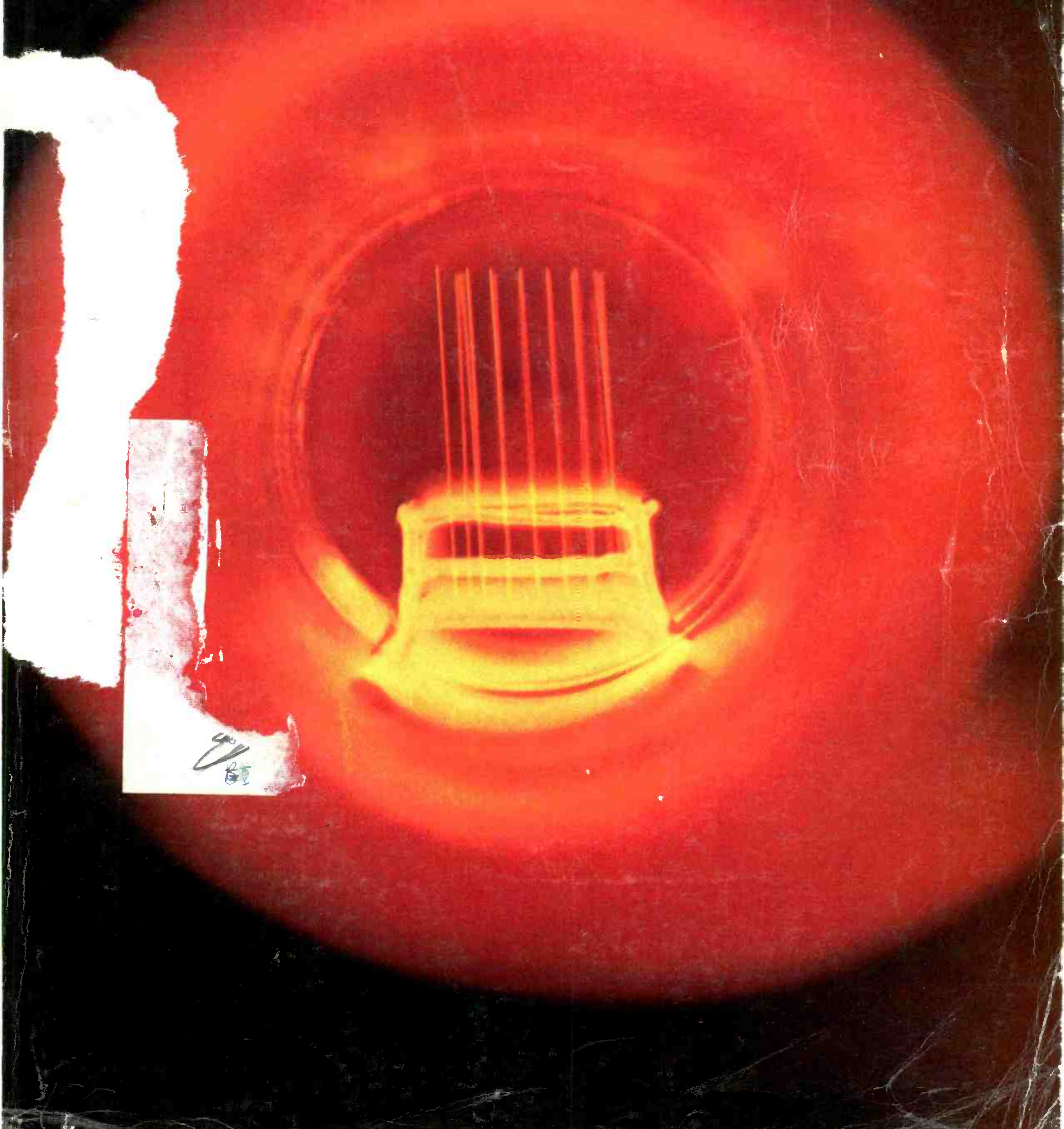
Wireless World

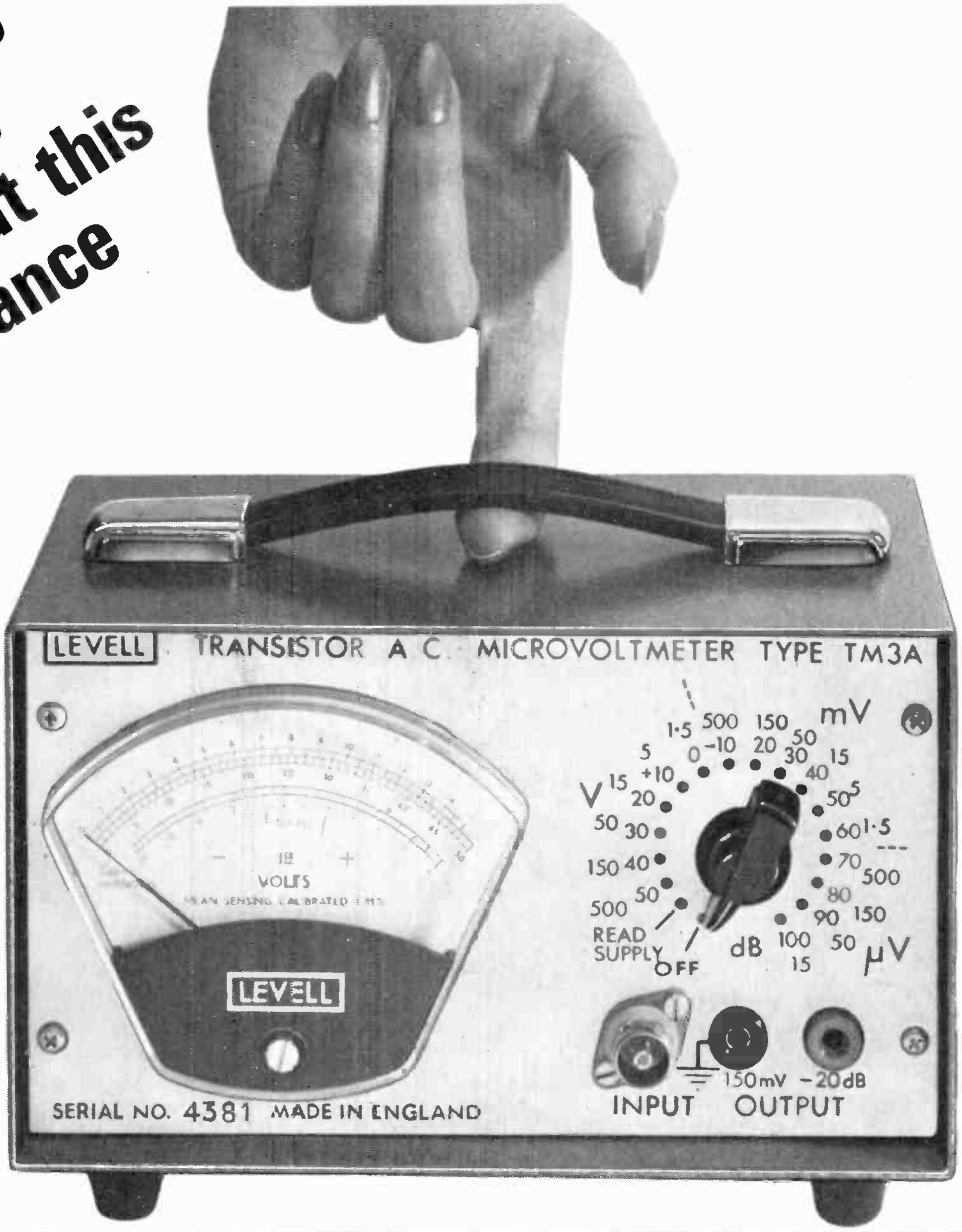
January 1971 3s 6d (17½p)

Wideband u.h.f. television aerial

Loudspeaker enclosures



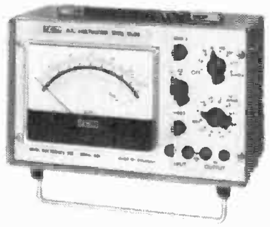
for just £49 you'll be surprised at this performance



A.C. MICROVOLTMETERS

VOLTAGE & db RANGES: 15µV, 50µV, 150µV . . . 500V f.s.d. Acc. ± 1% ± 1% f.s.d. ± 1µV at 1kHz. − 100, − 90 . . . + 50dB. scale − 20dB/+ 6dB rel. to 1mW/600 Ω.
RESPONSE: ± 3dB from 1 Hz to 3MHz, ± 0·3dB from 4Hz to 1MHz above 500µV. Type TM3B can be set to a restricted B.W. of 10Hz to 10kHz or 100kHz.
INPUT IMPEDANCE: Above 50mV: > 4·3M Ω < 20pf. On 50µV to 50mV: > 5M Ω < 50pf.
AMPLIFIER OUTPUT: 150mV at f.s.d.

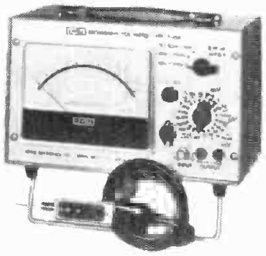
type TM3A **£49** type TM3B **£63**



D.C. MULTIMETERS

VOLTAGE RANGES: 3µV, 10µV, 30µV . . . 1kV. Acc. ± 1% ± 1% f.s.d. ± 0·1µV. LZ & CZ scales.
CURRENT RANGES: 3pA, 10pA, 30pA . . . 1mA (1A for TM9BP) Acc. ± 2% ± 1% f.s.d. ± 0·3pA. LZ & CZ scales.
RESISTANCE RANGES: 3 Ω, 10 Ω, 30 Ω . . . 1kM Ω linear. Acc. ± 1%, ± 1% f.s.d. up to 100M Ω.
RECORDER OUTPUT: 1V at f.s.d. into > 1k Ω on LZ ranges.

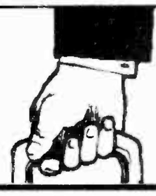
type TM9A **£75** type TM9B **£89** type TM9BP **£93**



BROADBAND VOLTMETERS

H.F. VOLTAGE & dB RANGES: 1mV, 3mV, 10mV . . . 3V f.s.d. Acc. ± 4% ± 1% of f.s.d. at 30MHz. − 50dB, − 40dB, − 30dB to + 20dB. Scale − 10dB/+3dB rel. to 1mW/50 Ω. ± 0·7dB from 1MHz to 50MHz. ± 3dB from 300kHz to 400MHz.
L.F. RANGES: As TM3 except for the omission of 15µV and 150µV.
AMPLIFIER OUTPUT: Square wave at 20Hz on H.F. with amplitude proportional to square of input. As TM3 on L.F.

type TM6A **£85** type TM6B **£99**



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PORTABLE INSTRUMENTS

Long battery life and large overload ratings are leading features of these solid state instruments. Mains units and leather carrying cases are optional extras. All A type instruments have 3¼″ scale meters and case sizes 5″ × 7″ × 5″, B type instruments have 5″ mirror scale meters and case sizes 7″ × 10″ × 6″.

PORTABLE VOLTMETERS

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Hire terms and leaflets covering our range of portable instruments are available.

WW—006 FOR FURTHER DETAILS

You can view X-ray pictures in daylight using only a 5 micro-Röntgen dosage

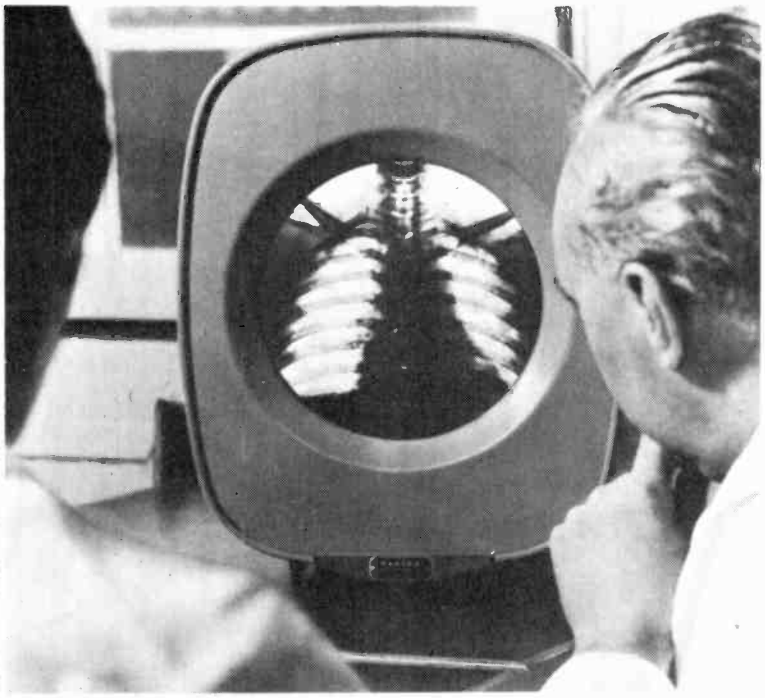
What would it mean to you? An X-ray picture that is so bright you can view it in direct daylight as it happens. EEV's Image Isocon is now being used in X-ray equipment for this very purpose – reducing X-ray dosages to as little as 5 micro-Röntgens, allowing longer exposure times for 'live' X-ray picture study, saving time by eliminating the need for operators' eyes to become 'dark-adapted'.

The Image Isocon is so sensitive that it can convert a very low dosage-level picture to a bright, clear picture on a cathode-ray tube. This in turn means simple direct-from-screen photography.

The Image Isocon is another product of EEV advanced tube technology. For complete data, please post the coupon.

English Electric Valve Co Ltd Chelmsford, Essex, England. Telephone: 0245 61777. Telex: 99103. Grams: Enelectico Chelmsford.

with the EEV Image Isocon



To: English Electric Valve Co Ltd Chelmsford, Essex, England.
Send for full details of EEV Image Isocon range.

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FOUR NEW COMPONENTS FROM ASSOCIATED AUTOMATION

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A.C. or D.C. operation. Panel mounting or plug-in to octal type socket. Will last for up to 5 million operations with 1, 2 or 3 poles switching up to 10 amps. Compact, lightweight and cheap.

2 Dry Reed Relay Type ERTN
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Switching capability up to 4 poles, up to 0.5 amp, 10 watt. Wide range of contact arrangements and mounting styles. Angle bases for terrace keyboards, panel mounting for either single or multiple fixing. Will last for at least 5 million operations. Easy to apply, readily available, economically priced.

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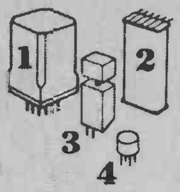
A T.O.5 transistor can envelope giving high isolation switching. Resists shock and vibrations, operates on powers down to 40 mW. Switching capability 1 amp at 28 V.D.C. to low level (single and double poles). Economical price—though comparable with any military equivalent.



Three relays and a switch, designed by Associated Automation to cut your switching costs. Built to the highest standards of engineering, these components join the already comprehensive range of switches and relays for all communication and control purposes. All economically priced and backed by Britain's most outstanding engineering service.
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COMPANY

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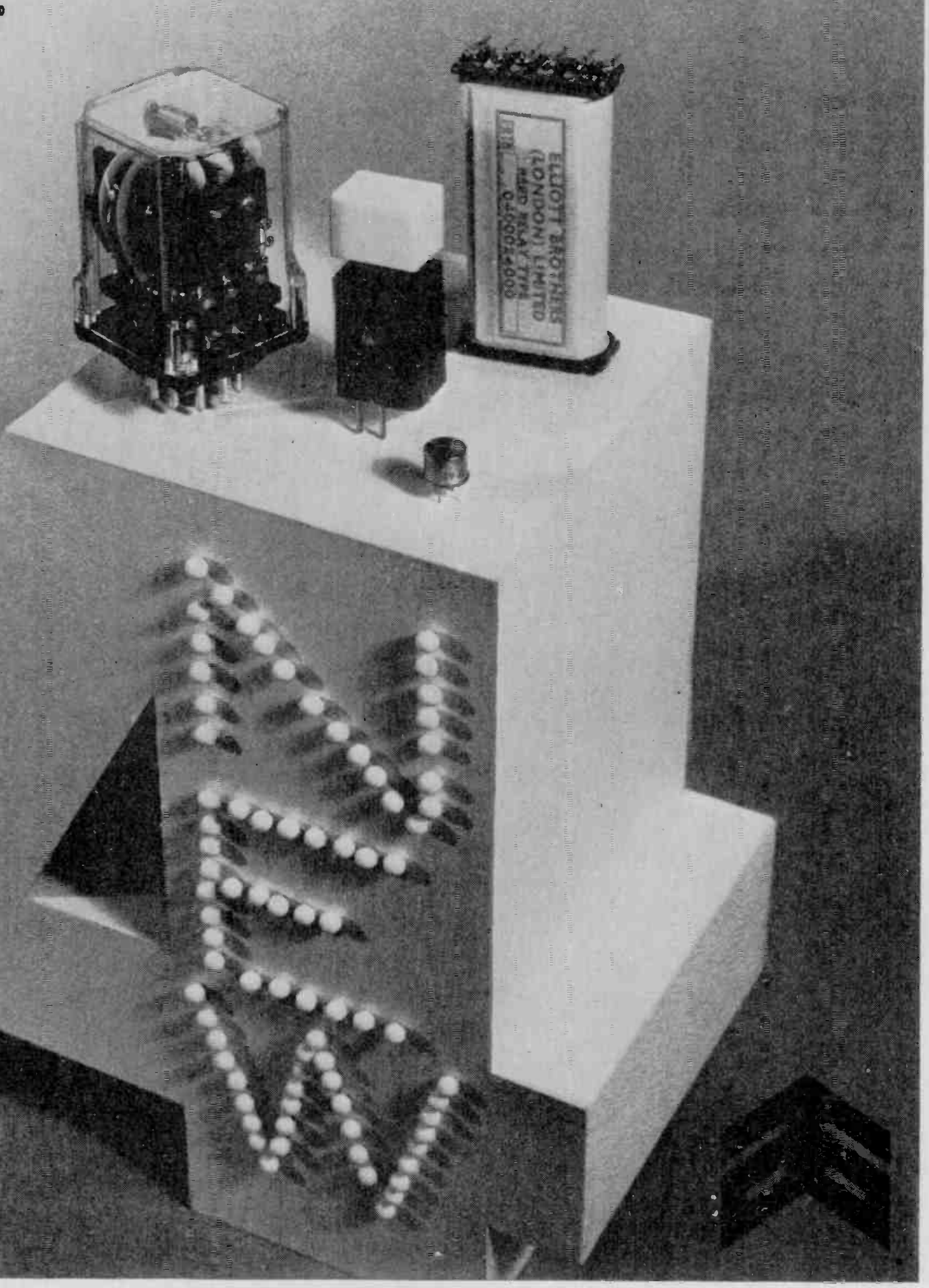
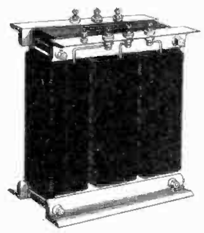
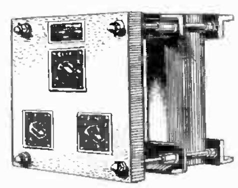


WW—013 FOR FURTHER DETAILS

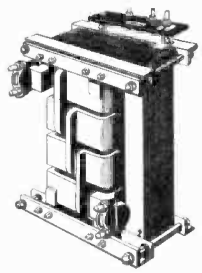
Transformers, Chokes
Saturable Reactors
Voltmobile voltage regulators
Rectifier Sets



Transformers
Air cooled power transformers from 0.5 to 300kVA at voltages up to 2kV. 1 or 3 phase, double or auto wound, step-up or step-down. We have manufactured transformers to over 5,000 different designs for many applications and the experience which has been accumulated from these designs is built into every Harmsworth, Townley transformer



Voltmobiles
The most robust and useful control device for loads such as furnaces, ovens, bar heating and high temperature research. Our Voltmobiles are in use in their thousands to control transformers and rectifier sets or they can be used directly between supply and load. 64 step on load switching. Voltmobiles are auto-transformers which give control from 1.6% to 100% of input volts. Over-Volts up to 125% of input is also available. Standard models are made for single and 3 phase supply and for outputs from 20 Amps to 200 Amps with on-load switching.



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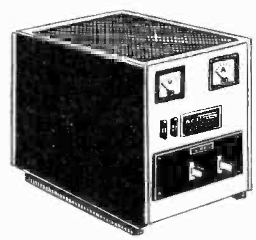
Years of experience have gone into the design and production techniques used in the manufacture of our low voltage, high current transformers for use in furnaces, high temperature research, heating and other applications. These techniques enable us to produce transformers with output currents up to tens of thousands of amps at economical prices



Rectifiers
Sturdily built air cooled equipment from 50W to 500kW for plating, plasma arc welding, electrolytic machining and many other applications. Equipment incorporates either silicon or selenium rectifiers and can be built with fixed or variable output. Variable outputs are obtained by the use of continuously variable auto transformers, saturable reactors or Voltmobile regulator.

Saturable Reactors
From 5kVA up to 300kVA for controlling the outputs from transformers or rectifier units. Saturable reactors are infinitely variable reactors which can control outputs from transformers etc, from 10% to 100% of full output.

Chokes
A.C. and D.C. chokes

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Rectifiers

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Telephone Todmorden 2601 Extension 22

WW—015 FOR FURTHER DETAILS

CS-1554
130mm Dual Trace Oscilloscope

TRIO's CS-1554 Passes The Most Rigid Testing Requirements

Waveform analysis and other electrical equipment and electronic installation testing is performed at the highest possible peak of efficiency with TRIO's CS-1554. This wide-band dual trace triggering oscilloscope operates at ultra-high sensitivity while also offering an over-all expansive range of test capabilities. Lightweight because of its all-solid state construction, this completely dependable instrument is remarkably versatile. For example, dual trace waveform analysis with very wide synchronization capabilities is possible from DC-10MHz. It has no equal for speedy analysis efficiency.

CS-1553
130mm Oscilloscope
An essential device for signal waveform analyses and TV alignment and servicing. Complete solid state circuitry. Trigger sweep and automatic sweep potential. Very high sensitivity with wide frequency response from DC to 10MHz extremely versatile.

VT-106
High sensitivity Electronic Voltmeter
This is a solid state electronic voltmeter employing IC and FET for high sensitivity and stability, capable of measuring voltages from 0.02mV to 300V.

AG-201
ALL SOLID STATE CR type low-frequency Oscillator
An all-transistor, compact CR type wide-band low-frequency oscillator, the AG-201 produces sine waves with a minimum of distortion and rectangular waves with a quick rise time at a low output impedance.

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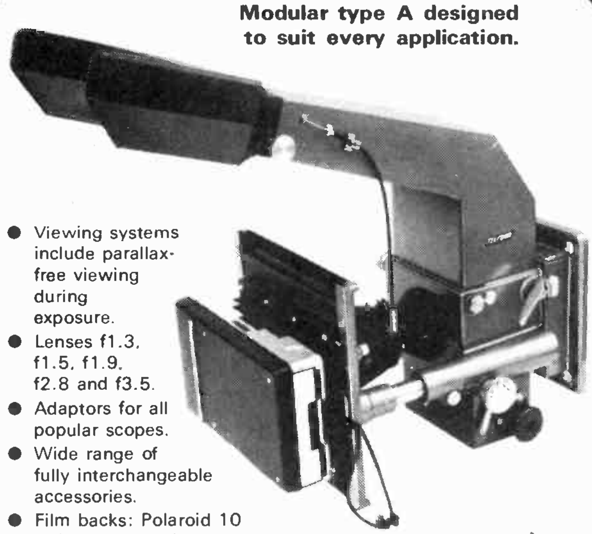
WW—017 FOR FURTHER DETAILS

TELFORD RANGE OF Oscilloscope Cameras

Modular type A designed to suit every application.



- Viewing systems include parallax-free viewing during exposure.
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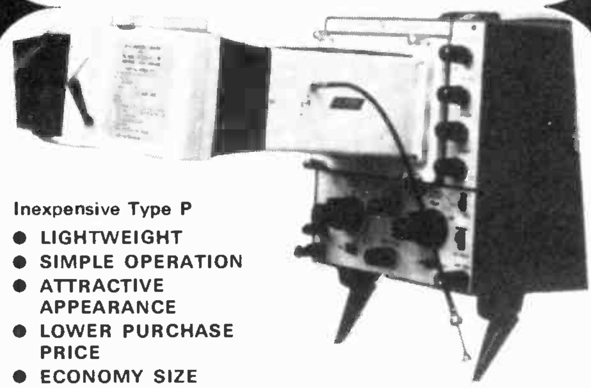
- Adaptors for all popular scopes.
- Wide range of fully interchangeable accessories.
- Film backs: Polaroid 10 second prints with roll, pack or cut film, conventional photo materials including 35mm.



Inexpensive Type P

- LIGHTWEIGHT
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- ATTRACTIVE APPEARANCE
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- ECONOMY SIZE POLAROID FILM TYPE 20
- PRE-EXPOSURE VIEWING
- **LENS** f4.5 2.4" (61mm) lens provides reproduction of trace and graticule with good linearity. The object/image ratio is 1:07 (nom).
- **SHUTTER SPEEDS** include fixed exposure 1/25th sec. (nom) time and brief.
- **ADAPTORS** Camera models available for most popular oscilloscopes.

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General Diesel Eng.
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Eng. Metallurgy
C. & G. Eng. Crafts
C. & G. Fabrication

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A.M.I.E.D.
Gen. Draughtsmanship
Die & Press Tools
Elec. Draughtsmanship
Jig & Tool Design
Design of Elec. Machines
Technical Drawing
Building

Electrical & Electronic
A.M.S.E. (Elec.)
C. & G. Elec. Eng.
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Installations & Wiring
Electrical Maths.
Electrical Science
Computer Electronics
Electronic Eng.

Radio & Telecomms.
C. & G. Telecomms.
C. & G. Radio Servicing
Radio Amateurs' Exam.
Radio Operators' Cert.
Radio & TV Engineering
Radio Servicing
Practical Television
TV Servicing
Colour TV
Practical Radio & Electronics (with kit)

Auto & Aero
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MAA/IMI Diploma
C. & G. Auto Eng.
General Auto Eng.
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Choose from 42 'O' and 'A' Level subjects including:
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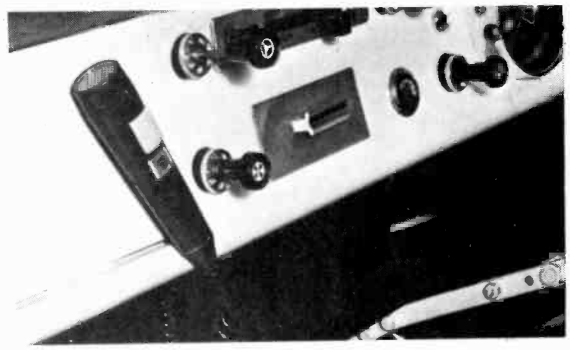
all-adaptable dual purpose MAGNETIC FIX 'CLASSIC' Microphone with *instantaneous-stowing* advantage



Magnetic Fix to stand or car dash-board equally fast

Dimensions
Overall body length 5½" (14 cm)
Maximum diameter 1¼" (3.17 cm)
Weight
Approximately 5 oz (141.75 g)
Inset – Moving coil-noise Cancelling
300 ohms Impedance

Output for normal speech
Approx 1 mV true r.m.s.
Magnetic adhesion
Measured on ⅛" (3.17 mm) flat mild steel plate with microphone mounted vertically. The vertical downward pull required to cause slipping is typically 14 oz (0.4 kg)

Type 1 C 601/1 is S G BROWN'S new 'Classic' dual-purpose microphone triumph.
- Fixed in split second
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- This instrument adapts to situation
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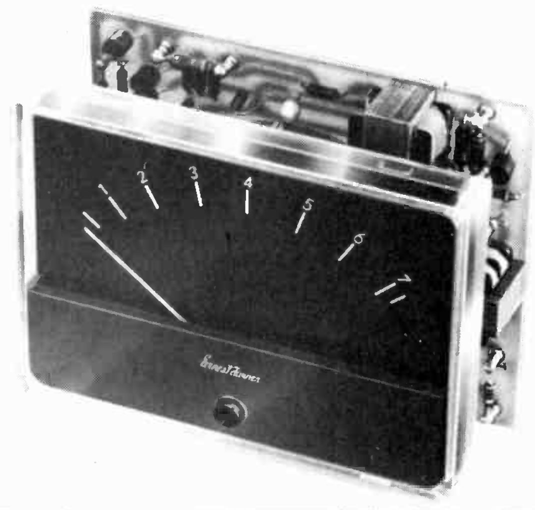
The AE PPM 3

The Audio Engineering Peak Programme Meter is designed well within the British Standards specification. This precision instrument is used throughout all major Broadcasting and Television Studios in the U.K. and Europe. The PPM 3 is always used where programme level must be accurately measured.



Printed circuit mounts directly to back of Ernest Turner 643 or 642 meter.
Three meter scales available: British Standard —BBC—European.
Nominal 24 Volts DC required.
High stability—all capacitors are Tantalum electrolytic.
Frequency response: 40 Hz–20 kHz ± 0.2 dB
10 Hz–40 Hz ± 2.0 dB
20 kHz–60 kHz ± 2.0 dB
Integration time: 10 m secs.
'Fall back' time: 3 secs.
Gold plated 10 way connector.
4 slave meters can be driven from 1 card.
Ferrous or Non-ferrous mounting.
Stereo PPM also available.

Manufactured by: Audio Engineering Ltd.,
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01-836 9373

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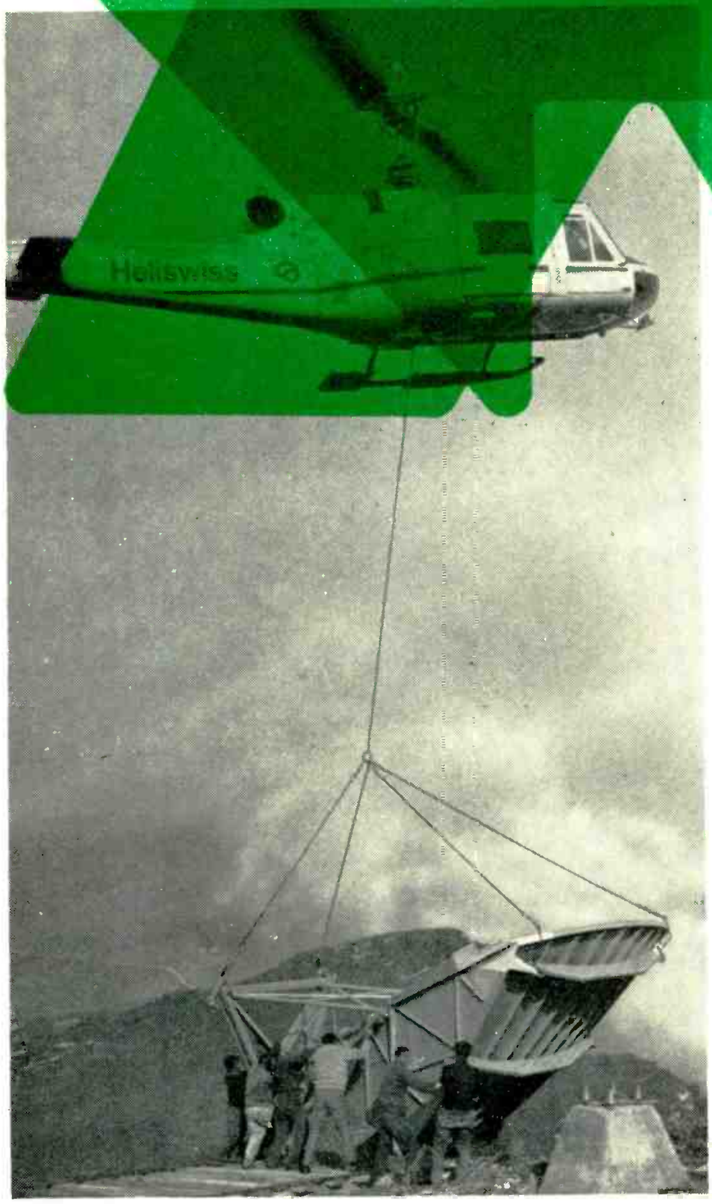

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Only the steinbocks climb where
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the repeaters of high capacity
radio link over the Alps.
In Holland, in Hungary, in Argentina,
in Australia we have also designed
and installed high capacity radio links
working at 4, 6, 7 GHz.
Grateful clients all over the world
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of ITALTEL equipment and services.

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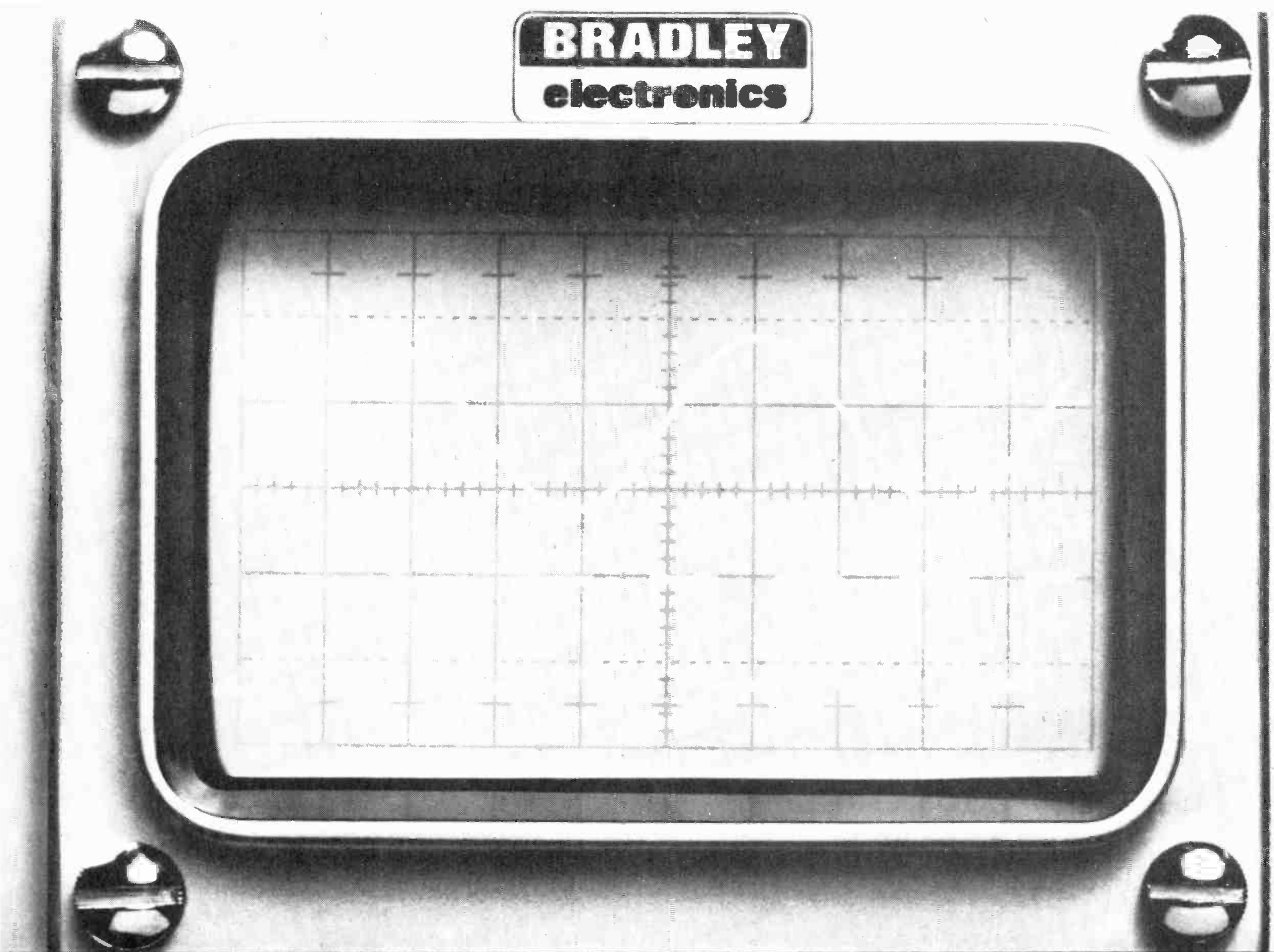
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TWC

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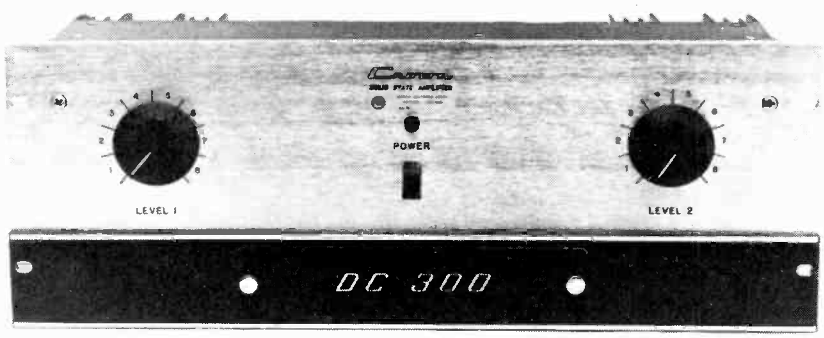
WW—026 FOR FURTHER DETAILS

DC300

DUAL-CHANNEL POWER AMPLIFIER



★ DC-Coupled throughout!

★ Short Circuit proof!

★ 500 Watts RMS Mono.

★ 70 Volt Balanced line out!

★ UNEQUALLED QUALITY!

★ 3 YEAR PARTS WARRANTY!

★ ONLY £320 inc. DUTY!

Frequency Response	± 0.1db Zero-20KHz at 1 watt into 8 ohms, ± 0.6db Zero-100KHz.
Phase Response	Less than 5° 0-10KHz.
Power Response	± 1db Zero-20KHz at 150 watts RMS into 8 ohms.
Power at Clip Point	Typically 190 watts RMS into 8 ohms, 340 watts RMS into 4 ohms per channel.
Total Output (IHF)	Typically 420 watts RMS into 8 ohms, 800 watts RMS into 4 ohms.
T.H.D.	Better than 0.03% at 1KHz at 190 watts level.
I.M. Distortion (60-7KHz 4:1)	Less than 0.1% from 0.01 watt to 150 watts RMS into 8 ohms, typically below 0.05% (max 0.05%.
Damping Factor	Greater than 200 (Zero to 1KHZ into 8 ohms at 150 watts RMS).
Hum and Noise (20-20KHz)	100db below 150 watts RMS output (unweighted, typical 110db).
Slewing Rate	8 volts per micro-second. S-R is the maximum value of the first derivative of the output signal.
Dimensions	19in. standard rack mount (W.E. hole spacing), 7in. height, 9¾in. deep (from mounting surface).
Weight	40 pounds net weight.
Finish	Bright-anodized brushed-aluminium front-panel with black-anodized front extrusion, access door, and chassis.

CARSTON ELECTRONICS LTD.
SHIRLEY HOUSE
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LONDON, N.W.1 9LN
01-267 2748

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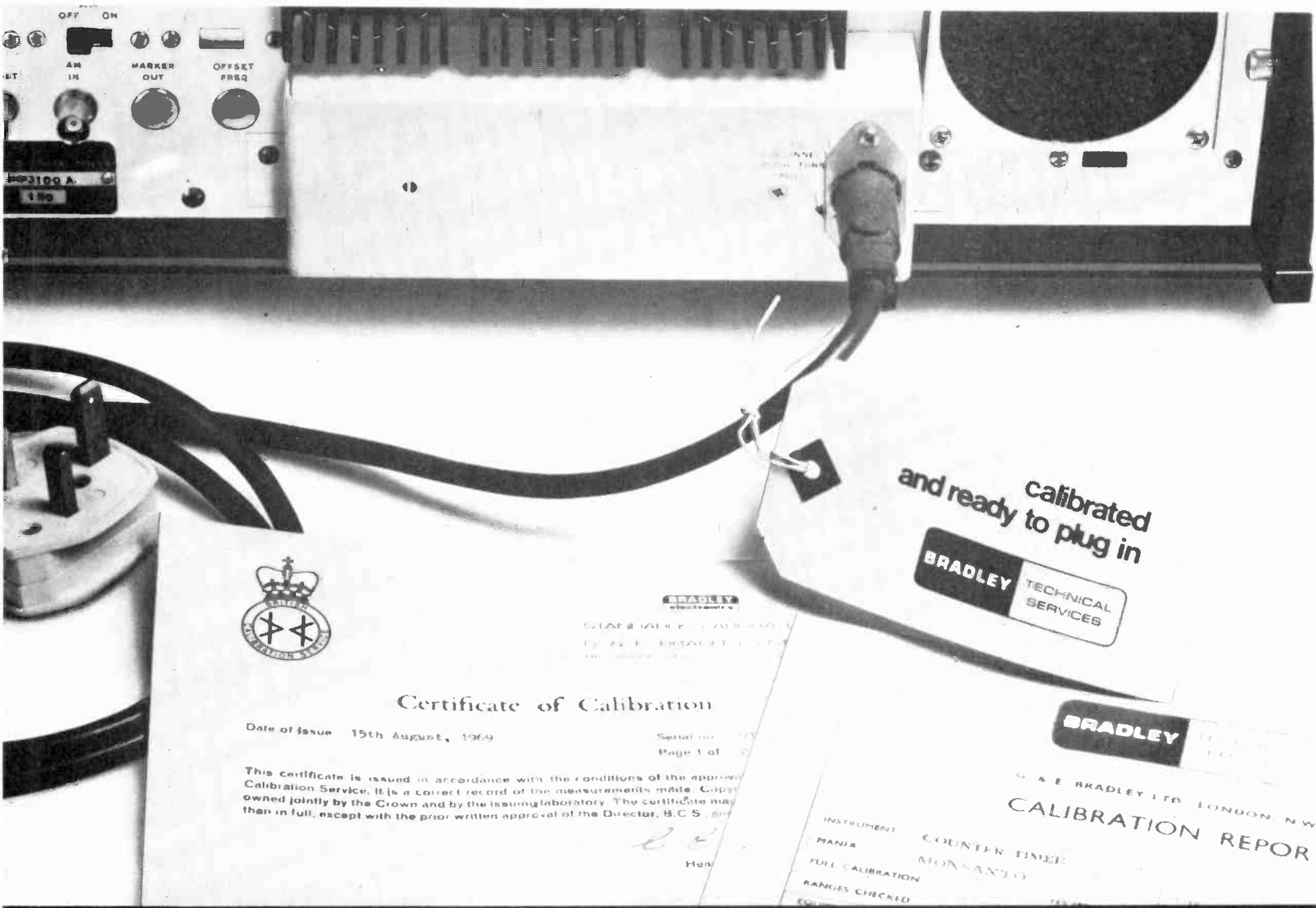

Bradley Calibration Service

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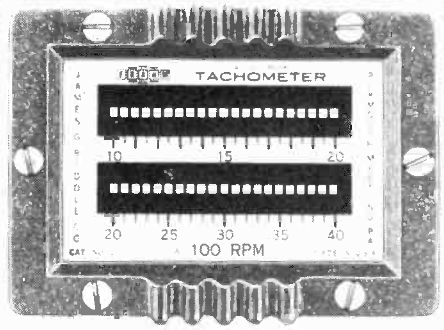

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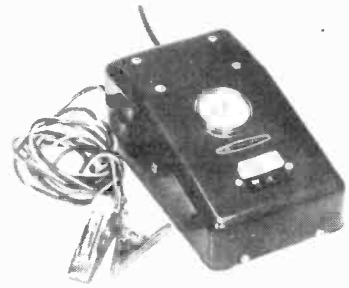

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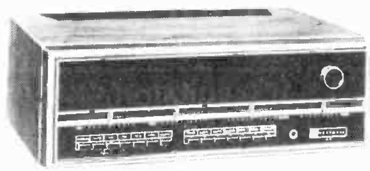

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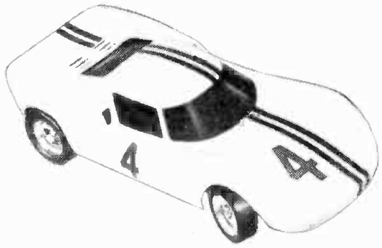

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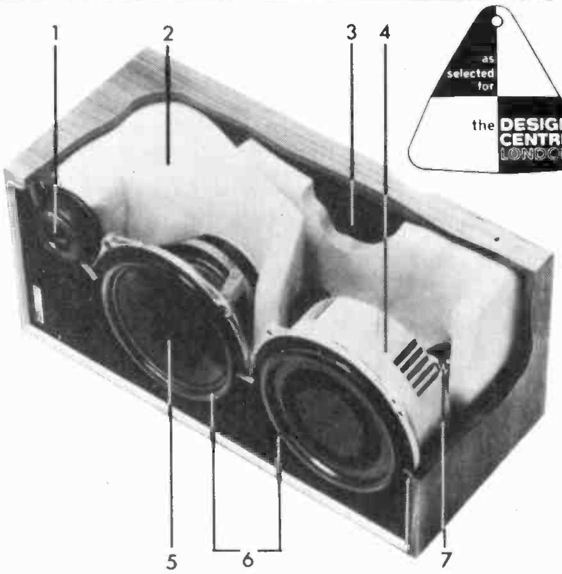

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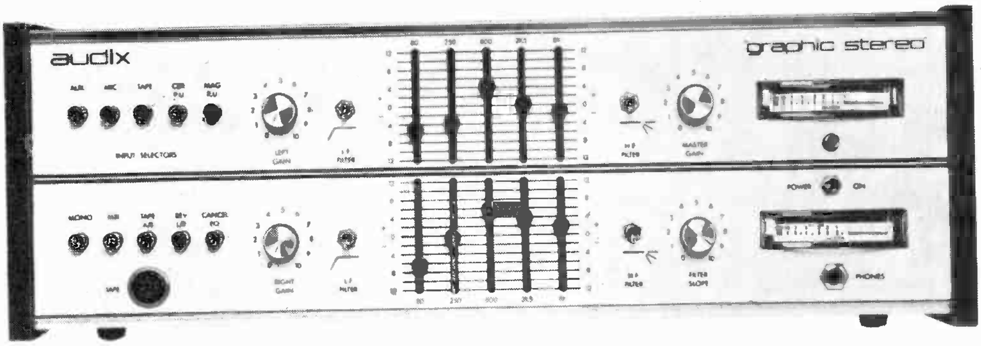

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GP65	2/6	7/6
GP67	2/6	7/6
GP73-1	6/6	9/6
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GP79	2/6	7/6
GP81-1	2/6	7/6
GP91-1	6/6	9/6
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GP91-3	6/6	9/6
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BSR C1 (ST3)	6/6	9/6
BSR TC8H	2/6	7/6
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BSR X1M	6/6	9/6
BSR X1H	6/6	9/6
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Collaro Studio 'O'	2/6	7/6
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GARRARD	Sapphire	Diamond
EV26 Stereo	2/6	7/6
GC2	2/6	7/6
GC8	2/6	7/6
GCE12	2/6	7/6
GCS10/1	2/6	7/6
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S 1—2—3	6/6	9/6
TS1	6/6	9/6
TS2	6/6	9/6
TS3	6/6	9/6
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CM60	2/6	7/6
MX1	2/6	7/6
MX2	2/6	7/6
Stereo CS80	2/6	7/6
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PE188	6/6	9/6
PHILIPS		
AG3016	2/6	7/6
AG3063	2/6	7/6
AG3306	6/6	9/6
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DC284	2/6	7/6
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X5M	S/S	27/9
X5H	S/S	27/9
SX5M	S/S	36/3
SX5H	S/S	36/3
SX5M	D/S	39/11
SX5H	D/S	39/11
X4N	D/S	27/3
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106	S/S	19/10
DC400	S/S	14/–
DC400SC	S/S	14/–
105	D/S	22/4
106	D/S	22/4
DC400	D/S	16/9
DC400SC	D/S	16/9
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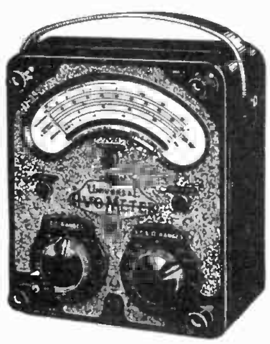

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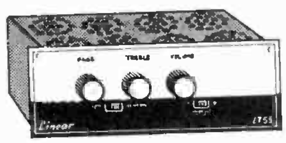

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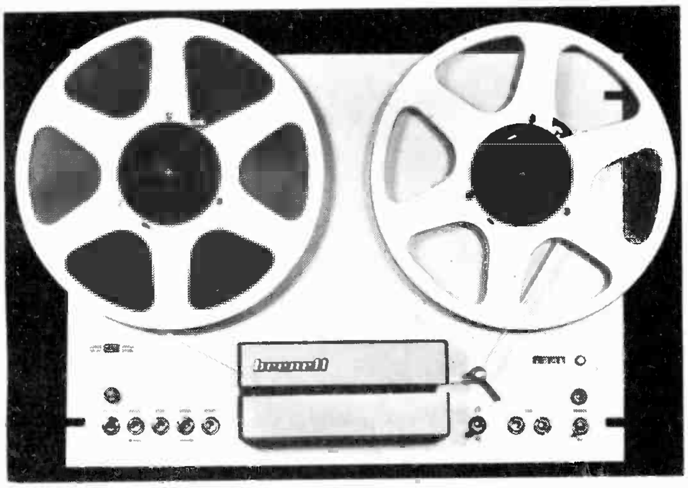

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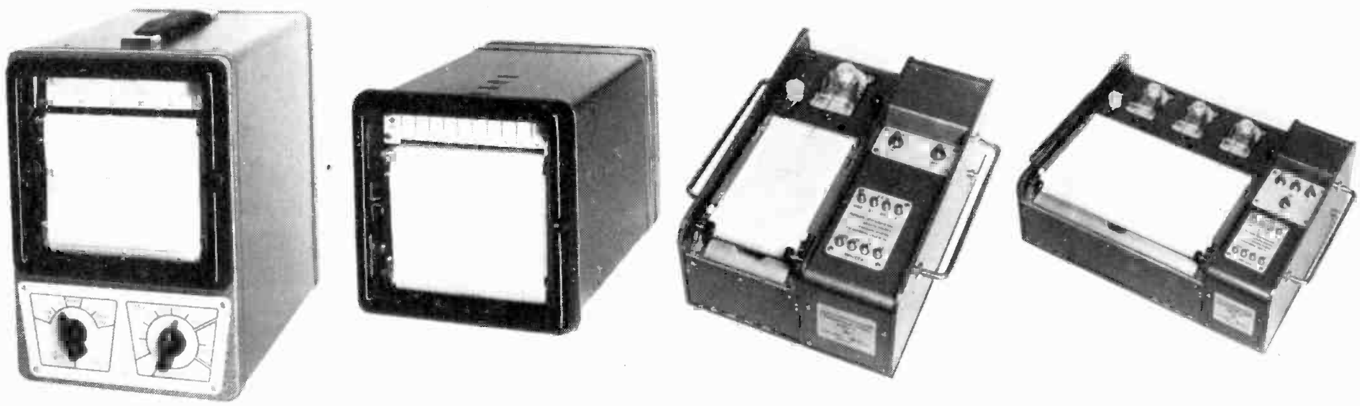

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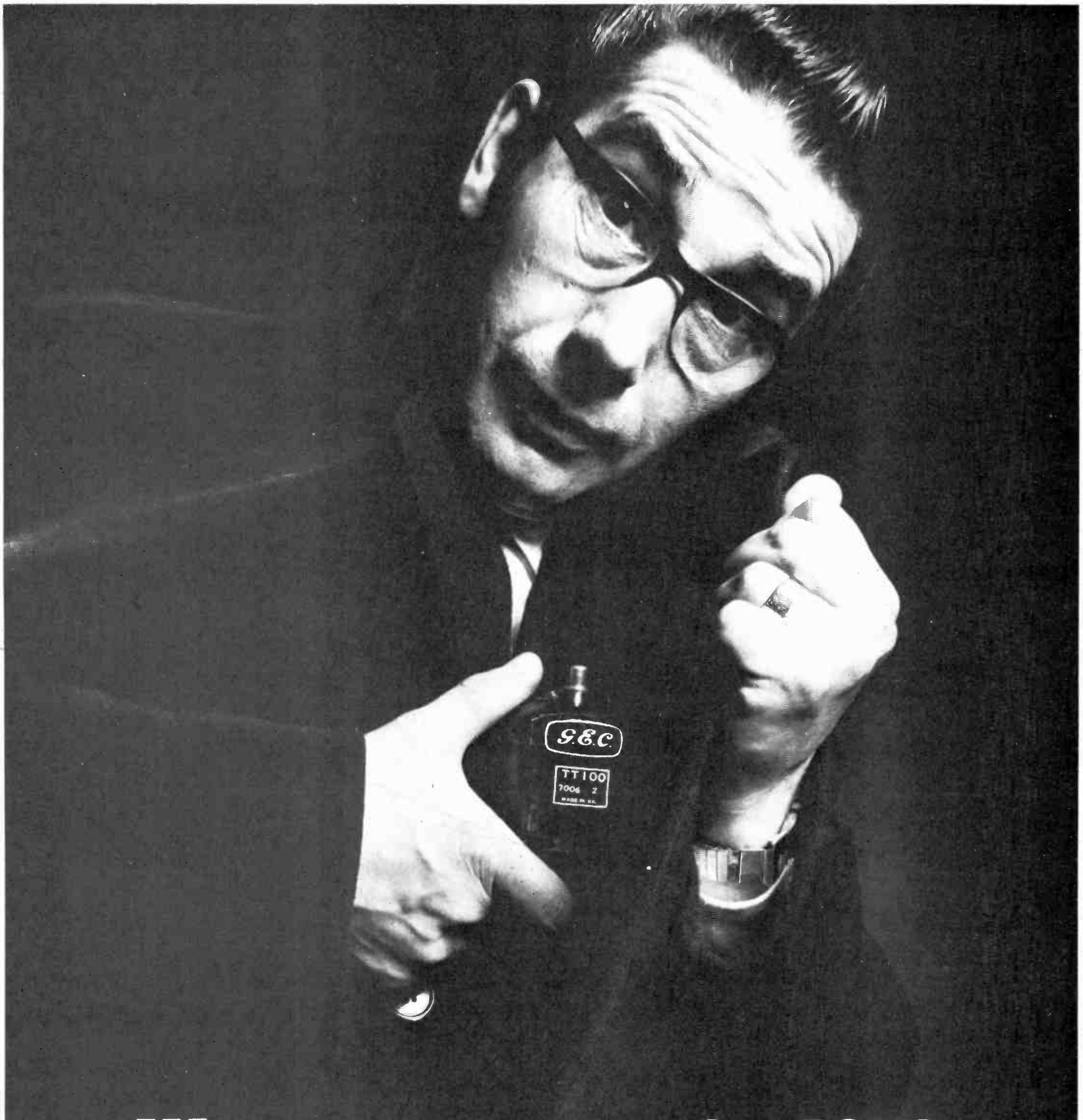

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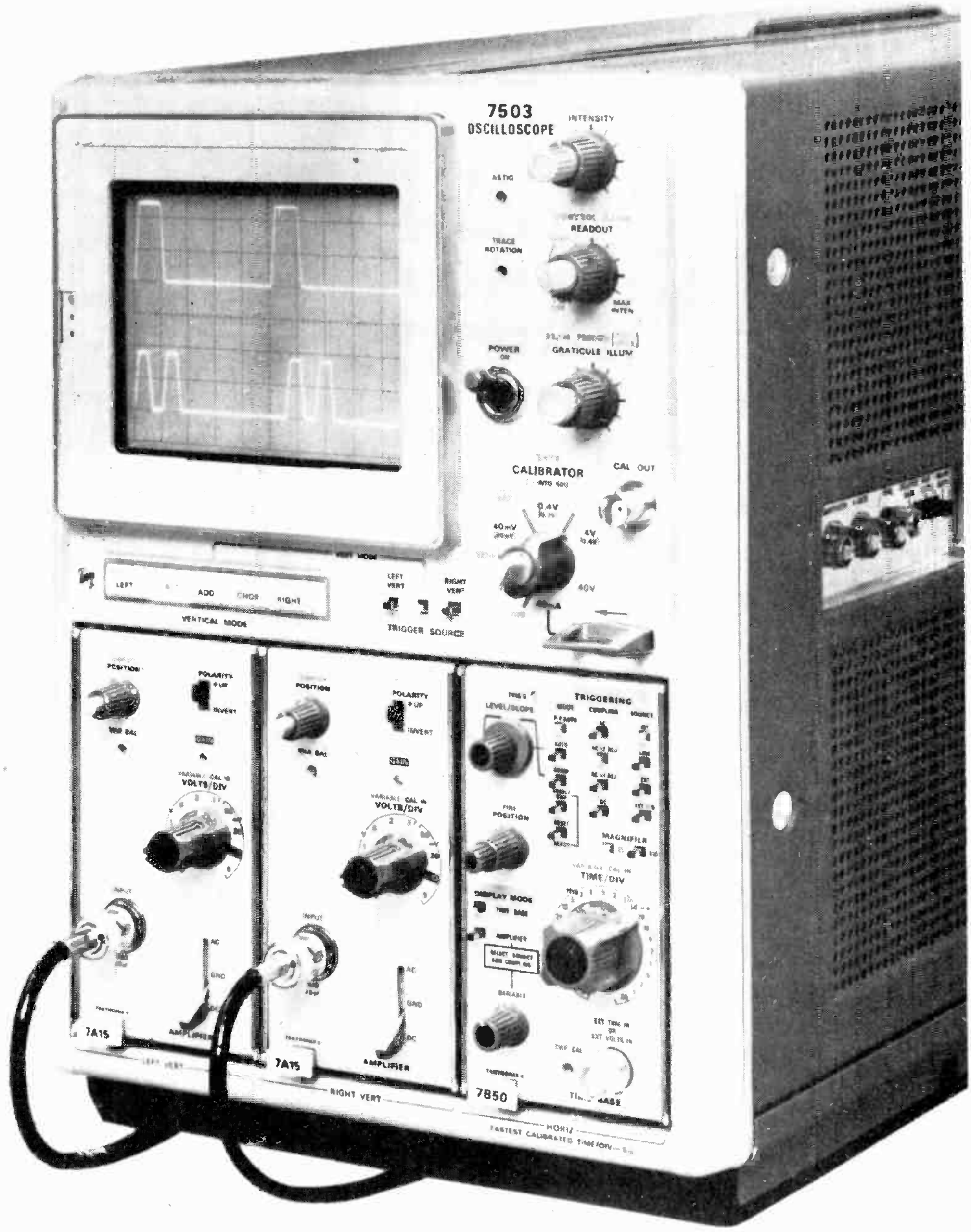

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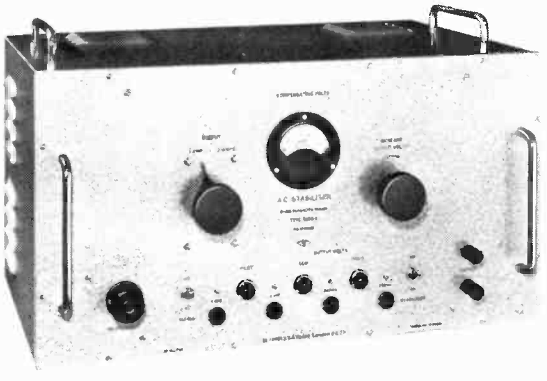

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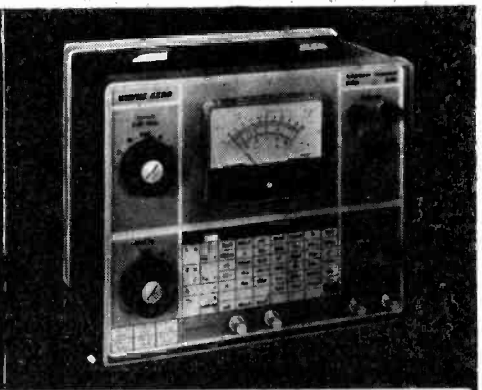

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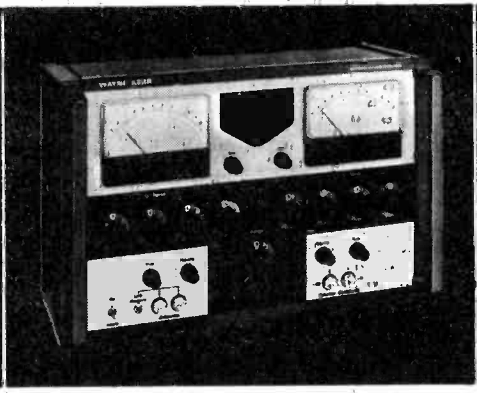

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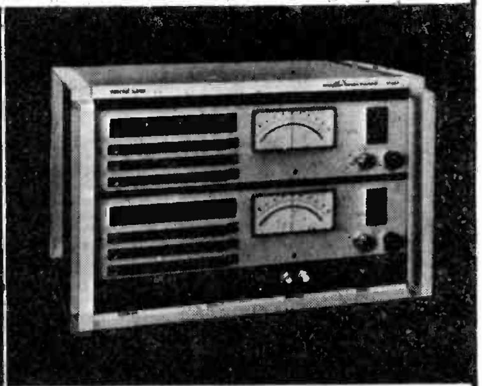

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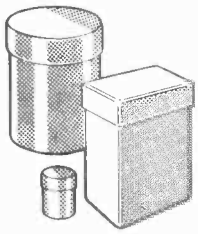

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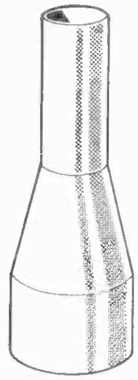

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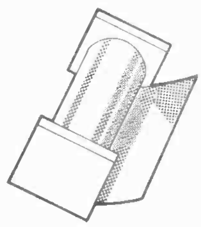

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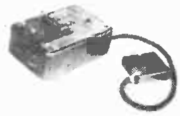

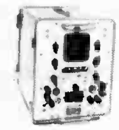

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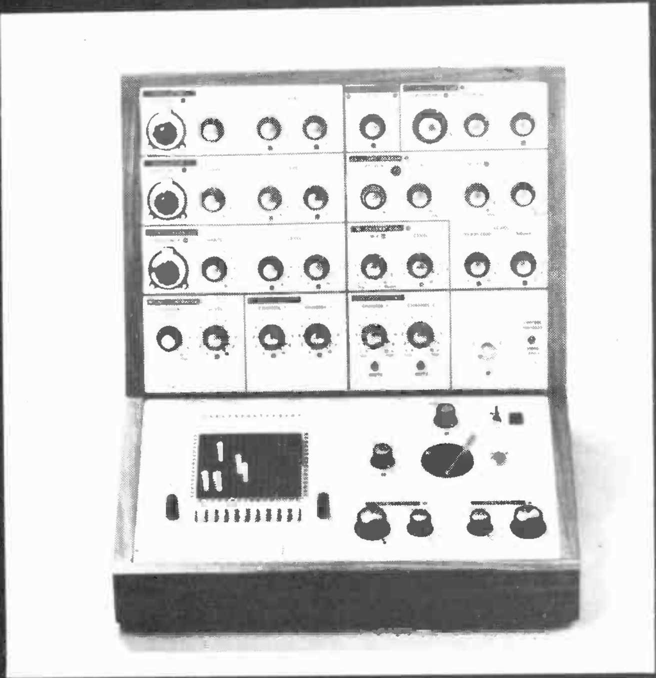

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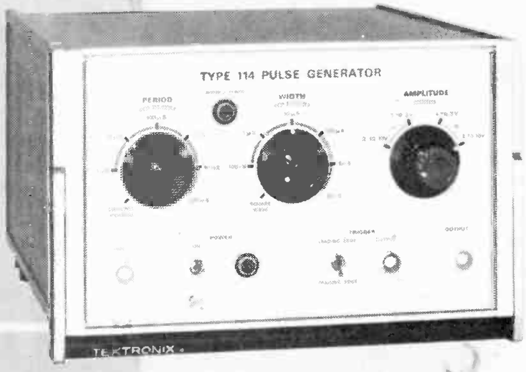

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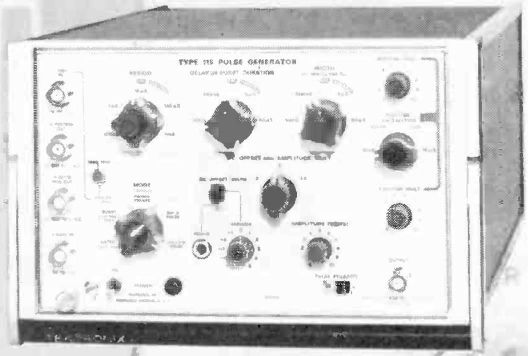

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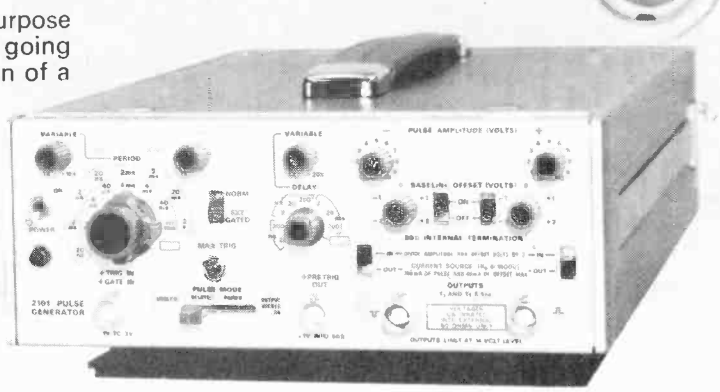

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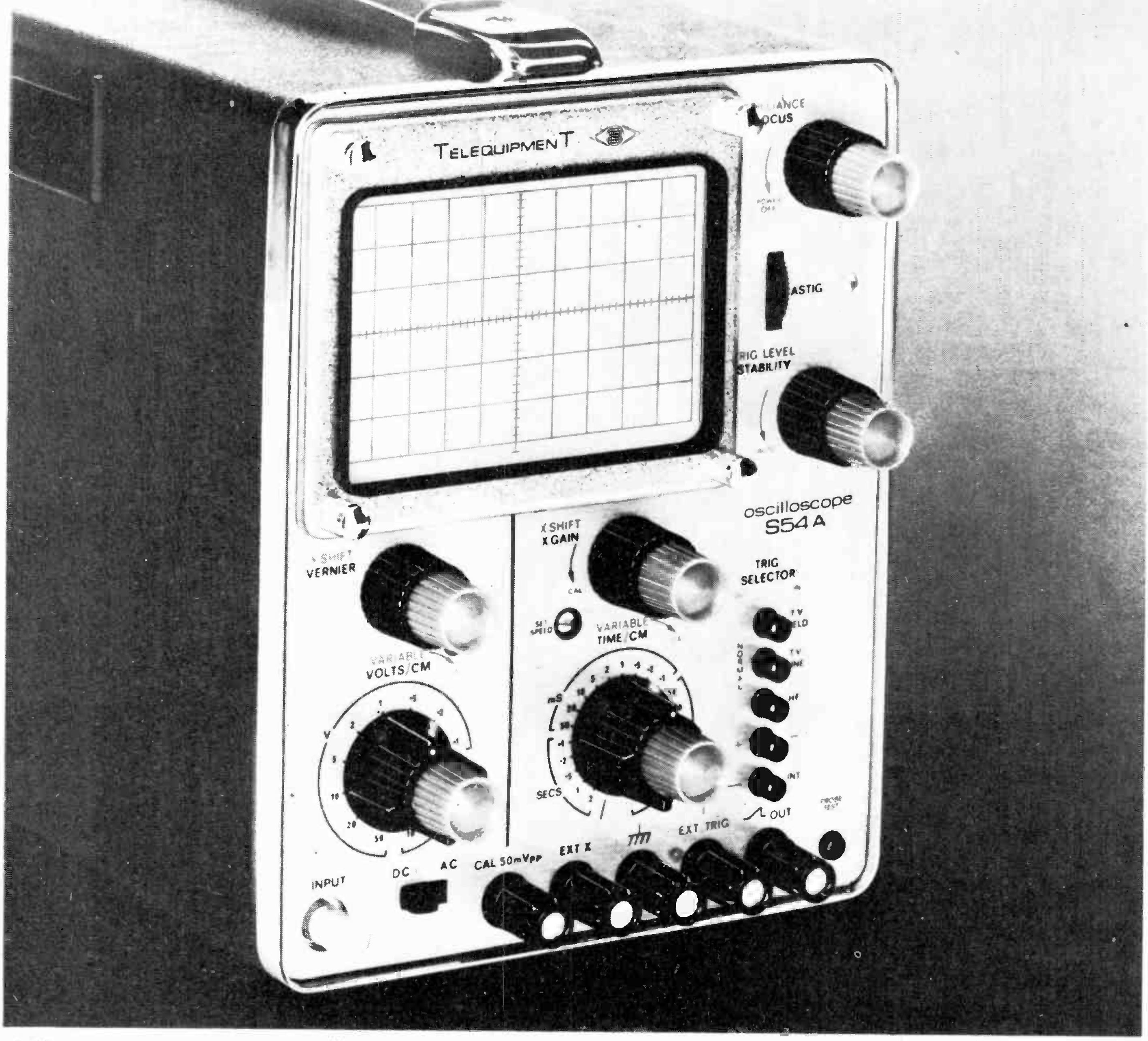

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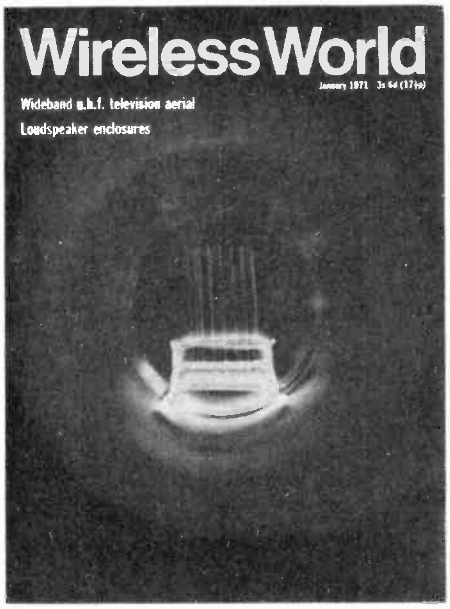
Electronics, Television, Radio, Audio

Sixtieth year of publication **January 1971** **Volume 76 Number 1423**



This month's cover picture depicts the high temperatures needed for semiconductor diffusion. It illustrates one of the 26 diffusion furnaces, which normally operate in the 900 to 1200°C range, at the Toulouse manufacturing plant of Motorola Semiconductors. Primarily used for the diffusion of integrated circuits each furnace has an output of at least 10,000 wafers per week.

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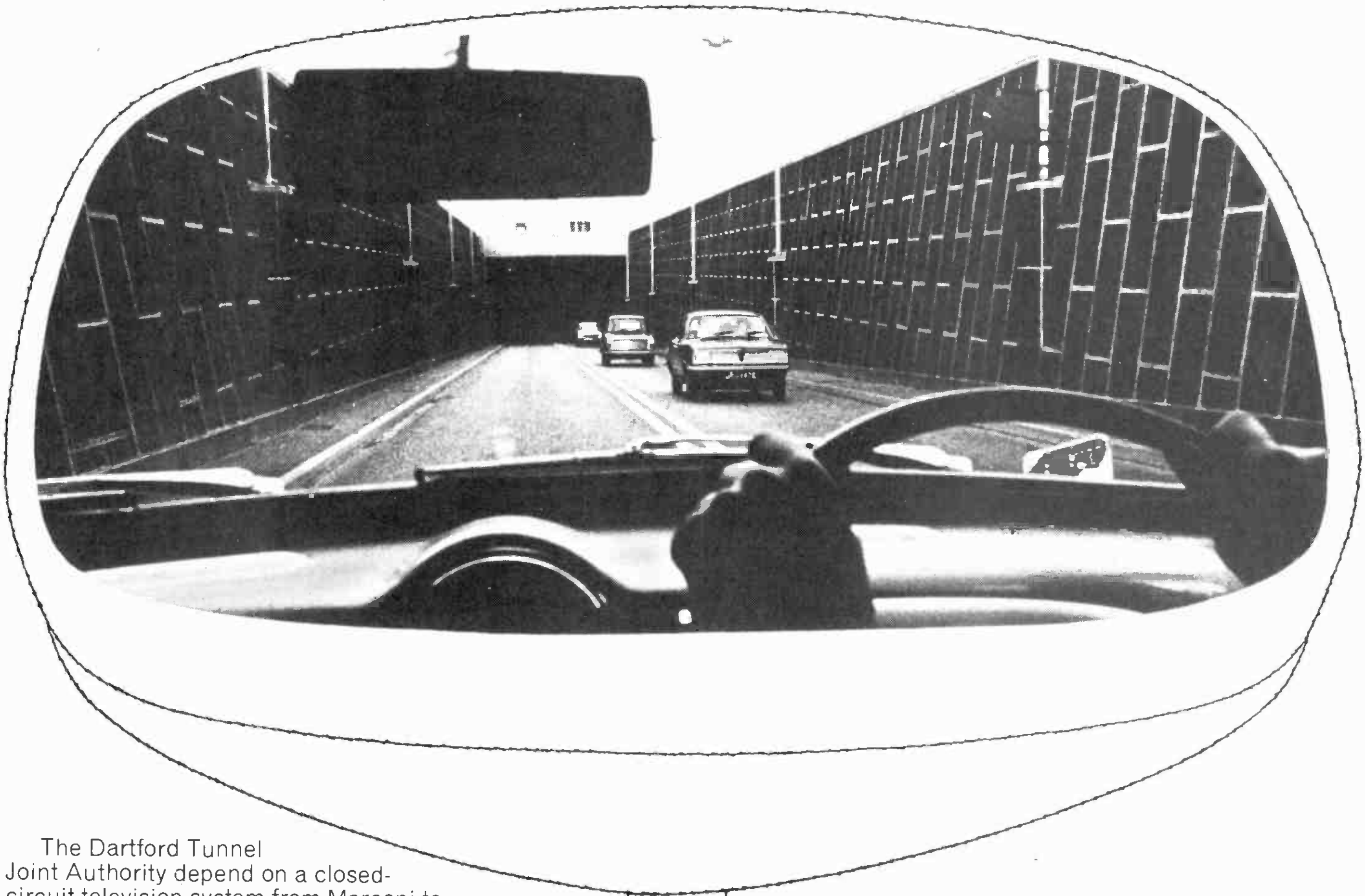

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Wireless World

Criteria for Frequency Allocations

Somebody pointed out to us the other day that, of the radio frequency spectrum below 1000 MHz (the most widely used, and useful, for equipment design reasons), over fifty per cent is occupied by television broadcasting. What is your reaction to this? If you have none, don't bother to read on. If you do react, you may clap your hands and say television is an excellent contribution to our culture and this allocation is just as it should be. Or you may say 500-odd MHz is an unreasonable amount of space for a public entertainment that only occasionally rises above the trivial, and there are other services which could use it to much better purpose. In either case you will be alive to the fact that the division of spectrum space is basically a social matter. Many engineers get absorbed in the technical problems of allocation and tend to forget this.

New Year 1971 is an appropriate time to look at the radio spectrum because there is going to be quite a burst of official activity during the year. The E.B.U. will be holding a meeting in Britain at which it may be considering such things as the spacing of m.f. broadcasting channels. There is to be a world conference on space telecommunications, and the I.T.U. will be considering whether to start work on a new broadcasting frequency plan to replace the 1949 Copenhagen Plan. Within the U.K. there is the expected Government White Paper on broadcasting, while the Frequency Advisory Committee, a body representing interested users, has been woken from its slumbers and will be advising the new Minister of Posts and Telecommunications.

The recent argument in *Wireless World's* correspondence columns about a part of the u.h.f. band—which roughly may be summed up as amateurs vs. mobile radio—has been conducted solely on the level of technology and economics. The mobile radio manufacturers seem to be casting covetous eyes on some of the spectrum space at present occupied by amateurs, and are arguing that lack of frequencies will seriously inhibit technical development, sales and exports. The amateurs, defending their territory, are drawing attention to the value of the pioneering experimental work they have done in the past and are still doing. Both arguments are valid from their own limited points of view, which are views of utility. But it should be possible for any group of users to start with the fundamental attitude "we are a living section of the community, and we have a right to live, regardless of whether our activities are 'useful' or not". After this they must accept certain restrictions, imposed by socially determined laws. The radio spectrum is a natural resource. It is, of course, exploited for economic advantage by particular groups, but ethically it 'belongs' to nobody—or to everybody.

At present it is difficult to discern any guiding principle by which spectrum space is allocated, either nationally or internationally. Probably the shape of any given plan is determined by the relative strengths of the various lobbyists. To find some formula based on a measure of social value would certainly not be easy. How, for example, to weigh 8 MHz-worth of "Coronation Street" against 8 MHz-worth of ambulance radio communication? But it seems we are in fact quite willing to spend a lot of money on putting high quality brains to work on frequency allocations. What we question is whether delegations consisting exclusively of engineers and technocrats are the right ones for the job.

Loudspeaker Enclosures

Types of baffle and the acoustical laws governing their application

by E. J. Jordan

Few subjects lend themselves so readily to amateur experiments as do loudspeaker enclosures. Almost any configuration of wooden panels will provide some obstruction to sound radiated from the rear of the loudspeaker cone, and will therefore contribute towards the first and foremost function of the enclosure, i.e. to prevent the radiation from the rear of the cone cancelling that from the front. A multitude of baffle arrangements and techniques can be used, but for the purpose of this article it is helpful to start by showing the relationships that exist between the more frequently used types. To this end the reader is referred to the lineage chart Fig. 1.

The "daddy" of them all is the infinitely large flat baffle (a). The two simplest derivatives of this are the finite flat baffle (b) and by folding the sides, the open backed box (c). Completely sealing the back of the box gives us the popular closed box infinite baffle (d)—leaving a small opening in the enclosure walls, results in the vented or reflex enclosure (e). If the sides of the open backed cabinet are extended we have the basic form of a tuned pipe (f), which may be tapered (g), flared to form a horn (h), or resistively loaded to provide an absorbing transmission line (i). Pipe systems may be combined with vented enclosures to produce various hybrids (j) (k) and (l). Forms shown are diagramatic only. Pipes and horns are usually folded.

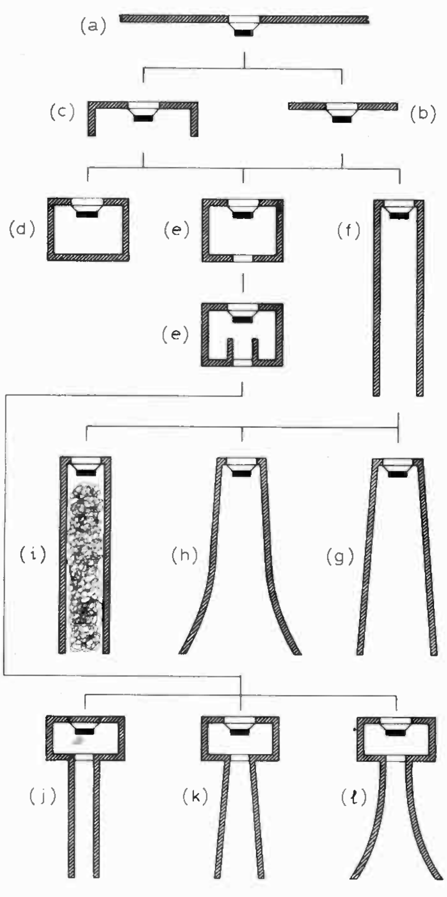


Fig. 1. The lineage of loudspeaker baffles.

These basic enclosure types have been with us for very many years, although variations of them are regularly re-invented. For example the closed box appeared in the "fifties" as the "acoustic suspension", what used to be known as the labyrinth has recently reappeared as the transmission line. No doubt sooner or later the flat baffle will be reincarnated as a "free field doublet".

Generally speaking enclosure systems fall into two broad categories. First there are those where the rear radiation from the loudspeaker cone is completely suppressed. The only two true examples of this are the infinite flat baffle and the completely closed box. Secondly there are the systems where the rear radiation is phase inverted, so that it is in phase with the radiation from the front of the cone and therefore augments it. Most types of enclosure, other than those just mentioned, fall into the second category although resistivity loaded systems such as (i) and (j) fall somewhere in between. We will now examine in detail the design and performance of each of the principal enclosure types and discuss their relative advantages.

Mechanical impedance

Any enclosure or baffle system will apply a mechanical impedance to the rear of the cone, and will appear as in series with the analogous circuit as shown in Fig. 2.

In the case of simple baffle systems, this impedance is due to the radiation impedance on the rear of the cone and is similar to that on the front of the cone. In all other systems however, the impedance applied to the rear of the cone is much higher than the radiation impedance and one of the major design considerations is the relationship between this impedance and the actual mechanical impedance of the cone. Before undertaking the design of an enclosure system, therefore, we must know the values of the cone impedance components. We may have the design details of the loudspeaker driver units in question, if so, well and good, but if we have to design an enclosure for a loudspeaker where these parameters are not available as is often the case, then we need some means of determining them. The techniques described below may be used to determine all of the low-frequency parameters of a moving-coil loudspeaker unit.

1. Measure the d.c. resistance of the voice coil R_{EDC}.

2. Plot the voice coil impedance curve subtracting from every reading R_{EDC}. The resulting curve will look something like Fig. 3.

3. This will represent the motional impedance Z_{EM} having a peak value at resonance of $Z_{EM\ peak}$.

4. To find the total moving mass (L_{Mt}), observe the resonant frequency (f_0) from the impedance curve. Apply a sufficient known weight (L_M) (a piece of plasticene) to

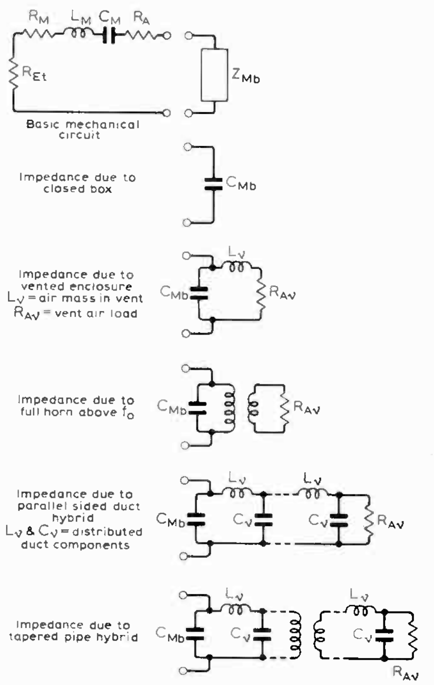


Fig. 2. Mechanical impedances applied to rear of cone by different enclosures. The impedance appears in series with the analogous circuit.

considerably reduce the resonant frequency (f_1). Then

$$L_{Mt} = \frac{L_M f_1^2}{f_0^2 - f_1^2}$$

5. To find the Q of the mechanical circuit (Q_M) find frequencies either side of the impedance peak on the Z_{EM} curve where the impedance has fallen to 0·707 of its maximum value. Let these frequencies be f_h above and f_l below the peak, then

$$Q_M = \frac{f_0}{f_h - f_l}$$

6. To find the equivalent electrical capacitive reactance X_{EM} due to the mechanical mass

$$X_{EM} = \frac{Z_{EM\,peak}}{Q_M} = \frac{1}{2\pi f_0 C_M}$$

7. To find transducing constant (Bl)

$$X_{EM} = \frac{B^2 l^2}{10^9} \cdot \frac{1}{X_M} \quad \text{where} \quad X_M = 2\pi f_0 L_M$$

$$\therefore\ Bl = \sqrt{X_{EM} \cdot X_M 10^9}$$

8. To find equivalent electrical inductance due to stiffness of suspension L_{EM}

$$f_0 = \frac{1}{2\pi\sqrt{L_{EM} C_{EM}}}$$

$$L_{EM} = \frac{1}{4\pi^2 f_0^2 C_{EM}}$$

9. To find compliance of suspension C_M

$$C_M = \frac{B^2 l^2}{10^9} \cdot \frac{1}{L_{EM}}$$

10. To find total closed circuit $Q(QT)$

$$Q_T = \frac{R_{Edc} + R_{Ea}}{X_{EM}}$$

$$= (R_{Edc} + R_{Ea}) 2\pi f_0 C_{EM}$$

R_{Ea} is the amplifier resistance, usually $\ll R_{Edc}$

Calculations 6–9 above are based upon the electro-mechanical relationships discussed in November's article.

The closed box

Sometimes known as an infinite baffle, the closed box completely seals off the radiation from the rear of the loudspeaker cone. The sealed volume of air acts as an elastic cushion adding a stiffness impedance to the motion of the cone. Obviously the smaller the box, the higher the stiffness. In the analogous circuit, it appears as a capacitive reactance and, as would be expected, its effect is to increase the bass resonant frequency, above its free air value. Normally the total circuit Q will also be increased.

Many modern small bookshelf loudspeakers employ this approach. In fact where a small loudspeaker with high power handling capacity is required, the closed box is the obvious solution. We must be careful however, in discussing *electrical* power handling capacity, when the real criterion is *acoustic* power handling capacity, i.e. not how much power we can put in, but how much sound we can get out. Therefore we should never consider power handling capacity without considering efficiency. The

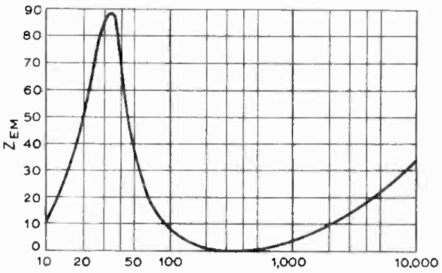


Fig. 3. Motional impedance circuit of moving coil loudspeaker in free air.

factor we are really concerned with is total available sound power over the required bandwidth. This is particularly relevant to small closed box systems, since in order to combat the rise in resonant frequency due to the enclosed air stiffness, the mass of the cone or diaphragm is usually made very high, resulting in a low efficiency system, even though as we shall see the Bl factor is normally increased to maintain a Q_T of unity at resonance. The inevitable mass of the cone and coil system limits the system to low frequency operation only, rendering the use of crossover techniques imperative.

An alternative to using heavy cones is to use a small cone. It can be shown that the impedance of any enclosure is proportional to the square of the cone area. The problem in this case however, is one of maintaining adequate power bandwidth down at the lowest frequencies.

The mechanical compliance (C_{Mb}) of an enclosed volume of air is

$$C_{Mb} = \frac{V_b}{\rho c^2 A^2}$$

where V_b is the volume of box in cm^3; $\rho = 1{\cdot}21 \times 10^{-3}$; $c = 3{\cdot}44 \times 10^4$ and A is cone area.

The effect of the enclosure on the free air resonant frequency and Q must be determined by considering C_{Mb} in series with C_M

$$Q \propto f_0 \propto \sqrt{\frac{C_{Mb} C_M}{C_M + C_{Mb}}}$$

In the majority of small closed box systems C_{Mb} is very much smaller than C_M and both Q and f_0 become substantially proportional to $1/\sqrt{C_{Mb}}$.

The overall mechanical closed circuit $Q(Q_T)$ is

$$Q_T = \frac{2\pi f_0 L_{Mt} R_{Et}}{B^2 l^2}$$

where R_{Et} is the total electrical resistance. From this, if $Q_T = 1$ then

$$B^2 l^2 \propto f_0 L_{Mt}$$

Maintaining this relationship, it can be shown that the mid-range efficiency ($\eta\%$) has the proportionality

$$\eta\% \propto f_0^3 V_b$$

Assuming the system is designed for maximum efficiency, i.e. there is no significant mechanical damping, then the above relationship is invariable for a moving-coil unit in a small closed box irrespective of whether the heavy cone or small cone approach is used. The point is, that any attempt to increase the mid-range efficiency by using a higher value of Bl than specified above will result in a value of Q_T lower than unity which in turn will give a *reduction* in the low-frequency efficiency. The effect of changing Bl is shown in Fig. 5.

Having stated the invariability of the relationship for a moving-coil unit in a small box we can now throw a spanner into the works by pointing out that the relationship can be broken by using *two* units connected in series. In this case, the Q will always be higher than unity irrespective of the Bl factor, therefore this may be increased as much as economics will allow, with the pro-rata increase in overall efficiency. Some mechanical means of controlling the Q must be used. One way of doing this is to fill the enclosure with absorbant material. This has the additional effect of increasing the effective enclosure volume by up to 40%.

Observations. One cannot speak of designing a closed box in the sense that the enclosure dimensions are calculated. There is no critical volume for any given unit, simply for a given low-frequency extension, the smaller the box the lower will be the efficiency.

A first class example of trading efficiency for size, is the Goodman's Maxim. Within the limits of its sound power, its performance is very comparable with much larger units. The general quality of the low-frequency performance from closed box systems can be superlative. The finest bass performance I have heard or measured, is provided by the well known American AR 3. Unfortunately it is almost inevitable that cross over techniques have to be employed

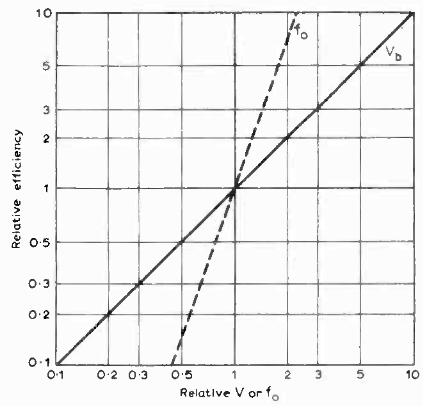


Fig. 4. Variation of efficiency with cabinet volume V_b and low-frequency limit f_0.

