC171	0·28	2N727	0·31			2N3903	0·31	2S327	0·77
OC200	0·28	2N743	0·22	2N2926(B)	0·11	2N3904	0·33	2S701	0·46
OC201	0·31	2N744	0·22			2N3905	0·31	40361	0·44
OC202	0·31	2N914	0·16	2N3010	0·77	2N3906	0·30	40362	0·50
OC203	0·28	2N918	0·33	2N3011	0·16	2N4058	0·13		
OC204	0·28	2N929	0·23						
OC205	0·39	2N930	0·23						
OC309	0·44	2N1131	0·22						
OCP71	0·48	2N1132	0·24						
ORP12	0·48	2N1302	0·16						
ORP60	0·44	2N1303	0·16						
ORP61	0·44	2N1304	0·19						
P346A	0·22	2N1305	0·19						
P397	0·46	2N1306	0·23						
ST140	0·46	2N1307	0·23						
ST140	0·14	2N1308	0·26						
ST141	0·19	2N1309	0·26						
TIS43	0·33	2N1613	0·22						
UT46	0·30	2N1711	0·22						
2G301	0·21	2N1889	0·35						
2G302	0·21	2N1890	0·50						
2G303	0·21	2N1893	0·41						
2G304	0·27	2N2147	0·79						
2G306	0·44	2N2148	0·63						
2G308	0·39	2N2160	0·66						
2G309	0·39	2N2192	0·39						
2G339	0·22	2N2193	0·39						
2G339A	0·18	2N2194	0·39						

DIODES AND RECTIFIERS

Type	Price	Type	Price	Type	Price
AA119	0·09	BY133	0·23	OA10	0·39
AA120	0·09	BY164	0·55	OA47	0·08
AA129	0·09	BYX38/30	0·46	OA70	0·08
AAY30	0·10			OA79	0·08
AAZ13	0·11	BYZ10	0·39	OA81	0·08
BA100	0·11	BYZ11	0·33	OA85	0·10
BA116	0·23	BYZ12	0·33	OA90	0·07
BA126	0·24	BYZ13	0·28	OA91	0·07
BA148	0·16	BYZ16	0·44	OA95	0·08
BA154	0·13	BYZ17	0·39	OA200	0·07
BA155	0·16	BYZ18	0·39	OA202	0·08
BA156	0·15	BYZ19	0·31	SD10	0·06
BY100	0·17	CG62 (OA91 Eq.)	0o06	SD19	0·06
BY101	0·13			1N34	0·8
BY105	0·19			1N34A	0·08
BY114	0·13	CG651 (OA70-OA79 Eq.)	0·07	1N914	0·07
BY126	0·16			1N916	0·07
BY127	0·17			1N414B	0·07
BY128	0·17	OA5	0·39	1S021	0·11
BY130	0·18	OA5SL	0·23	1S951	0·07

FULL RANGE OF ZENER DIODES VOLTAGE RANGE
2-23V. 400mV (DO-7 Case) 15p ea. 1½W (Top-Hat) 20p ea. 10W (SO-10 Stud) 33p ea. All fully tested 5% tol. and marked. State voltage required.

10 amp POTTED BRIDGE RECTIFIER on heat sink. 100PIV. 99p each

NEW LINE
Plastic Encapsulated 2 Amp. BRIDGE RECTS.

50v RMS	35p each
100v RMS	40½p ,,
400v RMS	50½p ,,

Size 15 mm × 6 mm.

UNIJUNCTION
UT46. Eqvt. 2N2646. Eqvt. TIS43. BEN3000 30p each, 25-99 27½p 100 UP 22p.

CADMIUM CELLS
ORP12 47½p
ORP60, ORP61 44p each

GENERAL PURPOSE NPN SILICON SWITCHING TRANS. TO-18 SIM. TO 2N706/8. BSY-27/28/95A. All usable devices no open or short circuits. ALSO AVAILABLE in PNP Sim. to 2N2906, BCY70. When ordering please state preference NPN or PNP.

		£p
20	For	0·55
50	For	1·10
100	For	1·92
500	For	8·25
1000	For	14·30

SIL. G.P. DIODES £p

300mW	30	0·55
40PIV(Min.)	100	1·65
Sub-Min.	500	5·50
Full Tested	1,000	9·90

Ideal for Organ Builders.

TRIACS

VBOM	2A TO-1 £p	6A TO-66 £p	10A TO-88 £p
100	33	55	82½
200	55	66	99
400	77	82½	1·21

DIACS
FOR USE WITH TRIACS
BR100 (D32) 40½p each

FREE
One 50p Pak of your own choice free with orders valued £4 or over.

BRAND NEW TEXAS GERM. TRANSISTORS
Coded and guaranteed

Pak No.			EQVT
T1	8	2G3713	OC71
T2	8	D1374	OC75
T3	8	D1216	OC81D
T4	8	2G381T	OC81
T5	8	2G382T	OC82
T6	8	2G344B	OC44
T7	8	2G345B	OC45
T8	8	2G378	OC78
T9	8	2G399A	2N1302
T10	8	2G417	AF117

All 55p each pak.

2N2060 NPN SIL. DUAL TRANS. CODE D1699 TEXAS. Our price 28p each.

120 VCR NIXIE DRIVER TRANSISTOR. Sim. BSX21 & C407, 2N1893 FULLY TESTED AND CODED ND 120, 1-24 19p each. TO.5 NPN 25 up 17p each.

Sil. trans. suitable for P.E. Organ. Metal TO-18 Eqvt. ZTX300 5½p each. Any Qty.

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Pak No.		Description	Price
U 1	120	Glass Sub-Min. General Purpose Germanium Diodes	0·55
U 2	60	Mixed Germanium Transistors AF/RF	0·55
U 3	75	Germanium Gold Bonded Sub-Min. like OA5, OA47	0·55
U 4	40	Germanium Transistors like OC81, AC128	0·55
U 5	60	200mA Sub-Min. Silicon Diodes	0·55
U 6	30	Sil. Planar Trans. NPN like BSY95A. 2N706	0·55
U 7	16	Sil. Rectifiers TOP-HAT 750mA VLTG. RANGE up to 1000	0·55
U 8	50	Sil. Planar Diodes DO-7 Glass 250mA like OA200/202	0·55
U 9	20	Mixed Voltages, 1 Watt Zener Diodes	0·55
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U11	25	PNP Sil. Planar Trans. TO-5 like 2N1132. 2N2904	0·55
U12	12	Silicon Rectifiers Epoxy 500mA up to 800 PIV	0·55
U13	30	PNP-NPN Sil. Transistors OC200 & 2S 104	0·55
U14	150	Mixed Silicon and Germanium Diodes	0·55
U15	25	NPN Sil. Planar Trans. TO-5 like BFY51, 2N697	0·55
U16	10	3 Amp Silicon Rectifiers Stud Type up to 1000PIV	0·55
U17	30	Germanium PNP AF Transistors TO-5 like ACY 17-22	0·55
U18	8	6 Amp Silicon Rectifiers BYZ13 Type up to 600 PIV	0·55
U19	25	Silicon NPN Transistors like BC108	0·55
U20	12	1·5 Amp Silicon Rectifiers Top Hat up to 1000 PIV	0·55
U21	30	AF. Germanium Alloy Transistors 2G300 Series & OC71	0·55
U23	30	MADT's like MHz Series PNP Transistors	0·55
U24	20	Germanium 1 Amp Rectifiers GJM Series up to 300 PIV	0·55
U25	25	300 MHz NPN Silicon Transistors 2N708, BSY27	0·55
U26	30	Fast Switching Silicon Diodes like 1N914 Micro-Min.	0·55
U27	12	NPN Germanium AF Transistors TO-1 like AC127	0·55
U29	10	1 Amp SCR's TO-5 can, up to 600 PIV CRS1/25-600	1.10
U30	15	Plastic Silicon Planar Trans. NPN 2N2926	0·55
U31	20	Silicon Planar Plastic NPN Trans. Low Noise Amp 2N3707	0·55
U32	25	Zener Diodes 400mW DO-7 case 3-18 volts mixed	0·55
U33	15	Plastic Case 1 Amp Silicon Rectifiers 1N4000 Series	0·55
U34	30	Silicon PNP Alloy Trans. TO-5 BCY26 2S302/4	0·55
U35	25	Silicon Planar Transistors PNP TO-18 2N2906	0·55
U36	25	Silicon Planar NPN Transistors TO-5 BFY50/51/52	0·55
U37	30	Silicon Alloy Transistors SO-2 PNP OC200, 2S322	0·55
U38	20	Fast Switching Silicon Trans. NPN MHz 2N3011	0·55
U39	30	RF. Germ. PNP Transistors 2N1303/5 TO-5	0·55
U40	10	Dual Transistors 6 lead TO-5 2N2060	0·55
U41	25	RF Germanium Transistors TO-5, OC45, NKT72	0·55
U42	10	VHF Germanium PNP Transistor TO-1 NKT667, AF117	0·55
U43	25	Sil. Trans. Plastic TO-18 A.F. BC113/114	0·55
U44	20	Sil. Trans. Plastic TO-5 BC115/NPN	0·55
U45	7	3A SCR. TO66 up to 600PIV	1·10

Code No's. mentioned above are given as a guide to the type of device in the pak. The devices themselves are normally unmarked.

QUALITY TESTED SEMICONDUCTORS

Pak No.			Price £p
Q1	20	Red spot transistors PNP	0·55
Q2	16	White spot R.F. transistors PNP	0·55
Q3	4	OC 77 type transistors	0·55
Q4	6	Matched transistors OC44/45/81/81D	0·55
Q5	4	OC 75 transistors	0·55
Q6	5	OC 72 transistors	0·55
Q7	4	AC 128 transistors PNP high gain	0·55
Q8	4	AC 126 transistors PNP	0·55
Q9	7	OC 81 type transistors	0·55
Q10	7	OC 71 type transistors	0·55
Q11	2	AC 127/128 Complementary pairs PNP/NPN	0·55
Q12	3	AF 116 type transistors	0·55
Q13	3	AF 117 type transistors	0·55
Q14	3	OC 171 H.F. type transistors	0·55
Q15	7	2N2926 Sil. Epoxy transistors mixed colours	0·55
Q16	2	GET880 low noise Germanium transistors	0·55
Q17	5	NPN 2 × ST.141 & 3 × ST.140	0·55
Q18	4	MADT'S 2 × MAT 100 & 2 × MAT 120	0·55
Q19	3	MADT'S 2 × MAT 101 & 1 × MAT 121	0·55
Q20	4	OC 44 Germanium transistors A.F.	0·55
Q21	4	AC 127 NPN Germanium transistors	0·55
Q22	20	NKT transistors A.F. R.F. coded	0·55
Q23	10	OA 202 Silicon diodes sub-min.	0·55
Q24	8	OA 81 diodes	0·55
Q25	15	1N914 Silicon diodes 75 PIV 75mA	0·55
Q26	8	OA95 Germanium diodes sub-min. IN69	0·55
Q27	2	10A PIV Silicon rectifiers IS425R	0·55
Q28	2	Silicon power rectifiers BYZ 13	0·55
Q29	4	Silicon transistors 2 × 2N696, 1 × 2N697, 1 × 2N698	0·55
Q30	7	Silicon switch transistors 2N706 NPN	0·55
Q31	6	Silicon switch transistors 2N708 NPN	0·55
Q32	3	PNP Silicon transistors 2 × 2N1131, 1 × 2N 1132	0·55
Q33	3	Silicon NPN transistors 2N1711	0·55
Q34	7	Silicon NPN transistors 2N2369, 500MHz (code P397)	0·55
Q35	3	Silicon PNP TO-5, 2 × 2N2904 & 1 × 2N2905	0·55
Q36	7	2N3646 TO-18 plastic 300 MHz NPN	0·55
Q37	3	2N3053 NPN Silicon transistors	0·55
Q38	7	NPN transistors 4 × 2N3703, 3 × 2N3702	0·55

ELECTRONIC SLIDE-RULE

The MK Slide Rule, designed to simplify Electronic calculations features the following scales:— Conversion of Frequency and Wavelength. Calculation of L, C and fo of Tuned Circuits. Reactance and Self-Inductance. Area of Circles. Volume of Cylinders. Resistance of Conductors. Weight of Conductors. Decibel Calculations. Angle Functions. Natural Logs and 'e' Functions. Multiplication and Division. Squaring, Cubing and Square Roots. Conversion of kW and Hp. A must for every electronic engineer and enthusiast. Size: 2 cm. × 4 cm. Complete with case and instructions. Price each: £3·68½

NEW LOW PRICE TESTED S.C.R.'s

PIV	1A TO5	3A TO66	5A TO66	5A TO64	7A TO48	10A TO48	16A TO48	03A TO48
50	0·26	0·28	0·39	0·39	0·52	0·55	0·59	1·27
100	0·28	0·37	0·52	0·52	0·55	0·64	0·70	1·54
200	0·39	0·41	0·54	0·54	0·63	0·67	0·83	1·76
400	0·48	0·52	0·62	0·62	0·74	0·83	1·03	1·93
600	0·59	0·63	0·75	0·75	0·85	1·07	1·38	—
800	0·70	0·77	0·88	0·88	0·99	1·32	1·65	4·40

SIL. RECTS. TESTED

PIV	300mA	750mA	1K	1·5A	3A	10A	30A
50	0·04	0·06	0·06	0·08	0·16	0·23	0·66
100	0·04	0·07	0·06	0·15	0·18	0·26	0·83
200	0·06	0·10	0·07	0·16	0·22	0·27	1·10
400	0·07	0·15	0·08	0·22	0·30	0·41	1·38
600	0·08	0·18	0·11	0·26	0·38	0·50	2·05
800	0·11	0·19	0·12	0·28	0·41	0·61	2·20
1000	0·12	0·28	0·16	0·33	0·51	0·70	2·75
1200	—	0·37	—	0·42	0·63	0·83	—

POWER TRANS BONANZA!

GENERAL PURPOSE GERM. PNP
Coded GP100. BRAND NEW TO-3 CASE. POSSIBLE REPLACE:—OC25-28-29-30-35-36. NKT 401-403-404-405-406-430-451-452-453. TI3027-3028, 2N250A 2N456A-457A-458A, 2N511 A & B. 2G220-222, ETC. VCBO 80V VCEO 50V IC 10A PT. 30 WATTS Hfe 30-170.

PRICE	1-24	25-99	100 up
	47½p each	44p each	39½p each

SILICON High Voltage 250V NPN
TO-3 case. G.P. Switching & Amplifier Applications. Brand new Coded R 2400 VCBO 250/VCEO 100/IC 6A/30 Watts. HFE type 20/fT 5MHZ.
OUR PRICE EACH:

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55p	49½p	44p

2N3055
115 WATT SIL POWER NPN 55p EACH.

