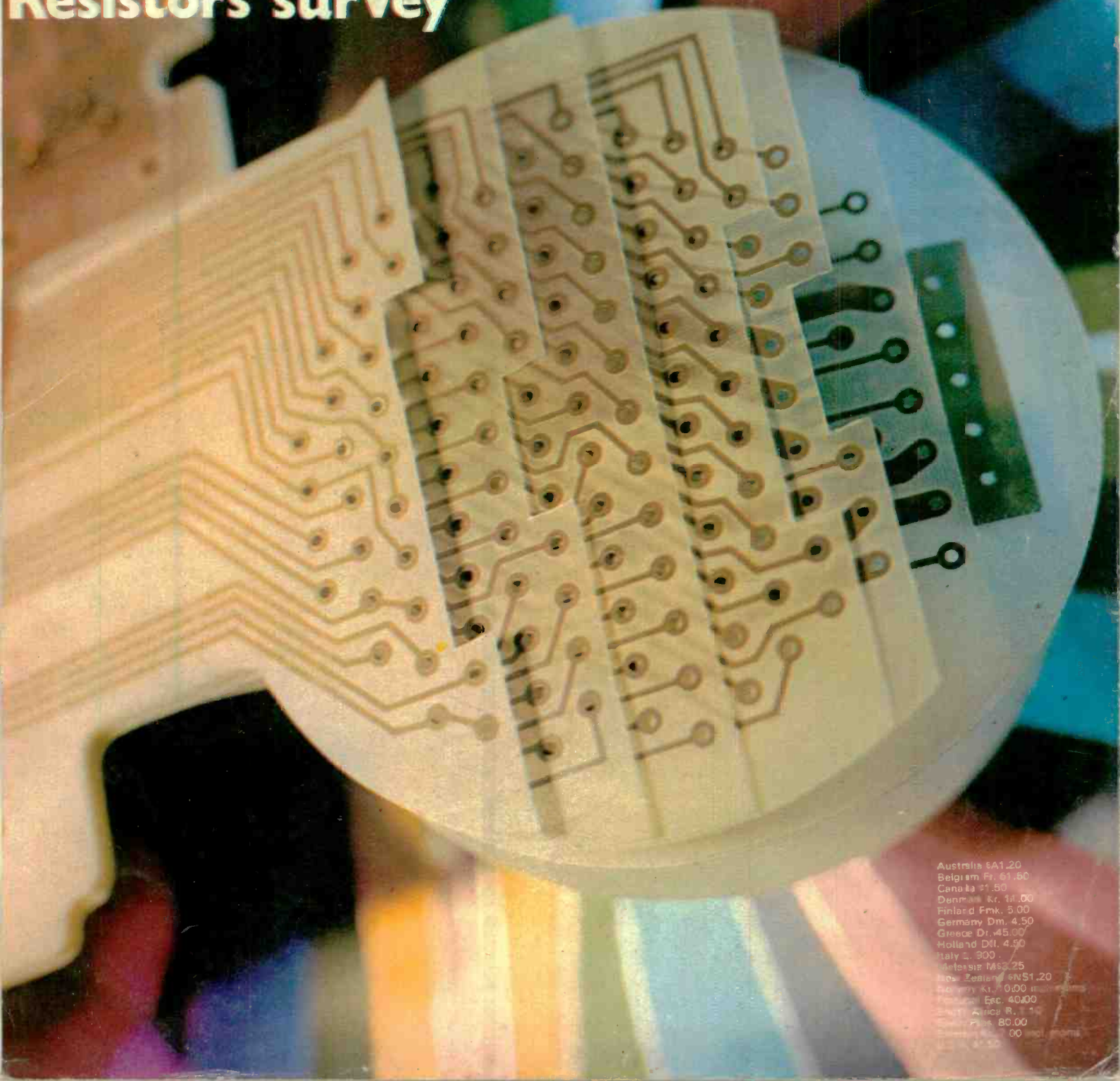


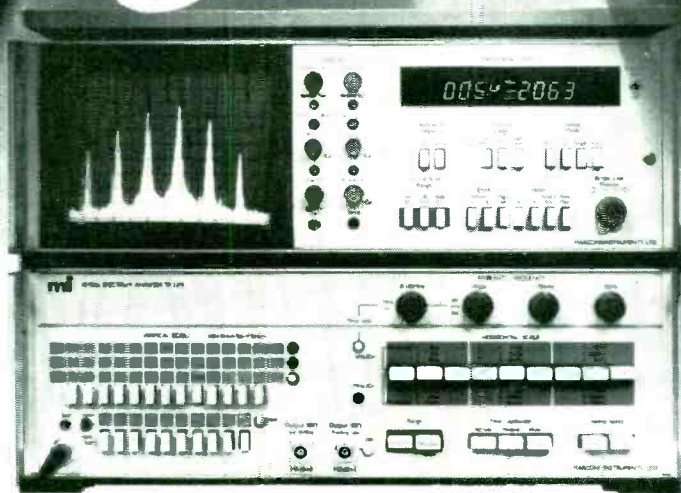
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OCTOBER 1975 35p

**TV sound tuner**  
**Resistors survey**



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# The Production Test Bottleneck Smasher!

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Slash your production-test times and divert your skilled engineers to more important work with our TF 2370 Spectrum Analyser. It will reduce to simple operations, complicated measurements such as response, level, gain, signal purity, modulation and many more, with a speed and degree of accuracy that has to be seen to be believed. Forget everything you have heard about spectrum analysers. The TF 2370 is unique. It employs advanced technology to make it reliable and as easy to operate as a multimeter. The facts speak for themselves.

- \* Flicker-free display of frequency response from 30 Hz to 110 MHz on a high-brightness c.r.t.
- \* Electronic graticule, with a  $\pm 15\%$  variation of horizontal divisions for pin-point positioning against waveform display.
- \* Press-button selection of three amplitude scales: one linear and two logarithmic with expansion to 1 dB/div. with an accuracy of  $\pm 0.1$  dB/dB.
- \* 9-digit electronic counter automatically gives centre frequency, reads any other frequency corresponding to manually-adjusted 'bright line' position on display, or the

difference frequency between the two, at the press of a button. All to an accuracy of  $\pm 2$  Hz  $\pm$  reference frequency accuracy on high resolution and manual. Internal reference frequency provided with setting accuracy of 1 in  $10^7$ .

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- \* Automatic adjustment of amplifier gain to give optimum lowest-noise performance with full protection against input overloading.
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- \* With the 5 Hz filter, signals 100 Hz from a response at 0dB can be measured to  $-70$  dB.

Now ask for a demonstration. It could prove that the TF 2370 is a better cure for your headaches than aspirin. We are standing by for your call.

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# LOW COST TESTERS



## LEVELL

### PORTABLE INSTRUMENTS

#### INSULATION TESTER



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

##### RESISTANCE RANGES

10M  $\Omega$  to 10T  $\Omega$  ( $10^{13}$   $\Omega$ ) at 250V, 500V, 750V and 1kV.

1M  $\Omega$  to 1T  $\Omega$  at 25V, 50V and 100V.

100k  $\Omega$  to 100G  $\Omega$  at 2.5V, 5V and 10V.

10k  $\Omega$  to 10G  $\Omega$  at 1V.

Accuracy  $\pm 15\%$  +800  $\Omega$  on 6 decade logarithmic scale.

Accuracy of test voltages  $\pm 3\%$   $\pm 50$ mV at scale centre.

Fall of test voltages  $< 2\%$  at 10 $\mu$ A and  $< 20\%$  at 100 $\mu$ A.

Short circuit current between 500 $\mu$ A and 3mA.

##### CURRENT RANGE

100pA to 100 $\mu$ A on 6 decade logarithmic scale.

Accuracy of current measurement  $\pm 15\%$  of indicated value.

Input voltage drop is approximately 20mV at 100pA, 200mV

at 100nA and 400mV at 100 $\mu$ A.

Maximum safe continuous overload is 50mA.