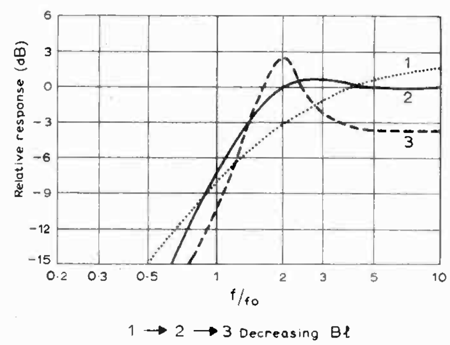


Fig. 5. Effect of Bl on response of small closed box.

in closed box systems, with the resulting problems discussed in the article in the November issue.

The vented enclosure

Sometimes known as reflex or phase inverter, the vented enclosure is in theory one of the neatest and most efficient forms of loudspeaker loading. In practice however, many reflex enclosure designs produce a bass response that wallows like a pregnant hippo in a mud bath. This is entirely due to incorrect design. Although no one ever seems to take any notice of anything I say I will once more cover this subject from the beginning.

The vented enclosure is closed except for the existence of a relatively small vent. Sometimes the vent is extended inwards by means of a duct. The enclosed air behaves in a manner very similar to that of the closed box, inasmuch that it provides an elastic cushion of air against which the cone has to work. The air in the vent or duct however, behaves as a mass which can "bounce" on the cushion, and therefore exhibits a resonant frequency of its own independently of the loudspeaker. When the air "brick" in the duct bounces on the cushion at its natural frequency, the reactive components are of course cancelled and the impedance to motion is only that provided by the friction of the sides of the vent, and the air load: the velocity is therefore very considerable.

When this resonance is excited by the loudspeaker cone, the enclosed air becomes subjected to compression and expansion by both the cone and the vent air mass, which at resonance operate in phase, i.e. moving into and out of the enclosure together. The effect from the point of view of the cone is that the stiffness of the enclosed air is increased enormously at this frequency, and the cone displacement is considerably reduced thus increasing the power handling capacity. The situation at the enclosure resonance therefore, is that the cone looks into a high impedance and the air load is fed mainly from the vent which is a low-impedance source.

This gives us the key to the correct way in which to regard the vented enclosure, i.e. as a matching device, matching the high mechanical impedance of the cone to the low impedance of the air load.

How then do we deal with the terrifying value of enclosure Q, which in a good system ought to be between 10 and 20? One frequently used technique, is to stuff a sock (or equivalent) in the vent and call it resistive loading. This means that the efficiency of the system is completely destroyed and the air load or the cone is considerably reduced. A better way is to introduce a leakage resistance in the enclosure walls. The acoustical resistance I described in an article in 1956* was an example of this. The ideal way however, is to use the loudspeaker itself. Imagine the vent and cavity in a condition of resonance. Forget for the moment that the loudspeaker is the energy source. From the point of view of the enclosed air, the loudspeaker constitutes an opening in the cavity wall. The cone can be driven in and out by the internal air pressures. In doing this, energy is dissipated in driving the cone against its own electro-magnetic damping. (We are assuming the coil is still connected to the amplifier). The lower the magnetic damping the easier it will be to drive the cone, i.e. the cone will constitute a more transparent cover over the hole in the enclosure wall and more energy will be dissipated. If, for example, the electro-magnetic damping were infinite, the cone would not move and there would be no energy dissipation here and, therefore, no damping.

Here then we have the interesting situation where if the enclosure Q is controlled by the loudspeaker Q, the one will be inversely proportional to the other, i.e. if we increase Bl to reduce the loudspeaker Q, the enclosure Q will increase. At some frequency above the resonance of the enclosure, the vent air mass will become too inert to move and the enclosure will behave as though it were completely closed. A resonance will occur exactly as described for the closed box. Radiation from the vent will be negligible. Below the resonance of the enclosure the vent air mass will be simply added to the mass of the cone and a further resonance will occur. The vent air mass will then be moving in anti-phase with that of the cone. The Q values of both the above secondary resonances will be a direct function of the loudspeaker Q.

We now have three resonant conditions to deal with, where the Q of two of the resonances is a direct function of the loudspeaker free air Q value, and one is an inverse function. Can we juggle this lot and get them under control? Yes, provided we accept the very important conclusion that the enclosure and loudspeaker unit are made parts of an integral design. In my early days in loudspeaker development, I was asked to "design a reflex enclosure for a 12 in loudspeaker", the Bl factors of which could vary from 10,000 gauss on a 1 in coil to 17,500 gauss on a $1\frac{3}{4}$ in coil. I actually did it and mused awhile on hippos.

The aim in the case of correct reflex design is to ensure that all Q values are at unity. It can be shown that this condition is met by letting $C_{Mb} = 0{\cdot}62C_M$, letting the free air Q of the loudspeaker be 0·62, and tuning the enclosure to the free-air resonance of the cone. The full approach is as follows

1. decide upon the required low-frequency limit f_0.

2. decide upon the mass and dimensions of the cone from consideration of the required overall power bandwidth and economics.

3. determine the compliance of the cone suspension system (C_M).

4. determine the volume of the enclosure air cavity (V_b) from:

$$V_b = \rho c^2 A^2 C_{Mb}$$

where $\rho = 1{\cdot}21 \times 10^{-3}$, $c = 3{\cdot}44 \times 10^4$, A is cone area sq cm, and $C_{Mb} = 0{\cdot}62\ C_M$.

5. design the magnet and coil system so that

$$Bl = \sqrt{\frac{2\pi f_0 L_{Mt} R_{Et}}{0{\cdot}62}}$$

6. design a vent and duct system to resonate with V_b at f_0. The basic equation here is

$$\frac{l + 1{\cdot}7 r_v}{r_v^{\,2}} = \frac{c^2}{4\pi V_b f_0^{\,2}}$$

where r_v is the effective radius of the aperture, and l is the length of aperture or duct.

If the aperture is not circular, then

$$r_v \doteq \sqrt{\frac{A_v}{\pi}}$$

where A_v is the cross sectional area.

It will be seen that there is an infinite range of values of l and r_v which will satisfy the above equation. The aim here is to make r_v as large as possible. It should not be less than about half the cone radius at the very least. The upper limit is set only by how big one can afford to make the box. It used to be said that it should not be longer than $\lambda/12$ at f_0. This is because of the danger of the pipe not behaving as a true mass. The implication of this will be discussed later. The volume of the duct system must of course be added to the enclosure to give the overall cabinet volume.

This approach will ensure that the system will be non-resonant and that maximum power bandwidth and power handling capacity is obtained from the system. The effect of varying Bl is shown in Fig. 6.

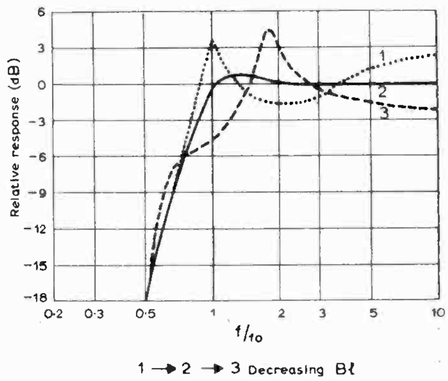


Fig. 6. Effect of Bl on response of vented enclosure.

Observations. In spite of their obvious advantages, vented or reflex enclosures are rarely used. There are various probable reasons for this. First there is the problem of having to design the loudspeaker and the enclosure specifically for each other. As far as I know, the design procedure described above is not generally used in spite of the fact that it was introduced in this country by my book† written in 1962. Certainly, I think, many incorrect designs have given the reflex enclosure a bad name. A further problem is that at subsonic frequencies the cone is virtually unloaded. This should not matter except where there is a high degree of turntable rumble.

The answer is, I would have thought, to use a better turntable, for even if the speaker can accommodate high-amplitude low-frequency swings, these will be using up available power in the amplifier. Another frequent source of high amplitude swing is the amplifier itself. Many transistor amplifiers exhibit a characteristic whereby if they

*Jordan, E. J., "Loudspeaker Enclosure Design", *Wireless World*, January and February 1956.

†Jordan, E. J., 'Loudspeakers', Focal Press.

receive a large low-frequency transient component in the signal, the h.t. voltage momentarily falls causing a near d.c. pulse to be applied to the loudspeaker. With a well designed reflex enclosure even with a small loudspeaker unit, adequate power bandwidth is secured with peak cone displacements due to the signal of not more than $\frac{1}{8}$ in. Where displacements are much higher than this, these are observed. It will usually be due to one of the problems already mentioned.

Seldom realized, but a very real problem with vented enclosures, is the need to provide a decorative grille cloth over the front of the enclosure. Since the output impedance of the vent is (or should be) extremely low, almost anything in the way of a covering will constitute a substantial impedance. This could easily halve the efficiency of the system, and further the high air velocities will cause the cloth over the vent to flop. For many years the only really satisfactory grille material has been expanded metal which does not appeal much domestically. However, there are now available synthetic materials having a rather complex pore structure, which renders them almost acoustically transparent, whilst being optically opaque. These materials provide an interesting decorative texture and come in a variety of colours. They are unfortunately rather expensive.

The pipe systems

The simplest of these is the parallel sided tuned pipe. This, like the organ pipe, will exhibit series of resonances and anti- resonances. By choosing an appropriate length, the lowest anti-resonance of an open pipe can be used to load a loudspeaker cone in a manner similar to a reflex, inasmuch as the cone will look into a high impedance at one end of the pipe and the air load will see a low impedance at the other. The length of pipe required for a cone resonant frequency f_0 is given by

$$l = \frac{3{\cdot}44 \times 10^2}{4f_0} - 1{\cdot}7 \text{ radius}$$

where all dimensions are in metres.

The problem here is the existence of the other resonances and anti-resonances which exist at all frequencies where the length of the pipe is an integral number of quarter wavelengths. It is not really possible to "kill" these without impairing the efficiency of the pipe.

An improved system, very popular many years ago, was the tapered pipe with the loudspeaker mounted $\frac{1}{3}$ wavelength down from the closed end. The taper tended to reduce the Q values of the resonances, and the position of the speaker was such as to remove the third harmonic resonance.

The labyrinth

This is a variation of the tuned pipe approach, where the pipe is heavily loaded with resistive material, thus eliminating its resonance characteristics. The system is extremely inefficient. The load applied to the cone is high and resistive, this tends to provide constant velocity operation requiring the application of the correct degree of bass boost from the amplifier. The loudspeaker must be capable therefore, of handling high power inputs. The advantage of the system is, that it is completely resonance free.

The horn

This can provide the most efficient form of loudspeaker loading, the efficiency being limited only by its physical size. Like the reflex enclosure the horn is an impedance matching device between the loudspeaker cone and the air load. However, the efficiency can be much higher and extend over a much wider bandwidth. The load applied to the cone by the throat of the horn is, basically very high, and resistive. It takes over the control of the cone so we are free to make *Bl* anything we like, limited only by cost. Three types of horn are encountered—conical, exponential and hyperbolic. These are determined by the particular flare law used.

In all cases the mouth diameter should not be less than $\frac{1}{3}$ wavelength at the lowest working frequency (f_0).

The rate of flare is determined by the flare law used, and f_0. In the case of the conical horn, the area A_x any distance (x) from the throat is given by

$$A_x = A_t x^2$$

where A_t is the throat area. The -3 dB point is given by

$$f_0 \simeq \frac{9x}{A_x} \quad \text{or} \quad x \simeq \frac{f_0 A_x}{9}$$

The impedance at the throat of an infinite conical horn is

$$Z_{A_t} = \frac{\rho c}{A_t}\left[\frac{(kx_t)^2}{1+(kx_t)^2} + j\frac{kx_t}{1+(kx_t)^2}\right]$$

where x_t = distance from throat to $A = 0$.

For similar overall dimensions, the exponential horn will extend the low-frequency limit by about three octaves compared with the conical horn.

In this case

$$A_x = A_t \varepsilon^{mx}$$

where $$m = \frac{4\pi f_0}{3{\cdot}44 \times 10^4}$$

and all dimensions are in cm.

The impedance at the throat of an infinite exponential horn is:

$$Z_{A_t} = \frac{\rho c}{A_t}\left[\sqrt{1-\left(\frac{f_0}{f}\right)^2} - j\frac{f_0}{f}\right]$$

The hyperbolic horn will gain about one third of an octave over the exponential horn. The flare is given by

$$A_x = A_t\left[\cosh\frac{x}{x_0} + T\sinh\frac{x}{x_0}\right]^2$$

where x_0 is the distance of the throat back to where $A = 0$, and T = shape factor (typically 0·6).

The low-frequency limit is given by

$$f_0 = \frac{c}{2\pi x_0}$$

and throat impedance by

$$Z_{A_t} = \frac{\rho c}{A}\frac{f_0}{f}\left[\frac{\sqrt{(f/f_0)^2-1}}{f/f_0-(1-T)} + j\frac{f/f_0}{f/f_0-(1-T^2)}\right]$$

From the throat impedance expressions, it is seen that in general horns apply a resistive air load to the cone above f_0 and a mass reactive load below f_0.

Observations. In spite of the fully documented theory showing the large dimensions necessary for the horn loading, there are horn systems much smaller than this that appear to work! It must be realized, however, that the efficiency of a full horn can be tremendous, i.e. of the order of 30–50%. This represents a gain of about twenty times higher than we are at present accustomed to, with modern loudspeakers. This may be very impressive, but do we need it? Is the average housewife going to accept a total of some hundred cubic feet or more in the shape of a loudspeaker system, so that hubby can use a one-watt amplifier, instead of twenty watts?

Further, a horn will only work over a restricted frequency range. Some other arrangements have to be made to deal with the middle and high frequencies. These again may be catered for with horn-loaded mid-range, and treble units, but this introduces many problems of coloration and distortion. Securing a good diaphragm/throat match is extremely difficult at higher frequencies, therefore, we need not be too ambitious with our horn design. If we can evolve a design whereby an efficiency of a few percent can be maintained at the lowest frequencies, whilst loading the cone to keep the power handling capacity up, then we shall be achieving as much as is required. This can be secured with relatively small horns. There is a problem in that a small horn will exhibit resonances similar to those in the tuned pipe, but this can be overcome by the use of hybrid systems which are now described.

The hybrids

There is an increasing number of these systems, from what I have read, and their designers are not always certain how they work. Being hybrids their manner of operation can be regarded from a number of points of view. Basically, the hybrid comprises a cavity coupled to a long duct. Varieties have appeared with straight sided ducts, and ducts which are tapered or flared in either direction. The most frequent analytical approach, is to place the emphasis on the duct design and regard the cavity as merely the coupling component to the cone. Another approach is to regard these systems as reflex enclosures with abnormally large ducts.

I propose to look at the system from both ends.

From the point of view of the loudspeaker cone, the hybrid provides loading conditions similar to those encountered in a highly efficient reflex enclosure, and the design approach is identical with the one we have set out. The difference arises when we come to determine the duct dimensions. In the hybrid the duct may be up to several feet in length with a pro-rata increase in its cross sectional area.

This offers a very great advantage over the conventional reflex enclosure, insomuch that very high volume velocities may be secured at the duct opening with relatively low particle velocities. High particle velocities may give rise to eddy current formation at the edges of the duct, in which case, the air moving into the vent will encounter a higher impedance than the air moving out resulting in a degree of rectification and consequent distortion. The use of a duct with a large cross sectional area reduces this, and increases the efficiency of the system.

Any duct will tend to resonate as a tuned pipe and in the case of the duct lengths being discussed, the resonant frequencies will be comparable to those due to the reflex mode of operation. Generally speaking, we need only be concerned with the lowest of these due to the fact that the cavity effectively decouples the duct above the enclosure resonance, so the higher duct resonances are not excited. What remains to be considered is that at the reflex resonance the air in the duct will not be operating as a pure mass.

This will give rise to three situations:

1. The resonant frequency of the enclosure will be modified. This can be countered by a readjustment of the duct dimensions.

2. The radiation from the end of the duct will be delayed in phase, but for the duct lengths under discussion, this will not be very significant and will favour the lower frequencies, i.e. the phase will move in retardation as frequency rises and the duct radiation becomes progressively unimportant.

3. The lowest of the duct resonances will be introduced into the system which could be dangerous, since there is no way of controlling it with the loudspeaker *Bl* factor.

This introduces us to the major problem of the hybrid—how to eliminate the lower resonances of the duct? The only thing that can be done is to introduce resistive material into the pipe. This however, tends to reduce the efficiency and throw away one of the principal advantages of the hybrid. The requirement is for the resistance introduced into the pipe to provide a high degree of absorption to pressure differentials within the pipe at the same time, offering a minimum resistance to the "through" air flow. Many compromise techniques have been developed to do this, but an almost perfect answer lies in the use of membrane absorbers. A membrane absorber consists basically of a layer of fibrous material covered with a thin impervious sheet, which acts as a membrane. If the membrane is subjected to air pressures it will compress the fibrous material and energy will be absorbed due to the mechanical friction between the fibres. This provides quite different absorption characteristics than would be obtained without the membrane.

In the latter case, energy is absorbed directly from air friction due to the air moving into and out from between the fibres which themselves are not displaced. Whereas a normal fibre-glass or wool lining becomes inoperative at low frequencies, the membrane absorber remains very effective and has the further great advantage that when used as a duct lining, the smooth surface of the membrane offers very little resistance to the through passage of air. It is a fact that if the cost can be accommodated, the membrane absorber provides a far more satisfactory solution to cabinet lining than the normally used materials.

We have so far been discussing a straight sided duct. Further advantages may be secured by using a tapered or flared duct such that the narrow end is at the cavity and the mouth feeds the air load. This is not only further reduces the losses and eddy current formation, but a further small increase in efficiency is secured due to the duct acting as a horn. The rate of flare must be determined from the expressions given in the section on horns above. A further advantage is that the load on the cone at very low frequencies is increased, due to the throat impedance.

Conclusions

It is a great pity that even in our writing, we tend to separate loudspeaker units from loudspeaker enclosures. It is just not possible to provide a satisfactory design for the one without considering in detail the other. In order to design a loudspeaker unit, it is necessary to settle one or two minor details such as how big to make the cone or diaphragm, and how heavy it should be. What should the maximum displacement be? The magnetic circuit and voice coil dimensions? The stiffness of the suspension? It is not possible to settle any one of these parameters without a detailed knowledge of the loading conditions. The correct approach to loudspeaker system design is first to specify the largest room volume in which the loudspeaker is to be used. From this can be calculated the required acoustic power to produce sound pressures that are consistent with the expected programme sources.

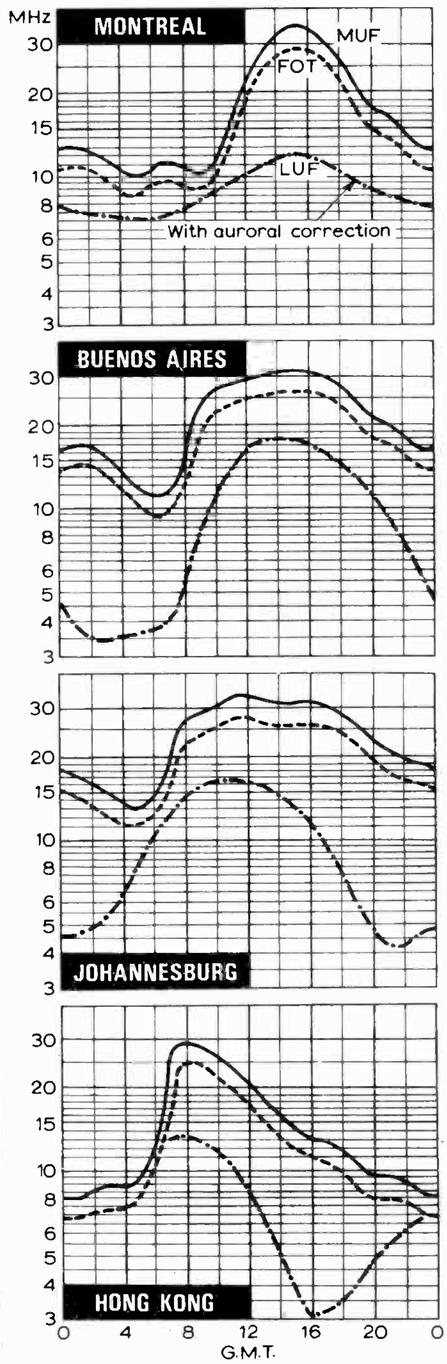
These sound pressures can be expressed in terms of the total volume of air that has to be moved into and out from the room; assuming the loudspeaker system is in the form of an enclosure, then the change of air volume in the room must equal the change in volume in the enclosure. The enclosure will have one aperture covered by the loudspeaker unit, it may or may not have one or more other apertures. The ingress and egress of air must take place through these apertures, and from this we can start to consider the relationship between the areas of the apertures (including the loudspeaker cone) and the air displacements through them. At this stage many other factors start to creep into the equations—the maximum permissible enclosure size, the available amplifier power, economics etc.

All this may be very obvious but it is the fundamental mode of thinking that ought to govern loudspeaker designers. I am not seriously proposing going through this exercise in detail every time, but the concept of the loudspeaker system being an enclosure that sucks and blows a predetermined volume of air is I think one which will start the designer off in the right direction.

H.F. Predictions—January

At the time of predicting there is no sign of a rapid decrease in the solar index so we can expect frequencies up to 25MHz to be of some utility particularly for transequatorial routes. A secondary MUF (maximum usable frequency) peak before dawn is a seasonal feature observed on some long-distance paths. Large day/night frequency differential is characteristic of winter conditions although low latitude routes of less than 2000km may have lower daytime frequencies than in the summer when propagation is via the E layer.

The LUFs (lowest usable frequencies) shown were calculated by Cable and Wireless Ltd for reception in the U.K. of point-to-point telegraphy. For other services the curves would be displaced vertically, the exact amount depending on service and equipment parameters.



U.H.F. Log-periodic Aerial

Constructional details of wideband aerial for television reception

by J. L. Eaton*, B.Sc., M.I.E.E. and R. D. C. Thoday*, M.I.E.R.E.

It is obviously desirable that viewers should use the type of television receiving aerial which gives the best results for their location. This usually implies the installation of an outdoor or loft aerial connected to the set with good quality coaxial feeder. Available field strength of the transmissions is only one of the factors which influences the type of aerial required. It must also be capable of discriminating against unwanted co-channel signals and delayed reflections over as wide an arc as possible. In some areas, discrimination against delayed reflections is the most critical requirement. Receiving aerials as supplied by manufacturers can be obtained with adequate gain and their directivity is normally adequate to give protection against co-channel interference.

Delayed reflections, however, need greater suppression in general if ghost images are not to be visible on the received television picture. Directional receiving aerials of the yagi type, which are the most common, tend to have side and back lobes in their horizontal radiation patterns which vary with frequency and therefore differ from channel to channel. At locations where delayed reflections are potentially troublesome it may be impossible to position a yagi aerial to give sufficient protection against ghosts on all the available channels. The log-periodic aerial on the other hand, although its gain is somewhat lower than a yagi of comparable size, can be designed to have a horizontal radiation pattern with extremely small back and side lobes, which remains constant over a wide frequency band. It is therefore especially suitable for areas of reasonable signal strength where delayed reflections are a particular problem. This article describes the design of a log-periodic aerial for u.h.f. television reception.

Log-periodic principle

Du Hamel and Isbell[1] predicted that a frequency-independent aerial could be designed by making its configuration vary periodically with the logarithm of the frequency; that is by giving it a log-periodic structure. The dipole type described in this article is only one of a number of possible configurations embodying this principle. A schematic representation of the log-periodic dipole array is shown in Fig. 1. The longest and shortest elements are made approximately half-a-wavelength long at the lowest and highest frequencies of the band to be covered. In operation the aerial has an active region involving a group of elements whose lengths are near to half-a-wavelength at the frequency of the incoming signal. At a given frequency in the band covered by the aerial three adjacent elements are fully active, the contributions from other elements falling off rapidly away from this region.

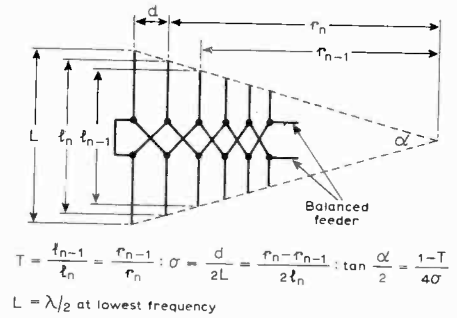


Fig. 1. Schematic representation of log-periodic aerial with dipole elements connected to balanced feeder. Longest and shortest elements are made approximately λ/2 at lowest and highest frequencies.

In this type of log-periodic aerial, all the dipole elements are connected to a balanced line; adjacent elements being connected in an alternate manner as shown in Fig. 1. The drive point of the balanced line is at the high-frequency end of the aerial, the other end being terminated in a short circuit behind the longest element. With this method of feeding the main lobe of the aerial pattern is in the direction of the high-frequency end. This means that an incident wave arriving in the main lobe passes over short non-resonant elements before reaching the active region appropriate to its frequency. Further, the signal from the active region travels along the feeder in the opposite direction, again only encountering non-resonant elements. Thus the pattern of the aerial is substantially that of the elements in the active region.

Two parameters (somewhat arbitrary) are required to define the aerial configuration, which specify the logarithmic spacing of the elements and the taper. The parameters T and σ defined in Fig. 1 are most often used for this type of aerial.

The design is based on data given by Carrel[2]. Optimum values for T and σ giving the best radiation patterns were arrived at by experiment; these were $T = 0.93$ and $\sigma = 0.17$. Calculation showed that these values of T and σ would give a gain of approximately 9.0dB relative to a dipole. The design bandwidth was made 2:1; slightly in excess of that occupied by channels 21 to 68 inclusive. This gave some

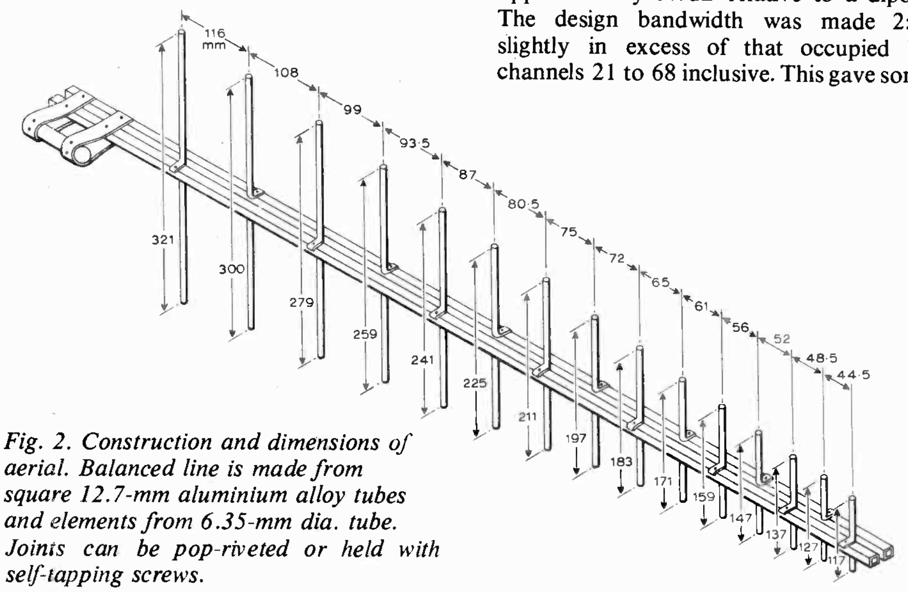


Fig. 2. Construction and dimensions of aerial. Balanced line is made from square 12.7-mm aluminium alloy tubes and elements from 6.35-mm dia. tube. Joints can be pop-riveted or held with self-tapping screws.

* B.B.C. Research Department

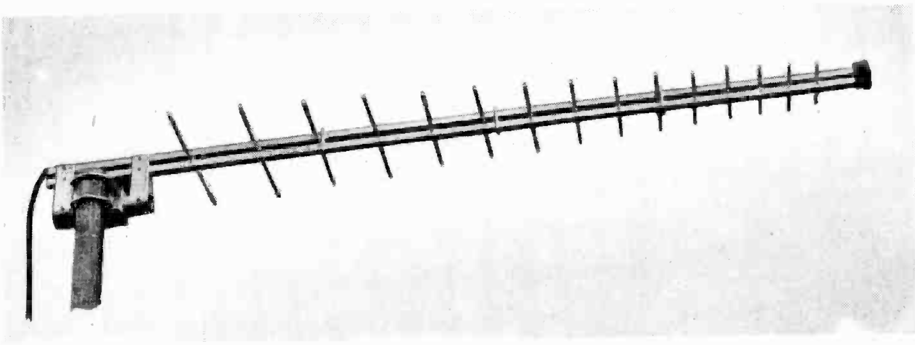


Fig. 3. Aerial and mount adjustable for either horizontal or vertical polarization.

latitude for possible deterioration of the aerial performance at both ends of the working range. Fifteen elements were required to obtain this bandwidth. All elements in the aerial were made from rod of constant cross-section and consequently it was necessary to make some allowance for the effective lengths of elements due to the variation of the ratio H/a (H is the element half-length and a its radius). The impedance characteristic is optimized by adding some shunt susceptance to the terminals of the transmission line.

Mechanical construction

Construction and dimensions of the aerial are shown in Fig. 2. The balanced line on the axis of the aerial is made from a pair of 12.7-mm (0.5-in) square cross-section, light aluminium-alloy tubes separated by 9mm (0.354in) between adjacent faces. (This is a standard size of square tube which is obtainable from metal merchants.) The elements are made from 6.35-mm ($\frac{1}{4}$-in) diameter aluminium-alloy rod flattened at one end and formed into a foot with a small turn-down as can be seen from Fig. 2. Elements are riveted with pop-riveting pliers to the square-section rods (rust-proof steel rivets are preferable). Self-tapping screws could be used in place of the rivets but the result would be less robust. The method for obtaining the alternating connection to the feeder can be seen in Fig. 2.

Aerial output is by way of an unbalanced feeder of 71-ohm characteristic impedance, carried through the centre of one of the balanced-line conductors to terminals at the drive point of the balanced line. Terminals are protected by a plastic moulding. Mechanical support for the aerial is provided by a bracket mounted on the balanced line behind the longest dipole element, which also acts as the terminating short circuit. This arrangement of coaxial feeder, balanced lines and short-circuit termination acts as a balanced-to-unbalanced transformer which minimizes the effect of pick-up on the outer conductor of the down lead. Fig. 3 shows the aerial with its normal mount which is adjustable for either horizontal or vertical polarization. The weight of the aerial, without clamps, is 1.02kg.

Discussion

Measured radiation patterns are shown in Fig. 4 for horizontal polarization and in Fig. 5 for vertical polarization. Although these patterns were measured at 650MHz they are typical of patterns at any frequency in Bands 4 or 5. Table 1 summarizes the pattern performance of the aerial over its entire frequency range. Fig. 6 shows a typical v.s.w.r. characteristic referred to a 71-ohm connector cable.

The C.C.I.R. template[3] for the recommended minimum directivity of u.h.f. receiving aerials is superimposed on the radiation patterns of the aerial in Figs. 4 and 5. The C.C.I.R. template is used as a criterion for planning purposes but greater rejection of signals from the back and side of the aerial than that implied by the template is necessary in certain areas to combat ghosting.

The E-plane pattern (horizontal polarization) meets this template although there is some transgression in the case of the H-plane pattern (vertical polarization). The aerial would therefore always be suitable for the reception of horizontally polarized transmissions, provided the gain is adequate. In general terms it will be satisfactory at locations having received field strengths in excess of 70dB (rel. 1μV/m). In situations where the received transmission is horizontally polarized but where the gain is marginal, the use of an aerial pre-amplifier could be considered, as the benefits of the very low back and side lobes would be preserved.

TABLE 1 Summary of radiation pattern performance

Frequency (MHz)	Half-power beamwidth (degrees) Polarization: Horizontal	Half-power beamwidth (degrees) Polarization: Vertical	Gain (dB rel. λ/2 dipole)	Minor lobes (dB below maximum field) Polarization: Horizontal	Minor lobes (dB below maximum field) Polarization: Vertical
450	27	34	8.6	26.7	23.5
500	26	32	9.3	33.2	33.6
550	26	33	8.9	30.0	25.6
600	26	32	9.2	34.4	31.5
650	26	32	8.9	30.2	30.0
700	27	34	8.7	27.0	25.0
750	27	35	8.4	25.0	25.5
800	26	33	9.0	35.5	24.0
850	26	33	8.7	26.0	24.0

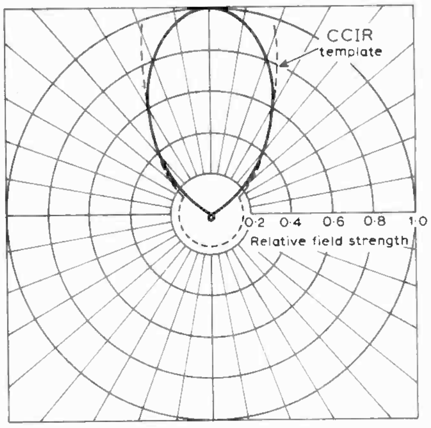


Fig. 4. Radiation pattern at 650MHz for horizontal polarization

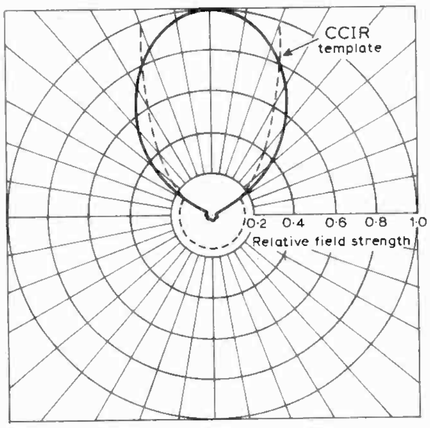


Fig. 5. Radiation pattern at 650MHz for vertical polarization.

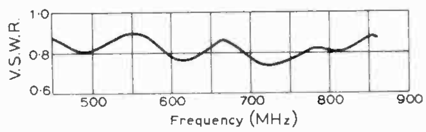


Fig. 6. Voltage standing-wave ratio referred to a 71-ohm connector cable.

For reception of vertically polarized transmissions the radiation pattern could be improved by using two aerials stacked side by side. In many situations where the transmission is vertically polarized, but where the advantages of low back and side lobes are needed, it is likely that the small transgression of the C.C.I.R. template will not be serious. The performance of the aerial indicates that the principal advantages claimed for the log-periodic form have been achieved, i.e. low back and side lobes and constancy of performance over all the u.h.f. television channels in use in the U.K.

We think there is a good case for introducing an aerial of this type to the public.

REFERENCES

1. Du Hamel, R. H. & Isbell, D. E. 'Broadband logarithmically periodic antenna structures'. *I.R.E. Nat. Conv. Rec.* March 1957, Part 1, p. 119.
2. Carrel, R. 'The design of log-periodic dipole antennas'. *I.R.E. Int. Conv. Rec.* Vol. 9, 1961.
3. C.C.I.R. Recommendation 419, Documents of the XIth Plenary Assembly, Oslo 1966, Vol. 5, p. 62.

Circuit Ideas

Voltage stabilizer

The "variable diode" (see for instance Peter Williams' letter to the editor, Feb. 1969) is a useful element for circuit work, and one application where it has been employed is in a stabilized power supply (Fig.1) used by the writer to provide a nearly constant 9V output from a nominal 12V car battery. The supply was found to vary from 12V to 14.5V under normal driving conditions and this was reduced to 9V ± 10mV by the

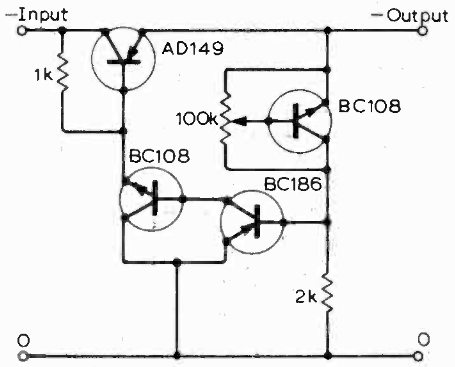


Fig. 1. Power supply giving 9V output from 12V input.

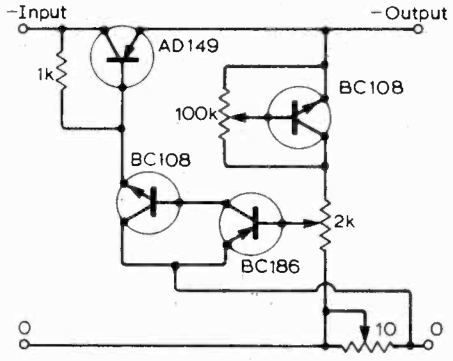


Fig. 2. Regulator with zero or negative output resistance.

stabilizer when supplying 150mA. The output voltage is also little affected by the output current, varying by less than 15mV when the output current varies from 0-150mA. The effective output resistance can be reduced to zero or made negative by modifying the circuit as shown in Fig.2. A negative resistance has been found to be desirable when a brush type d.c. motor, such as used in battery operated tape recorders, record players and model trains, must maintain a nearly constant speed regardless of variable mechanical loading. A single speed (3.75 i.p.s.) battery operated tape recorder was modified to provide an extra speed of 1.875 i.p.s. by operating the motor below its mechanically governed speed from the circuit of Fig.2. The sliders of the 2kΩ and 10Ω preset resistors were set to approximately mid. position for best results in the particular recorder used by the writer. The circuit would seem to be readily adaptable for many purposes, for higher or lower currents and for different transistors.

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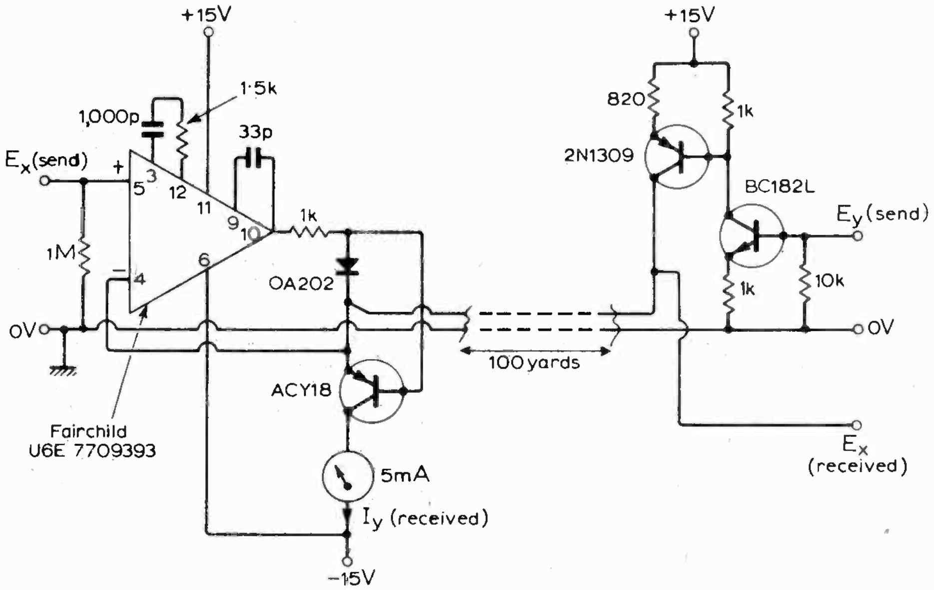
Northwood,
Middx.

Two-way d.c. along single wire

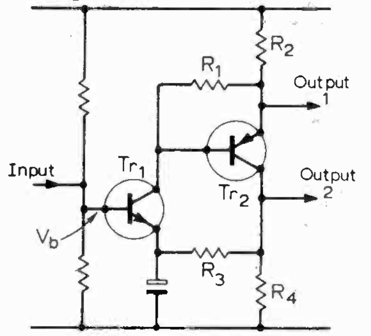
The need arose for two d.c. signals to be conveyed in opposite directions along each wire of a multi-way cable 100 yards long. For each wire there is a control signal of 0 to 5V d.c. terminated into a high resistance (1MΩ) and a return signal of 0 to 5mA. Using the circuit shown it was found that: (1) With a change of I_y from 0 to 5mA (which corresponds to a change E_y of 1 to 5V) the change in E_x was less than 20mV throughout the entire range of E_x from 0 to 5V. (2) With a change of E_x from 0 to 5V the change in I_y was less than 30μA throughout the entire range of I_y from 0 to 5mA.

R. C. ALCINDOR,
Canvey Island,
Essex.



Phase splitter

It may not be well known that the split-load phase splitter can be designed to have approximately the same output impedance at each output point. This is achieved by making the emitter side a bootstrap follower. A glance at the diagram makes the principle clear. If a voltage is applied to the emitter of Tr_2, very nearly the same voltage



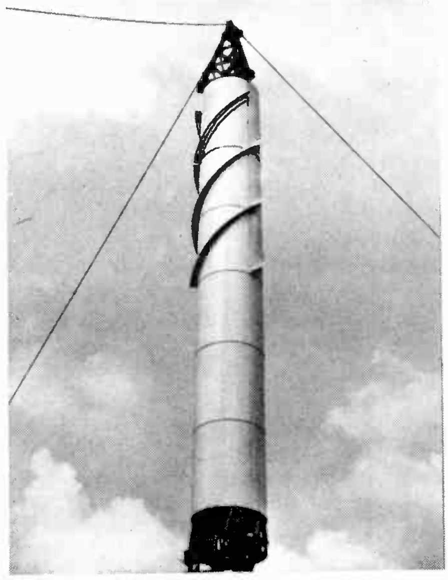
appears at the base of Tr_2, since the collector impedance of Tr_1 is much greater than R_1. Consequently very little current flows in Tr_2, and the output impedance is R_2 in parallel with a high resistance. The output impedance at output 2 is the parallel connection of R_3, R_4 and the high collector impedance of Tr_2. For balanced outputs R_2 is made equal to $R_3R_4/(R_3+R_4)$. If I_1 is the desired collector current of Tr_1, R_1 is taken to be $0.8/R_1$ amps (assuming silicon transistors). The collector current of Tr_2 is

$$V-0.8-I_1(R_3+R_4)/R_4.$$

The circuit has given good performance in a transistor amplifier, and is a useful alternative to the long-tailed pair.

L. R. SAUNDERS,
Auckland 3,
New Zealand.

News of the Month



The upper section of the television aerial system for the new mast at Emley Moor undergoing tests at E.M.I. The aerial system, which is 180ft long, will be hoisted up the centre of the 900ft concrete mast. The helical strakes are designed to reduce mechanical oscillation under severe wind conditions.

B.A.C. to assist with the re-usable space shuttle

The British Aircraft Corporation have signed an agreement which means that they will be starting preliminary design studies with the North American Rockwell Space Division on an international space shuttle as conceived by the American National Aeronautics and Space Administration.

The space shuttle is a two-stage, re-usable, transport system and consists of a booster (mother ship) which carries an orbiter piggyback fashion. The assembly is launched vertically as with today's rockets and the two craft separate at about 200,000 ft. The booster then drops away to land at an airfield using ordinary jet engines like a conventional airliner. The orbiter with a crew of two and twelve passengers, or the equivalent in cargo, continues into space to either place a satellite in orbit, to assist in building a space station or to dock at a completed space station. The orbiter then returns to earth to land at an airfield after a subsonic cruise through the atmosphere.

The role of the B.A.C. teams will be to assist in an investigation into structures, aerodynamics and flight test instrumentation. B.A.C's experience with the mechanical and electronic aspects of Concorde, Lightning, TSR2, Jaguar, Rapier, Swingfire, Thunderbird and Bloodhound as well as various space projects will be of great value to them in this project.

The work carried out on the project by B.A.C. will be paid for by Britain and one is bound to ask what the returns are likely to be. It is difficult to see any returns in the form of hard cash in the near future but the benefits in terms of increased knowledge and experience could be enormous. Spin-off from the research could bring benefits in all sorts of fields not even remotely connected with space research as new materials and techniques are developed. When the large scale commercial utilization of space begins then Britain will have the advantage of being in at the ground floor.

Using the space shuttle the cost of putting an object into space will be about one-tenth of that at present. This means that even small nations will be able to design satellites and the like and have them launched into space at minimal cost.

Space consortium

Seven European companies have agreed to collaborate in the field of international satellite programmes and have announced the formation of a new consortium. The new consortium brings together a group of companies whose capacities extend throughout the whole range of aerospace, telecommunications and electronic systems technology.

The members are: Marconi Space and Defence Systems Ltd, from the United Kingdom; Etudes Techniques et Constructions Aerospatiales (ETCA) from Belgium; Societe Nationale Industrielle Aerospatiale (SNIAS) and Societe Anonyme de telecommunications (SAT) from France; Messerschmitt-Bolkow-Blohm (MBB) and Siemens A.G. from the Federal Republic of Germany; and Selenia SpA from Italy.

Another British scientific satellite to be built

The Science Research Council, under the U.K./U.S. co-operative programme, is to finance a new scientific satellite project for the study of cosmic X-ray sources which will be known as UK-5. The satellite will carry six instruments, five to be contributed by British universities and one by the Goddard Space Flight Center of the N.A.S.A. In addition British scientists will be collaborating with several American astronomers to correlate X-ray observations from UK-5 with optical observations. The satellite will be the first in the Ariel series to use core stores in which all the experimental data will be assembled before transmission.

The Council will provide the finance and manage the project through its Space Research Management Unit. The Ministry of Aviation Supply will be agents for the Council and the Royal Aircraft Establishment, Farnborough, will be the research and development authority.

Marconi Space and Defence Systems Ltd will be the prime contractor for the space craft. In the Ariel III and the UK-4 projects they were the subcontractors for the common user electronics.

The satellite is scheduled for launch by the National Aeronautics and Space Administration using a Scout launch vehicle in 1973. The project, including the experiments but excluding the cost of the launch, is expected to cost more than £2M.

The UK-5 will be approximately cylindrical in shape and will be about 1m in diameter and a little under 1m tall. It will be spinning at about 10 r.p.m. and will be attitude controlled by a propane gas jet system directed by on-board logic units which will be programmed by command from the ground stations. The attitude control sub-system is based on designs developed by R.A.E., Farnborough, and the other common user sub-systems are based on designs being developed by Marconi for R.A.E. initially intended for the Black Arrow spacecraft.

Einstein's theory of relativity upheld

Experiments carried out by the American National Aeronautics and Space Administration using the Goldstone tracking station and the Mars Mariner-6 and -7 space craft so far appear to uphold Albert Einstein's theory of relativity. The theory stated that the velocity of light should apparently be slower in the gravitational field of the sun; this theory should also be true for radio signals.

More recent theories, namely by Drs. Charles Brans and Robert H. Dicke, put Einstein's predictions in error by between 7 and 10%. The delay of radio signals to the Mariner space craft were accurately measured once the Martian mission had been accomplished. The delay was 204 μ against a 200 μ prediction using Einstein's calculations. If the more recent theories were correct the delay would have been about 186 μ

Airborne systems monitor

The DC-10, a three-engined jet airliner due to come into service next year, will have some new instrumentation on board which has been developed by the aerospace division of Honeywell. Called the performance and failure assessment monitor (Pafam) the new equipment provides the pilot and first officer with a prediction of touch-down point on two-colour c.r.t. displays when the aircraft is under the control of the all-weather automatic landing system.

Using data from a number of the aircraft's systems Pafam calculates the expected touchdown point as much as 150 seconds ahead and displays it as a cross on a drawing of the runway on the c.r.ts. If the predicted performance of the auto-land system, and this means all the equipment which feeds the auto-land system as well, is not satisfactory a 'take over' command replaces the landing symbols and the pilot has the choice of landing manually or over-shooting.

These passive electronic tags can be attached to animals so that they can be accurately identified later. The tags are 'read' by a hand-held instrument which has a digital readout as described below.

Giving farm animals and baggage electronic identities

In the farming world it is generally accepted that if an animal can be individually identified throughout its life farmers can increase their efficiency by up to 20%. Branding, number tags, etc, have been tried but without a great deal of success for one reason or another. Apparently the problems are particularly acute with pigs.

A partner in an electronics firm, Cotron Electronic Ltd at Coventry, decided to search for an electronic solution to the problem. His efforts have resulted in a laboratory prototype of an instrument which is called an electronic tag identifier.

A passive electronic circuit, or tag, which consumes no power, is implanted in the ear or under the skin of an animal. An associated instrument indicates the number of the animal when brought into proximity with the tag. So pigs, and like creatures are about to be digitized like almost everything else in this world nowadays.

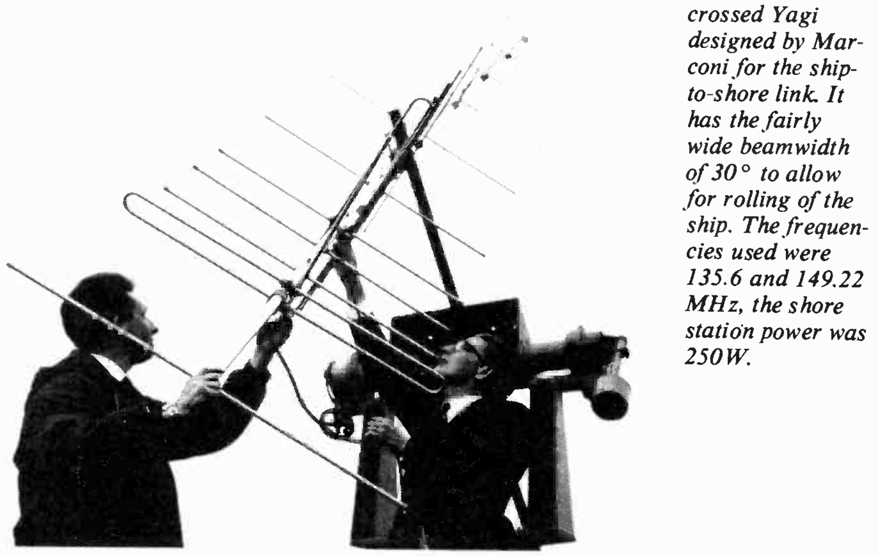
Cotron Electronics have succeeded in obtaining a National Research Development Corporation grant so that they can further develop the idea and put it into production. They foresee many other uses for their system in security, baggage control, on production lines, etc. The main advantage lies in the passive nature and very small size of the tags.

Readers of *Wireless World* may see other industrial uses for the device and if so Cotron Electronics (Red Lane, Kenilworth, Warwickshire, CV8 IPD) would like to hear about them.

Ship-to-shore via satellite communications experiment

A series of tests carried out by the Post Office to assess the use of satellites in ship-to-shore communications has been successful. Signals have been passed from the Post Office radio station at Burnham-on-Sea, Somerset, through an application technology satellite (ATS-3), made available by N.A.S.A., to the Cunard-Brocklebank container ship *Atlantic Causeway*. Only simple aerials were employed on the v.h.f. link and the use of Lincompex and Compandor speech processing techniques were tried out successfully. Speech, teleprinter, facsimile, data and selective call transmissions worked well over the link.

The major advantage to be gained in using a satellite for this purpose is that the link is only marginally affected by changing ionospheric conditions which can create havoc with conventional transmission systems.



The mutli-element crossed Yagi designed by Marconi for the ship-to-shore link. It has the fairly wide beamwidth of 30° to allow for rolling of the ship. The frequencies used were 135.6 and 149.22 MHz, the shore station power was 250 W.

Electronic gearbox

A gearbox which has no direct transmission of mechanical power from input shaft to output shaft, but instead a rack of electronics and a motor, is a typical example of the work of the Cranfield Unit for Precision Engineering. It was demonstrated, among other exhibits, at the official opening of C.U.P.E. by Lord Stokes in December. The gearbox typifies the Unit's work because it illustrates the use of advanced electronic techniques to do things which traditionally have been the function of mechanical engineering. In

Publication date

We regret that, as a result of a recent printing dispute, this issue is a fortnight late appearing and the February issue will be published on January 25th instead of the 18th.

this case the object was to develop a gearbox which was extremely accurate (e.g. no transmission errors due to gear-wheel machining) for a machine-tool drive application.

The basic principle of the electronic gearbox (which is the subject of a patent application) is to convert input shaft rotation into a sequence of pulses by means of an optical digitizer, pass these into a digital divider set to give the required gearbox ratio, and use the output to operate a phase control servo which includes an electric motor driving the output shaft. For servo operation the output shaft also carries an optical digitizer, and the gearbox incorporates an ingenious logic system which receives the pulses from the two digitizers and automatically corrects errors resulting from eccentricity in the mounting of the digitizer discs. Transmission errors are claimed to be reduced by a factor of 5 to 10.

C.U.P.E. is one of several industrial R & D units set up by the former Ministry of Technology at universities, and is on the campus of the Cranfield Institute of Technology, Bedfordshire. It is intended to bridge the gap between academic and industrial work in precision mechanical engineering, and at present has a bias towards machine tools and inspection machines. It does three main types of work-consultancy, investigatory and development programmes, design and development of prototype machines—and makes charges to enable it to be financially self-supporting. So far it has finished 24 projects and has 29 in progress. On a personal note, the principal research engineer, and a member of the management, is Jack Dinsdale, designer of the well-known 'Dinsdale' audio amplifier. He is well equipped for the job, for, besides being an electronics man of considerable experience, he is a graduate mechanical and electrical engineer.

Shoenberg memorial lecture

The Royal Television Society has announced a new annual lecture, the 'Shoenberg Memorial Lecture', to be sponsored by EMI. Each year, an internationally recognized authority will be invited to speak on a 'significant aspect of the television industry'. The subject covered by the annual lecture will reflect the growing involvement of television in almost every facet of modern life and the rapid and complex developments taking place throughout the world in methods, equipment, techniques and scope of application.

The decision to commemorate Sir Isaac Shoenberg in an annual memorial lecture is a practical tribute to a man whose work led to the development of the electronic television system used in the world's first high-definition public service in the U.K. in 1936. He was knighted in 1962 for his services in the development of both television and sound recording. The first lecture will be given in London on February 4th 1971 by Professor J. D. McGee and will be called 'The life and work of Sir Isaac Shoenberg'.

High-speed data link

The first of a new generation of Post Office leased data links is operating between an I.C.L. 4/50 computer at Bootle and a similar computer at Pudsey for the Midland Bank. The wideband system operates at a fixed speed of 48k-bits per second in both directions simultaneously and also provides two-way speech between the two terminals. Data are transmitted serially and at the 48k-bit rate the whole of the Bible could be transmitted in just sixteen seconds. Post Office leased data links are increasing rapidly; there are now about 12,000 data terminals operating at a slower rate in the U.K.

Exporting electrical goods

Most European countries have certain minimum standards regarding the quality of electrical goods that can be sold in that country. In some countries these standards are enforceable by law or, in others, they are applied voluntarily. The International Commission on Rules for the Approval of Electrical Equipment (CEE) have, until recently, insisted that approval tests should be carried out in two countries*. A revised version of publication-21 sets out new rules, called procedure-2, which states that a test report from one testing station is now sufficient.

We have two such test stations, or certification bodies, in this country. One is the British Electrical Approvals Board's Appliance Testing Laboratory at Leatherhead and the other is the British Standards Institution's Hemel Hempstead Test Centre. B.S.I. is the U.K. agent of the CEE.

The whole object of the new procedure is to speed up the granting of approval certificates, to make exporting easier and to help remove the trade barriers existing between European countries.

* CEE Publication 21, obtainable from B.S.I.

Television relay up-converter

Subscribers to television v.h.f. relay systems face a problem when they come to purchase a new receiver because most of the new receivers being produced are single-standard u.h.f.-only types.

Realizing this problem Teleng are producing a v.h.f. to u.h.f. converter which will allow single-standard u.h.f. receivers to operate from v.h.f. relay systems. The converter, which is contained in a plastic box 122 × 85 × 56mm (4.75 × 3.375 × 2.25 inches), consists of a wideband amplifier and mixer (with an overall gain of 4dB) which is connected between the relay aerial socket and the receiver's aerial input. The unit is mains powered and contains traps to eliminate 405-line signals. The converter will be available in a few weeks and will cost £8 10s. The type number is DN6328.

Microelectronics liaison unit

A new wing has been added to the Electrical Engineering Department of the University of Edinburgh greatly increasing the facilities the University has for research into various aspects of microelectronics. The new wing was made possible by a grant of £130,700 awarded to the University by the Wolfson Foundation under its technical award scheme. The existing microelectronics laboratories and the new wing is now called the Wolfson Microelectronics Liaison Unit and will foster the already strong collaboration between the growing number of science based industries in Scotland and the University.

The unit is aimed to help companies that lack adequate diagnostic services or whose research and development departments are overloaded with work and also assist them to tackle 'fringe areas' of microelectronics or likely speculative developments. Work is currently in progress on the following projects: amorphous semiconductors, silicon epitaxy, gallium arsenide epitaxy, growth of epitaxial films of cadmium sulphide, surface studies, integrated computer memories, microwave and h.f. devices, thin film thermistors, m.o.s. structures, electron beam technology, X-ray topography, lasers and holography, biomedical telemetry, m.o.s. circuit analysis and special purpose digital computing elements.

Come on now—speak English!

It is odd that since the electronics industry was founded on providing communications that one of its greatest problems is communications within itself. How easy it is when speaking of, or writing about, electronic devices to rely on jargon. The same old phrases are used over and over again, often five long words are used when two short ones would be better.

In a long-overdue recognition of this problem the Council of Engineering Institutions is including two new compulsory papers in its examination. These are 'The presentation of engineering information' and 'The engineer in society'.

Voltmeter using F.E.Ts Measures Capacitor Insulation Resistance

Voltage follower circuit gives teraohm input impedance and low offset voltage

by Lloyd E. MacHattie. BSc., Ph.D.*

A good review of voltage following methods appeared about two years ago in the pages of this journal[1]. As indicated, the ideal voltage follower is characterized by an infinite input impedance, zero output impedance and zero offset.

The field-effect transistor is the natural choice for the input device because of its inherently high input impedance. This can be raised further by feedback. Output impedance is made low by negative feedback, which may be further enhanced by positive feedback within the negative feedback loop[1,2]. Low offset voltage (output minus input voltage) is best ensured by using a balanced long-tailed pair to compare the input and output voltages[1,3]. Finally, a number of advantages will be realized by operation at constant tail current.

Basic circuit

These considerations lead to the type of circuit shown in Fig. 1. Transistor Tr_3 acts

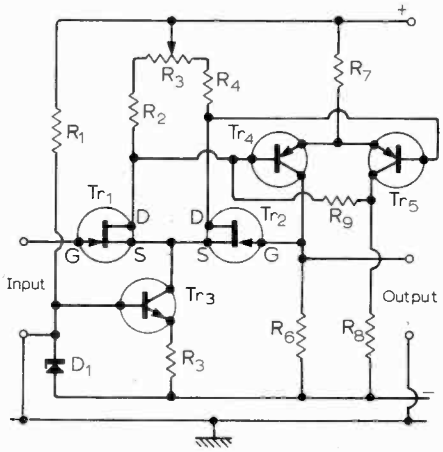


Fig. 1. Basic voltage follower circuit. Field-effect-transistor differential amplifier gives high input impedance with low offset voltage. Low output impedance is achieved by both negative feedback from Tr_4 collector and positive feedback from Tr_5 collector.

as a constant-current tail for the differential pair of f.e.ts Tr_1 and Tr_2 which drive a second long-tailed pair (bipolar transistors) complementary to the first. One second stage collector supplies the in-phase output which is fed back to Tr_2 gate while the other makes possible a simple positive-feedback connection R_9 around the second stage.

Matching

Transistors Tr_1 and Tr_2 should be matched, since freedom from temperature and supply voltage effects depends directly on similarity of characteristics. A method will be described which provides compensation for a certain latitude in characteristics, hence only selection for rough matching is necessary. The results given below were obtained from two low-cost plastic n-channel f.e.ts (2N3819) which required 0.68 and 0.81V source-to-gate bias to give the desired operating drain current of 230μA at about 5V. Examination of a number of these on a curve tracer revealed that mutual conductance at a given drain current tends to be fairly uniform from sample to sample although the required bias may vary rather widely. It would therefore appear that a pair could be effectively matched if a constant voltage device could be placed in the source lead of the higher-bias unit to make up the difference.

Fig. 2 shows a circuit which uses diodes to approximate constant voltage devices and is designed to accommodate bias differences of up to half a volt. Transistors Tr_7 and Tr_8 act as diodes in the source leads of the f.e.ts, the drop across one (Tr_8) being fixed while the drop across the other (Tr_7) is adjustable. R_{13} carries a constant current and provides the desired bias voltage between the bases of Tr_7 and Tr_8. The fact that many silicon transistors can be operated down to $V_{CE}=0.1$ to 0.2V before reaching saturation allows Tr_7 to exhibit a diode characteristic (V_{CE} vs I_c) which may be displaced by as much as 0.5V, with little change of shape, by changing the V_{BC} bias voltage.

If the two f.e.ts have been selected to have a bias difference less than 0.5V, they can now be adjusted to have equal currents (and nearly equal mutual conductances) with their gates grounded. But there is a further source of unbalance which arises if the source-to-drain voltage is changed and the two f.e.ts differ in slope resistance. This effect can be cancelled by shunting the unit having the higher resistance with an appropriate resistor from source to drain (R_{12}).

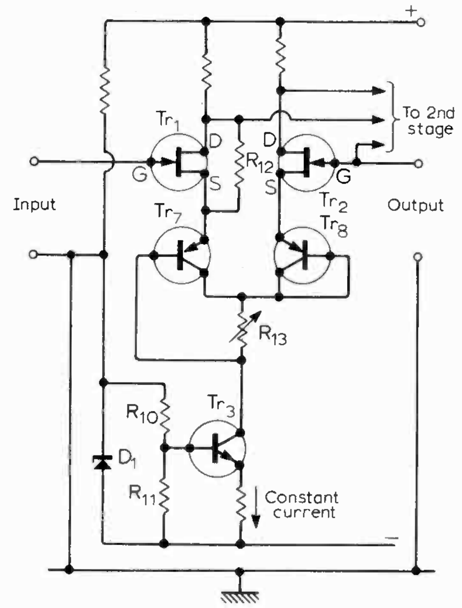


Fig. 2. Circuit compensates for bias differences by using diodes (Tr_7 & Tr_8) to approximate constant voltage devices.

To minimize the effects of any temperature gradients, Tr_1 and Tr_2 are mounted side by side and a coil of copper wire wrapped about the pair. Tr_7 and Tr_8 are treated similarly for the same reason.

Transistor voltmeter

The most direct method of using the follower as a voltmeter is to insert the follower between the source of voltage and the meter. This impresses the input voltage across the meter; consequently the lowest or most sensitive range cannot be less than the meter voltage drop at full scale.

Alternatively if the follower is used to determine the current through the meter, the most sensitive range may be reduced below the meter voltage drop, the new limit being the point at which the follower offset error becomes unacceptably large in relation to full scale. At the same time, any error due to variation of meter resistance with temperature is eliminated. A further advantage accrues in the case of alternating voltage measurements. The follower is made to control an alternating current which is then passed through the meter in rectified form. The circuit is shown in Fig. 3.

*Defence Research Establishment, Toronto, Ontario

Switching requirements are simplified by leaving the bridge rectifier in circuit for direct voltage measurements. As a result polarity selection is automatic. A momentary push-button switch is provided for interrogation if polarity is not already known. When this switch is closed the needle deflects up the scale for positive input and down the scale for negative input. With such an arrangement a direct voltage measurement is not affected by a superposed alternating voltage unless the peak alternating value exceeds the direct value. When this cannot be prevented by the usual low-pass filter in the input circuit, extra meter switching may be warranted.

The circuit shown omits the input range divider, function switch, etc., since there is no need to deviate from standard practice in this section. The follower is designed to accommodate input ranges of 0 to ± 0.5V for voltage measurement and 0 to + 1.5V for resistance measurement (which allows use of a dry cell). A 22-V battery supplies the follower circuit through a simple emitter-follower regulator with a zener reference. Additional zener stabilization is provided for the constant-current transistor Tr_3. The low total current drain of 1.8mA is made possible by the use of transistor emitter-base junctions for the zener diodes[4]. These retain good regulation down to about 5μA. Incidentally, when a transistor is used as a zener, the collector should be left open circuit and not connected to the base, as there are some types for which the e-c characteristic may be lower than the e-b characteristic or the two may cross.

In several cases a specific transistor type has been used, not because it was uniquely suited to the application but because it was adequate and conveniently available. An exception is the 2N3563, found to have lower zener voltages than any of the other types examined and is preferred for the constant-current reference. Depending on the particular zener voltage used, Tr_3 emitter resistor may require adjustment to obtain satisfactory operating conditions. With input shorted and the meter on zero, Tr_5 collector should lie between, say, −0.5 and +0.5V.

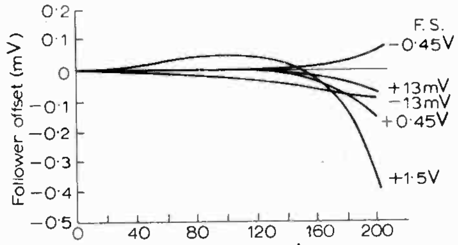


Fig. 4. Plot of offset voltage vs meter current for five scales (± 15mV, ±0.5V and + 1.5V) by changing R_S shows total variation in offset is within 0.1mV on ± 15mV scales. This shows feasibility of a ± 5mV scale at ± 1% error.

Resistor R_S determines the sensitivity of the follower and meter combination. Its value for direct voltage scales is given by

$$R_S = \frac{\text{full scale voltage at follower input}}{\text{full scale meter current}}$$

while for sinusoidal alternating voltages an additional factor of $(2\sqrt{2})/\pi$ must be applied in order to increase the reading from the average rectified value (to which the meter responds) to the desired root mean square value.

At zero input to the follower, the positive feedback resistor carries about 10μA. Resistor R_{15} is intended to carry an equal current and thus maintain symmetry between Tr_1 and Tr_2. Omission of R_{15} would not be serious as its benefit is only marginal. The small capacitor across the rectifier bridge supplies high-frequency negative feedback. Without it, operation becomes noisy in a narrow region near zero where the germanium diodes are non-conducting, with the result that the meter cannot be set to zero.

The zener voltage of D_1 will vary a certain amount because its current must change by twice the full scale meter current. Fortunately, it is a simple matter to prevent this from appreciably affecting the current in Tr_3 by introducing feedback from Tr_5 collector to Tr_3 base via R_{16}. The positive feedback is adjusted by means of R_9 so that the offset voltage variation over the operating range of the follower is at a minimum.

Voltmeter performance

Fig. 4 shows results obtained with a 200-μA 1200-ohm meter and with the same positive feedback setting for five scales: ±15mV, ±0.5V and +1.5V. Offset values were measured directly with a digital voltmeter reading to 0.01mV. (The inputs to the follower, for all but the + 1.5V (ohms) range, were 10/11 of the values given because a $\times 10^6$ probe was used with a $\times 10^7$ range divider.) Total variation of offset is within a 0.1mV range for the ±15mV scales. It therefore appears feasible, if we accept a ±1% error due to offset, to have ±5mV scales, whereas the meter drop at full scale is 0.24V.

When measuring alternating voltage, this follower circuit and meter exhibit a flat response from 10Hz, the lowest frequency which the meter will average satisfactorily, to over 100kHz. Response is down 3dB at 320kHz. A consequence of the rectified average response is that alternating voltage readings are relatively insensitive to the zero setting.

Output impedance

Fig. 5 demonstrates the output characteristics of the follower. To obtain these data R_S was disconnected and Tr_4 collector connected to Tr_2 gate, shorting out the rectifier bridge and meter. Offset voltage is shown as a function of external current fed into or drawn from Tr_4 collector. The three curves are for three values of input voltage to Tr_1 gate. Slope of the central portion is slightly negative in this case (−0.75 ohm) but can be made zero or positive by adjusting the positive feedback (R_9). Again in the central portion, the ±0.45-V curves may be moved vertically to make either one coincide with the zero curve or with the other by adjusting the shunt across Tr_1 or Tr_2, but curvature prevents coincidence of all three. The optimum adjustment is when the ±0.45-V curves coincide. The breadth of the central region can be increased or decreased by using more or less current in Tr_4 and Tr_5 by changing R_6, R_7 and R_8.

Input impedance

Method adopted for measuring the input current was as follows. With the follower connected as a voltmeter (without any input divider), a polystyrene capacitor C was placed across the input. After the voltmeter

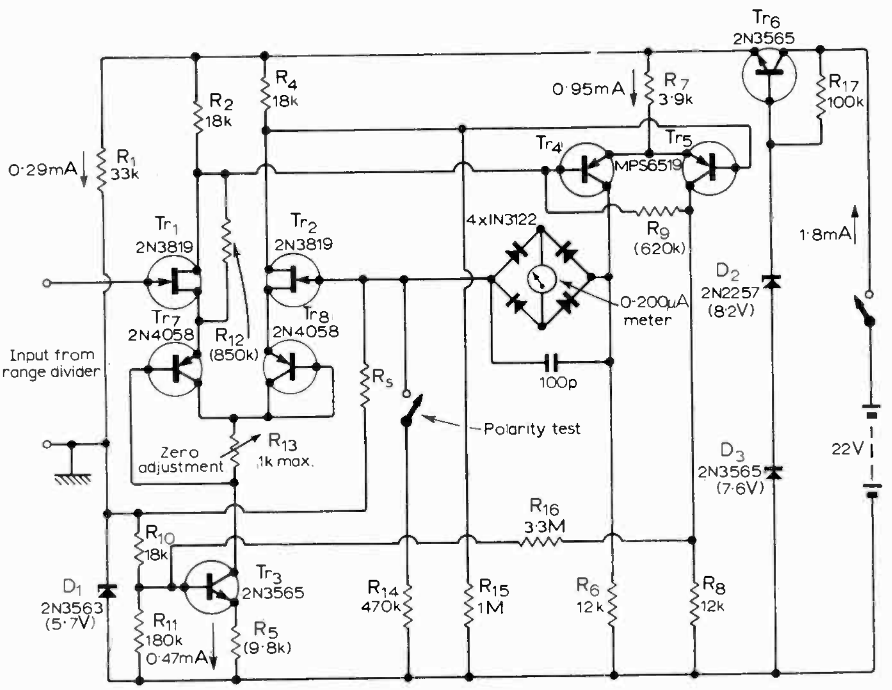


Fig. 3. Circuit of follower voltmeter. Input range divider and function switch omitted. Leaving bridge rectifier in circuit for direct voltage measurement simplifies switching. Rs determines sensitivity. Values in parentheses depend on semiconductor devices used.

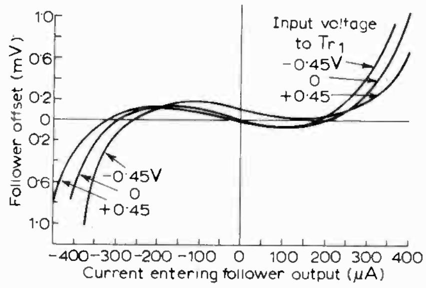


Fig. 5. Follower output characteristics for three values of input voltage. Slope of central part is altered by adjusting R_9. Curves for ±0.45V are moved vertically by adjusting Tr_1 shunt and breadth altered by changing R_6, R_7 & R_8.

was set to the desired value by momentary connection to a variable voltage source, the rate of drift of the reading $\Delta V/\Delta t$ was observed. If, as was found to be the case, the capacitor leakage and dielectric absorption are negligible, the capacitor must be receiving a current $C\Delta V/\Delta t$, when the input is floating. When the voltmeter is connected to an external voltage source, this same current becomes the input current, with the sign convention that the current be positive when it flows out of the voltmeter. The observed value, 2×10^{-12}A, decreased linearly as the input voltage was raised which meant that the voltmeter input appeared (over the −0.5 to +0.5V range) as +10 volts behind 5×10^{12} ohms.

Feedback

As the input impedance could obviously be raised still further by feeding back a current which would largely cancel the input current, an attempt was made to find out how much improvement could actually be realized in this way and how reproducible the results were. Feedback current was obtained by impressing a drop of several volts across the reverse-biased junction of a f.e.t. similar to Tr_1. This voltage, which must vary as the input current varies, may be represented by $a+be_{in}$ where e_{in} is the input voltage to Tr_1 gate while a and b are constants which are adjusted to cancel the input current at two points, one near zero and the other near full scale. Values arrived at were $a=-3.8$V and $b=2.6$V.

The circuit used is Fig. 6. Values of a and b are adjusted by R_{18} (which varies both) and R_{19} (which varies chiefly a). Settings could be made such that the voltmeter reading would change by as little as 1% of full scale in 30 minutes with a 0.01μF input capacitor, but results were not reproducible. Measures were therefore taken to reduce or eliminate the influence of ambient temperature and humidity.

For subsequent measurements the voltmeter was put in an enclosure, operating several degrees above ambient, which maintained its temperature within ±0.1°C.

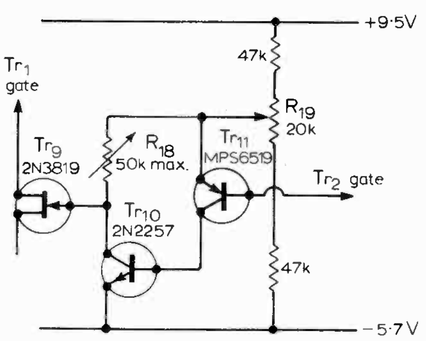


Fig. 6. Feedback circuit for raising input impedance. With this circuit voltmeter reading changed by only 1% of full scale in 30 min with a 0.01μF input capacitor (self time constant 400 days).

Guard ring

The chief effect of changes in humidity would likely be to change leakage currents flowing across the surfaces of insulators supporting the components of the input circuit. Such currents can be eliminated by the guard ring technique, which is particularly effective when the gain of the follower, as in this case, is accurately unity. Bands of conductive silver paint connected to Tr_2 gate were placed around the input turret lugs on both sides of the circuit board and around Tr_1 gate lead on the plastic transistor case, as well as around the middle of the input capacitor and the drain and source leads of Tr_9. The input lead was a stiff wire supported only by the circuit board and extending almost to the centre of a hole in the metal instrument case. Shielding afforded by the instrument case was necessary, otherwise readings could be affected, for example, by shuffling one's feet.

Input impedance stability

With the above precautions and after near optimum adjustment of R_{18} and R_{19}, a series of measurements of input current was made, extending over a period of two weeks, to test for reproducibility. Drift runs are shown in Fig. 7. To speed up the measurements these were made with a 1250pF input capacitor. A more or less random component persists and description of the input characteristics in terms of a resistance and a voltage value would not be particularly apt. Input current remains within the limits $\pm10^{-14}$A over the range 0 to +0.45V, and that compensation has reduced the input current by a factor of 200.

In lieu of temperature control, temperature compensation could be applied without much difficulty to the circuit of Fig. 6 to bring the temperature coefficient of the input current within $\pm10^{-15}$A/°C. Diodes introduced in series with R_{18} would make the temperature coefficient more positive while diodes in series with the upper end of R_{19} would make it more negative.

Application

With such a high impedance voltmeter it is possible to measure the insulation resistance of the best capacitors, some of which are nowadays very good indeed, the 0.01-μF polystyrene capacitor mentioned above, a component available in Toronto for 20 cents (1s 6d), proved to have a self time constant of 400 days. It was initially charged to +0.45V and its voltage measured

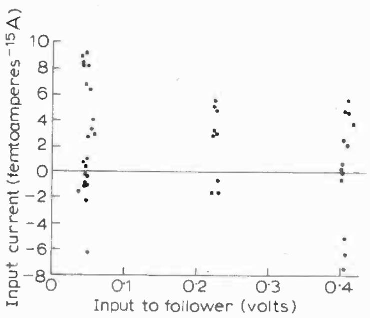


Fig. 7. Measurements of follower input current over two-week periods show input current is within $\pm10^{-14}$A and that compensation reduces input current by 200.

daily, using the voltmeter with the 1250-pF input capacitor. The capacitor being measured was handled only by its ground lead and for a measurement its hot lead was touched momentarily to the voltmeter input after the latter had been preset at the expected reading. In this way a voltage reading could be made without appreciably changing the charge on the capacitor. During eight days when the relative humidity ranged between 45 and 60%, the capacitor voltage decreased by not quite 2%. Corresponding value for the insulation resistance is 3.5×10^{15} ohms.

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2. Miller, J. M. "Combining positive and negative feedback". *Electronics*, March 1950, p.106.
3. Towers, T. D. "Balanced transistor d.c. amplifiers". *Wireless World*, August 1968, p.269.
4. Williams, P. "Ring-of-two reference". *Wireless World*, July 1967, p.318.

Eventful History

A History of the Marconi Company, by W. J. Baker. The history of a company can make dull reading for all but those who have been associated with its development, but this cannot be said of the history of the Marconi company for inextricably woven into it is the fascinating story of the development of wireless and its off-spring electronics. The book opens with a brief résumé of scientific discoveries setting the scene for the founding of the Wireless Telegraph & Signal Company (as Marconi's was first known) in 1897. The author, who has been with the company since 1952 and is now technical editor (research), stresses that the book is not a product of company sponsorship nor was commercial censorship exercised and it therefore records the setbacks as well as the successes. A selection of the chapter headings will give some idea of the variety of subjects covered in this very readable, lively review of the ups and downs in technical as well as commercial enterprise: Tuning: a great step forward; The invention of the diode; The directional antenna; 'The Marconi scandal'; The start of sound broadcasting in Britain; Short-wave beam system; Wireless and aviation; Evolution of radar; and, after two chapters covering World War II, the concluding six or more chapters deal with the developments in radar, aviation, sound and television broadcasting and communications in the period 1945-65. Pp. 414; 23 illustrations plus diagrams. Price £5. Methuen & Co. Ltd, 11 New Fetter Lane, London E.C.4.

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

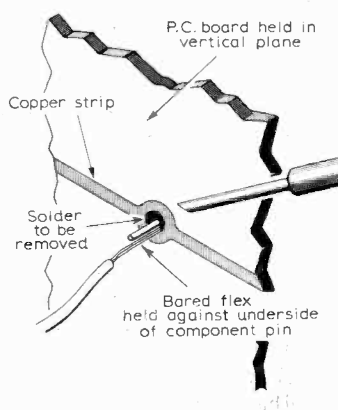
was quite deliberately "impressionistic" and linked to the layman's everyday experience of voltage.

I am surprised at Mr. Smith's statement that components obeying Ohm's Law are "few and far between in the world of electronics". From a rough count I would say there are two or three hundred of them shown in every issue of your journal.
JAMES FRANKLIN

A desoldering tip

I was recently reading "TV Engineers' Pocket Book", by Hawker & Reddihough, when I noticed that no less than six pages are devoted to "servicing TV boards". Much of this is concerned with the awkward problem of removing components, particularly valve bases and i.f. transformers, that are mounted on a number of pins, each of which is individually soldered to the copper-foil circuit. To soften the solder on all of these joints simultaneously, without doing considerable damage, is difficult almost to the point of impossibility; even if one goes to the trouble of making such a curious modification to the soldering iron as is illustrated in Fig. 7 p. 224 of the above book. The other methods described, such as sucking or blowing the solder away pneumatically, or brushing it off with an old toothbrush, are, in my opinion, clumsy and not to be recommended either. They tend to scatter pellets of hot solder around.

There is, however, a method, in which capillary action and gravity are simultaneously enlisted, that I have found to be singularly effective. It has not been, to my knowledge, described anywhere, and I am sure it would be of value to many a gently perspiring technician. The illustration is self-explanatory.



The wire "brush" used should be of reasonably new and clean multi-strand flex, such as 23× No. 36 s.w.g. A 1 to 1½in. end should be stripped, gently twisted, and liberally treated with flux. The tip of the iron should be clean with, obviously, a minimum of solder on its surface. More than one application, using a fresh brush each time, may be needed if there is much solder on the joint and in the neck of the hole. But the result will be to leave the pin standing clear in the hole, and the surrounding foil with no more than a thin film of solder on it.

Finally, may I make a plea to manufacturers of p.cs to use translucent boards? By placing a small light behind the printed side the circuit can easily be traced from the component side.
G. W. SUTTON,
Cranleigh,
Surrey.

E.M.F. and the volt

I do not feel that James Franklin's article "Electronic Building Bricks, 5, The Electronic Circuit" in the October issue can be allowed to pass without comment.

He states, while talking about sources of e.m.f. that: "A strong electro-motive force will move more electrons in a given time than a weak electro-motive force.

"The unit by which this force is measured is the volt. Thus in a given circuit 2 volts will move twice as many electrons in a given time (cause twice the current to flow) as 1 volt".

To say this as a general statement is very misleading. It is true only if the source of e.m.f. is connected to a component obeying Ohm's Law, and let us face it these are few and far between in the world of electronics.

The definition of the volt is:

$$1 \text{ volt} = 1 \text{ joule/coulomb}$$

It is, therefore, a measure of the energy given to each one of the electrons as they pass through the source of e.m.f. A circuit may quite easily be devised where the application of two volts instead of one will have no effect on the current flowing. The only change being that each electron will have acquired twice as much energy.
ALAN E. SMITH,
Watford, Herts.

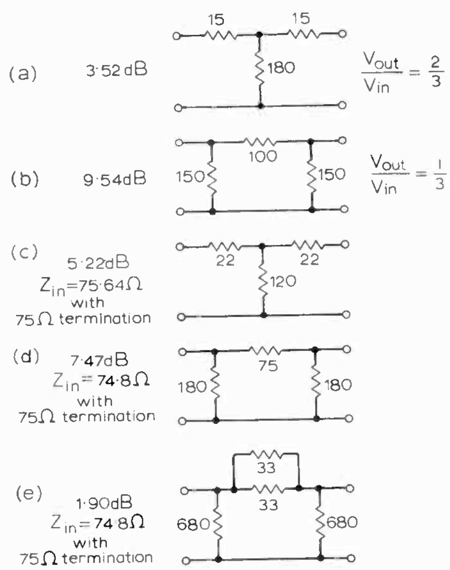
The author replies:
Mr. Smith's qualification is, of course, essential for anyone studying the fundamentals of electricity. "Electronic Building Bricks", however, is not intended for this type of reader (see May 1970 issue, p. 225) and my explanation of e.m.f. and the volt

Attenuators

I was interested to see Mr. Cocking's article on attenuators in the December issue.

Your readers, particularly television amateurs, may find it useful to know a few 75-ohm T and π attenuators made up from preferred value resistors.

The characteristic impedance of networks 1 and 2 is 75 ohms exactly. The characteristic impedances of the other three networks shown are not quite 75 ohms, but this may not be unduly disastrous for many applications. For the best match, of course,



one should select the resistors using a bridge, and not merely pick ±20% components at random from the spares box.

Constructional information may be found in "Attenuators for High Frequencies" by R. F. Privett in *Wireless World*, March 1954, page 141.
DONALD S. REID,
Brentwood,
Essex.

"Direct Radiator Loudspeakers"

I have received a letter from Mr. R. C. Driscoll, of the Northern Polytechnic, questioning the use of the unrationalized electromagnetic system of units in my article "The Design & Use of Moving-coil Loudspeaker Units" in the November issue. He also states that all figures quoted in my expressions of power ratio on the dB scale "are a factor of two higher than would be obtained from the accepted definition of this scale". I must thank him and stand corrected on both counts.

In the section of the article "Effect of mechanical impedance on radiated power", the expressions relating P_{MA} and f are correct, but the rates quoted in dB/octave should refer to 'pressure response' not P_{MA}, i.e. the vertical axes in Figs 5a, b and c should be 'pressure response' not P_{MA}. My apologies for this oversight.

E. J. JORDAN,
Marlow,
Bucks.

Loudspeakers in corners

H. D. Harwood (*Wireless World*, April 1970) takes exception to my stated opinion that loudspeakers work better in a corner (February 1970 issue).

Submitted herewith is a pair of response curves, both of the same loudspeaker (not one of ours), one curve showing the response of the loudspeaker located against the wall (dihedral corner between wall and floor) and the other in a trihedral corner. This pair of curves is typical of the many we have run on loudspeakers ranging from a fraction of a cubic foot to several cubic feet, single driver, 2-way, 3-way, direct radiators and horns.

I'll concede one point to Mr. Harwood: corner placement may be excessively 'beneficial' if the loudspeaker has been heavily 'equalized', with the result that removal of some of the excess 'equalization' may be needed to restore a flat response. This of course is really beneficial, as the decreased overdrive results in smaller diaphragm excursions and consequently smaller total modulation distortion for a given sound pressure level output.

Back to the response curves. Lay a straight edge on the peaks between 40 and 400 in curve (a) and note that the line rises about 5dB; lay the straight edge along the peaks from 400 to 8,000 and note that the line recedes about 9dB. This 'gable roof' response results in a slightly 'honky' sound.

Now look at curve (b) for the same loudspeaker in the corner. First, the whole s.p.l. is up about 5 to 6dB, meaning that we can cut the input level and distortion to get the original (non-corner) s.p.l. Next do the straight-edge act again and note that the 'gable roof' effect is 2dB and 5dB compared to 5dB and 9dB for the non-corner placement. The sound was noticeably less 'honky'.

The idea of corner placement was first called to my attention about 1933 when I was a graduate student in E. E. at Stanford University. I wish I could recall just who conveyed that idea; it may have been Madison R. Jones who was writing his thesis on loudspeakers. The explanation for the superiority of corner placement lies in the existence of a family of mirror images, each reinforcing the pressure from the original (actual loudspeaker) source.

A point to be considered important is the proximity of these mirror images. To be coherent, the images must be close together. That means the loudspeaker must be nested back into the corner with intimate wall contact. This explains why one speaker was drastically improved in performance—its instructions were to place it several feet (3 or 4) from one wall, slightly more or less from the other wall, 2 or 3 feet above the floor. A curve run in the prescribed location and another run with the speaker in a corner showed an improvement over the entire spectrum, and such a large increase in the bottom 2 octaves as to require re-equalization. Since this speaker exhibited over 10% total modulation distortion when placed as specified, corner placement reduced distortion for a given sound pressure level. In this case the 'recommended' location necessitated excessive bass compensation which could be reduced drastically.

The argument for the 'unusual' placement was creation of a 'reverberant field' but it has been shown that such a reverberant field is impossible to avoid in a listening room with normal listening quality. So corner placement has everything to gain and nothing to lose.

PAUL W. KLIPSCH,
Hope,
Arkansas.

The author replies:

P. W. Klipsch queries my contention that conventional loudspeakers sound worse in a corner than in the centre of a wall and shows curves which he claims prove his point. First, let us get the fact clear.

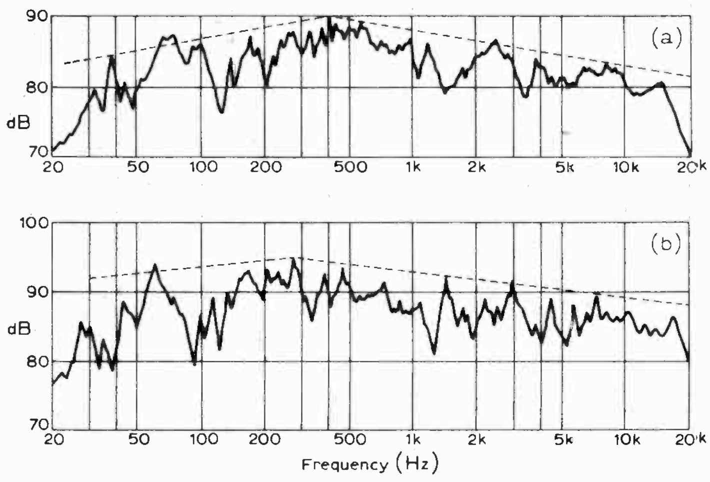
We started our investigation into this problem because sound mixers complained that the sound from loudspeakers hung in corners sounded coloured. This effect was noticed in all rooms although some control rooms were worse than others. Furthermore, these complaints were by staff who were able to compare directly the real sound in the studio with that from the loudspeaker. An additional fact was that the mixers were quite content with the sound from the same loudspeakers when they were placed in a conventional though, in this case, inconvenient position. It was also noted that the better the loudspeaker, i.e. the freer it was of colouration itself, the more noticeable the effect was. The fact that colouration exists for corner mounting is therefore clear and not open to doubt. As the loudspeaker was absolved from being the cause and the facts pointed strongly to the location we did our best to measure the effect of this. We therefore employed warble tone and a cardioid type microphone, both factors designed to largely remove the effects of room modes in themselves. This was desirable not only because the unwanted colouration was present in rooms of varying shapes and sizes but also because it is a fact that we listen mainly to the sound coming from in front and relegate reverberation to a secondary place. If this were not so a person's voice would sound very different in different rooms and we know well that this is not so.

The curves we obtained thus agreed well with simple theory, see Fig. 4 in the article. Furthermore they accounted well for the colouration actually heard and finally, the measures which were designed to alleviate the trouble were found to be successful.

At no time did the article attempt to defy the laws of physics. It is clear that placing a loudspeaker in a corner will give rise to a bass lift; what we were after was quality not just quantity. Quantity can be achieved in a number of ways, quality is much more difficult to obtain. It is of course quite possible that if lower middle colouration is already present in the loudspeaker this additional colouration may pass unnoticed.

I have no doubt that by throwing away the measures we had taken to remove the effects of room modes on the curves, i.e. if we used pure tones and/or an omnidirectional microphone, we too could have produced curves such as those shown by Mr. Klipsch where the room modes effectively disguise the general trends. Even so I would not have thought negligible the crevasse shown in this curve (b) centred around 100Hz and 15dB deep, nor would I regard a single sharp peak at 60Hz as constituting a real bass response!

Since my article was published, the existence of colouration for a corner source has been clearly demonstrated in a neat way, due, I think, to Mr. J. Shuttleworth. A person talks, standing with his back at least 1 metre from the corner of a room, to give a standard of reference. He then moves into the corner so that the back of his head touches the two walls and



Response curves for a loudspeaker placed against a wall (a) and in a corner (b).

talks again. There is a rise in bass response but more important it is obvious even to the densest clothear that the sound is highly coloured. I therefore repeat my earlier statement that under these circumstances the presence of colouration is not open to doubt.