SILICON 50 WATTS MATCHED NPN/PNP
BIP 19 NPN TO-3 Plastic. BIP 20 PNP. Brand new. VCBO 100/VCEO 50/IC 10A. HFE type 100/ft 3mHZ.
OUR PRICE PER PAIR:
1-24 prs. 66p 25-99 prs. 61p 100 prs. 55p

AD161/162 *PNP*
M/P COMP GERM TRANS. OUR LOWEST PRICE OF 60p *PER PAIR*

SILICON PHOTO TRANSISTOR
TO-18 Lens end NPN Sim. to BP × 25 and P21. BRAND NEW. Full data available. Fully guaranteed.

Qty.	1-24	25-99	100 up
Price each	49p	44p	38p

F.E.T.'S

2N3819	31p	2N5458	35p
2N3820	55p	2N5459	44p
2N3821	39p	BFW10	66p
2N3823	31p	MPF105	41p

JUMBO COMPONENT PAKS
MIXED ELECTRONIC COMPONENTS
Exceptionally good value
Resistors, capacitors, pots, electrolytics and coils plus many other useful items. Approximately 3lbs in weight. Price incl. P. & P. £1·65 only.

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Pri. 10-0-200-220-240v. Sec. 240v. Centre tapped 1·2kva. Conservatively rated. Size 8½ x 7 x 8½ ins. Wgt. 59 lbs. Open frame type, terminal connections. Fraction of maker's price. **£17·00** carr. £1·00.

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Pri. 240v. Sec. 150v. 4kva. Size 9 x 8½ x 7 ins. Wgt. 70 lbs. **£22·50** carr. £2·00.

RICH AND BUNDY. Pri. 220-230-240-250v. Sec. 265-270-275v. 1400 watts. Conservatively rated. Size 8 x 8 x 7 ins. Terminal block connections. **£17·00** carr. £1·00.

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No. 1 T.E.C. Pri. 380-400-415-440v. Sec. 33 60 amps. Size 9 x 9 x 8 ins. Terminal block connections. Conservatively rated. **£20·00** carr. £2·00. No. 2 Davenset. Pri. 415-440-525v. Sec. 220v. 2kva. Size 9 x 8½ x 8 ins. **£25** carr. £2·00. No. 3 Davenset. Pri. 380-400-415-440v. Sec. 110v. 8 amps. Size 6 x 6½ x 5½ ins. **£8·50** carr. £1. No. 4 Davenset. Pri. 380-400-417-437v. Sec. tapped 110-270v. 0·15kva. Size 7 x 5½ x 5 ins. **£6·50** carr. 75p. No. 5 Rich and Bundy. Pri. 380-400-420-440v. Sec. 240v. 40 watts. Size 4 x 4 x 4 ins. Terminal block connections. **£2·50** carr. 50p. Drake. Pri. 440v. Sec. 220-240v. 100 watts. Shrouded. **£3·25** postage 40p.

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Pri. tapped. 100-110-200-220-230-240-250v. Sec. 115v. 13·5 amps. Conservatively rated, fully shrouded. Table top connections. Size 13 x 10 x 8½ ins. **£32·50** carr. £2·00. Pri. tapped 200-210-220-230-240-250v. Sec. tapped 90-100-110-120v. 7·5 amps. Conservatively rated table top connections. Size 9 x 8 x 8 ins. **£22·50** carr. £1·50.

ADVANCED COMPONENTS CONSTANT VOLTAGE TRANSFORMERS
Input 190-260v. Output 230v. 150 watts. Type 140A **£7·00** carr. 75p. Output 28v. 8 amps open frame type **£4·50** carr. 75p. Output 4v. 3 watts **75p** carr. 25p. Output 240v. 30 watts enclosed type **£1·50** carr. 35p.

BODINE ELECTRIC GEARED MOTORS
HP. 1/35 A.C. 115v. 50 cycles. RPM 137. Torque 9 in lbs. Ratio 10-1. Pulley Drive. Complete with Control Box containing Capacitor. On/Off Switch. Micro switch reversing connections. Ideal for electric door systems. **£10·00** carr. £1.

ALL PRICES INCLUDE VAT

SMITHS 12v. D.C. VEHICLE HEATER MOTORS
3 dia. length 4 ins. Spindle 3/16. Length 1½ ins. Very powerfull **£1** carr. 25p. With 6½ in. fan **£1·25** carr. 25p. As above with twin turbo fans **£1·50** carr. 35p.

A.C. GEARED MOTORS BY FAMOUS MAKERS
230/250v. 50 cycles Induction type. 4·2 r.p.m. Cont. rating 5 lb. ins. Right angle worm drive. Overall size 7 ins. Dia. 3 ins. Spindle length 3 ins. Dia. ½ in. **£4·75** carr. 45p. Gear motors 50v. D.C. Shunt wound. Cont. rating. 34 r.p.m. 2 lb. ins. Right angle worm drive. Overall size 6 x 3 ins. dia. Spindle 1 in. ¼ in. dia. **£3·75** carr. 35p.

A.C. 220-240v. SHADED POLE MOTORS
1500 r.p.m. Double spindle. Length ¾ in. and ⅝ in. Overall size 3 x 3½ x 2 ins. Similar to turbo fan heater motors. **50p.** P.P. 15p.

MINIATURE 24v. D.C. GEARED MOTORS
500 r.p.m. Size 2 x 1½ x 1 ins. Length of spindle 1 in., dia. ⅛ in. **75p.** P.P. 15p.

RADICON WORM REDUCTION GEAR BOXES
Size 1½ ins. Ratio 14·5/1. Drive spindle: length 1½ ins., dia. ⅜ in. Reduction spindle: length 1½ ins., dia. ⅜ in. Overall size 5 x 4½ x 5 ins. **£2·00** carr. 50p.

NEWMARK SYNCHRONOUS MOTORS
220-240v. 50 cycles, 3 watts, 8 r.p.m. Overall size 2 x 2 x 2 ins. **50p.** P.P. 10p.
6 revs. per hour. Size 2½ x 2 x 2 ins. **50p.** P.P. 10p.

GENTS 6v. D.C. ALARM BELLS
6 in. dia. gong. Overall size 4½ x 6 x 6 ins. **£3·00** carr. 50p.

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Omron 24v. A.C. or 12v. D.C. 2 7A CO contacts. Size 1½ x 1½ x 1 in. Single hole fixing. **45p.** Postage 5p.
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G.P.O. RELAYS
3000 type. 100Ω 1 25 amp. make contact **60p.** 2000 + 130Ω 1 normal CO **40p.** 75Ω 3M. 1B. 1 CO normal contacts **40p.** P.P. on all relays 10p.
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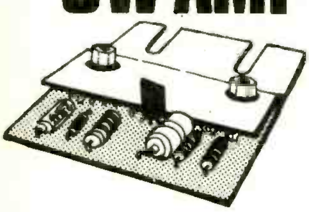

- ★ Nominal 12-14V (650mA into 3 ohm)
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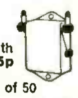

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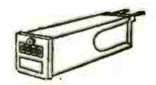
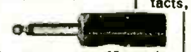


JACK PLUGS



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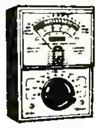

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New style 20,000 o.p.v. pocket multimeter. 5/25/50/250/2500V. D.C. 10/50/100/500/1000V. A.C. 50µA/250mA. 6K/6 meg ohms. —20 to +22db. **£3·75.** Post 20p.

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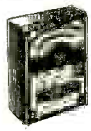

20,000 o.p.v. Overload protection. Slide switch selector. 0/·25/2·5/10/50/250/1000V. D.C. 0/10/50/250/1000V. A.C. 0/50µA/25/250mA D.C. 0/3K/30K/300K/3 meg. —20 to +50db. **£4·97.** Post 15p.

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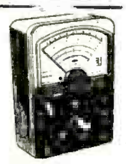

30,000 O.P.V. with overload protection. mirror scale. 0/·5/2·5/10/25/100/250/500/1,000 v. D.C. 0/2.5/10/25/100/250/500/1,000 v. A.C. 0/50µA/5/50/500 mA. 12 amp. D.C. 0/60/K/6 meg/60 meg Ω. **£9·95.** Post paid. Leather case **£1·75.**

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Extremely sturdy instrument for general electrical use. 667 o.p.v. 0/·3/1·5/7·5/30/60/150/300/600/900 VDC and 75mV. 0/·3/1·5/7·5/30/60/150/300/600/900 VAC. 0/300µA/1·5/6/15/60/150 600MA/1·5/6 AMP. D.C. 0/1·5/6/15/60/150/600MA/1·5/6 AMP. A.C.0/200 Ω/3K/30K Ω. Accuracy DC 1%. AC 1·5%. Knife edge pointer, mirror scale. Complete with sturdy metal carrying case, leads and instructions. **£9·50.** Post 25p.

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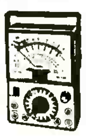
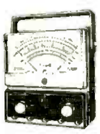


100,000 O.P.V. Overload protection. Mirror scale, ·3/·6/1·2/1·5/3/6/12/30/60/120/300/600/1200 VDC. 1·5/3/6/12/30/60/150/300/600/1200 VAC. 15/30vA/3/6/30/60/150/300 mA. 6/12 AMP DC. 2K/200 K/2 Meg/20 megohm. —20 to +63db. **£13·50.** Post 20p.

MODEL C-7080 EN



Giant 6in. mirror scale. 20,000 o.p.v. 0/·25/1/2·5/10/50/250/1000/5000V. D.C. 0/2·5/10/50/250/1000/5000V. A.C. 0/50µA/1/10/100/500mA/10 amp. D.C. 0/2K/200K/20 meg. —20 to +50 db. **£13·95.** Post 35p.

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High sensitivity tester. 200,000 o.p.v. Overload protection. Mirror scale. Ranges 0/·06/·3/3/30/120/600/1200V. D.C. 0/3/12/60/300/11,200V A.C. 0/6µA/1·2mA/120mA/600mA/12A. D.C. 0/12A. A.C. —20 to +63dB. 0/2K/200K/2 meg/200 meg ohms. **£16·95.** Post 30p.

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370 WTR MULTIMETER

Features A.C. current ranges. 20,000 o.p.v. 0/·5/2·5/10/50/250/500/1000 V DC 0/2·5/10/50/250/500/1000 V AC 0/50µA/1/10/100MA/1/10 Amp DC. 0/100MA/1/10 Amp AC. 0/5K/50K/500K/5MEG/50MEG. —20 + 62 db. **£15.** Post 25p.

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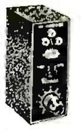
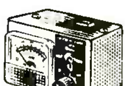


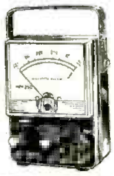
Tests PNP or NPN transistors. Audio indication. Operates on two 1.5v batteries. Complete with all instructions etc. **£4·50.** Post 20p.

LB3 TRANSISTOR TESTER



Tests ICO and B. PNP/NPN. Operates from 9v. battery. Complete with all instructions etc. **£3·95.** Post 20p.

KAMODEN HM.350 TRANSISTOR TESTER



High quality instrument to test Reverse Leak current and DC current Amplification factor of NPN, PNP, transistors, diodes, SCR's etc. 4in. × 4½in. clear scale meter. Operates from internal batteries. Complete with instructions leads and carrying handle. **£12·50** Post 30p.

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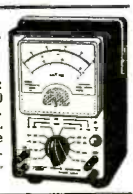
Checks true A.C. beta in/out. Checks Icbo. Checks diodes in/out. Checks SCR etc. Beta HI 10-500. LO2-50. Icbo 0-5000µA. 220/240V. A.C. operation. **£17·50.** Post 25p.

KAMODEN HM.720B F.E.T. V.O.M.

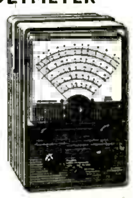
Input impedance 10 meg. ohms. Ranges: 0/·25/1/2·5/10/50/250/1000V, D.C. 0/2·5/10/50/250/1000V. A.C. 0/25µA/2·5/25/250 MA D.C. —20 to +62dB 0/5K/50K/500K/5 meg/500 meg ohms. **£14·95.** Post 30p.

T.E.40 HIGH SENSITIVITY A.C. VOLTMETER



10 meg. input 10 ranges: .01/.03/.1/.3/1/3/10/30/100/300 v. R.M.S. 4 cps.-1.2 Mc/s. Decibels —40 to +50 dB. Supplied brand new complete with leads and instructions. Operation 230 v. A.C. **£17·50** Carr. 25p.

TE-65 VALVE VOLTMETER



High quality instrument with 28 ranges. D.C. volts 1.5-1,500 v. A.C. volts 1.5-1,500 v. Resistance up to 1,000 megohms. 220/240v. A.C. operation Complete with probe and instructions. **£17·50.** Post 30p. Additional Probes available: R.F. **£2·12** H.V. **£2·50.**

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Sensitivity 330 ohms/Volt A.C. and D.C. Accuracy ·5% D.C. 1% A.C. Scale length 165mm. 0/300/750µA/1·5/3/7·5/15/30/75/150/300/750mA/1·5/3/7·5 Amp. D.C. 0/3/7·5/15/30/75/150/300/750mA/1·5/3/7·5 Amp. A.C. 0/75/150/300/750mV/1·5/3/7·5/15/30/75/150/300 750V. D.C. 0/750mV/1·5/3/7·5/15/30/75/150/300/650V. A.C. Automatic cut out. Supplied complete with test leads, manual and test certificates. **£49.** Post 50p

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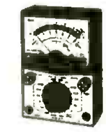
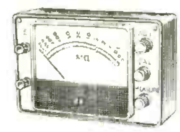
MODEL L-55 FET V.O.M.



Input impedance 10 meg. ohms. 0/·3/1·2/6/30/120/600V. D.C. 0/3/12/60/120/600V. A.C. 0/120µA/120mA. D.C. 0/1K/100K/10 meg/100 meg ohms. **£15·97.** Post 25p.

KAMODEN HMG-500 INSULATION RESISTANCE TESTER



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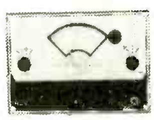

Output max. + 10 dB (10 K ohms). Operation internal batteries. Attractive 2-tone case 7½in. × 5in. × 2in. Price **£17·50** Carr. 17p.