##### MEASUREMENT TIME

$< 3$ s for resistance on all ranges relative to CAL position.

$< 10$ s for resistance of 10G  $\Omega$  across 1 $\mu$ F on 50V to 500V.

Discharge time to 1% is 0.1s per  $\mu$ F on CAL position.

##### RECORDER OUTPUT

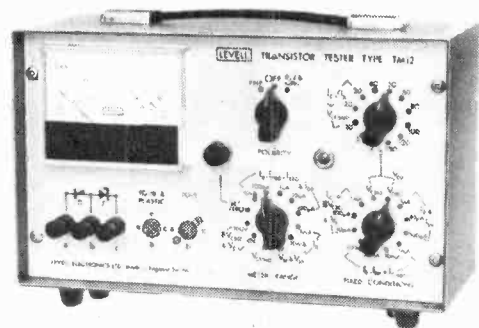
1V per decade  $\pm 2\%$  with zero output at scale centre.

Maximum output  $\pm 3$ V. Output resistance 1k  $\Omega$ .

type  
TM14

## £88

#### TRANSISTOR TESTER



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

##### TRANSISTOR RANGES (PNP OR NPN)

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

$BV_{CBO}$ : 10V or 100V f.s.d. acc.  $\pm 2\%$  f.s.d.  $\pm 1\%$  at currents of 10 $\mu$ A, 100 $\mu$ A and 1mA  $\pm 20\%$ .

$I_B$ : 10nA, 100nA, 1 $\mu$ A... 10mA f.s.d. acc.  $\pm 2\%$  f.s.d.  $\pm 1\%$  at fixed  $I_E$  of 1 $\mu$ A, 10 $\mu$ A, 100 $\mu$ A, 1mA, 10mA, 30mA, and 100mA acc.  $\pm 1\%$ .

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

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

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

##### DIODE & ZENER DIODE RANGES

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

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

$V_{DF}$ : 1V f.s.d. acc.  $\pm 20$ mV at  $I_{DF}$  of 1 $\mu$ A, 10 $\mu$ A, 100 $\mu$ A, 1mA, 10mA, 30mA and 100mA.

type  
TM12

## £88

### LEVELL ELECTRONICS LTD.

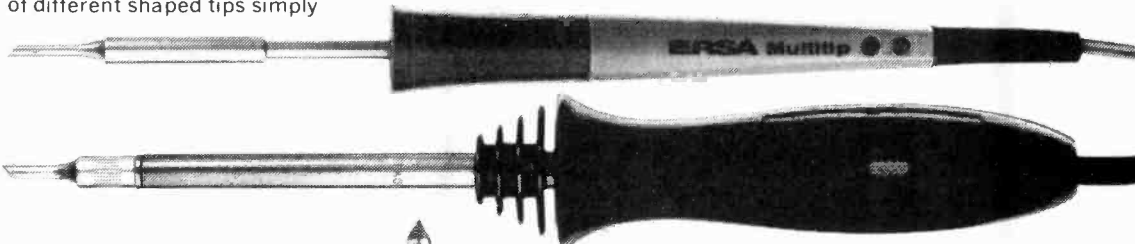
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Prices include batteries and U.K. delivery. V.A.T. extra.  
Optional extras are leather cases and mains power units.  
Send for data covering our range of portable instruments.

# The Greenwood guide to professional soldering.

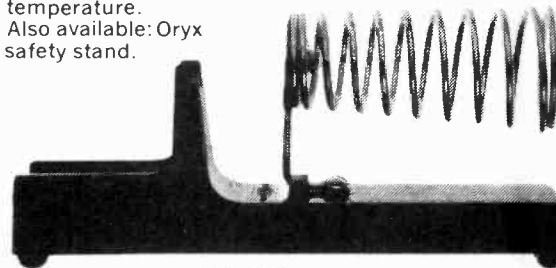
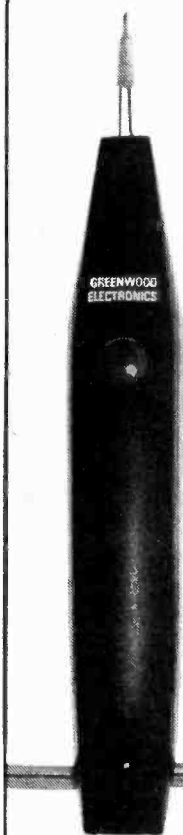
The Ersa Multitip. A top-quality iron that's ultra-light, offering reliability so necessary to achieve constant production flow. A range of different shaped tips simply

push onto the stem of the iron. It has the unique advantage that you can change the element in seconds.



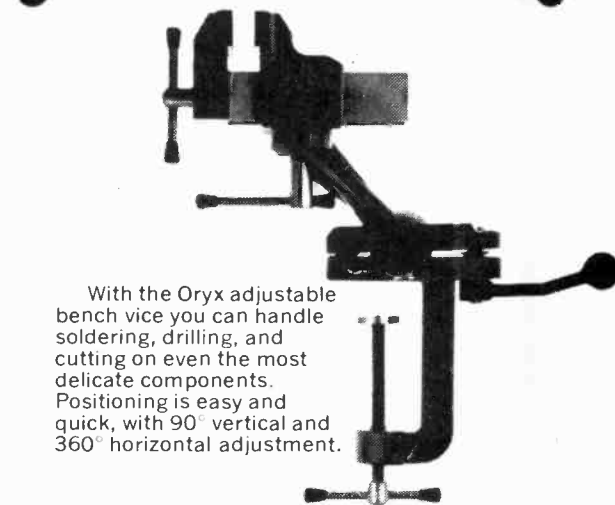
The Iso-Tip. A safe, high-powered iron which works anywhere without a mains lead. The breakthrough? Nickel Cadmium cells that are re-chargeable. (A charging stand is included for 240v or 115v A.C.) Each charge gives at least 60 soldering joints. Weight? Only 6oz.

The Oryx 50. A temperature controlled mains soldering iron. (Temperature control within  $\pm 2\%$ .) Adjustment ( $200^{\circ}$ – $400^{\circ}$  C) can be made whilst iron is operating using the same tip. Light, compact and easy to handle. A large 50W element loading gives rapid heating and high performance with constant tip temperature. Also available: Oryx safety stand.



The Ersa Sprint. Unique – it heats up to maximum temperature in only 10 seconds, and is the lightest gun on the UK market. Ideal for the service-man. With its lightweight (only 7oz.) and compact construction, it can be manoeuvred in even the most awkward areas.

With the Oryx adjustable bench vice you can handle soldering, drilling, and cutting on even the most delicate components. Positioning is easy and quick, with  $90^{\circ}$  vertical and  $360^{\circ}$  horizontal adjustment.



Oryx SR3A desoldering tool. Ideal where components are tightly grouped. Instantly removes unwanted solder from printed circuits etc. Accurate, reliable, speedy, and safe.

**Greenwood Electronics offer a range of highly advanced products specifically for professional soldering applications. For more detailed information about the comprehensive Greenwood range, write to address below.**

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**Due to expansion we are seeking additional distributor/stockists.**

# News of the Decade



**RESISTANCE  
CAPACITANCE  
INDUCTANCE**  
over 60 different models  
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CONTACT US IF YOU NEED MORE INFORMATION OR DEMONSTRATION

## DECADE BOXES

### "Junior" Series—Resistance—1%

	Decades	Ohms Range	Ohms Resolution	£
J1	5	0— 1,111,100	10	30.83
J2	5	0— 111,110	1	30.49
J3	4	0— 111,100	10	25.09
J4	4	0— 11,110	1	24.75
J5	3	0— 11,100	10	20.51
J6	3	0— 1,110	1	20.42
J60	6	0— 1,111,110	1	37.13
J70	7	0— 1,111,111	1	43.65

### "Junior" Series—Capacitance—1%

	Decades	pF Range	pF Resolution	£
JC1	3	100— 111,000	100	22.20
JC2	2 + var	30— 11,140	"Infinite"	23.20