To sum up I have never questioned Mr. Klipsch's contention, well supported by theory, that corner placement gives more bass, but I have shown, clearly I hope, that such a position gives rise to a coloured quality and this too is supported by theory and easily observed by listening on good loudspeakers and to original sources.

H. D. HARWOOD,
B.B.C. Research Dept.,
Surrey.

'Linear Scale Millivoltmeter'

If a car salesman, anxious to persuade you to change your Rover for a Jaguar, adduced that a Jaguar is better than a Cortina, he would be unlikely to make a sale. Yet this is the kind of argument put forward by A. J. Ewins (Dec., 1970 p.592). He invites us to add two transistors to D. E. O'N. Waddington's already excellent circuit for a feedback millivoltmeter because the end result gives a better performance than a *non*-feedback circuit.

So what? What is called for are measurements comparing the original Waddington circuit with the revised one. Not only are these absent, but the experienced eye notices two very significant differences between the circuit (Fig. 5) which Mr. Ewins used to convince himself that he was on to a good thing and the actual circuit (Fig. 2) in which the improvement is allegedly incorporated.

In the test circuit, the emitter resistor (9.1k) of the output transistor (Tr_1) is unbypassed. In the final circuit (Fig. 2) it is bypassed. The result is that the transistor in question presents a much lower output impedance in the final circuit than in the test circuit.

Secondly, there is a most important invisible component in Fig. 5. This is the impedance of the signal-source. It is important because it governs the amount of internal voltage feedback in Tr_1. This feedback is negligible in most ordinary amplifier stages, but it is by no means negligible here. If the load on Tr_1 is indeed 'constant-current', i.e. infinite then the voltage gain of Tr_1 is equal to the voltage amplification factor, which is usually 1000 or more. In this case, a signal-source impedance of a few hundred ohms can make a significant reduction in the output impedance.

In the final circuit, the signal-source impedance seen by the base of Tr_5 ($=Tr_1$ in the test circuits) depends mainly on R_{17} (100k) and the current gain (h_{fe}) of Tr_4, being roughly R_{17}/h_{fe}. This is 1k for a low-limit 2N3707 (Tr_4), and is by no means negligible.

The idea of using an artificially high output impedance in voltmeters is not new. A logical development of Mr. Ewins' arrangement is to drive the upper transistor (Tr_7) in phase with Tr_5. This forms a high-impedance complementary push-pull output stage. Such a circuit has been described in *Wireless World* by G. Wareham ('Inexpensive Tape Recording Amplifier', March, 1966) and in a more elegant form by F. Butler ('Gyrators—Using Direct-Coupled Transistor Circuits', February, 1967).

In any case, the effect of the negative feedback in voltmeter circuits like Mr. Waddington's is also to increase the impedance *seen by the meter*. If the open-loop gain is high enough, effective meter-circuit impedances of several megohms can be obtained.

G. W. SHORT,
Croydon,
Surrey.

The author replies:

It would appear that the essence of Mr. Short's criticisms are that I am guilty of comparing the constant current loaded output transistor circuit with the conventional resistor loaded one under conditions which are not identical with the final circuit arrangement. I accept these criticisms, particularly with respect to the fact that the emitter resistor in the test circuit is un-decoupled; increasing, Mr. Short says, greatly the output impedance of the transistor. I must confess that I had not appreciated this point, if, in fact, it really is so. I do not, however, accept the implied criticism that the constant current loaded output transistor does not operate as well in the final circuit arrangement as in the test circuit. I am sure that no one will argue that the output impedance of the output transistor in my final circuit arrangement is not very much greater than the output impedance of the equivalent stage in Waddington's circuit.

The two test circuits were intended to illustrate the effect of a high-output impedance upon the linearity of the meter's scale and to give some idea of what might be expected from using a constant current source as the load instead of a resistor.

The constant current loaded test circuit may be biased in favour of better results than would be obtained by the equivalent stage in the final circuit design; the resistor loaded test circuit certainly is. The value of the collector resistor in the test circuit is ten times higher than the value in Waddington's equivalent stage, with the result that the output impedance of the stage in the test circuit is very much higher than in Waddington's final arrangement, improving the linearity of the meter's scale.

In the final circuit arrangement of my millivoltmeter design, the decoupled emitter resistor may reduce the effective output impedance of the final stage, but this is adequately compensated for by the fact that the voltage gain of the stage is greatly increased for the same reason. Mr. Short rightly points out that the effect of negative feedback in voltmeter designs of this sort is to increase the output impedance as seen by the meter stage. The output impedance as seen by the meter is roughly the product of the open loop output impedance of the final stage and the amount of negative feedback applied. Thus, in my final circuit arrangement, what is lost in terms of output impedance of the final stage by decoupling the emitter resistor is more than compensated for by the increased amount of negative feedback that may be applied due to the increased voltage gain of the stage.

Mr. Short's criticism about the signal-source impedance is not really valid since the output impedance of the test oscillator used was 600 ohms, which is comparable with the source impedance seen by the output transistor in the final circuit arrangement.

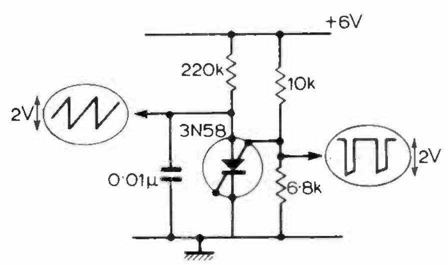
Mr. Short says that a logical development of my circuit is to drive the upper transistor (Tr_7) in phase with Tr_5, forming a complementary push-pull stage of high output impedance. In fact this was the first step that I took in designing the circuit and I soon found that my final circuit arrangement was simpler to construct, using fewer components, and that the net result of both methods was identical.

Finally, may I say that a comparison between my circuit and Waddington's is obviously what is required to convince readers like Mr. Short of the benefits to be obtained from my more complex circuits. Unfortunately I do not have these precise comparisons, but I invite readers who decide to construct my circuit to satisfy themselves of its benefits by replacing the constant current load with a 27kΩ resistor, as in the test circuit, without alteration to any other values. If Mr. Short had challenged me on the *need* to improve Waddington's design I would have had a much more difficult case to answer. As it is 'the proof of the pudding is in the eating', and as I am unable to detect any non-linearity in the meter's scale of my design, even at 1% and 3% of f.s.d., I am satisfied that my design achieves what I set out to do.

A. J. EWINS

New names for old concepts

The tendency to invent new names for old concepts seems to increase faster than ever. The "Programmable Unijunction" described by Mr. Greiter in the September issue is, surely, none other than the silicon controlled switch minus its cathode gate.



The s.c.s. has been in use for many years, why give it a new name? The circuit shown above, using a General Electric 3N58, produces much the same result as Fig. 14 in Mr. Greiter's article.

A. G. JONES,
Porthcurno,
Cornwall.

High-quality Tape Recorder

3. Extensions and modifications

by J. R. Stuart, B.Sc.

The variable high-frequency bias allows optimum recordings to be made with a variety of tapes and speeds, and it is a simple matter to reset any bias condition with the meter. Although the A–B monitoring allows an excellent attempt to be made by ear, it is not always straightforward to discover the required bias initially. In particular, if the recording is to be replayed on another machine, it may be necessary to bias for maximum sensitivity, minimum distortion, or some arbitrary standard.

The normal criterion for low tape speeds is to increase the bias until the sensitivity at 1 kHz is 1 dB below maximum. To allow easy setting of this bias current many high-quality recorders include a 1 kHz reference oscillator.

Such an oscillator would either be an *RC* arrangement with amplitude definition and stabilization provided by a thermistor or field-effect transistor, or a current switching *LC* oscillator[9] of the type shown in Fig. 25. The output of this oscillator is well defined by the dynamic impedance of the tuned circuit and the tail current. However the values of *L* and *C* required do not lead to accurate prediction of the frequency of oscillation.

To calibrate the recorder using a reference, switch the meter to record and set the input level to −6 dB, then, while recording, switch the meter to replay and adjust the high-frequency bias for the required sensitivity. Note the bias voltage.

It is probable that in a large number of applications a simple stereo signal is not available. This will certainly be true of live or special-effect recordings, and for these a linear mixer is essential.

Fig. 26 shows a mixer which could be built as part of the recorder unit. For simplicity a CA 3048 integrated quad amplifier has been used, giving two inputs per channel. By extrapolation, further addition of i.c.s will give the required number of inputs.

The i.c. should be powered by a regulator identical to that shown in Fig. 17. Output *M* is satisfactory providing that it is not intended to cascade amplifiers in the same chip—to do so may cause low-frequency instability, so the dual output regulator (*K*, *L*) should be used.

This mixer is intended for a 250 mV rated output, with a 12 dB overload margin. R_x defines the gain of each mixer stage and a range of values is given in Fig. 26. However, if at any time high sensitivity is required, better noise performance would result from a lower gain mixer feeding the 25 mV input.

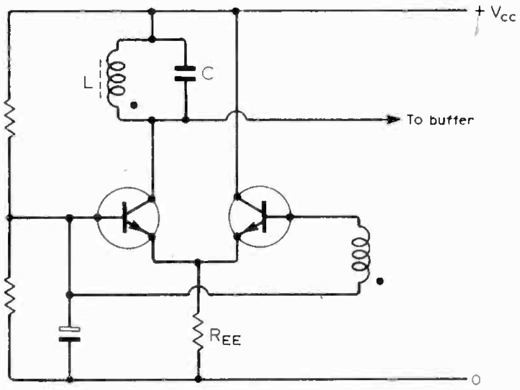
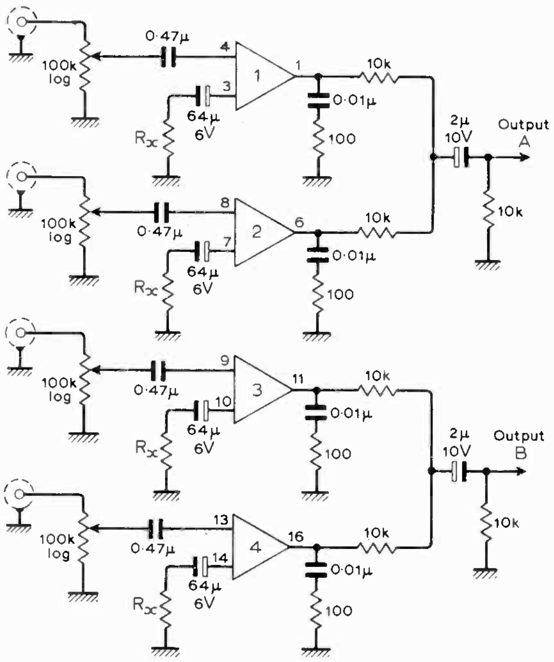


Fig. 25. A current-switching oscillator.



R_x	Stage gain (dB)	Mixer gain (dB)
∞	12	6
5·6k	20	14
2·2k	26	20
1k	30	24
560	36	30
390	40	34
56	50	44

Fig. 26. Circuit of a linear mixer.

Superimposition was at one time a common facility on good quality recorders. However, this is extremely unsatisfactory as each recording erases to some extent the high frequency information of the previous recordings. By rearranging the track-switching and making use of the mixer and the logarithmic meter, signals may be superimposed by recording from one track to another. This allows the quality of the initial signal to be maintained through several superimpositions. For this two switches replace S_2, one for record and the other for replay.

Discrete component version

Some constructors may prefer to build discrete amplifiers in place of the integrated version recommended and described in parts 1 and 2. This could be suitable for a mono record-only machine where all replay equalization is performed in the pre-amplifier.

A discrete-component replay amplifier is shown in Fig. 27 and the circuit values for equalization are given in Table 6.

Transistors Tr_{13-15} form a direct-coupled triple with a mid-band open-loop forward voltage gain of around 80 dB; the closed loop

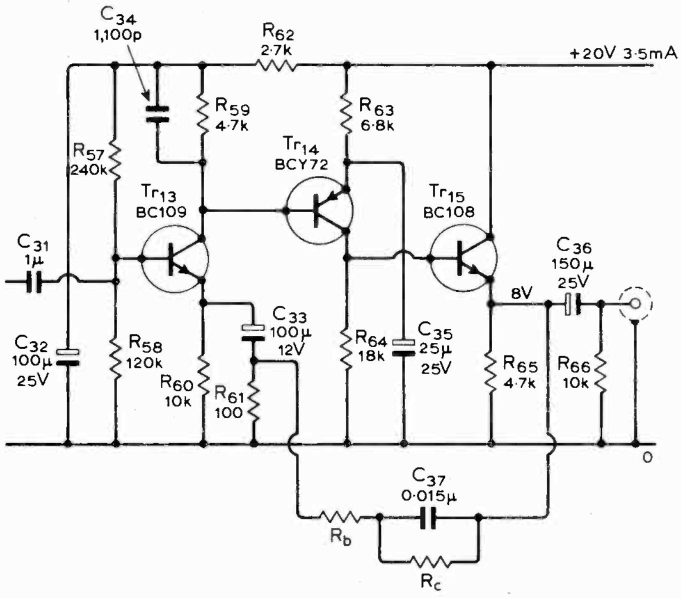


Fig. 27. A discrete-component replay amplifier.

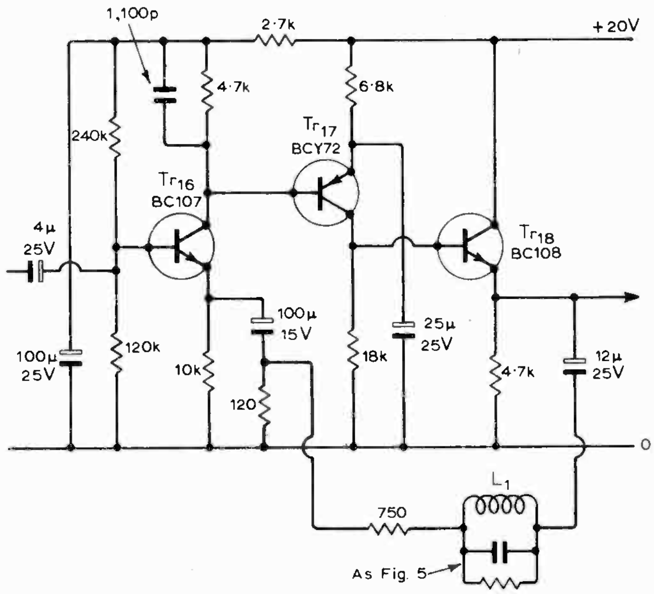


Fig. 28. Recording equalized amplifier.

gain has been arranged to give an output of 250 mV r.m.s. at the rated input, with a signal-to-noise ratio of 70 dB.

Capacitor C_{31} should be paper or plastic to ensure low leakage and avoid polarization of the head, C_{34} stabilizes the loop at high frequencies and the maximum output is 4·5 V r.m.s.

There should be no discernible differences between the performance of this amplifier and the integrated version.

The recording pre-emphasis pre-amplifier can be replaced by the amplifier shown in Fig. 28. This is very similiar in performance to that of Fig. 27 and the equalization components will be identical to those used in the integrated version. By replacing the equalization network with a 17 kΩ resistor the amplifier of Fig. 28 will have a forward gain of 140, to drive the meter.

Record output

It was stated in part 1, that the best method of ensuring a constant-current recording characteristic, is to include the head in the feedback loop of a high-gain amplifier. Such an arrangement is shown in Fig. 28. The performance of this circuit is excellent. Measured total harmonic distortion in the current waveform was less than 0·01 % at an output of 140 µA r.m.s.

However the problem of bias rejection is considerable and it is strongly recommended that only an experienced constructor, with access to a good oscilloscope, should attempt this type of output stage. The problem arises because the rejection must take place at an input, where only 50 mV r.m.s. bias will switch the amplifier output between the rails.

Erase and bias oscillator

Although the oscillator described in part 2 performs very well on mono or stereo, a direct method of ensuring that bias and erase current calibration is retained in all modes, is to employ a separate output stage for each erase head, synchronizing these outputs by a master oscillator.

Considerable thought was given to the output stage. Class A and B were ruled out directly because of cost, and as it is extremely

TABLE 6. Equalization details for Fig. 27

time constants µs	R_b Ω	R_c Ω
35+ ∞	2·2 k	∞
50+3180	3·3 k	220 k
70+ ∞	4·7 k	∞
50+ ∞	3·3 k	∞
140+ ∞	9·1 k	∞
90+3180	5·6 k	220 k
140+3180	9·1 k	220 k
90+ ∞	5·6 k	∞
280+ ∞	18 k	∞
120+1590	8·2 k	110 k
120+ ∞	8·2 k	∞

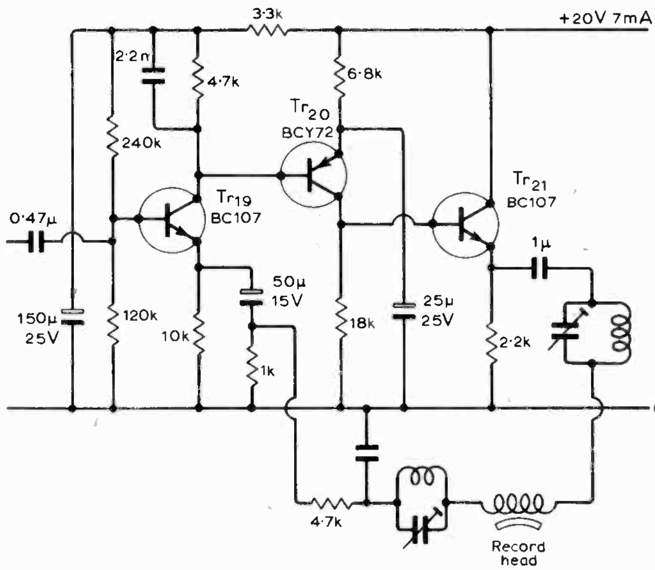


Fig. 29. A feedback recording output stage.

difficult to predict the performance of a class C amplifier, a current switching design was evolved. Fig. 30 shows an erase oscillator of this type; only one output stage has been drawn but several may be driven from the master oscillator without modification.

Transistors Tr_{22} and Tr_{23} form an emitter-coupled multivibrator which runs at 93 kHz. Tr_{24} is a buffer, the output of which is arranged to have a positive maximum a few hundred millivolts above V_{ref}.

Frequency of oscillation is stabilized by the two zener diodes, and the long-term drift is less than 0·1 %. A current, defined by V_{ref} and R_m, is switched alternately between Tr_{25} and Tr_{26} and its magnitude must be arranged so that these transistors nearly saturate at the required output level.

In order that the bias waveform will decay slowly at switch-off, the time constants are arranged so that the multivibrator continues to oscillate on frequency until C_m has been discharged, allowing an exponential decay in the output current.

The transformer primary must have a high unloaded Q, and to achieve low distortion the loaded Q factor must be at least 10. The amplitude of the nth harmonic in the output for an ideal current-switching operation is

$$\frac{100}{(n^2-1).Q_l}\ \%$$

where Q_l is the loaded Q factor. A good L/C ratio is necessary to allow reasonable loading of the tuned circuit. In Fig. 30 measured values for Q were 90 unloaded and 30 loaded, however the final values are considerably affected by construction, in particular long cables connecting the oscillator to the head can radically modify the levels.

Modification for alternative heads

The designs described in these articles were intended to be used with the Brenell Mk 6 deck, which incidentally, uses the same heads as the Mk 5 range. However a large number of readers may possess perfectly good decks which have recording, replay and erase heads whose parameters are very different from the Bogen heads.

It is expected that a large variety of heads can be accommodated with a few component changes, the critical parameters for the various heads are as follows:

(a) recording—a.f. current (μA)
—bias current and voltage
—bias frequency
—inductance
(b) replay —playback level at 1 kHz, 7·5 i.p.s. and 32 mMx/mm
(c) erase —voltage and current.

In Fig. 7 the transconductance of the output stage was expressed as $1/R_{12}$. Thus the input sensitivity can be deduced for any output current, and by calculation the constructor can decide whether or not sufficient output voltage swing is available. The recording sensitivity may be deduced as the pre-emphasis low-frequency gain is 7·25.

The only modification to the replay amplifier would be to adjust the forward gain to change the sensitivity from 2 mV.

As the open loop gain of the input i.c. is only 50 dB it is not advisable to attempt to increase the closed-loop gain by more than 6 dB although it may be reduced by some 10 dB. Any further adjustment should be made in the gain stage by adjustment of R_{22}, as described in Fig. 30.

The closed loop gain G of the amplifier shown in Fig. 36 is given by

$$G = \frac{R_c}{R_d}\cdot\frac{\dfrac{R_b+R_c+R_d}{R_c}+j\omega t_1}{1+j\omega t_2}$$

if $A \gg G$

where t_1 is the upper time constant $= C_a(R_b+R_d)$ e.g. 70 μs, 140 μs
and t_2 is the lower time constant $= C_aR_c$ e.g. 3180 μs.

The appropriate equalization values may thus be determined.

It is not so simple to calculate the component changes to the erase oscillator.

Ensure that Tr_6 and Tr_7 are allowed to saturate. If this is not the case excessive power will be dissipated probably resulting in device failure. Beware also of raising the supply voltage above 15 V as the theoretical peak collector potential could be $\pi\times$ supply voltage.

Mono and four-channel

To construct a single channel version of the recorder it is necessary only to re-arrange the i.c. amplifiers for one i.c., and to modify the erase oscillator. The author suggests that i.c. amplifiers 2 and 3 be used for the replay section and 1 and 4 for recording pre-emphasis and meter circuits. A block diagram is given in Fig. 32. For those wary of modification, the erase oscillator can be built in standard form with C_{26} and R_{56} permanently wired in. See Figs 3 and 15. Otherwise R_{56} may be omitted, along with one bias winding, and the circuit operated from a lower supply—around 7 V.

Only one bias chain will be used in the meter; thus R_{28}, R_{30} and D_2 are omitted, and the current will be set to 3 μA by R_{29}.

At the time of writing the author knows of no source of decks fitted with four-track heads, for four channel recording, however it is straight forward to multiply the circuitry to cater for this—at any point in the future the replay and recording amplifiers can be duplicated, but the erase oscillator must be replaced by a design similar to Fig. 30, or by a more powerful version of Fig. 15. There are no strong arguments for re-arranging the i.c.s. The CA 3048 lends itself to a four channel cassette replay system, although at present no deck of suitable quality is available.

The author thanks Brenell Engineering Ltd, for valuable assistance given during the development of this recorder.

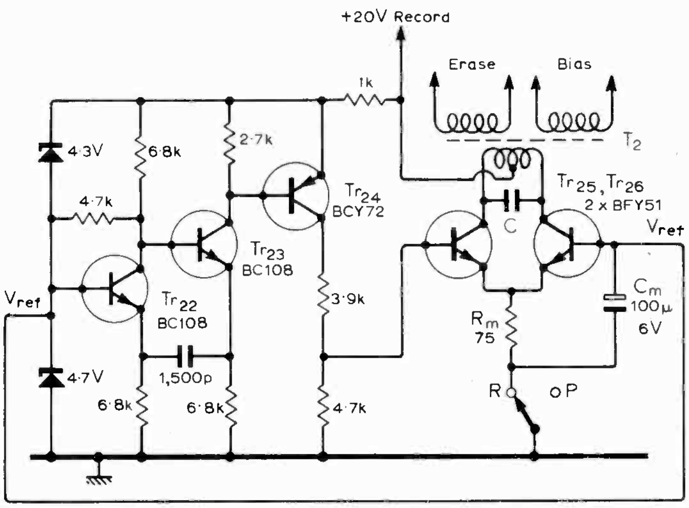
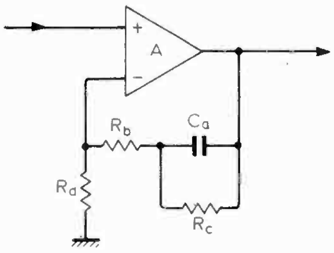


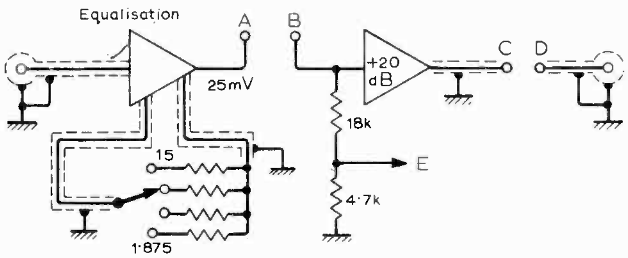
Fig. 30. Circuit diagram for an erase-bias oscillator.



$$G = \frac{A}{1+A\beta} \simeq \frac{1}{\beta} \text{ when } A \gg G$$

$$\beta = \frac{R_d(1+j\omega C_aR_c)}{R_c+(R_b+R_d)(1+j\omega C_aR_c)}$$

Fig. 31. Replay amplifier equivalent circuit.



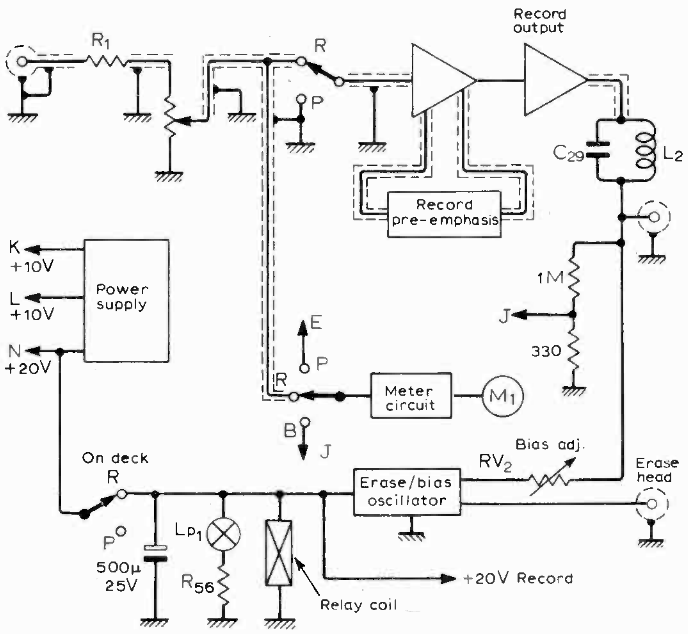


Fig. 32. Block diagram for mono.

Corrections to Part 2 on p.32

Heat Sink Abac

by J. Johnstone, B.Sc.

The abac given here has two uses. First it will find the heat sink thermal resistance required for a selected maximum transistor junction temperature and secondly it will give the area of matt black aluminium sheet needed.

In the instructions which follow

θ_{sa} = thermal resistance of heat sink
T_j = junction temperature
T_{amb} = ambient temperature
θ_{ja} = thermal resistance of device junction to ambient
θ_{jc} = thermal resistance of device junction to case
θ_{cs} = thermal resistance of device to case heat sink

Using the abac

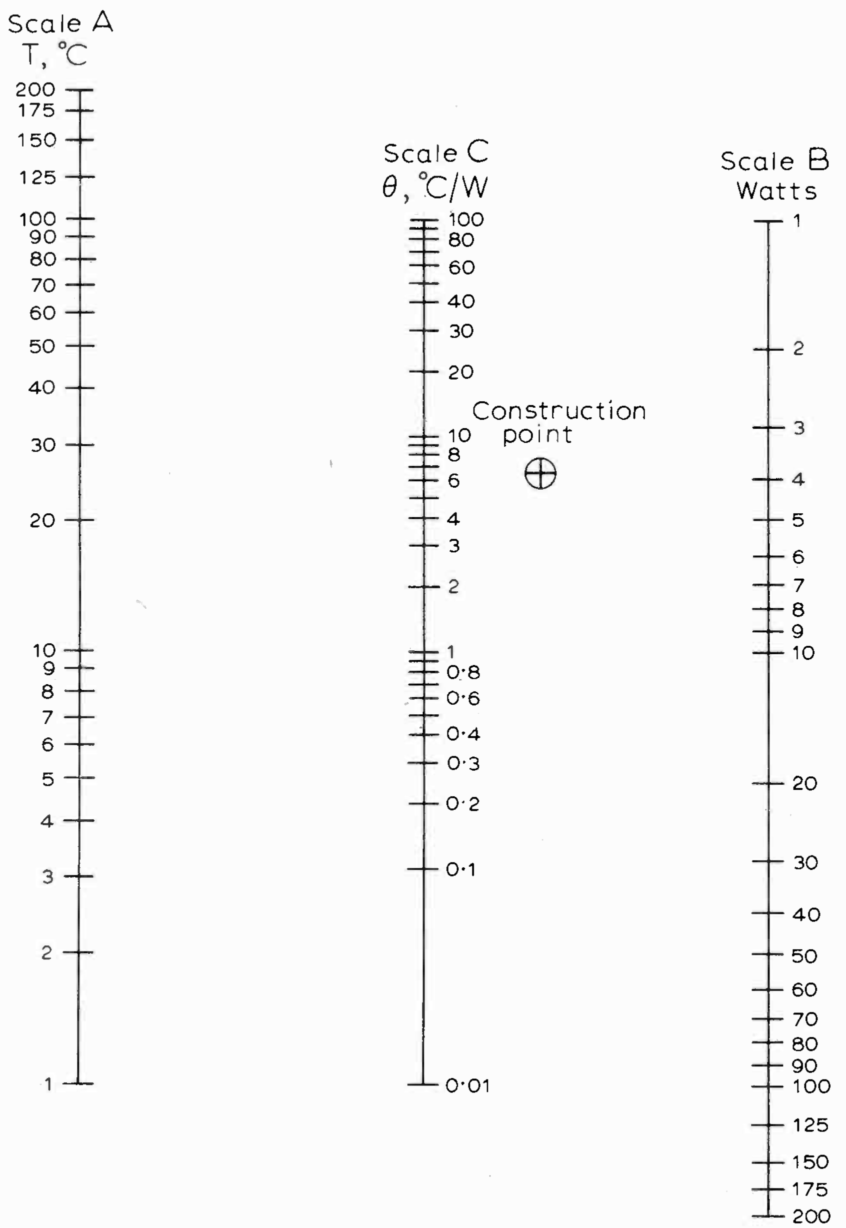
1. Calculate the maximum dissipation in the device.
2. Calculate the maximum junction temperature (ΔT_j) rise from $T_j - T_{amb}$.
3. Set ΔT_j on scale A and the dissipation on scale B. Read θ_{ja} on scale C.
4. Calculate the required heat sink thermal resistance from $\theta_{sa} = \theta_{ja} - (\theta_{jc} + \theta_{cs})$. Typical values of θ_{cs} will be found in the table.
5. Join θ_{sa} on scale C to scale D via the construction point.

The heat sink is assumed to have a free air flow on both sides; to have sides of a ratio not exceeding 2:1 (i.e. a 50 sq.in heat sink may be 7.1 × 7.1 or 5 × 10 inches but not 2 × 25 inches). If bright aluminium is employed areas should be increased by 20%.

Typical values of θ_{cs}

case	direct contact	mica washer	hard anodized Al washer
TO-3	0.05	2	0.15
TO-66	0.4	2.4	0.6
case 77	3	6	—
case 90	1.2	2.2	—

It is assumed that a thermal compound, such as Jermyn Thermaflow or Dow Corning D340 is used in all cases. Cases 77 and 90 are Motorola plastic types.



Elements of Linear Microcircuits

4: Three generations of operational amplifiers

by T. D. Towers, M.B.E.*

Talk to the new breed of engineers practised in designing their circuits around readily available, economic, standard, monolithic operational amplifiers of the 1970s and you will find that for them op-amp is taking on a meaning different from the classical definition. Nowadays they think of it as a broadband, low-frequency, very-high-gain amplifier, for use from d.c. to about 1MHz in many circuit configurations.

If you look hard enough, you will find some 2,000 differently numbered operational amplifiers on the market. All but a few of these are of monolithic construction. The rest are specialist discrete-component or hybrid versions which designers turn to usually as a last resort when they cannot find the right monolithic.

First-generation

Until the appearance of monolithic op-amps in quantity in the late 1960s, a designer who needed such an amplifier would take conventional capacitors, resistors and transistors to make up a circuit something like Fig. 1. This employs a long-tail-pair balanced input followed by a long-tail-pair level shifter to return the single ended output to zero.

The first monolithic op-amp with a performance comparable to discrete-component versions was introduced in 1965. This was the Fairchild μA709. It is now available from most semiconductor manufacturers under many different code numbers, but it is always spoken of as the '709'. In the U.K. there are many variants such as Motorola's MC1709, Mullard/Philips TAA521, National Semiconductors' LM709, Newmarket's LIC709, ITT's MIC709, Texas Instruments' SN72709 and Transitron's TOA2709, as well as Fairchild's own 709 series with code numbers such as U6A7709393.

Although the circuit of the 709, given in Fig. 2, achieved the same sort of performance as discrete circuits of the type of Fig. 1, it can be seen even under superficial inspection to be much more complex. This is because monolithic techniques for diffusing such an op-amp into a silicon chip (about 0.055 sq. inches) had difficulty in producing directly the high-value resistors and the high-gain transistors of the discrete version. For those interested in design details, a brief description follows.

In Fig. 2, the input transistors, Tr_1 and Tr_2 form a balanced long-tail pair with a fixed 40μA tail current provided by the transistor Tr_{11}. This is biased as a constant current source by the emitter resistor R_{11} and the diode-connected transistor Tr_{10} which is forward-biased by current through R_8, R_{10}. The collector load resistors of the long-tail pair, R_1, R_2, provide a balanced output.

The network Tr_7, R_5, Tr_3, Tr_5, R_3, and Tr_{15} provide balanced stabilization against temperature and supply voltage changes. The single-ended output from R_2 drives the common-emitter Darlington pair, Tr_4, Tr_6, to give a further amplified signal level across R_6. This is used to drive Tr_8 which in turn (via the common-base stage Tr_9) controls the pre-output common emitter driver Tr_{12}. The collector of the driver (with its collector resistor R_{14}) is directly connected to the bases of the complementary-symmetry class-B output pair, Tr_{13}, Tr_{14}. The output is taken from the common emitters of Tr_{13}, Tr_{14}, the d.c. level having been shifted back to zero through transistors 4, 6, 8, 9, 12, 13 and 14.

In the discrete op-amp circuit of Fig. 1, capacitors C_1 and C_2 were included to cut the top frequency response of the circuit to avoid h.f. instability. In the 709 it was not

*Newmarket Transistors Ltd

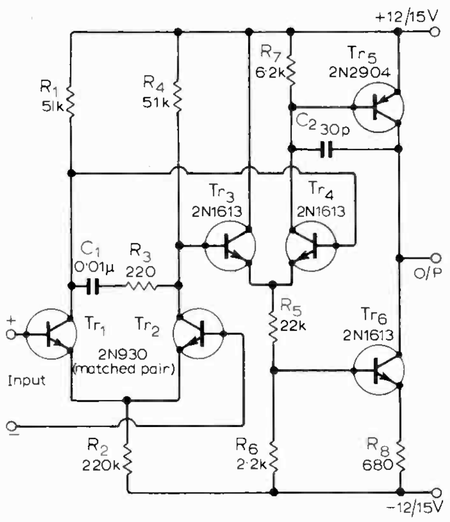


Fig. 1. Discrete component operational amplifier.

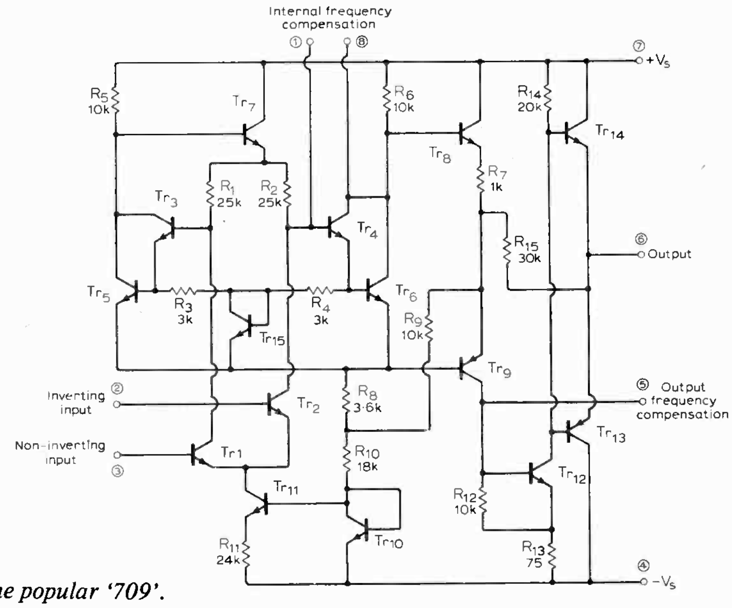


Fig. 2. The popular '709'.

possible to include capacitors and so terminals 1, 8 and 5 were provided to enable separate external compensation capacitors to be connected. The 220k Ω resistor R_2 in Fig. 1 also could not be provided in the monolithic version, and was replaced by the constant current transistor, Tr_{11}, in Fig. 2.

Selections of the 709 are available, but the loosest specification version (and the most commonly used), the 709C, has the following characteristics on ± 15V d.c. supply at 25°C ambient temperature:

A_{VOL} (open loop d.c. voltage gain)= 94dB (× 50,000) typ., 84dB min.

V_{IOS} (off-set voltage, 10kΩ source resistance)= 2.0mV typ., 7.5mV max.

I_{IOS} (off-set current) 100nA typ., 500nA max.

I_B (input bias current)= 300nA typ. 1,500nA max.

R_{IN} (input resistance, differential)= 250kΩ typ., 50k min.

R_{OUT} (output resistance)= 150 Ω typ.

V_{OUT} (output voltage available swing) = ± 12V min. (R_L = 10k) = ± 10V min. (R_L = 2K)

c.m.r.r. (common mode rejection ratio)= 90dB typ., 65dB min.

v.s.r.r. (supply voltage rejection ratio)= 25μV/V typ., 200μV/V max.

V_{in}*c.m.* (common mode input voltage range)= ± 10V typ., ± 8V max.

V_{in} *diff.* (differential input voltage range)= ± 5V max.

V_S (supply voltage range)= ±9 to ± 15V.

SR (unity-gain slew rate)= 0.5V/μS typical.

BW_{OL} (open loop bandwidth)= 100Hz typ.

BW_{VF} (voltage follower or unity gain bandwidth)= 1MHz typ.

These characteristics are given in some detail so that you can see how far the first generation operational amplifiers matched up with the five ideal characteristics of an op-amp i.e. infinite gain, zero current and voltage input offset, infinite input impedance, zero output impedance and zero response time (infinite bandwidth). They also set levels to judge how later generation op-amps improved.

Improved first-generation

Users found that the 709 had certain practical drawbacks. In ordinary use it was liable to latch up when the common mode input range of ±8V was exceeded. It was liable to 'blow up' if the output was short circuited. Its input resistance of 50kΩ min. was rather low. Without at least two external compensation capacitors it was virtually certain to oscillate on open loop. Its quiescent current consumption of about 2.5mA was too large.

The first improvement of the 709 was the LM101 brought out in 1967 by National Semiconductors with the circuit of Fig. 3. It is now almost as well known as the 709 and commonly referred to as the '101'.

The principal improvements incorporated in the 101 were frequency compensation by a single 30pF external capacitor, voltage supply range extended to ±5 to ±20V, quiescent current reduced to 1.8mA typical, continuous output short-circuit protection provided, common mode input voltage limit raised to ±15V, and differential input voltage range raised to ±30V. Also a separate terminal was used for easy offset zeroing (balancing) with a single 5MΩ potentiometer.

These improvements were substantial, but the 101 is usually regarded merely as a slightly better 709, because the offset voltage and offset currents were only marginally improved. The Fairchild μA748 has very similar specifications. The Motorola MC1533 is another well known improved 709.

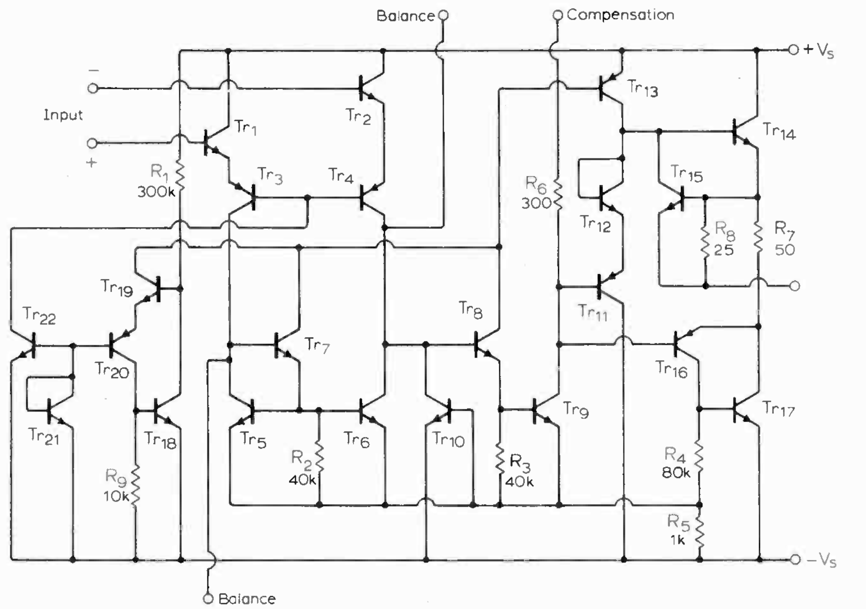


Fig. 3. An example of an improved first generation op-amp, the LM101.

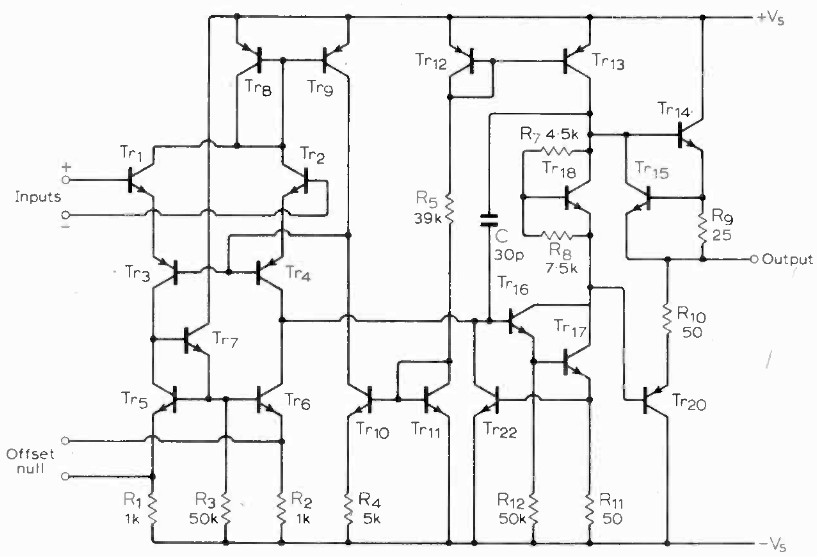


Fig. 4. The μA741. Note the diffused compensation capacitor.

First generation internally-compensated

The 101 still could not be used open-loop without an external compensating capacitor, and almost inevitably in 1968 there came out the first fully internally compensated op-amp, the μA741. This was followed soon by the LH101, or RM4101, (compensated 101).

In the case of the LH101, the modification to the LM101 was merely to diffuse a 30pF capacitor internally between the compensation and top balance terminals of Fig. 3.

In the case of the 741, a completely new circuit as Fig. 4 was used. In this the high-gain n-p-n transistors Tr_1, Tr_2 are used in combination with the low-gain lateral p-n-p transistors Tr_3, Tr_4 to provide effectively a high-gain p-n-p input pair. Transistors Tr_8 and Tr_9 provide a constant-current long-tail source of about 30μA total for this input pair. Transistors Tr_5 and Tr_6 are biased to act as 2MΩ loads for the composite input transistors. The amplified signal appearing at the collector of Tr_4 is further amplified by the high-input-impedance Darlington pair Tr_{16},

Tr_{17}. The collector load of this Darlington is the collector output resistance of the constant-current-biased transistor Tr_{13}. This drives the output complementary-symmetry, transistors Tr_{14}, Tr_{20} which are biased class AB to about 60μA quiescent current by the forward voltage drop across Tr_{18}. The forward bias on the output transistors eliminates the cross-over distortion of the 709 (where the bases of the output transistors are connected together —see Fig. 2).

The 741 is proof against continuous output short-circuits because the output is current limited. For positive excursions R_9, Tr_{15} in Fig. 4 act as a 25mA current limiter. Above this output current, the voltage drop across R_9 brings Tr_{15} into conduction and limits the drive. For negative excursions the output current is limited by the 50-Ω series resistor R_{10} combined with the transistor Tr_{22} shunted across the drive. On the negative excursion the current through R_{11} tends to turn Tr_{22} on and limit the drive to the output.

The completely new feature of the 741 op-amp was that the chip incorporates a 30pF m.o.s. capacitor (C in Fig 4). As a result the amplifier does not need any external frequency compensation, even for closed loop gains down to unity.

It has an internal 6dB/octave roll-off commencing at 10Hz, passing through unity gain at 800kHz, to ensure a typical 80° phase margin at unity gain.

The high emitter-base breakdown voltages of the lateral p-n-p transistors Tr_3, Tr_4 means that the 741 circuit is able to withstand $\pm$30V differential input signals without breakdown (compared with the $\pm$5V max of the 709).

The process improvements of the 741 did not make much overall improvement in the characteristics of the 709 (except for slightly increased gain and higher input resistance). Improvements were rather that the 741 had protection against output short circuit damage and input latch up, a larger differential voltage range, internal frequency compensation, simple offset voltage nulling with a single 10kΩ potentiometer (connected across emitters of Tr_5, Tr_6, in Fig. 4), wider operating voltage range ($\pm$3 to $\pm$20V) and lower quiescent supply current (1.7 as against 2.5mA typical).

The 741 appears under various numbers such as Motorola's MC1741, National Semiconductors' LM741, Newmarket's LIC741, Transitron's TOA2741, ITTs MIC 741 and Texas Instrument's SN72741.

As a parallel development, we find manufacturers providing two op-amps in one package with the useful characteristic of close thermal tracking between the chips. Well known examples of dual 709s are the Transitron TOA2809, and Motorola MC1437, and of dual 741s the TOA2841 and MC1558.

Second generation

All the op-amps discussed so far have input offset and bias currents measured in hundreds of nanoamps which led to unacceptable voltage drifts with temperature in high-impedance circuits.

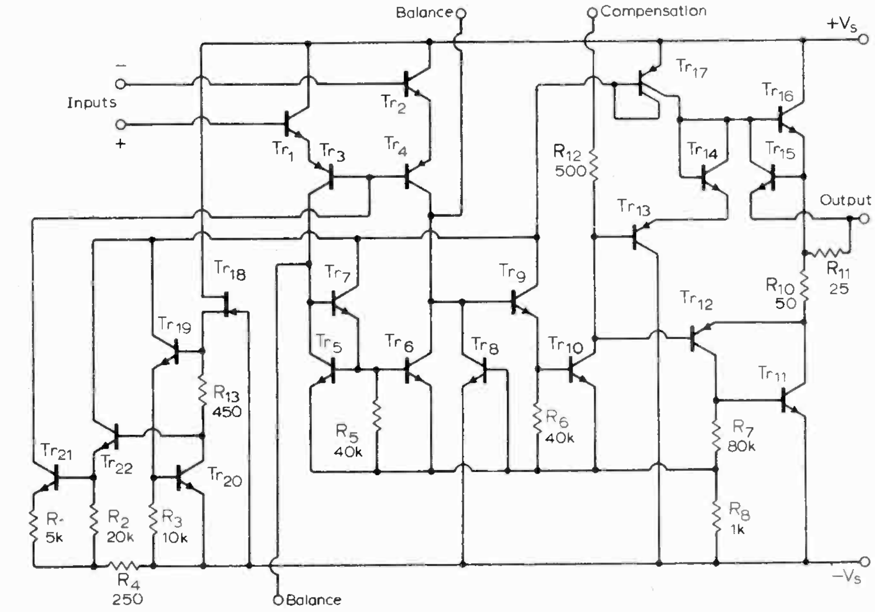


Fig. 5. Second generation example, the LM101A. Both bipolar and field effect transistors are used.

The second generation of monolithic op-amps was characterized by an order of magnitude improvement in bias and offset currents. The National Semiconductor's LM101A was the archetype of these. It has 20nA max. offset current compared with the 500nA limit of the 709 and its previous successors. Similarly in the 101A the input bias current was improved from 1.5μA to 0.25μA max.

The circuit of the LM101A, given in Fig. 5, has several interesting features, making extensive use of transistors and f.e.ts as active collector loads, high-gain lateral p-n-p transistors and pinch resistors.

You can make your way through the circuit of the 101A in Fig. 5 by noting that Tr_5 and Tr_6 act as active collector loads for the balanced input stage Tr_1/Tr_3, Tr_2/Tr_4. The right hand transistor Tr_4 drives the common-emitter Darlington pair Tr_9, Tr_{10}, whose collector load is Tr_{17} (via Tr_{13}, Tr_{14}). The drives to the bases of the output transistors Tr_{16}, and Tr_{11} are from Tr_{17} collector and from Tr_{10} collector via Tr_{12}.

The active collector loads Tr_5, Tr_6 are better than resistor loads. They avoid the use of large resistances to achieve low current operation (important in reducing input bias currents and power consumption). They do not require much voltage to be dropped across them for correct operation, which leads to an increase in common-mode input range, an increase in voltage swing, a wider permissible range of supply voltages, and higher stage gains (lessening the number of stages required and simplifying frequency compensation).

Transistor Tr_{18} in Fig. 5 is an example of an f.e.t. used as an active constant-current-source collector load for transistor Tr_{20}.

Lateral p-n-p transistors first featured in the 709 (Tr_9 in Fig. 2) were originally very low-gain devices (with current gains much less than 10) and low frequency cut-offs (typically about 1MHz). By the time the 101A was brought out in late 1968, processes had improved so much that lateral p-n-p current gains of greater than 100 were achieved. Tr_3 and Tr_4 in Fig. 5 are examples of such later transistors. A further development of the lateral p-n-p is the 'controlled gain' transistor in which the collector is split into two segments and one of them is connected back to the base. The effective current gain is determined by the relative areas of the two collector segments. Tr_{17} in Fig. 5 is such a controlled-gain transistor.

'Pinch' or 'pinched-base' resistors are special high-value diffused resistors originally developed to get round the fact that conventional base-diffused resistors of values above a few thousand ohms were impracticable. The cross sectional area of a base-diffused resistor is effectively reduced or 'pinched' by an emitter-diffusion on top of it. By this process resistor values up to 100kΩ are feasible. R_2, R_5, R_6 and R_7 in Fig. 5 are examples of such high-value 'pinch' resistors.

Further examples of other op-amps of this lower input current second generation are the well-known Motorola MC1539/1439 and the Sprague 2139.

Third Generation

The second generation 101A had given input bias and offset currents of 250nA and 20nA max. compared with 1,500 and 500nA in the first generation 709. By 1970, monolithic bipolar technology had enabled a further order of magnitude reduction in input currents in the 'third generation' op-amps. In them the National Semiconductors LM108 led the way. In this, input bias and offset currents dropped to 2nA and 0.2nA max.

This improvement is achieved by using 'super-gain' or 'punch-through' transistor at the input. The current gain of an n-p-n transistor in a monolith depends for one thing on the length of the emitter diffusion cycle in the manufacture.

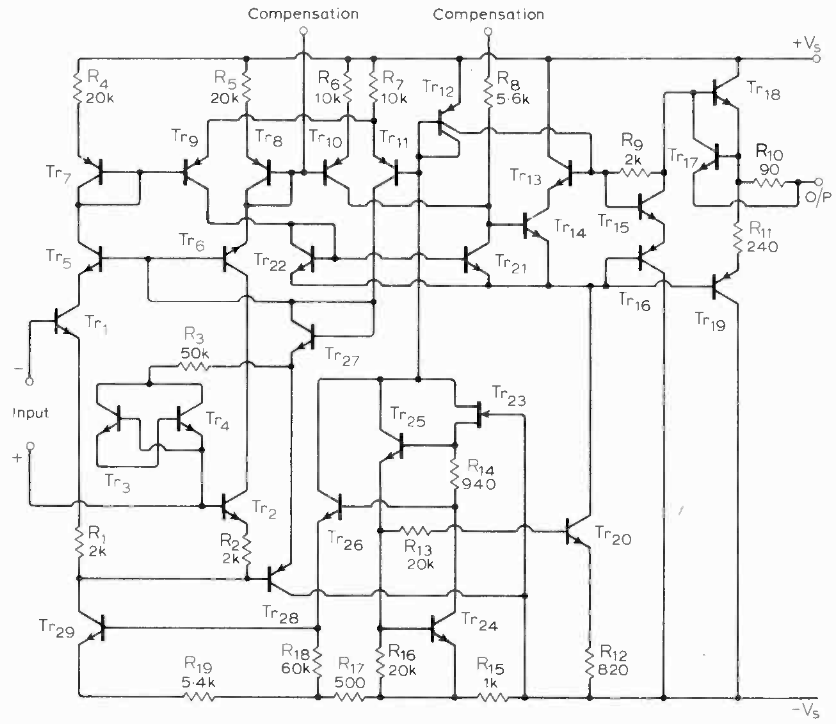


Fig. 6. Third generation example, the LM108. Tr_1 and Tr_2 are 'super-gain' or 'punch-through' transistors which operate at very low voltages.

Devices emitter diffused for unusually long time exhibit increased current gain at the expense of collector breakdown voltage. Current gains of 4,000 can be obtained but with a collector breakdown voltage of 4V.

In Fig. 6, the circuit of the LM108, low-voltage super-gain transistors are used as Tr_1, Tr_2, the input transistors. To prevent voltage breakdown they are operated in cascode connection with Tr_5 and Tr_6, which stand off the common-mode voltage. The bases of Tr_5 and Tr_6 are bootstrapped via Tr_{27} and Tr_{28} to the common-mode voltage seen by the input transistors. Thus the input transistors are always operated with near-zero collector-base voltage, and high temperature leakage currents do not show up at the input.

The super-gain input transistors give other bonuses. The 108 input resistance is 30 MΩ min. compared with the 50kΩ min. of the 709. Voltage gain improves to 94dB min. instead of 84dB. Common mode rejection ratio becomes 80dB min. instead of 65dB. Typical supply current drops from 2.5mA to 0.15mA.

The Motorola MC1556 is another third generation op-amp. using super-gain input transistors, and you will also find similar transistors incorporated in the unity gain, voltage-followers LM102 and LM110.

High input impedance

The low input resistance of the 709 led to the development of special high R_{IN} monolithics along two lines—Darlington pairs and f.e.ts for the inputs.

At first sight a Darlington compound should give the same sort of result as a super gain device. However the Darlington pair voltage mismatch tends to be worse because it depends on current gains; also it tends to be higher noise and exhibits lower common mode rejection. The Transitron TOA8709 is a well known example of such a Darlington input.

The f.e.t. input transistor approach is used in the Fairchild μA740 where an input resistance of $10^{12}\Omega$ is achieved with a typical offset current of only 20pA. Against this, f.e.t.—input op-amps exhibit offset voltages and voltage drifts about twenty times higher than the typical 1mV and 2μV/°C of the super-gain transistor approach. (Even lower bias and offset currents have been obtained by hybrid assembly using selected matched f.e.t. chips at the input as in the Teledyne AD503.)

Higher slew rate

One of the defects of earlier generation op-amps was the limited small signal and power bandwidths, usually specified by unity gain bandwidth (for small signal) and unity gain slew rate for full output. The 709 had a 1MHz typical bandwidth and 0.5V/μs slew rate, the major restriction being the low gain, low frequency lateral p-n-p used (Tr_9 in Fig. 2). Process improvements in later generation general-purpose op-amps pushed gain-bandwidths out to about 5MHz and slew rate to about 5V/μs.

However for higher slew rate requirements, special op-amps have been developed such as the Signetic 531 (typical 40V/μs) or the Optical Electronics 9694 (100V/μs).

Micropower

Another area where specialist op-amps have been developed is low power consumption. In this area, the Solitron UC4250 indicates the sort of performance aimed at.

This micropower op-amp uses so little power that its batteries last as long as their shelf life. It can operate on rails from ±1V to ±18V. It has typical input bias currents of only 3nA and zero input offset temperature drift. On ±1V it has a power consumption of only 20μW.

Conclusion

The second half of the 1960s was an astonishing time when the monolithic op-amp developed from the old-faithful 709 (which in 1970 still does well over half the op-amp. jobs around) through the 101A up to the 108. We now have a situation where the handy monolith is bidding fair to oust all discrete or hybrids of the balanced differential input type, is giving a performance near to chopper stabilized types, and could well in time even match the heights of the varactor-bridge and electrometer valve.

Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses

MANCHESTER

Jan. 5-7 — The University
Solid State Physics
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

OVERSEAS

Jan. 12-14 — Washington
Reliability—Meeting the Demand
(J. W. Thomas, Vitro Laboratories, 14000 Georgia Ave, Silver Spring, Maryland 20910)

Jan. 14-20 — Paris
Audiovisual et Communication Salon
(S.D.S.A., 14 rue de Presles, 75 Paris 15e)

Jan. 19-21 — Oaxtepec, Mexico
Systems, Networks and Computers
(Dr. Roberto Canales, Instituto de Ingenieria, Ciudad Universitaria, Mexico 20, D.F., Mexico)

Jan. 26 & 27 — Chicago
Soldering Technology
(William Dunbar, Illinois Institute of Technology, 3241 South Federal Street, Chicago, Illinois 60616)

An Equation-solving Aid

Signal-flow graph methods applied to solution of simultaneous equations in up to six variables

by V. J. Phillips, B.Sc.(Eng.), Ph.D., D.I.C., A.C.G.I., M.I.E.E.*

Many techniques are available for the solution of simultaneous equations. The simple, schoolboy method involves multiplying the equations by various numbers and subtracting one from another so that the variables can be eliminated one at a time. Anyone who has tried to carry out such a procedure for a set of equations having more than three variables will know that it becomes very difficult to remember what one is multiplying by and subtracting from what—in fact, the difficulty increases very rapidly with the number of variables in the equations. The more advanced methods of solving equations, such as "triangulation of the matrix" procedures, Cramer's Rule, and matrix inversion, are a help because they lay down the procedure which has to be followed. One still has the task of performing the various arithmetical operations involved but at least one is relieved of the necessity of making decisions about the multiplying factors to be used and the order in which to use them.

In other words, the solution of a set of simultaneous equations can be divided into two parts:

(i) Deciding what steps to take, and

(ii) Actually performing the arithmetic involved in those steps.

If one is trying to solve a set of equations in, say, twenty variables, the only sensible course is to do it on a digital computer using one of the numerous routines available in the soft-ware library. However, if one wishes to solve a set of equations in five or six variables, one has to decide whether it is worth the effort of going to the computer centre, looking out the programme, punching up the cards or tape, correcting any errors, etc. or whether it is really much easier to press on and do the job by hand. Reference has already been made to some of the standard matrix methods for equation solving. These are easy enough in theory but when one is working out the determinant for a 5×5 matrix the expressions which result as the order of the matrix is reduced become more and more clumsy to handle, and there is always that pestilential business of remembering the signs and working them out correctly.

The piece of equipment described here is an aid to manual solution of equations in reasonably small numbers of variables. The particular version constructed by the author will handle up to six variables, but there is no reason why the principle should not be extended up to higher numbers if required. The apparatus is based on the "signal flow graph" method of solving equations.

The signal flow method

The signal flow graph is a pictorial representation of a set of equations demonstrating the inter-relationships between the variables. Consider first the equations

$$\left.\begin{aligned} 4.x_1+1.x_2+2.x_3 &= 4 \\ 2.x_1-1.x_2-4.x_3 &= 4 \\ 3.x_1+8.x_2-1.x_3 &= 20 \end{aligned}\right\} \qquad (1)$$

The first step is to rewrite these as

$$\left.\begin{aligned} x_2 &= 4-4.x_1-2.x_3 \\ x_1 &= 2+0{\cdot}5.x_2+2.x_3 \\ x_3 &= -20+3.x_1+8.x_2 \end{aligned}\right\} \qquad (2)$$

The equations may be used in any order to produce expressions for x_1, x_2 and x_3. Obviously if a particular equation involves $1.x_n$ then it is sensible to use that equation for x_n to avoid fractions as far as possible. This is why the first equation above has been used for x_2 and the second for x_1. Four dots called "nodes" are now marked on a piece of paper as shown in Fig. 1, one representing

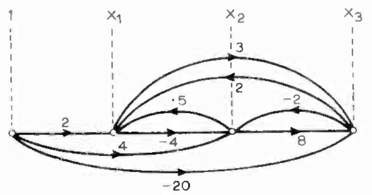


Fig. 1. Signal-flow graph for equations (2).

unity, the others x_1, x_2, and x_3. "Branches" are now drawn representing the contributions of the nodes to one another according to equation (2) as shown. For example, the first equation of (2) for x_2 says that the variable x_2 is made up of 1 multiplied by $+4$, x_1 multiplied by -4, and x_3 multiplied by -2. The relevant numbers are marked on the branches and are referred to as the "transmittances" of the branches. The arrows on the branches are read as "contributes to"—for example, the bottom branch would be interpreted as "node one contributes itself multiplied by -20 to node x_3". Note especially that it is not possible to reverse the arrow and alter the sign as one can when labelling currents in a circuit. Fig. 2 shows why; the first graph represents the

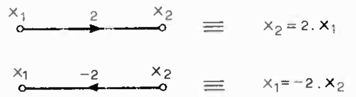


Fig. 2. Erroneous reversal of arrow and sign.

equation $x_2 = 2.x_1$, whereas the second represents $x_1 = -2.x_2$ which is not the same thing at all.

The complete graph shows the inter-relationship between the variables, but it should be noted that there are several ways of writing equations (2), and hence there are several possible signal flow graphs to represent the original equations (1). The particular graph obtained depends on how the variables were selected in equations (2). The procedure used to solve the equations is very useful in that it enables the graph to be simplified in easy stages, a bit at a time. In order to explain the overall procedure for solution it is first necessary to establish a set of simple rules for graph manipulation.

RULE 1. For parallel branches

If there are two branches in parallel as shown in Fig. 3(i) this represents the equation

$$x_2 = a.x_1 + b.x_1$$

which equals, of course, $(a+b).x_1$ (3)

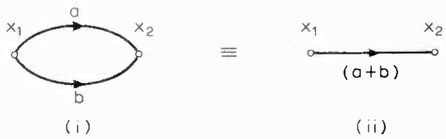


Fig. 3. Branches in parallel.

Thus the two branches may be replaced by the single branch labelled $(a+b)$ as in Fig. 3(ii).

RULE 2. For cascaded branches

If two branches are simply in cascade as shown in Fig. 4(i), this graph represents the two equations

$$x_2 = c.x_1 \qquad x_3 = d.x_2 \qquad (4)$$

* University College of Swansea.

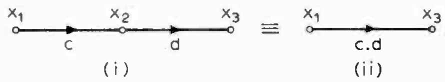


Fig. 4. Branches in simple cascade.

Thus $x_3 = cd.x_1$ as represented by Fig. 4(ii). Note that in order to apply this rule the branches must be in simple cascade with no other branches entering or leaving node x_2.

RULE 3. For reduction of loops

Inspection of Fig. 1 will show that several loops appear in the complete graph. A "loop" may be formally defined as "a path which, following the arrows, starts and ends on the same node, and along which no node is encountered more than once". A loop such as that between x_1 and x_2 of Fig. 1 where there is a forward contribution of -4 and a backward contribution of 0·5 is often referred to as a "feedback" loop.

Consider now the equation

$$4x_1 + 3x_2 = 7$$

which may be rewritten as

$$x_1 = -3x_1 - 3x_2 + 7 \qquad (5)$$

This is a rather unusual way of doing things, but nevertheless it is algebraically correct. Equation (5) may be represented by the signal flow graph of Fig. 5, and the "self

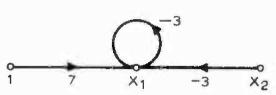


Fig. 5. A self-loop.

loop" on node x_1 can be interpreted as x_1 contributing to itself multiplied by -3. One would not normally choose to draw the signal flow graphs in this way, but such self-loops arise frequently in signal flow work and it is necessary to know how to handle them. The signal flow graph of Fig. 6(i) will be taken as an illustration of how loops are treated.

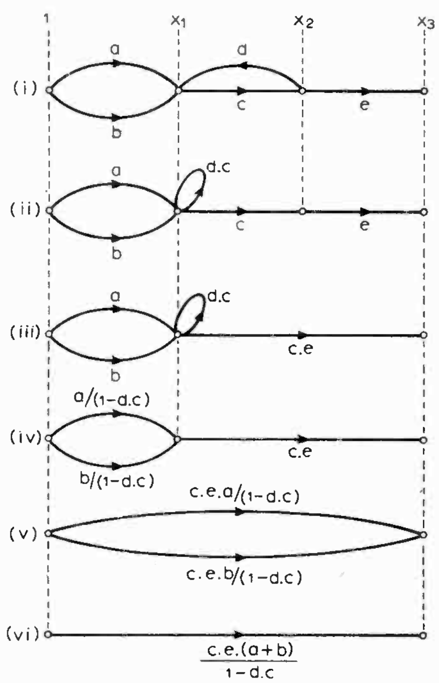


Fig. 6. Rules for feedback loops, self-loops and node elimination.

This graph corresponds to the equation

$$\left.\begin{aligned} x_1 &= a+b+d.x_2 \\ x_2 &= c.x_1 \\ x_3 &= e.x_2 \end{aligned}\right\} \qquad (6)$$

$a, b, \ldots e$ are constants; the first equation may be simplified using the parallel branch rule for a and b, but it will be left as it stands for the moment in order to illustrate a later point.

Simple manipulation of these equations reduces them to

$$\left.\begin{aligned} x_1 &= a+b+d.c.x_1 \\ x_2 &= c.x_1 \\ x_3 &= e.x_2 \end{aligned}\right\} \qquad (7)$$

The graph will now appear as shown in Fig. 6(ii), and it will be seen that the feedback loop has been transformed into a forward branch c and a self loop $d.c$ on the x_1 node. This, in fact, constitutes the rule for dealing with simple feedback loops. By application of Rule 2, the graph reduces to Fig. 6(iii) corresponding to equations

$$\left.\begin{aligned} x_1 &= a+b+d.c.x_1 \\ x_3 &= c.e.x_1 \end{aligned}\right\} \qquad (8)$$

The first of these equations is equivalent to

$$x_1(1-d.c) = a+b$$

or

$$x_1 = \frac{a}{1-d.c} + \frac{b}{1-d.c} \qquad (9)$$

and the left-hand part of the graph of Fig. 6(iv). The rule for removal of a self-loop is now established. If the self-loop on a node has a transmittance T, every incoming branch to that node is multiplied by $1/(1-T)$.

Note here that T can never $= 1$ because this corresponds to the meaningless equation $x_1 = a+b+x_1$, so multiplication by infinity never arises for sensible equations.

RULE 4. For node elimination

The last equation of (8) may now be written

$$x_3 = \frac{c.e.a}{1-d.c} + \frac{c.e.b}{1-d.c}$$

and the graph appears in Fig. 6(v). Node x_1 has in fact been eliminated, and the rule for this operation may be expressed as follows: "when x_1 is eliminated two paths are destroyed, viz. from 1 to x_3 via the upper route, and from 1 to x_3 via the lower route. Replace these by the paths of Fig. 6(v)."

Finally, the two branches may be combined by Rule 1 as in Fig. 6(vi).

The simple rules for dealing with individual features of signal-flow graphs have now been established, but the reader should be warned that there are pitfalls in attempting to solve complete graphs using these as they stand. It is much better to embody them in a general set of procedures which will now be illustrated by solution of equations (1), corresponding to Fig. 1, and Fig. 7. It will be assumed that in the first instance the value of x_3 is required. The general procedure is to eliminate the nodes of the other variables in turn. At each elimination *all* paths passing through the eliminated node which are destroyed must be restored. First let x_1 be

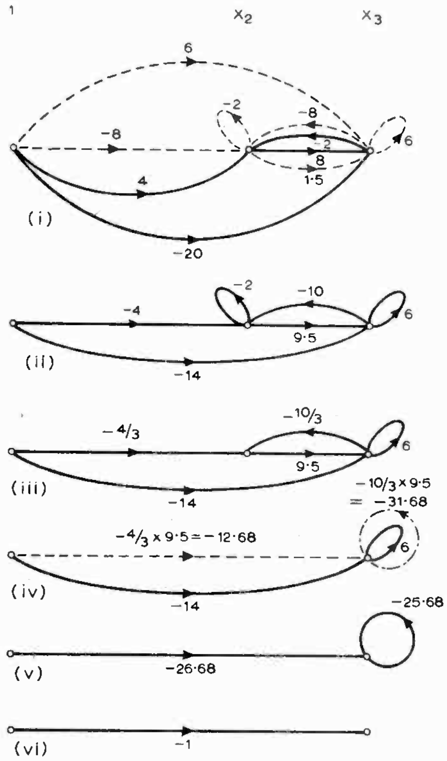


Fig. 7. Solution of the signal-flow graph of Fig. 1 by successive node elimination.

eliminated from Fig. 1. The paths which are destroyed are:

From 1 to x_2 via x_1 . . . replace by direct path transmittance -8
From 1 to x_3 via x_1 . . . replace by direct path transmittance 6
From x_2 to x_3 via x_1 . . . replace by direct path transmittance 1·5
From x_3 to x_2 via x_1 . . . replace by direct path transmittance -8
From x_2 to x_2 via x_1 . . . replace by self loop -2
From x_3 to x_3 via x_1 . . . replace by self loop 6

The resulting graph now looks like that of Fig. 7(i) where the new replacement paths are shown dotted for clarity. This may be tidied up using the rule for parallel branches, producing the graph of Fig. 7(ii). Notice particularly the last two replacements listed above; this is how self loops appear in this sort of analysis, and it is important to remember them. The elimination process which has now been carried out is exactly equivalent to substituting for x_1 in the other two equations of (2). Such a substitution would yield two equations in x_2 and x_3 only, corresponding precisely to the graph of Fig. 7(ii).

The next stage is the elimination of node x_2, but before this can be done the self loop on that node must be removed. This is done according to Rule 3 by multiplying each incoming branch to that node by

$$\frac{1}{1-(-2)} = 1/3$$

resulting in Fig. 7(iii).

Node x_2 is now eliminated, replacing paths:

From 1 to x_3 via x_2 . . . replace by $-12{\cdot}68$
From x_3 to x_3 via x_2 . . . replace by self loop $-31{\cdot}68$

Fig. 7(iv) shows the picture at this stage, and Fig. 7(v) shows the result after combining parallel paths.

Removal of the self loop according to the rule produces Fig. 7(vi) which says, simply, that $x_3 = -1 \times 1 = -1$, which is the solution required. Notice that if the value of x_2 is also wanted one does not have to start again from square one; elimination of node x_3 from Figs 7(ii) or (iii) will yield the value of x_2.

A simple set of procedural rules for reducing these signal flow graphs may now be drawn up as follows:

1. Select a node to be eliminated.
2. If this node has a self-loop remove it by multiplying all incoming branches to that node by $1/(1-T)$ where T is the transmittance of the loop.
3. Eliminate the node, replacing all paths thus destroyed (remembering paths which result in self-loops—it's easy to forget these!).
4. Combine the new branches with any existing branches.

Repeat all these steps for the next node selected for elimination.

This is essentially a very simple procedure, but the one difficulty which does exist lies in making sure that *every* path destroyed is replaced. With a more complicated graph involving, say, eight or nine nodes this can be quite a tricky business. The only way to do it safely is to set about it in a logical manner. Take node 1 as a starting point and inspect in turn the paths to the other nodes $x_1, x_2 \ldots x_n$ via the chosen node to be eliminated x_e. At each stage add the replacement branch to any direct branch which exists between the nodes. Next start at x_1, and look for paths to $x_1, x_2, \ldots x_n$ via x_e, and so on using each node in turn as a starting node. In this way every combination of nodes is tested in logical order. Notice that there can never be a self loop on node 1, since all arrows point from that node. This is only to be expected since 1 is a constant uninfluenced by the values of the variables.

The apparatus which is to be described assists in this logical searching process and reduces it to a simple repetitive procedure which can be carried out step by step. As the photograph Fig. 8 shows, it consists of a display board accompanied by one of two possible plug-in units. The first of these (in the foreground of Fig. 8) is a simple manual control unit; the other (actually connected to the display board in the photograph) is a fully automatic control unit.

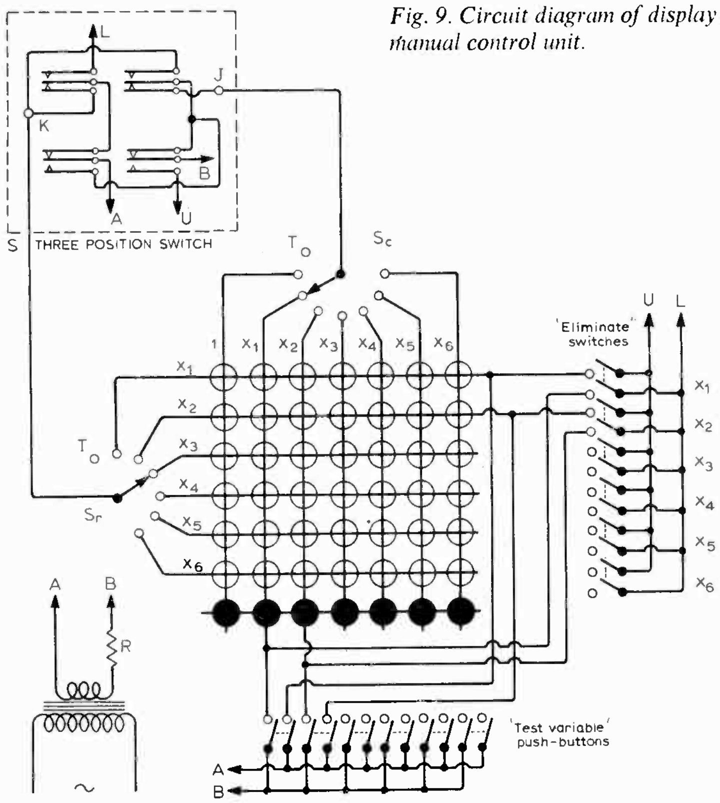


Fig. 9. Circuit diagram of display board and manual control unit.

Principle of simple manual model

The display unit consists of an array of torch bulbs connected to a matrix of wires as illustrated in Fig. 9. The circles on the cross-points represent bulbs connected between the two wires. According to the settings of the switches S_r and S_c the source of e.m.f. can be connected between any horizontal (row) wire and any vertical (column) wire, thereby lighting up the bulb at the junction of those two wires. However, the current path via the chosen bulb is not the only one which exists since all the other bulbs are connected to the e.m.f. in various series/parallel combinations. The net result of this is that the selected row and column glow with diminished brightness. Provided the number of rows in the matrix is the same as the number of columns, a cross of dimly-lit bulbs appears with the one bulb at the crossing glowing brightly. By correct selection of the resistance R (which in practice is a piece of resistance wire cut to the correct length) the light from the unwanted row and column bulbs can be reduced to a very dull glow while the required bulb still glows very prominently. Although this effect seems at first sight to be a nuisance, it is actually quite useful as a quick check to the correct operation of all the bulbs. If S_r is set to one position while S_c is rotated through all possible positions the faint glows provide a good indication that all is well and it saves having to run through all combinations of settings of S_r and S_c. It will be found that if a bulb should happen to go open-circuit it soon shows up, as the distribution of currents on the matrix is disturbed and various unusual combinations of lights appear.

The bulbs are mounted on a perspex sheet marked out in squares (see Fig. 10), each square being big enough to have a number written on it in easily-erased wax pencil. The rear of the perspex sheet is painted white for ease of visibility. The columns on the board are marked $1, x_1, x_2 \ldots$ etc. (or whatever the variables may happen to be) and the rows are labelled $x_1, x_2 \ldots$.

The number of rows is one fewer than the number of columns, so in order to keep the current distributions in balance as previously mentioned, a further row of bulbs is also present but is hidden under the board.

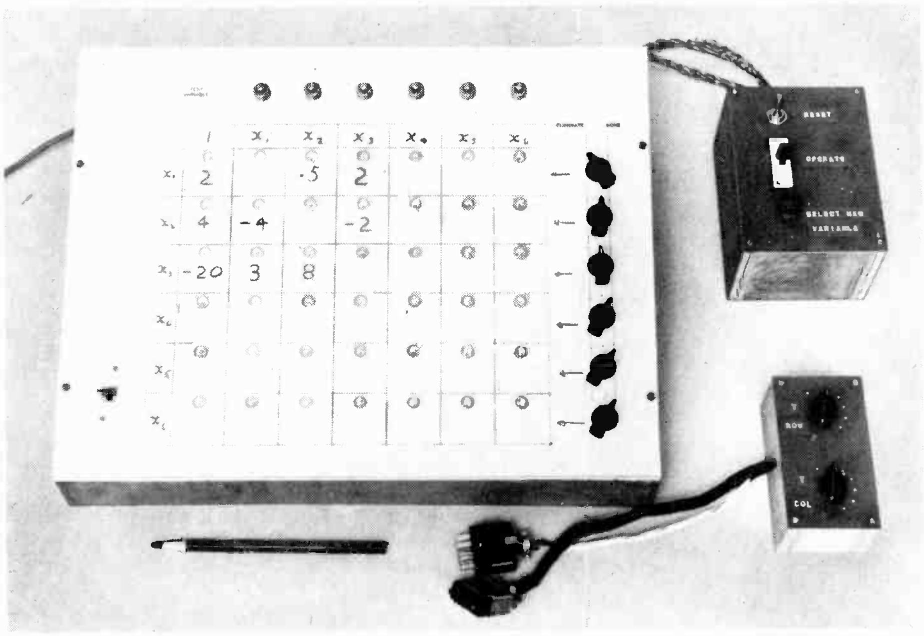


Fig. 8. The complete apparatus.

These bulbs are indicated as black circles on the matrix of Fig. 9. Switches S_c and S_r are mounted on a separate box connected to the display board via multiway plugs and sockets. The transformer is under the display board.

The whole display unit provides a slightly amended way of representing a signal flow graph. The coefficients of the equations in signal flow form (equations 2) are written on to the board so that a row represents the contribution of the quantities at the head of the columns to the variable of that row. For example, the first row, representing x_1, has 2×1, $0{\cdot}5 \times x_2$ and $2 \times x_3$. The equations can therefore be set out very simply and easily on the display board.

By setting the switches S_r and S_c one may now ask, for example, the question "is there a direct contribution from x_1 to x_3?" The switches are set as in Fig. 9 so that row x_3 and column x_1 are connected to the e.m.f. and the light indicates the required contribution which is the direct branch in signal-flow graph terms. If no such path exists, the blank square indicates that this is so.

The board now has to be modified so that one may ask the question "is there a path from x_1 to x_3 via some other chosen node (say x_2)?" The method of doing this is also indicated in Fig. 9. The rather complicated-looking switch S* is actually just a way of obtaining a double-pole, 3-way switch with a convenient toggle action. It is mounted on the lower left-hand corner of the display unit. When the switch lever is in the central position the four changeover contacts are in the positions shown in Fig. 9. The incoming voltage from the transformer is thus applied to the rotary contacts of S_r and S_c.

A row of double-pole rotary switches called the "eliminate" switches is fixed to the right-hand side of the display, one switch for each variable. On the display board shown in Fig. 10 these are provided with the three settings "off", "eliminate" and "gone". (The "gone" setting is used in connection with the automatic control unit, and is inoperative with the simple manual plug-in.) When a variable, say x_2, has been chosen for elimination the corresponding "eliminate" switch is closed. This connects lines U and L to row x_2 and column x_2.

*Type S.W.11-002AHH made by S.T.C. and available from I.T.T. Electronic Services Ltd., Edinburgh Way, Harlow, Essex.

When the lever of switch S is moved to one extreme position the two lower sets of contacts *only* change over so that the e.m.f. is now connected between column x_1 and row x_2. When S is moved to the other extreme the e.m.f. is connected between column x_2 and row x_3.

Therefore one may now ask the two questions:

(i) "Is there a direct path from x_1 to x_3?" Answer: indicated by the light which glows when S is in its central position.

(ii) "Is there an indirect path from x_1 to x_3 via x_2?" Answer: indicated by the two lights which flash when the switch S is moved from one extreme to the other.

One further facility is available. Before elimination of a variable can be carried out, any self-loop must be removed from the corresponding node. A row of push-button switches marked "test variable" is mounted above the variable columns. When switches S_c and S_r are set at the "test" position "T", depressing one of these buttons will light up the square on which the self-loop will be represented if present. These push buttons enable one to identify self loops very quickly.

The procedure for solving equations is thus as follows:

1. Write the equations in signal-flow form and enter the numbers on the board as described previously.

2. Select the first variable for elimination. Set switches S_r and S_c to "T", and use the push button to see if there is a self-loop on that variable. If so multiply all numbers in the row where the light appears by $1/(1-T)$, T being the self-loop transmittance, indicated by the light. If one has a choice of which variable to eliminate first, it clearly saves work if one picks a variable with no self-loop.

3. Set the "eliminate" switch for the selected variable.

4. Set S_c to 1, and S_r to the other variables in turn. At each setting, move the lever of S up and down. Two lights will flash; take the product of the numbers in these squares (i.e. the transmittance of the path being destroyed) and add it to the number in the square illuminated when S is in the central position. The use of a wax pencil makes this easy. Do *not* erase any numbers at this stage except that in the "addition" square.

5. Set S_c to x_1, and repeat step 4. Repeat again for all the rest of the settings of S_c so that all possible combinations are tested in logical sequence.

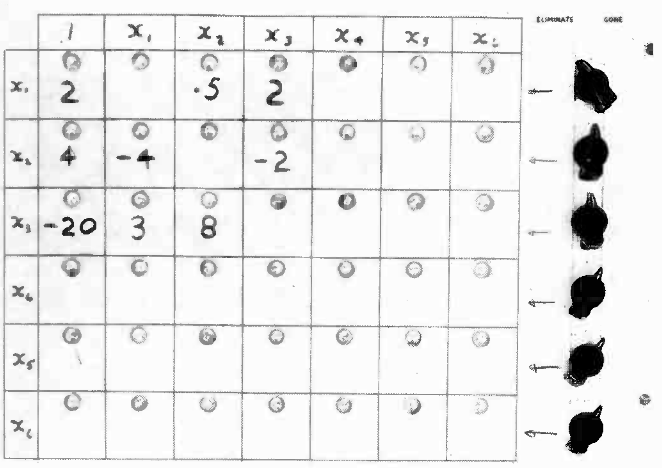


Fig. 10. Detailed view of display board set ready for solution of equations (2).

6. When the last setting of S_c and S_r has been reached, rub out the numbers in the row and column of the eliminated variable. Restore the "eliminate" switch to its "off" position.

7. Select a new variable for elimination, and repeat steps 2 to 6 until all but the desired variable have been eliminated—the value of that variable can easily be obtained from the last remaining equation.

Note: once a variable has been eliminated there is no need ever to set either S_r or S_c to that variable again. Once it's gone, it's gone!

When one goes through this procedure step by step as described above, a little thought will show that occasionally one is asking the machine a nonsensical question. For example, if S_c was set to x_1 and S_r to x_3, and the "eliminate" switch for x_1 was set, this would be asking the question "is there a path from x_1 to x_3 via x_1?" which really makes no sense. An even more pointless question is asked if S_r, S_c and the "eliminate" switch are all set to the same variable, say x_3. This would correspond to the question "is there a path to x_3 from x_3 via x_3?"

Fortunately one does not have to remember to avoid these questions. When a sensible question is asked, three separate lights in three separate squares will light up for the three positions of S. For any nonsensical question the same light will be lit for two or more of the settings of S. The rule is thus simply this: only if three separate lights come up need multiplication and addition be carried out. In all other cases ignore the whole thing and carry on to the next setting of S_r and S_c.

As long as the procedure is followed—and it is one of these things that is really very much easier to do than to describe—the solution of the equations is reduced to a series of very simple multiplications and additions as described by the lights. As long as the machine knobs are rotated according to the strict logical sequence described above, it is deciding what steps should be taken; the operator merely has to take them as instructed.

Automatic model

The manual model just described is simple to construct, easy to operate and is ideal for instructional purposes, but it does demand a certain degree of alertness because of two minor operational disadvantages, viz.

1. When one has eliminated a variable, one must remember not to set the switches to that variable again. If one forgets this, nothing tragic happens to the calculations; one is merely carrying out unnecessary operations which will eventually be ignored.

2. Sometimes, following the strict logical procedure one is asking silly questions of the machine. These cases are easily spotted as previously indicated.

The more fully automated model about to be described was designed to remove these slight disadvantages thereby removing (almost!) all necessity for the operator to think, leaving him one job only; namely to carry out whatever operations the machine demands.

The basic machine is the same as before, but the two manually operated switches

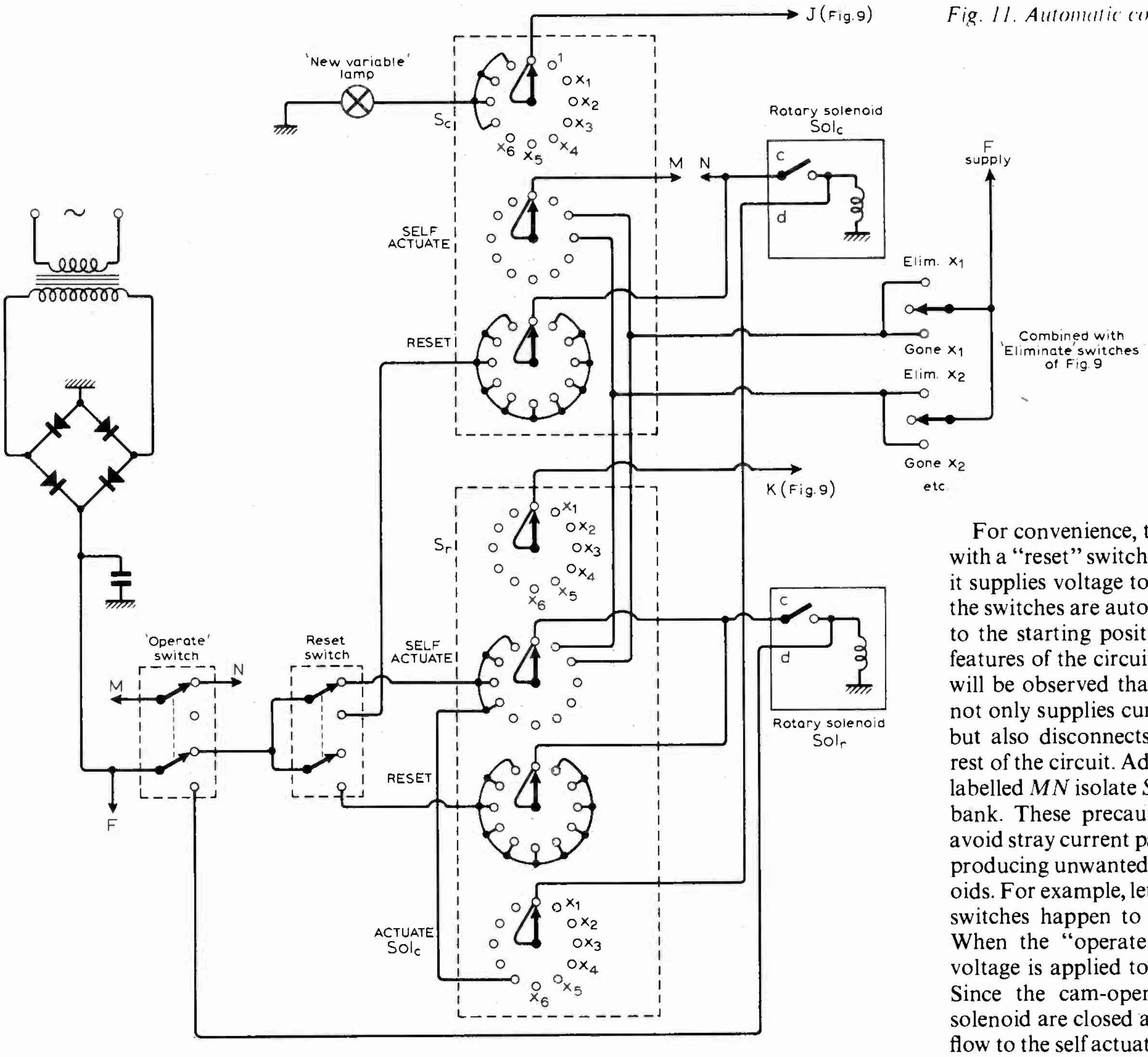


Fig. 11. Automatic control unit.

S_r and S_c in the control box are replaced by switches operated by rotary solenoids designated Sol_r and Sol_c in Fig. 11. Sol_c operates three banks of contacts; Sol_r operates four banks. Each bank is a one-pole 11-way switch. In the twelfth position the moving contacts are connected to themselves. The banks S_r and S_c are connected to the display board exactly as shown before in Fig. 9.

The solenoids can be operated in two ways. If voltage is applied to the terminal labelled *d*, the coil is energised and the solenoid moves on one step. It remains energised until the voltage is removed, and a further application of voltage is needed to move it on again. If the voltage is applied to the terminal labelled *c*, the voltage is applied via a set of cam-operated make/break contacts so that the switch will continue to step on until the voltage is removed.