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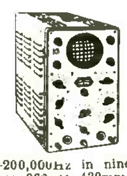
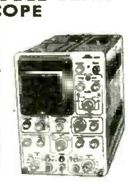


For display of pulsed and periodic waveforms in electronic circuits. VERT. AMP. Bandwidth 10MHz. Sensitivity at 100KHz VRMS/mm. .1-25; HOR. AMP. Bandwidth 500KHz. Sensitivity at 100KHz, V RMS/mm. .3-25; Preset triggered sweep 1-3,000µsec.; free running 20-200,000Hz in nine ranges. Calibrator pips. 220 × 360 × 430mm. 115-230V. A.C. operation. £39·00. Carr. paid.

TO-3 PORTABLE OSCILLOSCOPE 3in. TUBE

Y amp. Sensitivity. ·1v p-p/CM. Bandwidth 1.5 cps —1.5 MHZ. Input imp. 2 meg Ω. 25 PF. X amp sensitivity. ·9v p-p/CM. bandwidth 1.5 cps—800 KHZ. Input imp. 2 meg Ω 20 PF. Time base. 5 ranges 10 cps—300 KHZ. Synchronization. Internal/external. Illuminated scale. 140 × 215 × 330 mm. Weight 15½lbs. 220/240 V. A.C. Supplied brand new with handbook **£47·50.** Carr. 50p.

RUSSIAN CI-16 DOUBLE BEAM OSCILLOSCOPE



5 mc/s Pass Band. Separate Y1 and Y2 amplifiers. Rectangular 5in. × 4in. C.R.T. Calibrated triggered sweep from ·2 µ/sec. to 100 milli-sec. per cm. Free running time base 50 c/s-1 mc/s. Built-in time base calibrator and amplitude calibrator. Supplied complete with all accessories and instruction manual. **£87** Carr. paid.

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Frequency range: 0–200KHz. Attenuator: 0-111db., 0·1db. step. Impedance 600 ohms. Max. input power 30dbm. Size 180 × 90 × 55mm. £12·50. Post 37p.

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All transistorised compact, fully portable. AF sine wave 18Hz. to 220KHz. AF square wave 18Hz. to 100KHz. Output sine/square 10v. P-P. RF 100KHz. to 200 MHz. Output 1v. maximum. Operation 220/240V. A.C. Complete with instructions and leads. **£29·95.** Post 50p.

TE-20 D RF SIGNAL GENERATOR

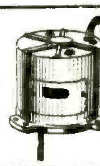
Accurate wide range signal generator covering 120 Kc/s-500 Mc/s on 6 bands. Directly calibrated Variable R.F. attenuator, audio output. Xtal socket for calibration. 220/240V. A.C. Brand new with instructions. Size 140 × 215 × 170 mm. **£17·50.** Carr. 37p.

TE22 SINE SQUARE WAVE AUDIO GENERATORS

Sine: 20 cps to 200 kc/s. on 4 bands. Square 20 cps to 30 kc/s.

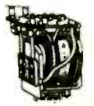
Output impedance 5,000 ohms, 200/250 v. A.C. operation. Supplied brand new and guaranteed with instruction manual and leads. **£17·50.** Carr. 37p.

230v/240v SMITHS SYNCHRONOUS GEARED MOTORS



Built-in gearbox. All brand new and boxed. 30 RPH CW; 2 RPH CW; 20 RPH CW; 2 RPH ACW; 30 RRH CW. **50p** each. Post 12p.

230 VOLT A.C. 50 c/s RELAYS



Brand new. 3 sets of changeover contacts at 5 amp rating. **50p** each. Post 10p (100 lots **£40**). Quantities available.

MODEL TE-15 GRID DIP METER

Transistorised. Operates as Grid Dip, Oscillator, Absorption Wave Meter and Oscillating Detector Frequency range 440Kc/s–280Mc/s in 6 coils. 500µA Meter. 9V. battery operation. Size 180 × 80 × 40mm. **£15·00.** Post 20p.

"YAMABISHI" VARIABLE VOLTAGE TRANSFORMERS

Excellent quality at low cost. All models—Input 230v. 50/60 c/s. Variable output 0-260v.

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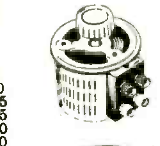

1 Amp ..	£7·00
2·5 Amp ..	£8·05
5 Amp ..	£11·75
8 Amp ..	£15·90
10 Amp ..	£22·50
12 Amp ..	£23·60
20 Amp ..	£49·00
25 Amp ..	£58·00
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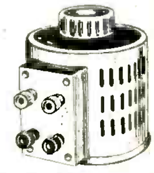
MODEL S-260B



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2250 W	£17·25	P. & P. 50p
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SAVE UP TO 33⅓% OR MORE! GWS

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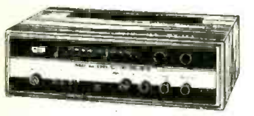

AA6300 AM/FM STEREO TUNER AMPLIFIER

20+20 watts rms. Magnetic, ceramic and tape inputs. FM 88-108 MHz. AM 535-1605 kHz. Dual stereo speaker outputs. Headphone socket. (Rec. List Price £117.46).

OUR PRICE **£61·95** P. & P 75p

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GXC46D Dolby Deck .. £83·55
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GXC65D Dolby Deck .. £92·65
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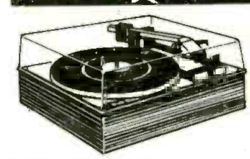

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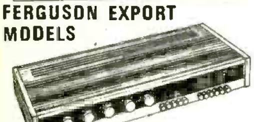

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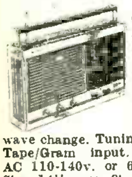
PHILIPS IC361 AM/FM MAINS/PORTABLE RADIO WITH AFC



Covers LW, MW, FM, SW1, SW2 and 49 metre band. Fine tuning of SW and Pre set tuning of three FM stations. Bass, treble and volume/on/off controls. Press button wave change. Tuning/battery indicator. Tape/Gram input. Earpiece socket. AC 110-140v. or 6 × 1.5v. batteries. Size 14¼in. × 9in. × 3¾in. approx. With mains lead and instructions. Rec. List Price £69·18.

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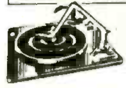

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METERS, 3½" diameter, sealed, 50-0-50 uA/1300R, **£2.25** each. 1 mA/130R, **£1.75** each.

BALL RACES Type RCL ⅛F. Flanged ⅛" bore 5/16" dia. Sealed packs, **25p** each.

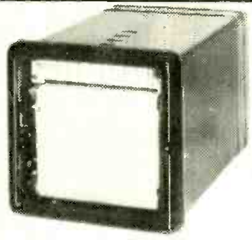
PANEL FUSE HOLDERS with indicator lamp. The cap of these 1¼" fuse holders is provided with an amber lens and min. flanged lampholder to allow a fuse failure neon to be fitted, bulb not included. **20p** each.

MINIATURE THUMBWELL SWITCHES, matt black, BCD and complement, as new, **70p** each.

V.A.T.
PLEASE ADD 10% V.A.T. TO ALL PRICES.

RING BEDFORD 51961 FOR AN APPOINTMENT TO VIEW TEST EQUIPMENT

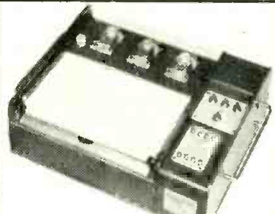
Fantastic value in Test Equipment



10 CHANNEL EVENT RECORDER

Designed for recording sequences of up to ten different operations, e.g. sequence of machine tool operation, switching sequences, etc. Record is presented in the form of square "pulses". When energised, pen moves by approximately 4mm. to the right of zero line. Response time 100 milliseconds. Chart width 110mm. Chart length 50ft. Inv. capacity 72 hours. Chart speeds 20-60-180-600-1800-5400 mm/hour. Size 160x160x255mm. Weight 9 lbs. Price complete with accessories

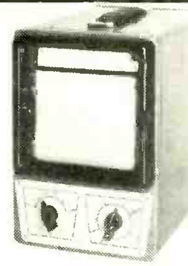
£52.00



THREE CHANNEL HIGH SPEED RECORDER

Strip Chart Recorder. Chart length 175ft. Footage indicator. Width of recording channel 80mm. Chart speeds (selected by pushbuttons) 1.2-12-30-60-120-300-600-3000 mm. per minute. Full deflection current 8mA. Internal impedance 210 ohms. External impedance 800 ohms. Dimensions 510x345x175 mm. Weight 44 lbs. Price complete with accessories

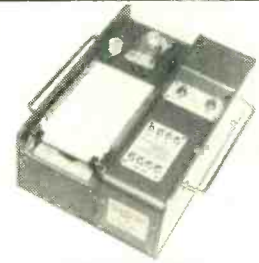
£90.00



PORTABLE AC/DC RECORDING VOLTAMMETER

Fitted with separate zero-marking pen. Accuracy 1.5% DC, 2.5% AC. Measurements ranges — AC and DC: 5-15-150 250-500mA 1.5-5 Amps 5-15-50-150 250-500V. DC only 150mV. Frequency range 45 to 1000 c/s. Chart width 100mm. Chart speeds 20-60-180-600-1800-5400 mm/hour. Weight 22 lbs. Price complete with accessories

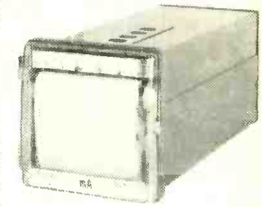
£78.00



SINGLE CHANNEL HIGH SPEED RECORDER

Chart length 175ft. Footage indicator. Width of recording channel 80mm. Chart speeds (selected by push buttons) 1.2-6-12-30-60-120-300-600-3000 mm per minute. Full deflection current 8mA. Internal impedance 210 ohms. External impedance 800 ohms. Dimensions 320x340x175mm. Weight 35 lbs. Price complete with accessories

£55.00



MINIATURE PEN RECORDER

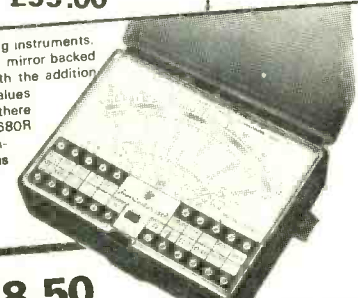
Provides permanent record of DC currents up to 1mA. Eminently suitable for use where space is limited. Separate time marker pen provided. Chart width 80mm. Chart length 40ft. Chart speeds: Slow 20-60-180 mm/hour. Fast 600-1800-5400 mm/hour. Dimensions 120x120x285mm. Weight 7.7 lbs (3.5 Kg). Price complete with accessories

£39.00

Supertester 680R.

Buy it for what it is. Or buy it for what it can be.

The Supertester 680R is a completely new concept in measuring instruments. In itself a high quality test meter with eighty ranges on a 128mm mirror backed scale. It is also the basis of a complete measurement system. With the addition of the appropriate accessories it can measure a wide range of values including light, temperature, gauss and phase sequence. And there are other accessories to greatly extend the 680R's range. The 680R System offers many advantages over conventional test meters including tremendous versatility and economy.



£18.50
Complete with case & probes

SUPER TESTER 680R SPECIFICATION

- Volts AC = 11 ranges from 2V to 2500V.
- Volts DC = 13 ranges from 100mV to 2KV.
- Amp DC = 12 ranges from 50μA to 10A.
- Amp AC = 10 ranges from 200μA to 5A.
- Ohms = 6 ranges from one tenth of Ohm to 100MΩ.
- Reactance = 1 range from 0 to 10MΩ.
- Capacity = 6 ranges from 0 to 500pF and from 0 to 0.5μF and from 0 to 50,000pF.
- Frequency = 2 ranges from 0 to 500Hz and from 0 to 5000Hz.
- Output Voltage = 9 ranges from 10V to 2500V.
- Decibels = 10 ranges from −24 to +70dB.

ACCESSORIES TO CONVERT THE SUPERTESTER 680R TO THE FOLLOWING:

Amperclamp

For measuring a.c. currents from 250mA to 500 amps. **£11.95**

Signal Injector

Producing 1KHz and 500 KHz signals for circuit testing. **£5.95**

Temperature Probe

Covering the range −30 to +200°C. **£11.95**

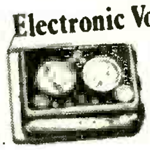
Gauss Meter

For measuring magnetic field strengths. **£11.95**

Phase Sequence Indicator

To indicate the phase sequence of a 3 phase supply. **£5.95.**

Electronic Voltmeter



Input resistance of 11Mohms for d.c. and 1.6Mohms shunted by 10pF for a.c. **£18.00**

Transistor Tester

For transistors and diodes. **£11.00.**

OTHER ACCESSORIES AVAILABLE SHUNTS D.C. 25, 50 and 100 amps. **£4.50** each. **CURRENT TRANSFORMERS** A.C. 25 and 100 amps. **£7.00** each. **E.H.T. PROBE** Extends d.c. voltage to 25,000v **£5.95.**

AC CLAMP VOLTAMMETER

Clamp-on Voltammeter is used for measurements of AC voltages and currents without breaking circuits.

Specification

Measurement ranges:—Current 10-25-100-250-500 Amps. Voltage 300, 600 V. Accuracy 4%. Scale length 60mm. Overall dimensions 283x94x36mm. Weight 1.5 lbs.

£10.50

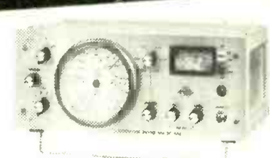
4-RANGE GENERAL PURPOSE TEMPERATURE RECORDER Type 01

Specially designed compact self-contained instrument for recording temperatures up to 500°C. The main design objectives were for an easy-to-use, robust instrument suitable for use in the laboratory and in the field. The four ranges are 10°C, 50°C, 100°C and 500°C. These are selected by push buttons allowing full use of the 3" wide chart. Two chart speeds 1" and 6" per hour are provided by the 240V 50Hz synchronous chart drive.

The 3% basic accuracy of the instrument which is adequate for most applications has been achieved without introducing stability problems in the d.c. amplifier, making the recorder ideal for use in schools, colleges and universities and by unskilled personnel. The recorder is complete with N1Ch/NiA1 thermocouple and mains lead. This product is brand new and manufactured in our own laboratories with three month guarantee.

£95.00

plus £5.00 packing and carriage.