### "Point One" Series—Resistance—0.1%

	Decades	Ohms Range	Ohms Resolution	£
R3	4	0— 1,111	0.1	47.25
R4	4	0— 11,110	1	46.97
R5	4	0— 111,110	10	46.13
R7	5	0— 1,111,100	10	57.38
R9	5	0— 111,110	1	57.94
R10	5	0— 11,111	0.1	58.50
R11	5	0— 11,111,000	100	66.71
R20	6	0— 1,111,110	1	69.42
R21	6	0— 111,111	0.1	70.31
R22	6	0— 11,111.1	0.01	76.50
R30	7	0— 11,111,110	1	87.75
R31	7	0— 1,111,111	0.1	81.56
R32	7	0— 111,111.1	0.01	82.13
R41	8	0— 11,111,111	0.1	99.56
R42	8	0— 1,111,111.1	0.01	95.63

### "Hundred" Series—Resistance—0.03%

	Decades	Ohms Range	Ohms Resolution	£
R400	4	0— 111,100	10	87.15
R401	4	0— 11,110	1	91.35
R402	4	0— 1,111	0.1	92.40
R403	4	0— 111.1	0.1	98.70
R600	6	0— 11,111,100	10	118.65
R601	6	0— 1,111,110	1	120.75
R602	6	0— 111,111	0.1	122.85
R603	6	0— 11,111.1	0.01	128.63
R701	7	0— 11,111,110	1	140.70
R702	7	0— 1,111,111	0.1	142.80
R703	7	0— 111,111.1	0.01	148.05
R802	8	0— 11,111,111	0.1	160.65

## DECADE BOXES continued

R803	8	0— 1,111,111.1	0.01	162.75
<b>High Dissipation—Resistance—1%</b>				
	Decades	Ohms Range	Ohms Resolution	£
HD1	5	0— 1,111,100	10	104.63
HD1/L	5	0— 111,110	0.2 Approx.	110.25
<b>"Point One" Series—Inductance—5%</b>				
	Decades	mH Range	mH Resolution	£
L1	3	0— 1,110	1	83.25
L2	2	0— 110	1	62.33
L3	2	0— 1,100	10	69.30
<b>"Hundred" Series—Inductance—0.3%</b>				
	Decades	mH Range	mH Resolution	£
L300	3	0— 1,110	1	277.00
L400	4	0— 11,110	1	360.00

## CAPACITANCE BOXES

Decades	Decades	pF Range	pF Resolution	Accuracy	£
C3	3	100— 111,000	100	1%	48.30
PC3	3	100— 111,000	100	5%	66.70
C4	4	100— 1,111,000	100	1%	73.60
PC4	4	100— 1,111,000	100	5%	103.50
<b>Decade plus Variables</b>					
	Decades	pF Range	pF Resolution	Accuracy	£
VC4	3	50— 111,150	INFINITE	1%	60.95
VC5	4	50— 1,111,150	..	1%	86.25
PVC5	4	50— 1,111,150	..	0.5%	128.80
SVC5	4	50— 1,111,150	..	0.05%	552.00
C500	4	50— 1,111,150	..	0.2%	238.50†
SVC5 special. Details on application					
<b>Variables</b>					
		pF Range		Accuracy	£
PVC1 Mk 2		5— 200		0.5%	101.20
PVC Mk. 2		20— 1,120		0.5%	92.00
VC2		20— 1,130		1%	42.55
PVC4		0— 10		1%	70.15
PVC1/S		20— 120		0.5%	60.98
<b>Switched</b>					
		uF Range	uF Resolution	Accuracy	£
C140		0— 140	1.0	5%	156.00†
C100		0— 100	1.0	5%	132.00†
C60		0— 61	0.1	5%	117.60†
C60P		0— 61	0.1	1%	239.00†

† Packing and Handling extra. Prices do not include VAT



## J.J. Lloyd Instruments Ltd

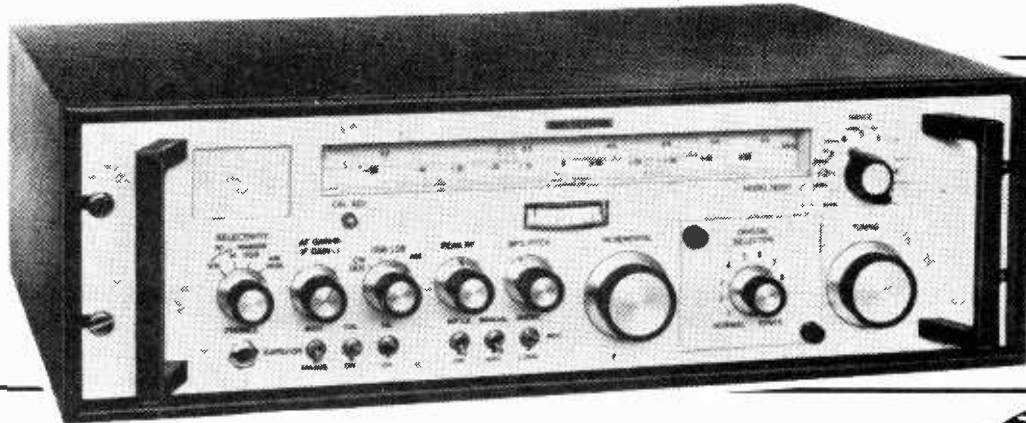
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WW—011 FOR FURTHER DETAILS

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The Eddystone 1830 series of general purpose HF/MF communication receivers is widely used in marine, military, police, broadcasting and other professional applications. Using the optional crystal control facility, stability is almost up to synthesiser standard – at a fraction of the cost!

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# Introducing the Heathkit 2700 Series. There are lots of ways of looking at it.



Not content with giving you a choice of four DC ranges, the new Heathkit 2700 Series Power Supplies can have either digital or analog readout.

And, naturally, being Heathkit, each model is available either factory assembled or as a complete kit.

But, whatever one you choose, you'll still get an exceptionally high degree of sophistication. With features like a remote sensing connection to compensate for voltage drops when using long leads.

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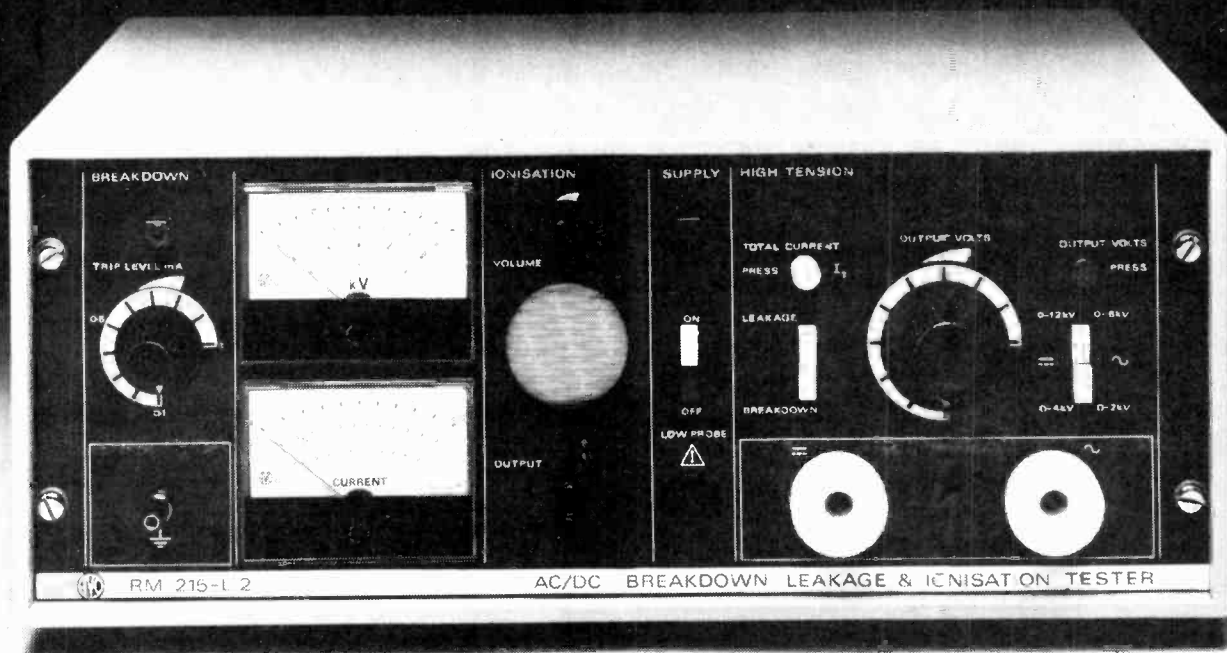
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The new Heathkit range of power supplies.