When the "operate" switch of Fig. 11 is depressed, voltage is applied to the *d* terminal of Sol_r so that it steps on one place. Thus by continued pressing and releasing of this switch the switches of Sol_r can be rotated as required. This particular machine is designed for 6 variables only. When the switches reach the seventh position, the last switch bank of Sol_r labelled "actuate Sol_c" applies voltage to terminal *d* of Sol_c stepping it one place. Further operation of the "operate" switch brings Sol_r on a further step. The "self actuate" bank then applies voltage to the *c* terminals of Sol_r so that it quickly steps itself back to the starting position. The arrangement thus far enables the whole array of lights to be scanned in sequence by continual depressing of the "operate" switch on the control unit. The "actuate Sol_c" bank acts as a sort of "carry" mechanism. When the lights have run through one complete sequence of all the columns and rows the S_c bank of Sol_c applies voltage to a bulb mounted on the control box, thereby indicating that one variable has been eliminated and that it is time to select another.

The "eliminate" switches on the display board are operated as three-pole, three-way switches when the automatic unit is in use. In the central "off" position, no connections are made at all. When the switch is set to the "eliminate" position, two of the poles operate exactly as in Fig. 9 and connect the appropriate rows and columns to the *U* and *L* lines. The other pole is used as indicated in Fig. 11 to connect a source of voltage to a position on "self actuate" switch banks. When either solenoid steps to this position, it is energised via its *c* contacts, thereby stepping it on one place. This ensures that disadvantage 2 is removed, so that the machine is never allowed to ask a nonsensical question. When a variable has been eliminated, the "eliminate" switch is set to the "gone" position. This releases the *U* and *L* line connections, but continues to supply voltage to the "self-actuate" banks so that the machine remembers that the variable has gone and never sets the switches to that position again.

For convenience, the machine is supplied with a "reset" switch. When this is operated, it supplies voltage to the "reset" banks and the switches are automatically stepped back to the starting position. One or two other features of the circuit are worthy of note. It will be observed that the "operate" switch not only supplies current to the coil of Sol_r, but also disconnects the voltage from the rest of the circuit. Additionally, the contacts labelled *MN* isolate Sol_c from its self-actuate bank. These precautions are necessary to avoid stray current paths through the circuit producing unwanted operation of the solenoids. For example, let us say that both sets of switches happen to be in the x_2 position. When the "operate" switch is depressed, voltage is applied to the terminal *d* of Sol_r. Since the cam-operated contacts of this solenoid are closed at this time, current will flow to the self actuate bank of this solenoid, and hence via the "eliminate/gone" rail to the self actuate bank of Sol_c causing unwanted operation of Sol_c. By isolating Sol_c with the *MN* contacts and removing voltage from the rest of the circuit this possibility is avoided. A similar difficulty arises during reset if the voltage source is not removed from the other banks of Sol_r causing stick-on of the solenoids.

Using this automatic plug-in, operation of the apparatus is very simple indeed, being reduced to continual operation of the "operate" switch. Each time this switch is pressed, one of the solenoids will operate, but if no light appears on the board, no further action needs to be taken other than pressing the "operate" switch again. When a light appears, the switch on the board is moved up and down and the usual multiplication and addition is carried out.

The complete procedure for solving a set of equations is as follows:

1. Set out the equations in signal-flow form and write them on to the display board as before. If less than the maximum number of variables is used (less than six on this board) set the "eliminate" switches for the unwanted rows to the "gone" position.

2. Operate the "reset" switch on the control unit, and keep it depressed until all solenoid clickings have ceased.

3. Select the first variable to be eliminated. Press the "test variable" button for that variable. If a number (*T*) appears in the square thus illuminated, multiply all entries

in that row by $1/(1-T)$. Set the switch for that variable to "eliminate". Note that it saves a bit of work if one selects a variable which does not show a self loop when tested.

4. Press the "operate" switch several times until the first light is illuminated on the board. Flick the switch on the display board to its two extreme positions; take the product of the numbers thus indicated and add to the square illuminated when the switch is in its central position.

5. Press "operate" again and repeat 4 above until the light labelled "select new variable" on the control unit glows.

6. Set the switch for the eliminated variable to "gone", and operate the "reset" switch. Select a new variable for elimination and repeat 3 to 5 above until all but one variable has gone.

7. At this stage, the board will still be filled with numbers, but only the numbers corresponding to the last remaining variable x_n are significant. The equation in row x_n will be of the form $x_n = \alpha(1)+\mu(x_n)$, from which the value of x_n is easily obtained. The appearance of the board at various stages in solution of equations (2) is shown in the appendix, and it is instructive to study this in conjunction with the signal-flow representation of Fig. 7.

Acknowledgement

The author wishes to express his thanks to R. Davies and A. G. Stone for their help in the wiring-up and testing of this apparatus.

Appendix

States of board for equations (2).

Initial state of board

	1	x_1	x_2	x_3
x_1	2		0·5	2
x_2	4	−4		−2
x_3	−20	3	8	

After elimination of x_1

	1	x_1	x_2	x_3
x_1	2		0·5	2
x_2	−4	−4	−2	−10
x_3	−14	3	9·5	6

Removal of self-loop from x_2

	1	x_1	x_2	x_3
x_1	2		0·5	2
x_2	$-\frac{4}{3}$	$-\frac{4}{3}$		$-\frac{10}{3}$
x_3	−14	3	9·5	6

After elimination of x_2

	1	x_1	x_2	x_3
x_1	2		0·5	2
x_2	$-\frac{4}{3}$	$-\frac{4}{3}$		$-\frac{10}{3}$
x_3	−26·68	3	9·5	−25·68

Since x_1 and x_2 have been eliminated, only x_3 remains and the last line represents

$$x_3 = -26{\cdot}68-25{\cdot}68x_3$$

or $$x_3 = -1$$

Books Received

Circuit Consultant's Casebook, by T. K. Hemingway, examines numerous circuit design errors. The examples given have all occurred frequently in the author's experience, and range from beginner's mistakes to the pitfalls encountered by experienced designers. Part 1 discusses basic problems and common errors, and part 2 deals with ways of meeting specification requirements not easily met by conventional circuits. This section brings to light some useful new configurations for multivibrators, triggers, timing circuits and constant current sources. This is a thoroughly practical book with a bibliography and very full index. Pp.210. Price 75s. Business Books, Mercury House, Waterloo Road, London S.E.1.

Amateur Radio Techniques (3rd Edition) by J. P. Hawker. The foreword to this book declares it is "not a book which aims at competing with or displacing the standard handbooks—but rather at extending the readers' awareness of new techniques and providing a source-book for many useful circuits and aerials: an *ideas book* rather than a constructional manual or conventional text book". The sections cover semiconductors, components and construction, receiver topics, oscillator topics, transmitter topics, audio and modulation, power supplies, aerial topics, and fault finding and test units. An i.f. list is given in the appendix and a useful index provided. Pp. 208. Price 20s plus 2s for postage. R.S.G.B. Publications, 35 Doughty Street, London W.C.1.

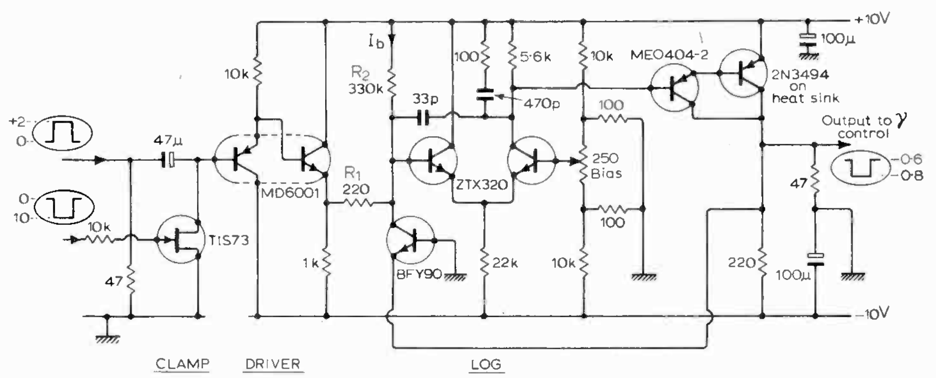
Radio Valve and Transistor Data, ninth edition compiled by A. M. Ball, tabulates the characteristics of 3000 valves and c.r.ts, and 4500 transistors, diodes, rectifiers and i.cs. Also included are tables of base diagrams and case and pin connections for valves, transistors, diodes and i.cs; and index to valve and transistor types with suggested near equivalents or comparable types; and a list of trade names and manufacturers' addresses. Price 15s. (£0.75). Butterworth & Co. (Publishers) Ltd, 88 Kingsway, London WC2B 6AB.

eurolec Electronic components, materials and sub-systems, companies and contacts. This book is the first of four replacing the previous single 'eurolec' editions. Items and areas covered in the first four sections of this volume are manufacturers and importers of valves and semiconductors, integrated circuits, passive components, and motor and servo equipment. The next two sections cover manufacturers and importers of raw materials for components, and assembly equipment. Two further sections deal with services to component makers and representatives of these in the U.K. The final section introduces complex companies: the book ends with a list of 833 foreign companies operating in the component sector, an index with telephone directory, and a summary of the firms operating in the 15 main product areas. Pp.432. Price 35s plus 2s postage. David Rayner Associates, Little Waltham, Chelmsford CM3 3NU.

Corrections

Variable power law video amplifier. Revised circuit is given below for the log amplifier of A. M. Pardoe's variable power law amplifier —published in the December issue, p.597. Fig. 6 should be disregarded. We apologise for the incorrect connections of the log and antilog transistors in Figs 5 and 7. The transistors should have their collector and base connections transposed. In Fig. 7 the emitter of the BFY90 antilog transistor should be joined to the emitter of the ME3002 transistor and some of the electrolytic capacitors should be reversed.

High-quality tape recorder. The following points should be noted with respect to part 2 (December). On p.587 the symbol μ was omitted in col.1 line 9 and col. 2 lines 4 and 15. On p.588 col.2, line 16 should read '24V r.m.s. at 0.7mA'. In the captions to Figs. 13 and 14 'connect R to A' should read 'connect R_{56} to A'. Table 5 is referred as Fig. 28 on Fig. 5. In Fig.15 the erase output should go to S_{kj} and S_{kk} —the first k is drawn as a 2. Table 2 (part 1 November issue) gives R_y as μF instead of Ω



The Long Run

Stability in the time domain

by Thomas Roddam

In the long run we are all dead. Even if you disagree with Maynard Keynes you can hardly doubt that all human wisdom and civilization is centred on Yorkshire: if you do, you are not a Yorkshireman and your opinion is worthless anyway. Never do owt for nowt.* Both these statements are the basic definitions of a stable system, although the second includes the superposition principle. What is a stable system? If there is no input, in the long run there will be no output. More generally, there will only be an output which is directly dependent on the input. The system with which we are usually concerned when we begin to talk about stability is generally one which can be split into a forward path containing active elements and a return path which usually contains only passive elements. This makes sense, because we must have an energy supply if we are to get an output with no input, and active elements are the way in which power is coupled into the system from an outside source. The restriction of activity to the forward path is not necessary. It just happens that the results we want are usually obtained this way.

The experienced reader will already be muttering $\mu/(1-\mu\beta)$ to himself. This old friend, the gain of a feedback amplifier, will, I am sure, crop up sooner or later. So will all that stuff about plotting $\mu\beta$ and seeing if it encircles the magic point. But μ and β do not contain any mention of time: what have they to do with what will be happening tomorrow?

Having mentioned feedback amplifiers it is necessary to say immediately that it is not necessary to have a feedback construction in order to have a system which is unstable. We can make use of two-terminal negative resistance devices. In studying these devices it is common practice to analyse them on a feedback basis, but this can be regarded as artificial, as a deliberate choice of a model which can be constructed out of other devices. We have, with the introduction of the transistor, spent much more time thinking about how active elements work than we ever did in the days of valves. In the pre-transistor days we left the valve-maker alone to get on with his job, and accepted that somehow he had produced the characteristics shown in the data sheets. This disclaimer noted, it may still be convenient, though not necessary, to mention feedback systems in the basic analysis.

Any study of the stability of a system which is assumed to be linear must be independent of the size of the signals in the system. Reasonably, then, we might simplify matters by having no signal at all. This, oddly enough, just will not work. An unstable system can be poised at a balance point. Like a good sheriff in a bad Western, it is ready to ride off in all directions. A neurotic sheriff, however, like what's-his-name's† ass, would be incapable of choosing any particular direction, and would remain at rest. A small shove is needed. In analytic terms, the essence of instability is that a signal will grow exponentially, but nothing can grow to nothing more than nothing. If we want to know whether a system is stable or is balanced at a point of instability like a needle standing vertically, we must apply a small disturbance.

One thing which I find repeatedly in writing these articles is that it is the obvious, simple, taken-for-granted things which are the awkward ones to discuss. When we are considering the behaviour of an amplifier we accept the idea of an input signal and an output. If we want to consider a two-terminal system we can get along with the idea of voltage as a cause, current as an effect. Without ever saying so explicitly we establish a set of rules which, because we have a pretty good idea of the answer, keep us out of a muddle. It is when we try to avoid relying on these instinctive, to engineers, rules that we begin to ask awkward questions. Just how awkward the questions can be has been shown fairly recently by the man who tried to build an un-ridable bicycle. Every schoolboy knows why a bicycle does not fall over as you ride it. The only trouble is that when you get rid of the schoolboy's stabilizing forces the bike is still stable.

As we are considering systems in terms of their behaviour in time, we may try to separate out cause and effect. Any real system will have some resistance somewhere in it. This is a less restricting assumption than appears at first sight: if it is an active system it can still have negative resistance elements which balance out the losses, but it must not simply store all the energy which has been put into it for ever. We now carry out our first bit of cheating. We know that an ideal transmission line terminated in its characteristic impedance looks like a resistance (Fig. 1). I do not think that this assumption requires for its proof anything which we are about to prove, so that it is not much of a cheat. Accepting this as permissible, we can

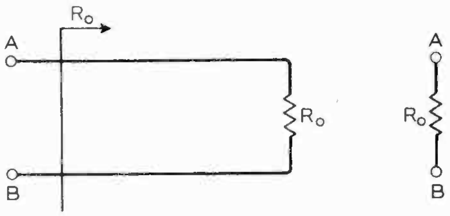


Fig. 1. Viewed from AB these two circuits look the same.

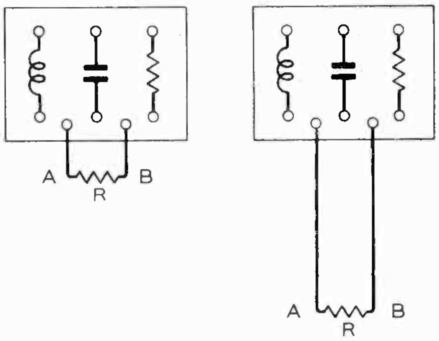


Fig. 2. We can move R away from the system on the end of a line of characteristic impedance R.

cut out of our system one convenient resistance, R, and connect into the system a length of transmission line in the way shown in Fig. 2. We shall treat the whole system as a two-terminal system, although it may in fact have a number of links to the outside world, and indeed, the outside world may be part of the system. A public address system, for example, includes the air path from loudspeaker to microphone, including any reflections from the microphone user, in the stability criteria.

There are restrictions on the choice of the resistance. I have never seen this discussed, because I think it only appears when the configuration is one which is not necessarily a minimum phase amplifier structure. If we take the resistance corresponding to the detector arm of a perfectly balanced bridge

*This is a shortened version of the extract: if tha does owt for nowt, do it for tha self.

†Buridan's.

it is not really part of the network at all. The resistance value does not affect the performance of the bridge, at balance. The rule which we can make is that R is a resistance which matters to the network.

With Fig. 2 we are all ready to go. Let us apply a signal across R. A convenient way of stirring up the network is to follow the example of Albert on his last visit to Blackpool. A quick prod, though not with an umbrella. Let us apply the pulse shown in Fig. 3. The immediate result will be that a current pulse $I_R = V_0/R$ flows through R. In addition, a current $I_T = V_0/R$ flows into the transmission line. We can calculate in formal terms the result which I am going to express in anthropomorphic terms. Provided that the line is long enough, and long enough means that $l > c/2t_0$, where c is the velocity of electromagnetic waves in the line, and is about 3×10^{10} cm/sec, the generator will think that the line is terminated in its charac-

Fig. 3. Signal applied to terminals AB.

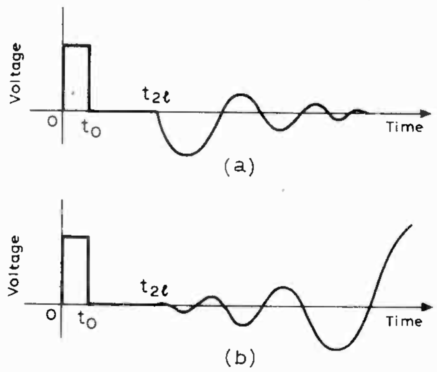


Fig. 4. Two possible results across AB.

teristic impedance. By the time we can get a message back from the far end of the line the generator has been disconnected. The system is completely isolated, but a current of V_0/R flows in at the terminals for a time t_0. We have roused the lion.

Current begins to flow in all directions inside the system. Any current which would have normally passed through the resistance R flows out into the transmission line and, when it reaches the end, is not reflected. By watching across the resistance we can see what is happening. Two kinds of behaviour may be observed, and versions of these are shown in Fig. 4. In (a), as in (b), we see the initial shock, followed by a rest period up to time t_{2l}, the time taken for the message to pass down the line and the reply to come back. In (a) the returning current swings up and down a few times, but dies away. In (b) it grows and grows. Using conventional language, (a) represents a stable system, while (b) represents an unstable system.

The use of a transmission line to separate out the comings and goings of power is a convenient technique even when it involves some assumptions which are wholly unjustified. An example of this is in the use of

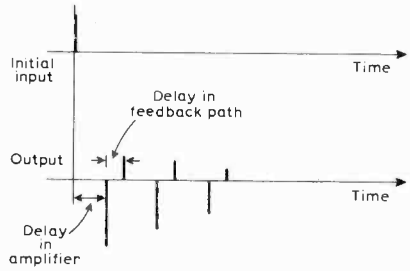


Fig. 5. Circulating pulse in feedback amplifier.

inverters with reactive loads. We can picture the reactive volt-amps heading down the line from the transistor and being reflected back. On reaching the inverter again we must provide a path for this energy, which means we must put in some diodes, and a reservoir for the resulting unidirectional "thing". The circuit configuration determines whether the reservoir is to be an inductance or a capacitance. If we fail to do this we find the reflected energy runs into a dead stop, and there is infinite current or voltage.

Pulse following can be applied to feedback amplifiers. The simple treatment shows a pulse going through the amplifier, then through the feedback path back to the input, and then round again. This is shown in Fig. 5. In any practical situation, of course, we do not get an output which is a short sharp pulse. The finite bandwidth of the amplifier broadens the pulse, and broadens it to such an extent that the first output has not died away before the second has begun to arrive. Very often the output is a composite of a substantial number of passages round the loop.

We must return to the general matter of stability. It is clear that it is a matter of what happens after the system is given a momentary shock. Because the output of an unstable system increases continuously it is not really very important what kind of a trigger shock we apply, so long as we keep it and its direct consequences small. The instability will dominate the behaviour once it really gets going. It is usually convenient to make use of a constant input, that is, to insert a battery at some point in the system.

The usual elements of a system are characterized either by time-independent proportionality, like

$$E = R \times I$$
$$E_{out} = \mu \times E_{in}$$
$$E_{sec} = n \times E_{prim}$$
$$I_{sec} = \kappa \times E_{prim}$$

for a resistance, an amplifier, a transformer, or a gyrator: by differentiation or integration, like

$$E = L\,dI/dt \qquad I = 1/L \int E\,dt$$

$$I = C\,dE/dt \qquad E = 1/C \int I\,dt$$

by delay, $E_2(t) = E_1(t - t_0)$, for a line.

Non-linearity can make matters more difficult, but for linear systems we have a whole set of equations of this kind which can be taken together to give a function of time which is the true description of the system behaviour. For a series LCR circuit

$$L\frac{dI}{dt} + RI + \frac{1}{C}\int I\,dt = E$$

The expression on the left, which we can write as

$$\left[L\frac{d}{dt} + R + \frac{1}{C}\int dt\right] I$$

describes the way current flows following the application of E. It is a fairly simple expression, and all the problems which matter, once you have dealt with this one in the examination room, are a good deal more complicated. The problem then is to deal with these very unwieldy functions of time. We must now look in more detail at a topic discussed several months ago, though now we shall consider it rather more formally. We are dealing with a function of time: we can reach solutions to our problems by a roundabout route, in which we transform this function to a function of another variable, manipulate this, and then transform back to time. Although it may seem to be involved, it is the essential principle of the by-pass: even though the apparent route is longer, you will not get bogged down on the way. The transformation we use is the Laplace transform. The basic requirement which is imposed on the function of time, $f(t)$, is that it must be defined and single valued almost everywhere for $t \leqslant 0$ when t is real, and

$$\int_0^\infty f(t) \exp(-\sigma t)$$

for some real number σ. The requirement that $f(t)$ is single valued almost everywhere allows for steps, but not for the odd functions one can dream up which seem to go on being in two places at once. In practice one can say that if an engineering function looks as though it is not transformable, look first for cross-talk between the X-plate and Y-plate connections of the oscilloscope.

Another feature of $f(t)$ is, in plain words, that if it increases with time, as it will in some unstable systems, it should not increase faster than exponentially. As long as $f(t)$ grows like $\exp(gt)$, where g can be as big as you like, we can choose a value of σ, say $(g+1)$, such that $f(t)\exp(-\sigma t)$ is decreasing. If we make the choice $\sigma = g+1$ we know that $f(t)\exp(-\sigma t)$ is less than $\exp(-t)$, and the integral will be finite. For ordinary circuits we know, and can prove rather easily, that the exponential is the *natural* thing: in a plant control problem it could be wise to check that $f(t)$ is not explosive.

Once $f(t)$ is known to satisfy the rules, we must take a new variable $s = a + jb$, with $a = \sigma$. Then the Laplace transform is described by the equation

$$\int_0^\infty f(t)\exp(-st)\,dt = \mathcal{L} f(t) = F(s)$$

The Laplace transform of $f(t)$ is a new function, a function of this new variable s, $F(s)$.

The inverse transform is needed, and can be written as

$$f(t) = \mathcal{L}^{-1}[F(s)]$$

subject to a limitation that $t \geqslant 0$. This is because we have defined the original transform as the integral from now to eternity, and it is too late to go raking up old promises, as the politicians say. In formal mathematical terms, we have

$$f(t) = \frac{1}{2\pi j}\int_{C-j\infty}^{C+j\infty} F(s)\exp(ts)\,ds$$

in which $C > \sigma$.

As we saw in a previous article, we can look up in tables the transform pairs we need. It will be useful here to consider one or two special cases. First let us take the unit step, at time $t = 0$. The unit step is unity almost everywhere: almost, because at $t = 0$ it is both zero, for $t \to 0$ from $t<0$, and unity, for $t \to 0$ from $t>0$. It is $\mathscr{L}$ transformable, and if we call it $u(t)$,

$$\mathscr{L}u(t) = \int_0^\infty 1.\exp(-st)\,dt$$

$$= \frac{1}{s}\exp - st\Big|_0^\infty = 1/s$$

Another transform worth looking at in the context of this article is the delayed function. Fig. 6 shows a quite arbitrary time function

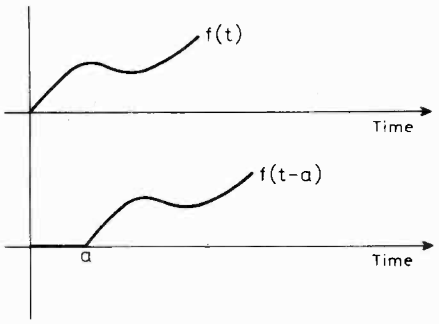


Fig. 6. A function, and the corresponding delayed function.

$f(t)$, and the delayed version, which is zero until $t = a$, and is then $f(t-a)$. Notice that if $f(t)$ has some shape at $t<0$, this part of $f(t)$ does not appear in $f(t-a)$. To find the transform of $f(t-a)$ we take a new variable $\tau = (t-a)$. Then

$$\mathscr{L}f(\tau) = \int_0^\infty f(\tau)\exp(-s\tau)\,d\tau = F(s)$$

Now

$$\int_0^\infty f(\tau)\exp(-s\tau)\,d\tau =$$

$$\int_a^\infty f(t-a)\exp(-st)\exp(as)\,dt$$

We are integrating with respect to t, so the constant $\exp(as)$ can be taken outside. Furthermore, as $f(t-a)$ is zero from $t = 0$ to $t = a$ we can take $t = 0$ as the lower limit for the integration.

Then

$$\int_0^\infty f(\tau)\exp(-s\tau)\,d\tau =$$

$$\exp(as)\int_0^\infty f(t-a)\exp(-st)\,dt$$

and so

$$\mathscr{L}f(t-a) = \int_0^\infty f(t-a)\exp(-st)\,dt$$

$$= \exp(-as)F(s)$$

in which $F(s) = \mathscr{L}f(t)$

This, the shifting theorem, enables us to form the transform for the pulse shown in Fig. 3. Here we have

$$P(t) = V_0(u(t) - u(t-t_0))$$

$$\mathscr{L}P(t) = V_0\left(\mathscr{L}u(t) - \mathscr{L}u(t-t_0)\right)$$

$$= V_0\left(\frac{1}{s} - \frac{1}{s}\exp(-st_0)\right)$$

$$= \frac{V_0}{s}(1-\exp(-st_0))$$

If we want a very short impulse we can make t_0 very small. To keep some meat in such a short pulse we increase V_0. If we make $V_0 t_0$ constant, say $V_0 = 1/t_0$, we get

$$\mathscr{L}P_i(t) = \frac{1-\exp(-st_0)}{st_0}$$

and now, as $t_0 \to 0$, the unit impulse at $t = 0$ becomes

$$\mathscr{L}\delta(t) = 1$$

This extremely simple result is a great encouragement to the use of the unit impulse in problems in which the Laplace transform method is adopted.

It must be pointed out that nothing has been said about the variable s having any physical meaning. If you ask your bank to get you a 10 Eurodollar bill you will be told that there isn't such a thing, yet bankers will whisk Eurodollars round the world as fast as the electric telegraph will carry them. For us, s is just a thing we use in the mathematics, and to anyone who confuses physical reality with the state of being a thing I would remind you that it has been ruled by the British courts that a goldfish is not a thing. There's glory for you.

A very important piece of basic mathematics, known since at least 1833, connects the response of a system to a unit impulse and its response to any arbitrary function of time. It is called the convolution integral. I do not think we need go through the analysis and proof. The procedure for using it is more to the point.

Let the response to the unit impulse be $f_1(t)$
Find the Laplace transform $F_1(s)$
Let the actual excitation be $f_2(t)$
Find the Laplace transform of this $F_2(s)$
Multiply $F_1(s).F_2(s)$
Find the inverse Laplace transform

$$\mathscr{L}^{-1}F_1(s).F_2(s) = \mathscr{L}^{-1}F(s)$$

$$= f(t)$$

This $f(t)$ is the response of the network.

Having got this far without mentioning frequency or frequency response, it would be nice if we could go right on in the same way. The real justification of the purely formal approach will appear when, in a later article, we examine non-linear systems. At least, I hope we do. They are much more complicated than linear systems, and it will be quite a struggle to get the skeleton of the techniques out in a clean and recognizable form. With linear systems the problem is simply how to make a change to the old familiar frequency without letting it look too important.

A procedure which will establish the "style" of $F(s)$ is to look at the transforms of some probable time functions. The simplest of these is the exponential decay,

$$f(t) = \exp(-\alpha t)$$

$$\text{For this } f(s) = \int_0^\infty \exp(-\alpha t)\exp(-st)\,dt$$

$$= \int_0^\infty \exp[-(s+\alpha)t]$$

$$= 1/(s+\alpha)$$

This is finite for all values of s except $s = -\alpha$. It has a *pole* at $s = -\alpha$. This is shown as a diagram in Fig. 7.

If we work the other way round we can start off with two poles positioned along the

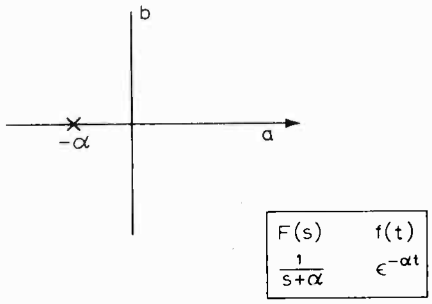


Fig. 7. The s-plane, ($s = a+jb$), showing the pole of s at $s = -\alpha$.

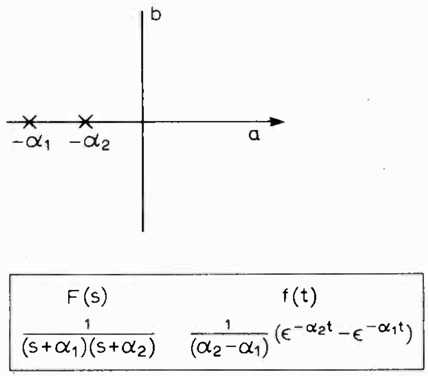


Fig. 8. S-plane with two poles on the $-a$ axis.

negative a-axis, shown in Fig. 8. Excluding all unnecessary constants, this is an s-function which is infinite for

$$s = -\alpha_1$$

and

$$s = -\alpha_2$$

It can be written

$$F(s) = \frac{1}{(s+\alpha_1)(s+\alpha_2)}$$

and the inverse Laplace transform will give

$$f(t) = \frac{1}{\alpha_2-\alpha_1}[\exp(-\alpha_2 t) - \exp(-\alpha_1 t)]$$

Given this form of

$$F(s) = 1/[(s+\alpha_1)(s+\alpha_2)]$$
$$= 1/[s^2+(\alpha_1+\alpha_2)s+\alpha_1\alpha_2]$$

it is not unreasonable to look at the general form

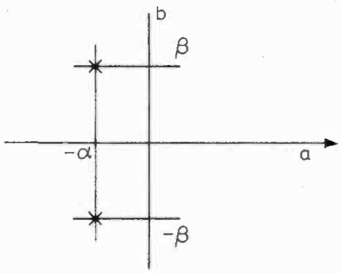
$$F(s) = 1/(s^2+ls+n)$$

When we solve the quadratic we may find that we have not the two real roots, but a complex conjugate pair. For this case we can write

$$F(s) = 1/[(s+\alpha)^2+\beta^2]$$

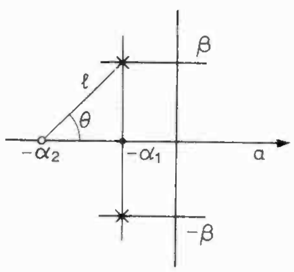
Fig. 9 shows the two poles at $(-\alpha\pm j\beta)$.

Perhaps one more, Fig. 10, showing a zero. I am not going to go into this except to point out that this gives us a reasonable basis for guessing the kind of functions we will normally encounter. Notice how in Figs 9 and 10 the poles off the a-axis have brought in the sine function. This, the function which repeats itself over and over again, is where the frequency concept really does burst into the picture.



F(s)	f(t)
$\frac{1}{(s+\alpha)^2+\beta^2}$	$\frac{1}{\beta}\epsilon^{-\alpha t}\sin\beta t$

Fig. 9. S-plane with complex conjugate poles.



F(s)	f(t)
$\frac{(s+\alpha_2)}{(s+\alpha_1)^2+\beta^2}$	$\frac{\ell}{\beta}\epsilon^{-\alpha_1 t}\sin(\beta t+\theta)$

Fig. 10. Two poles and a zero in the s-plane.

A useful theorem is the final value theorem. This tells us where $f(t)$ will finish up at infinite time:

$$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$$

The only trouble with this, for our purposes, is that there must be no singularities of $sf(s)$ on the b-axis or in the right-hand half of the s-plane. Whichever way we turn we are faced with this basic reference back, in the end, to Cauchy. It would seem that one should be able to determine the stability of a system in terms of time alone. In one sense you can, you can give it, the complete system, a tap. Equally you can write down all the equations and solve them by conventional means. There is nothing wrong with this as an approach. In ordinary circuits you take your stand on Maxwell or Kirchhoff and bulldoze your way through to the end. I do not know what the most convenient form of disturbance would be for this treatment.

But: the system is not stable and must be modified. It is here that time domain analysis turns out to be unprofitable. You simply cannot get any feel, any intuition, to guide you towards the necessary changes. Everyone who has worked with feedback systems knows how quickly one does get this intuitive feeling for the kind of behaviour, in the frequency domain, which can be made stable. Everything conspires to force us into the s-plane. Oddly enough, none of the economics texts I have looked at ever mentions anything of this kind: economists are apparently not interested in stability.

It is in the s-plane that we find it relatively easy to combine systems, to add on lag and lead networks. And so we are back to Nyquist. We have tried to stick to the time domain, we have introduced a transformation which will let us combine circuits and apply arbitrary inputs, and at every turn a mathematician has sprung up waving a placard which says "Hands off the right-hand half of the plane".

There is one feature of the Laplace transform approach which is not really made clear in some of the texts. In Fig. 8 we saw what happened with two poles at $-\alpha_1$ and $-\alpha_2$. Suppose that we run them together. When

$$F(s) = \frac{1}{(s+\alpha)^2}$$

we have $\quad f(t) = t\exp(-\alpha t)$

We have seen that we can obtain roots which are off the axis, and we might expect that somehow, somewhere, we should get solutions of the form

$$f(t) = t\sin\omega t$$

In fact this is one of the odd cases which is just caught by Cauchy's theorem. It is of special interest, however, because it would appear that this kind of behaviour can be especially significant in systems which incorporate a gyrator or its mechanical equivalent, the gyroscope. In most circuit problems an increase in the losses will usually tend to shift the roots in the s-plane towards increased stability. If the system is held stable simply by the gyro action, an increase in losses may cause instability. The terminology I find for this is that the system is ordinarily stable but secularly unstable. It would appear to be a particular form of what we usually call conditionally stable.

All through this article I have had the feeling which I assume is experienced by a member of a crowd which is being "controlled" by the soft, sophisticated, technique. We all want to march thataway, but somehow we seem to be moving thisaway. What is there about the time function which makes it so difficult to get to grips with it. There seem to be several features which may explain our trouble. When we are dealing with frequency we can adopt the root locus method, or a distant relation of it, and single out a critical factor which will dominate the stability in a particular range of parameters. While we are watching the movement of this root we do not care too much what the other roots are doing, provided always they stay to the left of the one we are following. It is not at all so easy to keep the critical term of the time function under surveillance.

Rather more fundamental, perhaps, is the fact that when we are working in the time domain we are working with functions, exponentials and sines are all over the place. The picture is a wavy line across the sheet of paper. In the s-plane the picture is simplified to fixed points arranged according to simple rules. Fig. 9 was easy to draw, but a damped sine wave, complete with phase shift, is not nearly so simple. It is much easier to answer the question "Where are you?" than to answer "Exactly what are you doing?". Although one can make a kind of fundamental case for refusing to use the Laplace transform or Fourier-Mellin or what have you, can you restrict your stand, or must you avoid sines and cosines and exponentials, remaining with the basic power series which these things represent? In modern engineering it takes all the mathematics you can learn to stay where you are. So, in the long run we are all dead, but meanwhile we are up the pole.

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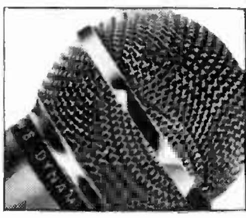

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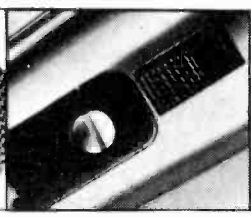

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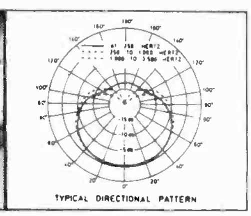

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Negative Feedback in Transistor Amplifiers

Principles of single-stage and two-stage circuits

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

There is little doubt that transistors will soon have replaced valves in all low-power applications—hardly surprising because in many respects they are superior. Transistors are, however, inferior to valves in that properties such as h_{fe} are subject to wide manufacturing spreads and to large variations with temperature. Moreover transistors have a leakage current which is highly dependent on temperature although at normal temperatures it is negligible in silicon devices. To manufacture transistor equipments with a consistent performance, the effects of differences in the value of h_{fe} must be minimized and the normal technique is to employ negative feedback. Provided sufficient feedback is used many significant properties of an amplifying stage can be made substantially independent of the parameters of the transistors, being determined instead by the components of the passive network used to apply feedback. Thus it is often possible to state the gain, transfer resistance, mutual conductance, etc., from an inspection of the component values. The use of negative feedback reduces gain, of course, but has advantages such as an improvement in linearity in amplifying stages.

In this article various circuits which can be used to apply feedback are discussed and typical calculations are given.

Derivation and injection of feedback signal

In general negative feedback is applied to an amplifying stage by taking a signal from the output and returning it to the input in such a way that the returned signal is in antiphase to the input signal. The input to the amplifier is now the difference between the source and feedback signals. The larger source signal required for a given amplifier output expresses the effective reduction in gain due to feedback. The link which feedback establishes between the input and the output of the amplifier enables a number of deficiencies in the output to be reduced. For example, if the gain of the amplifier falls at high frequencies, so also does the feedback signal amplitude. If the source signal is of constant amplitude, the amplifier input is thus greater at high than at low frequencies. This tends to offset the reduced gain and maintain a constant output signal. In this way negative feedback improves frequency response: it also brings about the other improvements in performance mentioned in the first paragraph.

The single-line diagram of Fig. 1 illustrates the principle of negative feedback

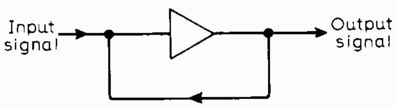


Fig. 1. Fundamental representation of negative feedback.

but does not show how the feedback signal is derived from the output or how it is injected into the input of the amplifier. The effect of feedback on the input resistance and output resistance of the amplifier is primarily determined by the way in which the feedback connections are made.

Two ways in which a feedback signal may be taken from the output of an amplifier are illustrated in Fig. 2. At (a) feedback is obtained directly from the output terminals

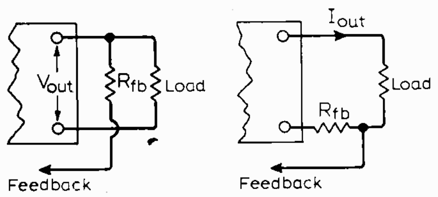


Fig. 2. General circuits for (a) parallel-derived and (b) series-derived feedback.

(or it can be taken from a potential divider connected across the output terminals). The significant feature is that the feedback circuit and the output circuit are in parallel and that the feedback signal is proportional to the output voltage. Any increase in the load resistor tends to increase the output voltage and hence the feedback signal. As a result the gain of the amplifier is reduced and the rise in output voltage minimized. Parallel-derived feedback thus tends to maintain a constant output voltage: in other words it effectively reduces the output resistance of the amplifier.

In Fig. 2(b) feedback is obtained from a resistor connected in series with the output load of the amplifier. The feedback signal is thus proportional to the output current of the amplifier. Any increase in the load resistor tends to reduce the output current and the feedback signal. As a result the gain of the amplifier is increased and the fall in output current is minimized. Series-derived feedback thus tends to maintain a constant output current: in other words it effectively increases the output resistance of the amplifier.

Two corresponding circuits for injecting the feedback signal into an amplifier are

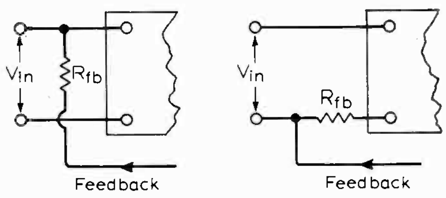


Fig. 3. General circuits for (a) parallel-injected and (b) series-injected feedback.

shown in Fig. 3. At (a) feedback is injected directly into the input terminals via a series resistor so that the feedback circuit and the input circuit of the amplifier are in parallel. The input signal has to offset the current from the feedback circuit and to supply the input current for the amplifier. For a given input voltage therefore, a larger input current is required as a result of the addition of feedback: this is equivalent to a reduction

Table 1

Type of feedback connection	Effect on input resistance	Effect on output resistance
series-derived		increased (= $g_m R_e r_c$)
parallel-derived		decreased (= R_b/h_{fe})
series-injected	increased (= $h_{fe} R_e$)	
parallel-injected	decreased (= R_b/A)	

The formulae given in the table are derived in the article

*Head of Technical Publications Section, B.B.C.

in input resistance. Thus parallel-injected feedback effectively reduces the input resistance.

In Fig. 3(b) the feedback signal is connected in series with the amplifier input circuit. The input signal thus has to offset the voltage from the feedback circuit and to supply the input voltage for the amplifier. For a given amplifier input current, therefore, a larger input voltage is required as a result of adding feedback; this is equivalent to an increase in input resistance. Series-injected feedback effectively increases the input resistance of the amplifier.

The effects of the two types of feedback derivation and injection are summarized in Table 1.

Current and voltage amplification

A knowledge of the input resistance of an amplifier is necessary if it is to be matched to an external source, e.g. a microphone, to obtain maximum input signal. Similarly a knowledge of the output resistance is important if the amplifier is required to feed a line which must be accurately terminated.

However, the input and output resistance of the individual stages of a multi-stage amplifier are also important. When transistor stages are connected in cascade the performance of each stage should not be seriously affected by the coupling to the previous or the following stage. There are two ways in which this isolation can be achieved. One method is to ensure that a stage with a low output resistance is followed by one with a high input resistance, the high resistance being large compared with the low. The output voltage of the first stage is then also the input voltage of the second and this common voltage is little affected by variations in input or output resistance. In such inter-transistor coupling circuits the signal is clearly most conveniently regarded as a voltage and the design of such circuits is best carried out in terms of this voltage.

Alternatively isolation can be achieved by arranging for a transistor with a high output resistance to be followed by one with a low input resistance, the high resistance again being large compared with the low. In a connection of this type the output current of the first transistor is the input current for the second and this current is little affected by variations in the two resistances. For transistor couplings of this type the signal is most conveniently regarded as a current and the design of the circuit is best carried out in terms of this current.

The input and output circuits of transistors can thus be classified as suitable for voltage or current operation depending on the magnitude of the resistance as indicated Table 2. However it is not the absolute magnitude of an input or output resistance which is of importance, but their ratio. For example a transistor stage with an input resistance of 2000 Ω is best regarded as a current amplifier if the source resistance is 100,000 Ω but as a voltage amplifier if the source is only 50 Ω.

The input and output resistances of common-emitter and common-base transistor stages are such that a cascade of them is best regarded as a current amplifier.

Table 2

Signal best considered as	Input resistance	Output resistance
voltage	high	low
current	low	high

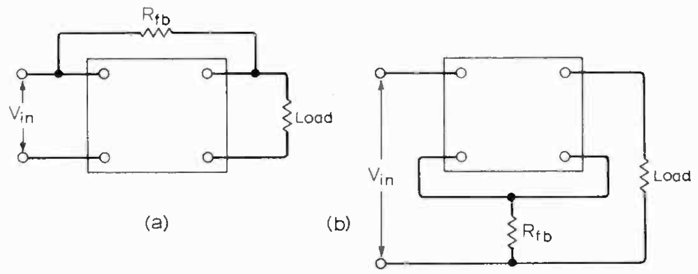


Fig. 4. General circuits for (a) parallel-derived, parallel-injected feedback and (b) series-derived, series-injected feedback.

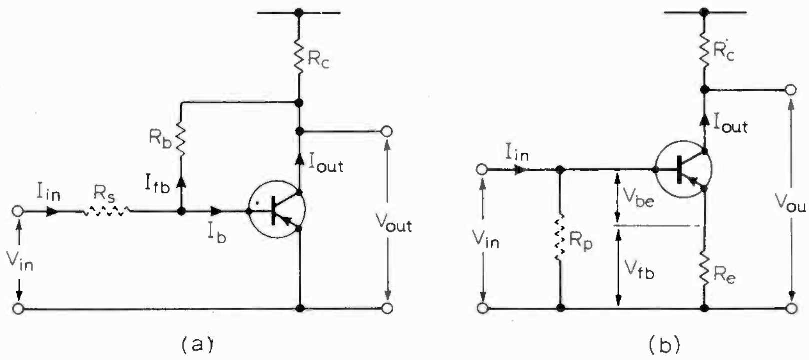


Fig. 5. A single-stage amplifier with (a) parallel-derived, parallel-injected feedback and (b) series-derived, series-injected feedback.

However, within limits we can make the input and output resistances what value we please by suitable choice of feedback circuit. Thus, by suitable design, we can make a transistor stage suitable for an input voltage or current and an output voltage or current. The performance of the stage can thus be measured by the values of I_{out}/I_{in}, V_{out}/V_{in}, I_{out}/V_{in} or V_{out}/I_{in} depending on the type of feedback applied to the stage.

Single transistor stage with base-collector resistor

By combining the circuits of Figs. 2(a) and 3(a) we can produce the circuit shown in Fig. 4(a) in which a single resistor bridges the input and output terminals. The resulting parallel-derived and parallel-injected feedback gives the amplifier a low input and a low output resistance.

Feedback of this type can be obtained by connecting a resistor R_b between base and collector of a common-emitter stage as shown in Fig. 5(a).

This resistor returns a current V_{out}/R_b (proportional to output voltage) to the base of the transistor and this gives rise to a collector current I_c where

$$I_c = h_{fe}V_{out}/R_b$$

from which

$$\text{output resistance} = \frac{V_{out}}{I_c} = \frac{R_b}{h_{fe}}$$

In the absence of feedback the output resistance is the collector a.c. resistance of the transistor which can be of the order of 200 kΩ for silicon transistors. In a practical circuit R_b might be 50 kΩ and h_{fe} 150, giving an output resistance of 330 Ω. This illustrates the effective reduction of output resistance brought about by parallel-derived feedback.

At the input circuit we have

$$I_{in} = I_b + I_{fb}$$

and if R_b is low enough, I_{fb} is large compared with I_b and we can say

$$I_{in} \approx I_{fb}$$

Now $I_{fb} = V_{out}/R_b$ and $V_{out} = AV_{in}$ where A is the voltage gain of the transistor from base to collector. Thus

$$\text{input resistance} = \frac{V_{in}}{I_{in}} = \frac{R_b}{A}$$

which is less than in the absence of feedback.

This may be written R_b/g_mR_c where R_c is the external collector load resistance. In an amplifier in which R_b = 50 kΩ, R_c = 5 kΩ and g_m = 40 mA/V, the input resistance is 250 Ω. In a practical circuit this may be effectively reduced by other resistors connected to the base for bias purposes.

By virtue of these low values of input and output resistance, the circuit is well suited for use with a current input and a voltage output and we are thus particularly interested in the value of V_{out}/I_{in}, the transfer resistance. We have already shown that if the degree of feedback is large I_{in} is approximately equal to I_{fb}. But $I_{fb} = V_{out}/R_b$.

$$\therefore \frac{V_{out}}{I_{in}} = R_b \qquad (1)$$

For the chosen numerical values

$$\frac{V_{out}}{I_{in}} = 50\ \text{k}\Omega$$

The circuit can also be used as a current amplifier. Because $V_{out} = I_{out}R_c$ we have

$$\frac{I_{out}}{I_{in}} = \frac{R_b}{R_c} \qquad (2)$$

and this has the value 10 for the numerical values used earlier.

Expressions (1) and (2) assume a current input but the circuit can be used with a voltage input provided a series resistor R_s is included as shown dotted in Fig. 5(a). R_s must be large compared with the input resistance of the amplifier so that the input current is given approximately by V_{in}/R_s. R_s could be the resistance of the signal source itself provided this is high enough and there is then no need to add a resistor to the circuit to provide the required high resistance. Substituting for I_{in} in (1) and (2) we have

$$\frac{V_{out}}{V_{in}} = \frac{R_b}{R_s} \qquad (3)$$

$$\frac{I_{out}}{V_{in}} = \frac{R_b}{R_c R_s} \qquad (4)$$

In the numerical example the input resistance was 250 Ω. R_s could then be 2·5 kΩ. From (3) the voltage gain is 20. From (4) the effective mutual conductance is 4 mA/V.

Circuit with emitter resistor

By combining the circuits of Figs. 2(b) and 3(b) we can produce the circuit shown in Fig. 4(b) in which a common resistor is included in the input and output circuits. The resulting series-derived and series-injected feedback gives the amplifier a high input and high output resistance.

Feedback of the type of Fig. 4(b) can be obtained by including a resistor R_e in the emitter circuit of a common-emitter stage as shown in Fig. 5(b). The voltage $I_c R_e$ (proportional to output current) developed across R_e is applied between base and emitter of the transistor. This voltage is amplified by a factor $g_m r_c$ where r_c is the collector a.c. resistance of the transistor if, as assumed in calculations of output resistance, the output load is infinite.

Thus

$$V_{out} = g_m r_c R_e I_c$$

and

$$\text{output resistance} = \frac{V_{out}}{I_c} = g_m r_c R_e$$

$g_m R_e$ is normally greater than unity, confirming the effective increase in output resistance. As r_c is commonly of the order of 200 kΩ for a silicon transistor, this type of feedback can give very high output resistances.

At the input circuit

$$V_{in} = V_{fb} + V_{be}$$

and if R_e is large enough V_{fb} is large compared with V_{be}

$$\therefore\ V_{in} \approx V_{fb}$$

Now $V_{fb} = I_e R_e = (h_{fe}+1)I_b R_e$. Thus the input resistance is given by

$$\therefore\ \frac{V_{in}}{I_b} = (h_{fe}+1)R_e \approx h_{fe}R_e$$

The input resistance is given by $h_{fe}R_e$ approximately and, for a transistor with $h_{fe} = 150$ and $R_e = 1$ kΩ, is equal to 150 kΩ. In a practical circuit this may be effectively reduced by resistors connected to the base e.g. for bias purposes.

By virtue of the high input and output resistances the amplifier is well suited for use with an input voltage and an output current and we are particularly interested in the value of I_{out}/V_{in} i.e. the mutual conductance g_m.

We have already shown that if the degree of feedback is large V_{in} is approximately equal to V_{fb}. But $V_{fb} = I_e R_e \approx I_c R_e \approx I_{out} R_e$.

$$\therefore\ \frac{I_{out}}{V_{in}} = \frac{1}{R_e} \qquad (5)$$

If, as assumed earlier, R_e is 1 kΩ the effective mutual conductance is 1 mA/V.

If the amplifier is required to give a voltage output, the low output resistance necessary is provided by R_c which can be given a suitably low value such as the 5 kΩ assumed earlier. If, however, the amplifier is required to give a current output, R_c should be removed: the high value of the internal collector a.c. resistance then provides the required high value of output resistance. Alternatively when the amplifier is required to give a current output, R_c can be taken as representing the low input resistance of the following stage.

When R_c is present $V_{out} = I_{out}R_c$ and thus, as a voltage amplifier, the gain of the circuit is given by

$$\frac{V_{out}}{V_{in}} = \frac{R_c}{R_e} \qquad (6)$$

For the numerical values quoted earlier the voltage gain is 5.

Expressions (5) and (6) are in terms of a voltage input but the amplifier can be used with a current input provided a low-value resistor R_p is connected across the input terminals as shown dotted in Fig. 5(b). Resistor R_p should be small compared with the input resistance of the amplifier so that $V_{in} = I_{in}R_p$. Resistor R_p could be the resistance of the signal source itself if this is small enough, and there is then no need to add a resistor to provide the required low resistance.

Substituting $I_{in}R_p$ for V_{in} in (5) and (6) we have

$$\frac{I_{out}}{I_{in}} = \frac{R_p}{R_e} \qquad (7)$$

$$\frac{V_{out}}{I_{in}} = \frac{R_p R_c}{R_e} \qquad (8)$$

If R_p is 5 kΩ, the current gain is 5 and the transfer resistance 25 kΩ.

Single-transistor circuit

The circuits so far discussed have been simplified by omission of all components except those essential for amplification or for feedback. In a practical circuit provision must be made for biasing the base to give the required value of mean collector current and for the stabilization of this current. For a single-stage amplifier a satisfactory means of meeting these requirements is that shown in Fig. 6 in which the base is returned to a potential divider across the supply. This, together with the emitter resistor (which

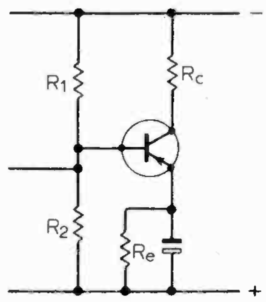


Fig. 6. Mean collector current stabilization by means of a potential divider and emitter resistor.

can be used for signal-frequency feedback also if desired) ensures reasonable stability of collector current and thus minimizes variations in performance due to variations in leakage current or in the value of h_{fe}. It also minimizes the effects of spreads in h_{fe} so permitting the construction of a number of circuits with consistent performance.

The circuit operates by impressing a constant potential on the base of the transistor. Any tendency of the emitter current to increase causes the voltage across R_e to rise and reduces the base-emitter voltage thus reducing the increases in emitter current. The circuit is an example of zero-frequency feedback. The effectiveness of the circuit in stabilizing collector current is increased by increasing the value of R_e and by decreasing the resistance of R_1 and R_2 in parallel (which is the effective internal resistance of the source of base voltage).

Stabilization could be improved by returning the potential divider to the collector instead of to the collector supply voltage because increase in collector current is now minimized in two ways. The emitter potential is raised (as in the simple potential divider circuit) as a result of the increased voltage generated across the emitter resistor. In addition, however, the base potential is lowered as a result of the increased voltage generated across the collector resistor by the increased collector current.

If however R_1 is simply transferred to the collector, difficulties arise from the potential-divider bleed current which now flows through R_c and from the unwanted signal-frequency feedback introduced by the potential divider. Because of these difficulties, collector feed of the potential-divider circuit is unlikely to be employed in this simple form. It is, however, the basis of a very effective form of stabilization used in two-stage amplifiers described later.

We will now consider the design of a practical single-transistor stage required to operate with a voltage input, to give a voltage output, the voltage gain being 20. The basic circuit of Fig. 5(b) is suitable and we will assume that a silicon n-p-n transistor with $h_{fe} = 150$ (at a collector current of 1 mA) is to be used with a supply voltage of 24. For good stabilization the voltage at R_1R_2 junction should be large compared with changes in base-emitter voltage due to temperature and transistor tolerances. For a silicon transistor V_{be} is commonly 0·7 V and thus the voltage across R_e is 0·7 V less than that at the potential-divider junction. A suitable voltage across R_e is 7 and this gives the value of R_e as 7 kΩ. The voltage across R_c and the transistor is thus 17 and, to permit the greatest output voltage swing, this should be shared equally between them. Thus the no-signal voltage across R_c is 8·5 and R_c should be 8·5 kΩ.

The voltage gain of the stage is given by R_c/R_e and to give the required value of 20, R_e should be 420 Ω. Thus for zero-frequency feedback R_e should be 7 kΩ and for signal-frequency feedback it should be 420 Ω. This can be achieved as shown in Fig. 7 by

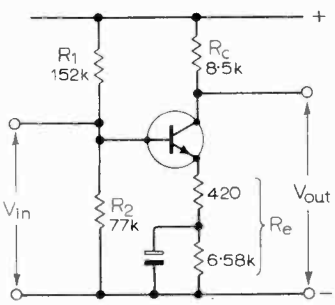


Fig. 7. Practical version of the circuit of Fig. 6, designed for a voltage gain of 20.

constructing R_e of 420 Ω and 6580 Ω in series and by decoupling the larger of the two resistors by a capacitor with a low reactance at the lowest signal frequency. The input resistance of the transistor at signal frequency is given by $h_{fe}R_e$, i.e. 73 kΩ but this is effectively reduced by R_1 and R_2.

For reasonable stability the current taken by the potential divider from the supply should be at least 10 times the standing base current of the transistor. I_b is approximately I_c/h_{fe}* i.e. 7 μA and a convenient value for the potential divider current is 100 μA. R_2 thus carries a current of 0·1 mA and the voltage across it is 7·7: the resistance is therefore 77 kΩ. R_1 carries 0·107 mA and the voltage across it is 27 − 7·7, i.e. 16·3 V: the resistance is therefore 152 kΩ. The input resistance of the amplifier is made up of 77 kΩ, 152 kΩ and 73 kΩ in parallel i.e. 30 kΩ. The output resistance is equal to R_c i.e. 8·5 kΩ.

The stability factor of this circuit, using the calculated component values, is 0·04,† that is to say the variations in collector current due to changes in h_{fe} or in leakage current are reduced to 4% of what they would be without the stabilizing circuit. We can also say that a spread of ±50% h_{fe} gives only a ±2% spread in collector currents.

*Strictly I_b is given by I_c/h_{FE} where h_{FE} is the static or d.c. current amplification factor. For simplicity we are assuming here that there is little difference between h_{fe} and h_{FE}.

†This is calculated from the expression

$$K = 1/[1 + h_{fe}R_e/(R_e + R_b')]$$

where $R_b' = R_1R_2/(R_1 + R_2)$.

Two-stage current amplifier

If we arrange for a Fig. 5(a) type of stage to feed into a stage of the type of Fig. 5(b) we obtain the two-stage amplifier shown in skeleton form in Fig. 8. The low input resistance and high output resistance

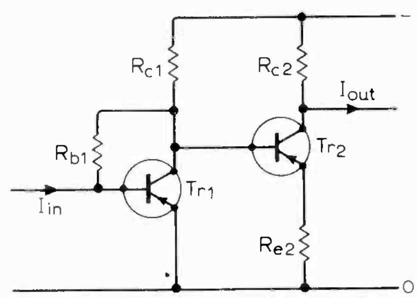


Fig. 8. Skeleton form of two-stage current amplifier.

of the two-stage circuit makes it suitable as a current amplifier. The input resistance of the second stage is high and it can be connected across the low output resistance of the first stage without mutual interaction. The output voltage of the first stage is the input voltage of the second.

The gain of the amplifier is easily assessed. We know from (1) that for Tr_1

$$\frac{V_{out}}{I_{in}} = R_{b1}$$

and for Tr_2 from (5)

$$\frac{I_{out}}{V_{in}} = \frac{1}{R_{e2}}$$

But $V_{in} = V_{out}$

$$\therefore \frac{I_{out}}{I_{in}} = \frac{R_{b1}}{R_{e2}}$$

If, as assumed earlier, R_{b1} = 50 kΩ and R_{e2} = 1 kΩ the current gain is 50.

Stability considerations

The signal at Tr_2 emitter is a copy of that at Tr_2 base which is directly connected to Tr_1 collector. Thus the performance of the circuit is unaffected if R_{b1} is transferred from Tr_1 collector to Tr_2 emitter as shown in Fig. 9. This modification is of considerable help in practical versions of this circuit because it makes possible a simple but very

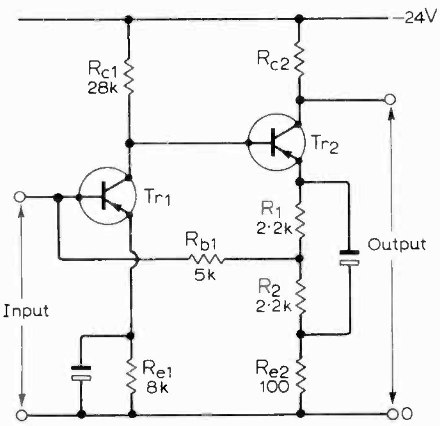


Fig. 9. More detailed version of the circuit in Fig. 8, designed for a current gain of 50.

effective means of stabilizing the mean collector current of both transistors.

If R_{b1} is returned to a potential divider R_1R_2 included, in addition to R_{e2}, in Tr_2 emitter circuit its value can be reduced whilst keeping the gain (R_{b1}/R_{e2}) constant. The circuit is now very similar to that of the potential divider method of stabilization (Fig. 6) but Tr_1 requires an emitter resistor (R_{e1}) to complete the circuit. This should be decoupled because it is not required to give signal-frequency feedback. This is a particularly good circuit because R_{b1}, R_1 and R_2 can be of low resistance and in addition the potential divider is returned in effect to the collector of Tr_1 by emitter-follower action in Tr_2. Both factors, as mentioned earlier, make for good stabilization. R_{b1} can be reduced to 5 kΩ and, for a current gain of 50, R_{e2} should be 100 Ω.

Estimation of component values

Suppose a 24-V supply is available. A suitable value for the no-signal voltage at Tr_1 collector is 10, giving the voltage across R_{c1} as 14. If we decide on a mean collector current for Tr_1 of 0·5 mA, R_{c1} is 28 kΩ. Tr_2 base voltage is 10 but because of the standing 0·7 V base-emitter voltage of silicon transistors, Tr_2 emitter voltage is 9·3. If Tr_2 is to take a mean emitter current of 2 mA, the total emitter resistance is 4·65 kΩ. Of this 100 Ω must provide signal-frequency feedback R_{b1} being taken as 5 kΩ, and the balance could consist of two 2·2 kΩ resistors in series, decoupled, the centre point providing bias for Tr_1 base. The voltage across R_{b1} caused by Tr_1 base current can be neglected and thus we can say that Tr_1 base voltage is approximately 4·7. Because of the voltage across Tr_1 base-emitter path, the emitter voltage can be taken as 4·0. The emitter resistance is thus 8 kΩ.

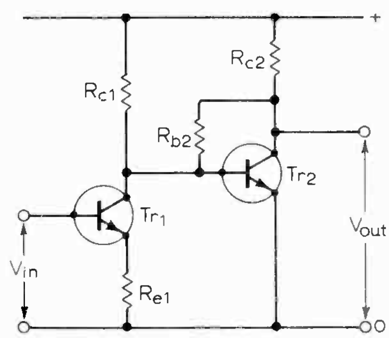


Fig. 10. Skeleton form of two-stage voltage amplifier.

The input resistance of the amplifier is given by R_{b1}/A where $A = g_{m1}R_{c1}$. The mutual inductance of a transistor is directly proportional to emitter current and for a current of 0·5 mA is approximately 20 mA/V. A is thus 560 and the input resistance is 5 kΩ/560 i.e. approximately 9 Ω. The output resistance is given by $g_{m2}R_{e2}r_{c2}$. If g_m is taken as 80 mA/V, $g_{m2}R_{e2}$ is 40 and the output resistance is thus several megohms, r_{c2} being say 200 kΩ.

Two-stage voltage amplifier

An amplifier consisting of a first stage of the type shown in Fig. 5(b) and a second stage of the type shown in Fig. 5(a) has a high input resistance and a low output resistance, making the amplifier (shown in skeleton form in Fig. 10) suitable for voltage amplification. At the inter-transistor coupling circuit the high output resistance of Tr_1 feeds into the low input resistance of Tr_2. There is no interaction provided the inter-transistor signal is taken as a current.

For Tr_1 from (5)

$$\frac{I_{out}}{V_{in}} = \frac{1}{R_{e1}}$$

For Tr_2 from (1)

$$\frac{V_{out}}{I_{in}} = R_{b2}$$

But $I_{in} = I_{out}$

$$\therefore \quad \frac{V_{out}}{V_{in}} = \frac{R_{b2}}{R_{e1}}$$

R_{b2} is normally connected to Tr_1 emitter instead of to Tr_2 base. It is not immediately obvious that such an alteration makes little difference to the performance of the circuit. In fact the input current for Tr_2 is (provided R_{c1} is large enough) the output current of Tr_1 and this is also the emitter current of Tr_1. Thus any current injected into Tr_1 emitter by R_{b2} is conveyed to Tr_2 base with little loss.

Suppose a voltage gain of 100 is required. Any values of R_{b2} and R_{e1}, provided their ratio is 100, will give this value of gain but high values of R_{b2} will give the amplifier an unnecessarily-high output resistance and low values of R_{e1} will give undesirably-low values of amplifier input resistance. A compromise such as $R_{e1} = 500\,\Omega$ and $R_{b2} = 50\,k\Omega$ is suitable.

Finally, means must be provided for stabilizing the collector currents of both transistors and here the same technique of zero-frequency feedback from Tr_2 emitter to Tr_1 base can be used as in the two-stage current amplifier and very similar component values can be used also. The emitter circuit of Tr_2 should be fully decoupled because no signal-frequency feedback is required here. In Tr_1 emitter circuit, however, a resistor of $8\,k\Omega$ is required for stability and $500\,\Omega$ for signal-frequency feedback. Both requirements can be met by using two resistors in series, the larger being decoupled as shown in Fig. 11. In the two-stage current amplifier R_{b1} provided the zero-frequency feedback necessary for stability and the signal-frequency feedback required to give the desired gain. In this voltage amplifier R_{b1} provides only zero-frequency feedback and R_{b2} provides signal-frequency feedback.

The input resistance of transistor Tr_1 is $50\,k\Omega$ if h_{fe} is taken as 100 and R_{e1} as $500\,\Omega$ but R_{b1} is in parallel with the base circuit. R_{b1} can be given any value within a wide range: high values degrade stability but give a high input resistance to the amplifier; low values give good stability but low input resistance. A compromise value such as $20\,k\Omega$ might be suitable and this gives an amplifier input resistance of $14\,k\Omega$.

The output resistance of the amplifier is given by R_{b2}/h_{fe} i.e. $500\,\Omega$ if $h_{fe} = 100$.

Some departures from the calculated resistor values indicated in Figs. 7, 9 and 11 may be desirable to permit the use of preferred-value resistors. Because of such departures and the spread of resistance likely to be encountered, it is advisable to use a preset component for one of the resistors in the amplifier and to adjust this to give the required working voltages. A suitable component to make preset is the decoupled part of Tr_1 emitter resistor.

No mention has been made in this article of the frequency range of the circuits discussed. Modern silicon planar transistors, even those intended for a.f. applications, have transition frequencies of hundreds of MHz and if these are used, the passband of the amplifiers will probably extend to several MHz. If the amplifiers are used for a.f. applications such a response could be an embarrassment (e.g. because of amplification of any r.f. signals present) and should be curtailed by making the feedback increase above say 15 kHz. This can be done, for example, by shunting R_{b2} in Fig. 11 by a capacitor so chosen that its reactance at 30 kHz equals the resistor value, i.e. approximately $0{\cdot}005\,\mu F$. For a.f. applications the decoupling capacitors should be large enough to perform adequately down to 30 Hz.

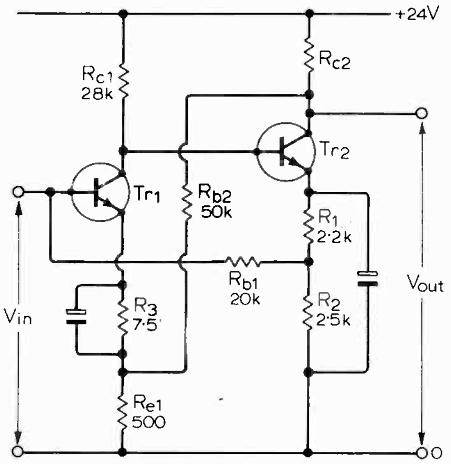


Fig. 11. More detailed version of the circuit in Fig. 10, designed for a voltage gain of 100.

Announcements

Two six-week courses are to be held at **Norwood Technical College.** The first, commencing 2nd February, is entitled "Pulse Code Modulation Techniques". The second, "Single Standard Colour Television Receivers" commences 25th January. Further details are available from The Secretary, Norwood Technical College, Knight's Hill, London S.E.27. Fee 30s per course.

Japanese made EVR players may soon become available in Britain as a result of a licence agreement which the EVR Partnership has concluded with Mitsubishi Electric of Japan for the manufacture and distribution of EVR teleplayers internationally (with the present exception of the U.S.A. and Canada). A similar agreement has also been made with Hitachi.

By mutual agreement the arrangement whereby Siemens components and telecommunications test equipment was handled in the U.K. by Cole Electronics has been terminated. From January 1st Siemens (U.K.) Ltd, Great West House, Great West Road, Brentford, Middx, will handle these products.

MCP Electronics Ltd, Alperton, Wembley, HAO 4PE, Middx, have been appointed sole U.K. representatives and distributors for Telefunken semiconductors.

LST Components, 7 Coptfold Road, Brentwood, Essex, now distribute heat sinks manufactured by Marston Excelsior Ltd (Imperial Metal Industries Group) and the 20 W integrated circuit amplifier made by Toshiba.

Russian test and measuring equipment. Z & I Aero Services now market a range of measuring equipment. Maintenance facilities are available. Z & I Aero Services Ltd, 44a Westbourne Grove, London W.2.

GDS (Sales) Ltd, of Michaelmas House, Salt Hill, Bath Road, Slough, Bucks, have been appointed a franchised distributor by **Radiatron Components Ltd.** The agreement covers the Elma range of collet knobs and rotary stud switches and Jaquet stopwatches.

Semicomps Ltd, 5 Northfield Estate, Beresford Avenue, Wembley, Middx, have been appointed **sole U.K. distributors** for the EMC range of dual-in-line i.c. sockets by Teknis Ltd, of Guildford, Surrey.

An agreement has been signed which gives AB Sonab, of Sweden, the sole **marketing rights in Northern Europe** for Ultra Electronics' range of communications equipment.

Microsystems International, of Canada, specialists in **standard and custom-designed microcircuits,** have appointed Pinnacle Electronics Ltd, Achilles Street, New Cross, London S.E14, as their first U.K. distributor.

Jason Electronic Designs Ltd are no longer wholesaling stocks of **Dansette and Perdio spares.**

AB Electronic Components are to take over the entire European manufacturing and marketing operations of the American component manufacturer, **CTS Corporation,** in exchange for 10% of their equity.

Jasmin Electronics Ltd have moved from Hainault, Essex, to a new factory at Station Road, Quorn, Leics. LE12 8BP.

The sales and service divisions of **Carston Electronics** have moved from Chinnor to Shirley House, 27 Camden Road, London N.W.1 (Tel: 01-267 2748).

The Broadcast Division of **Rank Precision Industries Ltd** are moving from Welwyn Garden City to Watton Road, Ware, Herts. (Tel: Ware 3939).

Interscan Data Systems (UK) Ltd have moved from London to Hoechst House, Salisbury Road, Hounslow, Middx. Tel: 01-572 2871.

Spectra-Physics Ltd have moved to premises at 5 Wolsey Road, Hemel Hempstead, Herts.

The Avionics Division of Plessey Electronics Group has been awarded contracts valued at £227,000 for **automatic and manual test equipment,** from the Ministry of Aviation Supply.

Pye Telecommunications Ltd has received a £$\frac{3}{4}$M contract to supply a **nationwide communications system** for the Sierra Leone police.

Racal-BCC Ltd, of Bracknell has received an order valued at over £1,300,000 from the Malaysian Ministry of Defence. The order is for over 1,000 **military radio telephones** with accessories and spares.

January Meetings

Tickets are required for some meetings: readers are advised, therefore, to communicate with the society concerned

LONDON

6th. Hosp. Physicists Assoc./Bio. Eng.Soc./ IEE/IERE — Symposium on "Physiological transducers for measurement in vivo" at 17.30 at Savoy Pl., W.C.2.

6th. IERE — "Recent advances in microwave ferrite devices" by E. Riches at 18.00 at 9 Bedford Sq., W.C.1.

7th. IERE/IEE — Colloquium on "Optical character recognition and allied techniques" at 18.00 at 9 Bedford Sq., W.C.1.

7th. R.T.S. — "Marconi Mk VII colour camera" by W. T. Underhill at 19.00 at I.T.A., 70 Brompton Rd., S.W.3.

8th. IEE — Colloquium on "Non-linear circuit analysis" at 14.30 at Savoy Pl., W.C.2.

11th. IEE — "Amorphous semiconductors" by R.W. Brander at 17.30 at Savoy Pl., W.C.2.

12th. IERE — "A review of computer control" by S.L.H. Clarke at 18.00 at 9 Bedford Sq., W.C.1.

12th. SERT — "Next steps in computer system design" by F.J.M. Laver at 19.00 at the London School of Hygiene & Tropical Medicine, Keppel St., W.C.1.

13th. IEE — "Developments in public data communication services" by M.B. Williams at 17.30 at Savoy Pl., W.C.2.

13th. IERE — "Integrated circuits for colour television" by J. C. MacKellar at 18.00 at 9 Bedford Sq., W.C.1.

15th. IEE — Colloquium on "Electronics on trains" at 10.00 at Savoy Pl., W.C.2.

15th. IEE/IERE — Colloquium on "Display systems" at 17.30 at Savoy Pl., W.C.2.

18th. IEE — "A communication and control system for motorways" by E. H. Walker at 17.30 at Savoy Pl., W.C.2.

19th. IERE — "ADSEL — selectivity addressed secondary radar" by C. Ullyatt at 18.00 at 9 Bedford Sq., W.C.1.

20th. Inst. Navigation — Discussion on "Area navigation" at 15.00 at the Royal Aeronautical Society, 4 Hamilton Pl., W.1.

21st. IEE — "The very early history of radio — from Faraday to Marconi" by Wing Cmdr G. R. M. Garratt at 17.30 at Savoy Pl., W.C.2.

27th. IERE — "Management of R.A.F. electronic engineering projects" at 18.00 at 9 Bedford Sq., W.C.1.

28th. IERE — Symposium on "Women in engineering?" at 18.00 at the London School of Hygiene & Tropical Medicine, Keppel St., W.C.1.

BATH

5th. Brit. Acous. S.—"Side-scan sonar applications" at 11.00 at the University.

BIRMINGHAM

6th. RTS—"Trends in television development" by A. V. Lord at 19.00 in the Viewing Theatre, ATV Studio Centre, Bridge Street.

14th. IEE Grads.—"M.O.S. transistors and micro-electronics" by M.B. Bandali at 19.00 at the Dept. of Electronic & Elect. Eng'g, the University.

19th. RTS—"Trade Union responsibility in the communications media" by Alan Sapper at 19.00 at the ATV Centre, Bridge St.

25th. IEE/IPOEE—"Radio propagation in the higher GHz frequencies" by E. M. Hickin at 18.00 at the MEB Summer Lane.

26th. IEE Grads.—"Electronic organs" at 19.30 at the Grapes, Hill Street.

28th. IEE—"Circuit conventions and phasors" by M. G. Scroggie at 18.15 at Sumpner Bldg, the University of Aston.

BLETCHLEY

12th. IEE — "Current trends in radio astronomy" by M. J. S. Quigley at 19.30 at P.O. College, Horwood House.

BRISTOL

12th. IEE — "Ultrasonics in medicine" by D. H. Follett at 19.30 at the Electricity House.

CAMBRIDGE

28th. IERE/IEE — "Flight recording" by R. Parsons at 18.30 at the University's Eng'g Labs.

CARDIFF

13th. IERE — "Recent developments in television tuners" by T. L. Harcombe at 18.30 at the University of Wales Inst. of Science & Technology.

CHATHAM

28th. IERE — "Control of projects" by S.C. Dunn at 19.00 at the Medway College of Technology.

CHELMSFORD

12th. IERE/IEE — "Management of a large electronics complex" by D. G. Smee at 18.30 at the Saracen's Head Hotel, High Street.

13th. IEE — "Electronics and the economy" by I. Maddock at 18.30 at the King Edward VI Grammar School, Broomfield Rd.

DONCASTER

12th. I.Prod.E. — "Fibre optics" by T. A. Clarke at 19.15 at the College of Technology, Waterdale.

DUBLIN

21st IEE — "Colour television systems" by E. J. Galagher at 17.30 at Trinity College.

EDINBURGH

6th. IERE — "Television field store standards convertor" by E. Rout at 19.00 at Napier College of Science & Technology, Colinton Rd.

FARNBOROUGH

12th. IEE — "Electronics in archaeology" by E. T. Hall at 18.30 at the Technical College.

GLASGOW

7th. IERE — "Television field store standards convertor" by E. Rout at 19.00 at the Inst. of Engrs & Shipbldrs, 183 Bath St.

26th. IEE Grads. — "Electronics — its future in navigation" by F. S. Stringer at 19.30 at the Music Room Livingstone Tower, Strathclyde University.

GUILDFORD

26th. IERE — "Computer graphics and the common man" by B. S. Walker at 19.00 at the University of Surrey.

HEADINGTON

13th. IEE — "U.K. developments in electronic telephone systems" by J. Martin at 19.00 at the Oxford Polytechnic.

HEMEL HEMPSTEAD

12th. IEE — "Digital instrumentation" by A. R. Owens at 19.15 at the Dacorum College of Further Education.

LEICESTER

20th. IERE — "Linear integrated circuits" by P. J. Jefferson at 18.30 at the University.

LIVERPOOL

7th. IEE — Colloquium on "R and D in electronics" at 09.00 at the University.

25th. IEE Grads. — "Computer graphics and the electrical engineer" by M. Clayton and D. W. Davis at 18.30 at the Polytechnic, Byrom Street.

MAIDSTONE

7th. IEE—"Invention as part of education" by Prof. M. W. Thring at 19.00 at the Royal Star Hotel, High Street.

MALVERN

28th. IEE/IERE — "Laser applications in electronics" by Prof. W. A. Gambling at 19.00 at the Abbey Hotel.

MANCHESTER

6th. IEE — "Logic circuits and their design in the solid" by D. J. Kinniment and A. Bardsley at 18.45 at U.M.I.S.T.

12th. IEE — "The impact of communications on society" by Prof. E. C. Cherry at 18.15 at the Renold Bldg, U.M.I.S.T.

14th. IERE — "Training and careers of electronic engineers in management" by H. Latham at 19.15 at U.M.I.S.T.

27th. IEE — "Electronic techniques in archaeology" Silvanus P. Thompson lecture by M. J. Aitken at 18.45 at the Renold Bldg. U.M.I.S.T.

MIDDLESBROUGH

6th. IEE — "Tomorrow's world in telecommunications" by W. J. Bray at 18.30 at the Cleveland Science Institute.

NEWCASTLE-ON-TYNE

13th. IERE — "Marine science and the electronic engineer" by M. J. Tucker at 18.00 at the Main Lecture Theatre, Ellison Bldg, the Polytechnic.

NEWPORT, I.O.W.

29th. IEE/IERE — "History and development of marine radars" by H. Giles at 19.00 at the County Hall.

PLYMOUTH

6th. RTS — "The Dolby noise reduction system" at 19.30 at the studios of Westward Television Ltd.

READING

28th. IERE — "Character generation" by G. Jones at 19.30 at the University.

RUGBY

27th. IEE — "Electronics in crime detection" by A. R. Torless at 18.15 at the Lanchester Polytechnic, Eastlands.

SALISBURY

25th. IEE — "Concorde electronics" by H. Hill at 18.30 at the Salisbury & South Wilts College of Further Education.

SOUTHAMPTON

13th. IEE/IERE — "Data transmission over radio links" by J. D. H. Alexander and J. S. Reynolds at 18.30 at the University.

STAFFORD

26th. IEE — "The Open University" by Prof. J. J. Sparkes at 19.00 at the North Staffordshire Polytechnic.

STOKE ON TRENT

12th. Keele University — "Hardware in the British NIMBUS satellite" by Dr. Ellis at 20.00 in the Physics Dept.

19th. Keele University — "How much of science is worthwhile?" by Prof. Ziman at 20.00 in the Physics Dept.

WORTHING

19th. IEE — "Colour television" by B. J. Rogers at 18.30 at the College of Further Education.

Electronic Building Bricks

8. Power in signals

by James Franklin

Electronics is often described as the "light current" side of electrical engineering, to distinguish it from the "power" side. Both in fact use electrical power, but since very little power is needed to represent and convey information, compared with the power needed to drive rolling mills or to light cities, there is a tendency to forget that it comes into electronics at all. We have to consider power in electronics because signals always have to operate or "drive" something, whether it is a building brick such as an amplifier or an adder (Part 1) or an output transducer such as a loudspeaker (Part 4). When we design a complete system made up of functional units and transducers we have to ensure that the signal emerging from each "brick" has adequate power to operate the next in line, or to operate the transducer which makes the signal information perceptible.

Power is a property which we understand intuitively in such forms as muscle power in the human body or engine power in cars. In the home, a 100-watt lamp gives a more "powerful" light than a 60-watt lamp. In all these cases there is a conversion of energy from one form to another—chemical to mechanical in the muscles, chemical to thermal to mechanical in the car engine, and electrical to light and heat in the lamp.

When an engineer talks about power he means something more precise than our intuitive idea, and something which can be measured. He defines power as the *rate at which work is done.* Thus if you lift up a chair in a given time you are doing work at a certain rate—using a certain power—and your muscles are converting chemical energy into mechanical energy for the purpose. If you lift up the chair the same distance in half the time, the rate of work, hence the power used, is doubled. When power is generated one can think of it as *flowing* from the energy converter (say a dynamo) to the load (which might be a lamp or a motor)—or, in mechanical terms, being *applied* to the load through some mechanical device such as a piston (see Fig. 1).

The unit by which power is measured is the watt*. There are other units, such as the horse-power (which is equivalent, to 746 watts), but, with the coming of metrication and SI (Système International) units, the watt is now being adopted as standard. Since power, as we have said, is defined as the rate of doing work, the unit of power, the watt, is defined as one unit of work done per second. Work done can be measured in units of energy—the energy which has done the work—and the SI unit of energy is the joule†. So watts =joules per second. But what exactly is a joule's worth of energy?

Energy exists in several forms—mechanical, thermal, chemical, electrical—and it can be converted from one form to another. We can therefore say, for example, that so much mechanical energy is equivalent to so much electrical energy; and the means by which we can equate them is the common unit, the joule. Mechanically, the joule is defined in terms of the work done in moving an object through a certain distance by the application of a certain force; thermally, in raising a certain mass of water through a certain temperature. Electrically, the joule is the work done in moving a quantity of electricity of 1 coulomb (see Part 3) through a resistance or reactance (Part 7) which is setting up an opposing e.m.f. of 1 volt.

We can see how this electrical definition applies in practice if we look at the simple circuit in Part 7 which is repeated here as Fig. 2. The e.m.f. source causes current to flow in the circuit and this is controlled by the resistor which sets up an opposing e.m.f. If this opposing e.m.f.—the potential difference measured across the resistor by the voltmeter—is 1 volt, and the source has driven a quantity of 1 coulomb of free electrons past a given point in the circuit, the work done is 1 joule.

If the e.m.f. source does this in one second there will be an electron flow rate of 1 coulomb/second = 1 ampere, and this will be indicated on the current meter ("mA") as 1000 milliamperes. Also, the rate at which the source is doing the work of forcing electrons through the resistance is 1 joule per second, which is a power of 1 watt. Thus the power being generated by the e.m.f. source and delivered to the load (the resistor) during that one second is 1 watt.

The e.m.f. source in Fig. 2 could be made to produce a varying e.m.f. Or it could be replaced by an energy-conversion transducer (Part 4). If the e.m.f. then produced varied in accordance with some meaningful pattern it would be representing information—it would be a signal. Thus the power being generated and delivered to the load (the resistor) would be *signal power.* As we saw in Part 2, a signal is any electrical variable which represents and conveys information; so here we have a variable, power, which has the dual purpose of representing information and "driving" a load. A graph of such a signal (power variation with time) is shown in Fig. 3. Since watts = joules/second, this graph also plots rate of doing work, or energy delivery, with time; so, over a given period of time we could work out the total energy delivered in the signal, on the principle joules = joules/second × seconds. In fact this is given by the area under the graph (shaded), which can be obtained by graphical integration.

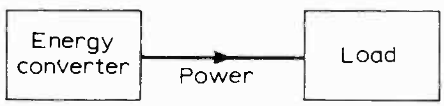


Fig. 1. Concept of power being transmitted from an energy converter to a load. The amount of power flowing is the rate at which work is done in the system.

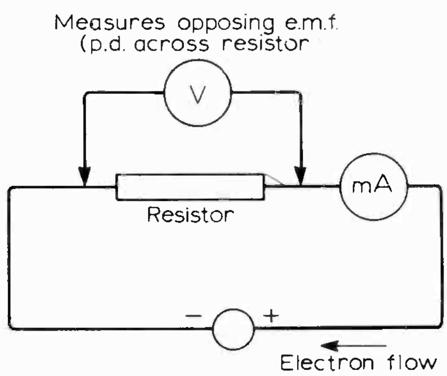


Fig. 2. Simple circuit illustrating work done by an e.m.f. source in moving electrons against resistance. The e.m.f. could be varied to form a signal.

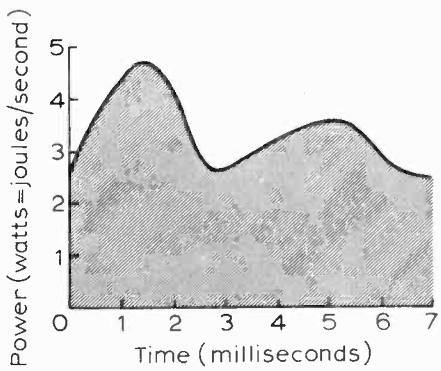


Fig. 3. Graph of a signal in which information is represented by a variation of power with time.

* Named after the Scottish engineer James Watt (1736–1819).

† Named after the English physicist James Prescott Joule (1818–1889).

World of Amateur Radio

British slow-scan TV

What is believed to have been the first British international two-way slow-scan television contact is reported by Robert Skegg, G3ZGO and G6ADJ/T, of Acton, West London. On November 21st on 14.23 MHz he exchanged pictures with the Greek station, SV1AB of Athens, after receiving a special Minpostel permit covering slow-scan transmissions. His hybrid valve/transistor monitor uses a 3FP7 radar tube and for transmission he uses the monitor as a flying-spot scanner with a 931A photo-multiplier, all equipment being driven by a solid-state pulse generator.

His transmitter is the relatively low-power Heathkit HW32 with only a dipole in his loft. He is anxious to try a higher e.r.p. in order to attempt to transmit to America and New Zealand where there is considerable interest in amateur slow-scan television transmission. He would like to hear from any British amateurs having experience of s.s. television transmission (18 Eastbourne Avenue, Acton, London W3 6JN). His Minpostel permit covers also the 144 MHz band.

Australis-Oscar 5 mystery

Analysis of the many reports gathered on the 29 and 144 MHz beacon transmitters carried in the amateur satellite Australis-Oscar 5 (launched in January 1970) could well cause some revision to current beliefs concerning h.f. satellite-to-ground propagation through the F layer. Earlier professional experiments, based mainly on the top-side sounders, had suggested ionospheric h.f. blockage to over-the-horizon reception, other than the now firmly recognized antipodal propagation (signal reappearance as satellite passes over a point antipodal to the observer). A number of amateur stations reported antipodal propagation on Oscar 5, almost always during afternoon or early evening local time.

On this 910-mile-high amateur satellite, Raphael Soifer, K2QBW, has pointed out that about two-thirds of the reports showed that the h.f. signals could be held longer than those from the v.h.f. beacon (contrary to some predictions), with well-equipped stations achieving pass durations well in excess of the theoretical 22.5 minutes. For example, Australian station VK3ATN, with large rhombic aerials, reported an average of 28 minutes, including one of 33 minutes 35 seconds. A comparison of stations achieving significant over-the-horizon results suggests that the signals were then arriving at extremely low angles to the horizon.

B.B.C. World Radio Club

The 15-minute World Radio Club broadcasts, which are transmitted on the B.B.C. World Service each week, are now being produced by Joy Boatman, who has taken over from John Pitman responsible for the programme for the past three years. Although intended primarily for short-wave listeners, the programmes often include items of interest to radio amateurs a number of whom regularly take part in the programme, as well as Doug Crawford (compere), Henry Hatch, G2CBB, and Marilyn Farthing. Each weekly programme is now broadcast first on Thursdays at 12.45 G.M.T., with repeats on Fridays at 23.45 G.M.T. and Sundays at 08.15 G.M.T.

Components for constructors

A browse through the advertisement columns of this journal would hardly suggest that home-construction by amateurs could possibly suffer from any shortage of suitable component parts. Never, it might seem, have so many parts been so readily available at such reasonable prices to the enthusiast. Yet, in practice, one of the thorniest problems facing those who wish to build their own equipment, often from designs published in books and periodicals, without extensive test and measuring equipment, has been the gradual disappearance of regular stock lines of components manufactured specifically for the transmitting amateur and those listeners wishing to build their own receivers. While this is particularly true of coils and coil packs, many other specialized parts are difficult to obtain from stock. In recent months, components specified for a number of popular designs have vanished from the market. Manufacturers undoubtedly are finding it difficult to justify products for which their is limited demand with high handling and postal charges.

This problem is by no means confined to the U.K. A recent article in the A.R.R.L.'s journal *QST* suggests that in the United States "the parts procurement situation seems to be going from bad to worse . . . parts are still available, but one must learn how and where to find them." The comment is made that the scarcity and high-cost of one-off parts mean that home-construction projects now often cost appreciably more than the comparable kits or manufactured gear. One West German publisher for the international amateur radio field is attempting to overcome the problem by offering kits and partial kits of the main designs in his periodicals—but this implies costs which amateurs, who traditionally like to build equipment basically from 'junk boxes' plus a few special parts, may find frustrating. Undoubtedly this is a problem which has played an important role in the greater dependence by many amateurs on manufactured equipment. All credit to those component firms who continue to cater for this specialized market.

In brief

Although over £500 has been raised by the Cheshire Homes Amateur Radio Network Fund—sufficient to equip 11 Homes with communications receivers—there are still 35 Cheshire Homes without equipment (secretary/treasurer W. M. Clarke, G3VUC, 66 Fillace Park, Horrabridge, Yelverton, Devon) . . . . The deaths of three well-known British amateurs have been reported recently: Fred Lambeth, G2AIW, who was the R.S.G.B's first v.h.f. manager; Norman Caws, G3BVG, who was for many years honorary treasurer of the R.S.G.B., and W. H. Martin, GI5HV who pioneered v.h.f. activity in Northern Ireland . . . . Amateurs operating in West Germany as members of foreign military forces are now being given the pre-fix DA. For example, DA1RAF is located at the R.A.F. base at Gatow, near Berlin . . . . Portsmouth Polytechnic students are trying to arouse more interest in amateur television in the south of England and plan to hold a series of lectures on the subject (details; the secretary, Electropol, Students Union Offices, Union House, St. Pauls Road, Portsmouth) . . . . A new 50.098 MHz beacon, VE8YT, on the north coast of Baffin Island has already been heard in Iceland and is thought likely to be heard in Europe during abnormal propagation conditions (reports to Larry Kayser, VE3QB, 59 Westfield Crescent, Ottawa 5, Ontario, Canada) . . . . The well-supported R.S.G.B. VHF National Field Day 1970 was won by the Mid-Essex VHF/UHF Contest Group—there were over 120 entries, with stations on 70, 144,432 and 1296 MHz.