AM-FM GENERATOR Type AF 1065

Permits fast and accurate calibration of modern radio receivers. Suitable for calibration and testing in the laboratory. AM frequency range: from 140 KHz to 46 MHz in 6 ranges expanded range 430-530 KHz. FM frequency range: 9.5-12 MHz; 85-110 MHz. Frequency accuracy: better than 1%. RF output voltage: adjustable from 0.1 μV to 0.1V. Output impedance: 75 Ohm constant. Modulation: AM; FM; AM + FM. Amplitude modulation: 400 Hz from 0-50% adjust. Frequency modulation: 1000 Hz adjust. Deviation from 0 − +/ 50 KHz. External modulation: AM; FM: from 30 Hz to 15 KHz

£225.00

MULTIMETER

0.1-1-10-100-1000mA. 2.5-10-20-250-500-1000V AC/DC. Sensitivity AC and DC all ranges except 10V 10.000 Ohm/V. Dimensions 212x118x75 mm. Weight 2.9 lbs. Price complete with steel carrying case and test leads

£4.95

AC/DC MULTIMETER

With taut band suspension movement. Sensitivity 20.000 ohms per volt on DC and 4.000 ohms per volt on AC.

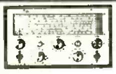
Technical Data:

0.06-0.6-6-60-600mA-3 Amps DC. 0.3-3-30-300mA-3 Amps AC. 0.6-1.2-3-12-30-60-120-600 DC. 1200 Volts. 3-6-15-60-150-1300-600-900 Volts AC. 45 to 20,000 Hz. 500Ω. 5-50-500kΩ resistance. Decibel range −10 to +12dB. Accuracy (% of F.S.D.):—DC and resistance measurements +2.5. Price with test leads, and storage case

£8.00

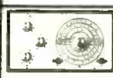
WIDE RANGE TRANSISTOR AUDIO GENERATOR

High stability low frequency generator. Basic circuit is a Wien-Bridge controlled sine wave oscillator and square wave is produced by means of a Schmitt trigger circuit. FREQUENCY RANGES: 4 from 10Hz to 100kHz. OUTPUT VOLTAGE: 1 millivolt p-p to 1 volt p-p ± 3% for sine and square wave. IMPEDANCE: 1K ohm. DISTORTION FACTOR: 0.2% for the sine wave output for the lower frequency range. < 1.0% for the upper frequency range. RISE TIME: < 0.1 microseconds for the square wave and 0.3 microseconds in the upper frequency range. WORKING VOLTAGE: 9 volt. 240mm x 140mmH x 100mmD. 2¼lbs. £27.



WIDE RANGE TRANSISTORISED R.F. SIGNAL GENERATOR

RF carrier can be internally and externally modulated from 0.5% — internal modulation frequency is variable between approximately 800 and 1200 Hz — AF output adjustable for level and frequency. FREQUENCY RANGES: 8 from 147kHz to 220.0 MHz. SCALE ACCURACY: 2% or ± 0.1% when set against internal crystal calibrator. RF OUTPUT VOLTAGE: 50 millivolts minimum on all ranges. AM MODULATION: Internal and external from 0 to 50%. AF OUTPUT: Variable for frequency and level. WORKING VOLTAGE: 9 Volt. 240mmL x 140mmH x 100mmD. 3½lbs. £36.



WIDE RANGE TRANSISTORISED R.F. SIGNAL GENERATOR

A low priced R.F. Generator. 8 ranges, covers from 150kHz to 300MHz. The output can be unmodulated by means of an internal 400Hz oscillator. The A.F. signal is available from a separate output socket. Both output sockets are provided with an isolating capacitor (500 D.C. max) FREQUENCY RANGES: 8 from 150kHz to 300.0MHz. ACCURACY: ± 2% R.F. OUTPUT VOLTAGE: 50 millivolts minimum A.F. OUTPUT VOLTAGE: Approximately 1 Volt at 800Hz WORKING VOLTAGE: 9 Volt. 240mmL x 140mmH x 100mmD. 2¼lbs. £19.50

TRANSISTORISED CAPACITY/RESISTANCE BRIDGE

The measuring ranges of this Capacity Resistance Bridge are 10pF to 100mfd capacity and 10ohms to 10 megohms. Bridge balance is shown by means of a luminescent balance indicator tube. A further switch position permits measurement of capacity leakage current. RESISTANCE RANGES: 3 from 10 ohms to 10 megohms. CAPACITY RANGES: 3 from 10pF to 10mfd. WORKING VOLTAGE: 9 volt. 240mmL x 140mmH x 100mmD. 2¼lbs. £18.50

OSCILLOSCOPE—TYPE 46

A compact general purpose single beam, solid state, DC

Y Amplifier	— 5mHz. 3 db bandwidth D.C. coupled — dc — 5mHz. 100mV — 50V. 9 steps. Maximum input (a.c. coupled) 300Vp Input impedance approx 1MΩ/47pf.
	Sweep speeds ± 5%. 4 ranges 10mSec/cm to 10Sec/cm
Trigger/Sync.	Automatic operation.
X Amplifier	3db bandwidth D.C. — 1mHz Input impedance approx 2.5 kΩ 220-240v 50-60Hz. Width 24cm. Depth 19cm. /lbs £59.65.

Also available: Function Gen. 0 1Hz ÷ 1mHz, frequency counter 5Hz ÷ 9.999mHz. Ask for more details.

ALL EQUIPMENT BRAND NEW AND GUARANTEED FOR 6 MONTHS

ADD 10% VAT TO ALL PRICES ● PROMPT DESPATCH MAIL ORDER

CALLERS WELCOME MON-FRI 9 A.M. to 5-30 P.M. SAT 9-30 A.M. to 2 P.M.

Add £2 towards the cost of packing and carriage on all items for U.K. delivery (except where packing and carriage are already indicated).

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WW—074 FOR FURTHER DETAILS

UNIQUE OPPORTUNITIES

GENERATORS

MARCONI TF867 STANDARD SIGNAL GENERATOR

Carrier Frequency. Range: 15Kc/s-30Mc/s in 11 bands. Calibration Accuracy: ± 1%. Stability: After warm up the drift in a 10-minute period is. typically, less than 0·005% for carrier frequencies up to 3·2Mc/s and less than 0·01% from 3·2-2·30Mc/s. Output Voltage: 0·4µV-4V. Impedance: 75 ohms nominal for outputs from 2-4 v. 75 ohms for outputs from 4µV-2V. 13 ohms for outputs from 0·4µV-0·4V.

Accuracy: below 3Mc/s ±0·25dB ot ±0·1µV. 3-10Mc/s ±0·5dB or 00·2µV. 10-30Mc/s ±1·0dB or ±0·5µV.
Power Supply: 100-125V, 200-250V 40-100c/s. Dimensions: 18 in. high × 21 in. wide × 14½ in. deep. **Price £165·00**

DOUBLE PULSE GENERATOR TYPE TF 1400/S

10 c/s-100 Kc/s. Complete with TM 6600. Pulse adjustable between 1·5 µsec. before and up to 3,000 µsec. **PRICE £145·00**

MARCONI A.M. SIGNAL GENERATOR TYPE TF801D

10-485Mc/s in five ranges. Output 0·1µV-1 Volt E.M.F. External Sine A.D. Frequency 30c/s-50Kc/s. **PRICE £195**

PHILIPS SQUARE WAVE GENERATOR MODEL GM2314

Range 15 c/s-200 Kc/s. Duration of square wave pulses between 0·75 µsec and 40 m/sec. Square wave voltage 10V **PRICE £75·00**

AMPLITUDE MODULATOR TF1102

100Kc/s-300Mc/s Sine-wave from 20 c/s-15 Kc/s and 20 x/s-500Mc/s **£35.00**

MARCONI Type TF987/1 NOISE GENERATOR

1-200 Mc/s ± 0·5DB **£20·00**

MARCONI TF2092 NOISE GENERATOR

£295·00

MARCONI VHF SIGNAL GENERATOR TF 1145

450-1900 Mc/s **£295·00**

PHILIPS VIDEO GENERATOR GM2887

£95·00

WAYNE-KERR VIDEO NOISE GENERATOR

£75·00

MARCONI H.F. CIRCUIT MAGNIFICATION METER TF886A

A direct reading Q Meter 15-170 Mc/s Magnification 60-7200 Q **£45·00**

MARCONI DISTORTION FACTOR METER TF142F

100 c/s-8 Kc/s 0·05%-50% Measures all spurious components up to 30Kc/s **£35·00**

MARCONI PULSE GENERATOR TF67SE

Repetition Frequency 50c/s-50Kc/s 0·15-40µSec **£35·00**

MARCONI WIDE RANGE R.C. OSCILLATOR TF130

Sine-waves 10c/s-Mc/s, square waves 10c/s-100Kc/s Directo outputs up to 31·6V. Attenuator with three impedances. **£120·00**

HETRODYNE UNIT TF1221

2Kc/s-100Mc/s **£45·00**

WAYNE-KERR NOISE GENERATOR CT410

A portable instrument for measuring the noise factor of radio receiving equipment, metric radar receivers, and radar wide-band i.f. amplifiers in the band 15KHz-160MHz. **£75·00**

MARCONI TYPE TF801A SIGNAL GENERATOR

Frequency range: 10HMz to 310MHz. O/P voltage: 0-100 db relative to 200 mV into 75ohm IV CW O/P available. Internal modulation: 400Hz, 1kHz and 5kHz to 80% sine or square. **£45·00**

ADVANCE TYPE D1/D SIGNAL GENERATOR

Frequency range: 10MHz-300MHz. O/P voltage: 1V-10mV. **£25·00**

KENT CHROMALOG 1 DIGITAL INTEGRATOR

For use with gas chromatography apparatus or anything with an output expressed as a varying direct voltage. Automatic print out and 0-10mA O/P to drive recorder. Offered in excellent condition. 3 months warranty and copy of handbook. Price £150. Carriage extra.

MINITRON

K.G.M. Type 3015F 7 Segment display showing figures 0-9 plus decimal point. Character of 9mm height. In 16 DIL case.

NEW LOW PRICE £1·40

SN7447N BCD Decoder Driver **£1·00**

MUTUAL INDUCTANCE BOX TYPE R.7005

Specification Range: 0-11.100 mH. in 0.002 mH. divisions. Accuracy: ±(0.3 × 0.012M/ where M=value of mutual inductance in mH. set on the box. Frequency range: 0-2.5 Kc/s for all decades except X1=0-15 Kc/s. Maximum current: 0.5A for decades 1A for variometer (both primary and secondary wingings). Case: Polished teak. List price £65. Our price **£9·50.**

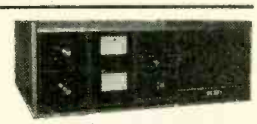
SINE COSINE POTENTIOMETER 47K

Precision component by Pye. Model 2002. Manufactured to rigid Ministry specification. The assembly consists of three units mounted in one frame. Each unit contains two sine and two coside potentiometer sections, the sliders being ganged together. Electrical connections, 2 end taps, slider and centre tap. Mechanical I/P: 30 r.p.m. Max. torque: 3½ oz./in. Dimensions: W. 6½ in. H. 5 in. D. 7½ in. Wt. 7½ lbs. Ex equipment. Good condition. Price £5. Carriage extra.

ROHDE & SCHWARZ Zg DIAGRAPHS HF IMPEDANCE PLOTTER

These instruments will rapidly plot the loci of the impedance or admittance of any item such as antennas, transformers, absorbers, filters and other networks. Impedance measurements are possible from 0·02Z, to 50Z, where Z°=50, 60 or 75 ohm.
Type ZDD 300—2400MHz. **Price £390.**

INFRA-RED SPECTROPHOTOMETER



Beckman Type IR-102

A single beam instrument designed primarily to analyse the effluent from a gas chromatograph, however the fast response and fast scan capabilities make it suitable for fast reaction studies involving conventional gas, liquid, or solid samples. The wave length range is 2·5 to 14·5 microns. In excellent condition. **Price £175·00**

TRANSISTROL TEMPERATURE CONTROLLER TYPE 990

Completely transistorised self-contained direct deflecting units for indicating and controlling temperature accurately over a wide range. Suitable where a signal can be converted into d.c. Sensitivity 10 ohms per MV. Minimum F.S.D. 8 MV. Cold junction compensation. Calibrated scale length 6·5", 0-800°C. Accuracy +/−1%. Front panel size 10" x 8½", weight 11 lbs. Mains supply 100-260 V. Control switching and thermo-couple connections all at back of case. Price £18·50 plus £2·00 packing and carriage.

ASCOP DIGITAL ENCODERS

Type 504A-8-001 **Price £20.** Type EDD8G **Price £20.**

SYNCHROVERTER SWITCH TYPE G1280 BY ELLIOTT

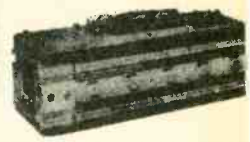
PRICE £3.

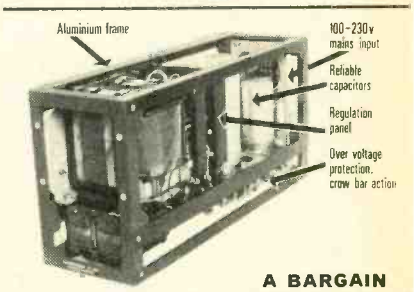
POWER SUPPLIES

POWER SUPPLIES, IBM EX-COMPUTE[R] HIGHLY STABILISED, TRANSISTORISE[D] LOW VOLTAGE POWER SUPPLIES.

These modular units incorporate overload protection on bo[th] INPUT and OUTPUT. Load regulation of 1% or better. Lo[w] ripple and fast response time. Input voltage 120-130 50 H[z]. Available in the following types:

6 volt	8 Amp	£21.00
8 Volt	12 Amp	£17·00
6 Volt	16 Amp	£20·00
12 Volt	4 Amp	£20·00
12 Volt	12 Amp	£22·00
12 Volt	20 Amp	£24·00
30 Volt	7 Amp	£19·00





A BARGAIN IN NEW POWER SUPPLIES AT LESS THAN HALF MANUFACTURERS PRICES.

O/P Voltage 7·5V-9V. Max. load current 10 Amps. Ma[x] ripple on full load approx. 60mV. p.p. Threshold curre[nt] 10·5A. Overvolt protection. **OUR PRICE £12·5**

EX COMPUTER HIGH GRADE FULLY STABILISED POWER SUPPLIES

Input 200/250V.

ADVANCE TYPE DC 207	20 Volts 9 Amps. 10 Volts 5 Amps. 10 Volts 3 Amps. 20 Volts 2 Amps.
ADVANCE TYPE DC 200	20 Volts 13 Amps. 10 Volts 5 Amps. 20 Volts 2·5 Amps.
ADVANCE TYPE DC 202	35 Volts 9 Amps. 24 Volts 4 Amps. 10 Volts 8 Amps.
ADVANCE TYPE DC 197	6 Volts 7·5 Amps. 6 Volts 11 Amps. 28 Volts 9 Amps.
WESTINGHOUSE Fully Fused Input 200/220/240/10	14 Volts 0·75 Amp[s]. 20 Volts 4 Amps. 25 Volts 2·5 Amps. 30 Volts 0·75 Amps
WESTINGHOUSE	6 Volts 7·5 Amps. 6 Volts 11 Amps. 28 Volts 9 Amps.