# Ion out your quality control problems

The AVO Breakdown and Ionisation Tester RM215-L/2 is specifically designed to help solve all manner of quality control problems.

It measures resistive leakage current under both AC & DC voltage testing conditions as well as total AC leakage current. Test voltages up to 12 kV DC and 6 kV AC are continuously variable and breakdown current level is adjustable up to 1 mA. A built-in loudspeaker gives audible detection of ionisation and there are connections for earphone or an oscilloscope.

The circuit features low internal resistance yet at the same time limits the maximum output current, even at short circuit.

With the RM215-L/2 you can carry out general flash testing, measurement of breakdown voltage – even after breakdown – and the detection (and counting) of spurious flashovers.

Equally suited to both destructive and non-destructive testing, the RM215-L/2 is a piece of test equipment you cannot afford to be without. If you have some problems that need to be 'ionised' out, get in touch for full details.

#### APPLICATIONS

- Flash testing of electrical components.
- Measurement of breakdown voltage on electrical components and materials.
- Measurement of insulation resistance at high voltage.
- Measurement of d.c. leakage current.
- Measurement of a.c. leakage current and total current.
- Non-destructive insulation testing of materials and components.
- Detection of ionisation in electrical assemblies.

Designed to meet B.S., V.D.E. and I.E.C. Safety Requirements.

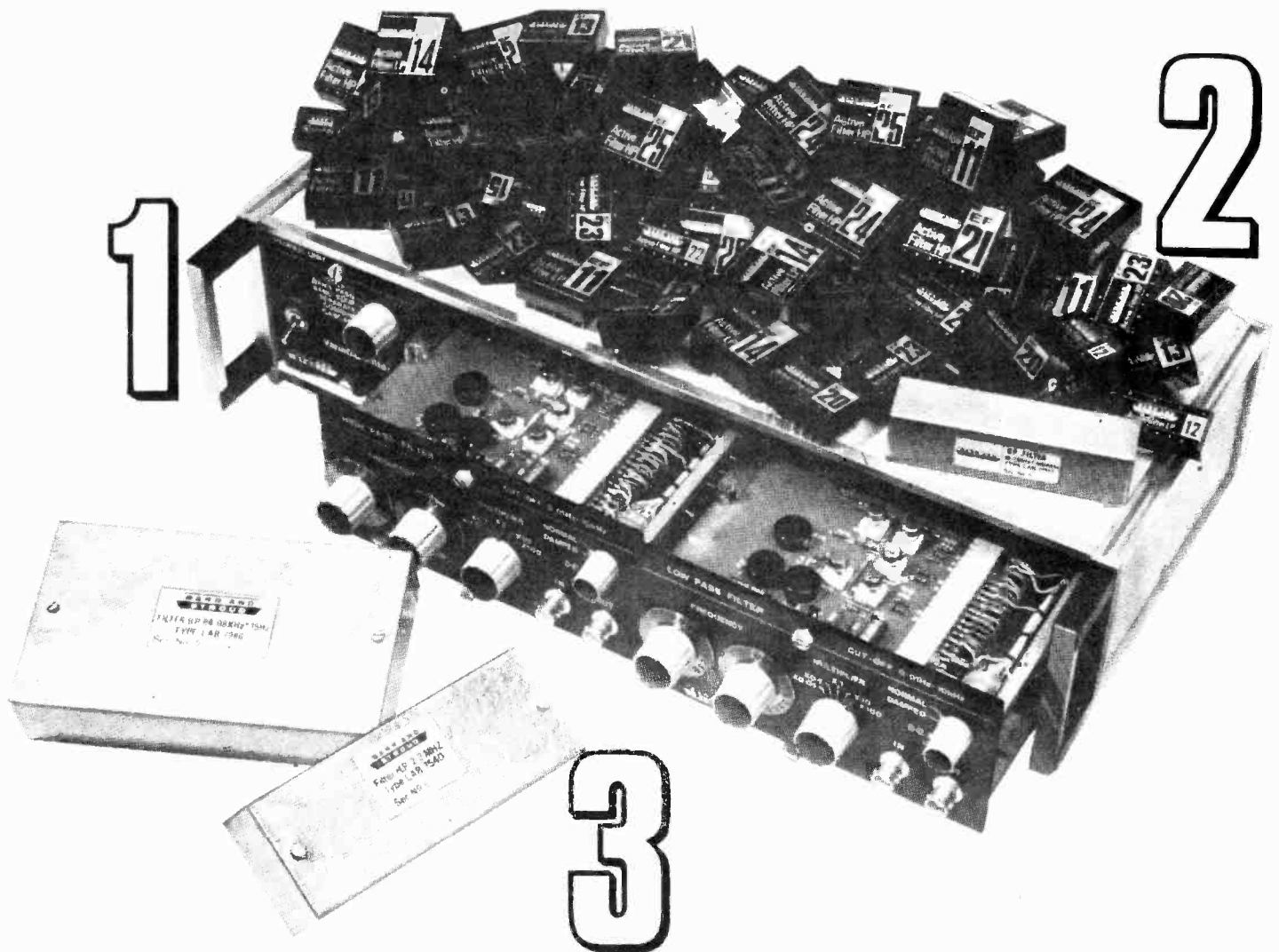


**Avo Limited**, Dover, Kent.  
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Thorn Measurement Control  
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## The 3 aspects of our service



### 1. System EF3

A flexible system of filter instrumentation using a modular approach to give plug-in interchangeability. The mainframe carries a power unit and accepts up to two filter units of either Low Pass or High Pass function. Integral switching allows individual or cascade operation and can give Band Pass, Band Stop, Band Separate or Band Combine modes.

### 2. Active Filter Modules

These are compact, solid state, encapsulated units providing basic filter functions to be customer set for cut-off frequency and characteristic. The present range contains Low Pass and High Pass types with cut-off frequency coverage from 1.0Hz to 30kHz in overlapping ranges, with attenuation rates up to 24dB/octave/module. Universal modules specifically for Band Pass and Band Stop operation are part of the range.

### 3. Custom Build Service

If our standard filter range does not meet your specification we welcome the opportunity to study your requirement. Broadly our capability stretches from d.c. to 25MHz with experience in passive and active designs. We can work to normal commercial standards or strict defence requirements and construction can be as dictated by the environmental conditions of your application.