PAT HAWKER, G3VA

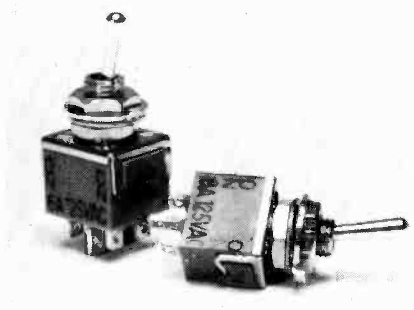
New Products

High-performance op-amp

Model 3500 monolithic op-amp made by Burr-Brown Research, and available from Fluke International, uses a cancellation technique to reduce input bias current to 10nA and thermal drift to 0.3nA/°C. Slew rate is 1.5V/μs. This is accomplished by a feedback loop that senses the instantaneous input current and supplies the appropriate compensating current. The technique compensates both the quiescent levels of bias current and its signal variations. Thus, the input impedance is boosted to 5,000MΩ common mode, and 10MΩ differential. The device can operate at power supply levels from ±3 to ±20V without significant change in its performance because it employs internal level-setting that is independent of power supply levels. Power supply sensitivities of 0.2dB/V, 20μV/volt, and 0.1nA/volt are attained over the full operating range of supply voltages. Noise is 1μV pk-pk. Typical common-mode rejection is 90dB, and open loop gain is 100dB. Unity gain bandwidth is 1MHz, input offset voltage 1.5mV, full power response 20kHz, and quiescent current 2.5mA. Input offset voltage drifts are limited to ±5μV/°C, ±10μV/°C, or ±30μV/°C, all guaranteed maxima. Rated output of the device is ±10 volts, ±10mA. Prices for the model 3500 start at £4 14s 0d in unit quantities. One hundred quantity prices start at £3 8s 0d each. Fluke International Corporation, Garnett Close, Watford WD2 4TT.
WW 328 for further details

Sub-miniature toggle switches

Two sub-miniature toggle switches with a rating of 6A at 125V or 3A at 250V a.c. are available from WEL. Both have a breakdown voltage of 1,000V a.c. with insulation resistance of more than 100MΩ at 500V d.c. Contact resistance is typically less than 5mΩ at 1A 2.4V d.c. The life expectancy is up to 10×10^4 operations at 1A rating and in excess of 2×10^4 at 3A 250V rating. Units are moulded in phenolic melamine with solder tag connections. Metal parts are bright plated. Two types are available: TS106D single-pole double-throw, and type TS206N double-pole double-throw. Prices are 7s 6d and 9s 6d,



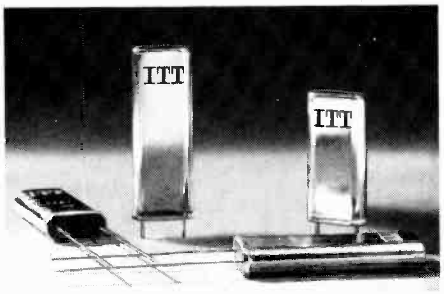
respectively, for TS106D and TS206N for quantities of 1-9. WEL Components Ltd, 5 Loverock Road, Reading, Berks.
WW 330 for further details

Miniature resistors

Low cost $\frac{1}{16}$-watt resistors are available from Solitronics of Hong Kong. They are made from metal glaze resistor paste and have a load life stability of ±5% over 500 hours. Voltage and temperature coefficients are ±0.3%/V and ±7 in 10^4/degC. Available in ±5% tolerance, values range from 51Ω to 100kΩ. Price is about $25 (U.S.) per 1000 for orders of over 10,000 reducing to about $15 for 500,000. Solitronics Engineering Ltd, 1531 Star House, Harbour Centre, Kowloon, Hong Kong.
WW 313 for further details

L.F. quartz crystals

A range of quartz crystal units from ITT covers the frequencies 54 to 65.499kHz; 65.5 to 83.999kHz; and 84 to 150kHz in three sizes of hermetically sealed metal holders. Each holder is supplied with either two-pin or two-lead-wire bases.



ITT Components Group Europe, Quartz Crystal Product Division, Edinburgh Way, Harlow, Essex.
WW303 for further details

Op-amp dual power supply

Model 707 dual power supply from Microtest is designed for op-amps requiring equal positive and negative supply voltages. The voltages are set by one control and the negative supply tracks the positive master supply. As a result any change of the internal reference source (e.g. drift, ripple) will cause an equal change in the outputs of both the master and slave supplies. A maximum current of 100mA may be drawn from each line and the loads on each line need not be equal. Foldback current limiting, which starts at approximately 120mA, ensures protection of the positive master line which then causes the negative line to follow. The negative line is protected by constant current limiting which does not affect the positive line. The specification includes the following:

input voltage	200V to 250V 50/400Hz
dual output voltage	±12V to ±16V at 0 to 100mA
mains regulation	0.01%
load regulation	0.02%
ripple and noise	< 250μV peak to peak
output impedance at 10kHz	< 0.1
short circuit protection	indefinite
tracking error	< 1%
temperature coefficient 0 – 70°C	0.3%
size	210×90×50mm

Microtest Ltd, 28 Walker Lines Industrial Estate, Bodmin, Cornwall.
WW301 for further details

Low leakage current diode

A silicon diode, type BAV45 from Mullard, has a leakage current of not more than 10pA at a junction temperature of 25°C and a reverse voltage of 20V. At a junction temperature of 80°C and a reverse voltage of 5V it does not exceed 150pA. The diode's capacitance is 1.3pF. The maximum reverse voltage rating is 20V and maximum forward current 50mA. With a forward current of 10mA the voltage drop across the diode is less than 1V. The BAV45 is enclosed in a TO–18 encapsulation and has a thermal resistance from junction to ambient of 0.5°C/mW. Mullard Ltd., Mullard House, Torrington Place, London WC1E 7HD.
WW307 for further details

Power transistors for v.h.f.

Three new 40W transistors manufactured by TRW Semiconductors Inc., California, are now available from MCP Electronics.

They are the PT8711 (12.5V, 4.5dB gain), the PT 8712 (24V, 6dB gain) and the PT8701 (28V, 7.5dB gain). The first two devices are in a 4-lead diamond package, while the PT8701 is in the TO-128 package. A fourth new device—the PT8710—is a stud package with very wide, low inductance base and emitter leads. The latter device is rated at 25W and needs 8W drive power at 175MHz and V_{ce} of 12.5V. MCP Electronics Ltd, Alperton, Wembley, HA0 4PE.
WW 308 for further details

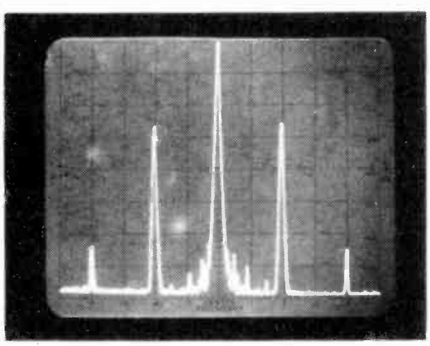
Digital error detector for p.c.m.

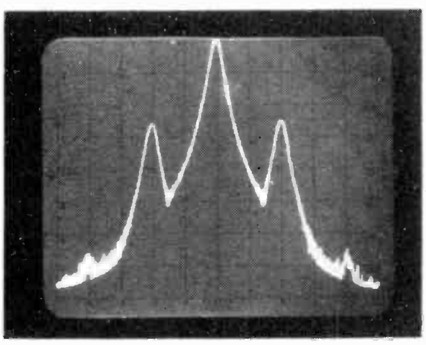
Designed for testing p.c.m. telephone links and terminal equipment, the new Marconi Instruments error detector can be used without breaking the signal path. The instrument, type TF2801, measures bipolar

errors in 24- and 32-channel equipment at bit rates of 1.536 and 2.048 Mbits/sec. A meter indicates presence of a signal and errors. A totalizer displays total errors over any period of time. It has an internal 9V battery. Marconi Instruments Ltd, St. Albans, Herts.
WW 310 for further details

RF spectrum analyser with 10Hz resolution

Hewlett-Packard i.f. section type 8552B gives their existing spectrum analyser a 10Hz resolution up to 110MHz. Used with the type 8553B r.f. section and the 141T display, 10-Hz resolution signals can be displayed from 1kHz to 110MHz. Scan range can be varied between 200Hz and 100MHz. Dynamic range is 70dB and both linear and logarithmic scales can be used with scale factors from 0.1μV per division to 100mV per division. Sensitivity is 25nV (−140dBm). Photographs of displays contrast the 10Hz resolution (left) and 50Hz resolution (right). Left-hand trace shows a 30MHz double sideband a.m. signal with 400Hz sidebands at −26dB and 2nd harmonic distortion at −64dB. Hewlett-Packard Ltd, 224 Bath Road, Slough, Bucks SL1 4DS.
WW 327 for further details



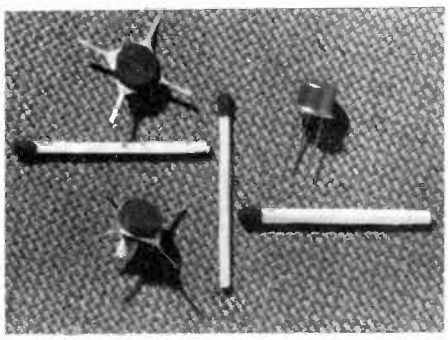


Portable video-recording system

The Akai VT100 video tape recording system, now available from Rank, employs a tape recorder smaller than most portable typewriters (using ¼in tape), and is able both to record and playback powered by its own internal batteries. The complete system—camera, recorder, clip-on monitor, and batteries—weighs less than 11kg. Twenty minutes recording is possible on one reel of tape costing £4. Price of system £568. Rank Audio Visual, Audio Products Department, P.O. Box 70, Great West Road, Brentford, Middx.
WW 333 for further details

U.h.f. power transistors

Intended for mobile u.h.f. communications systems, three new n-p-n transistors are announced by Mullard. The three differ in encapsulation. Types 351BLY and 352BLY have capstan-type encapsulations, the second being studless. Type 353BLY is



housed in a TO-39 package. The first two give an output of 3 watts at 470MHz from a drive of 350mW and a power supply at 13.8V. Output is limited to 2 watts in the TO-39 case. As well as low power output stage applications they can also be used for driving types BLY35A and 266BLY in transmitters with outputs up to 17W. Mullard Ltd, Torrington Place, London WC1E 7HD.
WW 320 for further details

High-voltage m.o.s.f.e.t. switch

A p-channel enhancement m.o.s.f.e.t., the M119, from Siliconix will operate at high voltages and accept signal swings of 40-0-40V. The device is TO-72 packaged and includes an internal zener diode to protect the gate. The on resistance is about 230Ω under signal conditions where the minimum V_{GS} is −40V. The required gate control signal is 40V plus the pk-pk signal voltage. Siliconix Ltd, Saunders Way, Sketty, Swansea, Glam.
WW 329 for further details

Op-amp with f.e.t. input

Use of a dual field-effect transistor input stage in the latest National Semiconductor operational amplifier, type NH0022, gives high input impedance and closely matched input characteristics. The amplifier is specially suitable for precision integrators and sample and hold circuits. The f.e.ts are monolithic devices with an interwired geometry that ensures tight tracking over the operating temperature range. Bias currents range from a few picoamps at room temperature to a few nanoamps at high temperatures. An external potentiometer nulls offset. A variant amplifier, type NH0020, handles load currents up to 50mA, with an open loop gain of 100dB. Two versions of each type are available for the temperature ranges −55 to +125°C and 0 to 85°C. National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051, U.S.A.
WW 325 for further details

Op-amp output stage

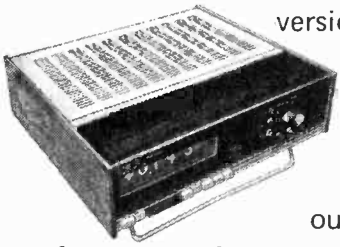
Power amplifier model 3329/03 for use with operational amplifiers allows currents of ±100mA to be controlled. The output stage is used inside the feedback loop and gives a low output impedance of ten ohms open loop. Output stage is protected against short-circuits at 85 deg C. Bandwidth is 5MHz with full output up to 500kHz. Input impedance is 10kΩ. Made by Burr-Brown, it is available in the U.K. from Fluke International Corporation, Garnett Close, Watford WD2 4TT.
WW 316 for further details

Limiter diodes

The Sylvania DLA5544 and DLA6190 are limiter diodes in an O-23 varactor package and intended for 50Ω stripline. They may be used as power sensitive attenuators. The incident r.f. power, which

From SE – the DVM's that mind your P's and Q's

SE's digital voltmeters look after Price as well as Quality, with a whole family of instruments – basic test and laboratory instruments, data logging units, right up to today's most accurate DVM representing the limits of present technology in stability, linearity and accuracy. You can specify exactly what you want from a wide choice of instruments each available in different versions, and pay only for what you need. All SE's integrating DVM's use an improved version of the well proven dual ramp system giving high rejection of AC signals. For the ultimate in linearity and accuracy this system is combined, in the SM 215, with inductive divider successive approximation. Available options include floating input, stored display, BCD outputs, auto and command ranging. All have an accuracy of at least ± .01% of reading ± 1 digit, 10 μ V resolution, 2,000 MΩ input impedance and typically less than 20 pA input current. All are elegantly styled, compact, with bright, maximum-visibility displays. Every one of them is top value. Write or ring for details.



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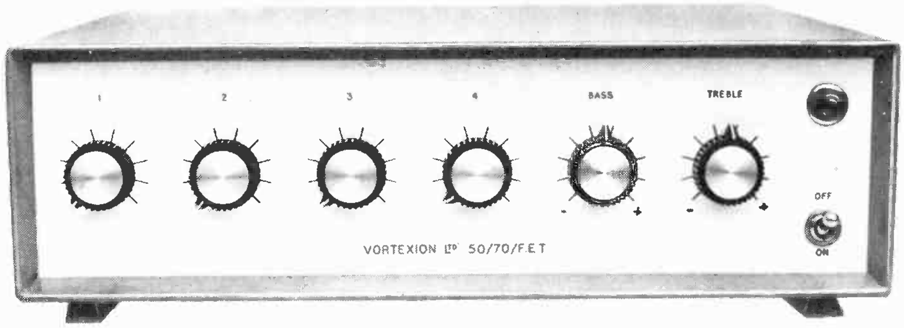
Transducers, recorders, oscilloscopes, digital instrumentation, data systems, medical electronic equipment, etc.

WW—079 FOR FURTHER DETAILS

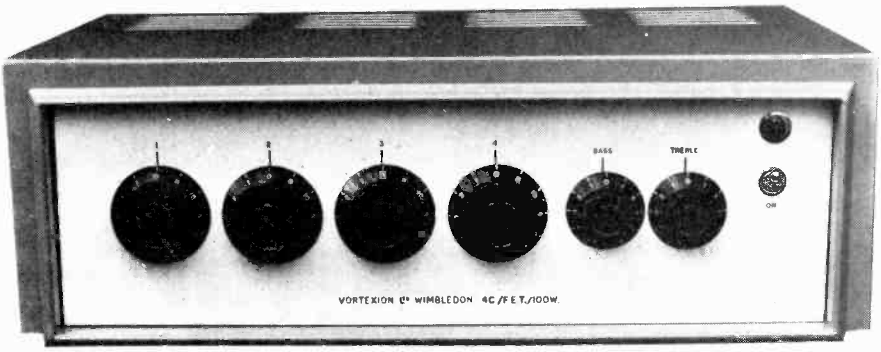
Vortexion

This is a high fidelity amplifier (0.3% intermodulation distortion) using the circuit of our 100% reliable—100 Watt Amplifier (no failures to date) 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 breakthrough. The mixer is arranged for 3-30/60Ω balanced line microphones, and a high impedance line or gram input followed by bass and treble controls. 100 volt balanced line output

THE VORTEXION 50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 4-WAY MIXER USING F.E.T.s.



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, 3 mic. 1 gram 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 silicon 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.

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.

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 2 dB 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 and Hi Z gram.

ELECTRONIC MIXERS. Various types of mixers available. 3-channel with accuracy within 1 dB Peak Programme Meter. 4-6-8-10 and 12-way mixers. Twin 2, 3, 4 and 5 channel stereo. Built-in screened supplies. Balanced line mic. input. Outputs: 0.5 V at 20K or alternative 1 mW at 600 ohms, balanced, unbalanced or floating.
Models available with 1 gram and 2 low mic. inputs, 1 gram and 3 low mic. inputs or 4 low mic. inputs.

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

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

WW—080 FOR FURTHER DETAILS

is reflected or diverted to another load, is reduced to levels that will not saturate or burn out a mixer crystal. The former is primarily designed for use in X and J bands while the latter may be used from u.h.f. to J band. Impectron Ltd., 23-31 King Street, London W.3.
WW306 for further details

Portable tachometer

Multi-purpose tachometer with rechargeable battery and using integrated circuits is made by Sapphire Research & Electronics Ltd. It has two sensors, magnetic and photoelectric, which in most cases will work off irregularities in the rotating component. It covers rotational speeds of up to two million rev./min. with an accuracy of 0.5%. The instrument features a state-of-charge indicator, sup-

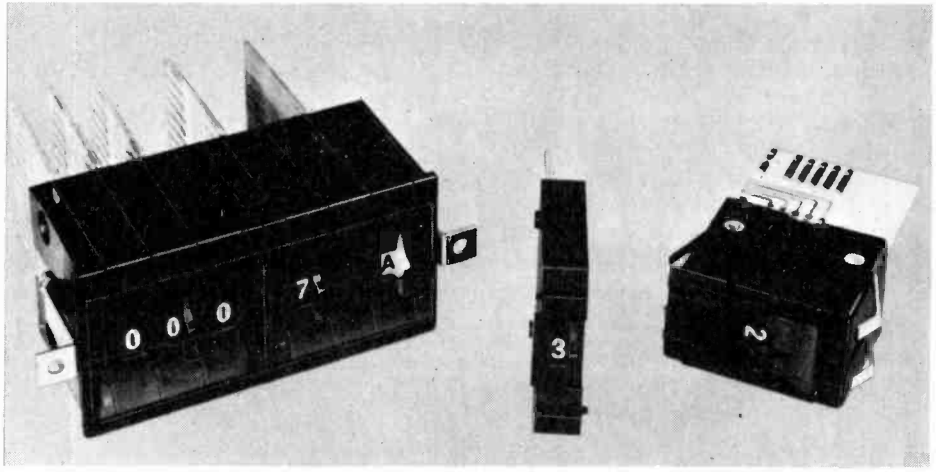
pressed zero meter for better resolution, automatic gain control and a chart recorder output. A charger unit is supplied with the tachometer, and because output voltage is low the terminals can be exposed on the charger—avoiding terminals on the hand-held unit. Price is £59. Sapphire Research & Electronics Ltd, Sapphire Works, Ferndale, Glam.
WW 309 for further details

Active filters

Butterworth, Bessel or Chebychev responses can be obtained with new active filters from Barr and Stroud by adding an external *RC* network. Although high-pass response can extend to 1MHz cut-off frequency range is 1Hz to 30kHz. High-pass filters are designated EF20 and low-pass EF10. Standard two- and three-pole modules can be combined to give networks of four, five or six poles. Attenuation is from 12 to 36dB/octave. Barr & Stroud Ltd, 1 Pall Mall East, London S.W.1.
WW 311 for further details

Miniature edge switches

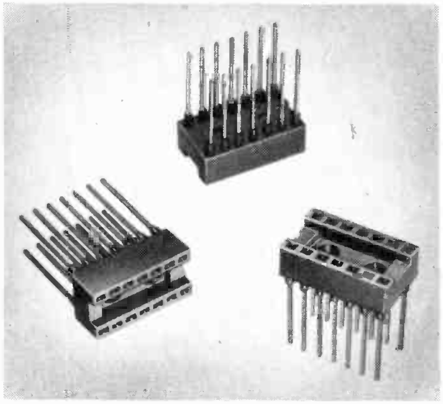
A range of miniature edge switches, the 33 series, is now available from Plessey. The switches can be panel mounted from the front or rear, and illuminated versions are available. A wide range of switching codes is possible including decimal,



binary, and binary with complement. Multi-pole switching is achieved by coupling together a switch and up to four slave modules. Terminations are for direct wiring or for edge connectors and are numbered. Contact rating is 100mA at 50V d.c. Life is specified as being not less than 10^6 operations. Dimensions of the switches are height 33mm, width 8mm. Professional Component Division, Plessey Components Group, Abbey Works, Titchfield, Fareham, Hants.
WW 305 for further details

14-lead socket

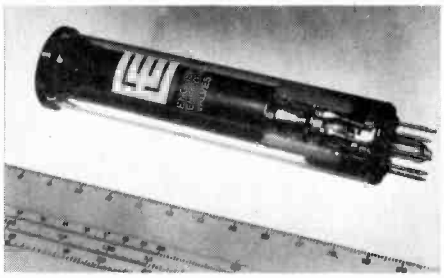
The A23/2041 socket from Jermyn will accommodate integrated circuits, relays and other electronic devices housed in 14-lead plug-in packages. Moulded from glass-loaded nylon, the socket is fitted



with pre-tensioned double wiper blade contacts. These have a life expectancy of up to 10,000 insertions with a typical contact resistance of 7 to 10mΩ. Jermyn Industries, Vestry Estate, Sevenoaks, Kent.
WW304 for further details

Vidicon camera tube

A short 1 inch diameter vidicon tube, type 7262A, from English Electric Valve Co, is intended for use in monochrome or colour closed-circuit television systems. The construction is integral mesh with magnetic focus and deflection. The photoconductive surface has high sensitivity and low lag. High voltage operation allows a limiting resolution of about 850 lines in the centre of the picture. Even when operated at low voltage, with minimum focus and deflection power, the centre resolution will normally



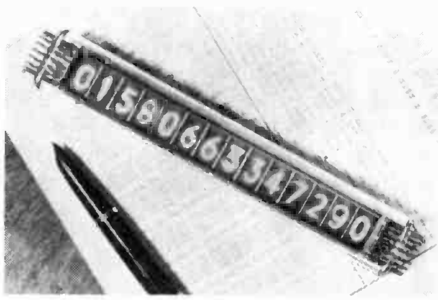
exceed 700 lines. The weight is approximately 60g. English Electric Valve Co Ltd, Chelmsford, Essex.
WW 334 for further details

Analogue multiplier

A monolithic four-quadrant multiplier made by Motorola is now available from Jermyn Industries. Type MC1595 gives a product of two input voltages with a linearity of 1%. It is useful for frequency doubling, as a balanced modulator and demodulator, for dividing, and taking the product, square root and mean square of functions. Input voltage is limited to $\pm$10V. Jermyn Industries, Vestry Estate, Sevenoaks, Kent.
WW 323 for further details

14-numeral display

Cold-cathode tube from Mullard can display 14 numerals in one envelope. The Pandicon type ZM1200 as it is called requires only 34 connections—as opposed to over 150 for separate tubes—and is



claimed to be more reliable than separate tubes. It uses a mixture of gases to give a luminance of 600cd/m^2. Coincident pulses of greater than 150μs are used to illuminate digits. Separate cathodes are provided for decimal points. Flicker can be eliminated by using an alternating supply of over 70Hz. Mullard Ltd, Torrington Place, London WC1E 7HD.
WW 324 for further details

Russian oscilloscope

Double-beam oscilloscope made in the U.S.S.R. is announced by Z & I Aero Services. Timebase generator provides for triggered operation and synchronization from an external source. A quartz crystal calibrator is included in the timebase. One of the vertical amplifiers can be switched to

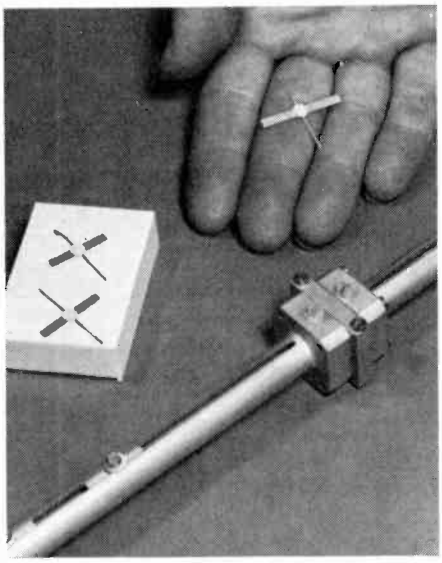
narrow passband, increasing sensitivity four times.

vertical bandwidth	5MHz (−3dB)
vertical sensitivity	500mm/V
input impedance	0.5MΩ, 45pF
input impedance (with attenuator)	5M , 13pF
amplitude range	40mV-400V
timebase range	0.2μs/cm to 100ms/cm
sync/trigger voltage	500mV
crystal frequency	100kHz

With standard accessories of 10:1 attenuator, coaxial leads and jacks, and viewing hood, the C1-16 scope costs £87 from Z & I Aero Services Ltd, 44a Westbourne Grove, London W2.
WW 318 for further details

4GHz transistor

Interdigitated structure is used to optimize emitter periphery in a new microwave power transistor developed at GEC Hirst Research Centre. Interlocking emitter and base fingers with widths of 1.25μm have enabled transistors to produce $\frac{1}{2}$ watt at 4GHz with a gain of 6dB. The structure also incorporates emitter stabilization resistors to provide overload protection. This transistor is being further developed



to give this performance over the whole of C-band (up to 6GHz). GEC Hirst Research Centre, East Lane, Wembley, Middx. HA9 7PP.
WW315 for further details

Pulse generator

Type PG-71 pulse generator from Lyons Instruments features double pulse operation. Starting from a common rate generator two independent but mixable channels are provided. The pulse rates for each channel is 1Hz-5MHz. Delay and width are between 50ns and 1s. Pulse amplitude is 0.5-10V.

The period generator is gateable over burst rates from d.c. to 1MHz by a +2V input applied via rear panel socket to the inhibit circuit. Each of the two delay and width generators employs a single t.t.l. package as the only active device. Both main output stages, and also the sync output, employ discrete silicon devices. Each main output consists of a three-stage current amplifier, providing a pulse amplitude of 10V from 50Ω source impedance (5V into 50Ω) with rise and fall times of less than 10ns.
The instrument measures 89 × 235 × 279mm and weighs approximately 3.2kg. Lyons Instruments Ltd, Hoddesdon, Herts.
WW 332 for further details

Heat sink resistors

The H.S. range of aluminium housed wirewound resistors recently introduced by C.G.S. is now available with resistance values down to 0.01Ω in each of the 10, 15, 25 and 50W sizes. Tolerances available are ±10% 0.01Ω to 0.1Ω and ±5% 0.1Ω to 1.0Ω. Prices range from 3s 2d each. C.G.S. Resistance Co. Ltd., March Lane, Gosport Street, Lymington, Hants. SO4 9YQ.
WW302 for further details

Improved plastic thyristor

Controlled rectifier type 2N5060 made by G-E (U.S.A.) is available in improved form, designated type C103 series. This 0.8A series has an increased surge rating of 8A and a lower forward blocking current of 1μA. Gate sensitivity is 200μA and the series has breakover voltages from 30 to 200V. In TO-18 plastic packages a typical price is about 11s for the 60-volt type. Jermyn Industries, Vestry Estate, Sevenoaks, Kent.
WW 321 for further details

Silicon photodiode

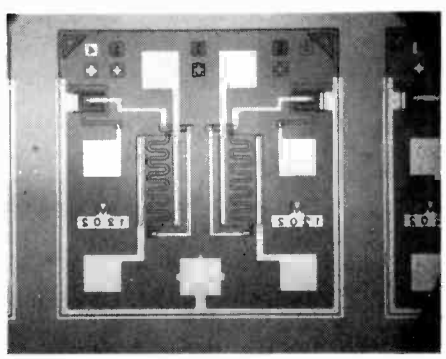
Photocurrent of 800pA per μW/cm^2 is typical for IPL32 diodes from Integrated Photomatrix. The diode is 1mm diameter and housed in a TO-5 case. Leakage current at 20°C is 50pA at 100mV, and 1nA at 10V. Breakdown voltage is 40V and the device costs 18s for 100+ orders. Integrated Photomatrix Ltd, Grove Trading Estate, Dorchester, Dorset.
WW 322 for further details

Transistors for television receivers

Three n-p-n transistors for video output stages are announced by Mullard. They can be used in both RGB and colour difference circuits and line scan driver stages as well as monochrome circuits. All three, BF336-8, have a minimum h_{FE} of 20 (I_c=30mA), minimum f_T of 80MHz, C_{re} of 3pF, power dissipation of 3W and a I_c maximum of 100mA. Maximum V_{CEO} is 180,200 and 225V for the three types and V_{CBO} is 185,250 and 300V. Package is TO-39. Mullard Ltd, Torrington Place, London WC1E 7HD.
WW 326 for further details

Silicon gate transistors

A range of silicon gate transistors is being produced by G.E.C. (Marconi-Elliott) Semiconductors. Such devices are new and

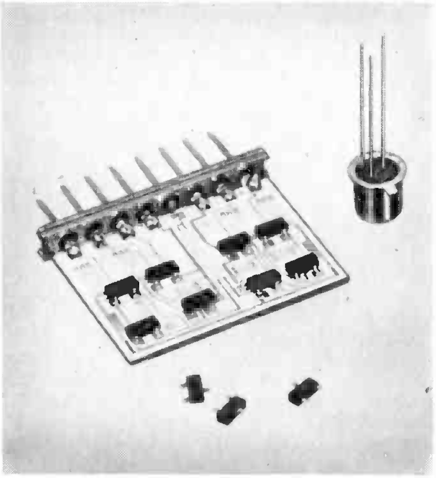


provide low gate/drain and gate/source capacitance (typically 0.5pF) and low threshold voltage (−1 to −2V). The latter feature allows the device to be driven directly by 5V bipolar logic. Series-shunt gates and n-path filters can be produced simply. Three standard devices have been produced—the M1102 single, the M1202 monolithic pair with independent source and drain connections, and the M1402 dual pair where each pair has common source connections. The devices have integral protection diodes to eliminate handling problems. G.E.C. Semiconductors Ltd U.K. (Marconi-Elliott), Witham, Essex.

WW 331 for further details

Transistors for thin/thick film circuits

Four high-voltage transistors in sub-miniature plastic packages are announced by Mullard. Intended for film circuits they are low level general purpose types with



V_{CEO} maximum ratings of 45V. Transistors measure 2.9 × 1.3 × 0.85mm excluding contacts. Types BCW69/70 are p-n-p types and BCW71/2 are n-p-n types. In the illustration they are compared with

	h_{FE} (2mA)	f_T (10mA)
BCW69R	120-260	150MHz
BCW70R	215-500	"
BCW71R	110-220	300MHz
BCW72R	200-450	"

TO-5 packages. $I_{CM}max$ is 200 mA and $P_{tot}max$ 150 mW. Mullard Ltd, Mullard House, Torrington Place, London WC1E 7HD.

WW 312 for further details

P.V.C. coating for p.c. boards

Printed circuit boards can be protected against chemical attack and the effects of moisture by the application of Vycoat ACA60 or CA.90 Polyvinyl plastic coating, available from Plastic Coatings. Available either in aerosol form as ACA 60 or in bulk as CA90 Vycoat air dries and cures at ambient temperatures. A thin and uniform coating (white, black, or clear) gives full protection, and yet allows components to be replaced by soldering through the layer. A quick respray to the affected area will restore the surface. It is usual practice to apply, in two stages, a film of approximately 100 microns, and at this thickness the layer will insulate against 3kV. Vycoat is available either in 14oz. aerosol cans or in 1 or 5 gallon drums. The safe working temperature range is −25°C to +70°C. Plastic Coatings Ltd, Products Division, Trading Estate, Farnham, Surrey.

WW 340 for further details

Linear i.cs

Quarndon Electronics announce they have the following Signetics i.cs in stock:

function	Signetics type	equivalent
op-amp	5558	MC1558
multiplier	5595	MC1595
balanced mod.	5596	MC1596
op-amp	531	
regulator	550	
function gen.	566	
regulator	5723	μA 723
diff. amp.	5733	μA 733
op-amp	5741	μA 741
op-amp	5748	μA 748, LM101

Quarndon Electronics Ltd, Stock Lane, Derby.

WW 319 for further details

Resistance bridge

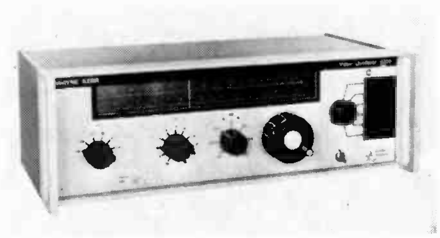
Available from J. J. Lloyd Instruments is a battery Wheatstone bridge which features electronic null detection. It can be used by unskilled operators by virtue of an overload protector which operates

when the bridge is out of balance. Accuracy is ±0.2% ±1 scale division. Resistance range is from 0.1 ohm to 1.1 megohms. J. J. Lloyd Instruments Ltd, Brook Avenue, Warsash, Southampton, Hants.

WW 314 for further details

Video oscillator

New Wayne Kerr oscillator type 0200 gives a sinusoidal output from 30kHz to 30MHz with an output level constant to within ±0.5dB. A 50ohm attenuator gives continuous adjustment of output level from −50dB to +10dB relative to 1V pk-pk.

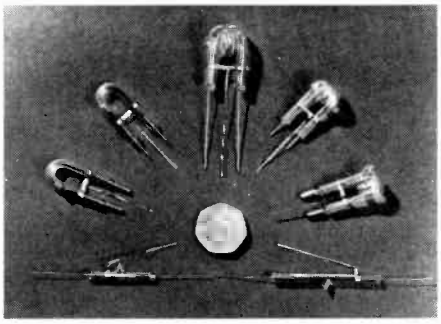


Direct reading frequency scale is accurate to 1% and a secondary output is provided for connection of a frequency meter. Frequency is unaffected by the load impedance and affected by only 0.5% by the attenuator. The generator works from 110 or 240V mains and weighs 6kg. Wayne Kerr Ltd, Roebuck Road, Chessington, Surrey.

WS 341 for further details

Range of flash tubes

A range of xenon and neon flash tubes is available from Hivac. These tubes have a wide variety of possible applications. Uses for neon tubes include low cost car ignition systems, timing guns, and warning lights for use in low level lighting conditions. The



xenon tubes, which emit white light pulses of high intensity, are particularly suitable for aircraft navigation lights, marine beacons and roadway emergency beacons. Hivac Ltd, Stonefield Way, South Ruislip, Middx.

WW 342 for further details

VHF transistors

New devices made by Communications Transistor Corpn of California, an affiliate of Varian Associates, are primarily intended for mobile v.h.f. systems covering 150 to 175MHz. The range includes transistors with 10dB gain and an output of 3 watts (type B3-12), 6.8dB gain with 12 watts output (type B12-12 and 6.2dB gain with 24 watts output (type B25-12). An amplifier using one B3-12, one B12-12 and two B25-12s will give 50 watts output for an imput of 250W. The range will be extended shortly to include 12V u.h.f. transistors and 28V microwave transistors. These transistors are constructed to withstand infinite v.s.w.r. at all phase angles and include integral ballast resistors to give safe operation. Samples are available. Obtainable in the U.K. from EMI-Varian Ltd, Hayes, Middx.

WW 343 for further details

Literature Received

For further information on any item include the appropriate WW number on the reader reply card

ACTIVE DEVICES

A booklet 'Rectifier and thyristor quality' (TP1198) has been published by Mullard Ltd, Torrington Place, London WC1E 7HD. It explains how the conformity and reliability of these devices can be assessed and achieved by careful control and manufacture WW401

We have received the following literature from AEI Semiconductors Ltd, Carholme Rd, Lincoln:
- List of U.K. distributors WW402
- Data sheet, CR30/31/50'04A thyristors, fast turnoff WW403
- Data sheet, CR1'01C 1-amp thyristors .. WW404
- Data sheet, CR30'03A 1.4kV, 63-amp r.m.s. thyristors WW405
- Data sheet, CR50'03A 1.4kV, 94-amp r.m.s. thyristors WW406

Claude Lyons Ltd, Hoddesdon, Herts, have available a technical data sheet (T-1092) which deals with Quadracs manufactured by the ECC Corp. of the U.S.A. .... WW 407

Integrated linear circuit chips, 23 of them, manufactured by Silicon General Inc., of the U.S.A., are the subject of a leaflet from Rastra Electronics Ltd, 275 King St, Hammersmith, London W.6 ..... WW 408

Transistors, diodes and integrated circuits are listed in the catalogue of AEG-Telefunken, Fabereich Halbleiter, Vertrieb, 7100 Heilbronn, Postfach 1042, West Germany .... WW 409

We have received a product data booklet from Intel Corp., Avenue Louise, 216-B-1050, Brussels, Belgium, which describes a fully decoded, m.o.s., l.s.i., random access, 1024-bit memory in an 18-lead d.i.l. flat pack type number 1103. The access time is 300ns and the cycle time is 580nsec WW410

'Cerberus elektronik, No.33' describes the use of cold-cathode relay tubes in sequence controllers. It is available from Cerberus Ltd, CH-8708 Männedorf, Switzerland .... WW 411

EMI Varian, Hayes, Middlesex, have a leaflet available which describes a range of microwave i.cs called 'microstrip circuits' .... WW 412

A. Marshall & Son (London) Ltd, 28 Cricklewood Broadway, London N.W.2, have sent us the following literature:
- Semiconductor price list .... price 2s 6d
- Data sheets for the transistors and diodes manufactured by Solid State Devices Incorporated of the U.S.A. .... WW 413

Semiconductors are also listed in the Comway catalogue mentioned in the next section.

PASSIVE COMPONENTS

The latest catalogue from Comway Electronics Ltd, Downshire Way, Bracknell, Berks RG12 1ND, is intended for hanging on the wall and contains details of capacitors, hardware, electromechanical components and semiconductors. It also contains a sporting calendar .... WW 414

'Connectors and connection systems' is the title of a booklet published by Ferranti Ltd, Dunsinane Ave, Dundee DD2 3PN .... WW 415

We have received the following literature from the Consumer Electronics Division of Mullard Ltd, Torrington Place, London WC1E 7HD:
- Leaflet 'New Mullard ceramic resonators revolutionise i.f. stages in radios' .... WW 416
- Ceramic resonators 'Introductory notes' . WW 417
- Data sheet, 540 series ceramic resonators 470kHz and 10.7MHz .... WW 418
- Data sheet, LP1175 block ceramic resonators 470kHz .... WW 419
- Data sheet, TAD100 integrated circuit—complete receiver .... WW 420

Potentiometers and trimmers in all shapes and sizes are described in a 'Product guide' received from Reliance Controls Ltd, Drakes Way, Swindon, Wiltshire .... WW 421

A range of push-button switches manufactured by Alois Zettler is obtainable from the U.K. agents J. H. Associates Ltd, 1 Church St, Bishops Stortford, Herts. A leaflet describes the range .... WW 422

Technical bulletin No. 2 from Alkaline Batteries Ltd, P.O. Box 4, Redditch, is called 'Nickel cadmium alkaline batteries of the vented type'. The bulletin describes the operation, construction and performance .... WW 423

Series 610 three-phase transformers, rated from 5 to 4200 VA, are described in a leaflet from Gresham Transformers Ltd, Hanworth Trading Estate, Feltham, Middlesex .... WW 424

We have received the following literature from Electrosil Ltd, P.O. Box 37, Pallion, Sunderland, Co. Durham:
- Data sheet T20/770, trimming potentiometers, TO-5 size (−55 to +150°C) .... WW 425
- Data sheet MT20/770 trimming potentiometer, TO-5 size (−20 to +125°C) .... WW 426
- Data sheet T40/1070, trimming potentiometers, oblong p.c. mounting .... WW 427
- Leaflet describing a boxed selection of metal oxide type C3 resistors .... WW 428

EQUIPMENT

Danavox (Gt Britain) Ltd, 'Broadlands', Bagshot Rd, Sunninghill, Berks, have the following two booklets available:
- 'Hearing-aid earphones and cords' WW429
- 'Hospital patients bedside listening sets' . WW430

A vast range of equipment for sound radio and television broadcasting equipment distributed by the Crow Company, P.O. Box 36, Reading RG1 4QD, is briefly described in their latest price list ... WW431

The 1971 catalogue of Heath (Gloucester) Ltd, Gloucester, GL2 6EE, lists a wide range of equipment, from audio to marine, which can be purchased in kit form or ready built. Use the reader reply service or write direct WW432

'Electronic speed variation control equipment for induction squirrel-cage motors' is the title of an article which was published in *Technique Suisse*. Reprints of the article, in English, are available from Berco Controls Ltd, Queensway, Enfield, Middlesex WW433

A leaflet describes the coaxial connectors which are available from Microwave and Electronic Systems Ltd, Marketing Division, 66 Tilehurst Rd, Reading RG3 2LU WW434

The following two booklets are available from Ferranti Ltd, Microwave Component Sales, Dunsinane Avenue, Dundee DD2 3PN:
- 'Communications components' WW435
- 'Radar systems components' WW436

Mark-two versions of a single (B.140) and a dual (B.240) pen recorder manufactured by Rikadenki Kogyo Co. Ltd, of Japan, with twelve chart speeds and a 166ms response time for f.s.d. (250mm) are the subjects of a leaflet from T.E.M. Sales Ltd, Gatwick Rd, Crawley, Sussex WW437

A data sheet which describes a low-cost angle position indicator with a five-digit display has been produced by North Atlantic Industries Inc., Terminal Drive, Plainview, New York 11803, U.S.A. WW438

From the National Research Development Corporation, Kingsgate House, 66-74 Victoria St, London S.W.1, we have received a leaflet describing a patent which covers a quarter wavelength coaxial cavity for an 8GHz Gunn-effect oscillator WW439

A 10kW transmitter, type RF-745, providing independent sideband operation in 100Hz increments is described in a leaflet. RF Communications Inc., 1680 University Avenue, New York 14610, U.S.A. WW440

A 90MHz dual trace oscilloscope with twin-timebases (A & B sweep), called type R070, is the subject of a leaflet from Roband Electronics Ltd, Charlwood Works, Charlwood, Horley, Surrey WW441

Outline details of a range of spectrum analysers manufactured by the Federal Scientific Corporation, of the U.S.A., are given in a short-form catalogue (GS-005-80564) received from A.E.P. International Ltd, 14a High St, Staines, Middlesex WW442

Details of all the accessories available for the '400 series' of signal recovery instruments are given in leaflet No. A1 from Brookdeal Electronics Ltd, Market St, Bracknell, Berks WW443

The latest Lasky's Radio 'Audiotronics' Catalogue lists a large range of audio and test equipment and other items. Lasky's Radio Ltd, 3-15 Cavell St, London E1 2BN WW444

GENERAL INFORMATION

The I.E.E. has prepared a series of pamphlets, contained in a pocket folder, which give careers information for boys and girls alike. Copies are available free of charge from The Secretary, The Institution of Electrical Engineers, Savoy Place, London WC2R OBL.

We have received the following literature from The British Standards Institution, 2 Park St, London W1A 2BS:
- BS 9500-N-001-003, B7G socket specification .... price 16s.
- BS 9500-W-004-006, B9A socket specification .... price 16s.
- BS 9563:1970, Specification for rotary (manual) switches of assessed quality: generic data and methods of test .... price 24s.
- BS 9562:1970, Specification for microswitches (sensitive switches) of assessed quality: generic data and methods of test .... price 24s.

The following literature may be obtained from The Engineering Information Department, B.B.C., Broadcasting House, London W1A 1AA:
- Information sheet 4919(7), map of B.B.C. u.h.f. TV main transmitting stations.
- Information sheet 4003(11), list of B.B.C. u.h.f. TV transmitting stations
- Information sheet 1919(4), map of v.h.f. radio transmitting stations; radios 2, 3 and 4.

The Redacal computer aided design service described in 'News of the Month' in our last issue is the subject of a leaflet. Redac Software Ltd, Newtown, Tewkesbury, Gloucestershire GL20 8HE WW445

Personalities

Christopher D. Colchester, B.A., has been appointed to the new post of chief scientist to Marconi Radar Systems Ltd and will relinquish his present position as assistant director of engineering in the Marconi Company. Educated at Rugby and Peterhouse, Cambridge, where he gained a 1st class honours degree in mechanical sciences, Mr. Colchester, who is 58, joined Marconi in 1933, to start work in the Telephone Laboratory. After the outbreak of war he was one of the group of Marconi engineers working in close association with the Admiralty on radar and was concerned with the development of radar aerials and associated equipment throughout the war years. Since 1965, Mr. Colchester has been the company's assistant director of engineering.

Two new executive directors have been appointed to the board of Marconi Elliott Avionic Systems Ltd. They are **W. H. Alexander,** B.Sc., A.Inst.P., and **Peter F. Mariner,** B.Sc., A.R.C.S., F.Inst.P., F.I.E.E., F.I.E.R.E., Mr. Alexander, who is 44 and a physics graduate of Edinburgh University, joined Elliott Brothers (London) Ltd in 1954 as a project leader engineer in the Aviation Division, and led the development work on gyro-stable platforms. In 1962 Elliott Flight Automation was formed at Rochester and Mr. Alexander was made joint general manager. He has been joint managing director since 1966. Mr. Mariner, 48, studied at the Royal College of Science where he obtained an honours degree in physics. After war service with the Fleet Air Arm he joined Elliotts in 1950 as group leader of the Aerials Laboratory. He became joint general manager of the Radar Group in Elliott-Automation in 1961 and managing director when the group became formally Elliott-Automation Radar Systems.

Giuliano Costamagna, the new 41-year-old general manager of SGS (United Kingdom) Ltd in succession to **Laurence A. Curry,** obtained a degree in electrical engineering at the University of Milan in 1953. After two year's service as a commissioned officer in the Italian Signal Corps he joined the communications division of the Marconi Company in Chelmsford, in 1956. Two years later he joined the SGS Group in Milan and since November 1969 has been temporarily running the SGS factory at Falkirk. Mr. Curry has been appointed a director of SGS (U.K.) and will act as a consultant to the company while developing his private business interests.

D. M. McCallum, B.Sc., F.I.E.E., general manager of Ferranti's Scottish group of factories since 1968, has been appointed to the board of directors of the company. Mr. McCallum (48), after obtaining a first class honours degree in electrical engineering at Edinburgh University, joined the research staff of the Admiralty Signal Establishment to work on

D. M. McCallum

the development of communications equipment. In 1947, after a short period with Standard Telecommunications Laboratories, he joined Ferranti Ltd and later was responsible for development of their 'AIRPASS' radar systems. From 1960-68 Mr. McCallum was manager of the company's Electronic Systems Department in Edinburgh.

Appointment of **D. Joseph Donahue,** M.S., Ph.D., to the newly-created position of division vice-president (solid state) Europe, has been announced by RCA Corporation. Dr. Donahue will be responsible for all solid-state activities in Europe, including sales, engineering, manufacturing and warehousing. His headquarters will be in London. RCA's first electronic manufacturing facility in Europe is a new 80,000 square-foot semiconductor plant in the Province of Liege, Belgium. Dr. Donahue, who received his degrees in physical chemistry from the University of Michigan, has been manager, solid state department, for the Solid State Division of RCA since 1967. He joined RCA in 1951 and was appointed manager, advanced development for the Semiconductor and Materials Division in 1960 and in 1962 was named manager, engineering, for the industrial semiconductor operation.

B. A. Clarke, M.I.E.E., is appointed business planning executive of the recently formed Underwater & Communications Divisions of Plessey Electronics Group. Mr. Clarke, aged 50, joined Plessey in 1960. He was general sales manager in the Radio Systems Division for a number of years and more recently was divisional manager of the Civil Radio Division. Originally he trained as a transmission engineer with S.T.C., and later was employed by A.E.I.

John Glaser has joined Aerialite Ltd as head of marketing in the Aerials Division. He has spent 24 years in the radio and electrical industries, but has been absent owing to ill-health for the past year. Mr. Glaser has been sales director with both Antiference and J. Beam Aerials.

The GEC Electronic Tube Co. Ltd, the management company combining the activities of the M-O Valve Co. and English Electric Valve Co., has announced several board appointments. **Roy H. Deighton,** commercial director of EEV, becomes commercial director of GECET; **F. C. Thompson,** Ph.D., B.Sc., F.I.E.E., director of EEV, is appointed a director of GECET, with responsibilities for the co-ordination of administration; **John Dain,** M.A., F.I.E.E., manager of the Microwave Division, EEV, is elected to the board of EEV and appointed general manager, Chelmsford; and **Frederick J. Munks,** commercial director, M-OV, is appointed general manager, M-OV. Mr. Deighton joined the Marconi Company in 1930, becoming chief of sales in Aeronautical Division in 1945. He became commercial manager of EEV in 1956 and was appointed president of English Electric Valve North America Ltd in 1968 and director of English Electric Valve Company in 1969. Dr. Thompson, a graduate of Liverpool University, served with A.A. Command before becoming a senior scientific officer at the Telecommunications Research Establishment, Malvern, in 1942. He joined EEV in 1945 as engineer in charge of microwave tube production, and was made manager of Radar Tube Division in 1956. He was appointed director of the English Electric Valve Company in 1969. Mr. Dain, after graduating from St. John's College, Cambridge, commenced his technical career as a scientific officer with the Telecommunications Research Establishment in 1942. In 1946 he transferred to the Atomic Energy Research Establishment and joined EEV in 1954 as chief of microwave research, subsequently becoming manager of the Microwave Tube Division. Mr. Munks joined M-OV in 1941. He became marketing manager in 1969.

Adam Hogg, M.I.E.R.E., has joined H. R. Smith (Technical Developments) Ltd, of Thame, Oxfordshire, as chief electronics designer. Mr. Hogg was with the Ministry of Defence (Air) for sixteen years engaged on design and development of group navigational aids and associated airborne equipment followed by five years as aerials project manager with C & S Antennas.

L. M. Thompson is appointed managing director of Rediffusion Vision Ltd and deputy chairman of Rediffusion Vision Service Ltd. He has succeeded **Maurice Exwood** who has been managing director of Rediffusion Vision Ltd since 1957. Mr. Exwood remains chairman of Rediffusion Vision and of Rediffusion Vision Service which is the company within the Rediffusion Group responsible for the television receiver retail business. Mr. Thompson, who is 53, joined Rediffusion in 1934 in Newcastle. He was appointed general manager of London Rediffusion Service Ltd. in 1958, general manager of Rediffusion Vision in 1962 and joined the board of Rediffusion Vision Service in 1963.

Sir Martin Ryle, F.R.S., Professor of Radio Astronomy in the University of Cambridge, is the 1971 recipient of the Morris N. Liebmann memorial prize award of the I.E.E.E., "for his contributions in applying aperture synthesis to extend the capabilities of radio telescopes, thereby increasing man's knowledge of the Universe." Sir Martin, who graduated at Christ Church, Oxford, in 1939, worked at the Telecommunications Research Establishment, Malvern, on radar systems and radio countermeasures throughout the war.

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I see that Mr. Bernard Hunn,* who was formerly one of Plessey's top men, has thrown in his hand at that establishment in order to start his own business. In this, I'm sure, we all wish him well, for it takes courage to abandon a safe job in favour of backing one's fancy. (Perhaps our technology might be in a healthier state if more of this went on, for I've a feeling that a lot of good ideas are mouldering in the graveyard-files of large companies for reasons which have nothing to do with lack of merit.)

Of the technical details of Mr. Hunn's idea I have no inside knowledge. In fact the only clue to its merits that I possess is that it is being backed financially by the Industrial and Commercial Finance Corporation, which, being an off-shoot of British banks, is not given to placing its money on also-rans. On the face of it, the project looks a sound one. It is, in essence, based on a credit card made of plastic in which are embedded strips of plastic tape having discrete blobs of magnetization imprinted on them. Each blob represents a monetary unit which can be used to buy goods.

As a pilot operation, Mr. Hunn plans to start with an unmanned petrol station. You drive up, insert the card into a suitable device and take what you want of petrol or other commodities. The outgoings are recorded and an appropriate number of magnetized blobs are erased. When the card is finished you throw it in the dustbin and buy another.

Naturally it isn't quite as simple as that; due regard, for instance, must be paid to the less honest citizens among us, otherwise stolen cards would become a thriving source of income. This, I believe, is taken care of by having your private identification number encoded on the card in such a way that only the machine-interrogator can read it. You manually insert your number (known only to yourself) and if the two tally you are home and dry (but not, let us hope, your petrol tank).

The aim of Mr. Hunn and others is to bring about a social revolution of some magnitude. The target is nothing less than that of a cashless society. You, sitting at home glumly surveying the year-end blizzard of bills, might be forgiven for supposing that this state of affairs is already with you; but that isn't quite what is meant.

The basic problem began when Ug in his cave developed an expertise in making flint-tipped arrows. Ig, his next-cave neighbour, couldn't make them for toffee, but had quite a knack at transforming skins into off-the-shoulder garments. So it wasn't long before an equitable rate of exchange was fixed between the two. Which was fine until a surfeit of arrows and tailor-mades was established; at that point not-so-near neighbours with other skills had to be persuaded to join the club.

This barter system worked quite happily even when trade assumed international proportions (and still persists today). Then some unknown genius (or fool, depending on your point of view) invented money. Now this, in concept, was a good thing. You sold your wares to someone who wanted them and instead of being lumbered with goods you didn't want in return, you were given a number of tallies (physically small and portable; usually of some precious metal) which could readily be exchanged elsewhere for goods you did want.

The system did, however, have its drawbacks. A merchant venturing out with a bag of gold was high up in the charts for being clobbered by footpads and so over the years to modern times there has been an increasing trend to keep the gold in a safe place and to issue pieces of paper—banknotes, cheques and so on—in lieu. But, while paper is more convenient to carry, banknotes are just as vulnerable to theft as gold, while cheques can be forged.

The next step was the credit card, a device which is rapidly gaining ground over here and is the norm in the U.S.A. where it has produced the paradox that only the very poor pay cash for goods. It has also produced something of a crisis in data transfer; if, in your travels in the U.S.A. you come across a mountain made of paper, you will, if you dig industriously, find a bank buried underneath it.

What Mr. Hunn *et al* intend to do is to replace the paperwork by electronics and at the same time make it fraud-proof. There are differing ideas of how this should be done, but whichever way it is it will add up to an awful lot of microcircuits and general electronics hardware.

In ten or fifteen years' time, if the visionaries have their way, you will receive, at the end of the month, not the customary handful of rice, but a magnetically encoded credit card in token of your labours. When you wish to buy something you take your card to the shop, make your purchase and then shove the card into an interrogation terminal. The amount of the purchase is wiped from the card and simultaneously the record of the transaction is sent by data link to a central computer, where your bank account is debited with that figure while the shop's account is credited. A logical extension would be the card-reading domestic telephone which I believe is already in prototype existence.

This sounds all right in principle, although I'm not sure how the details will work out. For instance it seems an elaborate way of buying a box of matches or gaining access to a public lavatory. And every married man knows the susceptibility of the distaff side to the blandishments of the supermarket (Darling, I only went in for a tablet of soap and somehow I seem to have spent £7.10.0.) so it would be financial suicide to turn the little woman loose with the entire credit card. Presumably there would have to be sub-cards for such items as house-keeping, junior's pocket-money and so on. On the reverse side of the coin (or rather, credit card), however, the government is likely to welcome a system whereby every monetary exchange is officially recorded and therefore subject to taxation scrutiny. The wad of notes under the floorboards seems to be on the way out.

In fact, the individual devices for such a system are mostly already in being, but a nation-wide network is another cup of tea. To mention only one snag, the Post Office is already submerged up to its cross-bars in communication problems (did somebody mention electronic exchanges?) The mind boggles at the task of data-linking 66 million people; and it boggles even more at the thought that the cost must inevitably be debited to your magnetic card and mine.

And this isn't all. Trade is international, so any system adopted must be world-compatible. It would be foolish for any one company (or even country) to go it alone in the vain hope of having its system adopted by every other nation. International co-operation at the design stage, and thereafter, would be vital.

One often hears that money is the root of all evil. This is a misquotation; what St. Paul wrote is 'the *love* of money is the root of all evil,' which is a different matter altogether. I should be the last to inflict a sermon upon you, so I'll merely suggest that the original concept of money as a convenient means of barter was torpedoed ages ago, when money was elevated to the rank of god. The cashless society concept does nothing to abolish the god; it merely makes him invisible.

* "Magnetic Credit for the Customer" *New Scientist, 22nd Oct. p 173*

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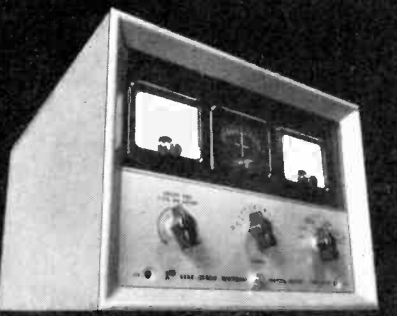

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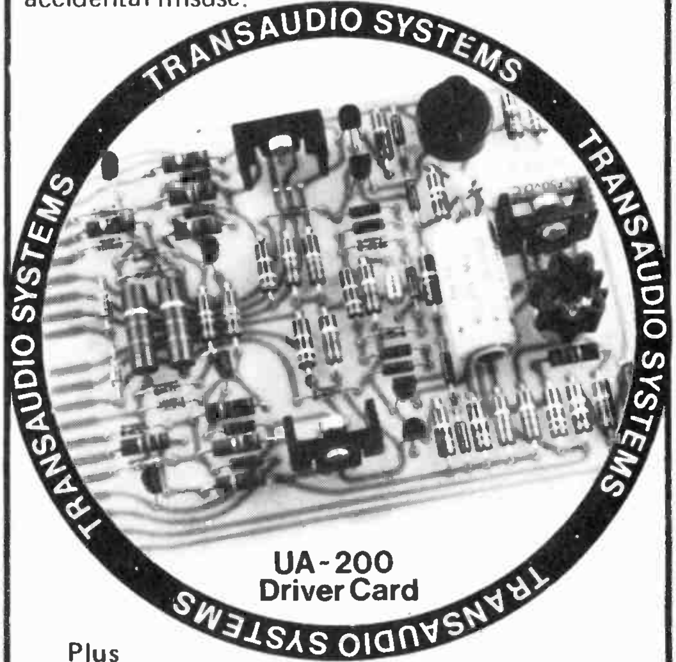

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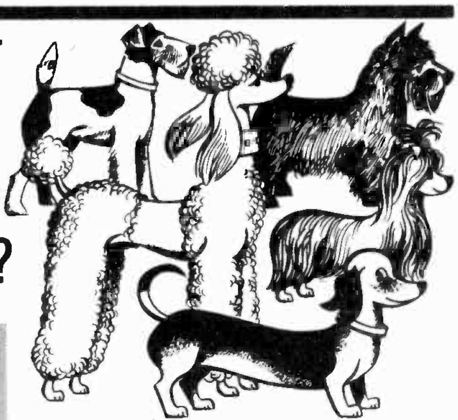

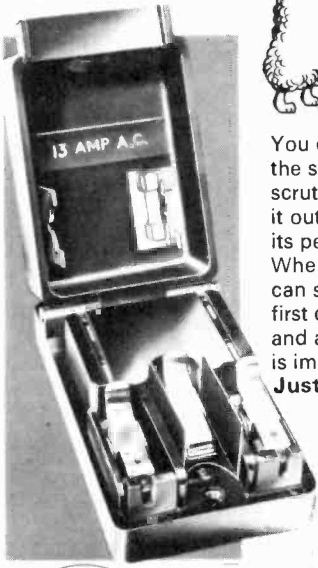

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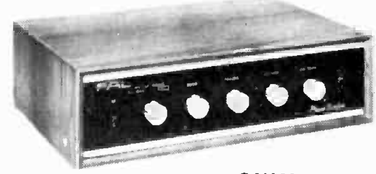

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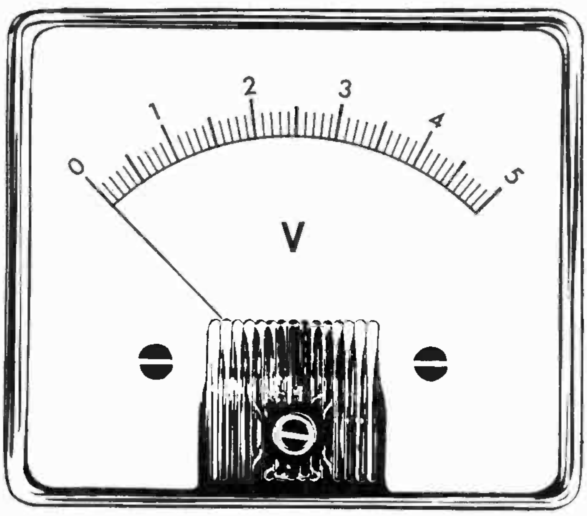

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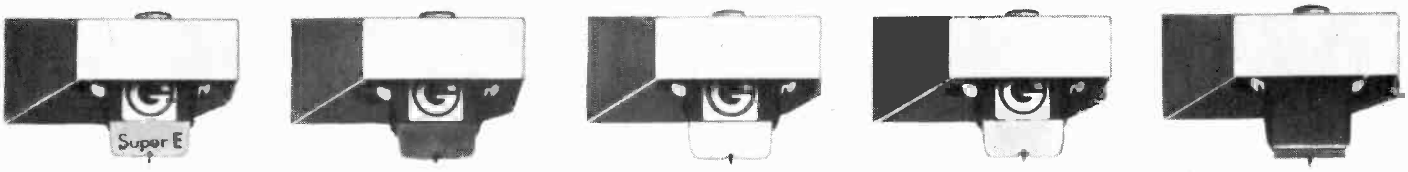

800 Super E For those aiming at perfection—extra low mechanical impedance for ultimate tracking is achieved by a duo-pivoting arrangement membrane-controlled to avoid longitudinal or torsional modes blemishing performance. Each cartridge supplied with individual curve and calibration certificate.

800/E Designed for transcription arms, a micro-elliptical diamond is fitted to a fine cantilever, end-damped against natural tube resonances, accurately terminated in a special conical hinge to give pin-point pivoting.

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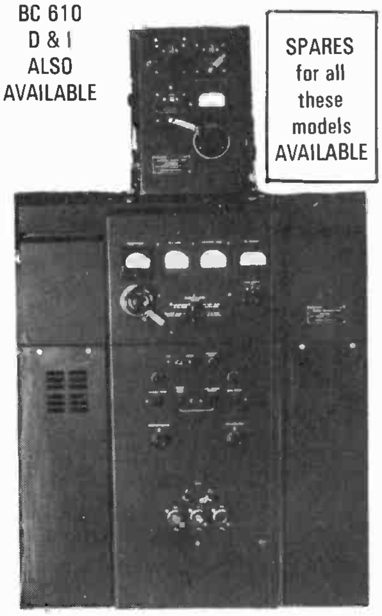

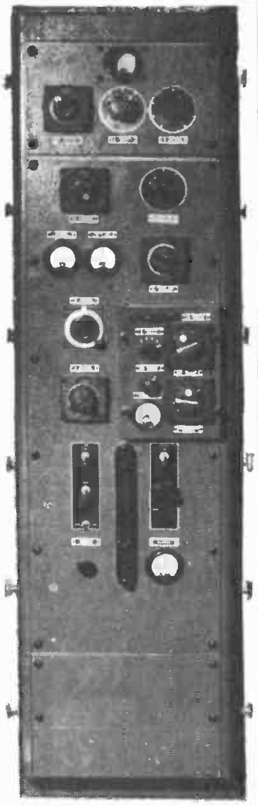

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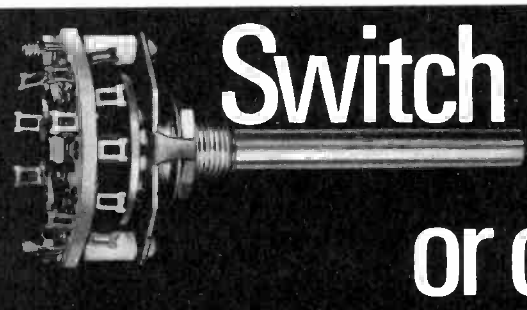

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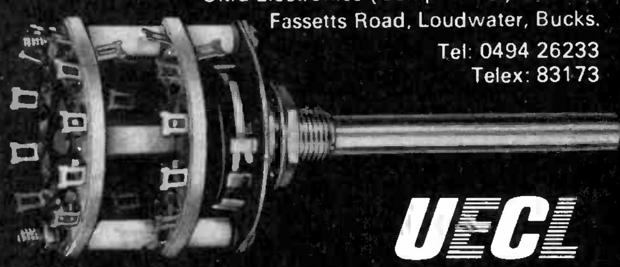

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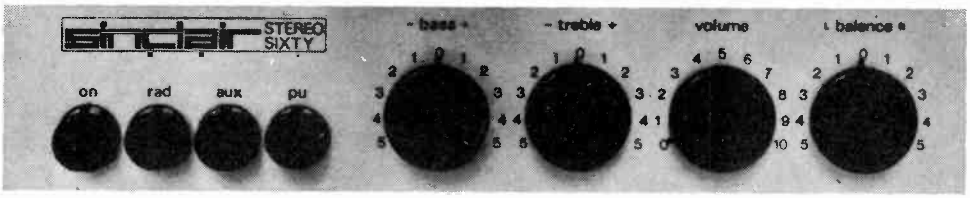
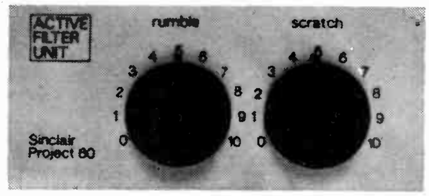
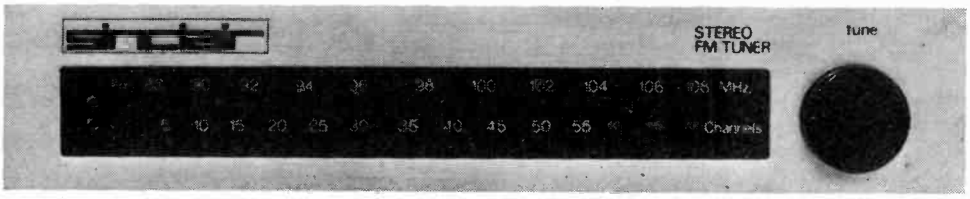
Project 60







the world's most advanced high fidelity modules

With the introduction of an entirely new and original high fidelity stereo F.M. tuner, the Project 60 range can be said at this stage to be complete. It offers the constructor a most attractive choice of modular arrangements whereby a high fidelity system can be selected to suit the user's personal requirements. Equally, it is possible to use any Project 60 modules separately or partially grouped and so benefit greatly from the flexibility in use these modules afford. The chart below shows some of the most popular applications for constructors to assemble. The Project 60 manual (free with the modules) suggests others as well and its 48 pages are packed with valuable information. The new tuner, for example can be used with any good high fidelity system as well as Project 60.

Project 60 now falls into four interdependent groups: – 1. The Z.30 and Z.50 amplifiers which have only 0.02% distortion at all output levels and are useful in a wide variety of other applications. 2. The control units comprising the Stereo 60 preamp and control unit and the Active Filter Unit (A.F.U.) with which both high pass and low pass filtering can be introduced between control unit and power amplifiers. 3. The Stereo F.M. tuner as described opposite: and 4. The power supply units PZ.5, PZ.6 and PZ.8. For most requirements when using Z.30 power amplifiers, the PZ.5 will be perfectly adequate; if low efficiency (high quality) loud speakers are used, the PZ.6 stabilised power supply unit will be used. The PZ.8 will be needed with Z.50s which can be used for any Project 60 system.

Project 60 modules incorporate some of the most advanced circuitry in the world to achieve unsurpassed standards of high fidelity and modern manufacturing techniques enable these modules to be sold at exceptionally attractive prices. Assembling the modules requires no skill or previous experience since the manual supplied with the modules explains clearly how everything can be done with nothing more than the simplest of domestic tools.

Project 60 manuals
How to assemble and use Project 60 modules to best advantage in the above and other applications will be found in the fully descriptive Project 60 manual included with Project 60 systems. This 48 page manual is available separately, price 2/6d including postage.

	System	The Units to use	In conjunction with	Cost of Units	+ Project 60 tuner
A	Car Radio	**Z.30**	Existing car radio, Sinclair Micromatic	**89/6**	
B	Simple battery powered record player	**Z.30**	Crystal pick-up, 12V or more battery supply and volume control	**89/6**	
C	Mains powered record player	**Z.30 and PZ.5**	Crystal or ceramic P.U. Volume control etc.	**£9.9.0**	**£34.9.0**
D	20+20 watts R.M.S. stereo amplifier for most needs	**Two Z.30s, Stereo 60 and PZ.5**	Crystal, ceramic or magnetic P.U., most dynamic speakers, F.M. tuner etc.	**£23.18.0**	**£48.18.0**
E	20+20 watts R.M.S. stereo amplifier for use with low efficiency (high performance) speakers	**Two Z.30s, Stereo 60 and PZ.6**	High quality ceramic or magnetic P.U., F.M. Tuner, Tape Deck, etc All dynamic speakers	**£26.18.0**	**£51.18.9**
F	40+40 watts R.M.S. de-luxe stereo amplifier	**Two Z.50s, Stereo 60 PZ.8 and mains transformer**	As for E	**£32.17.6**	**£57.17.6**
G	Outdoor public address system	**Z.50**	Microphone, up to 4 P.A. speakers, 12V car battery with converter, or 45V d.c., controls	**£5.9.6**	
H	Indoor P.A.	**One Z.50, PZ.8 and mains transformer**	Microphone, guitar, heavy duty speakers etc., controls	**£17.8.6.**	
J	High pass and low pass filters	**A.F.U.**	D, E or F as above	**£5.19.6**	

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Sinclair Radionics Limited, 22 Newmarket Road, Cambridge
Telephone (0223) 52731

WW—091 FOR FURTHER DETAILS

Z.30 & Z.50 power amplifiers

Z.50

Z.30

The Z.30 together with the Z.50 are both of advanced design using silicon epitaxial planar transistors to achieve unsurpassed standards of performance. Total harmonic distortion is an incredibly low 0.02% at full output and all lower outputs. Whether you use the Z.30 or Z.50 power amplifiers in your Project 60 system will depend on personal preference, but they are the same physical size and may be used with other units in the Project 60 range equally well. For operating from mains, for the Z.30 use PZ.5 for most domestic requirements, or PZ.6 if you have very low efficiency loudspeakers. For Z.50, use the PZ.8 described below.

SPECIFICATIONS ***(Z.50 units are interchangeable with Z.30s in all applications).***
Power Outputs
Z.30 15 watts R.M.S. into 8 ohms, using 35V 20 watts R.M.S. into 3 ohms using 30 volts.
Z.50 40 watts R.M.S. into 3 ohms from 40 volts 30 watts R.M.S. into 8 ohms, using 50 volts.
Frequency response 30 to 300,000 Hz ± 1dB
Distortion 0.02% into 8 ohms
Signal to noise ratio better than 70dB unweighted
Input sensitivity 250mV into 100 Kohms.
For speakers from 3 to 15 ohms impedance.
Size 3½ x 2¼ x ½ ins.

Z.30
Built, tested and guaranteed with circuits and instructions manual **89/6**

Z.50
Built, tested and guaranteed with circuits and instructions manual **109/6**

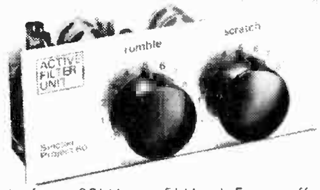
Stereo 60 pre amp/control unit

Designed for the Project 60 range but suitable for use with any high quality power amplifier. Again silicon epitaxial planar transistors are used throughout, achieving a really high signal-to-noise ratio and excellent tracking between channels. Input selection is by means of push buttons and accurate equalisation is provided for all the usual inputs.

SPECIFICATIONS
- Input sensitivities – Radio – up to 3mV. Mag. p.u. – 3mV: correct to R.I.A.A. curve ± 1dB: 20 to 25,000Hz. Ceramic p.u. – up to 3mV: Aux. – up to 3mV.
- Output – 250mV.
- Signal-to-noise ratio – better than 70dB.
- Channel matching – within 1dB.
- Tone controls – TREBLE +15 to –15dB at 10kHz: BASS +15 to –15dB at 100Hz.
- Front panel – brushed aluminium with black knobs and controls.
- Size 8¼ x 1½ x 4 ins.

Built, tested and guaranteed **£9.19.6**

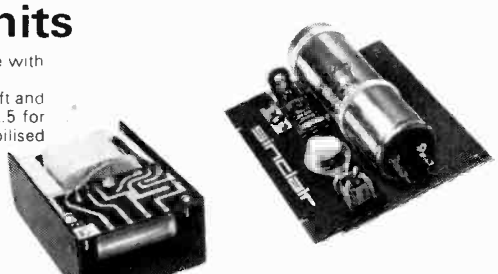
Active Filter Unit



For use between Stereo 60 unit and two Z.30s or Z.50s, the Active Filter Unit matches the Stereo 60 in styling and is as easily mounted. It is unique in that the cut-off frequencies are continuously variable, and as attenuation in the rejected band is rapid (12dB/octave), there is less loss of the wanted signal than has previously been possible. Amplitude and phase distortion are negligible. The Sinclair A.F.U. is suitable also for use with any other amplifier system.
Two stages of filtering are incorporated – rumble (high pass) and scratch (low pass). Supply voltage – 15 to 35V. Current – 3mA. H.F. cut-off (–3dB) variable from 28kHz to 5kHz. L.F. cut-off (–3dB) variable from 25Hz to 100Hz. Filter slope, both sections 12dB per octave. Distortion at 1kHz (35V supply) 0.02% at rated output.

Built, tested and guaranteed **£5.19.6**

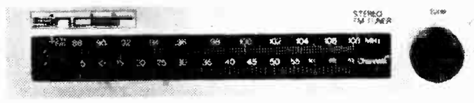
Power Supply Units



The units below are designed specially for use with the Project 60 system of your choice.
Illustration shows PZ.5 power supply unit to left and PZ.8 (for use with Z.50s) to the right. Use PZ.5 for normal Z.30 assemblies and PZ.6 where a stabilised supply is essential.

PZ-5 *30 volts unstabilised* **£4.19.6**
PZ-6 *35 volts stabilised* **£7.19.6**
PZ-8 *45 volts stabilised (less mains transformers)* **£5.19.6**
PZ-8 *mains transformer* **£5.19.6**

Stereo FM tuner

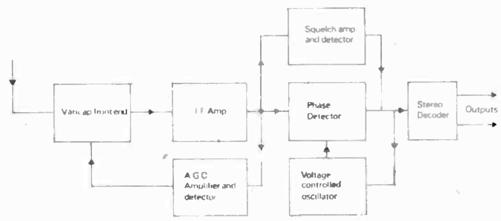


first in the world to use the phase lock loop principle

Before production of this tuner, the phase lock loop principle was used for receiving signals from space craft because of its vastly improved signal to noise ratio over other systems. Now, for the first time the principle has been applied to an FM tuner with fantastically good results. By the inclusion of other original features such as varicap diode tuning, printed circuit coils and an I.C. in the specially designed stereo decoder, the tuner has an unsurpassed specification, which also incorporates a squelch circuit for silent tuning between stations. A.F.C. and A.G.C. Sensitivity is such that good reception becomes possible in difficult areas, foreign stations can be tuned in suitable conditions and often a few inches of wire are enough for an aerial. In terms of high fidelity, this tuner has a lower level of distortion than any other tuner we know. Stereo broadcasts are received automatically as the tuning control is rotated, a panel indicator lighting up as the stereo signal is tuned in. Although the tuner is intended primarily for use with a Project 60 system, it can be used to advantage with any other high fidelity system. It is easily mounted into any cabinet as shown in the manual supplied with it.

Specifications

Number of transistors 16 plus 20 in I.C.
Tuning range 87.5 to 108 MHz
Capture ratio 1.5dB
Sensitivity 2μV for 30dB quieting
7μV for full limiting
Squelch level 20μV
A.F.C. range ± 200 KHz
Signal to noise ratio >65dB
Audio frequency response 10Hz—15kHz (±1dB)
Total harmonic distortion 0.15% for 30% modulation
Stereo decoder operating level 2μV
Pilot tone suppression 30dB
Cross talk 40dB
I.F. frequency 10.7 MHz
Output voltage 2 x 150mV R.M.S.
Aerial Impedance 75 Ohms
Indicators Mains on; Stereo on; tuning indicator
Operating voltage 25-30 VDC
Size 3.6 x 1.6 x 8.15 inches: 91.5 x 40 x 207 mm



Price: £25 built and tested. Post free.

GUARANTEE *If within 3 months of purchasing Project 60 modules directly from us, you are dissatisfied with them, we will refund your money at once. Each module is guaranteed to work perfectly and should any defect arise in normal use we will service it at once and without any cost to you whatsoever provided that it is returned to us within 2 years of the purchase date. There will be a small charge for service thereafter. No charge for postage by surface mail. Air-mail charged at cost.*

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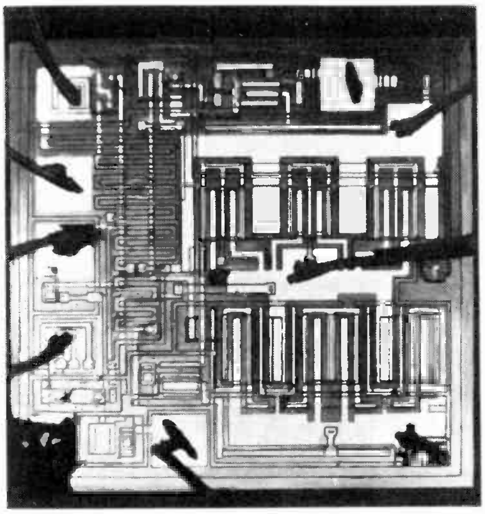
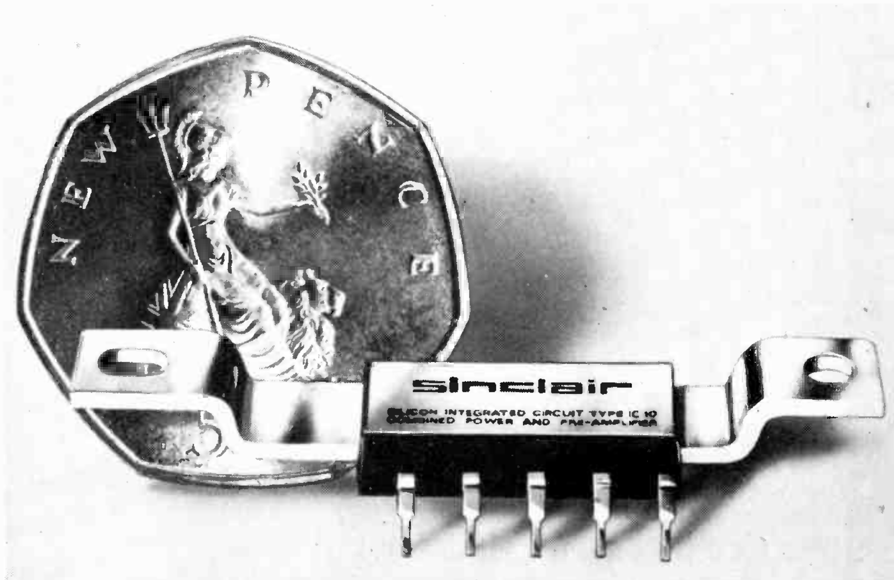
for which I enclose cash/cheque money order

WW 1.71

Sinclair IC-10





the world's most advanced high fidelity amplifier

Specifications

Output: 10 Watts peak, 5 Watts R.M.S. continuous
Frequency response: 5 Hz to 100 KHz±1dB
Total harmonic distortion: Less than 1% at full output.
Load impedance: 3 to 15 ohms.
Power gain: 110dB (100,000,000,000 times) total.
Supply voltage: 8 to 18 volts.
Size: 1 x 0.4 x 0.2 inches.
Sensitivity: 5mV.
Input impedance: Adjustable externally up to 2.5 M ohms.

Circuit Description

The first three transistors are used in the pre-amp and the remaining 10 in the power amplifier. Class AB output is used with closely controlled quiescent current which is independent of temperature. Generous negative feedback is used round both sections and the amplifier is completely free from crossover distortion at all supply voltages, making battery operation eminently satisfactory.

Applications

Each IC-10 is sold with a very comprehensive manual giving circuit and wiring diagrams for a large number of applications in addition to high fidelity. These include oscillators, etc., whilst the pre-amp section can be used as an R.F. or I.F. amplifier without any additional transistors.

The Sinclair IC-10 is the world's first monolithic integrated circuit high fidelity power amplifier and pre-amplifier. The circuit itself, a chip of silicon only a twentieth of an inch square by one hundredth of an inch thick, has 5 watts R.M.S. output (10w. peak). It contains 13 transistors (including two power types), 2 diodes, 1 zener diode and 18 resistors, formed simultaneously in the silicon by a series of diffusions. The chip is encapsulated in a solid plastic package which holds the metal heat sink and connecting pins. This exciting device is not only more rugged and reliable than any previous amplifier, it also has considerable performance advantages. The most important are complete freedom from thermal runaway due to the close thermal coupling between the output transistors and the bias diodes and very low level of distortion.

The IC-10 is primarily intended as a full performance high fidelity power and pre-amplifier, for which application it only requires the addition of such components as tone and volume controls and a battery or mains power supply. However, it is so designed that it may be used simply in many other applications including car radios, electronic organs, servo amplifiers (it is d.c. coupled throughout), etc. Once proven, the circuits can be produced with complete uniformity which enables us to give a full guarantee on every IC-10, knowing that every unit will work as perfectly as the original and do so for a lifetime.

SINCLAIR
IC-10 *with IC-10 manual Post free.* **59/6**

To: SINCLAIR RADIONICS LTD., 22 NEWMARKET RD., CAMBRIDGE

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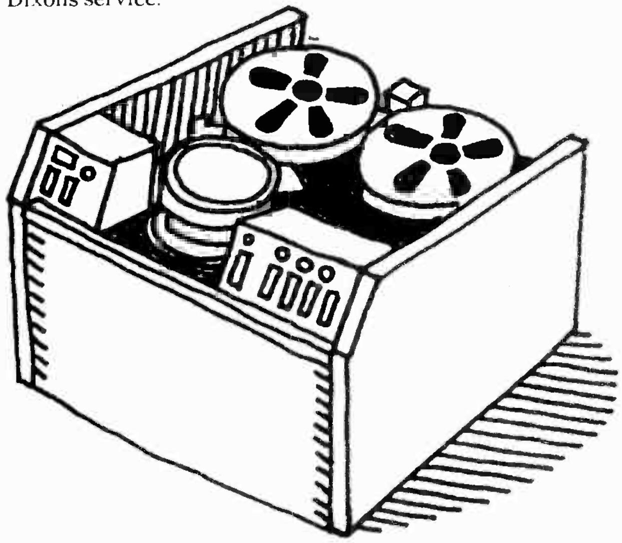

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for the discerning builder

BAILEY PRE-AMPLIFIER still offers lowest distortion level and best overload capability. Edge Connector Mounted Printed Circuit in Fibreglass or Paxolin material to choice. Highest quality parts including gain graded transistors.

BAILEY 30w POWER AMPLIFIER. Edge Connector Mounted Printed Circuit in Fibreglass or Paxolin material, size 4¼" × 2¾". This unit and the above Pre-amplifier can both be used in our new Metalwork Assembly.

BAILEY 30w POWER SUPPLY. We have now designed a Printed Circuit Board for the power supply, again intended to be used with our Metalwork, which also has edge connector mounting. Available in Fibreglass material only.

BAILEY 20w AMPLIFIER. Special driver transformer and bifilar wound mains transformer. Printed circuits and all parts available for this design.

LINSLEY HOOD CLASS A. Full sets of parts now available to the new specification given in the December, 1970, Wireless World.

LINSLEY HOOD CLASS AB. We have some parts for this design but a Printed Circuit will not be available. We can supply information re thermal stability to constructors interested in this circuit.

SUGDEN CLASS A AMPLIFIER. A Hi-Fi News design. All parts are in stock except the Metalwork.

DINSDALE. We shall be putting the parts for this design into honourable retirement shortly, so please order quickly if there is anything you require.

J. R. STUART TAPE CIRCUITS. We will be designing Printed Circuit Boards and supplying parts for this interesting design.

Full details are given in our Free lists. Please send foolscap s.a.e.

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2N2924	4/-	2N5163	5/-	ASY28	6/6	BD124	20/-	ZTX301	3/6
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2N3055	15/-	2N5459	9/9	BA156	4/-	BF195	7/6	ZTX501	5/-
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2N3706	2/6	40512	39/-			BFY51	4/-		

RESISTORS

Code	Power	Tolerance	Range	Values available	1 to 9	10 to 99 (see note below).	100 up
C	1/20W	5%	82Ω–220KΩ	E12	18	16	15
C	1/8W	5%	4·7Ω–330KΩ	E24	2·5	2	1·75
C	1/4W	10%	4·7Ω–10MΩ	E12	2·5	2	1·75
C	1/2W	5%	4·7Ω–10MΩ	E24	3	2·5	2·25
C	1W	10%	4·7Ω–10MΩ	E12	6	5	4·5
MO	1/2W	2%	10Ω–1MΩ	E24	9	8	7
WW	1W	10% ± 1/20Ω	0·22Ω–3·9Ω	E12	1/6 all quantities		
WW	3W	5%	12Ω–10KΩ	E12	1/6 all quantities		
WW	7W	5%	12Ω–10KΩ	E12	1/9 all quantities		

Codes: C = carbon film, high stability, low noise.
MO = metal oxide, Electrosil TR5, ultra low noise.
WW = wire wound, Plessey.

Prices are in pence each for quantities of the same ohmic value and power rating. NOT mixed values. (Ignore fractions of one penny on resistor order.)

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.

ZENER DIODES 5% full range E24 values: 400mW: 2·7V to 30V, **3/9 each**; 1W: 6·8V to 82V, **9/- each**; 1·5W: 4·7V to 75V, **12/- each**.
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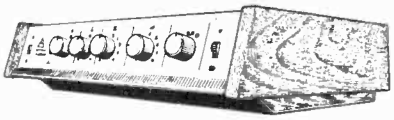
MULLARD SUB-MIN ELECTROLYTICS
C426 range, axial lead . . . . . . 1/3 each
Valves (μF/V): 0·64/64; 1/40; 1·6/25; 2·5/16; 2·5/64; 4/10; 4/40; 5/64; 6·4/6·4; 6·4/25; 8/4; 8/40; 10/2·5; 10/16; 10/64; 12·5/25; 16/40; 20/16; 20/64; 25/6·4; 25/25; 32/4; 32/10; 32/40; 32/64; 40/16; 40/2·5; 50/6·4; 50/25; 50/40; 64/4; 64/10; 80/2·5; 80/16; 80/25; 100/6·4; 125/4; 125/10; 125/16; 160/2·5; 200/6·4; 200/10; 250/4; 320/2·5; 320/6·4; 400/4; 500/2·5.

LARGE CAPACITORS
High ripple current types: 1000/25, **5/6**; 1000/50, **8/2**; 1000/100, **16/3**; 2000/25, **7/4**; 2000/50, **11/4**; 2000/100, **28/9**; 2500/64, **15/5**; 2500/70, **19/6**; 5000/25, **12/6**; 5000/50, **21/11**; 5000/100, **58/3**; 10000/15, **17/-**; 10000/25, **24/6**; 10000/50, **44/-**; 10000/70, **61/-.**

COMPONENT DISCOUNTS
10% on orders for components for £5 or more.
15% on orders for components for £15 or more.
(No discount on nett items.)

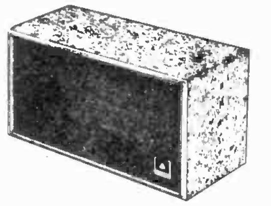
POSTAGE AND PACKING
Free on orders over £2.
Please add 1/6 if order is under £2.
Overseas orders welcome: carriage and insurance charged at cost.

PEAK SOUND PRODUCTS



ENGLEFIELD 12+12 AMPLIFIER

Stereo amplifier in modular kit form 12 watts per RMS channel into 15Ω **£38/9/-**;
Cabinet kit only **£6.** These prices nett.
As reviewed in *Hi Fi Sound* and other important journals.



BAXANDALL SPEAKER SYSTEM

Designed by Peter Baxandall. Superb reproduction for its size. Handles 10 watts with ease. Uses ELAC 15Ω 59RM109 speaker unit. Kit **£13/12/-** nett; built **£19/8/6** nett.

MAINLINE AMPLIFIER KITS

RCA/SGS designed main amplifier kits. Input sensitivity 500–700mV for full output into 8Ω.

Power	*Kit price including components*	*Suitable unreg. power supply kit*
12W	**168/-** nett	**92/-**
25W	**190/-** nett	N/A
40W	**210/-** nett	**115/1**
70W	**252/-** nett	**138/10**

30 WATT BAILEY AMPLIFIER PARTS

Sensitivity 1·2V for full output into 8Ω.
Transistors and PCB for one channel **£7/5/6**
Transistors and PCBs for two channels **£14/11/-**
Capacitors and resistors (metal oxide), **40/-** per channel.
Complete unregulated power supply pack, **£4/15/-**

INTEGRATED CIRCUITS

PLESSEY SL403A 3 watts into 7·5 ohms. Data book supplied FREE when two of these units are purchased. Price per unit, nett **42/6.**

SINCLAIR IC.10 as advertised, complete with instructions and applications manual **59/6** nett.
Components pack for stereo inc. transformer, controls, etc., **£4/15/0** nett.