£18 EACH. P. & P. £2.

EVERSHED SAFETY OHMETER

for testing the continuity and resistance of circuits, consist[s] of a hand-driven generator and a direct reading ohmmete[r]. Range in ohms 0-4, 0-5, 0-10, 0-100, 0-300. £1

IGNITION TESTER

Ideal for garages, this brand new instrument is used to displa[y] all ignition faults. Supplied complete with instruction manua[l] showing photographs of displays, making use very simple. Sold complete with isolating transfer for use on 240V 50H[z] supply. Display cards also available for garages and othe[r] places wishing to advertise this equipment is in use. Made b[y] British Physical Laboratories Ltd., originally for use on th[e] Canadian market. **Price £7**

AVOMETERS

Model	Price	Model	Price
D	£14	40	£16
7	£19·50	47A	£16
8	£29·50	48A	£16
8X	£35		

NB. 47A and 48A are Admiralty versions of Model 40, th[e] only difference being that the resistance ranges 0-1·2, 0-1 ohms, which are available on the Model 40 with the use of a[n] external power supply are not available on the 47A and 48A.
CASES AND LEADS EXTRA

PHILIPS VALVE VOLTMETER

MODEL GM6014

Max. 300mV, 1000Hz-30MHz. **PRICE £30·00**

ADD 10% VAT TO ALL PRICES

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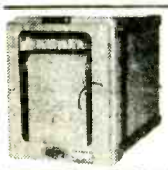
to purchase some of the World's finest calibration instruments at savings of 33⅓% AND MORE!

PEN RECORDERS

BRAND NEW MINIATURISED STRIP CHART RECORDER BY RUSTRAK

of America. This Recorder indicates the magnitude of applied currents or voltages by a continuous distortion-free line on pressure sensitive paper. Moving coil movement, scale calibrated 0-1 milliamp d.c. internal resistance 100 ohms. Chart drive motor 240 V 50Hz. Chart speed 1" per hour. Complete with handbook. Price £35·00 plus £5·00 packing and carriage.



SINGLE PEN RECORDER

by Record Electrical. 3" chart, sensitivity 1 milliamp, chart speed 1" and 6" per hour. Size 8" x 11" x 6". Offered complete with pen assembly and spare chart. Listed at over £100—this month's special price due to bulk purchase . . . £39·50 plus £5·00 packing and carriage.

A.E.I. POTENTIOMETRIC RECORDER

0-2·5 MV, 5, 7·5, 10, 15 MV. Chart speed 1 rpm-3 rpm DR 1 rph-3 rph. **PRICE £45·00**

FOSTER CHART RECORDER TYPE 3671 RY-6

Sensitivity 0-20 MV, —50 MV, 100 MV. Chart speed 1·5 cm/hr-6 cm/hr. **PRICE £35·00**

DUPLEX RECORD 2 PEN RECORDER

30 day clockwork —50/0/50 m/A **PRICE £55·00**

DUPLEX RECORD 3 CHANNEL PEN RECORDER

0-10 M/A. Speed 1" per hour. **PRICE £95·00**

HONEYWELL ELECTRONIC POTENTIOMETRIC RECORDER

The following types are available:
1. Model Y15301115-01-01-0-(150)-01-022-202. Range 600-1300°C.R. **PRICE £95·00.**
2. Model Y153X18-/VAH/-11-111-118-/P8/DN2 Range 0-20 MV. **PRICE £95·00**

LEEDS & NORTHRUP STRIP CHART RECORDER

This well-known instrument is fitted with a Series 60 control unit servo amplifier 101041 BR EQ. Range: 5·571 to 18·855. Ref. Junction 320F. Primary element: P1. P1. 13% RH JMC. Response time: 5 secs. for f.s.d. Chart width: 7 in. Chart speed: 1 in. per hour. Power supply: 120V 50 Hz (auto-transformer available). Dimensions: Ht. 18", width 11", depth 12¼". Weight 51 lbs. **PRICE £80·00**

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ELLIOTT SINGLE PEN RECORDER

TYPE 230

A most versatile pen recorder producing a trace on a curvi-linear 3 in. strip chart. Two synchronous speeds: 1 in. and 6 in. per hour.

Fitted with high and low alarm contacts operated by the moving coil. Basic movement 0·1mA DC coil resistance 400 ohms. Fitted with rectifier to allow operation on AC effective coil impedance at 50Hz 1800 ohms.

Power supply required: 230V 50Hz.

Applications: Ideal for recording relatively slow changing pehenomena such as:

Temperature: Gas or liquid Flow Rates. Sound Levels. Speed variations. Power Demand. Rainfall, humidity, etc. **PRICE £25·00**

Clockwork version also available.

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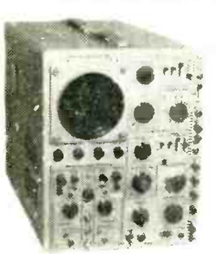

TEKTRONIX 545. With delay time base £295

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1Y2 7100 1X2 Oscilloscope, D al channel with sweep delay, suitab for computer maintenance and most laboratory applications 30MHz, 1mV 10ys to 5s delay.
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HEWLETT PACKARD 185B

Sampling Oscilloscope DC-IGC. Complete with 187C Dual Trace Amplifier. Has a 350 p.sec. rise time (1000MC) £39

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	CDU120	DC-50MHz.	£27.
DYNAMCO	7100	Main Frame. DC-30HMz.	
	7200	Main Frame. 3Hz-15MHz. Batt./Mains.	
EMI	101	DC-15MHz. 50mV/cm. Batt/Mains. Single Trace.	
HEWLETT PACKARD	175A	Main Frame. DC-50MHz.	£360
	180A	Main Frame. DC-100MHz. Net Wt. 11·6 kg.	
	181A	Main Frame. Vari-Persistence, 0·2-1hr. Storage.	

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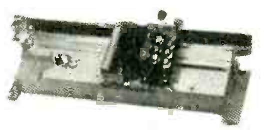

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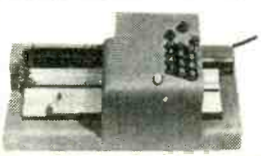

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Carriage extra.

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50 KVA to 60 Hz power frequency converter. Fully overhauled.
Specification:

Prime Mover:	Electric Motor
Input:	220/380V 50Hz 3ph
Output:	220V 60Hz 3ph

at 50 KVA with PF of 0·8. **PRICE £450·00**

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HEWLETT PACKARD SAMPLING OSCILLOSCOPE MODEL 185B

Including 187C. DC—100 Meg Hz. **PRICE £395·00**

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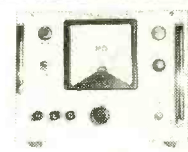

Range from 0·3-20,000 Megohms in 4 ranges at 500V. Used for the measurement of components or circuits having high parallel capacitance. **PRICE £20·00**

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These machines, originally ex-computer, are multi-track recording units. Ideal for data storage. Record and Replay Heads encased in one common unit. Low resistance heads. Frequency response approximately 0 Kc/s to 50 Kc/s. Bit density 557 b.p.i. ½ in., 10½ in. spools, 230 V to 380 V. Capstan motor speed 1,500 r.p.m. 48 V DC rewind motors complete with vacuum assembly. Finished in brush aluminium and matt black. Size 27 in.×26 in.×8 in. Weight 90 lbs. Price £72·50.

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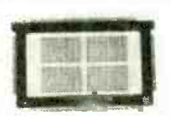

Ferrite core memory planes with wired Ferrite cores. Used for building your own computer or as an interesting exhibit in the demonstration of a computer. Mounted on plastic material frame 5 in.×8 in. Consisting of matrices 40×52×4 cores, each one individually addressable, and divided into 2 halves with independent sense and inhibit wires. **Price £2·50.**

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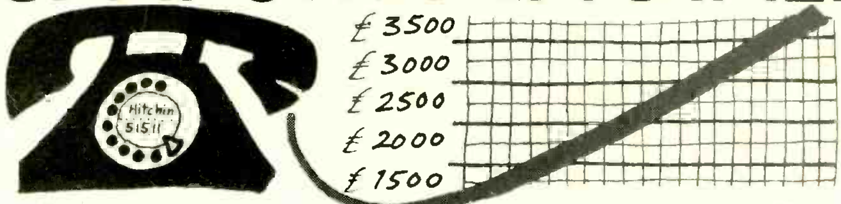

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W. J. C. Foster, Personnel Manager,
Rendel, Palmer & Tritton
Southwark Bridge House,
61 Southwark Street, London SE1 1SA.

[2828

LONDON BOROUGH OF HILLINGDON

VISUAL AND AURAL AIDS TECHNICIAN

suitably qualified and experienced required to assist in the day to day maintenance and repair of visual and aural aids equipment in emerging comprehensive schools. Salary £1,635-£1,908 p.a. incl. L.W. Current clean driving licence essential.

Application forms from the Personnel Officer, Ref. E/186/65, Belmont House, 38 Market Square, Uxbridge UB8 1TR. Tel. Uxbridge 38290 Ext. 294. Closing date 27 July.

[2866

COMMUNICATIONS

Overseas

Openings exist for qualified Engineers and Technicians

TAX FREE

SALARIES

* In excess of **£5,200** p.a. for Engineers
* In excess of **£4,000** p.a. for Technicians
* In excess of **£3,600** p.a. for Junior Technicians

PLUS

Terminal gratuity of **£2,000** after 30 months

PLUS

* Free Housing
* Free Vacation Travel
* Liberal Holidays
* Leave every 6 months

Lockheed Aircraft International and International Aeradio Limited are operating a large Electronic programme in the Gulf Area and need the following qualified personnel. All appointments will be on bachelor status for periods of 30 months.

TELECOMMUNICATIONS ENGINEERS

Experienced in all aspects of the engineering and maintenance of high-power point-to-point communications systems. Experience must include troposcatter systems, multiplexing techniques, and familiarity with high-capacity multi-channel data transmission. A degree is desirable but extensive experience is acceptable.

GROUND RADIO TECHNICIANS

Communication Technicians responsible for the maintenance of HF point-to-point and communications networks using multiplex techniques in the SHF, UHF and VHF bands.

RADIO RELAY TECHNICIANS

Personnel required to maintain Radio Relay stations employing Voice and Data Communication links. They should be experienced in the operation/maintenance of troposcatter and microwave high-capacity multichannel systems.

TELEGRAPH EQUIPMENT TECHNICIANS

Experienced in the maintenance of teleprinter equipment, tape perforators, page printers and the associated ancillaries, and have some knowledge of the maintenance of small telephone exchanges and subscribers' equipment.

Ring in or write for an application form to: **The Recruitment Officer (W), International Aeradio Ltd., Aeradio House, Southall, Middx.**

01-571 1808

28

INTERNATIONAL AERADIO LTD-LOCKHEED AIRCRAFT INTERNATIONAL

RADIO OFFICERS would you come ashore for £2,300 a year?

As a Radio Operator with the Post Office Maritime Service you can continue your career ashore in an interesting and expanding service. And earn over £2,000 a year, including compulsory pension contributions, at 25 years of age working only a 41-hour week of shift duties —with overtime this could rise to £2,300 and possibly more.

Post Office Radio Operators benefit from a shorter pay scale than sea-going officers. You have good opportunities for promotion to positions earning basic salaries of up to £3,290, and prospects of further advancement into Post Office Senior Management.

To apply you need to be 21 or over and to hold a 1st class or General Certificate issued by the MPT or an equivalent certificate issued by a Commonwealth administration or the Irish Republic.

If you would like to know more, please write to the Inspector of Wireless Telegraphy, Post Office, IMTR/WTS1.1.3, Union House, St. Martin's-le-Grand, London EC1A 1AR. L50

Post Office
Telecommunications

91

SUMLOCK COMPTOMETER LTD.

ANITA

ELECTRONIC DESK CALCULATORS
PROGRAMMABLE CALCULATORS
VISIBLE RECORD COMPUTORS
PERIPHERALS

There are vacancies in our Field Service Organisation for Engineers to service the above range of equipment installed in London and the Home Counties.

Applications are invited from:–

- **Electronic Engineers qualified to Intermediate City & Guilds Certificate or equivalent standard and**
- **Electro/Mechanical Engineers experienced in Triumph/Adler and/or IBM input/output typewriters, readers and punches.**

Excellent training facilities and first class conditions of employment.
For further information please contact:–

Administration Manager,
Sumlock Comptometer Ltd.,
Anita House,
Rockingham Road,
Uxbridge,
Middlesex.
Tel: 89-51522

Lamson Industries Group

CHIEF INSPECTOR

Thorn Consumer Electronics (Chigwell) Limited is the Audio division of the Thorn Group of Companies and in order to satisfy the continuing increase in demand for our products, both at home and abroad, it has become necessary to undertake an expansion programme. A new audio factory has been established at Harold Hill in Essex, which will ultimately be the largest manufacturing unit of its kind in Europe using sophisticated production techniques.

An exceptional opportunity occurs for a suitably qualified man to join the new organisation, which will be involved in quantity volume production of high wattage unit audio equipment, as Chief Inspector.

The job will be concerned with all aspects of the inspection, test and troubleshoot functions associated with the flowline production of the units. In addition, close liaison, with the Training Department in forward planning and training requirements will be necessary.

The successful candidate will hold suitable electronics qualifications, have experience of high volume production methods, be a capable staff motivator and will possess the drive and enthusiasm which the job will demand.

Written applications, setting out brief career details to date and current salary to:

The Personnel Manager,
Thorn Consumer Electronics,
62/70 Fowler Road,
Hainault,
Ilford,
Essex.

THORN A member of the Thorn Group

2879

Test and Quality Engineers

For our award-winning computerised X-ray equipment

The 1972 MacRobert Award of £25,000 for an outstanding contribution by way of innovation and technological achievement was won by a scientist at EMI for his invention of new X-Ray techniques applied to brain scanning equipment.

The World-Wide demand for this successful equipment – the EMI Scanner – has produced an urgent requirement for experienced TEST ENGINEERING STAFF to set-up and test our production equipments from the printed circuit board stage through to overall system testing, working to exacting specifications.

Candidates should have a good working knowledge of digital and analogue techniques and should hold HNC Electronics (minimum) or equivalent.