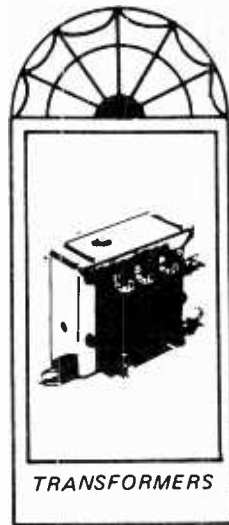
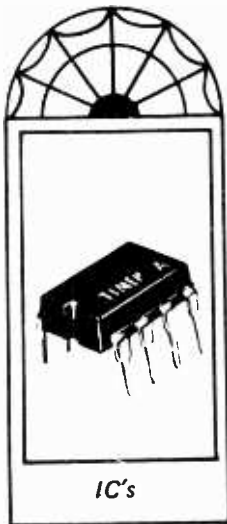
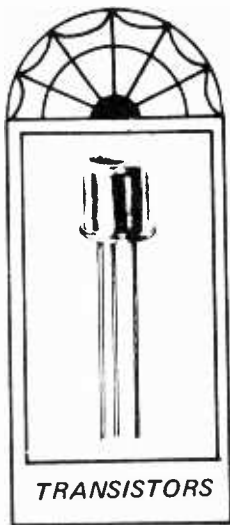
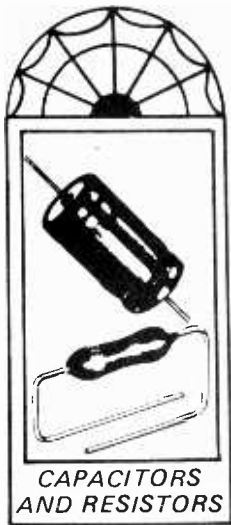
**BARR & STROUD LIMITED**  
London Office: 1 Pall Mall East, London SW1Y 5AU  
Telephone: 01-930 1541 Telex: 261877

WW-067 FOR FURTHER DETAILS

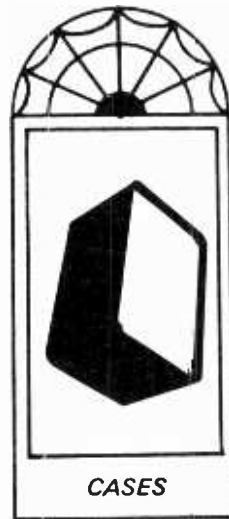
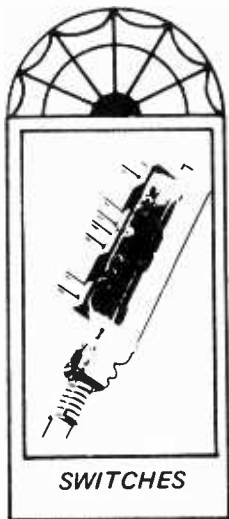
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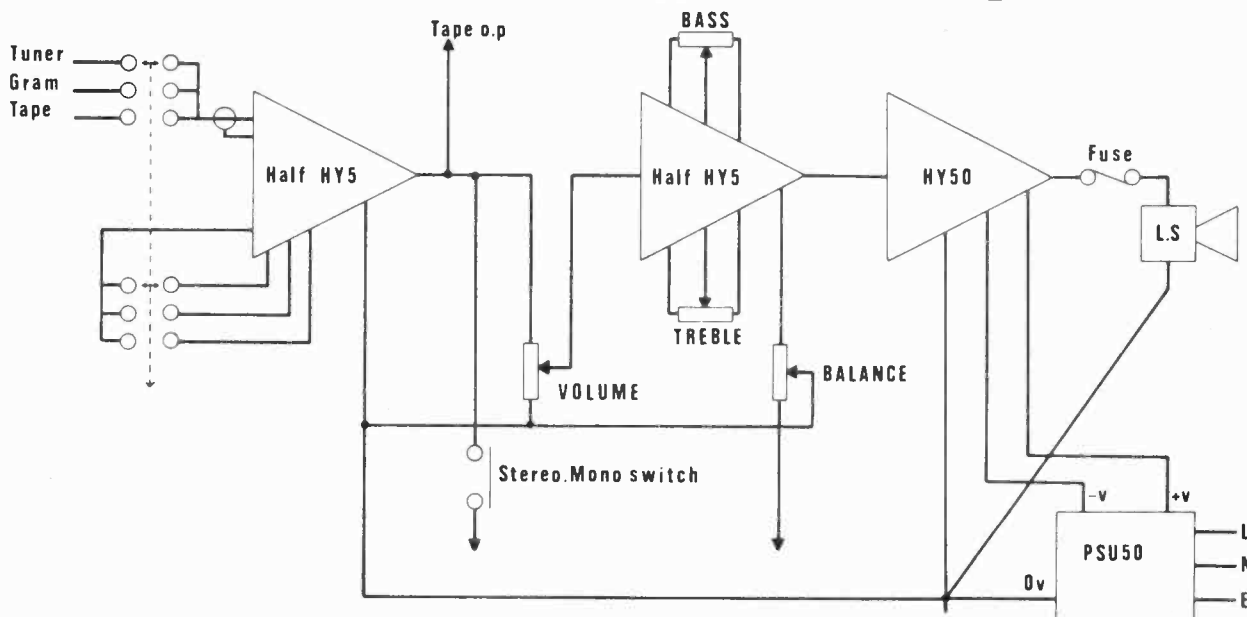
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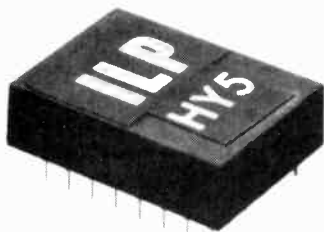
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## SHEER SIMPLICITY!



Mono electrical circuit diagram with interconnections for stereo shown



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

**TECHNICAL SPECIFICATION**

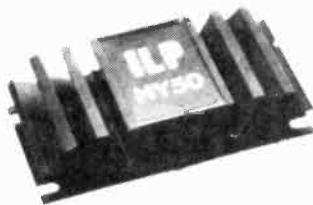
**Inputs**  
 Magnetic Pick-up 3mV, RIAA  
 Ceramic Pick-up 30mV  
 Microphone 10mV  
 Tuner 100mV  
 Auxiliary 3-100mV  
 Input impedance 47kΩ at 1kHz

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

**Active Tone Controls**  
 Treble +12db at 10kHz  
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**Distortion** 0.05% at 1kHz  
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**Overload Capability** 40db on most sensitive input  
**Supply Voltage** +16-25 volts.

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

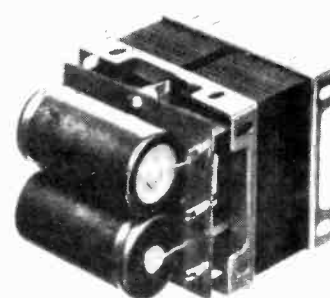


The HY50 is a complete solid state hybrid Hi-Fi amplifier incorporating its own high conductivity heatsink hermetically sealed in black epoxy resin. Only five connections are provided: Input, output, power lines and earth.

**TECHNICAL SPECIFICATION**

**Output Power** 25 watts RMS into 8Ω  
**Load Impedance** 4-16Ω  
**Input Sensitivity** 0db (0.775 volts RMS)  
**Input Impedance** 47kΩ  
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The PSU50 incorporated a specially designed transformer and can be used for either mono or stereo systems.

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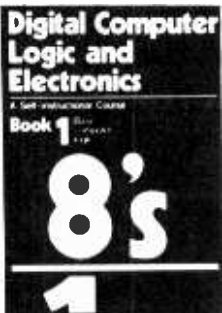
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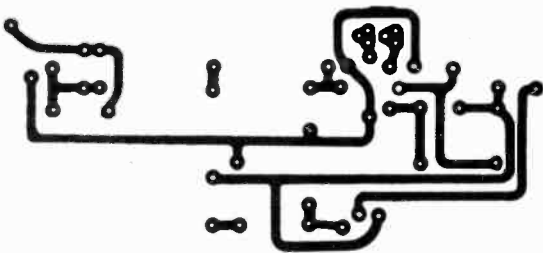


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SOLID MAHOGANY CABINET

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PRICE: £47.95 + 99p p&p + VAT.



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

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PRICE: Mono £25.46 + 85p p&p + VAT;

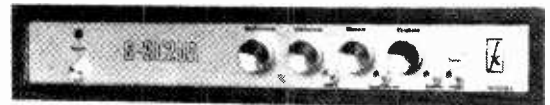
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PRICE: £29.95 + 99p p&p + VAT.



## STEREO MODULE TUNER

A low-cost Stereo Tuner based on the Mullard LP1186 RF module requiring no alignment. The IF comprises a ceramic filter and high-performance IC. Variable INTERSTATION MUTE. PLL stereo decoder IC.

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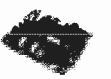
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Mk II version of this design (WW Sept. 1970). The lowest distortion phase-locked stereo decoder kit available (Typ. 0.05% @ N-J Tuner O/P level). Separation 40dB up to 15KHz. Complete kit comprises PCB and all components, inc. stereo LED.