S-DeCs PUT AN END TO BIRDS NESTING
Components just plug in—saves time—allows re-use of components. S-Dec (70 points), **20/-.**
Complete T-Dec, may be temperature-cycled (208 points), **50/-.**
Also μ-Decs and IC carriers.

MEDIUM RANGE ELECTROLYTICS
Axial leads: 50/50, **1/9**; 100/25, **1/9**; 100/50, **2/6**; 250/25, **2/6**; 250/50, **3/9**; 500/25, **3/9**; 500/50, **4/6**; 1000/25, **4/-**; 1000/50, **6/-**; 2000/25, **6/-.**

SMALL ELECTROLYTICS
Axial leads: 4·7/10, 4·7/25, 5/50, **1/- each**; 10/10, 10/25, 10/50, 33/10, 50/10, **1/- each**; 25/25, 25/50, 47/25, 100/10, 220/10, **1/3 each.**

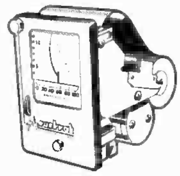
ELECTROVALUE CATALOGUE

48 pages plus cover. Well printed and generously illustrated to show products, diagrams, etc. Crammed with thousands of items excellently classified for quick and easy reference. POST FREE **2/-.** Add 4/- if required to be sent by air mail.

ELECTROVALUE

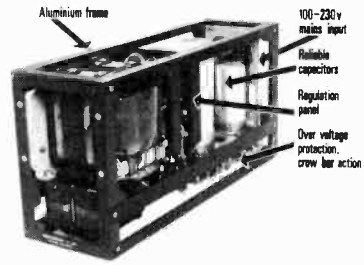
DEPT. WW.171, 28 ST. JUDES ROAD, ENGLEFIELD GREEN, EGHAM, SURREY,
Hours: 9-5.30, 1.0 p.m. Saturdays. ***Phone: Egham 5533 (STD 0784-3) Telex 264475***

LOW COST ELECTRONIC & SCIENTIFIC



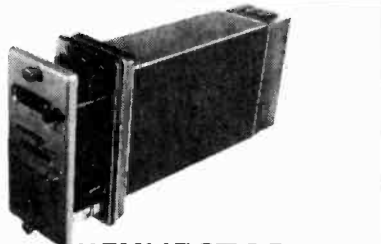
BRAND NEW MINIATURIZED AUTOMATIC STRIP CHART RECORDER

by RUSTRAK of America. This recorder indicates the magnitude of applied currents or voltages by a continuous distortion-free line on pressure sensitive paper. Chart width 2⅜ in. Chart speed ½ in. per min. Moving coil movement, scale calibrated 0-100 microamps. Int. resistance 4,600 ohms. Chart drive motor 12v. D.C. Supplied less case. C/W handbook. Price **£40**. P. & P. 10/-.



A BARGAIN IN NEW POWER SUPPLIES. AT LESS THAN HALF MANUFACTURERS PRICES

O/P Voltage 7.5v.-9v. Max. load current 10 Amps. Max ripple on full load approx. 60mV. p.p. Threshold current, 10.5A. Overvolt protection. **OUR PRICE £19.10.0**



KEYNECTOR

Connects anything electrical in seconds without plugs or sockets. No more worries about dangerous live wires. Now you can make electrical connections safely, in seconds with the revolutionary new Keynector. Cuts out plugs, sockets and saves time. A hundred different uses in the home, and a must for the do-it-yourself enthusiast. **Only 48/6** plus P. & P. 5/-. Or send for a leaflet.

MOTORS

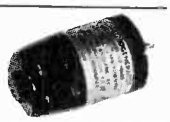
LOW TORQUE HYSTERESIS MOTOR MA23

Ideal for instrument chart drives. Extremely quiet, useful in areas where ambient noise levels are low. High starting torque enable relative high inertia loads to be driven up to 6-oz/in. Available in the following speeds and ranges: 240V 50 Hz, 1/30 r.p.m. 1¼ r.p.m., 1/5 r.p.m., 1/12 r.p.m., 1/20 r.p.m., 1/60 r.p.m., 1/45 r.p.m.; 120V 50 Hz 1/6 r.p.m., 1/15 r.p.m., 1/16 r.p.m., 1/20 r.p.m., 1/24 r.p.m. 1/30 r.p.m., 1/240 r.p.m., 1/300 r.p.m., 1/720 r.p.m., **25/-** each. P. & P. 3/-.

SYNCHRONOUS MOTORS

Model S 71 r.p.h. and 1/60 r.p.h. Self starting complete with gearing shaft ⅛ in. dia. ⅛ in. long. 200/250V 50 Hz. New condition Ex-Equipment. **30/-**. P. & P. 5/-.

D.C. TACHOGENERATOR



Type 9c/106 16v. at 1000 r.p.m. Drive shaft dia. 3/16 in., 3/8 in. long. Price **£16/10/0**.

HIGH PRECISION MAINS SYNCHRONOUS MOTOR 3 Phase—1 Phase

230V 50 Hz 1/8 h.p. continuously rated. 3000 r.p.m. Made by Croydon Engineering. Model KA 60 JFB. Suitable for capstan motor. Size 8 in. long, 4¾ in. diameter with 6 in. diameter flange and 4 fixing holes. **60/-** each. P. & P. 25/-.

ACTUATOR

By English Electric. Type 4519 Mk. 1 D.C. Motor AE 1560 Mk. 1 28V 3A. 500 r.p.m. Intermittent rating. **£16**. P. & P. £1.

NEW MINIATURE RELAYS

Alma Read type NSC 32/R/1A, 650 ohm coil. **£3**. P. & P. 5/-. Smiths Micro-Relay type 14 PCR/7/R 26.5 m/A. **£3**. P. & 5/-.

E.F. ATTENUATOR MARCONI TF 1073A

DC—150 MHz 1dB steps 75 Ohms. Double Screened construction. Tested and in VG condition. **£25**.

CODER SHAFT POSITION

By Datex Corporation. Type 4166-7003 "V" Scan Code National Binary Diode Pos. Diameter: 1¾ in. × 2½ in. long. Servo Mounting. **£15**. P. & P. 5/-.

ANALOGUE—DIGITAL CONVERTER

By United Aircraft. Type 6-8PT-C. Model 13-BNRY-B. 13 Digit encoder Grays code. Length 3 in., diameter 1¾ in. Servo Type mounting. **£15**. P. & P. 7/6.

ACCELEROMETERS

Model LA 2 3C Potentiometric + or — 10 G operating Voltage 30V. Nominal resistance 17.5K and Model LA 2 3C + or — 100G 34V, Rel 20 K. Price **£26**. P. & P. 5/-.

TYPE SE 55/A Range + or — 1G **£26**. P. & P. 5/-.
TYPE F by G.E.C. Up to 1,000 G. Ceramic type giving o/p of 23 mV. Supplied c/w technical leaflet. Weight 14.8 grammes. 2BA stud mounting. **£3.15.0**. P. & P. 5/-.
Many other types in stock

TAPE RECORDERS

E.M.I. Professional Audio tape recorder model BTR1C. This was the type of equipment used by the BBC. Fully overhauled and in excellent condition. Price **£175**.

DATA TAPE SYSTEM 14 CHANNEL

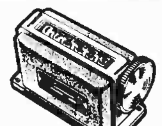
By Solartron. Versatile 14 Channel tape recorder having many applications. The installation is capable of recording and reproducing by analog i.e. Pulse Modulation of frequency modulated methods. Capstan motor constant speed controlled by a tuning fork Oscillator. Tape speeds (1) ⅛ in. per sec. (2) ⅜ in., 7½ in., 15 in., 30 in., 60 in. Maximum reel diameter: 14 in. Information on application. P.O.A.

E.M.I.

Portable L.F. Tape Recorder. Ex-service equipment consisting of Three Unit housed in transit cases (Tape Deck, Amplifier, P.S.U.). ¼ in. track speed 30 in., 15 in., 7½ in. and ½ in. min. Price **£75**. Many control facilities. This is a good quality recorder.

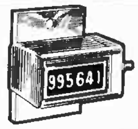
COUNTERS

VEEDER ROOT 6 DIGIT COUNTER



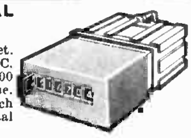
Suitable for counting all kinds of production runs, business machine operation. Mechanically driven Type KA1337. Reset manual knob. Ex-equipment but new condition. Special price **25/-** plus 5/- P. & P.

MINIATURE SQUARE COUNTER 6 DIGIT



By Veeder Root. Rotary ratchet type, adds 1 count for each 36° movement of shaft. **9/6** plus 2/6 P. & P.

NEW 6 DIGIT ELECTRICAL IMPULSE COUNTER



With electrical and mechanical reset. Counter driven by a 24 v. D.C. 500 ohms coil. Reset 24 v. D.C. 500 ohms coil. Housed in plastic-alloy case. The units can be interlocked with each other to give vertical or horizontal displays.

Volts D.C.	Power	Resistance	Count/Sec	Reset	Price
12	1.7w	85 ohms	10	Mech	£4.0.0
24	1.7w	330 ohms	10	Mech	£4.0.0
110V/110V		4400/800	10	Elect/Mech	£3.0.0

P. & P. Free

BERKELEY DECIMAL COUNTING UNIT 0-9

Direct reading octal base plug in unit electronic counter. The number counts received is indicated by one of ten neon lamps behind acetate panel. The unit counts from 0-9 the tenth pulse resetting to zero and simultaneously generating an o/p signal. Circuits can be connected in cascade. Power supply 6.3V D.C. Cut on/Cut off. 15V. Price **70/-**, P. & P. Free.

a
Prosperous
New Year

5 DIGIT COUNTER

A very sturdy counter. Coil resistance 100 ohms. Minimum operational voltage 5v. Counting speed 13 counts per sec. Suitable for continuous counting with sine wave drive. Coincidence, recording and frequency meter **35/-** p. & p. 5/-.

HI-SPEED ELECTRIC RESET ELECTRO MAGNETIC COUNTER

6 Digit 24v. D.C. 3½W. 20 counts/second. Size 3¾ × 2½. Panel Mounting. List £10/19/6.
Our Price **£4/9/6**. P. & P. 5/-.
4 Digit 24v. **79/6**. P. & P. 5/-.

HIGH SPEED IMPULSE COUNTER

DAVIS WYNN and ANDREWS 4 in dial with pointer registering up to 100 plus a 4 digit counter mounted in dial. Uses an inverse air escapement. Coil resistance 100 ohms. 20V operation. **£6**. P. & P. 7/6.

Many other types of counters are available ranging from 3-6 digit with various supply voltages. Ring our Sales Office for further information.

TEKTRONIX Plug in Unit Type E—BRAND NEW. Price **£75**. P. & P. 10/-.

GENERATORS

L.F. SIGNAL GENERATOR SG66
Frequency range 5 c/s to 125 kc/s in five bands. Accuracy ±(1%+1 c/s). Sine wave distortion less than 1% at 1W. Output Sine wave continuously variable, 0 to 30V r.m.s. into 600Ω. Sine wave 0 to 1W into 5Ω. Square wave 0 to 30V pk.pk. Output impedance varies up to 5kΩ depending on output level setting. Rise and fall times up to 0.75μs maximum. Power requirements 100 to 130V and 200 to 260V, 40 to 60 c/s, 100W. Dimensions 19in. wide × 10½in. high × 8¾in. deep. Weight 32½lb. Rack mounting. Price **£75** carriage extra.

OSCILLATORS & SIGNAL GENERATORS

SOLARTRON DC 1015. 2. Single beam DC—15 MHz (—3 dB) and DC—21 MHz (—6 dB) Rise Time 23 Manosec. Sensitivity 50 mV/cm. Time Base 500 manosec/cm—20 msec/cm in 18 ranges. 3½ inch CRT Green Phosper medium persistence. H13½ in., W10 in., D19 in., weight 36 lb. in VG condition c/w copy of handbook...... Price **£85**

(I1) CRYSTAL CONTROLLED OSCILLATOR STC. 16-LXU-52A Mk. II. 0-20 MHz. Sweep facilities. O/p attenuation 0-70 dB. Complete with power supply unit 14-LXU-52B........ Price **£85**

SOLARTRON CD 1220. DC—40 MHz 6 cm × 10 cm Display Delayed and Mixed Sweeps Plug in "Y" Units. Dual Trace Displays. Time Base *A* 0.1 micro sec.—5 sec/cm 24 Ranges. *B* 2 u sec/cm—1 sec/cm in 18 Ranges. This Oscilloscope is offered with 7 plug in units........................ Offered at bargain price of **£130**

(I108) LOW FREQUENCY DECADE OSCILLATOR D-638-A MUIRHEAD. Range 0.1 Hz-2.12 KHz. O/p 0-50V. Mains supply. Max. O/p 1W in 600Ω above 30 Hz.................. Price **£45**

20,000,000 MEGOHMETER MODEL 29A by E.I. This is a direct reading electronic megohmeter covering the range 0.3-20 million megohms in 7 decodes. Ideal testing resistors capacitors, cables and dielectrics. Uses 6 in. edgwise indicator with mirror scale. Test voltages applied are 85 V, 300 V or 500 V. Ext. facility up to 1000 V. Price **£75**

(I13) R.C. OSCILLATOR AND AUTOMATIC FREQUENCY MONITOR—SMITHS. Oscillator range 10 Hz-100 KHz. Price **£75**

(I130) AUDIO FREQUENCY OSCILLATOR—PYE. Range 20-20 Khz. O/p. 0-20V. Mains operated.................. Price **£15**

(118) SIGNAL GENERATOR CT218. Range 30-85 MHz O/P Facilities include crystal calibrator, modulation ...... Price **£85**

MINIATURE UNISELECTORS. 3 bank, 12 way, 250 ohm, 24V. Type 2200A. Supplied complete with plug-in base. Size 3 in. × 1 in. × 2 in. A very neat precision component. Price **£4.19.6**. P. & P. 5/-.

(I83) SIGNAL GENERATOR CT 480 SANDERS. Range 7 KHz-12 KHz. O/p. 0-±50V. Attenuation range —10 to +100 dB. Price **£85**

(I79) WOBULATOR GM 2877/02 PHILLIPS.......... Price **£65**

TRANSDUCER OSCILLATOR-AMPLIFIER-DEMODULATOR. An encapsulated unit for matching with S.E. Transducers. Suitable where space or adverse environmental conditions prevail. Supplied with a matching transducer a typical o/p is ± 3V into 50KOhms. Supply voltage 12v. D.C. Range of transducers available 0-50: 0-750: 0-1000: 0-4000 psi.......................... Price **£65**

TRANSDUCERS ONLY. Ref. C.1........................ Price **£15**

TRANSDUCER—New Resistive Bordon Tube Principle pressure Transducer by K.D. Instrument. Model TD 216 0-2000 psi. Ref. C. 6.. Price **£15**

TRANSDUCER NEW EX-GOVERNMENT DISPLACEMENT BONDED RESISTANCE STRAIN GAUGES. Range ± ¼ mechanical displacement equivalent to 0.3% resistive change. 3.5 + 3.5 KOhms. Model IT-2-31-35.................................. Price **£10**

OSCILLATOR. High discrimination, by Marconi T.F. 1168. This instrument suitable for H.F. Communication. Due to its high discrimination makes it suitable for crystal filter response in Tx and Rx drive units. Frequency range 90-110 KHz. 2Hz discrimination. Crystal and Standardised centre frequency. Calibration accuracy ± 1% Ref.I.5.......................... Price **£135**

RECORDERS 4 PEN OSCILLOGRAPHS SOUTHERN INSTRUMENTS M942C. 4 Channel fitted with 4 speed gear boxes giving 1, 5, 25, 100 m.m. per sec. Frequency response 0-55 Hz, sensitivity 0/m.m./M.A.................................. Price **£150**
2 PEN OSCILLOGRAPH MR450 as per 4 Pen. Ref. I.2.. Price **£90**
PLUS CARRIAGE

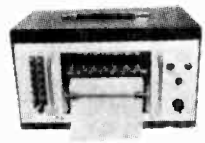
NEW B.P.L. MULTIMETER T.V.M. 1063. Employing silicon planar F.E.T., this instrument gives long-term stability and negligible drift over a wide temperature range. Wide frequency band 0-300 MHz using HPV 1063. Voltage range 0-30 KV. Centre zero on DC ranges for differential circuit application. Input resistance 1 M.ohm/Volt on all DC ranges. Accuracy + 3% F.S.D. Meter scale 5 in. with IM different colour for different scales. Special price **£50** each. Carriage £1.10.0.

ELECTRONIC BROKERS LTD

EQUIPMENT AND COMPONENTS

MEASURING INSTRUMENTS AND RECORDERS

NEW 6-CHANNEL TIME & EVENT RECORDER

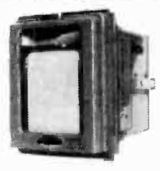


A self-contained instrument, specifically for recording events without the need for a combined recorder. There is a separate and independent paper drive, with a monitor lamp indicating when it is in operation. The pens are displaced 1/16 in., activated by a close contact system. Each of the 6 channels works independently of each other, with the pens writing at 72 hours per filling at a maximum speed of 10 pulses per second. **£75.** Send for leaflet.

FACSIMILE RECORDERS

D649 G/A 18 in. Chart Recorder. Helix speed: 60, 90, 120 rev./min. Transmission speed: ¾ in.; 15/16 in.; 1½ in. per min. Scanning rate: 96 lines/in.
Ref. C3........ Price **£350**. Completely overhauled + carriage

SINGLE PEN RECORDER By Record Electrical (R3)



3 in. chart, sensitivity 500 micro amps. Coil res. 1.53k. Fully interchangeable gears available to make a wide range of chart speeds. 200/250V. Size: 8 × 11 × 6 in. Almost new—complete with chart and ink. List over £100.
Our price **£52.10.0**
0-1mA version **£49.10.0**

POWER SUPPLY UNITS

O/P V	O/P A	S or U*	Input volt.	Price	Make	Type	Dimensions W H L inches	Location	Ref. No.
6 adj 4-16v	7	S	240	£30	Coutant	ELV700/6	6¾ × 5¼ × 11¼	876	36
6 adj 3-15v	5	S	240	£25	Coutant	ELV500/6	4¼ × 7 × 12	876	37
4-15v	5	S	240	£20	Advance	PM7	4¾ × 5¼ × 9¼	876	38
12	1	S	240	£15	Farnell	SSU12-1	4 × 6 × 10 5/16	876	39
± 150	200 mA	S	240	£12	Roband	B101/200	7¼ × 6¾ × 9	876	40
28 adj 26-37	7	S	240	£30	Coutant	E8700/28	8¼ × 7 × 12	875	42
+30 −20	300 mA	S	240	£10	B.P.L.	3	19 × 8¾ × 12	875	41
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	879	66
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	878	70
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	878	57
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	878	56
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	878	59
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	878	58
12	20	S	110	£25	I.B.M.	Ex. comp.	6 × 5¼ × 16	877	67
6	16	S	110	£23	I.B.M.	Ex. comp.	6 × 5¼ × 13¼	879	54
48	6	S	110	£19.10	I.B.M.	Ex. comp.	6 × 5¼ × 16	879	55
30	7	S	110	£17	I.B.M.	Ex. comp.	6 × 5¼ × 13¼	879	62
12	15	S	110	£22.10	I.B.M.	Ex. comp.	6 × 5¼ × 13¼	879	64
12	12	S	110	£22	I.B.M.	Ex. comp.	6 × 5¼ × 13¼	874	60
12	12	S	110	£22	I.B.M.	Ex. comp.	6 × 5¼ × 13¼	874	61
20	6	S	110	£18	I.B.M.	Ex. comp.	6 × 5¼ × 13¼	874	65
6	8	S	110	£12.10	I.B.M.	Ex. comp.	6 × 5¼ × 9¼	874	68
6	8	S	110	£12.10	I.B.M.	Ex. comp.	6 × 5¼ × 9¼	874	63
12	4	S	110	£18	I.B.M.	Ex. comp.	6 × 5¼ × 9¼	874	72
12	4	S	110	£18	I.B.M.	Ex. comp.	6 × 5¼ × 9¼	874	71
6	8	S	110	£12.10	I.B.M.	Ex. comp.	6 × 5¼ × 9¼	874	69
20 −10 −10	4½ 4 300 mA	U/S S S	240	£25	Power Electronics	SP110	8 × 6 × 13¼	877	43
Do.	Do.	Do.	240		Do.	Do.	Do.	877	44
48	4	U/S	240	£18.10	Advance	DC8	5½ × 6 × 17	877	80
24	5	U/S	240	£18.10	Advance	DC22	5½ × 6 × 17	873	73
48	2	U/S	240	£15	Advance	DC122	5½ × 6 × 17	866	74
12/15	5	S	240	£25	Advance	DCR12/12	5¼ × 8 × 17	873	53
6	20	S	240	£45	Coutant	R205	19 × 8¾ × 13¼	873	51
+ 6 − 6	10 2	S	240	£45	Coutant	R206	19 × 7 × 12	873	47
28	20	S	240	£50	Coutant	R204	19 × 8¾ × 14	870	85
190-250	350 mA	S	240	£16.10	Airmec	705	19 × 12 × 8½	872	52

* = Stab./Unstab.

This is a small selection of our range. Further details on application.

PRECISION POTENTIOMETERS

TEN TURN 3600° ROTATION (Ref. C5) BRAND NEW

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
100/100/100		Beckman	A	160/-
100	0.5	Beckman	A.S.	60/-
200	0.5	Beckman	A.	60/-
500	0.1	Beckman	S.	70/-
500		Colvern	2501	45/-
500		Foxes	PX4	40/-
500		Colvern	2610	50/-
500		Colvern	26/1000/11	60/-
500	1.0	Relcon	HEL107-10	45/-
1K		Relcon	HEL0710	45/-
2K	0.5	Beckman	SA1101	60/-
2K	0.25	Beckman	7216	60/-
2K		Reliance	GPM15	40/-
2K		General Controls	GPA15/4	40/-
5K		Relcon	07-10	50/-
5K		Colvern	CLR2503	60/-
10K	0.5	Beckman	A	60/-
10K	0.1	Beckman X	A	70/-
10K	0.1	Colvern	CLR26/1001	70/-
15K		Colvern	CLR2402	60/-
18K		Beckman	A	60/-
25K	0.5	Helipot	SAJ337	60/-
29K	0.05	Beckman	SA1244	90/-
30K		Colvern	2402	30/-
30K		Beckman	SA95C	60/-
30K	0.1	Beckman	A.SS	70/-
30K	0.5	Beckman	SA1692	60/-
30K	0.25	Beckman	SA1679	65/-
30K	1.0	Colvern	2402/1	30/-
50K		Reliance	07.10	45/-
50K			07.5	45/-
50K		Colvern	2503	45/-
50K	X	Foxes	PX4	45/-
50K	0.5	Beckman	A	60/-
50K	0.1	Beckman	A	70/-
100K/100K		Ford	A	100/-
100K	0.1	Beckman	A	70/-
100K	0.5	Beckman	A	60/-
100K		Colvern	2501	45/-
100K		Colvern	2610	50/-
298K	0.1	Beckman	SA3902	70/-
300K	0.1	Beckman	A	70/-

THREE TURN 780° ROTATION

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
100/100	0.5	Beckman	C	60/-
100/100		Beckman	Type C	60/-
300		Beckman	9303	45/-
1K		Fox	PX2/H3	45/-
10K	0.5	Beckman	C.ss	45/-
20K/20K	0.1	Beckman	C.S	60/-
10K/10K	0.1	Beckman	C	60/-
50K	0.5	Beckman	C.S	35/-

FIFTEEN TURN 5400° ROTATION

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
25K/25K		Beckman B	10 watts	£6/10/-
46K/46K		Beckman B	10 watts	£6/10/-

TWENTY TURN 7200° ROTATION

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
1 Meg		General Controls	PXM130	80/-
50K		Reliance		40/-

156 TURN 56160° ROTATION

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
460		Kelvin Hughes	KTP0701	£9/10/-

FIVE TURN 1800° ROTATION

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
200		Relcon	HELO7.05-F/11	45/-
500		Colvern	CLR2505	40/-
U1.5K		Colvern	CLR2605	40/-

FIVE-AND-A-HALF TURN

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
500		Colvern	2405	40/-

SINE COSINE

Values	Type	Maker	Price
5 Kohms	CLR 8601	Colvern	£17/10/0
14 Kohms	SCP 5	Smith	£22/10/0
15 Kohms	CLR 8601	Colvern	£17/10/0
20 Kohms	CLR 8602	Colvern	£22/10/0
25 Kohms	CLR 9602	Colvern	£17/10/0
30 Kohms	CLR 8601	Colvern	£17/10/0
32 Kohms	SCP 4	Kelvin-Hughes	£17/10/0
35 Kohms	SCP 1	Smiths	£17/10/0

P. & P. EXTRA

LOW FREQUENCY RESOLVED COMPONENT INDICATOR BY SOLARTRON

Type VP 253.2A. This instrument will indicate by means of two centre zero 6 in. scale meters the resolved components of a signal voltage with respect to the applied reference energisation. Frequency Range: 0.5 c/s-1 Kc/s. Signal Voltage Ranges: 50MV, 150MV, 500MV, 1.5V, 5V, 15V, 50V and 150V with either balanced or unbalanced input. Signal Input Resistance: 10MΩ unbalanced, 20MΩ balanced. Reference Input. Voltage 90/130 or 230/240V. Standard Rack Panel, 19 in. 12¼ in. high, **£175**, new condition, complete with manual.

VIBRON ELECTROMETER

This unit is a vibration condenser amplifier which is suitable for the measurement of small D.C. potentials covering the range of 1M-1V. This unit can also be used as high impedance null detector for the comparison of ironation currents of very high resistance. **£89.10.0.**

7 HOLE NON PARITY TAPE PUNCH

New condition.

LOW SPEED 7 HOLE TAPE PUNCH

60 characters per second by well-known manufacturer.

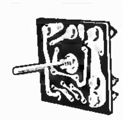
TELETYPE 8 HOLE PAPER PUNCH BRPE11 £260.

Also available 5 hole punch BRPE2 as above. This model has interchangeable heads. Complete with spooler. Price **£75**.

5/7 HOLE OPTICAL READER BY FERRANTI

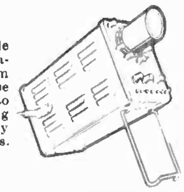
20 characters per second. **£20.**

LINEAR THRYRISTER CONTROLLED LIGHT DIMMER



400w. module. Ideally suitable for photo-flood or speed controller, etc. Will mount into standard socket boxes.
Our price **59/6**. P. & P. 5/-.

OSCILLOSCOPE TYPE CT 52



A very handy miniature portable instrument for general purpose applications. 2¾ in. diam. tube. Wave form investigation from 10 Hz-20 MHz. Pulse monitoring duration 50 microseconds to 0.1 microsecond. Time base free running 10 Hz-40 kHz. Also single sweep facility from 50 microseconds to 3 microseconds.

Price **£22/10/0.** P. & P. 30/-.

BRAND NEW COMPUTER TAPES AND EMPTY SPOOLS

Made by well known manufacturers

½ in. certified 2,400 ft. 800 b.p.i.	£8.10.0
½ in. 2,400 ft.	£6.10.0
¾ in. Highest grade 2,400 ft.	£3. 0.0
½ in. 10½ in. dia. spool and cassette	£1.10.0
½ in. 8½ in. dia. spool and cassette	£1.10.0
1 in. metal 10½ in. dia. spool and cassette	£2.10.0
½ in. N.A.B. centres 10½ in. spool only	£1. 0.0

EICHNER 8 HOLE PUNCH OR READERS

No motor drive required. Solenoid operated equipment using 48v Reader **£29.10.0**; Punch **£49.10.0**. Carriage 25/-.

PLATINUM RESISTANCE THERMOMETER PROBES

SOLARTRON Type NT 1198/c and NT 1687. Accuracy ± 1°C. Probes in stainless steel case. ½ in. diameter. Temp. range NT 1198/C-50°C to + 250° C. Price **£12.10** each. p. & p. 3/6.

FENLOW LOW FREQUENCY ANALYSER

0.3 Hz to 1 K Hz. Power density 0-10. Bandwidth switching range. .06: 0.3: 1.5: 7.5: 37.5 Hz. Price **£275.**

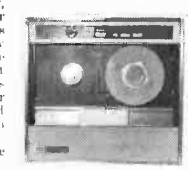
SYNCHRONOUS CHOPPERS

Base B-9. Coil 6.3 v., 50-60 Hz. Proportion of time contacts are closed 45%. Models CK3, CK4 available. Also available 100 Hz and 400 Hz. Price **£5.** P. & P. 5/-.

AVO TRANSISTOR ANALYSER CT 446

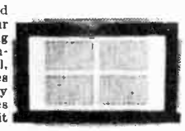
A portable direct-reading instrument capable of giving accurate transistor measurements in the grounded emitter configuration. Battery power unit 1.5V to 10.5V in 5 steps. Base current 0-1 mA, 1-40 mA. Collector current 250 mA. Size: 15½ × 9½ × 5 ins. Weight with batteries: 15 lbs. Price **£42.10.0.** Carriage extra.

7-TRACK DIGITAL MAGNETIC TAPE STORAGE DECK (Ref. 13)



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. A.C. Capstan Motor speed 1,500 r.p.m. 48 v. D.C. Rewind motors. Finished in brush aluminium and matt-black. Size 27 in. × 26 in. 8 in. Weight 90 lb. Price **£65.** Carriage extra.

MEMORY PLANES (Ref. C4)

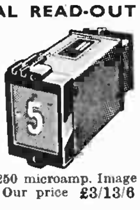


Ferrite core memory planes with wired Ferrite cores. Used for building your own computer or as an interesting exhibit in the demonstration of a computer. Mounted on plastic material, frame 5 × 8 in. Consisting of matrices 40 × 25 × 4 cores each one individually addressable and divided into 2 halves with independent sense and inhibit wires. **£6/10/0.** P. & P. 3/-.

MINIATURE DIGITAL DISPLAY

Operates on a rear projection 6.3 pilot lamp. The lamp projects the corresponding digit on the condensing lens through a projector lens, on to the viewing screen at the front of the unit. 1 in. width, 3 5/16 in. deep, 1 3/16 in. high. Weight 3½ oz. Character size ⅝ in. high, 0.9 with 8 right hand decimal point and degree. Available to special order, words and other characters or colour, at cost of artwork or plates. List price 6 gns. ⅝ in. characters **49/6**, 1 in. characters **55/-**, 4 in characters **£8.12.0.**

EAC DIGIVISOR Mk. II DIGITAL READ-OUT DISPLAY



Ideally suitable for use in conjunction with transistorised decade counting devices. No need for amplifiers or relays as only a few milliwatts of power are required to charge the digits. The DIGIVISOR incorporates a moving coil movement which moves a translucent scale through an optical system and the resultant single plane image is projected on a screen. The translucent scale is made to represent digits 0.9. Specification: 6.3 volt, 250 microamp. Image height ⅞ in. Size 4 9/16 × 2 39/64 × 1⅝ in. Our price **£3/13/6** List price 8½ gns.

NUMICATORS

Cold cathode gas-filled, in-line 0-9 digital display tubes. Long life expectancy. Maximum striking voltage 180v. Side reading type XN3 amber and red, XN7, 12, 23 (as XN24) amber and red. Price **18/6** each. P. & P. 2/6.

(Dept. W.W.) 49-53 PANCRAS ROAD, LONDON, N.W.1. Tel: 01-837 7781/2. Cables: SELELECTRO
Telex No. 267307 (Open Mon-Fri 9 a.m. - 6 p.m.)

ALL ORDERS ACCEPTED SUBJECT TO OUR TRADING CONDITIONS A COPY OF WHICH MAY BE INSPECTED AT OUR PREMISES DURING TRADING HOURS OR WILL BE SENT ON APPLICATION THROUGH THE POST.

Samson's (ELECTRONICS) LTD.

9 & 10 CHAPEL ST., LONDON, N.W.1

01-723-7851 01-262-5125

CURRENT RANGE OF BRAND NEW L.T. TRANSFORMERS. FULLY SHROUDED (*excepted) TERMINAL BLOCK CONNECTIONS. ALL PRIMARIES 220/240v

No.	Sec. Taps	Amps	Price	Carr.
1A	25–33–40–50	15	£10 10 0	12/6
1B	25–33–40–50	10	£7 12 6	9/6
1C	25–33–40–50	6	£6 15 0	9/6
1D	25–33–40–50	3	£4 0 0	7/6
2A	4–16–24–32	12	£7 2 6	8/6
2B	4–16–24–32	8	£5 7 6	8/6
2C	4–16–24–32	4	£3 12 6	7/6
2D	4–16–24–32	2	£2 7 6	5/–
3A*	25–30–35	40	£16 10 0	12/6
3B*	25–30–35	20	£10 5 0	10/6
3C	25–30–35	10	£7 5 0	8/6
3D	25–30–35	5	£4 2 6	7/6
3E	25–30–35	2	£3 2 6	7/6
4A*	12–20–24	30	£13 0 0	12/6
4B	12–20–24	20	£8 5 0	9/6
4C	12–20–24	10	£4 5 0	8/6
4D	12–20–24	5	£3 12 6	7/6
5A	3–12–18	30	£9 12 6	9/6
5B	3–12–18	20	£7 2 6	8/6
5C	3–12–18	10	£4 5 0	7/6
5D	3–12–18	5	£2 17 6	7/6
6A	48–56–60	2	£3 12 6	6/6
6B	48–56–60	1	£2 12 6	6/6
7A*	6–12	50	£10 7 6	10/6
7B	6–12	20	£6 2 6	8/6
7C	6–12	10	£3 17 6	7/6
7D	6–12	5	£2 15 0	6/6
8A	12–24	1	£1 12 6	6/6
9A	17–32	8	£6 5 0	8/6
10A*	9–15	2	£1 9 6	6/6
11A	6·3	15	£2 10 0	7/6
12A	30–25–0–25–30	2	£3 12 6	6/6

Note: By using the intermediate taps many other voltages can be obtained.
Example: No. 1 .. 7–8–10–15–17–25–33–40–50v.
No. 2 .. 4–8–12–16–20–24–32v.
No. 5 .. 3–6–9–12–15–18v.

AUTO TRANSFORMERS

240v.-110v. or 100v. Completely Shrouded fitted with Two-pin American Sockets or terminal blocks. Please state which type required.

Type	Watts	Approx. Weight	Price	Carr.
1	80	2½ lb	£1 19 6	5/6
2	150	4 lb	£2 12 6	6/6
3	300	6½ lb	£3 12 6	6/6
4	500	8½ lb	£5 2 6	8/6
5	1000	15 lb	£7 2 6	9/6
6	1500	25 lb	£9 15 0	10/6
7*	1750	28 lb	£14 15 0	12/6
8*	2250	30 lb	£17 17 6	15/-

* Completely enclosed in beautifully finished metal case fitted with two 2-pin American sockets, neon indicator, on/off switch, and carrying handle.

T.E.C. 240-110v. ISOLATION TRANSFORMERS

Pri Tapped 10. 0. 200. 220. 240v. sec. Tapped 110-112.5-115v. Conservatively rated at 9 amps. Tropicalised open frame type. Terminal Board connections. Size 9×9×7 ins. Weight 60 lbs. **£15.** Carr. 17/6.

ISOLATION TRANSFORMERS

By Magestic Winding Co. Pri 240v. Sec. 240v. Centre tapped. 2kva. Mounted in strong metal case. Size 11 × 9 × 8 ins. Conservatively rated. **£27.10.0.** Carr. 30/-.

GARDNERS HT TRANSFORMERS

Fully tropicalised "C" core table top connections all new and guaranteed. Primaries tapped 200-220-240v.
No. 1. 475-0-475v. 165 m/a. 215-0-215v. 60 m/a. 6·3v. 8·2a. 6·3v. 5a. 6·3v. 0·75 m/a. 5v. 3a. **89/6.** P. & P. 9/6. No. 2. 130v. 185 m/a. twice. 200v. 350 m/a twice. **59/6.** P. & P. 8/6. No. 3. 300-0-300v. 60 m/a. 6·3v. 4a. **25/-.** P. & P. 5/-. No. 4. 350v. 44 m/a. 20v. 10 m/a. 6·3v. 3a. **17/6.** P. & P. 4/6. No. 5. Tapped 44-45-46v. 87·5 m/a. 6·3v. 4·5a. 6·3v. 1·6a. 6·3v. 1·5a. 6·3v. 1·35a. **37/6.** P. & P. 5/-.
GARDNERS POTTED TYPE. PRI. 200-230-240v. 5.E.C. 250-1-250v. 100 m/a. 250v. 300 m/a. 9v. 3a. 6·3v. 2A. 6·3v. 2a. 12-0-12v. 0·5a. **65/-.** P. & P. 8/6. PRI 200, 220-240v. 5EC 500v. 30m/a. 6·3v. 0·8a. 6·3v. 0·6a. 6·3v. 0·2a., 6·3v. 0·4a. 4v. 1·5a. **35/-.** P. & P. 5/-.

PARMEKO C CORE TRANSFORMERS

Pri. tapped 110-200-240v. Sec. 1 250v. 197 m/a. Sec. 2 161v. 110 m/a. Sec. 3 152v. 76 m/a. Sec. 4 124v. 25 m/a. Sec. 5 28v. 0·4a. Sec. 6 6·4v. 6·2a. 6·3v. 3·25a. 6·3v. 1·4a. Table top connections. Size 5 × 4 × 4 ins. Brand new boxed. **35/-.** P. & P. 7/6. Special prices for qtys.

REDCLIFF 'C' CORE

Pri. 10-0-200-220-240v. Sec. 500-0-500v. 120 m/a. 6.3v. 2.5a. 6.3v. 1.6a. 6.3v. 0.6a. 6.3v. 0.45a. 5v. 3a. **55/–.** Carr. 8/6. Pri. 10-0-200-220-240v. Sec. tapped 370-390-400v. 6 m/a. **10/–,** p. & p. 3/6. 3 for **25/–,** p. & p. 7/6. Pri. 10-0-200-220-240v. Sec. 90-0-90v. 100 m/a. **17/6,** p. & p. 4/6.

SPECIAL OFFER OF PARMEKO NEPTUNE SERIES TRANSFORMERS ALL PRIMARIES TAPPED 115-230v.

Sec. 6·3v. CT 5a. 6·3v. CT 3a. 6·3v. CT 2a. **37/6** P. & P. 5/-.
Sec. 9-10v. 0·5a. 6·3v. 3·5a. 6·3v. 1·2a. **19/6** P. & P. 4/-.
Sec. 400-0-400v. 150 m/a. **50/-** P. & P. 7/6.
Sec. 350-0-350v. 100 m/a. 3-8-12-18v. 5a. **£3.19.6** P. & P. 8/6.
Sec. 6·3v. CT 5a. 6·3v. 1·2a. 6·3v. 1·2a. **27/6** P. & P. 5/-.
Sec. 6·3v. 1·8a. 6·3v. 1a. 6·3v. 1a. **17/6** P. & P. 3/6.
Sec. 29·5-32·5v. **32/6** P. & P. 5/-.
Sec. 4v. 0·5a. four times. **15/-** P. & P. 3/6.
Sec. 6·3v. CT 0·6a. 6·3v. 0·6a. **12/6** P. & P. 3/6.

Pri 200-220-240v. Sec. 250-0-250v. 50 M/A. 6·3v. 1a. **22/6** P. & P. 5/-. Pri 230v. 4·2v. 1a. **10/6** P. & P. 3/6.

GRESHAM L.T. TRANSFORMERS

Pri tapped 115-230-240v. Sec. 6·3v. CT 5a. Twice 6·3v. CT 3a. Fully tropicalised "C" core. **32/6** P. & P. 5/-. Pri 200-220-240v. Sec. 62v. 750 M/A. Potted type. Conservatively rated **30/-** P. & P. 5/-.

SPECIAL OFFER OF GRESHAM CHOKES

15H 300m/a 50 ohm. "C" Core Potted Type. **62/6.** Carr. 10/-.
10H 300m/a 60 ohm. "C" Core Potted Type. **55/-.** Carr. 10/-.
15H 180m/a. 200 ohm. "C" Core Potted Type. **45/-.** P. & P. 8/6.
20H 350 m/a. 200 ohm. "C" Core Potted Type. **69/6.** Carr. 12/6.
1H 1a. 15 ohm. **69/6.** Carr. 15/-.
Swinging Chokes. 20H 100m/a.-10H 450m/a. **55/-.** Carr. 10/-.
All Chokes supplied new and guaranteed.

PARMEKO CHOKES—NEPTUNE SERIES

10H. 180M/A., **25/-.** P. & P. 5/-. 10H. 120M/A., **12/6.** P. & P. 4/-. 10H. 75M/A., 15H. 75M/A., 15H. 50M/A., 5H. 120M/A, .5H. 60M/A., 50H. 25M/A., all types, **8/6** each, P. & P. 3/6. 0·7H. 450M/A. **12/6.** P. & P 4/6. 1H. 300M/A. **10/6** P. & P. 4/6. 5H. 150M/A. **17/6.**

LOW TENSION SMOOTHING CHOKES

By Redcliffe. 100MH. 2 amps. **49/6.** P. & P. 7/6. Swinging Type. 10MH. 6.5 amp—50 MH. 2 amps. **45/-.** P. & P. 7/6. Both types less than ½ ohm res. Hermetically sealed. Oil filled. Brand new. In makers cartons.

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Pri tapped 110v. 220-250v. Sec. 55v. 24a., 14v. 10a., 60v. 2a. All windings very conservatively rated. Tropically finished. Terminal connections. Size 9×7¼×7ins. Weight 65lb. **£10.19.6.** Carr. 15/-.
Pri tapped 200-250v. Sec. 46v. Very conservatively rated at 29 amps. Size 11×7×7in. Weight 75 lb. approx. Manufactured by Partridge. **£12.19.6.** Carr. 15/-.

GARDNERS H.T. TRANSFORMERS

Pri 200-220-240v. Sec. 375-0-375v. 250 M/A. 200-0-200v. 50 M/A. 60-0-60v. 125 M/A. 6·3v. 6·5a. 6·3v. 4a. 6·3v. 2a. 6·3v. 1·6a. 6·3v. 600 M/A. 5.v 3a. Unshrouded. Fully tropicalised. Table top connections. **85/-** P. & P. 10/6.

T.C.C. OIL-FILLED BLOCK CAPACITORS

Type 82 8MFD 500v. wkg at 60 deg. C. **8/6** P. & P. 2/6. Visconol 4 MFD 1500v. wkg at 70 deg. C. **15/-** P. & P. 2/6. 4 MFD 500v. wkg at 60 deg. C. **4/6** P. & P. 1/6. 2 MFD 500v. wkg at 60 deg. C. **2/6** P. & P. 1/6. 2 MFD 1500v. wkg at 70 deg. C. **7/6** P. & P. 2/-. 0·01 MFD 12 kv. wkg at 60 deg. C. **7/6** P. & P. 1/6.

G.P.O. TYPE RELAYS

3000 Type. 250 Ω 3 B. 1M. H duty. M contacts. **8/6.** 200 Ω 6 M. contacts **8/6.** 75 Ω 3 M. 1 B. 1 Co Contacts **6/6.** 2000 Ω + 130 Ω 1 M. before B. contacts **6/6.** 5000 Ω 1 Co. 1 M. contacts **6/6.** 1000 Ω 6 M. contacts **8/6.** All new and boxed. P. & P. 1/- per relay.
600 Type. 150 Ω 4 Co. Contacts. **7/6.** 1700 Ω 3 M. contacts. **5/-** P. & P. 1/-.

MAGNETIC DEVICES LTD SEALED RELAYS

5000 Ω 48v. DC. 3 CO. Contacts. **8/6** P. & P. 1/6. Open type 3·6v. DC. 3 heavy duty makes. **7/6** P. & P. 1/6. AC 2·3v. 1 heavy duty Co. Contact. **7/6** P. & P. 1/6.

AMERICAN WILLARD

Miniature accumulators 6v. 1.2 A.H. Size ⅞ × 1¼ × 4 ins. Wt. 5½ oz. These batteries were designed for meteorological balloon transmitters. Easily filled with a hypodermic syringe. Self sealing. **7/6.** P. & P. 1/6.

MINIATURE 24v. D.C. GEARED MOTORS

500 rpm. Size 2 × 1¼ × 1 in. Length of spindle 1 in., dia. ⅛ in. **15/-.** P. & P. 2/-.

PULLEN SHUNT WOUND 24. D.C. REVERSIBLE MOTORS

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MAGNETIC DEVICES 6v. D.C. CONTACTORS

3 Heavy Makes contacts. Size 2×1½× 1 in. **8/6.** P. & P. 2/-.

ORGAN DIVIDER BOARDS, built to high industrial/computer standards. 5 octave set **£15,** complete with connection data and oscillator details.

COPPER LAMINATE PRINTED CIRCUIT BOARD
8½×5½×1/16 in. **2/6** sheet, 5 for **10/-**
11×6½×1/16 in. **3/-** sheet, 4 for **10/-**
11×9×1/16 in. **4/-** sheet, 3 for **10/-**
Offcut pack (smallest 4×2 in.) **10/-** 300 sq. in.

RADIATION MONITORING EQUIPMENT. Portable and bench models (brand new) S.a.e literature.

KLYSTRON POWER SUPPLY (Solartron AS562). **£40.** Carr. 50/-.

KLYSTRON POWER SUPPLY (Elliott PKU1). **£100**

120 AMP. AUTO TRANSFORMERS. 190-270v. 50 c/s (tapped every 5 volts). **£50** ea. (Carr. by arrangement.)

801A SIGNAL GENERATOR. 10-300 mc/s in 4 bands. Ext. 50 c/s-10 Kc/s. Output 200 m/v **£50** ea. P.P. 25/-.

SPEAKERS
"E.M.I." 19×14 in. 50 watts. 8 ohm (14A/600A.) Four tweeters mounted across main axis. Separate "X-over" unit balances both bass and h.f. sections. 20 Hz. to 20,000 Hz. Bass unit flux 16,500 gss. A truly magnificent system. **£25.** P.P. 50/-.
E.M.I. 13×8 in. with two tweeters and cross-over. 8 or 15 ohm. **75/-.** P.P. 5/-.
"E.M.I." 13 × 8 in. Bass Unit. 10 watts 3-8-15 ohm models. **50/-** each. P.P. 5/-.
"E.M.I." 6½ in. Rd. 10 watt woofers. 8 ohm. **30/-** ea. P.P. 2/6.
"FANE" 12 in. 20 watt. 15 ohm. (122/10A.) With integral tweeter. **£6** ea. P.P. 7/6.
SPEAKER SYSTEM (20×10×10 in.) Made to Spec. from ¾ in. board. Finished in black leathercloth. 13×8 in. speaker with twin tweeters complete with "X-over" 50 Hz. to 20,000 Hz. **£7 10s.** P.P. 10/-.

EXTRACTOR FANS/BLOWERS
"AIRMAX" 7½ In. FAN. In aluminium diecast housing (9 in.). 240v. Brand new. **£4 10s.** P.P. 10/-.
"PLANNAIR" 6½ In. FAN. (Type 5 PL 121-122.) Diecast housing. 240v Brand new. **£6.** P.P. 10/-.
"SOLARTRON" TANGENTIAL BLOWERS. Overall size 16×5¾×3½ in. Air outlet 12×1½ in. 240v, Brand new. **50/-** ea. P.P. 7/6.
BULK COMPONENT OFFER. Resistors/capacitors. All types and values. All *new* modern components. Over 500 pieces, **£2.** (Trial order 100 pieces **10/-.**) We are confident you will re-order.

HIGH SPEED MAGNETIC COUNTERS (4×1×1 in.) 4 digit 24/48v. (state which), **6/6** ea. P.P 1/-.

LEVEL METERS (1½ × ½ in.) 200 micro-amp. Made in Germany. **15/-** each.
MICROAMMETERS (4-in. sq. Weston). 25-0-25 micro-amps. **45/-.** P.P. 5/-.
RELAYS H.D. 2 pole 3 way 10 amp. contacts. 12v.w. **7/6** ea.
LIGHTWEIGHT RELAYS (with dust-proof covers) 4 c/o contacts. 24v. 500 ohm **7/6** ea.
PRECISION CAPACITANCE JIGS. Beautifully made with Moore & Wright Micrometer Gauge. Type 1 18.5 pf-1,220 pf. **£10** ea. Type 2 9.5 pf-11.5 pf. **£6** ea.
POT CORES LA1/LA2/LA3. **10/-** ea.
71 WAY PLUG & SOCKET (Painton Series 159). Gold plated contacts with hood & retaining clips. **30/-** pair.
50 WAY PLUG & SOCKET (U.C.L. miniature). Gold plated contacts **20/-** pair. 34 way version **15/-** pair.
12 VOLT H.D. RELAYS (3×2×1 in.). 2 pole change-over (silver points) **8/-** each, p. & p. 1/-.
COMPUTER BOARDS
4-OC23; 4-2N1091; 4-2G302; 4-OA10. **20/-** ea
8-OC42 (long leads); 16-OA47. **7/6** ea
8-DA11A; 14-OA47. **5/-** ea
Bargain pack of 5 boards. Components too varied to enumerate. At least 100 transistors and diodes **£2** lot.

TRANSFORMERS

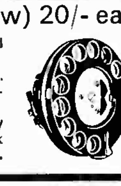
L.T. TRANSFORMERS (shrouded). Prim. 200/250v. Sec. 20/40/60v. 2 amp. **42/6.** P.P. 7/6.
L.T. TRANSFORMERS. Prim. 200/250v. Sec. 20/40v. 1.5 amp. **30/-.** P.P. 5/-.
"ADVANCE" CONSTANT VOLTAGE. Prim. 190/250v. ±15%. Sec. 115v. 2,250 watts. **£15** ea. P.P. 50/-.
H.T. TRANSFORMERS. Prim. 200/240v. Sec. 300-0-300v. 80 m/a. 6.3v. C.T. 2a. **30/-** ea. P.P. 7/6.
350-0-350v. 60 M.A. 6.3v. C.T. 2a. **20/-** ea. P.P. 5/-.
L.T. TRANSFORMER. Prim. 240v. Sec. 33-0-33v. 5 amp. **45/-.** P.P. 10/-.
STEP DOWN TRANSFORMER. Prim. 200/240v. Sec. 115v. 100 watts. **20/-** ea. P.P. 5/-.
L.T. TRANSFORMERS Prim. 240v. Sec. 8/12/20/25v. 3.5 amp models **20/-;** P.P. 5/6.
L.T. TRANSFORMERS Prim. 240v. Sec 14v. 1 amp **10/-** ea. P.P. 2/6.

LIQUID LEVEL DETECTOR. Detects even mildly conductive liquids, i.e. ether, etc. N.O./N.C. Contacts fails to safe. **£10.** S.A.E. literature.

ELECTRIC SLOTMETERS (1/-) 25 amp. L.R. 240v. A.C. **85/-** ea. P.P. 5/-.
QUARTERLY ELECTRIC CHECK METERS, 40 amp 240v. A.C., **20/-** ea. P.P. 5/-.
"LONG LIFE" ELECTROLYTICS (screw terminal)
25,000 u.f. 40v. (4½×2½ in.). **20/-** ea. P.P. 2/6.
10,000 u.f. 75v. (4½×2½ in.) **17/6** ea. P.P. 2/6.
3,150 u.f. 40v. (4¼×1½ in.). **15/-** ea. P.P. 2/6.
EXECUTIVE "SIXTY" AMPLIFIER. (60 w. r.m.s. into 8 ohm.) British designed and built. True hi-fi performance. Built-in filters to protect speakers. Three independently mixed inputs. High-Low impedance. Mic. Crystal-Ceramic-Magnetic Cartridge, or aux. equipment. **£55.** P.P. 50/-. S.a.e. literature.

TELEPHONE DIALS (New) 20/- ea.

RELAYS (G.P.O. '3000'). All types. Brand new from **7/6** each. 10 up quotations only
TELEPHONE EXTENSION CABLE (ex. G.P.O.) 3 core/cream p.v.c. 100 yd. coil **40/-** 200 yd. coil **75/-** P.P. 5/- coil.
UNISELECTORS (Brand new) 25-way 75 ohm. 8 bank ½ wipe **65/-.** 10 bank ½ wipe **75/-.** Other types from **45/-.**



REED RELAYS 4 make 9/12v. (1,000 ohm.) **12/6** ea. 2 make **7/6** ea. 1 make **5/-** ea. Reed Switches (1¾ in.) **2/-** ea. £1 per doz.
SUB-MINIATURE REED RELAYS (1in.×½in.). Weight ⅛ oz. Type 1. 960 ohm, 3/9v. 1 make. **12/6** ea. Type 2. 1800 ohm, 3/12v. 1 make. **15/-** ea.

SILICON BRIDGES. 100 P.I.V 1 amp. (⅜×⅜×⅜ in.), **8/6** ea.

"ADVANCE" VOLSTAT TRANSFORMERS. Input 190-260v. Output 6v. R.M.S. 25 Watt. **40/-** each. P.P. 5/-.

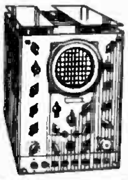
PLUG-IN RELAYS. (Siemans-Varley) 4 c/o. 700 ohm, **10/-** ea. complete with base. (Other make-ups and coils available.)

PATTRICK & KINNIE

191 LONDON ROAD · ROMFORD · ESSEX

ROMFORD 44473 **RM79DD**

TYPE 13A DOUBLE BEAM OSCILLOSCOPES BARGAIN

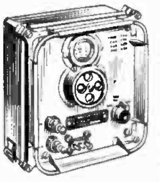


An excellent general purpose D/B oscilloscope. T.B. 2 cps-750 Kc/s. Bandwidth 5.5 Mc/s Sensitivity 33 Mv/cm. Operating voltage 0/110/200/250 v. A.C. Supplied in excellent working condition, **£22/10/-.** Carriage 30/-.

AVO CT471A MULTIMETER

Battery operated, fully transistorised. Sensitivity 100 MΩ/v. Measures A.C./D.C. voltages 12mV. to 1,200 V A.C./D.C. current 12µA. to 1.2 Amp. Resistance 12 ohm to 120 mΩ H.F., V.H.F., U.H.F. voltage with multiplier 4V. to 400V. up to 50 Mc/s., 40 mV. to 4V. up to 1,000 Mc/s. Offered in perfect condition. **£55** each. Carr. 10/-.

CRYSTAL CALIBRATORS NO. 10

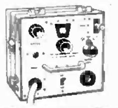


Small portable crystal controlled wavemeter. Size 7in. × 7¼in. × 4in. Frequency range 500 Kc/s—10 Mc/s (up to 30 Mc/s on harmonics). Calibrated dial. Power requirements 300 V.D.C. 15mA and 12 V.D.C. 0.3A. Excellent condition. **89/6** Carr. 7/6.

LELAND MODEL 27 BEAT FREQUENCY OSCILLATORS

0-20 Kc/s. Output 5K or 500 ohms. 200/250 v. A.C. Offered in excellent condition, **£12/10/-.** Carriage 10/-.

CLASS D. WAVEMETERS

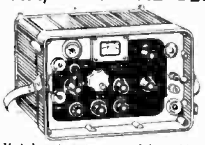


A crystal controlled heterodyne frequency meter covering 1.7-8 Mc/s. Operation on 6 v. D.C. Ideal for amateur use. Available in good used condition **£5.19.6** Carr. 7/6. or Brand New **£7.19.6** Carr. 7/6.

B.C. 221 FREQUENCY METERS

Latest release 125 KHz-20 MHz. Excellent condition. Fully tested and checked and complete with calibrator charts. **£27.10.0** each. Carr. 10/-.

AM/FM SIGNAL GENERATORS

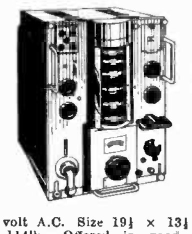


Oscillator Test No. 2. A high quality precision instrument made for the Ministry by Airmec. Frequency coverage 20-80 Mc/s. AM/CW/FM. Incorporates precision dial, level meter, precision attenuator 1µV-100Mv. Operation from 12 volt D.C. or 0/110/200/250 v A.C. Size 12 x 8½ x 9in. Supplied in brand new condition complete with all connectors, fully tested, **£45.** Carr. 20/-.

AVO CT.38 ELECTRONIC MULTIMETERS

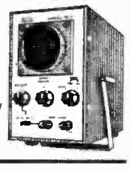
High quality 97 range instrument which measures A.C. and D.C. Voltage. Current, Resistance and Power Output Ranges D.C. volts 250 mV-10,000v. (10 meg Ω-110 meg Ω input). D.C. current 10µA-25 amps. Ohms. 0-1,000 meg Ω A.C. volt 100mv.-250V (with R.F. measuring head up to 250 Mc/s) A.C. current 10µA-25 amps. Power output 50 micro-watts-5 watts. Operation 0/110/200/250V. A.C. Supplied in perfect condition complete with circuit lead and R.F. probe. **£25.** Carr. 15/-.

ADMIRALTY 62B RECEIVERS



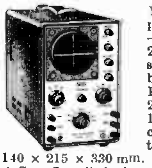
High quality 10 valve receiver manufactured by Murphy. Coverage in 5 bands 150-300 Kc/s, 560 Kc/s-1.5Mc/s, 3.9-30.5 Mc/s. I.F. 500 Kc/s. Incorporates 2 R.F. and 3 I.F. stages, bandpass filter, noise limiter, crystal controlled B.F.O. calibrator I.F. output, etc. Built-in speaker, output for phones. Operation 150/230 volt A.C. Size 19½ × 13½ × 16in. Weight 114lb. Offered in good working condition. **£22/10/0,** carr. 30/-. With circuit diagrams. Also available B41 L.F. version of above. 15 Kc/s-700 Kc/s. **£17/10/-.** Carr. 30/-.

TO-2 PORTABLE OSCILLOSCOPE



A general purpose low cost economy oscilloscope for everyday use. Y amp. Bandwidth 2 CPS—1 MHZ. Input imp. 2 meg Ω. 25 PF. illuminated scale. 2" tube. 115 × 180 × 230 mm. Weight 8lbs. 220/240v. A.C. Supplied brand new with handbook. **£22/10/-.** Carr. 10/-.

TO-3 PORTABLE OSCILLOSCOPE. 3" 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 **£37.10.0** Carr. 10/-.

SEW PANEL METERS

USED EXTENSIVELY BY INDUSTRY, GOVERNMENT DEPARTMENTS, EDUCATIONAL AUTHORITIES, ETC.

● LOW COST ● QUICK DELIVERY ● OVER 200 RANGES IN STOCK ● OTHER RANGES TO ORDER

NEW "SEW" DESIGNS!

CLEAR PLASTIC METERS

TYPE SW. 100
100 x 80 mm.

		20V. D.C.	59/6
50µA	69/6	50V. D.C.	59/6
50-0-50µA	67/6	300V. D.C.	59/6
100µA	67/6	1 amp. D.C.	59/6
100-0-100µA	65/-	5 amp. D.C.	59/6
500µA	62/6	300V. A.C.	59/6
1mA	59/6	VU Meter	75/-

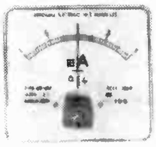
BAKELITE PANEL METERS

TYPE S-80
80 mm.
square fronts

50µA	62/6	50V. D.C.	49/6
50-0-50µA	59/6	300V. D.C.	49/6
100µA	59/6	1 amp. D.C.	49/6
100-0-100µA	57/6	5 amp. D.C.	49/6
500µA	52/6	300V. A.C.	52/6
1mA	49/6	VU Meter	67/6
20V. D.C.	49/6		

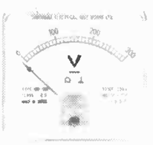
"SEW" CLEAR PLASTIC METERS

Type MR.85P. 4¼in. × 4¼in. fronts.



		10mA	52/-
		50mA	52/-
		100mA	52/-
		500mA	52/-
		1 amp.	52/-
		5 amp.	52/-
		15 amp	52/-
		30 amp.	52/-
		20V. D.C.	52/-
		50V. D.C.	52/-
		150V. D.C.	52/-
50µA	72/-	300V. D.C.	52/-
50-0-50µA	62/-	15V. A.C.	52/-
100µA	62/-	300V. A.C.	52/-
100-0-100µA	62/-	8 Meter 1mA	57/6
200µA	57/6	VU meter	72/-
500µA	55/-	1 amp. A.C.*	52/-
500-0-500µA	52/-	5 amp. A.C.*	52/-
1mA	52/-	10 amp. A.C.*	52/-
1-0-1mA	52/-	20 amp. A.C.*	52/-
5mA	52/-	30 amp. A.C.*	52/-

Type MR.38P. 1 21/32in. square fronts.



		200mA	27/6
		300mA	27/6
		500mA	27/6
		750mA	27/6
		1 amp.	27/6
		2 amp.	27/6
		5 amp.	27/6
		10 amp.	27/6
		3V. D.C.	27/6
50µA	40/-	10V. D.C.	27/6
50-0-50µA	37/6	15V. D.C.	27/6
100µA	37/6	20V. D.C.	27/6
100-0-100µA	35/-	100V. D.C.	27/6
200µA	35/-	150V. D.C.	27/6
500µA	30/-	300V. D.C.	27/6
500-0-500µA	27/6	500V. D.C.	27/6
1mA	27/6	750V. D.C.	27/6
1-0-1mA	27/6	15V. A.C.	27/6
2mA	27/6	50V. A.C.	27/6
5mA	27/6	150V. A.C.	27/6
10mA	27/6	300V. A.C.	27/6
20mA	27/6	500V. A.C.	27/6
50mA	27/6	8 meter 1mA	32/-
100mA	27/6	VU meter	42/-
150mA	27/6		

Type MR.52P. 2½in. square fronts.

50µA	62/-	10V. D.C.	40/-
50-0-50µA	52/-	20V. D.C.	40/-
100µA	52/-	50V. D.C.	40/-
100-0-100µA	47/6	300V. D.C.	40/-
500µA	45/-	15V. A.C.	40/-
1mA	40/-	300V. A.C.	40/-
5mA	40/-	8 Meter 1mA	42/-
10mA	40/-	VU Meter	62/-
50mA	40/-	1 amp. A.C.*	40/-
100mA	40/-	5 amp A.C.*	40/-
500mA	40/-	10 amp. A.C.*	40/-
1 amp.	40/-	20 amp. A.C.*	40/-
5 amp.	40/-	30 amp. A.C.*	40/-

Type MR.45P. 2in. square fronts.

50µA	45/-	5 amp.	30/-
50-0-50µA	42/-	10V. D.C.	30/-
100µA	42/-	20V. D.C.	30/-
100-0-100µA	37/6	50V. D.C.	30/-
200µA	37/6	300V. D.C.	30/-
500µA	32/-	15V. A.C.	30/-
500-0-500µA	30/-	300V. A.C.	30/-
1mA	30/-	8 meter 1mA	37/6
5mA	30/-	VU meter	45/-
10mA	30/-	1 amp. A.C.*	30/-
50mA	30/-	5 amp. A.C.*	30/-
100mA	30/-	10 amp. A.C.*	30/-
500mA	30/-	20 amp. A.C.*	30/-
1 amp.	30/-	30 amp. A.C.*	30/-

Type MR.65P. 3¼in. × 3¼in. fronts.

50µA	67/6	10V. D.C.	42/-
50-0-50µA	55/-	20V. D.C.	42/-
100µA	55/-	50V. D.C.	42/-
100-0-100µA	52/-	150V. D.C.	42/-
200µA	52/-	300V. D.C.	42/-
500µA	47/6	15V. A.C.	42/-
500-0-500µA	42/-	50V. A.C.	42/-
1mA	42/-	150V. A.C.	42/-
5mA	42/-	300V. A.C.	42/-
10mA	42/-	500V. A.C.	42/-
50mA	42/-	8 meter 1mA	47/6
100mA	42/-	VU meter	67/6
500mA	42/-	50mA A.C.*	42/-
1 amp.	42/-	100mA A.C.*	42/-
5 amp.	42/-	200mA A.C.*	42/-
10 amp.	42/-	500mA A.C.*	42/-
15 amp.	42/-	1 amp. A.C.*	42/-
20 amp.	42/-	5 amp. A.C.*	42/-
30 amp.	42/-	10 amp. A.C.*	42/-
50 amp.	47/6	20 amp. A.C.*	42/-
5V. D.C	42/-	30 amp. A.C.*	42/-

"SEW" BAKELITE PANEL METERS

Type MR.65. 3½in. square fronts.

		500mA	35/-
		1 amp.	35/-
		5 amp.	35/-
		15 amp.	35/-
		30 amp.	35/-
		50 amp.	35/-
		5V. D.C.	35/-
		10V. D.C.	35/-
		20V. D.C.	35/-
		50V. D.C.	35/-
		150V. D.C.	35/-
		300V. D.C.	35/-
25µA	70/-	30V. A.C.*	35/-
50µA	47/6	50V. A.C.*	35/-
50-0-50µA	45/-	150V. A.C.*	35/-
100µA	45/-	300V. A.C.	35/-
100-0-100µA	45/-	500mA A.C.*	35/-
500µA	42/-	1 amp. A.C.*	35/-
1mA	35/-	5 amp. A.C.*	35/-
1-0-1mA	35/-	10 amp. A.C.*	35/-
5mA	35/-	20 amp. A.C.*	35/-
10mA	35/-	30 amp. A.C.*	35/-
50mA	35/-	50 amp. A.C.*	35/-
100mA	35/-	VU meter	62/-

✻MOVING IRON—
ALL OTHERS MOVING COIL
Please add postage

EDGWISE METERS

Type PE.70. 3 17/32in. × 1 15/32in. × 2½ in. deep.

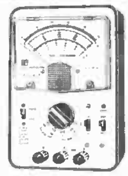
50µA	60/-	500µA	52/-
50-0-50µA	57/6	1mA	47/6
100µA	57/6	300V. A.C.	47/6
100-0-100µA	55/-	VU meter	65/-
200µA	55/-		

SEND FOR ILLUSTRATED BROCHURE ON SEW PANEL METERS—DISCOUNTS FOR QUANTITIES

POWER RHEOSTATS

High quality ceramic construction. Windings embedded in vitreous enamel. Heavy duty brush wiper. Continuous rating. Wide range available ex-stock. Single hole fixing. ¼in. dia. shafts. Bulk quantities available.
25 WATT. 10/25/50/100/250/500/1000/1500/2500 or 5000 ohms. 14/6. P. & P. 1/6.
50 WATT. 10/25/50/100/250/500/1000/2500 or 5000 ohms, 21/-. P. & P. 1/6.
100 WATT. 1/5/10/25/50/100/250/500/1000 or 2500 ohms, 27/6. P. & P. 1/6.

FTC-401 TRANSISTOR TESTER

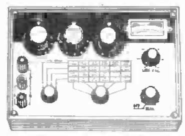


Full capabilities for measuring A, B and ICO. NPN or PNP. Equally adaptable for checking diodes. Supplied complete with instructions, battery and leads. **£6.19.6** & 3/- P. & P.

MARCONI TF.142E DISTORTION FACTOR METERS

Excellent condition. Fully tested **£20.** Carr. 15/-.

TRANSISTORISED L.C.R. A.C MEASURING BRIDGE.

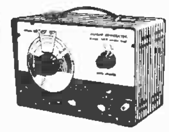


A new portable bridge offering excellent range and accuracy at low cost. Ranges: R. 1Ω—11.1 MEG Ω 6 Ranges ± 1%. L. 1µH—111 HENRIES. 6 Ranges — 2%. C. 10PF ± 1110MFD. 6 Ranges ± 2%. TURNS RATIO 1:1/1000—1:11100. 6 Ranges ± 1%. Bridge voltage at 1,000 CPS. Operated from 9 volts. 100µA. Meter Indication. Attractive 2 tone metal case. Size 7¾" × 5" × 2". **£20.** P. & P. 5/-.

COSSOR 1049 DOUBLE BEAM OSCILLOSCOPES

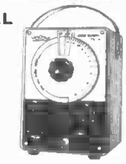
D.C. coupled. Band width 1 Kc/s. Perfect order. **£25.** Carr. 30/-.

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, **£16.10.0.** Carr. 7/6.

TY75 AUDIO SIGNAL GENERATOR



Sine Wave 20 CPS—200 Kc/s. Square Wave 20 CPS—30 Kc/s. High and low impedance output. Output variable up to 6 volts. 220/240 volts A.C. Brand new with instructions. **£16.** Carr. 7/6. Size 210 × 150 × 120 mm.

MARCONI TF885 VIDEO OSCILLATORS

0-5 mc/s Sine Square Wave **£45.** Carr. 20/-.

LAFAYETTE TE-46 RESISTANCE CAPACITY ANALYSER

2 pf-2,000 mfd. 2 ohms-200 megohms. Also checks impedance turns ratio insulation, 200/250 v. A.C. Brand New, **£17.10** Carr. 7/6.

270° 500 MICROAMP METER

Incorporated in Radio Altitude Indicator ID-14APN. Ideal for rev. counter etc. **15/6.** P. & P. 3/-.

TE-20D RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120 Kc/s—500 Mc/s on 6 bands. Directly calibrated. Variable RF. attenuator, audio output. Xtal socket for calibration. 220/240V. A.C. Brand new with instructions. **£15.** Carr. 7/6. Size 140 x 215 x 170 mm.

ADVANCE TEST EQUIPMENT

Brand new and boxed in original sealed cartons.

JIB. AUDIO SIGNAL GENERATOR
15 c/s to 50 Kc/s. Sine wave. Output 600 ohms or 5 ohms. **£30.0.0.**

VM79. UHF MILLIVOLT METER
100 Kc/s to 1,000 Mc/s. A.C. 10 mV to 3v. D.C. 10 mV. to 3v. Current 0.01 uA to 0.3 mA. Resistance 1 ohm to 10 megohm. **£125.0.0.**

TTIS. TRANSISTOR TESTER
Full range of facilities for testing PNP or NPN transistors in or out of circuit. **£37.10.0.**
Carriage 10/- per item.

MARCONI TF195M BEAT FREQUENCY OSCILLATORS

0-40 kc/s. **£20.** Carr. 30/-.

G. W. SMITH & Co. (Radio) Ltd.

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BCY42	3/-
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BCY71	6/-
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BD121	13/-
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BD124	12/-
BF115	5/-
BF117	9/6
BF167	5/-
BF173	6/-
BF180	7/6
BF181	7/6
BF182	6/6
BF184	5/-
BF185	5/-
BF194	3/6
BF195	3/-
BF200	7/6
BF224	6/-
BF225	6/-
BF244	9/6
BFX12	4/6
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BFX29	6/-
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BFX44	7/6
BFX85	8/-
BFX86	6/6
BFX87	6/6
BFX88	5/-
BFY18	5/-
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BFY50	4/6
BFY51	4/-
BFY52	4/6
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OA202	2/-
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OC23	10/-
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OC29	12/6
OC35	10/-
OC36	12/6
OC41	5/-
OC42	6/-
OC44	3/6
OC45	3/-
OC46	5/6
OC70	2/6
OC71	3/-
OC72	5/-
OC73	6/-
OC74	6/-
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OC78	4/-
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6SN7	5/6
6SQ7	8/-
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6X4	5/-
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6X5GT	5/6
10C2	10/-
10F1	18/-
10P13	11/-
10P14	20/-
12AT6	5/-
12AT7	4/-
12AU7	5/-
12AX7	6/-
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20P3	12/-
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30C15	15/-
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30L17	17/-
30P12	16/-
30P19	15/-
30PL1	15/6
30PL13	18/-
30PL14	17/-
35L6	9/6
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35Z4	5/-
35Z5	7/-
50B5	7/-
50C5	7/-
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1625	6/-
5763	13/-
6146	30/-
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DK96	8/-
DL92	7/-
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DL96	7/6
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EAF42	10/-
EB91	3/3
EBC41	10/6
EBC81	6/6
EBF80	8/-
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ECC85	5/6
ECC88	8/-
ECF80	7/-
ECF82	7/-
ECF86	12/6
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ECH35	12/-
ECH42	13/-
ECH81	5/6
ECH83	8/6
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ECL83	12/6
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PC97	8/6
PC900	9/6
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PCC88	12/-
PCC89	10/6
PCC189	11/-
PCF80	6/6
PCF82	6/9
PCF84	9/-
PCF86	11/-
PCF800	15/-
PCF801	10/-
PCF802	10/-
PCF805	15/-
PCF806	13/-
PCF808	15/6
PCL82	7/9
PCL83	13/-
PCL84	8/9
PCL85	9/6
PCL86	9/6
PFL200	11/-
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PL82	9/-
PL83	8/-
PL84	7/-
PL500	15/-
PL504	16/-
PY32	11/-
PY33	12/6
PY80	6/6
PY81	6/-
PY82	6/-
PY83	7/6
PY88	8/-
PY800	10/-
PY801	10/-
U25	15/-
U26	15/-
U50	6/-
U52	6/-
U191	14/-
U281	8/-
U282	8/-
U301	11/6
U801	20/-
UABC80	6/9
UAF42	10/6
UBC41	9/6
UBC81	8/-
UBF80	7/3
UBF89	7/-
UCC84	9/9
UCC85	8/-
UCF80	10/6
UCH21	11/-
UCH42	13/-
UCH81	6/6
UCL82	7/-
UCL83	12/-
UF41	10/-
UF80	7/6
UF85	8/-
UF89	7/-
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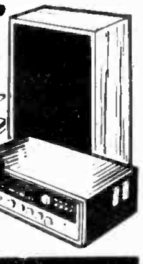

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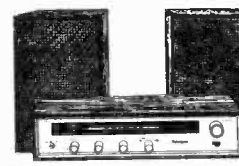

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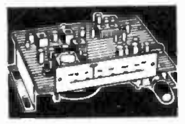
G800 Super E	£16 16 0

P. & P. 2/6 any type.

TRANSISTOR FM TUNER



6 TRANSISTOR HIGH QUALITY TUNER SIZE ONLY 6in. x 4in. x 2½in. 3 I.F. stages. Double tuned discriminator, ample output to feed most amplifiers. Operates on 9 volt battery. Coverage 88-108 Mc/s. Ready built ready for use. Fantastic value for money, £6/7/6. P. & P. 2/6.

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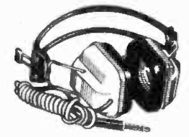
Cassette Head Cleaner 11/3 All Post Extra.

ECHO HS-606 STEREO HEADPHONES



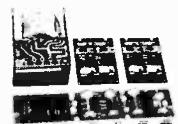
Wonderfully comfortable. Lightweight adjustable vinyl headband, 6ft. cable and stereo jack plug, 25-17,000 cps., 8Ω imp. 67/6. P. & P. 2/6.

HOSIDEN DH-08S DE-LUXE STEREO HEADPHONES

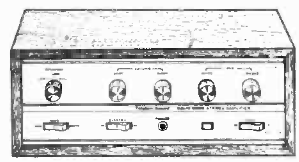
Features unique mechanical 2 way units and fitted adjustable level controls 8 ohm impedance. 20-20,000cps. Complete with spring lead & stereo jack plug. £7.19.6. P. & P. 2/6.

SINCLAIR EQUIPMENT

Project 60. Package Offers



2 × Z30 amplifier, stereo 60 pre-amp, PZ5 power supply. £19.0.0. Carr. 7/6. Or with PZ6 power supply, £21.0.0. Carr. 7/6 2 × Z50 amplifier, stereo 60 pre-amp, PZ8 power supply. £21.10.0. Carr. 7/6. Transformer 4 PZ8, 59/6 extra. Add to any of the above £4.17.6 for active filter unit and £16.0.0 for a pair of Q16 speakers. PROJECT 60 FM TUNER £20.19.6. Carr. 7/6. All other Sinclair products in stock: 2,000 amplifier £23.0.0. Carr. 7/6. 3,000 Amplifier £36. Carr. 7/6. Neoteric amplifier £46.0.0. Carr. 7/6.



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Popular solid state hi-fi amplifier incorporating 16 semi-conductors. Output 6 watts r.m.s. Inputs for magnetic ceramic, tuner and aux. Stereo phone socket and tape output. Controls: Volume, balance bass, treble. Oiled Walnut case with brushed aluminium front panel. SPECIAL PRICE £20. Carr. 7/6.

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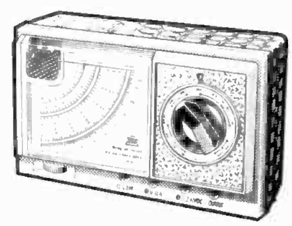
MODEL C-1051 MULTIMETER

Miniaturised multimeter employing ultra compact slimline impact resistant cabinet. Buff/green finish, size 4¾ x 3⅛ x 1⅛in. Features—Large easy to read meter with mirror scale. D'Arsonval movement. Overload protection circuit. Fine calibration gives extremely high standard of accuracy on all ranges. Ohms zero adjustment. Click stop range selection switch. Colour coded scales.



- DC/V: 0-3-15-150-300—1.2KV at 20K/ohms/V
- AC/V: 0-6-30-300—1.2KV at 10K/ohms/V
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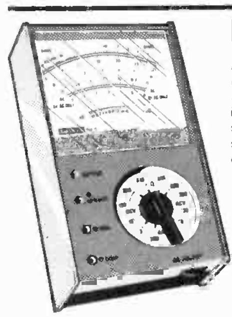
- Resistance: 0-60K—6M/ohms
- Decibels: −20dB to +17dB
- Complete with battery and test leads.

LASKY'S PRICE **85/-** POST 2/6



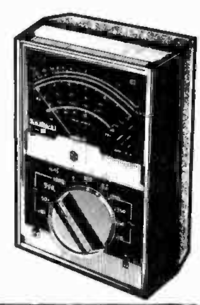
LASKY'S TM5

Another new look pocket multimeter from Lasky's providing top quality and value. The "slimline" impact resistant case—size 4⅞in. x 2⅞in. x 1⅛in., fitted with extra large 2⅞in. square meter. Readability is superior on all low ranges; making this an excellent instrument for servicing transistorised equipment. Recessed click stop selection switch. Ohms zero adjustment. Buff finish with crystal clear meter cover.

- **DC/V: 3-15-150-300-1,200 at 5K ohms/V**
- **AC/V: 6-30-300-600 at 2.5K ohms/V**
- **DC Current 0-300μA 0-300mA**
- **Resistance: 0-10K ohms, 0-1M ohms**
- **Decibels: −10dB to 16dB**
- **Complete with test leads, battery and instructions**

LASKY'S PRICE 59/6 P & P 2/6

LASKY'S TM1



The first of Lasky's new-look top value meters, the TM1 is a really tiny pocket multimeter providing "big" meter accuracy and performance. Precision movement calibrated to ±3% of full scale. Click stop range selection switch. Beautifully designed and made impact resistant black case—with white and metallic red/green figuring. Ohms zero.

- **DC/V: 0-10-50-250-1000 at 1K ohms/V**
- **AC/V: 0-10-50-250-1000 at 1K ohms/V**
- **DC CURRENT: 0-1mA, 100mA**
- **Resistance: 0-150K ohms**
- **Decibels: −10+22dB**
- **Complete with test leads, battery and instructions**

Size only 3¼in. x 2⅜in. x 1¼in.

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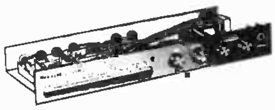
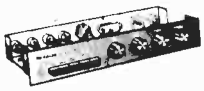


IC STEREO

FET 154



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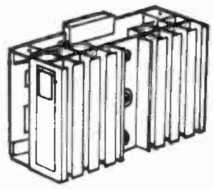

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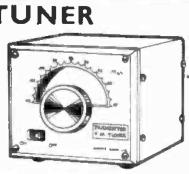

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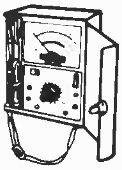

AF105 50k/volt multi-meter (illus.). **Price £8.10.0** p.p. 3/6. Leather case **28/6.**

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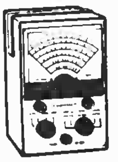

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VM51 Transistorised AF/RF millivoltmeter. **Price £32.**

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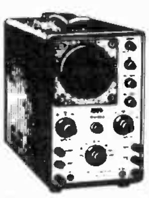
TE15 Grid dip meter. **Price £12.10.0** p.p. 3/6.



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CI-5 Scope. 3" tube. 10 Mc/s PB. **Price £39.** p.p. 10/-.

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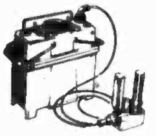

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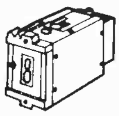

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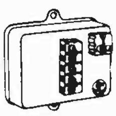

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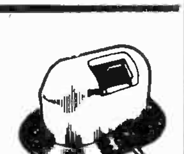

Fire Detector Unit containing 931A photo multiplier and cold cathode tube. Shock and fire proof. Originally made for £74. Price complete with data sheet **£6.** Brand new.

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BP50	7450N	Dual 2-Input NAND/OR/NOT GATE —expandable	6/6	5/6	4/6
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SA1	150	Germ. Trans PNP Mixed lots	10/-
SA2	200	Germ. & Sil. Alloy Trans. PNP	10/-
SA3	100	Germ. A.F. Trans. 300mW PNP	10/-
SA4	200	Sil. Alloy Low gain switching Trans. PNP	10/-
SA5	100	Sil. planar plastic trans. PNP	10/-
SA6	100	Sil. plastic planar trans. NPN	10/-
SA7	100	Sil. planar Trans. TO5 plastic PNP 800mW	20/-
SA8	100	Sil. planar trans. TO18 plastic NPN 500mW	20/-
SA9	100	Sil. planar trans. plastic NPN med. & high gain	20/-
		DIODES	
SB1	200	GERM. Diodes Gen.P.	10/-
SB2	200	GERM. Gold Bonded	10/-
SB3	200	Sil. Switching Diodes 50mA	10/-
SB4	200	Sil. Gen.P. Diodes 200mA	10/-
SB5	300	Sil. & Germ. Mixed Diodes	10/-

The following are all new and Fully Tested Transistor Packs.

ST1	50	PNP Trans. Mixed all coded Germ.	20/-
ST2	40	NPN Germ. To-5 2G339 Eqvt. 2N1302 AC127	20/-
ST3	40	PNP Germ. AF 2G371B OC71-75 type	20/-
ST4	30	PNP Germ. VHF-2G407L=AF117=OC170 uncoded	20/-
ST5	30	PNP Metal Alloy VHF 800m/cs Trans.	20/-
ST6	40	PNP/NPN Assorted Trans. all coded	20/-
ST7	40	D1374 RF Trans. Eqvt. ASY52 OC44/45	20/-
ST8	40	2N706 NPN Switching Sil. Trans.	20/-
ST9	30	2N708 NPN Sil. Trans.	20/-
ST10	30	BSY28 NPN Sil. Trans.	20/-
ST11	25	2N3703 PNP Sil. Trans.	20/-
ST12	25	TI848 = 2N2368 NPN 400m/cs.	20/-
ST13	25	SE/2N3646 NPN TO-18 plastic 350m/cs	20/-
ST14	40	283010 Sil. Alloy Trans. PNP TO5	20/-

WHEN ORDERING PLEASE MENTION PAK. ORDER NO. IN ALL CASES. CLUBS, SCHOOLS & OTHER ORGANISATIONS REQUIRING LARGER QUANTITIES (100 MIN.; 100 MIN. ST1 to ST14; 1,000 MIN. SA1 to SB5) MAY SUBMIT THEIR OFFERS NOT LATER THAN 1st FEBRUARY, 1971.

QUALITY-TESTED PAKS

- 6 Matched Trans. OC44/45/81/81D 10/-
- 20 Red Spot AF Trans. PNP 10/-
- 16 White Spot RF Trans. PNP 10/-
- 5 Silicon Rects. 3A 100-400 PIV 10/-
- 2 10 A Silicon Rects. 100 PIV 10/-
- 2 OC1 140 Trans. NPN Switching 10/-
- 1 12 A SCR 100 PIV 10/-
- 3 Sil. Trans. 2S303 PNP 10/-
- 3 200 Mc/s Sil. Trans. NPN BSY26/27 10/-
- 3 Zener Diodes 1W 33V 5% Tol 10/-
- 4 High Current Trans. OC42 Eqvt. 10/-
- 2 Power Transistors 1 OC26 1 OC35 10/-
- 5 Silicon Rects. 400 PIV 250mA 10/-
- 4 OC75 Transistors 10/-
- 1 Power Trans. OC20 100V 10/-
- 10 OA202 Sil. Diodes Sub-min. 10/-
- 2 Low Noise Trans. NPN 2N929/30 10/-
- 1 Sil. Trans. NPN VCB 100 ZT86 10/-
- 8 OA81 Diodes 10/-
- 4 OC72 Transistors 10/-
- 4 OC77 Transistors 10/-
- 4 Sil. Rects. 400 PIV 500mA 10/-
- 5 GET884 Trans. Eqvt. OC44 10/-
- 5 GET883 Trans. Eqvt. OC45 10/-
- 2 2N708 Sil. Trans. 300Mc/s NPN 10/-
- 3 GT31 LF Low Noise Germ Trans. 10/-
- 6 IN914 Sil. Diodes 75 PIV 75mA 10/-
- 8 OA95 Germ. Diodes Sub-min. IN69 10/-
- 3 NPN Germ. Trans. NKT773 Eqvt. 10/-
- 2 OC22 Power Trans. Germ. 10/-
- 2 OC25 Power Trans. Germ. 10/-
- 4 AC128 Trans. PNP High Gain 10/-
- 4 AC127/128 Comp. pair PNP/NPN 10/-
- 3 2N1307 PNP Switching Trans. 10/-
- 7 CG62H Germ. Diodes Eqvt. OA71 10/-
- 3 AF116 Type Trans. 10/-
- 12 Assorted Germ. Diodes Marked 10/-
- 4 AC126 Germ. PNP Trans. 10/-
- 4 Silicon Rects. 100 PIV 750mA 10/-
- 3 AF117 Trans. 10/-
- 7 OC81 Type Trans. 10/-
- 3 OC171 Trans. 10/-
- 5 2N2926 Sil. Epoxy Trans. 10/-
- 7 OC71 Type Trans. 10/-
- 2 28701 Sil. Trans. Texas 10/-
- 2 10 A 600 PIV Sil. Rects. IS45R 10/-
- 3 BC108 Sil. NPN High Gain Trans. 10/-
- 1 2N910 NPN Sil. Trans. VCB 100 10/-
- 2 1000 PIV Sil. Rect. 1.5 A R53310 AF 10/-
- 3 BSY95A Sil. Trans. NPN 200Mc/s 10/-
- 3 OC200 Sil. Trans. 10/-
- 2 GET880 Low Noise Germ. Trans. 10/-
- 1 AF139 PNP High Freq. Trans. 10/-
- 3 NPN Trans. 1 ST141 and 2 ST140 10/-
- 4 Madt's 2 MAT100 and 2 MAT120 10/-
- 3 Madt's 2 MAT101 and 1 MAT121 10/-
- 4 OC44 Germ. Trans. AF 10/-
- 3 AC127 NPN Germ. Trans. 10/-
- 1 2N3906 Sil. PNP Trans. Motorola 10/-
- 2 Sil. Power Rects. BYZ13 15/-
- 1 Sil. Power Trans. NPN 100Mc/s TK201A 15/-
- 2 2N1132 PNP Epitaxial Planar Sil. 10/-
- 3 2N697 Epitaxial Planar Trans. Sil. 15/-
- 4 Germ. Power Trans. Eqvt. OC16 15/-
- 1 Unijunction Trans. 2N2646 15/-
- 2 Sil. Trans. 200Mc/s 60Vch ZT83/84 15/-
- 20 NKT Trans. AF, RF, VHF, Coded + Eqvt. List 10/-
- 2 2N2712 Sil. Epoxy Planar HFE225 15/-
- 8 BY100 Type Sil. Rects. 20/-
- 25 Sil. and Germ. Trans. Mixed, all marked, New 30/-

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Satisfaction GUARANTEED in Every Pak, or money back.

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U3	75 Germanium Gold Bonded Diodes sim. OA5, OA47	10/-
U4	40 Germanium Transistors like OC81, AC128	10/-
U5	60 200mA Sub-min. Sil. Diodes	10/-
U6	30 Silicon Planar Transistors NPN sim. BSY95A, 2N706	10/-
U7	16 Silicon Rectifiers Top-Hat 750mA up to 1,000V	10/-
U8	50 Sil. Planar Diodes 250mA OA/200/202	10/-
U9	20 Mixed Volts 1 watt Zener Diodes	10/-
U11	25 PNP Silicon Planar Transistors TO-5 sim. 2N1132	10/-
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U16	10 3-Amp Silicon Rectifiers Stud Type up to 1000 PIV	10/-
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U24	20 Germanium 1-amp Rectifiers GJM up to 300 PIV	10/-
U25	25 300Mc/s NPN Silicon Transistors 2N708, BSY27	10/-
U26	30 Fast Switching Silicon Diodes like IN914 Micro-min.	10/-
U28	Experimenters' Assortment of Integrated Circuits, untested Gates, Flip-Flops, Registers, etc., 8 Assorted Pieces	20/-
U29	10 1 amp SCR's TO-5 can up to 600 PIV CRSI/25-600	20/-
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U31	20 Sil. Planar NPN trans. low noise Amp 2N3707	10/-
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U33	15 Plastic case 1 amp Silicon rectifiers 1N4000 series	10/-
U34	30 Sil. PNP alloy trans. TO-5 BCY26, 28302/4	10/-
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U37	30 Sil. alloy trans. SO-2 PNP, OC200 28322	10/-
U38	20 Fast Switching Sil. trans. NPN, 400Mc/s 2N3011	10/-
U39	30 RF Germ. PNP trans. 2N1303/5 TO-5	10/-
U40	10 Dual trans. 6 lead TO-5 2N2060	10/-
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U42	10 VHF Germ. PNP trans. TO-1 NKT667 AF117	10/-
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Code Nos. mentioned above are given as a guide to the type of device in the Pak. The devices themselves are normally unmarked.