The positions offer the opportunity to become part of a team involved in an exciting product which is a world leader in its field.

Salaries will be between £1,700 and £2,350 commensurate with experience and ability.

Please write or telephone for an application form from: **R.N.L. Black, Personnel Department, EMI Limited, 135, Blyth Road, Hayes, Middlesex.**
Tel: 01-573 3888 Ext. 2887.

EMI

International leaders in Electronics, Records and Entertainment.

SPANISH FIRM NEAR MADRID

is looking for design and development engineers with a minimum of three years of experience in the field of P.C.M. equipment to be used by the telephone industry.
Areas of interest are encoders and decoders, P.C.M. multiplexers and R.F. equipment to transmit P.C.M. data.
Salary open.

Send résumé to:
NORTRON
Fernando el Católico, 63
Madrid 15
SPAIN

2584

Computer Commissioning Engineers

Resulting from our expansion programme, our Quality Control Department have vacancies in Letchworth and Stevenage factories for Engineers to commission and test computer equipments before delivery to the customer.

We offer attractive conditions and salaries to applicants who should have practical experience in fault finding and testing of complex electronic equipment. Whilst qualifications to ONC standard are desirable they are not essential.

Housing may be available for applicants living in the Greater London Council's area.

Write for an application form, quoting reference WW/41/2/M to Area Personnel Recruitment Officer, ICL House, Broadway, Letchworth, Herts SG6 3PG.

International Computers ICL

In-House Sales Engineers

Racal Communications Limited, the world leader in the manufacture of HF radio communication capital equipment and systems, wish to engage two In-House Sales Engineers to assist in the preparation of system tenders and proposals, and also to prepare quotations.

Applicants should have previous HF communications commercial experience OR a relevant technical background in the Armed Forces and preferably have obtained HNC or City and Guilds (Radio/Telecomms) qualifications.

The Company offer a competitive salary, pension and free life assurance scheme, and over four weeks holiday each year.

Communicate with Racal

Please apply in writing to:
Mr. A. J. Franklin, Personnel Manager,
Racal Communications Limited,
Western Road, BRACKNELL, Berks.

RACAL
The Electronics Group

ENGINEER

DESIGN AND DEVELOPMENT

for transistorised converters etc.

Small company South Coast
Commencing £2,500 advancing managerial 2-3 years, with board appointment.
Qualifications and and experience to

BOX No WW 2887

Electronic Service

OFFICE MACHINE COMPANY
has the following vacancy:

SENIOR SERVICE ENGINEER

to assist Workshop Manager, must have experience of repairing digital printed circuit boards, preferably electronic calculators, good electronic knowledge and experience in a Service Department. Salary £2,000 plus and L.V.'s.

Apply to:- Mr. V. Knight.
Automatic Business Machines Ltd.,
Wyfold Road, Fulham, S.W.6.
Tel: 385 3311

[2823

Telecommunications Technician

West Midlands Gas makes extensive use of U.H.F. radio, digital techniques and microwave for data trasmissions and telementary.

A vacancy exists for a technician to assist in the commissioning and maintenance of U.H.F., visual display and Modem equipment. Knowledge of modern testing and maintenance procedures and ability to work without direct supervision are necessary.

Initial salary will be in the range £1419-£2055 p.a., with possible progression to Senior Technician in that range £1860-£2337 p.a. on proven ability.

The post is based at Solihull, but also involves travel and work throughout the Region.

Please apply in writing, quoting reference number WWA488, **to the Senior Personnel Officer (Headquarters), West Midlands Gas, Wharf Lane, Solihull, Warwickshire, B91 2JP.**

WEST MIDLANDS GAS

Leicestershire
LOUGHBOROUGH TECHNICAL COLLEGE
Principal: F. Lester, BSc. PhD. FRIC

Department of Electrical Engineering

Lecturer Grade I

The person appointed will be required to teach Radio and Television Theory and Practic to Final Certificate level in Technicians' courses. Applicants should have recent trade-experience and be fully conversant with broadcast receiving equipment. They should be suitably qualified and preferably be members of a Professional or Technician Institution. Teaching experience and teacher training will be advantageous.

Salary will be in accordance with Scales for Teachers in Establishments for Further Education 1972 (under review), viz., Lecturer Grade I, £1,500—£2,525; Assistant Lecturer, £1,160—£2,242 (plus 2 × £81 for good Honours in both cases), with placing according to qualifications and experience.

Further particulars may be obtained from the Principal, Loughborough Technical College, Radmoor, Loughborough, Leicestershire, LE11 3BT, to whom completed applications should be returned within 14 days of the appearance of this advertisement.

[2834

MEDICAL ELECTRONICS ENGINEER

required for development of electro-medical equipment. The successful applicant will have had previous experience in the hospital equipment field either within the N.H.S. or medical industry and will be able to work without supervision.

Apply in writing to:

Mr. D. E. OLIVER,
Technical Director,
Electro-Medical Supplies
(Greenham) Ltd.,
Wantage, Berkshire

[2888

The University of Leeds
DEPARTMENT OF PHYSIOLOGY
CARDIOVASCULAR UNIT

Applications are invited for the post of **EXPERIMENTAL OFFICER** in Electronics. A degree or HNC is required. Responsibilities include PDP12 and PDP8 computers, electronic equipment in three physiological laboratories and three hospital catheter laboratories, and the supervision of four electronics technicians. Salary scale £1,413-£2,046. Preliminary enquiries may be made to the Director of the Cardiovascular Unit, Department of Physiology, The University, Leeds, LS2 9TJ.

Forms of application and further particulars from **the Registrar, The University, Leeds, LS2 9JT** (please quote 43/11/CI).
Closing date, 31 July, 1973.

[2595

G. R. INTERNATIONAL ELECTRONICS LTD.

have a challenging position for an

ELECTRONIC DEVELOPMENT AND DESIGN ENGINEER

Applicants should have had extensive experience in the fields of design and manufacture. We have a senior position for someone capable of making a significant contribution in the creation and design of audio consumer products.

The successful applicant will receive some assistance with costs of relocation and local government housing may also be available. The Company is situated in one of the nicest parts of Scotland, with educational, sporting, and social amenities of the highest order in the immediate environment.

Please write in first instance to:
THE PERSONNEL MANAGER,
G.R. INTERNATIONAL ELECTRONICS LTD.,
CRIEFF ROAD, PERTH
or telephone Perth 27272
for further information.

[2872

Senior Television Technician

Chessington

Rediffusion are looking for a Senior Technician to join their Chessington laboratories. You will be responsible for

- Television Signal Generation Equipment
- H.F. Cable Distribution System
- V.H.F. and U.H.F. Generation and Distribution System
- Production Test Equipment for colour receivers
- High quality laboratory equipment and instrumentation

This is an ideal opportunity for a suitably qualified and experienced Technician, who is anxious to demonstrate his potential as part of a very important team. You can reasonably look forward to taking responsibility for this section, over the next two years.

Please apply in writing, quoting reference EW, to:— H. Brearley, Esq., Head of Technical Services, Rediffusion Vision Limited, Fullers Way South, Chessington KT9 1HJ, Surrey.

REDIFFUSION

WAKEFIELD HOSPITAL MANAGEMENT COMMITTEE

Electronics Technician

(Technician II Grade)

A vacancy exists, on the staff of the Group Engineer, for a qualified and experienced Electronics Technician (new post) to take charge of a Group Department maintaining a wide range of electronic and light current electrical equipment.

The successful applicant will require, in addition to technical ability, the administrative qualities necessary to develop, in conjunction with engineering staff, maintenance policies and procedures for a wide range of medical and non-medical equipment used within this Group of 10 Hospitals.

Qualifications required are H.N.C. in Electronics or City and Guilds Final Certificate in Telecommunications or an approved equivalent. Previous Health Service experience would be advantageous.

Salary Scale £1,911 to £2,508 per annum.

Application forms can be obtained from the Group Secretary, Pinderfields General Hospital, Aberford Road, Wakefield, to whom they should be returned not later than 23rd July, 1973.

[2596

Research Fellowships

for a fixed period of 3 years, are available at the Royal Military College of Science, Shrivenham, Wiltshire, as follows:

Electrical Engineering
Investigation of the physical limitations of electrical machines (e.g. power and speed) and the way in which these limitations may be overcome by use of semi-conductor devices.

Electronic Engineering
Work on (a) active and passive antenna synthesis and design or (b) signal processing, speech coding, and feedback communication or computer simulation of communication system performance.

Appointment will be as Senior Research Fellow (£2460-£3100) or Junior Research Fellow (£1670-£2195) according to qualifications and experience. Accommodation in a Hall of Residence is available for a single male staff.

Candidates must have a 1st or 2nd class honours degree, or an equivalent qualification, in an appropriate subject and at least 2 years' postgraduate research experience (3 years' for a Senior Fellowship)

For an application form (to be returned by 3 August 1973) contact the Registrar, Royal Military College of Science, Shrivenham, Wiltshire, telephone Shrivenham 782551. Please quote SC/1/EP/6.

PROCUREMENT EXECUTIVE, MINISTRY OF DEFENCE 2855

Slough College of Technology
Department of Engineering

Applicants are invited for the post of:

Lecturer I in Radio and T.V. Servicing
(E/1/5)

Required to teach radio, television and electronic servicing in Radio, T.V. and Electronics Mechanics and Technician Courses.

Applicants should hold CGLI Radio & T.V. Servicing Certificate and have had good industrial experience. Teaching experience desirable but not essential.

Salary on Burnham Technical Scale, viz. £1,500 — £2,525 plus additions for qualifications and training. Removal expenses up to £115 may be paid in approved cases.

Further particulars and application forms obtainable from the Vice Principal, Slough College of Technology, Wellington Street, Slough SL1 1YG, Bucks, to whom they should be returned within two weeks of the date of this advertisement. 2843

SCT

THE HATFIELD POLYTECHNIC
Department of Humanities
MALE OR FEMALE

TECHNICIAN

required for light interesting duties in Language Laboratories, for copying and recording tapes and to assist with servicing. Must be capable of working on own initiative. Previous experience desirable but not essential.

Salary £1,143-£1,530 according to age and experience.

Please quote ref: 285/WW.

Application forms from the Staffing Officer P.O. Box 109, Hatfield, Herts AL10 9AB.

[2587

THE QUEEN'S UNIVERSITY OF BELFAST

ELECTRONICS TECHNICIAN

Department of Pure and Applied Physics. Required to undertake design, construction and maintenance of a wide range of electronic measuring and control equipment for a large programme of research in atomic and molecular physics. Candidates should offer H.N.C. or equivalent qualifications, plus 7-9 years relevant experience. The appointment will be from 1st August 1973, or as soon after this date as can be arranged. Salary scale (Grade 5) £1,881-£2,241.

Application forms obtainable from the Personnel Department, The Queen's University of Belfast, University Road, Belfast BT7 1NN should be returned not later than 30th July, 1973.

[2592

WANTED FOR GERMANY

For Electronic Developments in the Video (Slow Scan) and Digital Field. We are looking for an Experienced Engineer who is willing to work in Germany in the vicinity of Bonn. Knowledge of the German language is not essential if the candidate is willing to learn German in an evening school.

Please write to:

Inform GMBH,
534, Bad Honnef,
Linzer Str. 11,
GERMANY.
c/o Mr. TH. Geutebrueck.

[2585

GIPSY HILL COLLEGE

Kenry House, Kingston Hill
Kingston-upon-Thames, Surrey
Telephone: 01-549 1141

CHIEF TECHNICIAN

To head a team in the Educational Aids Department which serves the needs of the whole College.

Good knowledge of electronic equipment, including c.c.t.v. servicing, and relevant qualifications, will be expected.

There is considerable responsibility attached to this key appointment. The salary scale is, at present, £1,908-£2,205 per annum, according to qualifications, plus £105 per annum London Allowance.

Details from the Senior Administrative Officer.

[2877

ELECTRONICS TECHNICIAN

Grades III, IV and V

Salaries as follows:-
- Grade V £1,209 x 7 increments to £1,563
- Grade IV £1,422 x 7 increments to £1,827
- Grade III £1,602 x 8 increments to £2,007

Qualifications:
- A levels for Grade V
- O.N.C. or H.N.C. or Equivalent for Grade IV.
- O.N.C. or H.N.C. or Equivalent for Grade III.

The Electronics Workshop is concerned with the repair and servicing of a wide range of electronic equipment, both medical and industrial. The wide variety makes for a most interesting job. Training is given to all members.

Application forms from the Group Engineer, Southampton University Hospital Management Committee, 121 Tremona Road, Shirley, Southampton. [2847

KING'S COLLEGE HOSPITAL MEDICAL SCHOOL
(University of London)
Denmark Hill, London SE5 8RX

ELECTRONICS EXPERIMENTAL OFFICER

A vacancy exists in the Department of Biomedical Engineering for an Experimental Officer to work as part of a multi-disciplinary team on the development and construction of prototype electronic instruments for use in medical research. Salary will be in the range of £1,401—£2,154 according to age and experience and the appointment will be for two years in the first instance. Candidates should have had adequate experience either in industry or in hospital and will be expected to hold an HNC in electronics or light current electronic engineering as a minimum. Applications to the Director, Department of Biomedical Engineering.

[2850

Senior Design Engineers

Broaden your horizons

Rediffusion is expanding again and needs, for its Design Laboratory at Chessington, Surrey, Senior Engineers to specialise in:

- Television Receiver Design
- Test Equipment Design
- Post Design Services

If you hold an Engineering Degree or H.N.C. and have several years' experience in a relevant discipline, this could be your opportunity to join a professional team in a forward looking Company. Salaries will attractively reflect the contribution you will make to our products. Relocation expenses may be paid where applicable.

If you have appropriate qualifications and wish to work in a stimulating and progressive environment, write to me today, saying which position interests you. H. Brearley, Head of Technical Services, Rediffusion Vision Ltd., Fullers Way South, Chessington, Surrey KT9 1HJ.

REDIFFUSION

BENCH SERVICE ENGINEERS

ASCOT ROAD – BEDFONT
(NEAR LONDON AIRPORT)

We require Bench Service Engineers with previous experience of TV (Monochrome and colour), Radio Hi-Fi and Tape Recorders for our Central Service Division. Preference will be given to holders of City & Guilds qualifications, though sound practical experience may outweigh formal qualifications.

Basic salary will be according to qualifications and experience.

Fringe benefits include a twice yearly bonus, L.V's, contributory pension and Staff Purchase schemes. Hours are 9.00 a.m.–5.30 p.m. Mon. to Fri.