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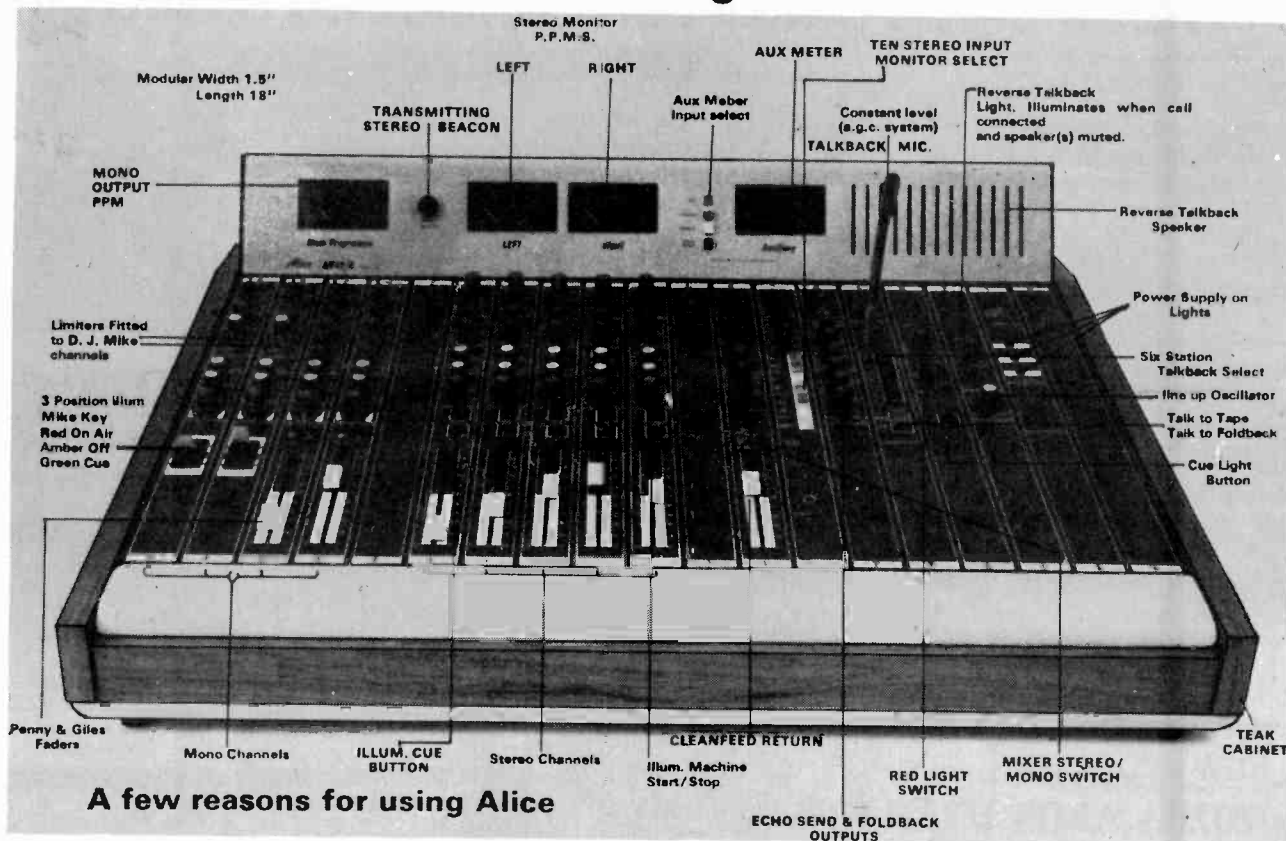
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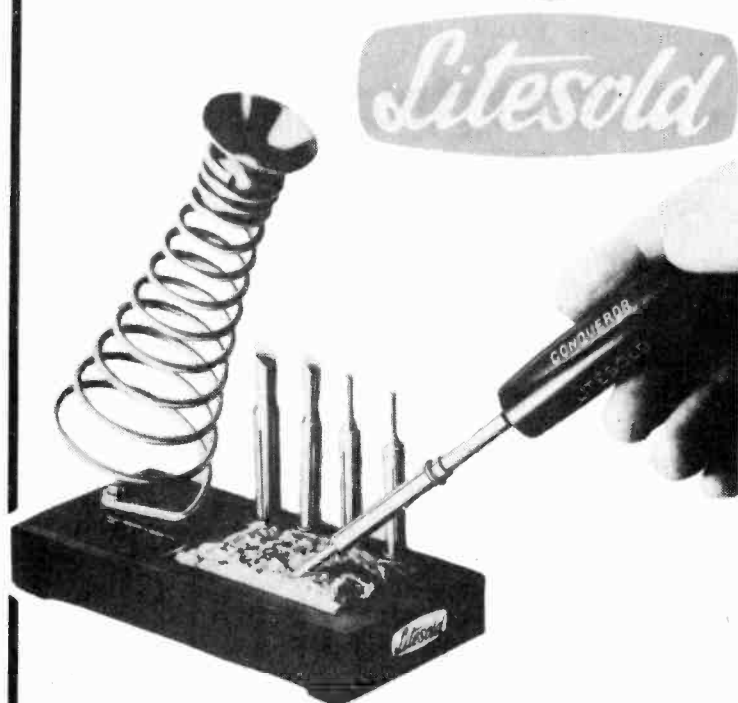
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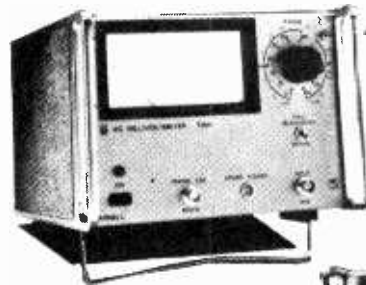
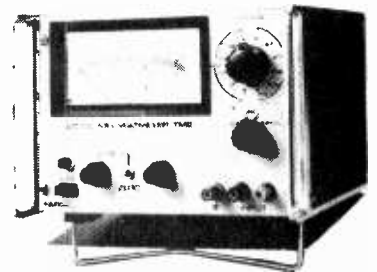
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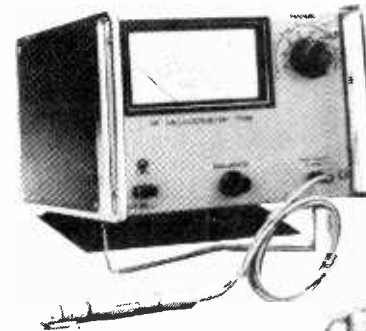
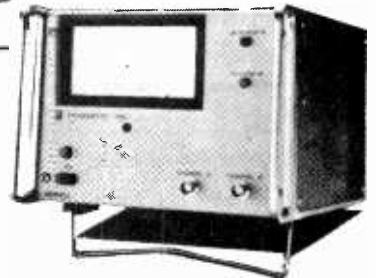


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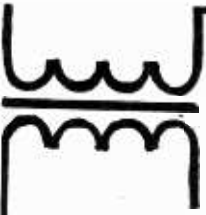