FREE One 10/- Pack of your own choice free with orders valued £4 or over. **FREE**

NEW LOW PRICE TESTED S.C.R's

PIV	1A (TO-5 case) each	3A (TO-66 case) each	7A (TO-48 case) each	16A (TO-48 case) each	30A PIV	each
50	4/6	5/-	9/6	10/6	25	20/-
100	5/-	6/6	10/6	12/6	50	23/-
200	7/-	7/6	11/6	15/-	100	28/-
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600	10/6	11/6	15/6	25/-	400	35/-
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SIL. RECTS. TESTED

PIV	750mA	3A	10A	30A
50	1/-	2/9	4/3	9/6
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200	1/9	4/-	4/9	20/-
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500	3/-	6/-	8/6	30/-
600	3/3	6/9	9/-	37/-
800	3/6	7/6	11/-	40/-
1000	5/-	9/3	12/6	50/-
1200	6/6	11/6	15/-	

AF239 PNP GERM. SIEMENS VHF TRANSISTORS. RF MIXER & OSC. UP TO 900 MHZ. USE AS REPLACEMENT FOR AF139-AF186 Ω 100's OF OTHER USES IN VHF. OUR SPECIAL LOW PRICE: 1-24 7/6 each. 25-99 6/9 each. 100+ 6/- each.

2A POTTED BRIDGE RECTIFIERS. 200V..10/- 600V..15/- 800V..20/-

DIACS

FOR USE WITH TRIACS

BR100 7/6 each

TRIACS

VBOM	2A (TO-1)	6A (TO-66)	10A (TO-48)
100	14/-	15/-	22/6
200	17/6	20/-	28/-
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VBOM Blocking voltage in either direction.

EX-EQUIPMENT MULLARD AF 117 TRANSISTORS

Large can 4 lead Type. Leads cut short but still usable. Real value at 15 for 10/-.

SILICON DIAC For use with Triacs BR100 7/6 each

PRINTED CIRCUITS EX-COMPUTER

Packed with semiconductors and components. 10 boards give a guaranteed 30 trans. and 30 diodes. Our price 10 boards 10/-, plus 2/- P. & P.

LUCAS 35A SIL. RECTS. Branded. 400 PIV. Special Price, stud type, flying lead....22/6 each

Silicon MICROWAVE DIODES—SYLVANIA (U.S.A.)

IN21B and IN21BR MATCHED PAIR S. BAND MIXER. Max. overall noise faction 13.7 dB at 3000 m/cs. BRAND NEW AND BOXED. CLEARANCE PRICE.... 6/- PAIR

DUAL-IN-LINE LOW PROFILE SOCKETS 14 AND 16 Lead Sockets for use with Dual-in-Line Integrated Circuits.

Order No.		Price each 1-24	25-99	100 up
TS014	14 pin type	7/6	6/-	5/3
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UNIJUNCTION UT46. Eqvt. 2N2646, Eqvt. TIS43. BEN3000 5/6 each; 25-99 5/-; 100 up 4/-.

NPN SILICON PLANAR BC107/8/9, 2/- each; 50-99, 1/10; 100 up, 1/8 each; 1,000 off, 1/6 each. Fully tested and coded TO-18 case.

SILICON HIGH VOLTAGE RECTIFIERS 10-Amp 3-K.V. 3000 P.I.V.) Stud Type with Flying Leads. 16/- each

CADMIUM CELLS

ORP12 8/6

ORP60, ORP61 8/- ea.

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OCP71 Type 8/6

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AD161 NPN AD162 PNP

MATCHED COMPLEMENTARY PAIRS OF GERM. POWER TRANSISTORS OUR LOWEST PRICE OF 12/6 *PER PAIR*

HIGH POWER SILICON PLANAR TRANSISTORS. TO-3. FERRANTI ZT1487 NPN

VCB60 1c6A fT, 1M/cs

VCE40 Ptot, 75W

VEB8 hFE15-45

PRICE 15/- EACH.

2N3055 115T WAT SIL. POWER NPN OUR PRICE 12/6 EA.

FULL RANGE OF ZENER DIODES VOLTAGE RANGE 2-33V. 400mV (DO-7 Case) 2/6 ea. 1½W (Top-Hat) 3/6 ea. 10W (SO-10 Stud) 5/- ea. All fully tested 5% tol. and marked. State voltage required.

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Pak No.		EQVT.
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T2	8 2G374	OC75
T3	8 2G3744A	OC81D
T4	8 2G381A	OC81
T5	8 2G382T	OC82
T6	8 2G344A	OC44
T7	8 2G345A	OC45
T8	8 2G378	OC78
T9	8 2G399A	2N1302
T10	8 2G417	AF117

All 10/- each pack.

2N2060 NPN SIL. DUAL TRANS. CODE D1699 TEXAS. Our price 5/- each.

120 VCB NIXIE DRIVER TRANSISTOR. Sim BSX21 & C407, 2N1893 FULLY TESTED AND CODED ND120. 1-24 3/6 each. To-5 NPN., 25 up 3/- each.

Please send all orders direct to our warehouse and despatch department.

Postage and packing add 1/-. Overseas add extra for Airmail. Minimum order 10/-. Cash with order please.

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SOLARTRON PULSE GENERATOR GP1101.2: Period—2 microsecs to 100 msec; Pulse Duration—1 microsec to 100 msec; Delay time—1 microsec to 10 msec. All continuously variable in 5 ranges with fine control. Accuracy ±10%. Pulse Amplitude—0.5V-100V. Accuracy ±10% continuously variable in 4 ranges with fine control. Double Pulses; Pre-Pulse; Triggering; Square Wave O/put; Squaring Amplifier. Input—100-250V, 50-60 c/s. New condition with Manual. Price: **£85.0.0** each + £1.5.0 carr.

SPECTRUM ANALYZER MODEL TSA: (Polarad Electronics Corp.). A general-purpose superheterodyne receiver designed to provide a visual display of the spectral distribution of RF energy. Typical application of the equipment includes determining the presence and measuring the frequency of RF Signals, determining the types of RF signal modulation, observing and measuring sidebands associated with modulated signals, determining RF pulse characteristics by spectrum analysis, checking the operation of pulsed magnetron oscillators, measuring noise spectra and checking the frequency difference between adjacent RF signals. RF signals are displayed on a cathode ray tube screen with amplitude plotted as a function of frequency. Complete with RF Tuning Unit type STU-2: Freq. Range—910-4560 Mc/s. Sensitivity: —85 to —95 dbm from 910-2200 Mc/s per sec. —75 to —87 dbm from 1980-4560 Mc/s per sec. RF Attenuation Range—0-100 decibels. Price: **£150.0.0** each + £2 carr.

SIGNAL GENERATOR TS-510A/U: (Hewlett Packard). A general-purpose signal generator designed to furnish signals with a very low spurious energy content, suitable for alignment of narrow-band amplitude modulated receivers. It may be amplitude modulated by internally generated sine waves or by externally applied sine waves or pulses. Freq. Range—10-420 Mc/s in 5 bands, ±0.5% accuracy. Emission—AM, CW, Pulse. O/put Voltage—0.1V-0.5V, calibrated ±2 db accuracy. Modulation—Internal 400, 1000 c/s (0-90%). Built-in Crystal calibrator (1, 5 Mc/s). Price: **£150.0.0** each, complete with transit case, manual and all leads; OR **£125.0.0** each, Sig. Gen. only. Carr. both types £2.

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—50 Ω. Price: **£120.0.0** each + £2 carr.

SIGNAL GENERATOR TYPE 902: (P.R.D.). A portable, general-purpose, broadband, microwave signal generator designed for testing and maintenance of aircraft radio and radar receivers in the SHF band. The RF output level is regulated by a variable attenuator calibrated in dbm. The frequency dial is calibrated in Mc/s. Provision is made for external modulation. Power Supply—115V, ±10% A.C., 50 c/s. Freq.—3650-7300 Mc/s. Internal Transmission—CW, Pulse, FM. External Transmission—Square Wave, Pulse. Power O/put—0.2 milliwatts. O/put Attenuator: —7 to —127 dbm. Load—50 Ω. Price: **£135.0.0** each + £2 carr.

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. at 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: **£75.0.0** each + £1 carr.

SIGNAL GENERATOR TS-418/URM49: Covers 400-1000 Mc/s range. CW, Pulse or AM emission. Power Range—0-120 dbm. Price: **£105.0.0** each + £1.5.0 carr.

SIGNAL GENERATOR TS-419/URM64: Freq. 900-2100 Mc/s. CW or Pulse emission. Accuracy—freq. ± 1%. Power ± 2 db. Price: **£125.0.0** each + £1.5.0 carr.

TELEMETRY AUDIO OSCILLATOR TYPE 200T: (Hewlett Packard). Freq.— 250 c/s-100 Kc/s. 5 over-lapping bands. High stability. O/put 160 mw or 10V into 600 Ω. Price: **£65.0.0** each + £1.5.0 carr.

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 50 Ω. Price: **£85.0.0** each + £1.10.0 carr.

FREQUENCY METER TS-74 (same TS-174): Heterodyne crystal controlled. Freq. 20-280 Mc/s. Accuracy .05%. Sensitivity 20 mV. Internal Mod. at 1000 c/s. Power Supply—batteries 6V and 135V. Complete with calibration book. (Manufactured for M.O.D. by Telemax. "As new" in cartons.) **£75.0.0** each. Fully stabilised Power Supply available at extra cost **£7.10.0** each. Carr. £1.10.0.

ROTARY CONVERTERS: Type 8a, 24 v D.C., 115 v A.C. @ 1.8 amps, 400 c/s 3 phase, **£6/10/-** each, 8/- post. 24 v D.C. input, 175 v D.C. @ 40mA output, **25/-** each, post 2/-.

CONDENSERS: 40 mfd, 440 v A.C. wkg., **£5** each, 10/- post. 30 mfd, 600 v wkg. D.C., **£3/10/-** each, post 10/-. 15 mfd, 330 v A.C. wkg., **15/-** each, post 5/-. 10 mfd, 1000 v, **12/6** each, post 2/6. 10 mfd, 600 v, **8/6** each, post 5/-. 8 mfd. 2500 **£5** + 12/6 carr. 8 mfd, 1200 v, **12/6** each, post 3/-. 8 mfd, 600 v, **8/6** each, post 2/6. 4 mfd, 3000 v wkg., **£3** each, post 7/6. 4 mfd 2000 v. **£2** + 5/- post. 4 mfd. 600 v. 2 for **£1**. 0.25 mfd, 2Kv, **4/-** each, 1/6 post. 0.01 mfd. MICA 2.5 Kv. Price **£1** for 5. Post 2/6. Capacitor: 0.125 mfd, 27,000v wkg. **£3.15.0** each, 10/- post.

TCS MODULATION TRANSFORMERS, 20 watts, pr. 6,000 C.T., sec. 6,000 ohms. Price 25/-, post 5/-.

SOLENOID UNIT: 230 v. A.C. input, 2 pole, 15 amp contacts, **£2/10/-** each post 6/-.

CONTROL PANEL: 230 v. A.C., 24 v. D.C. @ 2 amps., **£2/10/-** each, carr. 12/6.

OHMITE VARIABLE RESISTOR: 5 ohms, 5½ amps; or 2.6 ohms at 4 amps. Price (either type) **£2** each, 4/6 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, **£4/10/-** each, 15/- carr.

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 **£6.10.0.** each, Carr. £1.

AUTO TRANSFORMER: 230-115V, 50-60c/s, 1000 watts, mounted in a strong steel case 5" × 6½" × 7". Bitumin impregnated. £5 each, Carr. 12/6. 230-115V, 50-60c/s, 500 watts. 7" × 5" × 5". Mounted in steel ventilated case. **£3** each, Carr. 10/-.

POWER UNIT: 110 v. or 230 v. input switched; 28 v. @ 45 amps. D.C. output. Wt. approx. 100 lbs., **£17/10/-** each, 30/- carr. SMOOTHING UNITS suitable for above **£7/10/-** each, 15/- carr.

MODULATOR UNIT: 50 watt, part of BC-640, complete with 2 × 811 valves, microphone and modulator transformers etc. **£7/10/-** each, 15/- carr.

CANADIAN HEADSET ASSEMBLY: Moving coil headphones 100 Ω, with chamois leather earmuffs. Small hand microphone complete with switch and moving coil insert. New condition. Price **35/-** each, post 5/-.

CATHODE RAY TUBE UNIT: With 3in. tube, Type 3EG1 (CV1526) colour green, medium persistence complete with nu-metal screen, **£3/10/-** each, post 7/6.

APNI ALTIMETER TRANS./REC., suitable for conversion 420 Mc/s., complete with all valves 28 v. D.C. 3 relays, 11 valves, price **£3** each, carr. 10/-.

ANTENNA WIRE: 100 ft. long. **15/-** + 5/- post.

APN-1 INDICATOR METER, 270° Movement. Ideal for making rev. counter. **25/-** each, 5/- post.

VARIABLE POWER UNIT: Complete with Zenith variac 0-230V., 9 amps.; 2½ in. scale meter reading 0-250V. Unit is mounted in 19 in. rack. **£15** each, 30/- carr.

AIRCRAFT SOLENOID UNIT D.P.S.T.: 24V, 200 Amps, £2 each, 5/- post.

RADAR SCANNER ASSEMBLY TYPE 122A: Complete with parabolic reflector, (24 in. diameter), meters, suppressors, etc. **£35** each, £2 carr.

DECADE RESISTOR SWITCH: 0.1 ohm per step. 10 positions. 3 Gang, each 0.9 ohms. Tolerance ±1% **£3** each, 5/- post. 90 ohms per step. 10 positions, total value 900 ohms. 3 Gang. Tolerance ±1% **£3/10/-** each, 5/- post.

MARCONI DEVIATION TEST SET TF-934: 2.5-100Mc/s (can be extended up to 500Mc/s on Harmonics). Dev. Range 0-75Kc/s in modulation range 50c/s-15Kc/s. 100/250V a.c. **£45** each, 30/- carr.

CRYSTAL TEST SET TYPE 193: Used for checking crystals in freq. range 3000-10,000Kc/s. Mains 230V, 50c/s. Measures crystal current under oscillatory conditions and the equivalent parallel resistance. Crystal freq. can be tested in conjunction with a freq. meter. **£12.10.0** each, £1 carr.

LEDEX SWITCHING UNIT: 2 ledex switches, 6 Bank and 3 Bank respectively, 6 Pos.; 1 Manual switch, 16 Bank 2 Pos. **£4** each, 10/- post.

GEARED MOTOR: 24v. D.C., current 150mA, output 1 rpm, **30/-** each, 5/- post. **ASSEMBLY UNIT** with Letcherbar Tuning Mechanism and potentiometer, 3 rpm, **£2** each, 5/- post. **SYNCHROS:** and other special purpose motors available. List **6d.**

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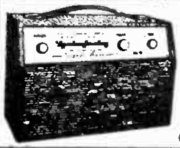

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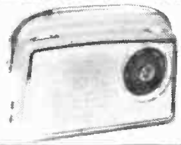

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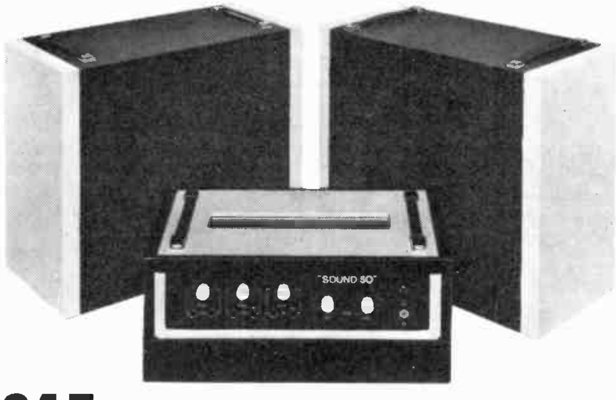

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AF118	8/10	BF152	13/6	MJ490	22/6	NKT222	6/-	NKT773	3/7	P346A	3/9	2N743	4/6	2N3392	5/-	2N5028	11/6	ZTX503	3/4	TD716	12/-
AF121	6/-	BF154	9/-	MJ491	29/6	NKT223	5/-	NKT774	6/-	RAS310AF	6/-	2N744	6/-	2N3393	5/-	2N5029	9/6	ZTX504	7/11	1B08T10	10/-
AF124	5/-	BF159	15/-	MPF102	8/6	NKT224	3/7	NKT0013	6/6	RAS508AF	15/-	2N911	10/-	2N3394	4/9	2N5030	8/6	ZTX510	3/4	1N34A	4/-
AF125	4/2	BF163	9/-	MPF103	7/6	NKT225	3/6	NKT10419	3/10	SIM	19/-	2N914	3/11	2N3402	5/6	2N5172	3/-	AA119	2/-	1N60	4/-
AF126	3/6	BF167	5/-	MPF104	7/6	NKT226	11/-	NKT10519	4/5	S4M	33/6	2N918	8/5	2N3403	5/6	2N5174	10/6	AAY11	2/-	1N64	4/-
AF127	3/6	BF173	6/-	MPF105	8/-	NKT227	9/6	NKT10339	4/7	ST2	9/9	2N929	5/3	2N3404	7/6	2N5175	10/6	AAY30	1/7	1N82A	9/6
AF139	15/-	BF178	10/6	NKT11	7/6	NKT228	6/6	NKT10439	5/5	T1407	9/8	2N930	6/-	2N3414	5/6	2S001	10/-	AAZ12	6/-	1N87A	4/6
AF178	9/6	BF179	12/6	NKT12	5/5	NKT229	3/11	NKT12329	8/5	TIC45	8/-	2N1131	6/-	2N3415	6/-	2S002	12/6	AAZ13	3/2	1N914	3/6
AF179	11/6	BF180	7/6	NKT32	6/-	NKT231	6/-	NKT12429	10/6	TIS34	17/6	2N1132	6/-	2N3416	7/6	2S003	12/6	BA102	9/-	1N3713	30/-
AF180	12/6	BF181	7/6	NKT42	6/-	NKT232	6/-	NKT13329	3/11	TIS44	1/9	2N1302	3/7	2N3436	15/-	2S004	15/-	BA110	6/-	1N3717	30/-
AF186	8/-	BF184	5/-	NKT43	6/-	NKT237	5/9	NKT13429	3/11	TIP31A	12/4	2N1303	4/6	2N3525	21/9	2S005	15/-	BA111	6/-	1N4001	1/6
AF239	7/6	BF185	5/-	NKT72	3/9	NKT238	4/-	NKT16229	8/5	TIP32A	14/10	2N1304	4/11	2N3528	19/-	2S006	15/-	BA112	18/-	1N4002	1/6
AFY19	22/6	BF194	3/6	NKT73	3/7	NKT239	4/-	NKT20329	6/8	V205	20/-	2N1305	4/11	2N3606	5/6	2S017	15/-	BA114	3/-	1N4003	2/-
AFZ11	8/-	BF196	4/-	NKT101	6/-	NKT240	3/10	NKT20339	6/4	V405A	9/3	2N1306	6/-	2N3607	4/6	2S018	17/6	BA115	1/6	1N4004	2/-
ASY26	4/5	BF200	7/-	NKT102	6/-	NKT241	3/9	NKT35219	15/9	40250	10/9	2N1307	6/-	2N3702	2/6	2S019	19/6	BA130	3/-	1N4005	2/6
ASY27	6/-	BFX13	5/-	NKT103	6/-	NKT242	2/11	OC19	5/-	40309	6/6	2N1308	6/-	2N3703	2/5	2S020	20/-	BAX13	1/6	1N4006	3/-
ASY28	4/5	BFX29	6/2	NKT104	6/-	NKT243	12/-	OC20	19/6	40310	9/-	2N1309	6/3	2N3704	3/2	2S104	12/6	BAY31	2/6	1N4007	4/-
ASY29	6/-	BFX44	8/-	NKT105	6/-	NKT244	3/1	OC22	8/-	40311	6/9	2N1613	4/6	2N3705	2/8	2S301	8/6	BAY38	3/-	1N4148	1/6
ASZ21	7/6	BFX84	5/2	NKT106	6/-	NKT245	3/-	OC23	10/-	40312	9/6	2N1711	5/-	2N3706	2/3	2S302	7/6	BC107	2/6	1S44	1/6
AUY10	30/-	BFX85	6/9	NKT107	6/-	NKT261	4/3	OC24	10/-	40314	7/3	2N2147	16/3	2N3707	2/10	2S303	10/-	BC108	2/6	1S100	3/2
B2M	12/6			NKT108	6/-	NKT262	4/3	OC25	7/6	40315	7/3	2N2148	12/6	2N3708	1/10	2S304	12/6	BC109	2/6	1S107	6/6
B3M	15/-	BFX86	4/11	NKT109	6/-	NKT263	4/8	OC26	6/6	40316	9/3	2N2160	12/6	2N3709	2/-	2S306	15/-	8C115	6/6	1S410	5/1
BC113	5 -	BFX87	5/11	NKT121	10/6	NKT264	4/3	OC28	12/-	40317	7/3	2N2217	5/5	2N3710	2/3	2S320	9/-	BC117	9/-	1S410R	5/1

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25+2/3 100+2/-

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115 watt silicon power transistor, Westinghouse
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2N2926 2/-
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Mullard lock-fit AM/FM Input & Mixer Transistor
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TOSHIBA TH9013P
INTEGRATED CIRCUIT AMPLIFIER as described WW December. Now available ex stock.
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0A91 SPECIAL OFFER
Mullard Diode
25+9d. 100+7d.

CHEAP LOGIC!!
(FAIRCHILD USA)

	1-11	12-24	25-99	100+
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Data and circuits article, 5-page, at 2/6. Article "30 Suggested Circuits for Micro-logic", at 3/-. TO5 to DIL conversion spreaders/adapters at 1/6 each.

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1 Amp Miniature Moulded Junction Rectifiers

	PIV	1-24	25+	100+	500+
1N4001	50	1/6	1/4	1/2	1/-
1N4002	100	1/6	1/4	1/2	1 -
1N4003	200	2/-	1/9	1/6	1/3
1N4004	400	2/-	1/9	1/6	1/3
1N4005	600	2/6	2/-	1/9	1/6
1N4006	800	3/-	2/10	2/6	2/3
1N4007	1000	4/-	3/3	2/9	2/6

In the event of any 1N4000 series going temporarily out of stock we reserve the right to send higher voltage types at no extra charge.

1000+ and over prices on application:

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400mW 10% GLASS CASE. TEXAS Mfr.

1S2036	3·6 volt	1S2082	8·2 volt
1S2039	3·9 volt	1S2100	10 volt
1S2043	4·3 volt	1S2110	11 volt
1S2047	4·7 volt	1S2120	12 volt
1S2056	5·6 volt	1S2160	16 volt
1S2062	6·2 volt	1S2180	18 volt
1S2068	6·8 volt	1S2270	27 volt
1S2075	7·5 volt	1S2300	30 volt

Prices: 1-24, 3/6; 25-99, 2/9; 100+, 2/3.

ULTRASONIC TRANSDUCERS

Operate at 40kc/s. Can be used for remote control systems without cables or electronic links. Type 1404 transducers can transmit and receive.
FREE: With each pair our complete transmitter and receiver circuit.

PRICE
£5.18.0 Pair
(Sold only in pairs)

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Some R.C.A. Linear Types

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CA3011	14/9	CA3021	31/3	CA3035	24/6	CA3044	24/-
CA3012	17/9	CA3022	26/-	CA3036	14/6	CA3045	24/6
CA3013	21/-	CA3023	25/3	CA3039	16/9	CA3046	15/2
CA3014	24/9	CA3026	20/-	CA3041	21/9	CA3048	40/9
CA3018	16/9	CA3028A	14/9	CA3042	21/9	CA3051	26/9

Application Notes for each individual type 2/6d. per copy.

PA234	GE IC 1 Watt Amplifier	17/6
PA237	GE IC 2 Watt Amplifier	37/6
PA246	GE IC 5 Watt Amplifier	52/6
PA424	GE IC Zero Voltage Switch	49/6
SL403A	Plessy 3 Watt Amplifier	42/6
SL702C	Plessy Linear	29/6
TAA263	Mullard Linear	15/-
TAA293	Mullard General Purpose Amplifier	20/-
TAA310	Record/Playback Amplifier	30/-
TAA320	MOS LF Amplifier	13/-
TAD100	Mullard IC Receiver	39/6
TAD110	Mullard IC Receiver	39/6
3N84	GE Silicon Controlled Switch	26/-

Data Sheets 1/- (SL403A 2/6. IC10 data not sold separately).

Prices quoted are current at time of going to press. E. & O.E. and may be subject to variation without notice. Items listed not in current production will be withdrawn when stocks advertised are sold. Semi-conductors offered carry full manufacturer's **guarantee** where applicable. **Data** sheets will be supplied on request 1/- per copy. **Price breaks** apply at 25+ and 100+ Please contact Sales Dept. for Price and Availability. Tel.: Brentwood 226470/1.
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WIRE-ENDED TYPES

REF. No.			REF. NO.			REF. No.			REF. NO.			REF. NO.		
G1/11	20/450V	2/-	H1/11	8/6V	6d	G4/13	400/50V	2/-	H7/2	20/15V	1/-	H7/10	60/15V	1/6
G1/13	40/50V	1/-	H2/1	32/150V	1/-	G4/14	500/4V	9d	H7/2A	20/6.4V	9d	H7/11	64/25V	1/6
G2/5	10/6V	9d	H2/2	64/2.5V	9d	H5/3A	500/25V	2/-	H7/3	25/12V	9d	H7/13	75/15V	1/6
G2/6	8/12V (REV)	9d	H2/6A	24/275V	1/-	H5/6A	40/3V	6d	H7/4	25/25V	1/6	H7/14	100/4V	1/-
G3/7	100/25V	2/-	H2/8	32/150V	1/-	H5/7	30/6V	6d	H7/4A	25/20V	1/6	H8/2	2/50V	1/-
G3/14	100/180V	2/-	H2/9A	2/150V	1/-	H5/11	400/6.4V	9d	H7/5	40/15V	1/6	H8/3	3/50V	1/-
G5/9	8/8/450V	3/-	H2/10A	16/32/350V	2/-	H5/12	320/10V	1/-	H7/6	50/3V	6d	H8/6	8/50V	1/-
G6/13A	40/450V	2/-	H2/11A	32/275V	1/6	H5/14	5/6V	6d	H7/6A	26/50V	1/6	H8/7	12/25V	1/6
H1/1	1/6V	6d	H3/7A	500/12V	1/6	H6/1	100/50V	1/6	H7/7	50/12V	1/6	H8/7A	15/15V	1/6
H1/3	4/4V	6d	H3/8	750/12V	1/6	H6/6	200/3V	6d	H7/7A	50/10V	1/-	H8/10	2/275V	1/-
H1/4	6/6V	6d	H3/10A	30/10V	6d	H6/7	200/16V	1/6	H7/8	50/15V	1/6	H8/11A	250/12V	1/6
H1/7	20/6V	6d	H3/12	16/50 (REV)	2/-	H6/13	500/3V	9d	H7/9	60/12V	1/6	H8/13	100/25V	2/-
H1/9	50/6V	6d	H4/1	20/4/275V	1/6	H7/1	10/12V	9d						

CAN TYPES

REF. NO.			REF. NO.			REF. NO.			REF. NO.			REF. NO.		
G2/1	6,000/30V	7/6	G4/1	300/700/320V	7/6	G5/4A	500/100V	3/-	G6/9	60/200/300V	5/-	H3/4	1,000/50V	6/-
G2/5	125/200V (REV)	5/-	G4/5A	60/350V	1/-	G5/5	400/275V	3/-	G6/11A	400/300V	3/-	H3/4A	3,000/25V	3/-
G2/10	50/50V	1/-	G4/6	60/200/275V	2/6	G5/7	100/400/300V	7/6	G6/12A	1,000/12V	3/-	H3/6	2,500/9V	2/6
G2/11	100/350V	2/-	G4/7	40/40/275V	1/6	G5/7A	45,000/12V	15/-	H5/4	325/25V	1/6	H3/6A	5,000/18V	4/-
G3/2	200/200/350V	6/-	G4/7A	40/40/450V	2/6	G6/1	12,000/15V	15/-	G6/14	400/275V	3/-	H3/9	100/275V	2/-
G3/2A	200/200/100/350V	7/6	G4/11	2,000/25V	3/-	G6/2	2,500/40/60V	7/6	H1/5	2,000/18V	3/-	H3/13	16/16/375V	2/-
G3/4	650/300V	7/6	G4/12	150/30V	1/-	G6/2A	2,500/50V	7/6	H1/6	125/200V	2/-	H4/3	500/12V	1/6
G3/9	100/200/250V	6/-	G4/13	100/200/16/275V	6/-	G6/3	2,000/50V	7/6	H1/12	200/275V	2/-	H4/5	32/32/350V	2/-
G3/10	40/20/10/10/350V	3/-	G5/1	8,000/70V	10/-	G6/3A	2,000/15V	3/-	H1/15	100/200/60/275V	5/-	H4/9	500/6V	1/-
G3/10A	200/350V	2/-	G5/2	300/300/350V	4/-	G6/5	1,000/1,500/25V	7/6	H2/6	50/275V	1/6	H4/11	75/400/16/275V	7/6
G3/13A	2,000/30V	5/-	G5/2A	30,000/40V	15/-	G6/5A	1,600/80V	7/6	H2/9	16/16/450V	2/-	H6/10	250/25V	1/6
			G5/3	35,000/15V	15/-	G6/6	1,000/60V	6/-	H2/10	1,000/100V	7/6	H8/13	6,000/6V	4/-
			G5/4	39,000/10V	10/-	G6/8	200/250V	3/-	H3/2	2,500/100V	7/6			

TAG ENDS

REF. NO.			REF. NO.			REF. NO.			REF. NO.			REF. NO.		
G1/4	4/150V	1/-	G2/4	40/300V	1/6	G4/9	8/8/350V	2/-	G6/7	100/275V	2/-	H4/2	250/25V	1/6
G1/5	8/275V	1/-	G2/13	100/50V	1/-	G4/10	350/25V	2/-	G6/12	1,000/12V	2/-	H4/7A	32/32/275V	2/6
G1/5A	32/350V	1/6	G4/3A	200/25V	1/6	G6/1A	3,000/15V	3/-	H1/9A	50/150V	1/-	H4/12	500/50V	2/-
G1/7	16/16/275V	2/-	G4/5	16/300V	1/-	G6/4	1,000/50V	6/-	H3/5	250/150V	2/-	H5/6	250/50V	2/-
G1/12	40/450V	2/-												

PRINTED CIRCUIT. CAN TYPE

REF. NO.			REF. NO.			REF. NO.			REF. NO.			REF. NO.		
G1/6	16/32/450V	2/-	G3/12	100/200/16/16/300V	5/-	G5/14	8/8275V	1/6	H3/9	100/275V	2/-	H5/2	64/32/8/275V	2/-
G1/8A	16/350V	1/-	G3/13	64/275V	2/-	G6/4A	1,000/25V	2/6	H3/10	100/250V	2/-	H5/3	500/25V (REV)	2/6
G1/10	32/275V	1/-	G4/3	250/150V	2/-	G6/11	40/350V	1/-	H3/13A	16/16/275V	1/6	H5/8	32/32/275V	1/6
G1/14	16/275V	1/-	G4/4	50/50/200V	2/-	G6/12	250/25V	2/-	H4/3A	500/50V	1/6	H5/9	100/100/150V	2/-
G2/10	100/100/350V	3/-	G4/8	40/40/450V	2/-	H1/10A	10/10/350V	1/6	H4/4	400/6 (REV)	2/-	H5/13	32/32/8/300V	2/-
G2/12	100/150V	2/-	G5/6	60/100/275V	2/6	H1/12	200/275V	2/-	H4/6	64/275V	2/-	H5/9	50/50/50/350V	3/-
G2/14	20/10/10/450V	2/-	G5/8A	100/65/250V	2/-	H1/13	250/150V	2/-	H4/7	32/32/350V	2/-	H6/4	150/150V	1/6
G3/1	60/100/350V	3/-	G5/10	100/100/50/350V	3/-	H2/4	50/80/300V	2/-	H4/8	8/8/8/275V	2/6	H6/14	1,000/20V	2/-
G3/6	100/250V	2/-	G5/11	100/200/25V	2/-	H2/5	100/100/100/275V	2/6	H4/10	10/10/425V	2/6	H8/11	250/25V	2/-
G3/6A	50/50/350V	2/-	G5/12	100/20/10/350/20/50V	2/6	H2/6	50/275V	1/6	H4/13	400/250V	3/-	H8/12	3,000/6V	3/-
G3/8A	100/25V, 100/12V	2/-	G5/13	40/100/350V	2/6	H2/11	32/32/250V	1/6	H5/1	150/200V	2/-	H8/13A	100/25/200/25V	1/6
G3/11	100/350V	2/6	G5/13A	40/40/40/40/350V	2/6	H2/12	50/50/150V	1/6				H3/11	150/200V	2/-

PRINTED CIRCUIT TYPE. WIRE LEADS.

REF. NO.			REF. NO.			REF. NO.			REF. NO.			REF. NO.		
G1/9	16/275V	1/6	H3/15	350/12V	1/6	H6/10	300/9V	1/-	H7/12	65/15V	1/6	H8/4	5/15V	1/-
H2/7	10/25V	1/-	H5/1	150/30V	1/6	H6/11	300/15V	1/6	H7/15	100/16	1/6	H8/8	20/9	1/-
H2/12A	350/12V	1/-	H5/14A	1,100/10V	2/-	H6/14A	900/15V	2/-	H8/1	1/350V	1/-	H8/9	40/15	1/6
H2/15	12.5/40V	1/6	H6/5	150/25V	1/6									

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SCREENED LEADS. Specially designed to fill the demand for the most popular types—all leads consist of 9 ft. screened lead—except SL 11 which has 10 ft. co-axial cable.

SL 1 Phono plug to Phono plug	5/3
SL 2 Standard Jack Plug to Standard Jack Plug	12/-
SL 3 Standard Jack Plug to Phono Plug	9/-
SL 4 3-pin DIN to Phono Plug	7/6
SL 5 Phono Plug to Wander Plugs	9/-
SL 6 Standard Jack Plug to Wander Plugs	9/-
SL 7 3-pin DIN to Wander Plugs	6/9
SL 8 Phono Plug to Phono Coupler	9/-
SL 9 3.5mm Jack to Phono Plug	7/6
SL 10 Co-ax Plug to Co-ax Plug	6/9
SL 11 Car Aerial plug to Car Aerial socket	7/6
SL 12 3-pin DIN to 3-pin DIN	9/-
SL 13 Co-ax plug to 3.5mm Jack Plug	7/6
SL 14 3-pin DIN to 3.5mm Jack Plug	8/3
SL 15 Standard Jack Plug to 3-pin DIN	10/6
SL 16 3.5mm Jack to Wander Plugs	6/9
SL 17 3.5mm Jack to Standard Jack	10/6
SL 18 3.5mm Jack to 3.5mm Jack	8/3
SL 19 3-pin DIN to 5-pin DIN 'A'	9/-
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SL 21 5-pin DIN 'B' to 2 Phono	9/-

MULLARD POLYESTER CONDENSERS
1,000 pf., 1,200 pf., 1,800 pf., 2,200 pf., 400 volts, **3d.** each. 25 per cent discount 100 any type. .15uf., .22uf., .27uf., 160 volts **6d.** each. 25 per cent discount 100 any one type.

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¼ and ½ watt. Most values in stock. **10/-** per 100 of any one value. **2/-** dozen. **3d.** singles. MAINS DROPPER TYPE. Hundreds on values from .7 ohm upwards. 1 watt to 50 watts. A large percentage of these are multi-tapped droppers for radio/television. Owing to the huge variety these can only be offered 'assorted'. **10/-** per dozen.

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RECORDING TAPE BARGAIN! The very best British Made low-noise, high-quality Tape! 5in. Standard, **7/6d.** Long-play **9/-.** 5¾in. Standard **9/-.** Long-play **12/-** 7in. Standard **12/-.** Long-play **16/3.** We are getting a fantastic number of repeat orders for this tape. Might we suggest that you order now whilst we still have a good stock available?

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1 watt, 8 ohm output. All transistor, complete with screened input lead, volume control and speaker leads. This excellent unit has built-in rectifier and smoothing components enabling it to be used direct from any 6 to 9 volt bell transformer. Perfect for baby alarm or inter-com. Few only left. Cannot be repeated at **30/-** each.

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Once again we have a supply of these excellent radios which offer superb quality sound and excellent sensitivity. They are packed in a colourful presentation box complete with battery, earpiece and carrying case. Each one is guaranteed. You would expect to pay at least £5—but our price due to a bulk purchase is only **37/6d.** Many of our customers have made a considerable profit by buying these radios and re-selling them to friends!

RECORD PLAYER CARTRIDGES. Well below normal shop price!
ACOS GP 67/2 **15/-.** (Mono). ACOS GP 91/3 **20/-.** (Compatible) ACOS GP 93/1 **25/-** (Stereo) ACOS GP 94/– **30/-.** (Stereo, Ceramic). ACOS GP 93/– DIAMOND **32/6.** ACOS 94/1 DIAMOND **37/6.**

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In our opinion these units are the best value for money ever offered. A complete stereo unit consisting of Control unit, Pre-amplifier, Two Main Amplifiers and Power Pack complete and ready for use—NO extra components to buy—yours for **£15.** (Normal retail price is £16.10s.)
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Spot Face Cutter 7/6. Pin Insert Tool 9/6. Terminal Pins (.1 or .15) 3/6 for 36.
Special offer pack consisting of 5 2½in. × 1in. boards and Spot Face Cutter 10/-

VOLUME CONTROLS
DOUBLE POTS. Most with concentric Spindles.

500k log	+ 50k lin.	+ Switch	3/-	10k log	+ 10k log	+ Switch	4/6
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100k log	+ 100k log	+ Switch	3/-	1M lin.	+ 2.5M lin.	no Switch	2/6
250k log	+ 500k log	+ Switch	3/-	500k lin.	+ 500k log	no Switch	2/6
250k log	+ 100k lin.	+ Switch	3/-	100k log	+ 100k log	no Switch	2/6
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(6 cells will power a Micromatic radio)		
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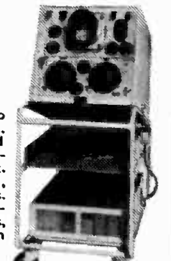
Mullard
TAA 300 38/6; TAA 320 11/6.

Plessey. SL402A 2·5W 42/6 SL403A 3·5 52/6

VALVE VOLTMETER TYPE TF 958
Measures AC 100mV; 20 c/s to 100 mc/s, DC 50mV to 100V, multiplier extends ac range to 1.5kV. Balanced input and centre-zero scale for DC. AC up to 100MHz. £32.10.0.

VIDEO OSCILLATOR TF 885A & 885A I
25Hz to 5MHz and 25Hz-12MHz respectively, fine and square wave output up to 31v £55 and £85 resp. Carriage 30/-.



SPECTRUM ANALYSER TYPE OA1094
Freq. range: 3 to 30MHz in 9 bands. Selectivity: 6, 30 and 150Hz at 3db. Spectrum width: 0-30kHz. Sweep Duration: 0.1, 0.3, 1, 3, 10 & 30 secs. Complete as illustrated, with manuals, etc. Price upon application.

AERIAL TUNING UNIT BC 939
Originally made to work with Hallicrafters BC 610E transmitters. 2mc to 18mc, for output up to 450 watts. Brand new £8.10.0. Carriage 20/-.

PRECISION VHF FREQUENCY METER TYPE 183. 20-300 Mc/s with accuracy 0.03% and 300-1,000 Mc/s with accuracy 0.3.%. Additional band on harmonics 5.0-6.25 Mc/s with accuracy + —2×10⁻⁴. Incorporating calibrating quartz 100 kc/s + —5×10⁻⁶ 120/220 v. A.C. mains. £85. Carriage £2.

AVO'S METERS
Model 48A complete with multiplier shunts, etc., in special fitted wooden case, £14.10.0. Carriage 7/6.

REDIFON
Twinplex combiner type AFS 13 £65
Twinplex converter type AFS 12 with P.S.W. £85
F.S.K. unit type GK 185A £58/10/0

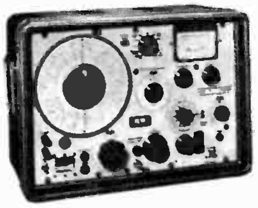
P. C. RADIO LTD.

PLEASE NOTE Unless offered as "as seen" **ALL EQUIPMENT** ordered from us is completely overhauled mechanically and electrically in our own laboratories

MARCONI TEST EQUIPMENT

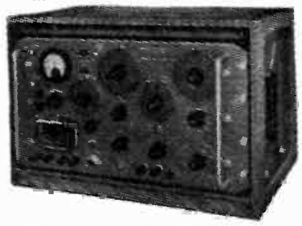
TF1041C VTVM A.C. voltage range 300 MV to 300V in 7 ranges. 20 Hz-1500 MHz. D.C. voltage ranges 300 MV-1000V in 8 ranges. D.C. resistance 50 ohms to 500 Mohms. Price £62.10.0.

TF144H SIGNAL GEN. Freq. range 10 KHz-72 MHz. R.F. output 2uV to 2V at 50 ohms 400 and 1000 Hz internal mod. Limited qty. only available. Full spec and price on request.



TF 144G SIGNAL GENERATOR. To clear. In very good "as seen" condition. Complete with mains and battery cables, etc. £15.

SIGNAL GENERATOR TF 801/A. 10-300 Mc/s. in 4 bands. Internal at 400 c/s. 1 kc/s. External 50 c/s to 10 kc/s. Output 0-100 db below 200 mV from 75 ohms source. £85. DITTO but 801/A/1 with additional high level output. £89. Both P. & P. 20/-, including necessary connectors, plugs, and instruction manual.



IMPEDANCE BRIDGE TYPE TF 936 (No. 5). Measures L & C at 80Hz, 1kHz, 10kHz. Ranges:—L: 1μH-100H. C: 1mF-100μF. R: 0.1ohms-100mohms. AC Bridge volts monitored and variable. Automatic detector sensitivity control. £105. Carriage 30/-.

F.M. DEVIATION METER TYPE TF934. Frequency range 2.5-100MHz. Can be used up to 500MHz. Deviation range 0-75kHz £67/10/0. Carriage 30/-

SOLARTRON EQUIPMENT
Regulated and stabilised **P.S.U. SRS 151A,** 20 to 500V positive at 300mA in two ranges. Variable and fixed 170V negative output, £35. Carriage 20/-.
CD 711S.2. Double beam, DC to 7MHz 'scope, £85. Carriage 30/-.
CD 643.2. Single beam Laboratory Model, DC to 14MHz price upon application.

SIGNAL GENERATOR TYPE CT 480. 7-12kMHz in one range, square and pulse modulation and C.W. £65.

SIGNAL GENERATOR TYPE CT 478. As above but 1.3-4.2kMHz in two ranges £55.

1½in. DIA. PANEL METERS. 7½-15v —ideal for "Battery Condition" indicators for cars 15/6.

BOONTON Q METER TYPE 160A. Freq. range 50kHz to 75MHz, main capacitor 30 to 500pF. Vernier capacitor ± 3pF; q range. 0-250 with 2.5× multiplier. £85 plus carriage.

NOISE GENERATOR CT 207. 100-600 M/c with built-in 8-minute timer Complete with cables. £57.10.0.

MULLARD PRECISION VARIABLE CAPACITOR TYPE F.2.
15 pF to 336 pF. Supplied with individual calibration certificate. Brand new in original packing. £17. Carriage 15/-.

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Pye £25. P. & P. 12/-.
Cambridge Instruments £12. P. & P. 12/-.

VACUUM CONDENSERS
12, 50, 55pF each 20,000v 30/-. P. & P. 4/-.

BRADLEY PORTABLE ELECTRONIC MULTIMETER TYPE CT471B. This instrument operates from three 1½V cells, is fully transistorised and measures A.C. and D.C. current, A.C. and D.C. voltage and D.C. resistance. Built-in battery check and calibration check. Full spec. and price on request.
As above but MODEL CT 471A manufactured by AVO, full spec and price on request.

4, 5 and 8 bank 25 way uniselectors, 24V, guaranteed perfect, £3.15.6; £4.10.0; £6.17.6 respectively.

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AVO VALVE CHARACTERISTIC METER complete with manual. £57.10.0. Carriage. 30/-.

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FIELD TELEPHONE TYPE "F". Housed in portable wooden cases. Excellent for communication in and outdoors for up to 10 miles. Pair including batteries, fully tested. £6.10.0, or with 220 yds field cable in drum £7.10.0.

FOR EXPORT ONLY
53 TRANSMITTERS. All spares available. COLLINS TCS. Complete installations and spare parts.
COLLINS TYPE 231D 5KW TRANSMITTERS. 10 channel, autotune and manual tuning. Complete with very comprehensive spares. Full specification and price on application.
Complete installations and all spares. No. 19 WIRELESS SETS. H.P. SETS and all spares R 210 RECEIVERS with all necessary accessories.
PYE PTC 2002N A.M. Ranger Mobile Radio Telephone, brand new and complete, £45.

★ **Open 9-12.30, 1.30-5.30 p.m. except Thursday 9-1 p.m.** ★

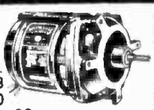
TELEPHONE ENQUIRIES relating to **TEST EQUIPMENT** should be made to 01-748 8006 Extension 23.
To view **TEST EQUIPMENT** please phone for appointment

All overseas enquiries & orders please address to:
COLOMOR (ELECTRONICS) LTD.
170 Goldhawk Rd., London, W.12
Tel. 01 - 743 0899

SERVICE TRADING CO

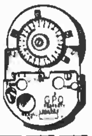
Postage and Carriage shown below are inland only. For Overseas please ask for quotation. We do not issue a catalogue or list.

BODINE TYPE N.C.1 GEARED MOTOR



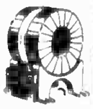
(Type 1) 71 r.p.m. torque 10 lb. in. **Reversible** 1/70th h.p. 50 cycle .38 amp. **(Type 2) 28 r.p.m.** torque 20 lb. in **Reversible** 1/80th h.p. 50 cycle .28 amp.
The above two precision made U.S.A. motors are offered in 'as new' condition. Input voltage of motor 115v A.C. Supplied complete with transformer for **230/240v A.C. input**
Price, either type **£3.3.0** plus 6/6 P. & P. or less transformer **£2.2.6** plus 4/6. P. & P.
These motors are ideal for rotating aerials, drawing curtains, display stands, vending machines etc. etc.

VENNER ELECTRIC TIME SWITCH



200/250 volt. Ex-GPO. Tested, perfect condition. Two ON, two OFF, every 24 hrs. at any manually pre-set time. Price: 10amp. **£2 15 0.** 15amp. **£3/5/0.** 20amp. **£3/15/0.** P. & P. 4/6. Also available with Solar Dial ON at dusk, OFF at dawn. Prices as above.

RING TRANSFORMER



Functional Versatile Educational

This multi-purpose Auto Transformer, with large centre aperture, can be used as a Double wound current Transformer, Auto Transformer, H.T. or L.T. Transformer, by simply hand winding the required number of turns through the centre opening. E.g. Using the RT.100 V.A. Model the output could be wound to give 8V @ 12½Amp., 4V. @ 25Amp. or 2V. @ 50Amp., etc.

Price:
RT 100VA 3.18 turns per volt, £2 5 0 + 3/6 p. and p.
RT 300VA 2.27 turns per volt, £4 4 0 + 5/6 p. and p.
RT 1KVA 1.82 turns per volt, £6 10 0 + 6/6 p. and p.
RT 2KVA 1.5 turns per volt, £10 10 0 + 9/6 p. and p.
RT 3KVA 1.5 turns per volt, £14 0 0 + 10/- p. & p.

L.T. TRANSFORMERS

All primaries 220-240 volts.

Type No.	Sec. Taps	Price	Carr.
1	12 v. at 5A	£1 17 6	5/6
2	30, 32, 34, 36 v. at 5 amps.	£4 13 6	6/-
3	30, 40, 50 v. at 5 amps.	£6 17 6	6/6
4	10, 17, 18 v. at 10 amps.	£4 19 0	4/6
5	6, 12 v. at 20 amps.	£6 8 6	6/6
6	17, 18, 20 v. at 20 amps.	£7 5 6	6/6
7	6, 12, 20 v. at 20 amps.	£6 17 6	7/6
8	24 v. at 10 amps.	£5 4 6	5/6
9	4, 6, 24, 32 v. at 12 amps.	£7 3 0	6/6

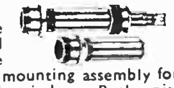
AUTO TRANSFORMERS. Step up, step down. 110-200-220-240 v. Fully shrouded. New. 300 watt type **£3/12/6** each, P. & P. 4/6. 500 watt type **£5/2/6** each, P. & P. 6/6. 1,000 watt type **£7/2/6** each, P. & P. 7/6.

LIGHT SENSITIVE SWITCHES

Kit of parts including ORP.12 Cadmium Sulphide Photocell. Relay Transistor and Circuit. Now supplied with new Siemens High Speed Relay for 6 or 12 volt operations. **Price 25/-**, plus 2/6 P. & P. **ORP. 12 and Circuit 12/6 post paid.**

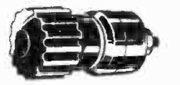
220/240 A.C. MAINS MODEL
incorporates mains transformer rectifier and special relay with 1 make, 1 break, H.D. contacts. Price inc. circuit 47/6, plus 2/6 P. & P.

LIGHT SOURCE AND PHOTO CELL MOUNTING



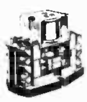
Precision engineered light source with adjustable lens assembly and ventilated lamp housing to take MBC bulb. Separate photo cell mounting assembly for ORP.12 or similar cell with optic window. Both units are single hole fixing. Price per pair **£2/15/0** plus 3/6 P. & P.

INSULATED TERMINALS



Available in black, red, white, yellow, blue and green. New 2/- each. Post paid.

A.C. CONTACTOR



2 make and 2 break (or 2 c/o) 15 amp. contacts. 230/240 v. A.C. operation. Ex-equipment, Tested. **22/6** plus 1/- P. & P.

PANEL METER AT BARGAIN PRICE A.C. VOLTMETER

Latest type 1¾" × 1¾"
0-300 volts A.C. Rectified moving coil 2¼ in. Price **29/-** each. Plus 1/6 P. & P.

GALVANOMETER

300-0-300 microamp. Calibrated 30-0-30. Mounted in sloping front case **£2/10/-.** P. & P. 3/6 **D.C. Voltmeter** 0-3 V and 0-15. V **£2** plus 3/6 P. & P.
D.C. Ammeter. 0-6 amp. and 0-3 amp. **£2,** 3/6 P. & P.
The set of 3 matching instruments **£6,** P. & P. 6/6.

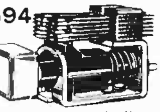
POWER RHEOSTATS

(NEW) Ceramic construction, winding embedded in Vitreous Enamel, heavy duty brush assembly designed for continuous duty. **AVAILABLE FROM STOCK IN THE FOLLOWING 11 VALUES: 100 WATT 1 ohm 10a., 5 ohm 4.7a., 10 ohm 3a., 25 ohm 2a., 50 ohm 1.4a., 100 ohm 1a., 250 ohm ·7a., 500 ohm ·45a., 1k ohm 280mA., 1·5k ohm 230mA., 2·5k ohm ·2a., 5k ohm 140mA., Diameter** 3¼in. Shaft length ⅜in. dia. ¼in., **27/6.** P. & P. 1/6.
50 WATT 1/5/10/25/50/100/250/500/1K/1·5K/2·5K/5K ohm. All at **21/-,** P. & P. 1/6.
25 WATT 10/25/50/100/250/500/1K/1·5K/2·5K ohm. All at **14/6,** P. & P. 1/6.
Black Silver Skirted knob calibrated in Nos. 1-9. 1½ in. dia. brass bush. Ideal for above Rheostats, 3/6 each.

MOTOROLA MAC11/6 PLASTIC TRIAC 400 PIV 8 AMP

Now available EX STOCK supplied complete with full data and applications sheet. Price 21/- plus 1/6 P. & P.

T.M.C. ILLUMINATED LATCHING PUSH BUTTON KEY SWITCH No. S525594 LOCK 4 c/o



Complete with mounting bracket, PushKnobandLenses (GREEN, AMBER, RED or CLEAR — state colour preference). PRICE 14/6 each excluding bulb, Post Paid. Discount for quantities of 200 or over.

STROBE! STROBE! STROBE!

THREE EASY TO BUILD KITS USING XENON WHITE LIGHT FLASH TUBES. SOLID STATE TIMING + TRIGGERING CIRCUITS. PROVISION FOR EXTERNAL TRIGGERING. 230-250v. A.C. OPERATION.
The Strobe is one of the most useful and interesting instruments in the laboratory or workshop. It is invaluable for the study of movement and checking of speeds. Many uses can be found in the psychiatric and photographic fields, also in the entertainment business. It is used a great deal in the motor industry and is a real tool as well as an interesting scientific device.

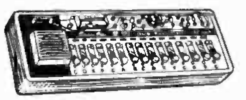
EXPERIMENTERS "ECONOMY" KIT
Adjustable 1 to 36 Flash per sec. All electronic components including Veroboard S.C.R. Unijunction Xenon Tube + instructions **£5.5.0** plus 5/- P. & P.

NEW INDUSTRIAL KIT
Ideally suitable for schools, laboratories etc. Roller tin printed circuit. New trigger coil, plastic thyristor Adjustable 1-80 f.p.s. Price **9 gns.** 7/6 P. & P.

HY-LYGHT STROBE
This strobe has been designed for use in large rooms, halls and the photographic field, and utilizes a silica tube for longer life expectancy, printed circuit for easy assembly, also a special trigger coil and output capacitor. Speed adjustable 1-30 f.p.s. Light output approx. 4 ioules. Price **£10.17.6.** P. & P. 7/6.

7-INCH POLISHED REFLECTOR. Ideally suited for above Strobe Kits. Price 10/6 and 2/6 P. & P. or post paid with kits.

ELECTRONIC ORGAN KIT



Ideal present for Electronically minded boy. Easy to build, solid state. Two full octaves (less sharps and flats). Fitted hardwood case, using two penlite 1½v. batteries. Complete set of parts including speaker, etc., together with full instructions and 10 tunes. Have all the pleasure of building this instrument and finish with a functional, instructive gift for any boy or girl. Price **£3.0.0.** P. & P. 4/6.

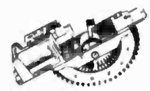
50 in 1 ELECTRONIC PROJECT KIT

50 easy to build Projects. No soldering, no special tools required. The Kit includes Speaker, meter, Relay, Transformer, plus a host of other components and a 56-page instruction leaflet. Some examples of the 50 possible Projects are: Sound level Meter, 2 Transistor Radio, Amplifier etc., etc. Price **£7.15.0.** P. & P. 6/-.

10 in 1 PROJECT KIT

10 easy to build Projects including: Radio, Morse Oscillator, L F Oscillator etc. A Solar Cell is included in this Kit as alternative power for some of the circuits also a 14-page step by step instruction leaflet. Price **£3.17.6.** P. & P. 4/6.

UNISELECTOR SWITCHES *NEW*



4 BANK 25 WAY FULL WIPER
25 ohm coil, 24 v. D.C. operation. **£5.17.6,** plus 2/6 P. & P.

6 BANK 25 WAY FULL WIPER 25 ohm coil, 24 v. D.C. operation. **£6.10.0,** plus 2/6 P. & P.

8-BANK 25-WAY FULL WIPER
24 v. D.C. operation, **£7.12.6,** plus 4/- P. & P.

RELAYS NEW SIEMENS PLESSEY, etc.

MINIATURE RELAYS AT COMPETITIVE PRICES.

1	2	3	4	1	2	3	4
52	6-9	6M	12/6*	700	12-24	2 c/o	12/6*
180	6-12	2 c/o E-E	8/6*	700	16-24	6M	12/6*
185	6-12	4 c/o E-E	10/-*	1250	24-36	4 c/o	12/6*
230	6-12	2 HD c/o	12/6*	1250	36-45	6M	12/6*
280	6-12	2 c/o	14/6*	2500	36-45	6M	12/6*
700	16-25	4M 2B	12/6*	5800	80-85	4 c/o	12/6*
700	16-24	4 c/o	15/6*	9000	40-70	2 c/o	10/-*
				15K	85-110	6M	10/-*

* including Base
(1) Coil ohms; (2) Working d.c. volts; (3) Contacts; (4) Price E-E Ex. Equipment. All Post Paid.

MINIATURE RELAYS

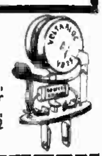
9—12 volt D.C. operation. 2 c/o 500 M.A. contacts. Size only 1in. × ⅞ × ⅝in. Price 11/6 Post paid.
30-36 v. D.C. operation. 2 c/o 500 M.A. contacts. 3.200 ohm coil. Size only 1 × 7/16 × 11/16in 8/6 post paid.

SPECIAL OFFER

Relay 18/24 v. D.C. 2 c/o 3 Amp contacts. 400 ohm coil. NEW. **9/6** P. & P. 1/6 or 3 for **30/-** post paid.
TYPE A.G.C. 1M 1B 12v. A.C. 3 amp contacts. NEW 9/6 + 1/6 p. & p. or 3 for **30/-** post paid.

MAINS RELAY
230 v. A.C. coil 3 c/o, 10 amp. A.C. contacts. **14/6** + 1/6 p. & p. Similar to above illustration.

RECHARGEABLE NICKEL CAD. BUTTON CELLS.

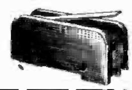


2 × 1.2 v. 250 MA/HR Nickel Cad. Cells, connected to give 2.4 v., at 25 milliamp/10 hour rate, complete with 200/250 v. A.C. charger, unused. Price 9/6 each plus 1/6 p. & p. or 2 units for £1 post paid.

HOSIDEN DH-02-S Stereo Headphones

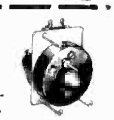
Outstanding performance. 8 ohm impedance and 20-12,000 cps. Adjustable head band. Price only 47/6. P. & P. 2/6. Complete with lead and stereo jack plug.

BURGESS MICRO SWITCH



Lever operated. c/o contacts. Price 4/- plus 9d. P. & P. 10in. maker's carton. **35/-** post paid.

200-250 VOLT AC 1 R.P.M. GEARED MOTOR

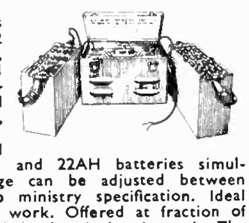


Dimensions: 4" × 3" × 2½". Spindle length 13/16", diameter ¼". Manufactured by SEC. Price 22/6 plus 3/6 p. & p.

VEEDER ROOT COUNTER

230 v. A.C. 50 cycle 5 figure counter (non resetable). 18/6, P. & P. 1/6.

COMPLETE NI. CAD. BATTERY OUTFIT (EX W.D.)



2 metal carrying cases each containing 10 × 1.2 volt 7 AH (12v) batteries, also 10 × 1.2v 22 AH (12v) batteries (40 batteries in all). 1 Dual voltage, dual meter, thyristor controlled charging unit. Designed for charging the 7AH and 22AH batteries simultaneously. Input voltage can be adjusted between 100-250v AC. Built to ministry specification. Ideal power supply for field work. Offered at fraction of makers price. 2 sets of batteries, 1 charging unit. The set **£45** c. & p. 30/-.

NICKEL CADMIUM BATTERY

1.2 v. 35 AH. Size 8¾ high × 3 × 1¼. **30/-** each, plus 4/- P. & P
Sintered Cadmium Type 1.2 v. 7AH. Size: height 3½ in., width 2⅛in. × 1 3/16in. Weight: approx. 13 ozs. Ex-R.A.F. Tested **12/6.** P. & P. 2/6.

NEW MODEL HIGH FREQUENCY TRANSISTORISED MORSE OSCILLATOR

Adjustable tone control. Fitted with moving coil speaker, also earpiece for personal monitoring. Complete with morse key. 45/- plus 3/6d. p. & p.

SEMI-AUTOMATIC "BUG" SUPER SPEED MORSE KEY

7 adjustments, precision tooled, speed adjustable 10 w.p.m. to as high as desired. Weight 2½lb. **£4/12/6** post paid.

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SHOWROOMS NOW OPEN
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Tel.: 01-437 0576

STANDARD GPO DIAL TELEPHONES (black) with internal bell. **17/6** each. P. & P. 5/-. Two for **30/-**. P. & P. 7/6.

TRANSISTORISED FIELD RATEMETER type 1368A range 0.05 to 25 mr/hr in 5 ranges size 12 × 3¼ × 7½ ins. **£10** each. P. & P. 10/-.
SURVEY METER RADIAC No. 3. Hand portable size 9¼ × 5 × 5¼ ins. 3 ranges (scale changes) 0.03; 0.3; 3 R/H. Internal Ion Chamber. Nice condition **£5** ea. P. & P. 10/-.
DOSIMETER 0-50R 0-150R and charger **£2**. P. & P. 7/6. Charger only **30/-**. P. & P. 6/6.

PHOTOMULTIPLIERS. EMI 6097X at **£8/10/-** ea. 6097B—**£5** ea.
TRANSISTOR OSCILLATOR. Variable frequency 40 c/s to 5 kc/s. 5 volt square wave o/p. for 6 to 12v DC input. Size 1⅛ × 1⅛ × 1¼in. Not encapsulated. Brand new. Boxed. **11/6** ea.
CRAMER TIMER 28V DC Sweep 1/100th sec & sweep 60 secs. 4" dial. Remote control stop/start reset **£6.10.0.**

RELAYS

G.E.C. Sealed Relays High Speed 24V. 2 make 2 break. **4/6** ea.
S.T.C. sealed 2 pole c/o, 2,500 ohms. (okay 24v) **2/6** ea.; 12v—**7/-** ea.
CARPENTERS polarised Single pole c/o 20 and 65 ohm coil as new, complete with base **7/6** ea.
Single pole c/o 14 ohm coil **6/6** ea.; Single pole c/o 45 ohm coil 6/6 ea.

POTENTIOMETERS

COLVERN Brand new. 50; 100; 250; 500 ohms; 1; 2.5; 5; 10; 25; 50k all at **2/6** ea. Special Brand new.
MORGANITE 2.5K; 250K; 500K 2.5 meg. 1" sealed. **3/6** ea.
INSTRUMENT 3" Colvern. 5; 25. **7/-** ea.
BOURNE TRIM POTS. 10; 20; 50; 100; 200; 250;. 500 ohms; 2.5 and 25K at **7/-** ea.
ALMA precision resistors 100K; 400K; 497K; 998K; 1 meg—0.1% **5/6** ea.; 3.25K—0.1% **4/-** ea.
DALE heat sink resistors, non-inductive 50 watt. Brand new 8.2K at **2/6** ea.
MULLARD VINKORS. Brand new boxed. LA2104 **12/-** ea.; LA2411 **9/-** ea.; LA2503 **6/-** ea.
SILVER ZINC Non-spill. Brand new. 7½V 5 cell. Size 1¼ × 1 × 1⅞ 2 oz. weight **£1** ea. Single cell 1.5V 4AH size 1⅝ × ¾ × 3¼. 4oz. weight **£1** ea.
MALLORY CELLS. **5/-** per set of 5.

CAPACITORS

ERIE feed through ceramicons 2200 pf—**9d.** ea.
Sub-min. **TRIMMER** ⅜ square. 8, 5pf. Brand new **2/6** ea.
Concentric **TRIMMER** 3/30 pf. Brand new **1/6** ea.
ELECTROLYTICS. Brand new. 250 mfd 70V **4/6** ea.
E.H.T. 2 mfd 5 KV. Brand new **30/-** ea.
VISCONOL EHT. Brand new 0.0005 25 kV. **16/-** ea.
Wego Caps 0.2 and 0.5 mfd 20 KV working. Brand new. **£4** ea. P. & P. 15/-.
E.H.T. 0.5 mfd 5 KV—**11/-** ea.; 0.5 mfd 2.5 KV **7/-** ea.

DECADE DIAL UP SWITCH. Finger-tip. Engraved 0/9. Gold plated contacts. Size 2¼" high, 2¼" deep ¼" wide. **15/-** ea. Bank of 4 with escutcheon plates, etc. 2¼" high, 2¼" deep, 2¼" wide **£2.10.0.**

PHOTOCELL equivalent OCP 71 **2/6** ea.
Photo-resist type Clare 703. (TO5 Case). Two for **10/-**.
BURGESS Micro Switches V3 5930. Brand new **2/6** ea.
HONEYWELL. Sub-min. Microswitches type 11SM3-T. Brand new. **3/6** ea.
PANEL mounting lamp holders. Red. **1/9** ea.

BRAND NEW PLUGS AND SOCKETS

CANNON. 50 way DDM50P **15/-** ea.; DDM50S **10/-** ea.; **£1** per pair.
As above but 25 way **10/-** ea. plug; **7/-** ea. socket, **15/-** per pair; 9 way **6/6** ea. plug and socket, **10/-** per pair.
U.H.F. Plugs fit UR57, 59, 65 etc. **8/-** ea.
B.N.C. to U.H.F. Adaptor **27/6** ea.; Min. B.N.C. to U.H.F. **30/-** ea.; 'T' junction B.N.C. **£1** ea.; B.N.C. plug to B.N.C. plug **£1** ea.; B.N.C. Right angle **£1** ea.; Min. B.N.C. right angle **25/-** ea.; Min. socket round **10/-** ea.; Standard B.N.C. round **7/-** ea. Many others too numerous to list. All prices quoted for 'one off.'

TRANSFORMERS. All standard inputs.

STEP DOWN ISOLATING trans. Standard 240v AC to 120V tapped 60-0-60 700W. Brand new. **£5** ea.
Transformer 0-215-250 120 MA; 6.3V 4A CT × 2; 2 × 6.3v 0.5A and separate 90v 100 MA **25/-** each P. & P. 4/-.
Matching contact cooled bridge rectifier **7/6** each.
4.5V 40 amp (180Va) **35/-** ea. incl. postage or 3 for **£4.10.0** incl. postage. Designed to be series/paralleled.
Parmeko 6.3v 2 amp × 4—**22/6** each.
Gard/Parm/Part. 450-400-0-400-450. 180 MA. 2 × 6.3v. **£3** ea.
CHOKES. 5H; 10H; 15H; up to 120mA, **8/6** ea. Up to 250mA **12/6** ea.
Large quantity LT, HT, EHT transformers. Your requirements, please.

NUCLEONIC INSTRUMENTS—JUST ARRIVED

Pulse analyser N101; Scaler 1009E; Coincidence unit 1036C; Anti coincidence unit Panax AU460; Amplifier N567; A/B/G Radiation Monitor 1257A; complete 1339A system A/B/G; EHT Potentiometer unit 1007; 1430 amplifier CF and head; Some scintillation castles; radiation monitor 1320C and 1320X (X-ray); survey meters no. 2; 3 and N555; Ratemeter scintillation 1413A and 1368A; Fast neutron 1262C; Fluori-meter 1080A and many others. Also 2000 SERIES. Amp 2002A; Low level amp 2024; PU's 2004; 2005B; nanosec time amplitude convertor 2011A; pulse amplitude analyser 2010B; discriminator 2007B; high level amp 2025 and others. Imformation available.

AMPEX VR7000. New heads, drum, ceramic tips, rotary transformer. In superb condition. Bargain at **£500.**

AMPEX TV CAMERA CC3324. As new **£150.**

The Pair **£550.**

TEST GEAR

OSCILLOSCOPES

TEKTRONIC 517A—Very fast 5 nan/secs sweep. **£250.**
E.M.I. WM16 DB—24 megs each channel. **£175** only.
E.M.I. WM 2 DC—13 mc/s **£25**
E.M.I. WM 8—**£50.**
SOLARTRON CD1012. DC to 25 megs. Very fine. **£85.**
SOLARTRON 711S.2 D.B. DC—9 mc/s. In fine condition **£50.**
SOLARTRON 643 DC—15 mc/s NOW only **£65.**
SOLARTRON DC—10 mc/s. CD513—**£35**, 513.2—**£40**, CD523S—**£45.**
COSSOR 1049 Mk. 3. DB. **£25**
HARTLEY 13A DB. **£20.**
All carefully checked and tested. Carriage 30/- extra.

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2N914	3/6	2N3709	2/-	40347	11/6	BC184L	3/-	BSX28	6/6	NKT404	12/6
2N916	3/6	2N3710	2/3	40348	10/6	BC212L	2/6	BSX60	16/6	NKT405	15/-
2N918	6/-	2N3711	2/6	40360	8/6	BCY10	5/6	BSX61	12/6	NKT406	12/6
2N929	4/6	2N3713	37/6	40361	9/6	BCY12	5/6	BSX76	4/6	NKT451	12/6
2N930	5/6	2N3714	40/-	40362	11/6	BCY30	5/6	BSX77	5/6	NKT452	12/6
2N987	10/6	2N3715	44/6	40370	6/6	BCY31	5/6	BSX78	5/6	NKT453	9/6
2N1090	4/6	2N3716	58/-	40406	11/6	BCY32	7/6	BSY10	5/6	NKT603F	6/6
2N1091	4/6	2N3773	48/-	40407	8/-	BCY33	4/-	BSY11	5/6	NKT613F	6/6
2N1131	5/-	2N3791	55/-	40408	10/6	BCY34	4/6	BSY24	3/-	NKT674F	6/-
2N1132	5/-	2N3819	7/-	40409	11/-	BCY38	4/6	BSY25	3/-	NKT677F	6/-
2N1302	3/6	2N3823	19/6	40410	12/6	BCY39	10/6	BSY26	3/6	NKT713	4/-
2N1303	3/6	2N3854	5/6	40412	10/-	BCY40	7/6	BSY27	3/6	NKT717	8/6
2N1304	4/6	2N3854A	5/6	40467A	11/6	BCY42	3/-	BSY28	3/6	NKT734	5/6
2N1305	4/6	2N3855	5/6	40468A	7/-	BCY43	3/-	BSY29	3/6	NKT736	7/-
2N1306	5/-	2N3855A	6/-	40528	14/6	BCY54	6/6	BSY32	5/-	NKT773	5/-
2N1307	5/-	2N3856	6/-	40600	11/6	BCY58	4/6	BSY36	5/-	NKT781	6/-
2N1308	6/-	2N3856A	7/-	40603	10/-	BCY59	4/6	BSY37	5/-	NKT10339	6/6
2N1309	6/-	2N3858	5/-	AC107	6/-	BCY60	19/6	BSY38	4/6	NKT10419	7/6
2N1507	3/6	2N3858A	6/-	AC126	4/-	BCY70	4/-	BSY39	4/6	NKT10439	7/6
2N1613	5/-	2N3859	5/6	AC127	5/-	BCY71	8/6	BSY40	6/6	NKT10519	6/6
2N1631	7/-	2N3859A	6/6	AC128	4/-	BCY72	3/6	BSY51	6/6	NKT20329	9/6
2N1632	6/-	2N3860	6/-	AC154	4/6	BCZ10	5/6	BSY52	6/6	NKT20339	7/6
2N1637	6/-	2N3866	30/-	AC176	5/-	BCZ11	8/6	BSY53	7/6	NKT80111	15/6
2N1638	5/6	2N3877	8/-	AC187	12/6	BD116	22/6	BSY54	8/-	NKT80112	19/6
2N1639	5/6	2N3877A	8/-	AC188	7/6	BD121	13/-	BSY56	18/-	NKT80113	22/6
2N1701	32/6	2N3900	7/6	ACY17	5/-	BD123	16/6	BSY78	9/6	NKT80211	18/6
2N1711	5/-	2N3900A	8/-	ACY18	5/-	BD124	12/-	BSY79	9/-	NKT80212	18/6
2N1889	6/6	2N3901	19/6	ACY19	5/-	BD131	19/6	BSY82	10/6	NKT80213	18/6
2N1893	7/6	2N3903	7/-	ACY20	5/-	BD132	19/6	BSY90	11/6	NKT80214	18/6
2N2147	16/6	2N3094	7/-	ACY21	5/-	BDY10	27/6	BSY95A	2/6	NKT80215	18/6
2N2148	11/6	2N3905	7/6	ACY22	4/-	BDY11	32/6	BSW41	8/6	NKT80216	18/6
2N2160	11/6	2N3906	7/6	ACY28	4/-	BDY17	30/-	BSW70	5/6	OC20	15/-
2N2193	8/-	2N4058	3/6	ACY40	4/-	BDY18	35/-	C111	15/-	OC22	10/-
2N2193A	8/6	2N4059	2/-	ACY41	5/-	BDY19	39/6	C424	5/6	OC23	10/-
2N2194A	6/-	2N4060	2/6	ACY44	8/-	BDY20	22/6	C425	11/-	OC24	10/-
2N2217	5/6	2N4061	2/6	AD140	10/6	BDY38	19/6	C426	8/-	OC25	8/6
2N2218	6/6	2N4062	2/6	AD149	11/6	BDY60	25/-	C428	7/6	OC26	5/6
2N2219	6/6	2N4244	9/6	AD150	12/6	BDY61	25/-	C744	6/-	OC28	12/6
2N2220	5/-	2N4245	8/6	AD161	7/6	BDY62	20/-	D16P1	7/6	OC29	12/6
2N2221	5/-	2N4254	8/6	AD162	7/6	BF115	5/-	D16P2	8/-	OC35	10/-
2N2222	6/-	2N4255	8/6	AF106	8/6	BF117	9/6	D16P3	7/6	OC36	12/6
2N2287	21/6	2N4284	3/6	AF114	5/-	BF163	7/6	D16P4	8/-	OC41	4/6
2N2297	6/-	2N4285	3/6	AF115	5/-	BF167	5/-	GET102	6/-	OC42	5/-
2N2368	3/6	2N4286	3/6	AF116	5/-	BF173	6/6	GET113	4/-	OC44	4/-
2N2369	3/6	2N4287	3/6	AF117	5/-	BF177	6/6	GET114	4/-	OC45	2/6
2N2369A	3/6	2N4288	3/6	AF118	12/6	BF178	10/6	GET118	4/-	OC46	3/-
2N2410	8/6	2N4289	3/6	AF119	4/-	BF179	14/6	GET119	4/-	OC70	3/-
2N2483	5/6	2N4290	3/6	AF124	4/6	BF180	7/-	GET120	10/6	OC71	2/6
2N2484	6/6	2N4291	3/6	AF125	4/-	BF181	6/6	GET873	2/6	OC72	2/6
2N2539	4/6	2N4292	2/6	AF126	4/-	BF184	5/-	GET880	6/-	OC74	6/6
2N2540	4/6	2N4303	9/6	AF127	3/6	BF185	8/6	GET887	4/6	OC75	4/6
2N2613	7/-	2N5027	10/6	AF139	7/6	BF194	3/6	GET889	4/6	OC76	4/6
2N2614	6/-	2N5028	11/6	AF178	8/6	BF195	4/-	GET890	4/6	OC77	6/-
2N2646	11/6	2N5029	9/6	AF179	14/6	BF196	8/6	GET896	4/6	OC81	4/-
2N2696	6/6	2N5030	8/6	AF180	10/6	BF197	8/6	GET897	4/6	OC81D	4/6
2N2711	5/-	2N5172	2/6	AF181	8/6	BF198	8/6	GET898	4/6	OC83	5/-
2N2712	5/-	2N5174	10/6	AF239	8/6	BF200	10/6	MJ400	21/6	OC84	5/-
2N2713	5/6	2N5175	10/6	AF279	9/6	BF224	4/-	MJ420	22/6	OC139	6/6
2N2714	6/-	2N5176	9/-	AF280	12/6	BF225	4/-	MJ421	22/6	OC140	6/6
2N2865	12/6	2N5232A	6/-	AFZ11	6/6	BF237	4/6	MJ430	20/6	OC170	6/-
2N2904	6/-	2N5245	9/-	ASY26	5/-	BF238	4/6	MJ440	19/-	OC171	6/-
2N2904A	6/6	2N5246	8/6	ASY27	7/6	BF244	6/6	MJ480	19/6	OC200	7/6
2N2905	7/6	2N5249	13/6	ASY28	5/6	BFW61	9/6	MJ481	25/-	OC201	9/6
2N2905A	8/-	2N5265	65/-	ASY29	5/6	BFX12	4/6	MJ490	20/-	OC202	12/6
2N2906	5/-	2N5266	55/-	ASY36	5/6	BFX13	4/6	MJ491	27/6	OC203	8/6
2N2906A	5/6	2N5267	52/6	ASY50	5/-	BFX29	6/-	MJ1800	43/6	OC204	8/6
2N2907	6/-	2N5305	7/6	ASY51	6/6	BFX30	6/-	MJE340	12/6	OC205	12/6
2N2923	3/-	2N5306	8/-	ASY53	5/-	BFX43	7/6	MJE520	17/6	OC207	15/-
2N2924	3/-	2N5307	7/6	ASY54	5/-	BFX44	7/6	MJE521	17/6	OCP71	8/6
2N2925	3/-	2N5308	7/6	ASY62	5/-	BFX51	4/-	MPF102	8/6	ORP12	12/6
2N2926		2N5309	12/6	ASY63	3/6	BFX68	13/6	MPF103	7/6	ORP61	10/-
Green	2/9	2N5310	8/6	ASY72	5/-	BFX84	5/-	MPF104	7/6	P346A	4/6
Yellow	2/6	2N5354	5/6	ASY83	5/-	BFX85	6/6	MPF105	7/6	TIS34	12/6
Orange	2/6	2N5355	5/6	ASY86	6/6	BFX86	5/-	MPS3638	6/6	TIS43	8/-
2N3011	6/-	2N5356	6/6	ASZ20	7/6	BFX87	5/6	NKT0013	9/6	TIS44	2/6
2N3014	6/6	2N5365	9/6	ASZ21	8/6	BFX88	5/-	NKT124	8/6	TIS45	2/6
2N3053	5/-	2N5366	6/6	AUY10	30/-	BFX89	12/6	NKT125	5/6	TIS46	2/6
2N3054	10/-	2N5367	11/6	BC107	2/6	BFX93A	14/-	NKT126	5/6	TIS47	2/6
2N3055	15/-	2N5457	7/6	BC108	2/6	BFY10	6/6	NKT128	5/6	TIS48	2/6
2N3133	6/-	2S005	15/-	BC109	2/6	BFY11	8/6	NKT135	5/6	TIS49	2/6
2N3134	6/-	2S020	40/-	BC113	5/6	BFY17	4/6	NKT137	6/6	TIS50	3/6
2N3135	5/-	2S102	10/-	BC114	5/6	BFY18	6/6	NKT210	6/-	TIS51	2/6
2N3136	5/-	2S103	5/-	BC115	8/-	BFY19	6/6	NKT211	6/-	TIS52	2/6
2N3340	19/6	2S104	5/-	BC116	12/6	BFY20	32/-	NKT212	6/-	TIS53	4/6
2N3349	26/-	2S501	6/6	BC116A	7/6	BFY21	8/6	NKT213	6/-	TIS60	4/6
2N3390	5/-	2S502	7/-	BC118	6/6	BFY24	9/-	NKT214	4/6	TIS61	5/-
2N3391	4/-	2S503	5/6	BC121	4/-	BFY25	5/-	NKT215	4/6	TIS62	5/6
2N3391A	6/-	3N83	8/-	BC122	4/-	BFY26	4/-	NKT216	7/6	TIP29A	10/-
2N3392	3/6	3N128	14/-	BC125	11/-	BFY29	10/-	NKT217	8/6	TIP30A	12/-
2N3393	3/-	3N140	15/6	BC126	11/-	BFY30	10/-	NKT219	6/-	TIP31A	12/6

PANEL METERS
38 Series—FACE SIZE 42 x 42 mm. All prices for 1-9 pieces. All meters D.C.

50	Microamp	37/6	5	Milliamp	25/-
100	"	35/-	10	"	25/-
200	"	32/6	50	"	25/-
500	"	27/6	100	"	25/-
50-0-50	"	35/-	500	"	25/-
100-0-100	"	32/6	1	Amp	25/-
500-0-500	"	25/-	5	"	25/-
1	Milliamp	25/-	10	Volts	25/-
			20	"	25/-
			50	"	25/-
			300	"	25/-
			500	"	25/-

SPEAKERS (3ohm)

10" x 6"	37/6	3"	12/6
9" x 4"	25/6	5"	14/6
8" x 5"	25/6	8" Ceramic	47/6
7" x 4"	19/6	12"	39/6
5" x 3"	12/6	*Post and packing 2/9.*	

PRESETS Carbon Miniature and Sub miniature. Vertical and Horizontal. 0.1 watt, 0.2 watt, all at 1/3 ea. 0.3 watt 1/6.

CARBON POTENTIOMETERS
Log. and Lin. Less switch 3/-
Log. and Lin. With switch 4/6

Wire-wound Pots (3 watts) 6/6
Twin Ganged Stereo Pots. Log. and Lin. Less Switch 7/6

HEAT SINKS
4.8" x 4" x 1" Finned. For Two To-3 Trans. .. 9/6
4.8" x 2" x 1" Finned. For One To-3 Trans. .. 6/6
For SO-1 6d. For TO-5 1/- Finned
For TO-18 1/- Finned For TO-1 1/- Finned

ZENER DIODES
400 m W (from 3.3v to 33v) 4/-
1 Watt (from 2.4 to 200v) 7/6
10 Watt (from 3.9v to 100v) 7/6
20W. BZY93 Series (from 7.5v to 75v) 12/6

CIR-KIT
5 ft. x 1/16 in. or ⅛ in. 2/-
D.G. 25 W. Soldering Irons .. .. .. 19/6 each

POSTAGE & PACKING CHARGES
U.K. 2/-
EUROPE .. .. 5/- (minimum)
COMMONWEALTH (AIR) .. .. .. 13/- (minimum)

SILICON RECTIFIERS

PIV	50	100	200	400	600	800	1000	1200	1400
1A	2/-	2/6	3/-	3/3	3/6	3/9	4/-	—	—
3A	3/-	—	—	4/6	—	6/-	—	—	—
6A	—	—	5/-	6/-	6/6	7/-	10/-*	—	—
10A	—	8/-	9/-	10/-	11/6	11/6	16/-	19/6	—
17A	—	9/6	10/6	12/6	14/6	17/6	21/-	28/-	—
35A	—	24/6	28/6	35/6	42/6	49/6	55/6	64/6	—

* 5 amp only. 1 amp are plastic encapsulation.

DIODES & RECTIFIERS

1N914	1/6	AAZ17	2/6	BAY38	2/6	OA5	3/6
1N916	1/6	BA100	3/-	BY100	3/6	OA10	4/6
1N4007	4/6	BA102	4/6	BY103	4/6	OA9	2/-
1S44	2/-	BA110	6/6	BY122	7/6	OA47	1/6
1S113	3/-	BA115	1/6	BY124	3/-	OA70	1/6
1S120	3/-	BA141	6/6	BY126	3/-	OA73	2/-
1S121	3/6	BA142	6/6	BY127	3/6	OA79	1/9
1S130	2/6	BA144	2/6	BY164	11/6	OA81	1/6
1S131	2/6	BA145	4/-	BYX10	4/6	OA85	1/6
1S132	3/-	BA154	2/6	BYZ10	7/-	OA90	1/6
1S940	1/6	BAX13	2/6	BYZ11	6/6	OA91	1/6
AA119	2/-	BAX16	2/6	BYZ12	6/-	OA95	1/6
AA129	2/-	BAY18	3/6	BYZ13	5/-	OA200	2/-
AAZ13	2/-	BAY31	1/6	FST3/4	4/6	OA202	2/-
AAZ15	2/6						

MAINS TRANSFORMERS
1 amp Charger. Sec. 0-3.5-9-18v 19/6
2 amp Charger. Sec. 0-3.5-9-18v 25/6
1 amp (Douglas) MT103 Sec. tappings from 6v to 50v .. 32/6
2 amp (Douglas) MT104 Sec. tappings from 6v to 50v .. 42/6
Post and packing 4/6.
5 amp (Douglas) MT107 Sec. tappings from 6v to 50v .. 110/-
Post and packing 7/6.
Various other Douglas Transformers ranging from ½A to 5A in stock (details in catalogue).

TRIACS
SC41A 6 amp 100v 20/-
SC41B 6 amp 200v 22/-
SC41D 6 amp 400v 24/-
SC50D 15 amp 400v 41/-
40512 TO-5 mod. 6 amp 400v 29/-
40430 TO-66 6 amp 400v 19/6
40486 TO-5 mod. 6 amp 400v 19/-
Economy Range Triacs
TC4/10 (Pressfit) 4 amp 100 PIV 15/-
TC4/20 (Pressfit) 4 amp 200PIV 17/-
TC4/40 (Pressfit) 4 amp 400 PIV 19/6
ST2 DIAC 3/3

INTEGRATED CIRCUITS
SEE OUR SEPARATE ADVERTISEMENT ON PAGE 70 SHOWING NEW I.C.s AT NEW LOW PRICES.

THYRISTORS

PIV	50	100	200	300	400
1A	5/-	5/6	7/6	8/-	9/6
4A	9/6	11/-	11/6	—	15/6
5A	—	11/-	13/-	—	15/-
7A	—	11/-	13/-	—	19/6

TIC47 0.6 amp. 200 PIV 11/-.
Also 12 Amp 100 PIV 15/-, 2N3525 at 22/6

VEROBOARD

	.15 Matrix	.1 Matrix
2½" x 3¾"	3/6	4/-
2½" x 5"	4/3	4/9
3¾" x 3¾"	4/3	4/9
3¾" x 5"	5/6	5/6
2½" x 17"	12/6	—
3¾" x 17"	16/-	21/6
5" x 17"	—	26/6
3¾" x 17" (Plain)	—	11/6
5" x 17" (Plain)	17/-	—
2½" x 17" (Plain)	9/6	—

Vero Pins (Bag of 50) 5/-. (Bag of 100) 8/-. Vero Cutter 9/-. Pin Insertion Tools (.1 and .15 matrix) at 11/-.

RESISTORS
Carbon Film
⅛ watt 5% .. .. 4d. 1 watt 10% .. 6d.
¼ watt 5% .. .. 5d.
2 watt 10% .. .. 1/3 ½ watt 5% .. 3d.
1 watt M/oxide .. 1/9

Wire Wound
2.5 watt 5% (Up to 270 ohms only) 1/6
5 watt 5% (Up to 8.2k ohms only) 2/-
10 watt 5% (Up to 25k ohms only) 2/6

CAPACITORS. Polyester, ceramics, Polystyrene, silver mica, tantalum, trimmers etc.
Electrolytics

MFD.	V.		MFD.	V.		MFD.	V.	
1	18	1/6	25	50	1/6	400	16	2/9
1.6	25	1/6	32	40	1/6	500	6	2/6
2	350	2/-	32	450	5/6	500	25	3/9
2.5	16	1/6	40	16	1/6	500	50	4/9
4	10	1/6	50	12	1/6	640	16	3/
4	40	1/6	50	25	1/6	1000	16	5/-
4	350	2/3	50	50	2/-	1000	25	5/-
5	18	1/6	64	25	1/6	1000	50	7/6
5	50	1/6	80	16	1/6	2000	25	8/6
6.4	6.4	1/6	80	25	1/6	2000	50	12/6
8	40	1/6	100	6.4	1/6	2500	12	5/-
8	450	3/-	100	12	1/6	2500	25	9/6
10	12	1/6	100	25	2/-	2500	50	13/6
10	25	1/6	100	50	2/6	2500	64	15/6
12.5	25	1/6	125	10	1/6	3000	25	10/6
16	10	1/6	200	10	1/6	4000	100	47/6
16	15	1/6	250	25	2/9	4500	75	45/-
16	450	3/3	250	50	3/9	5000	25	12/6
25	6.4	1/6	320	10	1/6	5000	50	19/6
25	10	1/6						
25	25	1/6						

THERMISTORS (MULLARD)

R53 (STC)	25/6	VA1010	2/6	VA1039	3/-	VA1077	4/-
		VA1015	3/9	VA1040	2/6	VA1091	4/6
K151 (Siemens) 1K	2/6	VA1033	2/6	VA1053	2/6	VA1096	4/-
		VA1034	2/6	VA1066	3/9	VA1097	4/-
		VA1037	2/6	VA1074	2/6		
VA1005	3/-	VA1038	2/6	VA1075	4/6	VA3705	17/6

Please note:—Due to bulk buying we can now offer Texas RCA and Newmarket Semiconductors at industrial distributor prices. New quantity Price List available for industrial users upon request.

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A. MARSHALL & SONS LTD
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SEND 1/- FOR NEW COMPREHENSIVE SEMI CONDUCTOR PRICE LIST. (24 pages)
CALLERS WELCOME
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FLUORESCENT CONTROL KITS

Each kit comprises seven items—Choke, 2 tube ends, starter, starter holder and 2 tube clips, with wiring instructions. Suitable for normal fluorescent tubes or the new "Grolux" tubes for fish tanks and indoor plants. Chokes are super-silent, mostly resin filled. Kit A—15-20 w. **19/6**. Kit B—30-40 w. **19/6**. Kit C—80 w. **23/6**. Kit E—65 w. **23/6**. Kit F for 8ft. 125 w. tube **35/-**. Kit MF1 is for 6in., 9in. and 12in. miniature tubes. **19/6**. Kit MF2 for 21in. 13 w. miniature tube, **20/-**. Postage on Kits A and B 4/6 for one or two kits then 4/6 for each two kits ordered. Kits C, D and E 4/6 on first kit then 3/6 for each kit ordered. Kit F 6/6 then 4/6 for each kit ordered. Kit MF1 3/6 on first kit then 3/6 on each two kits ordered.