We would be interested to hear from experienced Engineers, who wish to work with products that are renowned for quality and reliability. Please write or call with details of past experience and current salary to:

SONY (U.K.) LTD, Pyrene House, Sunbury Cross, Sunbury on Thames, Middlesex. Tel: Sunbury 87644. 2830

SONY®

TECHNICAL AUTHORS

Senior, Junior and Trainee

1. Vacancies
We are offering long term employment in an exciting, expanding industry where change is the rule rather than the exception.

2. The Job
Development of technical manuals for our customers to meet the requirements of Av P70, ATA 100 or other customer requirements.

3. Man Requirements
A good working knowledge of electronics is required, and the ability to obtain, sift and use information from all sources.

4. The Benefits
Holiday entitlement rises to four weeks after a short length of service. Salaries by negotiation and according to experience. Relocation expenses paid in suitable cases. Nomination for local housing can be made.

5. IF YOU ARE NOT ALREADY AN AUTHOR, AND YOU THINK THAT YOU HAVE POSSIBILITIES, CONTACT US AND SEE IF WE CAN COME TO AN ARRANGEMENT REGARDING SUITABLE TRAINING.

Telephone Crawley 35155 and speak to W. H. Stanbrook, The Technical Publications Manager, or Crawley 22962 in the evening.

2842

REDIFON

Electronics Test Engineers

Pye Telecommunications of Cambridge and Haverhill have immediate vacancies for Production Test Engineers. The work entails checking to an exacting specification VHF/UHF radio-telephone equipment before customer delivery; applicants must therefore have experience of fault finding and testing electronic equipment, preferably communications equipment. Formal qualifications while desirable, are not as important as practical proficiency. Armed service experience of such work would be perfectly acceptable. Pye Telecommunications is the world's largest exporter of radio-telephone equipment and is engaged in a major expansion programme designed to double present turnover during the next five years. There are, therefore, excellent opportunities for promotion within the company. Pye also encourages its staff to take higher technical and professional qualifications.

These are genuine career opportunities in an expansionist company, so write or telephone without delay for an application form to:

Mrs A E Darkin at
Cambridge Works, Elizabeth Way, Cambridge CB4 1DW.
Telephone: Cambridge 51351.
or Mrs C Dawe at
Colne Valley Road, Haverhill, Suffolk.
Telephone: Haverhill 4422.

PYE Pye Telecommunications Ltd

A member of the Pye of Cambridge Group

2802

INSTITUTE OF
OCEANOGRAPHIC SCIENCES
Barry, Glamorgan

ELECTRONICS ENGINEERS

(Professional and Technology Officers Grade IV)

Electronics Engineers with a sound knowledge and practical experience of modern electronic, analogue and digital recording techniques are needed to supplement an existing team engaged on the installation, operation and maintenance of oceanographic instruments in Research Vessels at sea. There will also be a feed-back of operating information and faults to the designers of the equipment. Sea going duty may total up to 4 months in each year. Although specialising in work afloat, successful candidates will also work in the servicing laboratories ashore as members of the base team at Barry, maintaining and modifying the various oceanographic equipment. Initial training will be given on the more specialised sea-borne instrumentation, e.g. Gravity meters and satellite navigation systems. In addition to salaries, overtime is paid when long hours are worked over a period.

Qualifications: O.N.C. or equivalent, plus apprenticeship or equivalent training appropriate to the duties of the post. Candidates will normally be expected to have had at least three years additional experience.

Salary Range: £1,577 (age 21) - £1,976 (age 28 or over) - £2,226. Superannuation arrangements.

Application forms and further particulars from:

Institute of Oceanographic Sciences
Research Vessel Base
No. 1 Dock
Barry, Glamorgan, CF6 6UZ
Tel: Barry (04462) 77451

Closing date: 10 August 1973

NATURAL ENVIRONMENT
RESEARCH COUNCIL [2883

TEST ENGINEERS

The leading U.K. manufacturer of high grade TV monitors require Test Engineers for their expanding Test Department.
Situated in the Berkshire town of Maidenhead, the Company offers pleasant working conditions, good salaries and friendly environment. Duties will cover the testing and trouble-shooting of monochrome and colour TV monitors together with other ancillary sophisticated TV broadcast equipment manufactured by the company. Previous experience of TV equipment would be an advantage. Please apply to:

PROWEST ELECTRONICS
Boyn Valley Road,
Maidenhead, Berks.
Maidenhead 29612

[2889

SUMLOCK COMPTOMETER LTD.

ANITA Electronic Desk Calculators
Programme Calculators
Visible Record Computers
Peripherals

To support an extensive Field Service Operation a Central Technical Service has been established.

There are vacancies for:—

Experienced Electronic Service Engineers

Electro/Mechanical Service Engineers experienced in Triumph/Adler and/or IBM input/output typewriters, readers and punches.

For further information, please contact:

**Mr. D. D. DAVIES,
SUMLOCK COMPTOMETER LTD.,
1 Frogmore Road,
Apsley, Hemel Hempstead, Herts.
Tel.: 0442-61771.**

[2893

Lecturer in Television Servicing

required for September 1973.

Applicants should have Television Servicing Experience and possess R.T.E.B. Finals Certificate or equivalent.

Salary: £1,600-£2,500. Hours: 32 hours, 5 day week with 8 weeks holiday per year.

Applications to:
**PEMBRIDGE COLLEGE OF ELECTRONICS,
34a Hereford Road,
London W2 5AJ.** [2594

Electronics Engineers

We are looking for experienced electronics engineers to meet a challenging forward development programme. The vacancies cover a wide variety of design and development work including:–

Low frequency receivers and transmitters for air and marine navigation.
V.H.F. mandatory air navaids.
Design and application of mini computers for navigation and instrumentation uses.
Logic design.
Digital signal processing
Electronic and electromechanical switching.

Selected applicants will join small teams of engineers, each with its own record of successful design. They will, with other members of the team, be responsible for complete projects from initial conception to customer trials, acceptance and production. In this way, those who have real ability have every opportunity to participate and prove themselves.

Our ideal candidates will be qualified to degree level and have 2 or 3 years' experience of both digital and analogue R & D work. However, we have a number of vacancies and would like to hear from anyone who is interested and has either more, or less, than the preferred level of experience.

Write of telephone for application form to:-

**Mrs. M. E. Wessier
Personnel Officer
The Decca Navigator Co. Ltd.,
247 Burlington Road
NEW MALDEN
Surrey KT3 4NF
Tel. No: 01-942 7711**

DECCA

Electronics Appointments Register

We can get you a better job than you can get yourself.

The best jobs don't necessarily appear in the sits. vac. columns.

They are often to be found in the Electronics Appointments Register.

Our individual approach gives you a wider choice—we have lots of jobs on our specialised registers and we may well have one tailor-made for you.

The service is absolutely free to you and completely confidential.

In effect we offer you the chance to find your ideal job, all for the cost of a phone-call.

So capitalise now on your specialised knowledge.

Call 01-734 4920, or fill in the coupon and we will send you an enrolment form by return of post.

Please send me details of how to enrol on one of your Appointments Registers:

Name

Address

Post to G.A.R. 76 Dean Street London W1 01-734 4920.

[G]raduate [A]ppointments [R]egisters

WW1

SPANISH COMMUNICATIONS EQUIPMENT MANUFACTURER

Applications are invited from qualified design engineers specialized on:

a) Ground/Air Communications
b) TV Colour Transmitters
c) Side Band Transmitters

At least 5 years experience desirable. Company located in Madrid. Salary open.

Send resumé to:

NORTRON
Fernando el Católico, 63
Madrid 15
SPAIN

[2539

REDIFFUSION/BARLOWS

TELEVISION ENGINEERING

Opportunity in South Africa

Two important appointments are to be made in the field of Television Engineering by Barlows Manufacturing Co. in preparation for the start of monochrome and colour television receiver production in South Africa next year.

1. **Chief Development Engineer**
2. **Chief Test Equipment Engineer**

Under licence agreement REDIFFUSION television receivers will be manufactured by Barlows in New Germany near Durban. The successful applicants will have a wide choice of excellent houses to purchase in beautiful residential areas, even very close to the laboratories.

Several years recent experience in television receiver production are necessary qualifications for these appointments and applicants by their knowledge of the product and the job title are expected to have an understanding of the responsibilities involved.

The start of this new industry in South Africa provides a wonderful opportunity for experienced and qualified engineers to advance into senior management.

Applications, which will be treated in strict confidence, should be addressed to:

A. A. Kay, Chief Engineer,
Rediffusion Vision Limited,
Fullers Way South, Chessington, Surrey KT9 1HJ

CHARING CROSS HOSPITAL (FULHAM)

ELECTRONIC TECHNICIAN

for Electrical Safety Duties

Candidates for this newly created post, must possess a qualification equivalent to at least HNC in Electrical/Electronic Engineering, and must have an extensive knowledge of electronic equipment, not necessarily in the field of medical electronics. Salary on scale £1,977—£2,508 plus £126 p.a. London Weighting.

Application form and full job description obtainable from Mr. C. J. H. Hill, Personnel Department, Charing Cross Hospital (Fulham), Fulham Palace Road, London W.6, telephone 748 2050 ext. 2992, to be returned by 1st August.

[2841

OPPORTUNITIES IN VIDEO ELECTRONICS

Rank Film Laboratories require several experienced electronics maintenance engineers to work in Wardour Street.

Training will be given, but applicants should possess a knowledge of Solid State Electronics and modern techniques in analogue and digital circuitry. Previous occupation may have been in the field of light electro-mechanics; computers; tape electronics; T.V. or radio transmission equipment; video tape; telecine; audio recording or testing of light electronic manufacturing equipment.

An excellent starting salary and good prospects. Free life and accident assurance and Contributory pension scheme.

Please apply in writing, providing full details of qualifications and previous experience to: The Personnel Manager, Rank Film Laboratories Limited, North Orbital Road, Denham, Uxbridge, Middlesex, UB9 5HQ or telephone Denham 2323 for application form. [2826

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Europe's Leading Manufacturer of C.A.T.V. Equipment

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Ability to converse with Builders, Architects and Customers necessary.

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Alert young man, aged between 20-30 years, required for the preparation of all types of Technical/Sales Publications, including Manuals and Catalogues covering a wide range of Wired Television Equipment. H.N.C. or equivalent qualifications preferred, previous record of achievement in a similar capacity with a good command of English.

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Fernando el Católico, 63
Madrid 15
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[2540

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PMG I
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2 YEARS OPERATING EXPERIENCE

POSSESSION OF ONE OF THESE QUALIFIES YOU FOR CONSIOERATION FOR A RADIO OFFICER POST WITH COMPOSITE SIGNALS ORGANISATION.

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Full details from:

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Government Communications Headquarters
Room A/1105
Priors Road, Oakley, Cheltenham, Glos GL52 5AJ
Telephone: Cheltenham 21491 Ext 2270

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are required to work on calibration, fault-finding and testing of telecommunications measuring instruments. The work is varied and will enable technicians with experience of r.f. circuits to broaden their knowledge of the latest techniques employed in the electronics and telecommunications industries by bringing them into contact with a wide range of the most advanced measuring instruments embracing all frequencies up to u.h.f.

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Telephone: Luton 33866, or
Mr P Elsip, Personnel Officer
Marconi Instruments Ltd
Longacres, St. Albans, Herts
Telephone: St. Albans 59292

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with good knowledge of Radio & Tape Recording circuits

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Factory Manager,
TELTRON INDUSTRIES (PTY.) LTD.,
11, RICHARD STREET,
SELBY, JOHANNESBURG,
REPUBLIC OF SOUTH AFRICA.

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LABORATORY TECHNICIAN

Salary £1,416—£1,635 per annum. Commencing salary according to qualifications and experience. Required at Stationers Company's School, Mayfield Road, N8 to work 36 hours per week x 52 weeks per annum.

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Candidates will be responsible for the maintenance of the language laboratory, and will be required to assist in the upkeep of Audio-Visual Aids throughout the school and help monitor a computer link line.

The post is ideal for a candidate who wishes to gain experience in the maintenance of a fairly wide range of equipment.

Application forms obtainable from Chief Education Officer, Somerset Road, N17, to be returned by 30 July, 1973.

[2340

LEVELL ELECTRONICS LIMITED

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Test Engineers

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Trainee Test Engineers

Opportunities for young engineers to broaden their experience in an established company manufacturing portable electronic instruments.

Levell Electronics Ltd.,
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Telephone: 01-440 8686

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MEDICAL PHYSICS TECHNICIAN

required for maintenance of the artificial kidney machines, both at the hospital and in patients' homes.

Experience in Dialysis Unit an advantage but not essential.

ONC, HNC or HND in electrical or mechanical engineering preferably with some electronics experience.

Salary according to qualifications and experience.

Further details from Mr. T. Fry, extn. 268.

Applications to: The House Governor, The London Hospital (Whitechapel), Whitechapel, London E1 1BB.
Tel. 01-247 5454, Extn. 388.

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Test Engineers

£1,700 p.a. to £2,100 p.a.

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22 days holiday,
opportunities for overtime.

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(GRADE 5)

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The post is superannuable, subject to medical examination, and carries excellent holiday arrangements.

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Education Television Service

Tennyson Street, London, S.W.8

Mobile Section Engineer

responsible for the technical operation and maintenance of one of the mobile Control Rooms, working with the Education Director and a crew of two. The MCR's are equipped with 3 monochrome Plumbicon cameras, an eight-channel sound desk and 2 inch or 1 inch videotape recorders as necessary. All members of the crew share rigging duties and the driving of vehicles. A current driving licence should be held and training will be provided for the taking of an HGV driving test.

Applicants should possess a thorough knowledge of broadcast television engineering practices, have appropriate qualifications and experience, and sound health.

Salary within the range £2,748-£2,970.

Hours of work will be in accordance with the requirements of the service but the basic week is 35 hours. Hours are, of necessity, rather irregular, often involving overtime, but time off in lieu will be granted or, where that does not prove possible, overtime payment will be made. Weekend working is very seldom necessary. The annual leave, after qualifying service, is 5 weeks and one day.

Application forms and further details from the Education Officer, Estab. 2A/2, The County Hall, SE1 7PB. Tel. 633 7546 or 633 7456.

Closing date for completed applications 3 August 1973.

[2898

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Animal Physiologist

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You will be given thorough training on ICL electronic equipment leading to computers.

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You should be aged between 21 and 25 and be on your final year or have attained City & Guilds electronic certificates or an HNC in electronics. You should have completed an electrical engineering apprenticeship or have at least two years' industrial experience on electronics.

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This engineer must have experience with the application of operational amplifiers, MOS logic, discrete components, small motor power control. Must have proven ability as a project leader responsible for the design and development of a successful industrial or consumer product.