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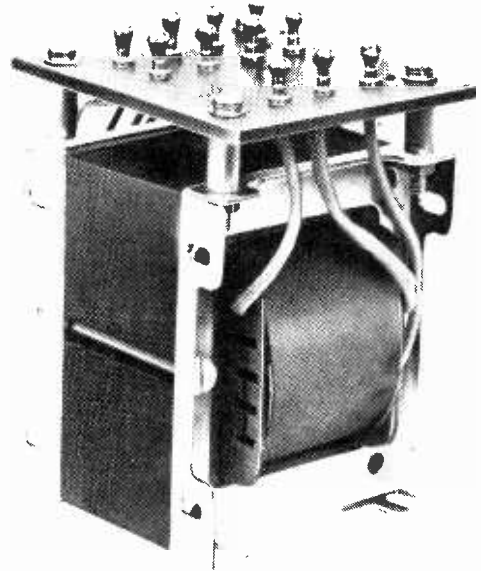
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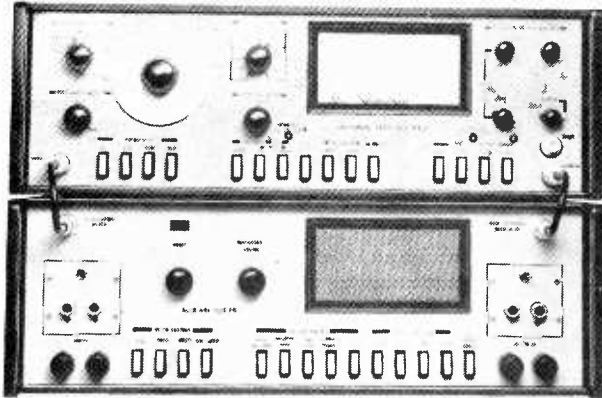
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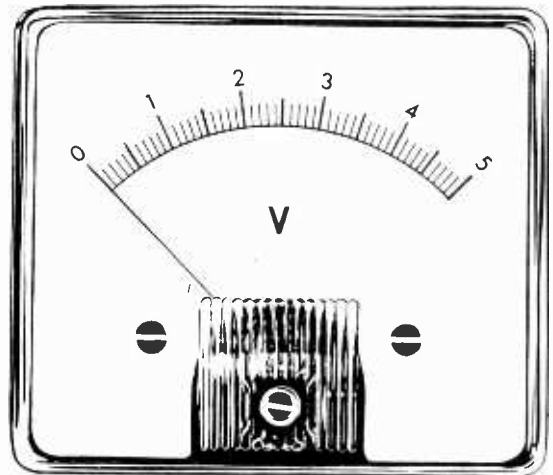
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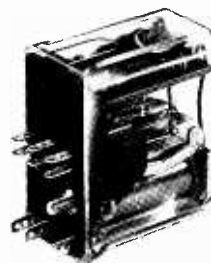
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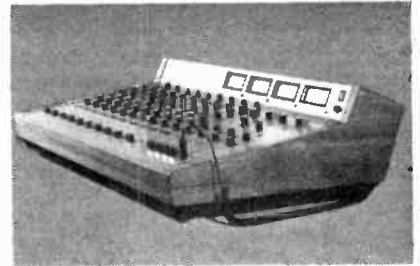
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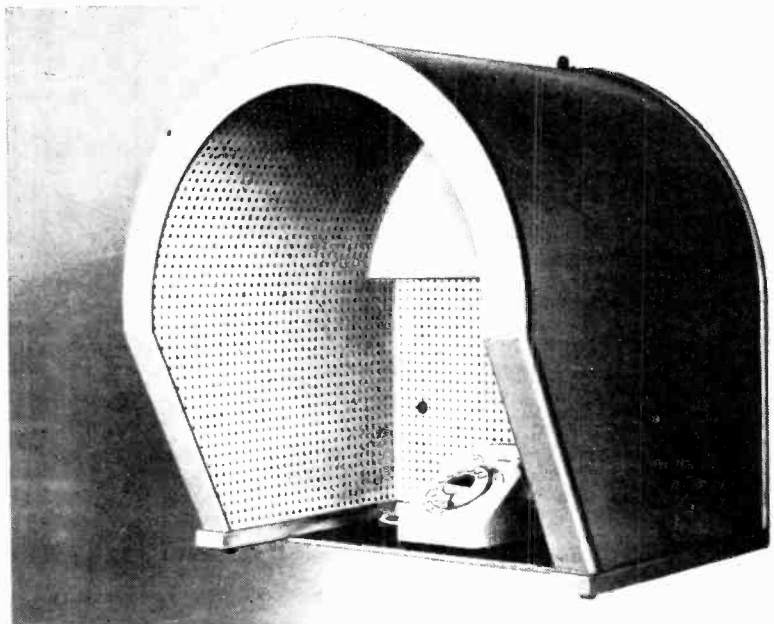
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# Whiteley

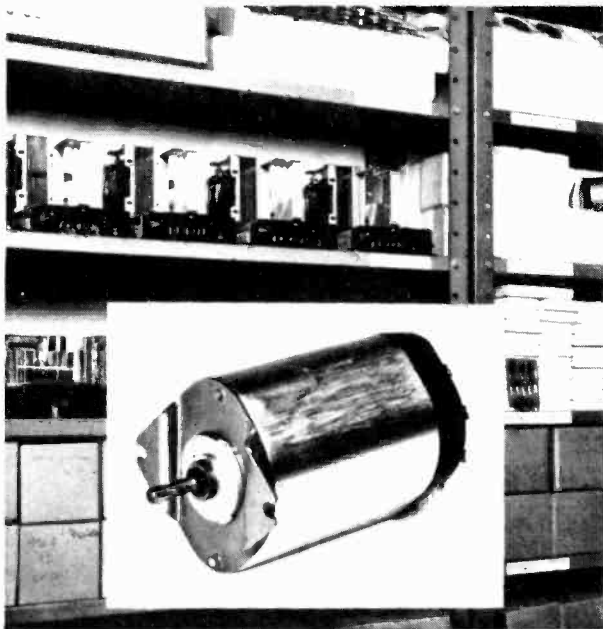
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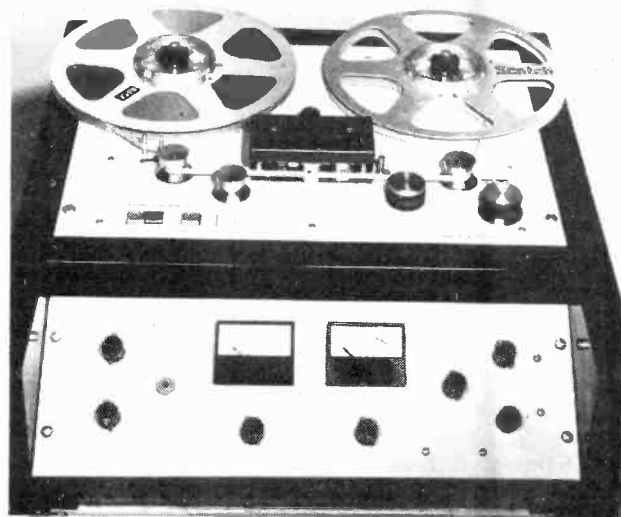
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at a professional recorder that offers high performance, excellent reliability and is very easy to maintain. Ask yourself why so many commercial radio stations and recording studios are doing their best to wear them out, and not having much success. Decide if you need mono or stereo, console transportable or rack mounting versions and then inquire about prices. We are sure you will be very pleasantly surprised.

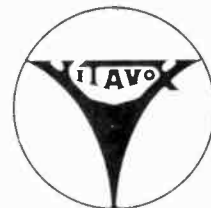
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WW-031 FOR FURTHER DETAILS

## Great Sound...



THE S3 PRESSURE UNIT has been designed to meet the growing demand for considerably increased power handling capacity without the sacrifice of either efficiency or frequency response. It features a powerful ceramic magnet and a strong but light diaphragm and voice coil assembly with many new features. It is a robust, reliable unit of exceptional quality. The S3 is one of the units of the Vitavox Power Range



Please send me further information on your product range

Name \_\_\_\_\_

Company \_\_\_\_\_

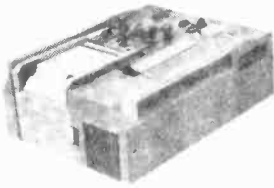
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# FAST RESPONSE STRIP CHART RECORDERS

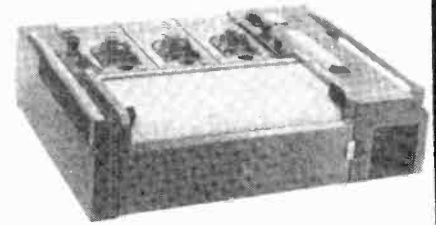
Made in USSR



Type H320-1  
Single pen

### Specification

Basic error.....	2.5%
Sensitivity.....	8mA F.S.D.
Response.....	0.2 sec.
Width of each channel.....	80mm
Chart speeds, selected by push buttons.....	0.1-0.2-0.5-1-2.5-5-12.5-25mm/sec.
Chart drive.....	200-250v 50Hz