3 amp 12v. Battery Charger Kit—comprising 230/40 mains transformer with 3 amp secondary and 3 amp rectifier **22/6** plus 4/6 post.

12 volt 1½ amp Power Pack. This comprises double-wound 230/240v. mains transformer with full wave rectifier and 2000 m.f.d. smoothing. Price **27/6**.

12 volt Car Battery Trickle Charger. Made in Japan, this is very small and neat. Regular use will keep your car battery in good trim throughout the winter. Silly price, **25/-** plus 4/6 postage and insurance.

Sonotone Stereo Cartridge. Turnover type, ref. No. 19 TI. This fits most British pick-ups and is a really excellent reproducer. Limited quantity, **19/6**.

5 amp 3 pin Sockets. These are always good stock, you never know when you will need some. Famous make, brown bakelite, standard size, 12 for **13/-** plus 4/6 post.

Ditto but with switch. 12 for **£1** plus 4/6 post.

13 amp sockets, flush mounting. Bakelite, cream, less switch. 6 for **£1**.

Bakelite Panels, many thicknesses. We have just taken delivery of approximately 10 tons of bakelite in varying thicknesses from 2 in. to a few thou. If you have a need for any of this then we would be glad to supply. The thickest is very heavy and could be used, for instance, as a bed for a motorised unit. Medium thickness is useful for front panels of instrument, etc., etc., Cut to your size price is **6/-** lb. plus 6/- cutting charge plus carriage.

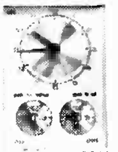
2 amp 3 pin Switched sockets for surface mounting, brown bakelite. Made by famous maker, **2/6** each or **24/-** dozen.

100 Assorted Silicon Rectifiers G.P. and Switching Diodes. Small and very small sizes. A real snip for experimenters, **12/6** per 100.

Mains Suppression Adaptor for preventing mains interference caused by vacuum cleaners, razors, sewing machines, etc., rated at 4 amps, simply plug this into your 5 amp 3 pin socket, **6/-** each.

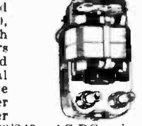
5 in. Cathode Ray Tube. Sylvania type, No. 8E5 J31, replacement in many scopes and instruments, brand new and unused, **£6.0.0** plus 10/6 postage and insurance. Mu Metal shield for this tube, **£2. 10. 0.**

ELECTRIC CLOCK WITH 25 AMP SWITCH



Made by Smith's, these units are as fitted to many top quality cookers to control the oven. The clock is mains driven and frequency controlled so it is extremely accurate. The two small dials enable switch on and off times to be accurately set. Ideal for switching on tape recorders. Offered at only a fraction of the regular price—new and unused only, **39/6** less than the value of the clock alone—post and insurance 2/9

MULTI-SPEED MOTOR



Replacement in many well-known food mixers. Six speeds are available 500, 850 and 1,100 r.p.m. from either or both of the nylon sockets (where the beaters of the food mixers normally go) and 8,000, 12,000 & 15,500 r.p.m. (ideal polishing speeds) from the main drive shaft. This drive shaft is ¼in. diameter and approximately 1in. long. A further point about this motor is that being 230/240v. AC-DC series wound its speed may be further controlled with the use of our Thyrister controller. This is a very powerful and useful motor size approx. 2in. dia. × 5in. long, mains 230/240v. Price **17/6** plus 4/6 postage and insurance. 12 or more post free.

Nicad Battery Charger. This plugs into a shaver socket, has switch for 240 or 115 v. mains, has a charge rate of 7 mA and 2 slide-in compartments designed to take 120 mAH. standard Nicads, but by using washers or rings these charger can be easily modified to take mercury deaf aid cells, complete with adaptor, **8/6**.

Quadruple Recording Tape. On a 3in. spool giving 600ft. of very good quality tape. Made by a famous company for talking books, especially suitable for message tapes and portable equipment. Regular price about 30/- per spool. Our price, **7/6** or **21/-** for 3 spools if ordered together.

8 ohm Speaker. 5in. round, made by E.M.I. Suit most transistor amplifiers, **14/6** ea.

Heat and Light Lamp 275 watt, internal mirrored, B.C. cap, **16/8** plus 3/6 post & ins.

Grundig Stenorettor. Portable office dictating machine, German made and very efficient. We have a few only of these, secondhand but in perfect working order, any not so would be exchanged. **£10** each.

Rechargeable Nicad Battery Packs for this machine, **£3.10** each.

110 r.p.m. Geared Motors. This is a powerful 2 pole mains-operated induction motor as used in record players but much more powerful (⅞in. stack). The gearbox is sealed and the final drive shaft is 1in. long and ¼in. diameter. Overall size of motor and gearbox 3 × 3 × 4in. approx., **35/-** each, post and ins. 4/6.

Mains Operated Relay. A small size relay but with 3 pairs of 10 amp contacts. **12/6** each.

Spot Welders. These comprise step-down transformer, welding heads, foot switch and auto cut-out. Not many of these available, price **£40** complete plus carriage at cost. Approx. weight 40lb.

6-way Shorting Switch. This resembles an ordinary rotary wave change switch, but the tags instead of being switched separately, are progressively shorted together. This is sometimes known as an incremental switch, **4/6** each.

Buzzer. This is a normal size bakelite buzzer, made for the G.P.O. so obviously very good. Ex-equipment but perfect order. **4/6** each or **48/-** dozen.

Miniature Fluorescent Tubes. These have a diameter of only approximately ⅜in. and are available as follows: 9in.—6 watt, 12in.—8 watt, 21in.—12 watts. All **10/6** each or **9/-** dozen lots. Control gear for these is available, MF1 for 6 and 12in. tubes and MF2 for 21in. tubes, **19/6** per set plus 3/6 post.

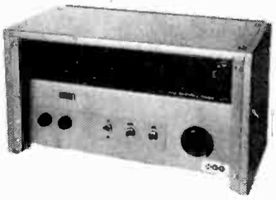
2 speed 12 volt Blowers. Made by Delco these are very powerful at full speed. Ideal if you are making a blower heater for car or caravan or for extracting bad air where only a 12 volt supply is available. **39/6** plus 4/6 p. & p.

Panel Lamp Holders. These require only one hole through the panel, removeable glass front and back, uses normal small M.E.S. bulb, **1/3** each, **12/-** dozen.

Spartan Radio. Long and medium wave 7 transistor radio, and size approx. 6 × 4 × 1½in., with larger than average speaker, better than average tone. Also telescopic aerial for receiving distant stations. A good set, complete with leather case and carrying sling, **£3.15** each plus 5/- post and ins.

13 Amp Fuses for ring main plugs. Made by G.E.C. these are very good, **5/-** per dozen, **50/-** gross.

ERGOTROL UNITS



These units made by the Mullard Group are for operating and controlling d.c. Motors and equipment from A.C. mains.

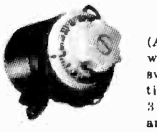
Thyristors are used and these supply a variable d.c. resulting in motor speed control and operating efficiency far superior to most other methods.

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 **£17.10.0**
Model 2411 for up to 10 amps **£27.10.0**
Model 2413 for up to 45 amps **£47.10.0**
Model 2415 for up to 80 amps **£95. 0.0**
Note: 2415 is a floor mounting unit.

HORSTMANN "TIME & SET" SWITCH

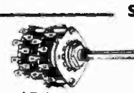


(A 30 Amp Switch.) Just the thing if you want to come home to a warm house without it costing you a fortune. You can delay the switch on time of your electric fires, etc., up to 14 hours from setting time or you can use the switch to give a boost on period of up to 3 hours. Equally suitable to control processing. Regular price probably around £5. Special snip price **29/6**. Post and ins. 4/6.

FULL FI 12" LOUDSPEAKER.

This is undoubtedly one of the finest loudspeakers that we have ever offered, produced by one of the country's most famous makers. It has a die-cast metal frame and is strongly recommended for Hi-Fi lead and Rhythm Guitar and public address. Flux Density 11,000 gauss—Total Flux 44,000 Maxwells-Power Handling 15 watts R.M.S. Cone Moulded fibre—Freq. response 30-10,000 c.p.s.—Specify 3 or 15 ohms—Mains resonance 60 c.p.s.—Chassis Diam. 12in.—12⅜in. over mounting lugs—Baffle hole 11in. Diam.—Mounting holes 4, holes—¼in. diam. on pitch circle 11⅝in. diam.—Overall height 5⅛in. A £6 speaker offered for only **£3.19.6** plus 7/6 p. & p. **Higher powered models with equally good specification:** 12in. 40 watt **£6.19.6** plus 8/6 p. & p.; 15in. 25 watt **£7.19.6** plus 10/6 p. & p.; 18in. 100 watt **£19.10** plus 30/- p. & p.

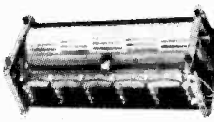
STANDARD WAFER SWITCHES



Standard size 1¼ wafer—silver-plated 5-amp contact, standard ¼" spindle 2" long—with locking washer and nut.

No. of Poles	2 way	3 way	4 way	5 way	6 way	8 way	9 way	10 way	12 way
1 pole	6/6	6/6	6/6	6/6	6/6	6/6	6/6	6/6	6/6
2 poles	6/6	6/6	6/6	6/6	6/6	6/6	6/6	10/6	10/6
3 poles	6/6	6/6	6/6	6/6	10/6	10/6	10/6	14/6	14/6
4 poles	6/6	6/6	6/6	10/6	10/6	10/6	10/6	18/6	18/6
5 poles	6/6	6/6	10/6	10/6	14/6	14/6	14/6	22/6	22/6
6 poles	6/6	10/6	10/6	10/6	14/6	14/6	14/6	26/6	26/6
7 poles	6/6	10/6	10/6	14/6	18/6	18/6	18/6	30/6	30/6
8 poles	10/6	10/6	10/6	14/6	18/6	18/6	18/6	34/6	34/6
9 poles	10/6	10/6	14/6	14/6	22/6	22/6	22/6	38/6	38/6
10 poles	10/6	10/6	14/6	18/6	22/6	22/6	22/6	42/6	42/6
11 poles	10/6	14/6	14/6	18/6	26/6	26/6	26/6	46/6	46/6
12 poles	10/6	14/6	14/6	18/6	26/6	26/6	26/6	50/6	50/6

TANGENTIAL HEATER UNIT



These heater units are the very latest type, most efficient, and quiet running. As fitted in Hoover and blower heaters costing £15 or more. Comprises motor, impeller, and two elements allowing variable heat switching and with thermal safety cut-out. Can be fitted into any metalline case or cabinet. Only need control switch. 1¾ kW. model **39/6**; 2 kW., **59/6**; 2½ kW., **69/6**; and 3 kW. model **88/-**. Postage and insurance 6/6. Control switch **8/6**.

THIS MONTH'S SNIP

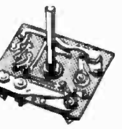
HONEYWELL PROGRAMMER

This is a drum type timing device, the drum being calibrated in equal divisions for switch purposes with trips which are infinitely adjustable for position. They are also arranged to allow 2 operations per switch per rotation. There are 15 change-over micro switches each of 10 amp type operated by the trips thus 15 circuits may be changed per revolution. Drive motor is mains operated 5 revs. per min. Some of the many uses of this timer are Machinery control, Boiler firing, Dispensing and Vending machines, Display lighting animated signs, Signalling etc. Price from Makers probably over £10 each. Special snip price **£5.15** plus 5/- post and ins. Don't miss this terrific bargain.

RESETTABLE FUSE

How long does it take you to renew a fuse? Time yourself when next one blows: Then reckoning your time at £1 per hour see how quickly our resettable fuse (auto circuit breaker) will pay for itself. Price only £1 each or £11 per dozen, specify 5, 10 or 15 amp—*simply fit in place of switch.*

THYRISTOR LIGHT DIMMERS

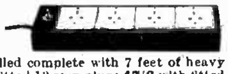


Will dim incandescent lighting up to 600 watts from full brilliance to out. Suitable to mount on M.K. switch plate, same size and fixing as standard wall switch, so may be fitted in place of this, or mount on surface. Price complete with control knob **59/6**.

INTEGRATED CIRCUITS

A parcel of integrated circuits made by the famous Plessey Company. A once in a lifetime offer of Micro-electronic devices well below cost of manufacture. The parcel contains 5 ICs all new and perfect, first grade device definitely not sub-standard or seconds. The ICs are all single silicon chip General Purpose Amplifiers. Regular price of which is well over £1 each. Full circuit details of the ICs are included and in addition you will receive a list of 50 different ICs available at bargain prices **5s.** upwards with circuits and technical data of each. Complete parcel only **£1** post paid or List and all technical data.

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 7 feet of heavy cable. Wired up ready to work, **39/6** less plug; **45/-** with fitted 13 amp plug; **47/6** with fitted 15 amp plug, plus 4/6 P. & I.

COMPUTER TAPES

2,400ft. of the best magnetic tape money can buy. Made by E.M.I., 1in. wide, almost unbreakable and on a 10½in. metal computer spool. Users have claimed successful results with video as well as sound recordings. **19/6** plus 6/6 post. Cassette to hold spool **10/-** extra.

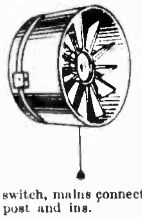
MAINS TRANSISTOR POWER PACK

Designed to operate transistor sets and amplifiers. Adjustable output 6 v., 9 v., 12 v. for up to 500 mA (class B working). Takes the place of any of the following batteries: PP1, PP3, PP4, PP6, PP7, PP9 and others. Kit comprises: mains transformer rectifier, smoothing and load resistor, condensers and instructions. Real snip at only **16/6** plus 3/6 postage.

A.C. Ammeter. These are very useful in the workshop as they will read very high currents in fact 0-250 amps, but being moving iron the most useful section of the scale permits accurate readings between 5-50 amps. These are beautifully made, 3in. dial, made by Sangamo Weston. Probable cost from the makers over £10 each. Our price **59/6**. Brand new in makers' cartons.

Case Handle. Bakelite with metal attachments. Ideal for all portable equipment and for tool boxes, etc., **1/3** each, **12/-** dozen.

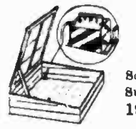
EXTRACTOR FAN



Cleans the air at the rate of 10,000 cubic ft. per hour. At the pull of a cord it extracts grease, grime and cooking smells before they dirty decorations. Suitable for kitchens, bathrooms, factories, changing rooms, etc., it's so quiet it can hardly be heard. Compact, 5¼" casing with 5¼" fan blades. Suitable wherever it is necessary to move air fast. Kit comprises motor, fan blades, sheet steel casing, pull switch, mains connector, and fixing brackets. **39/6** plus 6/6 post and ins.

DOOR INTERCOM

Know who is calling and speak to them without leaving bed, or chair. Outfit comprises microphone with call push button, connectors and master intercom. Simply plugs together. Originally sold at £10. Special snip price **49/6**, plus 3/6 postage.



Be first this year!

SEED AND PLANT RAISING

Soil heating wire and transformer. Suitable for standard size garden frame. **19/6**, post and ins. 5/6.

BLANKET SWITCH

Double pole with neon let into side so luminous in dark. Ideal for dark room light or for use with waterproof element—new plastic case. **5/6** each. 3 heat model **7/6**.

WATERPROOF HEATING ELEMENT. 26 yards length 70W. Self-regulating temperature control. **10/-** post free.

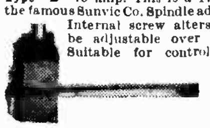
2½kW FAN HEATER

Three position switching to suit changes in the weather. Switch up for full heater (2½kW), switch down for half heat (1¼kW), switch central blows cold for summer cooling—adjustable thermostat acts as auto-control and safety cut-out. Complete kit **£3.15.0**. Post and ins. 7/6.

THERMOSTATS

Type "A" 15 amp. for controlling room heaters, green-houses, airing cupboard. Has spindle for pointer knobs. Quickly adjustable from 30-80 deg. F. **9/6** plus 1/- post. Suitable box for wall mounting, **5/-**. P. & P. 1/-.

Type "B" 15 amp. This is a 17in. long rod type made by the famous Sunvic Co. Spindle adjusts this from 50-550 deg. F. Internal screw alters the setting so this could be adjustable over 30 deg. to 1000 deg. F. Suitable for controlling furnace, oven, kiln, immersion heater or to make flame-stat or fire alarm, **8/6** plus 2/6 post and insurance.

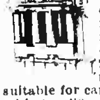


Type "D". We call this the Ice-stat as it cuts in and out at around freezing point, 2/3 amps. Has many uses, one of which would be to keep the loft pipes from freezing, if a length of our blanket wire (16 yd. **10/-** is wound round the pipes. **7/6**. P. & P. 1/-.

Type "E". This is standard refrigerator thermostat. Spindle adjustments cover normal refrigerator temperature. **9/6**, plus 1/- post.

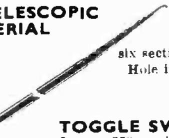
Type "F". Glass encased for controlling the temperature of liquid—particularly those in glass tanks, vats or sinks—thermostat is held (half submerged) by rubber sucker or wire clip—ideal for fish tanks—developers and chemical baths of all types. Adjustable over range 50 deg. to 150 deg. F. Price **18/-** plus 2/- post and insurance.

3 STAGE PERMEABILITY TUNER



This Tuner is a precision instrument made for the famous Radiomobile Car Radio. It is a medium wave tuner (but set of long wave coils available as an extra if required) with a frequency coverage 1620 Kc/s-525 Kc/s and intended to operate with an I.F. value of 470 Kc/s. Extremely compact (size only 2¾ × 2 × ½in. thick) with reduction gear for fine tuning. **12/6**, with circuit of front end suitable for car radio or as a general purpose tuner for use with Amplifier.

TELESCOPIC AERIAL



For portable, car radio or transmitter. Chrome-plated—six sections extends from 7¼ to 47in. Hole in bottom for 6BA screw. **7/6**

TOGGLE SWITCH

3 amp 250v. with fixing ring. **1/6** each **15/-** doz

80 OHM BALANCED ARMATURE EAR PIECE

Usable as microphone or loudspeaker. **5/6** each.

Rod Thermostats. As normally used in water heaters, 2 lengths 10in. and 18in. **12/6** each.

13 amp Ivory Sockets. Unswitched, **3/6** each, switched **4/6** each.

15 amp Micro Switch. Made by Burgess this is standard, 15 amp on/off, **2/6** each, **27/-** dozen.

Resettable Impulse Counter. 24 volt operated and each impulse moves one digit and the instrument is resettable by push button. Ideal for any counting operations, 49/6.

Error in Last Month's A.A. News. Some copies of this described a 12 volt ½ amp Power Pack at 29/6. This should have read 12 volt 1½ amp Power Pack at 29/6. Sorry for this mistake.

Where postage is not stated then orders over £5 are post free. Below £5 add 2/9. S.A.E. with enquiries please.

ELECTRONICS (CROYDON) LTD

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Also 102/3 Tamworth Road, Croydon

Z AND I AERO SERVICES LTD

ZAERIX BRAND

TWO NEW MULTIMETERS FROM RUSSIA

TYPE 4312—low sensitivity (6670 p.v.) extremely sturdy instrument for general electrical use.
D.C. ranges: 0.3-1.5-7.5-30-60-150-300-600-900V and 75mV 300 μA-1.5-6-15-60-150-600 mA 1.5-6 amps.
A.C. ranges: 0.3-1.5-7.5-30-60-150-300-600-900V. 1.5-6-15-60-150-600mA. 1.5-6 amps.
Resistance: 0.2-3-30kΩ.
Accuracy: D.C. 1%; A.C. 1.5%
PRICE, with carrying case and leads £9.75

TYPE 4313—high sensitivity for general electronic and TV-radio repair applications.
Sensitivity: 20,000 o.p.v. DC and 2,000 o.p.v. AC.
D.C. ranges: 75mV-1.5-3-7.5-15-30-60-150-300-600V. 60-120-600μA-3-15-60-300mA-1.5Amp.
A.C. ranges: 1.5-3-7.5-15-30-60-150-300-600V. 600μA-3-15-60-300mA-1.5A.
Resistance: 0.5-5-50-500kΩ
Capacity and Transmission level scales.
Accuracy: 1.5% D.C.; 2% A.C.
PRICE, with carrying case and leads £10.50.
Both instruments have knife edge pointers and mirror scales.

WHEN ORDERING BY POST PLEASE ADD 0·12½ (2/6) IN £ FOR HANDLING AND POSTAGE.
NO C.O.D. ORDERS ACCEPTED
ALL MAIL ORDERS MUST BE SENT TO HEAD OFFICE AND NOT TO RETAIL SHOP.

INTEGRATED CIRCUIT AMPLIFIERS

	£
CA3005 RF amplifier, 100mc/s bandwidth	1·35
CA3012 Wide Band Amplifier for IF applications	1·10
CA3020 550mW Audio Amplifier	1·50
CA3036 Two super-alpha pairs for stereo pick-up systems	0·95
CA3052 Latest addition to RCA range. Four-in-one amplifier	2·10
PA222 1.2 watt Audio Amplifier	3·25
PA234 1 watt Audio Amplifier	1·30
PA237 2 watts Audio Amplifier	2·00
MC1709G—G.P. operational Amplifier	1·15
TAA263 3-stage direct coupled Amplifier	0·75
TAA293 3-stage direct coupled Amplifier	1·00
TAA320 MOST input + bi-polar stage	0·65
TAD100 All active components required to construct an AM receiver	2·25
SL403A 3 watts Audio Amplifier	2·40

ZENER DIODES

BZY88 series, from 3.3V to 9.1V ± 5% 400mW	0·17½ each
BZY94 series, from 10.0V to 12.0V ± 5% 400mW	0·20 each
D814 series, from 7.5V to 13.0V ± 10% 340mW	0·15 each
D815 series, from 4.7V to 18.0V ± 10% 8 Watts	0·35 each
D816 series, from 22V to 47V ± 10% 5 Watts	0·35 each
D817 series, from 56V to 100V ± 10% 5 Watts	0·35 each

Outlines: BZY series—miniature—wire ended
D814—'Top Hat' type
D815-D817—stud mounted, supplied complete with hardware

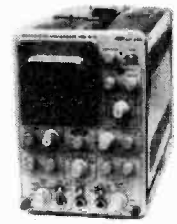
Please state voltage required—nearest standard voltage will be supplied.

TWO NEW OSCILLOSCOPES FROM RUSSIA

CI-5 SINGLE BEAM OSCILLOSCOPE

10 mc/s passband, triggered sweep from 1 μ sec. to 3 milli-sec. Free running time base from 20 c/s to 200 kc/s. Built-in time marker and amplitude calibrator, 3-in. cathode ray tube with telescopic viewing hood. **£39·00**

CI-16 DOUBLE BEAM OSCILLOSCOPE



5 mc/s passband. Separate Y1 and Y2 amplifiers, rectangular 5 in. × 4 in. cathode ray tube. Calibrated triggered sweep from 0.2 μ sec. to 100 milli-sec. per cm. Free running time base 50 c/s to 1 mc/s. Built-in time base calibration and amplitude calibrator .... **£87·50**

Full details on request. Full servicing facilities and spares available.

OUR NEW CATALOGUE 1970/1971 IS NOW READY. PLEASE SEND S.A.E. FOR YOUR FREE COPY.

FULLY GUARANTEED ZAERIX BRAND FIRST QUALITY VALVES

	£
OA2	0·38
OA3	0·45
OA4G	1·15
OB2	0·35
OB3	0·60
OC2	1·00
OC3	0·38
OD3	0·35
1A3	0·30
1A5GT	0·32
1B3GT	0·38
1B24	4·00
1C5GT	0·35
1CP31	6·00
1G4GT	0·45
1G6GT	0·40
1H5GT	0·42
1L4	0·20
1N5GT	0·48
1Q5GT	0·50
1R4	0·35
1R5	0·35
1S4	0·27
1S5	0·25
1T4	0·25
1T5GT	0·45
1U4	0·27
1U5	0·50
1V2	0·45
1X2B	0·40
2A3	0·40
2AP1	2·25
2C26A	0·50
2C39A	7·00
2C40	3·50
2C51	0·45
2C53	4·50
2CW4	0·65
2D21	0·35
2E24	2·55
2E26	1·50
2K25	8·00
2X2	0·37
3A4	0·35
3B4	0·60
3B28	2·15
3BP1	2·75
3D6	0·20
3D21A	2·00
3Q4	0·40
3Q5GT	0·45
3S4	0·35
3V4	0·45
4-125A	8·00
4-400A	16·00
4B32	4·00
4HA5	0·48
4THA	0·45
5AR4	0·60
5B/254M	2·25

	£
5B/255M	2·00
5CP1	5·00
5D21	5·00
5R4GY	0·60
5U4G	0·33
5U4GB	0·42
5V4G	0·42
5W4GT	0·40
5X8	0·50
5Y3GT	0·32
5Z3	0·50
5Z4G	0·40
6/30L2	0·75
6A8G	0·35
6AB4	0·35
6AC7	0·25
6AF4A	0·50
6AG5	0·22
6AG7	0·40
6AH6	0·50
6AJ8	0·30
6AK5	0·30
6AK5W	0·40
6AK6	0·57
6AL3	0·43
6AL5	0·20
6AM5	0·32
6AM6	0·33
6AN8	0·50
6AQ5	0·35
6AQ6	0·55
6AR5	0·35
6AR6	0·40
6AS5	0·35
6AS6	0·37
6AS7G	0·80
6AT6	0·30
6AU6	0·25
6AV5GTA	0·70
6AV6	0·30
6AW8A	0·55
6AX4GTB	0·45
6AX5GT	0·65
6B4G	1·00
6B7	0·40
6B8G	0·20
6BA6	0·25
6BE6	0·30
6BF5	0·80
6BF6	0·50
6BH6	0·45
6BJ6	0·45
6BK4B	1·20
6BK7A	0·55
6BL7GTA	0·65

	£
6BN6	0·40
6BQ5	0·25
6BQ6GTB	0·65
6BQ7A	0·40
6BR7	0·85
6BR8	0·65
6BS7	1·30
6BW6	0·85
6BW7	0·70
6BX6	0·25
6BX7GT	0·75
6BZ6	0·35
6C4	0·33
6CB6	0·30
6CD6GA	1·15
6CG7	0·50
6CH6	0·55
6CL6	0·50
6CU6	0·65
6CW4	0·63
6CY7	0·65
6D3	0·45
6DC6	0·75
6DK6	0·48
6DQ6B	0·63
6DS4	0·75
6EA8	0·58
6EH7	0·30
6EJ7	0·35
6F5	0·50
6F6G	0·30
6F11	0·38
6F13	0·38
6F14	0·65
6F15	0·65
6F17	0·50
6F18	0·45
6F22	0·30
6F23	0·80
6F24	0·75
6F25	0·75
6F28	0·60
6GK6	0·60
6J4	0·50
6J5GT	0·30
6J7	0·45
6K6GT	0·55
6K7	0·35
6K8G	0·35
6K8GT	0·50
6K23	0·55
6K25	0·75
6L6GT	0·45
6L7	0·40
6L18	0·45
6LD20	0·40
6N7GT	0·40
6P1	0·60
6P28	0·65
6Q7	0·40

	£
6R7G	0·45
6S2	0·40
6S4A	0·60
6SA7	0·40
6SC7	0·70
6SG7	0·35
6SH7	0·35
6SJ7	0·40
6SK7	0·35
6SL7GT	0·35
6SN7GT	0·35
6SQ7	0·40
6SR7	0·40
6SS7	0·20
6T8	0·35
6U4GT	0·60
6U8A	0·40
6X4	0·30
6X5GT	0·35
6X8	0·55
6Y6G	0·65
6Z4	0·35
7B5	0·75
7B6	0·70
7B7	0·45
7C5	0·85
7F8W	0·85
7Y4	0·60
7Z4	0·50
9BW6	0·50
10C2	0·50
10D1	0·50
10D2	0·40
10F1	0·90
10F9	0·50
10F18	0·45
10L1	0·45
10LD11	0·60
10P13	0·55
10P14	1·10
11D3	0·45
11D5	0·45
11E2	2·50
11E3	4·00
12AB5	0·60
12AC6	0·40
12AH7GT	0·30
12AL5	0·45
12AQ5	0·43
12AT6	0·30

	£
12AT7	0·33
12AU6	0·30
12AU7	0·30
12AV6	0·33
12AV7	0·50
12AX4GTB	0·55
12AX7	0·30
12AY7	0·70
12B4A	0·55
12BA6	0·35
12BA7	0·35
12BE6	0·35
12BH7	0·40
12BY7	0·55
12C8	0·35
12E1	1·35
12E14	3·57
12H6	0·30
12J5GT	0·25
12J7GT	0·45
12K5	0·55
12K7GT	0·35
12K8	0·50
12Q7GT	0·30
12SC7	0·35
12SG7	0·35
12SH7	0·30
12SJ7	0·30
12SK7	0·45
12SN7GT	0·45
12SQ7	0·50
12SR7	0·35
12X4	0·45
14S7	0·80
20CV	3·15
20D1	0·45
20L1	1·10
20P1	0·50
20P3	0·60
20P4	1·10
20P5	1·20
25C5	0·50
25L6GT	0·45
25Z4G	0·30
25Z6GT	0·65
30A5	0·45
30AE3	0·40
30C1	0·30

	£
30C15	0·80
30C17	0·85
30C18	0·75
30F5	0·85
30FL1	0·70
30FL12	0·93
30FL14	0·75
30L1	0·40
30L15	0·85
30L17	0·80
30P12	0·80
30P19	0·80
30PL1	0·70
30PL13	0·93
30PL14	0·90
35A5	0·75
35B5	0·65
35C5	0·40
35D5	0·70
35L6GT	0·50
35W4	0·30
35Z3	0·60
35Z4G	0·30
35Z5GT	0·40
42	0·50
50A5	0·70
50B5	0·45
50C5	0·40
50CD6G	1·65
50EH5	0·60
50L6GT	0·50
52KU	0·40
53KU	0·70
75B1	0·50
75C1	0·45
80	0·50
83	0·40
85A2	0·40
85A3	0·40
90AV	2·50
90C1	0·60
90CG	1·25
90CV	1·25
108C1	0·35
150B2	0·60
150B3	0·60
150C4	0·60
305	0·65
310A	1·50
311A	2·00
328A	2·00

	£
329	1·15
329A	1·90
715A	2·50
715C	5·00
723A/B	7·00
807	0·50
811A	1·60
813	3·75
829B	3·50
833A	17·00
837	0·85
866A	0·75
872A	3·00
884	0·60
889RA	50·00
927	3·00
931A	3·50
955	0·25
4378	1·40
4687	1·75
5544	6·50
5551A	16·00
5654	0·40
5670	0·50
5751	0·60
5763	0·70
5796	14·00
5814A	0·50
5894	5·50
6072	0·85
6080	1·50
6146	1·50
6146B	2·50
6293	3·25
6360	1·25
6870	2·50
6883	2·50
6939	2·15
7199	0·75
7586	1·25
7591A	1·00
7895	1·25
8005	7·00
9002	0·35
9003	0·50
A1834	0·80
A2293	1·20
AC/HL/DD	0·50

	£
AC/TH1	0·45
C1A	4·50
C1K	4·50
CBL1	0·80
CBL31	0·90
CL4	0·60
CL33	1·00
CY31	0·35
DAF41	0·50
DAF91	0·25
DAF92	0·50
DAF96	0·42
DC90	0·45
DF91	0·25
DF92	0·20
DF96	0·42
DH76	0·35
DH81	0·60
DH101	0·55
DK40	0·55
DK91	0·35
DK92	0·50
DK96	0·42
DL66	1·25
DL68	0·65
DL69	1·75
DL91	0·27
DL92	0·35
DL93	0·35
DL94	0·45
DL95	0·40
DL96	0·42
DY86	0·33
DY87	0·35
DY802	0·50
E55L	2·75
E80CC	1·10
E80CF	1·50
E80L	0·95
E81L	1·15
E83F	1·10
E84L	0·50
E86C	0·90
E88C	1·15
E88CC	0·65
E88CC/01	1·90
E90CC	0·45
E91H	0·60
E130L	5·00

	£
E180F	0·95
E182CC	1·20
E186F	1·25
E188CC	0·90
E280F	2·10
EA50	0·20
EA52	4·50
EABC80	0·35
EAF42	0·55
EAF801	0·50
EB34	0·20
EB91	0·20
EBC33	0·50
EBC41	0·55
EBC81	0·30
EBC90	0·30
EBC91	0·30
EBF80	0·40
EBF83	0·40
EBF89	0·30
FBL31	1·50
EC53	0·50
EC86	0·60
EC88	0·60
EC90	0·33
EC92	0·35
EC93	0·50
EC8010	2·25
ECC34	0·40
ECC40	0·60
ECC70	0·85
ECC81	0·33
ECC82	0·30
ECC83	0·30
ECC84	0·30
ECC85	0·60
ECC86	0·50
ECC88	0·40
ECC89	0·50
ECC91	0·20
ECC189	0·60
ECF80	0·35
ECF82	0·35
ECF86	0·65
ECF804	1·50
ECH35	0·60
ECH42	0·70
ECH81	0·30
ECH83	0·40

	£
ECH84	0·45
ECL80	0·40
ECL81	0·45
ECL82	0·35
ECL83	0·65
ECL84	0·55
ECL85	0·55
ECL86	0·40
ECLL800	1·50
EF9	0·50
EF37A	0·60
EF39	0·40
EF40	0·50
EF41	0·65
EF42	0·70
EF80	0·25
EF83	0·55
EF85	0·35
EF86	0·30
EF89	0·28
EF91	0·33
EF92	0·40
EF93	0·25
EF94	0·25
EF95	0·30
EF96	0·22
EF97	0·65
EF98	0·65
EF183	0·80
EF184	0·35
EF800	1·00
EF804	1·25
EF811	0·75
EF812	0·80
EF814	0·75
EH90	0·40
EK32	0·45
EK90	0·30
EL5	0·55
EL33	1·25
EL34	0·50
EL35	0·40
EL36	0·50
EL41	0·55
EL42	0·58
EL81	0·55
EL83	0·42
EL84	0·25
EL85	0·43
EL86	0·40
EL90	0·35

	£
EL91	0·32
EL95	0·35
EL360	1·15
EL803	1·00
EL821	0·55
EL822	0·90
ELL80	0·75
EM34	0·90
EM71	0·75
EM80	0·40
EM84	0·35
EM85	1·00
EM87	0·55
EN10	4·00
EN11	3·50
EN32	1·50
EN91	0·35
EY51	0·40
EY80	0·45
EY81	0·40
EY83	0·55
EY84	0·55
EY86	0·40
EY87	0·43
EY88	0·43
EZ35	0·35
EZ40	0·45
EZ41	0·45
EZ80	0·25
EZ81	0·28
EZ90	0·30
FG17	4·50
FW4/500	0·75
FW4/800	0·75
GC10B	3·75
GN4	1·50
GR10M	1·50
GS10C	5·00
GS10D	5·75
GS10H	3·10
GS12D	7·00
GS47X	3·00
GU50	1·75
GY501	0·80
GZ30	0·40
GZ31	0·33
GZ32	0·48
GZ33	0·70
GZ34	0·60
HABC80	0·45

	£
HBC90	0·30
HBC91	0·33
HF93	0·35
HF94	0·30
HK90	0·35
HL23	0·40
HL23DD	0·40
HL42DD	0·50
HL92	0·40
HL94	0·45
KT8	2·00
KT36	1·00
KT44	0·50
KT45	2·00
KT66	1·70
KT71	0·50
KT76	0·40
KT88	1·75
KTW63	0·50
ME91	0·45
MH4	0·50
ML4	0·45
ML6	0·40
MSPEN/T	0·50
MT17	4·50
MU12/14	0·60
N78	1·15
NSP1	3·50
NSP2	4·00
PABC80	0·40
PC86	0·60
PC88	0·60
PC900	0·48
PCC84	0·40
PCC85	0·40
PCC88	0·55
PCC89	0·50
PCC189	0·55
PCC805	0·85
PCC806	0·80
PCE800	0·70
PCF80	0·30
PCF82	0·35
PCF84	0·50
PCF86	0·60
PCF87	0·85
PCF800	0·80

	£
PCF801	0·50
PCF802	0·50
PCF805	0·75
PCF806	0·70
PCF808	0·75
PCH200	0·70
PCL81	0·50
PCL82	0·35
PCL83	0·65
PCL84	0·45
PCL85	0·40
PCL86	0·45
PCL88	0·90
PCL800	0·93
PCL801	0·70
PCL805	0·50
PD500	1·50
PEN4DD	0·50
PEN45	0·40
PEN45DD	0·75
PEN46	0·40
PEN383	0·55
PEN384	0·60
PEN453DD	0·60
PF86	0·60
PF818	0·85
PFL200	0·70
PL33	0·35
PL36	0·55
PL81	0·50
PL82	0·45
PL83	0·45
PL84	0·40
PL302	0·80
PL504	0·80
PL508	0·90
PL509	1·30
PL801	0·60
PL802	0·75
PLL80	0·55
PM84	0·50
PX25	2·00
PY31	0·30
PY33	0·63
PY80	0·35
PY81	0·30
PY82	0·30
PY83	0·38
PY88	0·40
PY500	1·00
PY800	0·50
PY801	0·50
PZ30	0·35
QQV02-6	2·15
QQV03-10	1·25

	£
QQV03-20A	5·25
QQV06-40A	5·50
QS83/3	0·40
QV03-12	0·70
QY3-125A	8·00
QY4-400A	16·00
R10	1·00
R18	0·55
RG3-250A	0·75
RL18	0·50
S130	1·75
S130P	1·75
SP2	0·50
SP4	0·50
SP41	0·45
SP61	0·55
TP22	0·60
TP25	0·40
TT21	2·65
TT22	2·80
U17	0·75
U18/20	0·75
U19	2·50
U20	0·75
U25	0·75
U26	0·75
U31	0·45
U37	1·50
U50	0·32
U52	0·33
U76	0·30
U78	0·30
U191	0·75
U201	0·35
U281	0·40
U282	0·40
U301	0·40
U403	0·50
U404	0·40
U801	1·00
UABC80	0·35
UAF41	0·50
UAF42	0·55
UB41	0·60
UBC41	0·50
UBC81	0·40
UBF80	0·40
UBF89	0·35
UBL1	0·50
UBL21	0·60
UC92	0·35
UCC85	0·40
UCF80	0·55
UCH21	0·60
UCH42	0·70

	£
UCH43	0·75
UCH81	0·35
UCL81	0·60
UCL82	0·35
UCL83	0·60
UF9	0·60
UF11	0·50
UF41	0·60
UF42	0·60
UF43	0·60
UF80	0·35
UF85	0·40
UF89	0·35
UL41	0·65
UL84	0·30
UM4	0·40
UM84	0·20
UU5	0·60
UY1N	0·50
UY11	0·65
UY41	0·45
UY82	0·50
UY85	0·30
VL8631	1·90
VP41	0·75
VP133	1·00
VR75/30	0·45
VR105/30	0·38
VR150/30	0·35
VU33	0·60
VU39A	0·60
VU111	0·60
VU120	0·80
VU133	0·60
W107	0·50
W729	0·60
X65	0·55
X66	0·55
X76M	0·50
XC11	0·75
XC12	0·35
XC12T	0·40
XC15	0·25
XC15T	0·40
XC23	0·90
XC25	0·35
XR1-1600	14·00
XR1-3200	6·50
Z329	0·85
Z520M	1·50
Z700U	0·40
Z700W	0·75
Z719	0·25
Z729	0·30
Z749	0·80
Z800U	1·75
Z801U	1·75
Z803U	0·90
Z900T	0·75

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Cables: **ZAERO LONDON**
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A.R.B. Approved for inspection and release of electronic valves, tubes, klystrons, etc.

WE WANT TO BUY:
SPECIAL PURPOSE VALVES. PLEASE OFFER US YOUR SURPLUS STOCK. MUST BE UNUSED

TELEX 261306

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BOX NUMBERS: Replies should be addressed to the Box number in the advertisement, c/o Wireless World, Dorset House, Stamford Street, London, S.E.1.
No responsibility accepted for errors.

Advertisements accepted up to MONDAY, 12 p.m., 11th JAN., for the FEBRUARY issue, subject to space being available.

New post at Southerngas Headquarters, Southampton.

RADIO TECHNICIAN

Salary £1,563—£1,845 per annum

Will assist with installation and surveying of new radio and trunk network schemes. Should have HNC Telecommunications or City and Guilds Certificate in an appropriate subject plus formal training with telecommunications manufacturer or major user plus several years experience; also knowledge of VHF, UHF, Microwave and Radio Multiplex techniques essential.

Salary within range shown according to qualifications, experience and ability.

Assistance with cost of removal will be given.

Application forms may be obtained from the Senior Personnel Officer, The Southern Gas Board, 164 Above Bar, Southampton SO1 0DU to whom they should be returned by 15th January 1971. Please quote reference P560/4.

SOUTHERNGAS

WESSEX REGIONAL HOSPITAL BOARD
ELECTRONIC TECHNICIANS I & III

Required for the following Hospital Groups:

Bournemouth and East Dorset Group Hospital Management Committee — 1 - Technician I
North Hants Group Hospital Management Committee — 1 - Technician III
Portsmouth Group Hospital Management Committee — 1 - Technician I, 1 - Technician III
Salisbury Group Hospital Management Committee — 1 - Technician III
Southampton Group Hospital Management Committee — 1 - Technician I

Salaries:
Electronics Technician I: £2,070, by 5 increments to £2,445 p.a.
Electronics Technician III: £1,356, by 8 increments to £1,764 p.a.
Applicants start at the minimum of the scale except in certain special circumstances; previous hospital experience desirable.

Qualifications:
Electronics Technician I—Higher National Certificate (Electronics) or equivalent.
Electronics Technician III—Ordinary National Certificate or preferably Higher National Certificate (Electronics) or equivalent.

Successful candidates will work in Departments of Electronics concerned with the installation, testing, maintenance and development of a wide range of medical, electronic and allied equipment.

Application forms, job descriptions and specifications available from the Secretary, Wessex Regional Hospital Board, Highcroft, Romsey Road, Winchester. Closing date: 13th January, 1971. 981

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TECHNICIANS AND ENGINEERS FOR ST. ALBANS AND LUTON

QUALIFIED OR NOT!

VACANCIES exist for work on testing and calibrating valve and solid-state electronic measuring equipments embracing all frequencies up to u.h.f. in Production, Service and Calibration departments.

APPLICATIONS are invited from people of all ages with experience or formal training in electronics and from ex-Armed Services technicians.

HIGHLY COMPETITIVE SALARIES, negotiable and backed by valuable fringe benefits.

RE-LOCATION EXPENSES available in many instances.

CONDITIONS excellent; free life assurance, pension schemes, canteen, social club.

37½-hour, 5-day, office-hours week.

WRITE or phone Personnel Department stating age, details of previous employment, training, qualifications, approximate salary required, quoting WW10

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MARCONI INSTRUMENTS LIMITED,
Longacres, St. Albans, Herts.
Tel: St. Albans 59292
Luton Airport, Luton, Beds.
Tel: Luton 31441.
A GEC-Marconi Electronics Company

893

Qualified...

Gilbert and Ellice Islands Colony
TELECOMMUNICATIONS TECHNICIAN
Up to £2498 + Gratuity

***Salary up to £2498**
***Low Taxation**
***25% gratuity**
***Appointments Grant payable in certain circumstances**
***Subsidised accommodation**
***Education allowances**
***Contract two years in the first instance**

Required by the Posts and Telecommunications Dept. to be directly responsible to the Senior Telecommunications Technician for the installation and maintenance of the installations in his charge and to give formal and/or practical training to local officers.

Candidates should possess the City & Guilds Final Certificate (Telecommunications) or equivalent and have experience in the installation and maintenance of H.F., M.F. and V.H.F. communications and navigation equipment, operation in C.W. and S.S.B. modes, experience of both valve type and transistorised solid state radio beacons, radio teleprinter using both tone on off and two tone keying and multi-channel V.H.F. equipment. Applicants lacking formal qualifications but with extensive experience may be considered.

M2K/701115/WF

Malawi
ENGINEERING OFFICER (CARRIER & V.H.F.)
Up to £2149 + Gratuity

***Salary up to £2149**
***Low Taxation**
***25% gratuity on completion of 30 month tour**
***Appointments Grant £100 or £200 in certain circumstances**
***Contract 24-36 months**
***Subsidised accommodation**
***Education allowances**

Required by the Posts & Telecommunications Department for the maintenance of carrier telephone and V.H.F. equipment and to give guidance and assistance to local staff under training.

Candidates, 28—45 years, must have received a minimum of two years approved training plus not less than five years experience on the maintenance of carrier systems and V.H.F. radio.

M2K/700207/WF

Crown Agents

FLIGHT SIMULATOR SERVICE ENGINEERS

Redifon Flight Simulator Division are designers and manufacturers of highly sophisticated simulators of current civil and military aircraft and linked products for use in the United Kingdom and world-wide export markets.

We need skilled service engineers to keep this complex and hard-worked equipment in continuous first-class operation.

You should preferably have a minimum of O.N.C. or City & Guilds Certificate and theoretical and practical experience of digital computing, hardware, software and computer peripherals, and/or a sound knowledge of pulse techniques. However, applications will be considered from those with relevant practical experience gained in the appropriate fields but who do not possess formal qualifications.

A knowledge of analogue computing and hydraulics would be advantageous. We will train those who have good experience in transistorised and integrated circuits.

The job is varied and interesting and in an expanding business. Promotion prospects are good. You must expect to travel anywhere in the United Kingdom and Overseas at short notice, possibly for extended periods. Excellent welfare benefits include contributory pension scheme coupled with free life assurance.

There are vacancies at both Aylesbury, Bucks, and Crawley, Sussex locations. Applications should be made in the first place to:

H. C. Hall
Personnel Manager
REDIFON LIMITED
Gatwick Road, Crawley, Sussex. Tel: Crawley 28811

REDIFON
A Member Company of the Rediffusion Organisation 1966 1970

Perkin-Elmer Ltd, of Beaconsfield

Who are members of an international organisation actively engaged in the development and manufacture of a wide range of analytical instruments have a vacancy for an

Electronics Engineer

This is a staff appointment in a department engaged in the testing of advanced analytical instruments involving a wide variety of electronic techniques.

The post offers an interesting and challenging appointment to a young engineer who after familiarisation with the product being manufactured is capable of working with minimal supervision.

Formal qualifications whilst desirable are not essential as practical experience of modern circuits using discrete components and integrated techniques is essential.

The minimum starting salary will be £1,400 per annum. Usual fringe benefits.

Write or telephone for an Application Form to:—

L. H. Oates, Personnel/Training Manager, Perkin-Elmer Limited,
Post Office Lane, Beaconsfield, Bucks.
Tel: Beaconsfield 5151

ISLE OF MAN CIVIL SERVICE

Applications are invited for the post of Telecommunications Technical Officer on the staff of the Isle of Man Airports Board at Ronaldsway Airport.

Candidates must be at least 25 years of age on the 1st April, 1971 and must either:—

(*a*) have an Ordinary National Certificate in Engineering including a pass in Electrical Engineering "A", or

(*b*) have obtained the City and Guilds Institute Intermediate Certificate in Telecommunications Engineering and the City and Guilds Institute Certificate in Radio II, or

(*c*) have obtained the City and Guilds Institute Intermediate Telecommunications Technicians Certificate and the City and Guilds Institute Certificate in Mathematics B, Telecommunications Principles B and Radio and Line Transmission B, or

(*d*) produce evidence of an equivalent standard of technical education

and

in addition to any of the above be able to show that they have sufficient experience in radio, radar or other electronic work.

The post is permanent and pensionable on a non-contributory basis (subject to medical fitness) and arrangements exist for the transfer of certain pension rights.

The standard rate of Manx income tax is 4s. 3d. in the £ and there is no surtax, capital gains tax or estate duty.

Further particulars and forms of application are obtainable from the Secretary, Civil Service Commission, Government Office, Douglas, Isle of Man.

970

If you're a telecommunications man and match up to the qualifications below cut yourself into a slice of Britain's future

Become a

Radio Technician

in the fast-growing world of Air Traffic Control

Please send me an application form and details of how I can join the fascinating world of Air Traffic Control Telecommunications.

Name ....

Address ....

....

Not applicable to residents outside the United Kingdom WWT/E3

To: A J Edwards, C Eng, MIEE,
The Adelphi, Room 705, John Adam Street, London WC2N 6BQ,
marking your envelope 'Recruitment'

Sending this coupon could be your first step to a job that's growing in importance every year.

The National Air Traffic Control Service needs Radio Technicians to install and maintain the vital electronic aids that help control Britain's ever-increasing air traffic.

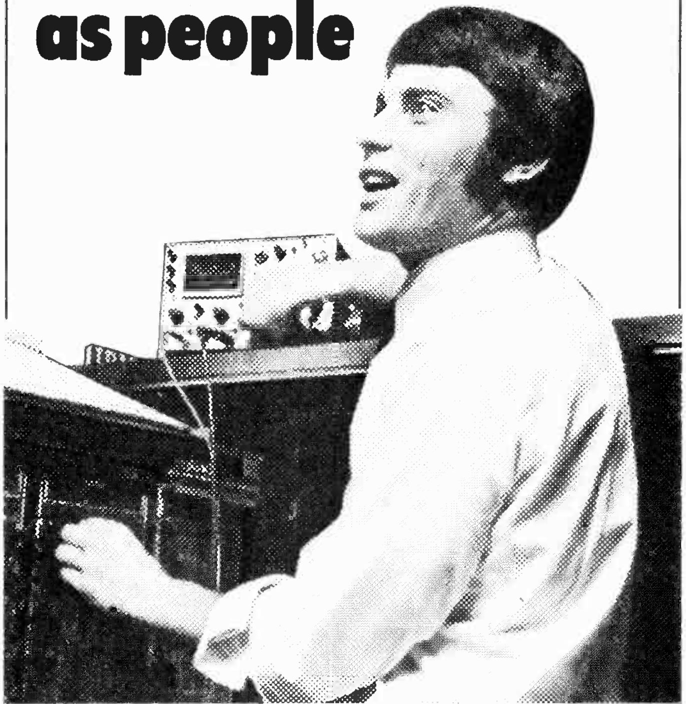
This is the kind of work that requires not only highly specialised technical skills but also a well developed sense of responsibility, and candidates must be prepared to undergo a rigorous selection process. Those who succeed are assured a steadily developing career of unusual interest and challenge. Starting salary varies from £1044 (at 19) to £1373 (at 25 or over): scale maximum £1590 (higher rates at Heathrow). There is a good annual leave allowance and a non-contributory pension for established staff.

You must be 19 or over, with at least one year's practical experience in telecommunications. ('ONC' or 'C and G' qualifications preferred).

NATCS
National Air Traffic Control Service

Engineers

If you understand machines as well as people



...then you could become a Customer Engineer at IBM.

Wherever there are computers, people are needed to keep them running. These people are known as either Service Engineers, Field Engineers or Maintenance Technicians. Because of their close involvement with the customer, IBM calls them Customer Engineers.

Today, computers are becoming essential to industry, science, government and commerce. And no computer manufacturer can operate without Customer Engineers. So the field is wide open, and this could be your opportunity to move into today's major growth industry.

What you will do

There are four groups of Customer Engineers. Three are in Data Processing and cover between them the entire range of D.P. equipment from card punching and Teleprocessing to highly sophisticated computer systems. The fourth group is the Office Products division which covers basic electric typewriters and typewriting systems, dictating equipment and composer systems. Whichever group you may join you will be given a first class training.

Qualifications

You should be between 20 and 35, educated to 'O' Level standard. In addition to a knowledge of basic electronics, a good mechanical aptitude is also necessary as part of the work involves repair and maintenance of the electro-mechanical devices. For engineers who will be trained for computer systems, a basic knowledge of electronics is also necessary. If you also have a logical mind then you could have a career as a Customer Engineer with IBM.

Your prospects

Starting salaries are excellent. IBM offers many fringe benefits such as non-contributory pension scheme, free Life Assurance and an excellent career-path. And it is IBM policy to promote from within.

Write now

Interested? Then write with details of your age, qualifications and experience to: Mr. D. J. Dennis, IBM United Kingdom Limited, 389 Chiswick High Road, London W.4. quoting reference WW/958.

IBM

Electronic Test Engineers

Pye Telecommunications of Cambridge has 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,
Pye Telecommunications Limited,
Cambridge Works, Haig Road, Cambridge.
Telephone: Cambridge 51351 Ext. 355

Pye Telecommunications Ltd

LEC

RADIO & TELEVISION SERVICING RADAR THEORY & MAINTENANCE

This private College provides efficient theoretical and practical training in the above subjects. One-year day courses are available for beginners and shortened courses for men who have had previous training.

Write for details to: The Secretary, London Electronics College, 20 Penywern Road, Earls Court, London, S.W.5. Tel.: 01-373 8721. 84

REDIFFUSION

COLOUR TELEVISION FAULTFINDERS & TESTERS

We have a number of vacancies in our Production Test Departments for experienced faultfinders and testers.

Knowledge of transistor circuitry and experience with Colour Receivers together with R.T.E.B. Final Certificate or equivalent qualifications required.

These will be staff appointments with all the expected benefits.

Applications to:

**Works Manager,
Rediffusion Vision Service Ltd.,
Fullers Way South,
Chessington, Surrey (near Ace of Spades).
Phone: 01-397 5411**

93

UNIVERSITY OF ABERDEEN TELEVISION SERVICE

Applications are invited for the following posts:

(a) SENIOR TELEVISION ENGINEER
(b) TELEVISION ENGINEER/ TECHNICAL OPERATIONS (I) & (II)

Senior Television Engineer:

The initial responsibility will be to co-ordinate the design specification, installation and equipping of a colour outside broadcast unit and the associated studio complex, both of which will be equipped to broadcast standards.

Candidates should be Chartered Engineers with professional engineering qualifications with a minimum of seven years experience in television broadcast engineering. They must be able to demonstrate wide experience ranging from colour studio operations to basic maintenance and installation techniques. It is essential that candidates have experience of studio lighting operations.

Television Engineer/Technical Operations (I):

Candidates, who should have a minimum of five years experience in broadcast engineering, must be able to demonstrate an understanding of the principles and current practices of colour studio and outside broadcast operations.

Experience of first line maintenance and studio lighting operations is essential.

Television Engineer/Technical Operations (II):

The successful candidate will be primarily concerned with the technical management of the new 600 seat Arts Lecture Theatre sited at King's College. He will be responsible to the Senior Television Engineer for the efficient operation and maintenance of all audio/visual aid facilities installed in the building. Opportunities exist for the successful candidate to work alongside other Television Service staff involved in the production of high quality teaching material.

O.N.C. or equivalent qualification desirable.

Normal colour vision is a requirement for all posts.

Salary on scale:

Post (a) —£3210 × 100 — £3810
Post (b) (I)—£2105 × 125 — £2605
(II)—£1160 × 85 — £1670

all with initial placing according to qualifications and experience. Superannuation (F.S.S.U.) and removal allowance.

Further particulars from The Secretary, The University, Aberdeen, with whom applications (8 copies) should be lodged not later than 19th January, 1971.

971

Electronics Maintenance Engineers

There are excellent opportunities in the Installation and Maintenance Division of U.K. Electronics and Industrial Operations of E.M.I. Ltd., at Hayes, Middlesex, for engineers to carry out maintenance work on a wide variety of electronic equipments including laboratory test gear and trans-ceivers.

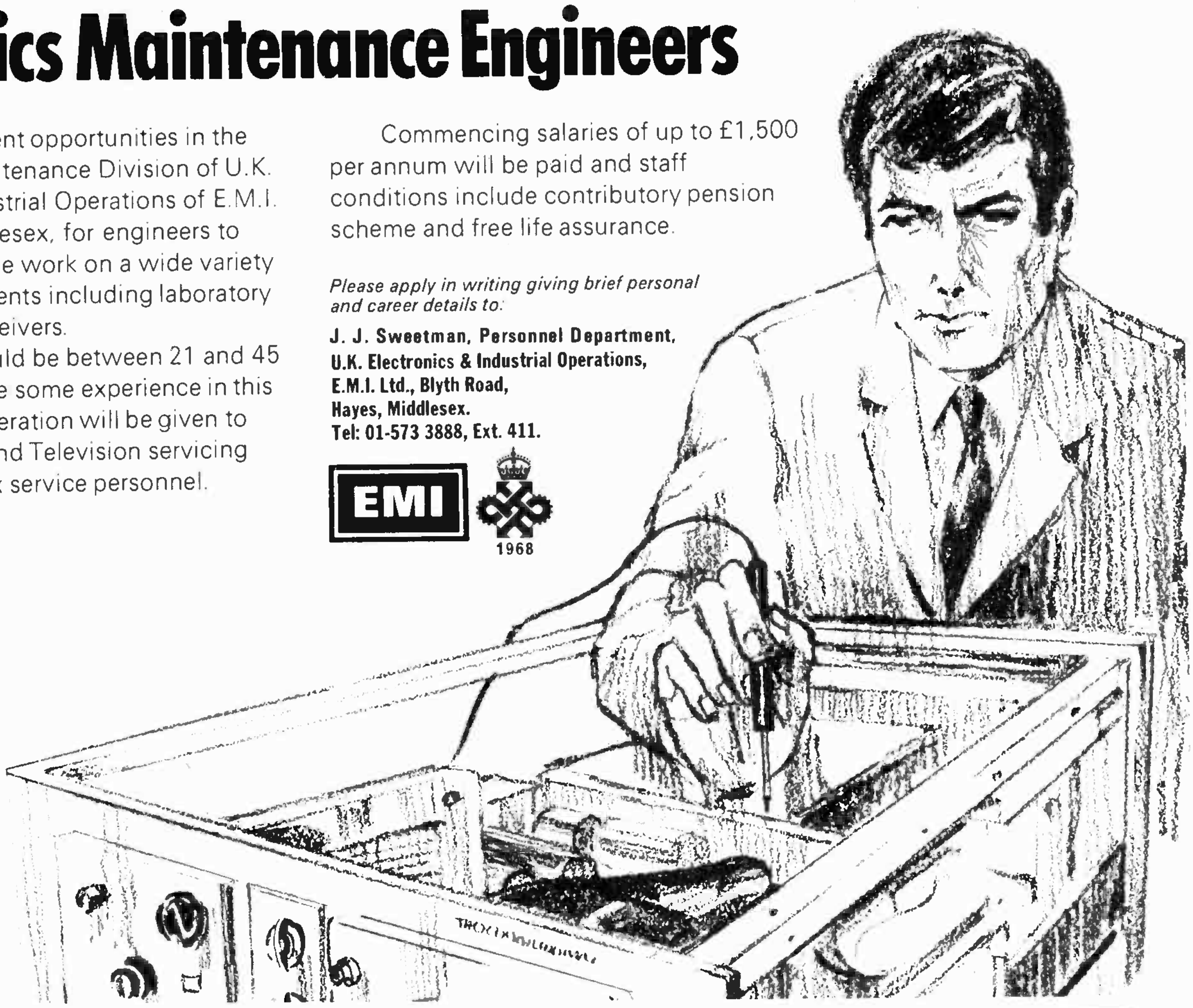
Candidates should be between 21 and 45 years of age and have some experience in this type of work. Consideration will be given to experienced Radio and Television servicing technicians and to ex service personnel.

Commencing salaries of up to £1,500 per annum will be paid and staff conditions include contributory pension scheme and free life assurance.

Please apply in writing giving brief personal and career details to:

J. J. Sweetman, Personnel Department,
U.K. Electronics & Industrial Operations,
E.M.I. Ltd., Blyth Road,
Hayes, Middlesex.
Tel: 01-573 3888, Ext. 411.

EMI 1968



836

computer engineering

NCR requires additional ELECTRONIC, ELECTRO MECHANICAL ENGINEERS and TECHNICIANS to maintain medium to large scale digital computing systems in London and provincial towns.

Training courses will be arranged for successful applicants, 21 years of age and over, who have a good technical background to ONC/HNC level, City and Guilds or radio/radar experience in the Forces.

Starting salary will be in the range of £900/£1,350 per annum, plus bonus. Shift allowances are payable, after training, where applicable. Opportunities also exist for Trainees, not less than 19 years of age, with a good standard of education, an aptitude towards and an interest in, mechanics, electronics and computers.

Excellent holiday, pension and sick pay arrangements. Please write for Application Form to
Assistant Personnel Officer
NCR, 1,000 North Circular Road,
London, NW2
quoting publication and month of issue.

Plan your future with **NCR**

85

RACAL - BCC LIMITED,

ASSISTANT TO PRODUCT PLANNING MANAGER

Racal BCC Limited, leaders in professional communications equipment are seeking an Assistant to the Product Planning Manager.

The successful candidate will assist in the preparation of technical specifications to CCIR. or similar standards, for equipment in the Racal range.

He will also generally assist in commercial activities related to the marketing and development of h.f. radio communications equipment and systems, and will liaise with engineering staff on technical aspects of equipment applications.

The applicant should have operational, installation or planning experience in telecommunications with some specialisation in radio systems. He should be capable of writing notes of meetings and of assisting generally in the administrative activities of the section.

Please apply in writing enclosing brief details of experience and qualifications to :-

RACAL THE ELECTRONICS GROUP

Mr. L. A. Jemmett,
Personnel Manager,
Racal-BCC Ltd.
Western Road,
Bracknell, Berks.

Sea-going Radio Officers can now make sure of a shore job and good pay.

If you'd like a job ashore, at a United Kingdom Coast Station, the Post Office will start you off on £1,080—£1,360, depending on age, with annual rises up to £1,850. There are good prospects of promotion to higher posts, opportunities exist for overtime and you would receive additional remuneration for attendance during the late evenings, at night and on Saturday afternoons and Sundays.

You will need to be 21 or over, with a 1st Class Certificate of Competence in Radiotelegraphy issued by the Postmaster General or the Ministry of Posts and Telecommunications, or a Radiocommunication Operator's General Certificate issued by the Ministry of Posts and Telecommunications, or an equivalent certificate issued by a Commonwealth administration or the Irish Republic.

Find out more by writing to: The Inspector of Wireless Telegraphy, External Telecommunications Services, Wireless Telegraph Section (W.W.), Union House, St. Martins-le-Grand, London, EC1A 1AR.

Post Office Telecommunications

JUNIOR TECHNICIAN

required at our Hampstead Laboratories, Holly Hill, N.W.3. Suitable for applicant in early 20's with some experience of workshop practice and an interest in electronic instrumentation. Minimum qualifications 4 G.C.E. 'O' Levels to include English, Maths and a science subject. Salary according to age on scale £706 to £1144 p.a.

Please apply quoting our reference WW78/1 to: **Mrs. A. Harrell, National Institute for Medical Research, The Ridgeway, Mill Hill, London, N.W.7. 1AA · Tel: 959 3666**

967

VOCATIONAL TRAINING

CIVILIAN INSTRUCTIONAL OFFICERS (GRADE III) RADIO AND TELEVISION SERVICING

required at

H.M. PRISON, NOTTINGHAM.
H.M. BORSTAL, PORTLAND, Dorset.
H.M. PRISON, STAFFORD.
H.M. PRISON, THE VERNE, Portland, Dorset.

Salary: The commencing salary is £1,415 (at age 26); £1,625 (at age 30 or over) rising to £1,790. An additional allowance of £92 a year is also paid. The posts carry the prospect of pensionable employment.
Hours: A 40-hour, 5-day week is worked with 18 working days annual leave in addition to the usual 9 public and privilege holidays.
Qualifications: Full apprenticeship plus at least five years practical experience in the Radio and Television and/or Electronics servicing industry. City and Guilds Certificate (or equivalent) is desirable. Teaching, instructing or colour TV experience are added advantages.
Duties: The successful candidates will train inmates in Radio and Television servicing and prepare them for City and Guilds examinations.
The candidate selected for the post at THE VERNE will be required to perform some relief duties at other Prison and Borstal Service establishments.
PLEASE WRITE FOR APPLICATION FORM TO: The Establishment Officer, Home Office, Portland House, R.9/4/42T, Stag Place, London, S.W.1, stating for which post you apply.
Closing date for the receipt of completed application forms: 15 January, 1971.

978

CITY OF LEEDS AND CARNEGIE COLLEGE

Senior Workshop Technician

T3 £1,089 – £1,272

Applications are invited for this post in the Audio Visual Aids section of the College, to be responsible for the maintenance of all electronic equipment including a closed circuit television apparatus and to assist in the other work of the section.

Application forms and further particulars from the Senior Administrative Officer, City of Leeds and Carnegie College, Beckett Park, Leeds, LS6 3QS, to whom completed applications should be returned as soon as possible.

945

CITY OF LEICESTER POLYTECHNIC

Applications are invited from Graduates for the post of

LECTURER (GRADE II) IN ELECTRONICS & COMMUNICATION ENGINEERING

for courses up to degree level, in School of Electrical Engineering.

Industrial, research or teaching experience in electronics, digital electronic systems or communication engineering desirable. Interest in digital communication techniques particularly appropriate.

Research and consultancy encouraged. Opportunity to join a small team studying applications of a small computer in communication engineering.

Salary: £1947—£2537 per annum, according to qualifications and experience.

Application form and further particulars from Chief Administrative Officer (Dept. Est.), City of Leicester Polytechnic, P.O. Box 143, LEICESTER, LE1 9BH.

982

Electronics Engineer
FOR N.C. MACHINE INSTALLATION

EMI Electronics have a vacancy for an Electronics Maintenance Field Engineer to work on numerical machine-tool control.

The work entails installation and maintenance of tape control systems in customers' workshops. Applicants should be prepared to travel. Experience in machine-tool control systems is preferable, but an engineer with experience of fieldwork in other branches of electronics may be suitable.

Starting salary around £1,850 p.a. according to qualifications and experience.

Apply in writing or ring:

EMI

J. J. Sweetman,
Personnel Department,
Electric & Musical
Industries Ltd., Blyth Road,
Hayes, Middx. Tel: 01-573 3888, Ext. 2523

EMI CAREERS

RADIO TECHNICAL OFFICERS

Up to £2,505 p.a.

The P.L.A. operate a wide telecommunications network from Tower Pier to the outer Thames Estuary, and vacancies exist at Gravesend and the King George V Dock for Radio Technical Officers to maintain the equipment at maximum efficiency.

To ensure adequate coverage, a shift system is operated.

Salary scale: £2,005–£2,505.

Minimum qualifications:
O.N.C. Electrical Engineering
or City & Guilds Intermediate Certificate in Telecommunications Engineering plus Radio II
or equivalent Service qualifications.

Applicants should have at least 5 years' experience in semiconductors and in at least two of the following fields:—

V.H.F. and U.H.F. Radio
Radar and Microwave Links
Telemetry and Digital
Teleprinters and Message Switching.

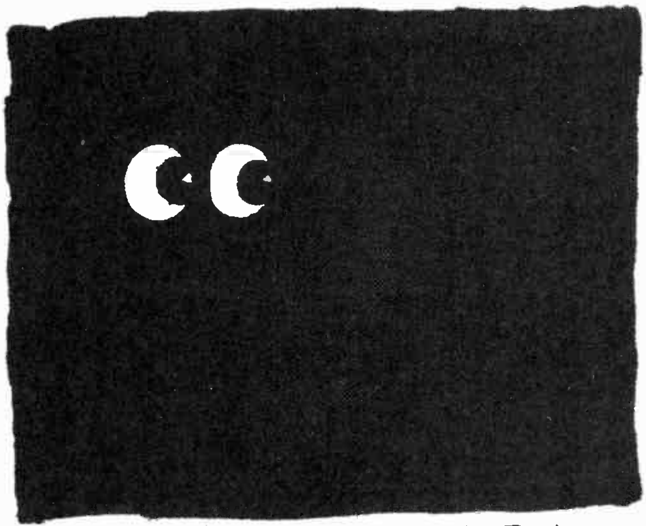
Application forms may be obtained from:—

The Chief Engineer (Personnel),
Port of London Authority,
P.O. Box 242, Trinity Square,
London, E.C. 3P 3BX

PLA

PORT OF LONDON AUTHORITY

Light engineering/ electronics and in the dark about computers?



Join us now as a Computer Service Engineer, and after six months' paid specialist training, you will be responsible for ensuring that our computers are in peak condition.

We are Britain's leading computer manufacturer; we give men who want a rewarding career an excellent basic salary while we train them in every aspect of customer engineering in the computer industry. You'll learn to deal with operational problems, and to use the most intricate machinery.

HNC or C&G in electronics engineering, a Forces' training in electronics, or similar qualifications, are your passport to our opportunities.

How far you progress is up to you—the experience you get will stand you in good stead for your future career development. You'll gain knowledge of new methods and techniques on the most sophisticated equipment.

To add to your basic salary, you can get generous overtime and shift rates There is a special allowance for working in central London. You will be operating in a computer environment on customers' premises in conditions well above the average for industry.

Age: 21/35.

Locations: Central London, Middlesex, Surrey, Essex, Hertfordshire, Manchester, Cardiff and Coventry.

Write giving brief details of your career, and quoting ref. WW630C to: A. E. Turner, International Computers Limited, 85/91 Upper Richmond Road, Putney, London SW15.

International Computers ICL

ERGONOMICS

Research Technician for Test Equipment

He will join a small team of physiological, psychological and environmental researchers being formed at British Rail headquarters in London.

The department works on human factors problems of modern railway operations, passenger amenities and comfort, and personnel testing.

He should have a talent for constructing test rigs, mock-up simulations and minor electronic apparatus and will operate and maintain research equipment, assist in preparation of experiments and processing of data, make technical drawings and diagrams for reports and presentations.

Salary will be in the range £1,290 to £1,845, plus £70 London allowance per annum, depending on experience and qualifications. There is a contributory pension scheme and the transfer of existing pension rights can be accepted. There are also free and reduced rate rail travel facilities.

Applications giving age, education, qualifications, experience and present salary should be sent to the **Headquarters Staff & Services Manager (quoting reference B.ID/ZH), British Railways Board, 222 Marylebone Road, London, NW1 6JJ.**

SONY®

are looking for an

ENGINEER

to work on closed circuit television equipment in the Service Department of the Commercial and Industrial Division at Bedfont in Middlesex. The work includes cameras, monitors and video tape recorders, both monochrome and colour.

Please write to :—

Mr. M. T. Morcom, Service Manager
Commercial and Industrial Division
Sony U.K. Limited
Ascot Road, Bedfont, Middlesex

975

RADIO TECHNICIANS

The Air Force Department has vacancies for Radio Technicians at
RAF Sealand, Near Chester
RAF Henlow, Bedfordshire and
RAF Carlisle

Interesting and vital work on RAF radar and radio equipment.

Applicants must be experienced technicians in the electronics field.

Starting pay according to age up to £1373 p.a. (at age 25) rising to £1590 p.a. with prospects of promotion.

5 day week—good holidays—help with further studies—opportunities for pensionable employment.

Write for further details to:

Ministry of Defence, CE3H (Air),
Sentinel House, Southampton Row, London WC1

Applicants must be UK residents.

944

RADIO OPERATORS

There will be a number of vacancies in the Composite Signals Organisation for experienced Radio Operators in 1971 and subsequent years.

Specialist training courses lasting approximately 8 months are held at intervals. Applications are now invited for the course starting in September 1971.

Salary Scales

During training with free accommodation provided at the Training School:

Age 21	£848 per annum
„ 22	£906 „
„ 23	£943 „
„ 24	£981 „
„ 25 and over	£1,023 „

On successful completion of course:

Age 21	£1 023 per annum
„ 22	£1,087 „
„ 23	£1,150 „
„ 24	£1,214 „
„ 25 (highest age point)	£1,288 „

then by 6 annual increments to a maximum of £1,749 per annum.

Excellent conditions and good prospects of promotion. Opportunities for service abroad.

Applicants must be United Kingdom residents, normally under 35 years of age at start of training course, and must have at least 2 years' operating experience *or* PMG qualifications. Preference given to those who also have GCE 'O' level or similar qualifications.

Interviews will be arranged throughout 1971.

Application forms and further particulars from: **Recruitment Officer, Government Communications Headquarters, Oakley, Priors Road, CHELTENHAM, Glos., GL52 5AJ.**
Tel: Cheltenham 21491 Ext. 2270

92

SERVICE TECHNICIAN

required in the Education Department of the London Borough of Croydon for the installation, repair and maintenance of tape recorders, radio receivers and other A.V.A. apparatus and equipment. Wages £23 6s. 8d. 5-day week (40 hours). Applications giving full details of previous employment and experience to Stores Assistant, Education Stores, Princess Road, Croydon, CRO 2QZ.

947

UNIVERSITY OF SURREY

Lecturer/Senior Lecturer

in

Recording Techniques

Applications are invited for the post of Lecturer/Senior Lecturer in Recording Techniques in the Music Department. The Lecturer will be responsible for teaching practical and theoretical aspects of recording for the Tonmeister Course leading to the degree of B.Mus. (Surrey) (Tonmeister).

Applicants should have a thorough knowledge and experience of studio work in the recording industry and should preferably be also qualified to lecture on some aspect of music in the general B.Mus. course.

Salary will be in the Lecturer/Senior Lecturer range: Lecturer, £1730-£3105 p.a. Senior Lecturer, £2955-£4000 p.a. with F.S.S.U. benefits.

Applications should be sent not later than Friday, 29th January, 1971, to the Academic Registrar (LFG), University of Surrey, Guildford, Surrey, from whom further particulars may be obtained.

959

The Hatfield Polytechnic

Department of Electrical Engineering and Physics

EXPERIMENTAL OFFICER

for work on Research in Digital Communication Systems.

The project, sponsored by the Ministry of Aviation Supply (Signals Research and Development Establishment), has been running successfully for a year. The work involves the construction and testing of digital integrated circuit systems. Applicants should preferably be educated to at least HNC standard and have a good Electronics background. The post is offered initially for one year but there are good prospects of a permanent appointment.

Salary in a range up to £1,766 p.a., depending on qualifications and experience.

Apply giving full relevant details, to the Secretary and Academic Registrar, The Hatfield Polytechnic, Hatfield, Herts. Quote ref.: 452/WW.

943

UNIVERSITY COLLEGE GALWAY, IRELAND

Applications are invited for 2 posts of Senior Technicians as follows:
Dept. of Oceanography: Advanced certificate in electronics of City & Guilds or equivalent is required together with appropriate experience.
Dept. of Experimental Medicine: electronic expertise and appropriate biological experience together with an advanced technical certificate. Salary scale £1,536—£1,800. Further particulars from head of department concerned.

989

LONDON BOROUGH OF RICHMOND-UPON-THAMES

TWICKENHAM COLLEGE OF TECHNOLOGY

LABORATORY TECHNICIAN required for Electronics Laboratory, to be responsible for producing and testing experimental equipment and maintenance and repair of Oscilloscopes, Signal Generators etc. Should hold suitable qualification. Salary Tech 4 (£1,362—£1,605).

Forms from:
Bursar,
Twickenham College of Technology,
Egerton Road, Twickenham,
Middlesex, returnable within 14 days (01-892 6656).

987

AERIAL DEVELOPMENT ENGINEER

Duties include Research and Development, Site Work, Propagation, etc., in connection with a V.H.F., U.H.F. and Microwave Laboratory.
Pleasant expanding town within easy reach of M1, and a large choice of cheap housing in the area.
Applicants should write giving details of experience and education to:

J. Beam Engineering Limited, Rothersthorpe Crescent, Northampton NN4 9JD

974

Junior Television Engineer

To assist in the operation and maintenance of Colour Telecine and allied equipment in Major Advtg. Agy. Applicant must have a basic knowledge of electronic equipment and some experience in its use, although experience of colour television is not essential as we are prepared to train the right applicant. Salary approx. £1,000 according to experience etc. Day release considered. Write or phone Doug Huxtable, Leo Burnett-LPE Ltd., 48 St. Martin's Lane, London, W.C.2. Tel.: 01-836 2424.

983

SENIOR TEST ENGINEERS

The leading U.K. Manufacturers of high grade T.V. monitors and ancillary T.V. studio equipment require Senior Test Engineers for their rapidly expanding test department.

Situated in the Berkshire town of MAIDENHEAD the company offers pleasant working conditions, good salaries, and a friendly environment.

Duties will cover the testing and troubleshooting of our complete range of equipment.

Previous experience on television equipment is not essential but candidates must have a thorough knowledge of electronics and testing procedures.

Reply to:

PROWEST ELECTRONICS LTD.,

Boyn Valley Road, Maidenhead, Berks.
Telephone: Maidenhead 29612

955

CHIEF TEST ENGINEER

Laser Associates, the leading laser manufacturers in Europe, require a capable Chief Test Engineer to systematically organise the testing and quality control of our range of lasers and laser systems. Although some experience of lasers would be an advantage, this position does call for someone with substantial experience in electronic circuitry as the power supply requirements of the laser systems and accessories are extensive. The successful applicant would be required to work in Slough until the end of 1971 when the two divisions of the company will be integrated in a new factory in Rugby, salary negotiable to £2,000 p.a. A vacancy also occurs for a test engineer to act as his assistant.
Please forward résumé to:

Mr. G. S. Bellis
LASER ASSOCIATES LIMITED
697 Stirling Road, Trading Estate, Slough, Bucks.

972

Tenders Invited

TENDER NOTICE No. 162-20/70-TPL (CP) DUE ON 4th FEB., 1971

Sealed Tenders are invited on behalf of the President of India for supply of:

1. UHF Radio Terminals complete with transmitters, receivers, branching filters installation materials, spares for 3 years requirement. — 72 sets
2. 'Yagi' or corner reflector antennae complete with matching balloon, cable harness and clamping materials etc. — 70 sets
3. Static type no break power plant, excluding battery, complete with installation material etc. (Input AC 230V 50Hz single phase and output DC 38.70V). — 45 sets
4. Field Strength meters. — 4 Nos.
5. UHF Signal Generators — 4 Nos.
6. UHF Relay Test Equipments and accessories. — 17 sets
7. UHF Foam dielectric Coaxial feeder cable with terminations, splices and jointing kits. — 6000 meters

N.B.

1. The cost of the equipment will be financed under the World Bank Loan and the relevant procedure will be followed.
2. The detailed specifications of each of the above items are available in the Tender Documents.

Intending Tenderers may obtain a copy of Invitation to Tender from Assistant Chief Engineer (CP), P & T Directorate, New Delhi, 1, on payment of Rs 20/- (Rs Twenty only). The payment will be accepted only in the form of a crossed Indian Postal Order (encashable in Parliament Street Post Office New Delhi) or Crossed Demand Draft (Drawn on any scheduled Bank in New Delhi). The Postal Order/Demand draft shall be drawn in favour of the Accounts Officer (C & A) Office of the Director-General of Posts and Telegraphs, New Delhi-1. The particulars of the Postal Order/Demand draft should be indicated in the Tender.

984

APPOINTMENTS

RADIO TECHNICIANS

With sound knowledge of at least three of the following types of equipment required immediately for Meteorological Office Ocean Weather Ships: Single Side-Band Transmitter, Radar (Navigational), Radar Height Finding, Echo Sounders, Radio Receivers, Automatic DF, VHF and Low Voltage Servo Recorders, Digital Telemetering Equipment.

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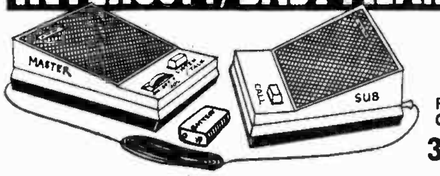

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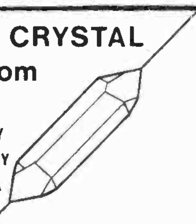

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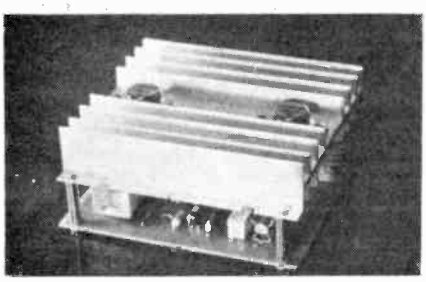

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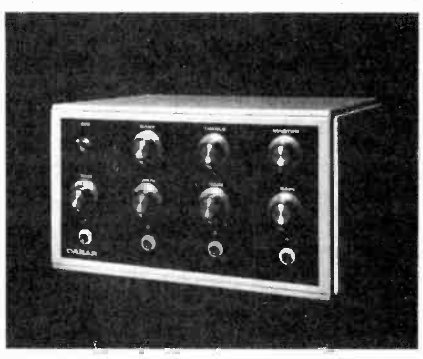

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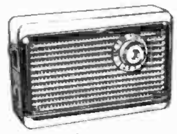

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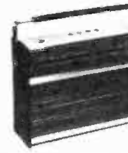

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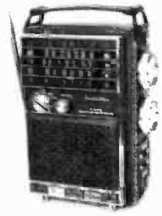

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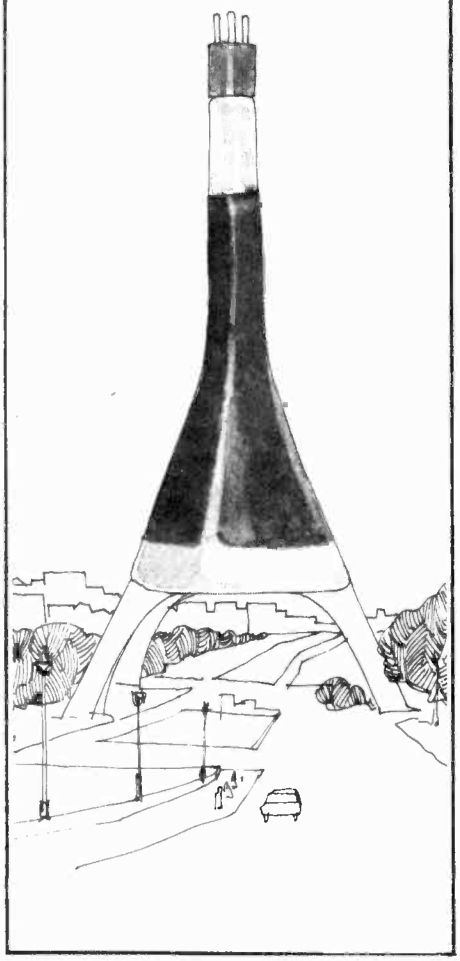

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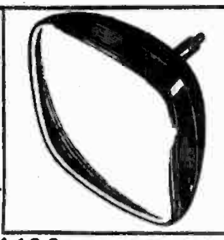

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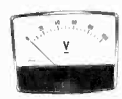

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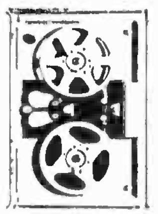

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Name ....

Address ....

....

RX/IND APN-9
This is a swt tuned Rx with CRT Ind unit, the Rx covers 1.8 to 2 Mc/s in 4 channels, the Ind section uses CRT type 3BP1 3in. green screen, also 34 octal type valves various types as follows: 6SN7, 6SL7, 6SK7, 6SJ7, 6H6, 6Y6, SZ3, 2X2, VR105, 6N7, 6SA7, there is also an high grade 100Kc xtal, all contained in case size 20 × 12 × 8in., black crackle finish. These units are for 115v. 400 c/s supply, the tube is well suited to scope use or possible mods. to 1.6 Mc/s. Pan adap. Supplied new with circ., magnifier & visor. £8 plus 15/- carr.

DIE CAST ALI BOXES
Heavy duty box with lid and sealing gasket, size internal 17 × 12 × 5½in., external size 19 × 14 × 8in., semi weatherproof, ex. equip. 50/-, plus 10/- carr.

TEKTRONIX SCOPE TROLLIES
Type 500/53A with drawer shelf, stowage for amps, good mech. order slightly soiled through storage, few only left. £14.10.0 plus 10/- carr.

H.V. CONDS
.5 Uf 50Kv. D.C. Wk. made by Wego, one pair only with some H.V. fittings, ex equip. £28 the pair plus £2 carr.

RACK BLOWERS
Heavy duty twin outlet blower in 19in. rack cabinet, 115v. 50c/s I/P at 4a, 2700 r.p.m., 2 phase motor with cap. Ex. equip U.S.A.F. surplus. £3.10.0 plus 12/6 carr.

RX UNIT 16048
V.L.F. Rx unit part of aircraft landing system contains large number of modern parts as follows, 8 type LA2503 Vinkors, 4 OC450 transistors, 6 EF72 valves, 5 min. printed circ. type relays, 2 high res. relays, OB2 & 85A2 Stab valves, 7 400 PIV diodes, Tant conds, pots, 1% conds., plugs & sks. etc., supplied in new condition. 42/- plus 7/6 post.

S.A.E. for list or enquiry.

A. H. SUPPLIES

57 Main Road, SHEFFIELD. S9 5HL

INDEX TO ADVERTISERS

Appointments Vacant Advertisements appear on pages 89-102

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ERSIN Multicore 5 CORE SOLDER

OVER 400 SPECIFICATIONS USED IN MORE THAN 63 COUNTRIES FOR FAST RELIABLE SOLDERED JOINTS

- Contains 5 cores of non-corrosive high speed Ersin flux. Removes surface oxides and prevents their formation during soldering. Complies with B.S. 219, 441, DTD 599A, Din 1707, U.S. Spec. QQ-S-571d.
- Savbit an exclusive Multicore Alloy which is saturated with copper to prevent absorption of copper from copper wires, circuit boards and soldering iron bits. Ministry approved under Ref: DTD 900/4535.
- Solder Tape, Rings, Preforms and Washers, Cored or Solid, are available in a wide range of specifications.

STANDARD ALLOYS INCLUDE

TIN/LEAD	B.S. GRADE	LIQUIDUS MELTING TEMP °C.	F.
60/40	K	188	370
Savbit No 1	—	215	419
50/50	F	212	414
45/55	R	224	435
40/60	G	234	453
30/70	J	255	491
20/80	V	275	527

HIGH AND LOW MELTING POINT ALLOYS

ALLOY	DESCRIPTION	MELTING TEMP. °C.	°F.
T.L.C.	Tin/Lead/Cadmium with very low melting point	145	293
L.M.P.	Contains 2% Silver for soldering silver coated surfaces	179	354
P.T.	Made from Pure Tin for use when a lead free solder is essential	232	450
H.M.P	High melting point solder to B.S. Grade 5S	296-301	565-574

COMPATIBLE PRINTED CIRCUIT SOLDERING MATERIALS

EXTRUSOL High Purity Extruded Solder

provides the most economical soldering. Its high purity and freedom from oxides, sulphides and other undesirable elements result in the following advantages:—

- Less dross on initial melting.
- More soldered joints per pound of solder purchased.
- Less reject joints.
- Improved wetting of electronic components & printed circuit boards.
- More uniform results.

All Extrusol is completely protected by plastic film packaging from the moment of manufacture until it is used. Available in bars and pellets. Can be released under AID authority and supplied to USA QQ-S-571d.

PC.2 MULTICORE TARNISH REMOVER

removes tarnishes and inorganic residues as the second half of a pre-cleaning process before soldering. It leaves the copper unaffected.

PC.90 MULTICORE PEELOFF SOLDER RESIST

is a temporary solder resist which can be peeled off with tweezers after soldering, leaving the original clean surface. It can be used for masking gold plated edge connections and holes to which heat sensitive or other components must be added later.

PC.41 MULTICORE ANTI-OXIDANT SOLDER COVER

which forms a liquid cover on the solder bath either side of the solder wave, largely preventing the formation of dross.

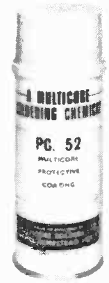
PC.80 MULTICORE SOLVENT CLEANER

removes organic contaminants such as grease, perspiration and residues of organic solutions from prior processes, as a pre-cleaning process before soldering. It is also very efficient in removing rosin-based flux residues after soldering.

PC.10A MULTICORE ACTIVATED SURFACE PRESERVATIVE

is a pre-soldering coating for preserving the clean surfaces established by the PC.80 Multicore Solvent Cleaner and PC.2 Multicore Tarnish Remover. PC.10A does not need to be removed before soldering and in fact contributes to the efficiency of the soldering process. PC.10A should be used whenever there is a delay between cleaning and soldering.

Gallon Containers
All liquid chemicals and fluxes supplied in 1 gallon polythene 'easy pouring' containers, with carrying handle.



Aerosols
PC.21A, PC.10A and PC.52 available in 16 oz. aerosol sprays.

SEVEN STANDARD MULTICORE LIQUID FLUXES

are now available, five of which are new:— PC.21A Multicore Non-Corrosive Liquid Flux is normally recommended for wave, dip, brush, spray and roller flux application methods. PC.25 Multicore Rosin Foam Flux is designed for foam fluxing and exhibits an unusually stable foam with a fine bubble size.

PC.52 MULTICORE PROTECTIVE COATING

is a lacquer which should be applied after soldering for protecting printed circuits from deterioration or failure in service. It can easily be soldered through if modifications or repairs are necessary at a later date.

SOLDERABILITY TEST MACHINE MARK 3

Use for testing to B.S 4393 : 1969, Section 10. A simple precision instrument for assessing the solderability of component termination wires. Complies with B.S 2011 Part 2 Test T and comparable international standards. Essential for quality control.

SOLDERING HANDBOOK

The most comprehensive book on soldering for industrial use, containing 120 pages with 100 illustrations and invaluable reference charts. Features practical methods of soldering in electronics and allied industries, and is divided into three headings.

Part 1. Making a joint.
Part 2. Choosing Methods and Materials.
Part 3. Reference Tables.
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WW—003 FOR FURTHER DETAILS