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To design and develop motor control circuitry for a major medical system. This engineer must have experience with the design of solid state controls for DC and AC motors and must be thoroughly conversant with modern circuit design.

Picker X-Ray Company Limited is a world leader of automated medical systems located near Toronto. Area offers city or rural living.

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[2586

SITUATIONS WANTED

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SITUATIONS VACANT

ASSISTANT TO TECHNICAL DIRECTOR required by Italian Radio Manufacturer/Distributor. The successful applicant must be a Service Engineer with Radio, T.V. and Audio background. A high degree of circuit knowledge is required together with the ability to work on own initiative. Commencing salary £2000/£2500 according to age and experience. Please write or telephone Mr. A. Massing, Europhen (Radio & Television) Ltd., 70 Caledonian Road, London N1 9BN. 01-837 3045/6. [2856

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SERVICE Engineer for Audio Visual Aids equipment, particularly 16mm projectors. Burgess Lane & Co. Ltd., Thornton Works, Thornton Avenue, Chiswick, London, W.4. 994 5752. [2850

HI-FI AUDIO ENGINEERS. We require experienced Junior and Seniors and will pay top rates to get them. Tell us about your abilities. 01-437 4607. [18

R.M.S. WRAY CASTLE, College of Marine Radio & Radar require Lecturer to commence September 1973. M.P.T./P.M.G. Certificate, D.T.I. Radar City & Guilds Certificate desirable. Apply Principal, R.M.S. Wray Castle, Ambleside, Westmorland. Tel. Ambleside 2320. [2836

TELEVISION Colour Service Engineer, private firm, glorious Devon, some Audio experience advantage, flat available. Suit young couple, no children. Full particulars. Coles, 14 Wolborough Street, Newton Abbot, Devon. [2895

THE University of Manchester Hester Adrian Research Centre for the study of learning processes in the mentally handicapped. A vacancy exists for a Technician (Grade 3) to work on a 4-year Government-supported project concerned with developing work skills in adults. Duties to be taken up as soon as possible include the construction and maintenance of electronic equipment and general servicing of mobile laboratories. Applicants should have O.N.C. or equivalent qualifications and have had 3-5 years relevant experience. Training will be given in the use and maintenance of V.T.R. equipment. Own car desirable, mileage allowance paid. Commencing salary £1,539 p.a. rising to £1,743 p.a. Applications stating age, qualifications and previous experience should be sent to Dr. E. Whelan, Hester Adrian Research Centre, The University, Manchester M13 9PL. [2835

ARTICLES FOR SALE

A LARGE quantity of radio telephone fixed and mobile equipment is offered by East Midlands Electricity. Full list available from the Purchasing Section, East Midlands Electricity, 398 Coppice Road, Arnold, Nottingham. NG5 7HX. Closing date for offers: Noon on 16 August 1973. [2884

AUDIO Test Gear, Heathkit IG-18 oscillator £20. Digitest digital multimeter £35, Racal valve frequency counter £20, Hewlett Packard pocket calculator £130, Advent cassette recorder £120. All in good working order.—Box No. WW 2598.

AARVAK ELECTRONICS. 3-channel sound-light converters, £18. Strobes, £16. Rainbow Strobes, £132.—12A Bruce Grove, N17 6RA. 01-808 9096. [23

BRAND NEW FIBRE GLASS P.C. BOARD—NOT OFFCUTS. Custom cut to your own specified sizes, up to 12 x 11½in. per piece. High quality FLAME RETARDANT approved NEMA grade 1/16in. single sided one ounce copper at just 5½p per 6 sq. in. including all VAT charges. We offer a first-class service of a quality branded product. Minimum order value 50p. Add 10p p. and p. per sq. foot. (10p min.). Send CWO (not stamps) to S. & D. Systems Ltd., The Ridgeway, Trading Estate, Iver, Bucks., SL0 9HW. [2663

BUILD IT in a DEWBOX quality plastic cabinet 2 in. x 2½ in. x any length. D.E.W. Ltd. (W.), Ringwood Rd., Fernwood, Dorset. S.A.E. for leaflet. Write now—Right now. [76

CONSTRUCTION AIDS—Screws, nuts, spacers etc., in small quantities. Aluminium panels punched to spec. or plain sheet supplied. Fascia panels etched aluminium to individual requirements. Printed circuit boards—masters, negatives and board, one-off or small numbers. Send 6p for list. Ramar Constructor Services, 29 Shelbourne Road, Stratford on Avon, Warwks. [28

COLOUR Monitor Decoder Units by leading British maker. Designed to BBC standards, units consist of chrominance module, P.A.L. filter and delay module, luminance module and encoded video input module. All units brand new and complete including edge connectors and service manual. £30. Also complete switchable PAL/NTSC decoder by same maker built in a 19in. Isep rack with power unit and sync separator. £75. Philips monitor decoder panels Type EL6818/50F PAL £20. NTSC £15. Advance stabilised power unit. Type PM53, 0-15 volt at 10 amp. Brand new £35. Savage 600 watt. P.A. amp contains 12 x KT88's no details. Offers B. Bamber, 20 Wellington St., Littleport, Cambs. CB6 1PN. [2704

Articles For Sale—Continued

COLOUR, UHF and TV SPARES. Colour and UHF lists available on request. New Philips G6 single standard convergence panels complete, incl. 16 controls, coils, P.B. switches, leads, etc. and circuit data £3.75, or with yoke £5.00, P/P 30p. New Colour Scan Coils, Mullard or Plessey plus convergence yoke and blue lateral, £10.00, P/P 40. Mullard AT1025/05 Convergence Yoke, £2.50, P/P 25p. Mullard or Plessey Blue Laterals, £1.25, P/P 10p. BRC 3000 type Scan Coils, £4.00, P/P 40p. Delay Lines DL20, £3.50, DL1E, DL1, £1.50, P/P 25p. Lum. Delay Lines, 50p, P/P 15p. EHT Colour Quadrupler for Bush Murphy CTV 25 111/174 series, £8.25, P/P 25p. EHT Colour Tripler ITT TH25/1TH suitable most sets, £2.00, P/P 25p. KB CVC1 Dual Stand. convergence panels complete incl. 22 controls, £3.75, P/P 35p. CRT Base Panel, £1.75, P/P 15p. Makers Colour surplus/salvaged Philips G8 panels part complete: Decoder incl. I/C, £2.50, IF incl. 5 modules, £2.50, T. Base, £1.00, P/P 25p. CRT base, 75p, P/P 15p. GEC 2040 panels, Decoder, £3.50, T. Base, £1.00, RGB and Sound, £1.00, P/P 25p. Pye CT70 Colour LOPT assembly incl. EHT output and Focus Control, £3.50, P/P 35p. B9D valve bases 10p, P/P 6p. VARICAP TUNERS. UHF ELC 1043 NEW, £4.50, Philips VHF for Band 1 and 3, £2.85 incl. data. Salvaged VHF and UHF Varicap tuners, £1.50, P/P 25p. UHF TUNERS NEW, Transistorised, £2.85 or incl. slow motion drive, £3.85. 4 position and 6 pos. push-button transistd., £4.95. UHF/VHF basic integrated tuners, £3.25, Cyldon UHF valve tuners, £1.50. All tuners P/P 30p. Transistd. UHF/VHF IF panels salvaged, £2.50 P/P 25p. MURPHY 600/700 series complete UHF Conversion Kits incl. tuner, drive assy., 625 IF amplifier, 7 valves, accessories housed in cabinet plinth assembly, £7.50 P/P 50p. SOBELL/GEC 405/625 Dual standard switchable IF amplifier and output chassis incl. cct., £1.50 P/P 35p. THORN 850 Dual standard time base panel, £1.00 P/P 35p. PHILIPS 625 IF amplifier panel incl. cct., £1.00 P/P 30p. VHF turret tuners AT7650 incl. valves for K.B. Featherlight, Philips 19TG170. GEC 2010, etc., £2.50. PYE miniature incremental for 110 to 830, Pam and Invicta, £1.95. A.B miniature with UHF injection suitable K.B, Baird, Ferguson, 75p. New fireball tuners Ferguson, HMV, Marconi, £1.90 P/P all tuners 30p. Large selection LOPTs, Scan Coils, FOPTs available for most popular makes. PYE/LABGEAR transistd. Masthead UHF Booster, £5.75, Power Unit, £4.65 P/P 30p or Setback battery operated UHF Booster, £4.65 P/P 30p. MANOR SUPPLIES, 172 WEST END LANE. LONDON. N.W.6 (No. 28, 59, 159 Buses or W. Hampstead Bakerloo and Brit. Rail). MAIL ORDER: 64 GOLDERS MANOR DRIVE, LONDON, N.W.11. Tel. 01-794 8751.

DIGITAL AND ANALOGUE EQUIPMENT. Sanborn F.M. Recorder Model 3914-09B in rack cabinet; £185. E.R.A. Solid State 400 Hz inverter. Single phase. 100VA; £15. Ekco Neutron Doserate Meter Type M3147A. Transistorised; £8.50. I.C.L. Power Supply. 25A stabilised. With twin meters and continuously variable from 4.5 to 8 Volts; £16. Tinsley 50Hz Tuning Fork in case; £7.50. Small I.B.M. memory drum; £10. Audio Generator 20Hz-200kHz; £9.00. 5 Range Solid State D.C. Amplifier; £4.50. Friden 8-hole paper tape punch units; £7; read units; £7. I.B.M. Golfball typewriter mounted on table; £55. Panel comprising 57 I.B.M. plug-in relays; £5.50. Hewlett-Packard six-speed tape loop unit, type 3900; £75 (new). Digital Development Corporation magnetic memory drum, type 10425, about 5 mega-bits, complete with electronics; £300. I.B.M. 6420/6425 accounting computer (includes two golfball printers); £125. Friden Flexowriter (two case); £85. Ekco six-digit Counter-Timer type M5024 (third generation); £45. C.D.C. tape transport; £15. Raymond ffoulkes, Mead Cottage, Castle St., Bletchingley, Surrey. Godstone 3106. [2875

FOR SALE. Marconi Sig. Gen 85KHz to 25 KHz in 8 ranges output 1 micro volt to 1 volt Internal or External Mod. £15.00. Hartley 13A Osciloscope £13.00 or £25.00 for both. Carriage to be paid by Purchaser. Seabourne Electronics Ltd., 33 Camperdown Tce, Exmouth. [2860

FOR SALE BRAND NEW AND IMMEDIATE DELIVERY. SELENIA UHF TELEPHONE LINK SRL 123C 123C. Two racks each containing two UHF transmitters and two UHF receivers, power supplies and EOW units. Crystals fitted for 401.3 MHz and 449.7 MHz, six sets of handbooks, extender boards, fuses etc. In addition 4 Marconi Italian MXT 120 36 way multiplex equipment each complete with carrier generation and signalling modules. The above is a fully duplicated 36 channel UHF link which can be used without duplication for 72 channels. £18,000. Qty. Marconi H 5000 2 tone VFT Transmitter and 2 H 5001 Diversity Receivers. Brand new. Immediate delivery. £8,000. Qty. 3 Rdifon HF multicoupler MCU 6B. £120 each. Qty. 9 R & S UHF Multicouplers 225 to 400 MHz type NV5/400Z. £250 each. Qty. 150 Pye Radiotelephones type AM10B S-ET. Reconditioned and 12.5 KHz channelling. 6 channels 12 or 24 volt 147 to 174 MHz. M.P.T. type approved. £100 each (with all accessories). Essex Telecomms, Unit 12 Coordinated Industrial Estate, Claydons Lane, Rayleigh, Essex. Tel: Rayleigh (03742) 79674. [2588

LARGE quantity test equipment receivers transceivers, meters, various P.S.U.'s; over 1,000 items for immediate disposal. S.A.E., plus 25p, refunded on purchase over £2.00. F.J.C., Colnemill, Alvington, Glos. [2881

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APPOINTMENTS

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Salary scale:
£2,305 p.a.–£2,825 p.a. (commencing salary depends on age, qualifications and experience).

Application forms may be obtained from:

The Personnel Manager, Manpower Directorate,
Port of London Authority, Basin South, North Woolwich, E.16.
Tel: 01-476 7365.

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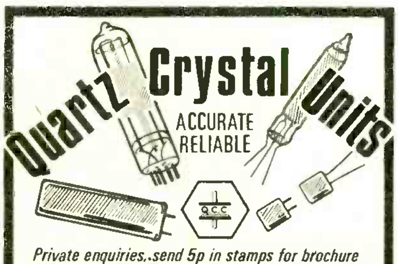

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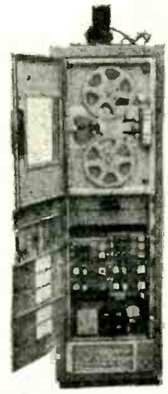

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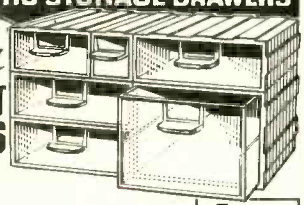

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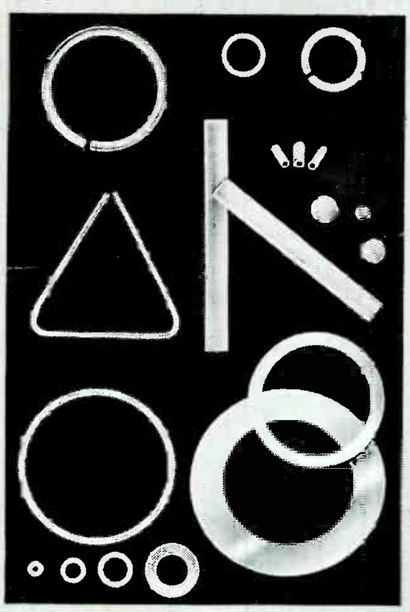

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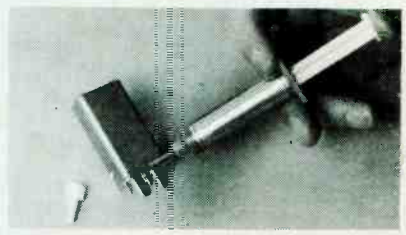
There are three types of Multicore Solder Cream – one of them may be just what you've been looking for.



Multicore Product Ref.	XM 27330	XM 27298	XM 27328
Alloy Composition	62/36/2 Sn/Pb/Ag	60/40 Sn/Pb	96/4 Sn/Ag
Melting Point or Liquidus °C	179	188	221
Recommended Flow Temperature °C	239	250	280
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