Type H320-3  
Three-pen

**Recording:** Syphon pen directly attached to moving coil frame, curvilinear co-ordinates

**Equipment:** Marker pen, Timerpen, Paper footage indicator, 10 rolls of paper, connectors, etc.

**Dimensions:** H320-1: 285x384x16.5mm  
H320-3: 475x384x16.5mm  
**PRICE:** H320-1 £80.00  
H320-3 £130.00  
Exclusive of VAT

Available for immediate delivery

## Z & I AERO SERVICES LTD.

44A WESTBOURNE GROVE, LONDON W2 5SF

Tel. 01-727 5641

Telex: 261306

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# NOW IT'S THE AMCRON M600

## M600 POWER AMPLIFIER



**1350 watts**  
**DC-Coupled**

The M600 amplifier is a new high-power amplifier capable of providing 1,350 watts RMS over a bandwidth of DC to 20 kHz, 70 volts RMS at the output terminals, very low noise and distortion, AC/DC selector switch, plug-in front panel circuit board, built-in fan for cooling and the ability to connect two M600s together to double the power and output voltage, are just some of the features which place the Amcron M600 in the forefront when considering power amplifiers. Driving shakers and vibrators, motors and difficult speaker systems, providing power for material or components testing or used as a large distribution amplifier, the M600 is equally at home.

**Brief specifications:**

RMS power out	750 watts into 8 ohms 1,350 watts into 4 ohms
DC output	20 amps (supply fuse limited)
Power bandwidth	DC to 20 kHz + 1 db - 0 db 600 W into 8Ω
Phase response	+ 0 db - 15 db DC - 20 kHz
Slew rate	16 V/μsecond
Damping factor (8Ω)	greater than 400 DC - 1 kHz
Hum & noise	120 db below 600 Watts
THD	less than 0.05% DC - 20 kHz, 600 W into 8Ω
Dimensions	19" std rack, 8 3/4" H, 16 1/2" deep, Wt. 92 lb.

Coupling two M600s together through a socket provided at the back of each amplifier produces a 140 Volt balanced output. This configuration is called an M2000, and produces 2 kilowatts into an 8ohm load. A peak catching meter, and threshold lights provide convenient front panel output monitoring.



**MACINNES LABORATORIES LTD**

**MACINNES HOUSE, CARLTON PARK INDUSTRIAL ESTATE,  
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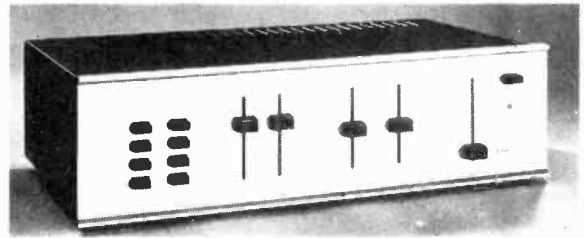
## A message for dealers in exclusive high quality audio equipment – everywhere.

It is now proposed to expand the distribution of RADFORD products by supplying from the factory in BRISTOL direct to franchised dealers outside the United Kingdom.

If you have a discriminating clientele looking for the finest audio equipment and loudspeaker components available, you could profit from a direct RADFORD franchise.

Write today for details and leaflets.

Radford Audio Ltd  
Ashton Vale Road  
Bristol BS3 2HZ England



### ZD22

#### Stereo Pre-amplifier Control Unit

A stereo pre-amplifier of virtually zero distortion. Inputs for disc, tuner, and two tape machines. Size 17" x 4½" x 10" deep.

£145.00

### HD250 Stereo Integrated amplifier

Incorporates ZD22 pre-amplifier with low distortion power amplifier of 50 watts per channel into 4-8 ohms load. Headphone output. Illustrated above. Size 17" x 4½" x 11".

£195.00

### ZD100 Power amplifier

Power output 120 watts in 4 ohms and 75 watts into 8 ohms. Distortion less than 0.004% up to clip level. Size 17" x 4½" x 13".

£175.00

### ZD200 Power amplifier

Power output 250 watts into 4 ohms and 150 watts into 8 ohms. Distortion less than 0.004% up to clip level. Size 17" x 7" x 13".

£295.00

WW—091 FOR FURTHER DETAILS



## when reliability and quality count

Magnetrons, Klystrons, T.W. Tubes, Transmitting Valves, Industrial Valves, T.V. Picture Tubes, Cathode Ray Tubes, High Reliability Valves and a full range of Receiving Valves always available.

Professional import and export enquiries welcomed.



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Redan House, 1 Redan Place, London W2 4SA  
Telephone: 01-727 0101 Telex: 265531  
Cables: Edicron London W2

WW—069 FOR FURTHER DETAILS

## Problem

Where to obtain a low-cost device to use as a linear output stage for mobile and marine radio under SSB conditions.

## Solution

M-OV long-life beam tetrodes.

A single TT21/22 gives 100W PEP at 1200V H.T. and one TT100 delivers 180W PEP at 850V H.T.

**EEV and M-OV  
know how.**

LAP 80



THE M-O VALVE CO LTD, Hammersmith, London, England W6 7PE  
Tel: 01-603 3431. Telex: 23435 Grams. Thermionic London.



WW—050 FOR FURTHER DETAILS

# TRANSFORMERS

## CASED TRANSFORMERS

Housed in smart resin coated steel cases with 3 core power or cable end outlet sockets. Based primary winding. Isolation types are fitted with 3-pin outlet sockets and are available with 110 volt or 240 volt output (Please state). Auto types are fitted with 2-pin flat style sockets up to 500 VA. 3-pin sockets from 750 to 3000 VA. See Auto and Isolation sections for prices. Plugs extra.



## SAFETY ISOLATING

Prim. 120/240V Sec. 120/240V Centre Tap with screen

VA (WATTS)	REF No.	PRICE Cased £	PRICES Plugs 2 Pin + 1 Earth £	PRICE Open £	Post £
60	149	8.35	0.88	4.37	0.56
100	150	9.15	0.88	4.90	0.64
200	151	11.45	0.88	6.14	0.80
250	152	12.90	0.88	6.80	0.88
500	153	15.50	0.88	11.80	0.95
500	154	17.25	0.88	13.62	1.13
750	155	27.10	1.10	20.59	0.80
1000	156	35.40	1.10	29.15	0.80
1500	157	42.00	1.10	33.37	0.80
2000	158	49.75	1.10	37.10	0.80
3000	159	73.15	2.64	58.55	0.80

## MINIATURE & EQUIPMENT

Primary 240V with Screen

VOLTS		MILLIAMPS		TYPE	PRICE	Post
Sec. 1	Sec. 2	Sec. 1	Sec. 2	No.	£	£
3-0-3	—	200	—	238	1.50	0.25
0-6	0-6	500	—	234	1.38	0.25
0-6	0-6	1000	—	212	1.90	0.47
0-9-9	—	100	—	13	1.40	-0.25
0-9	0-9	330	—	235	1.50	0.25
0-9-9	0-9-9	500	—	207	1.93	0.34
0-9-9	0-9-9	1000	—	208	2.75	0.47
15-0-15	—	40	—	240	1.35	0.25
0-15	0-15	200	—	236	1.38	0.25
20-0-20	—	30	—	241	1.35	0.25
0-20	0-20	150	—	237	1.38	0.25
0-15-20	0-15-20	500	—	205	2.73	0.56
0-20	0-20	300	—	214	1.93	0.47
0-20	—	3500	No Screen	1116	3.30	0.64
20-12-0	—	700	—	221	2.20	0.47
12-20	—	1000	(D.C.)	—	—	—
0-15-20	0-15-20	1000	—	206	3.50	0.56
0-15-27	—	500	—	203	3.00	0.56
0-15-27	0-15-27	1000	—	204	3.85	0.56

## 12 and 24 VOLTS PRIMARY 200-240 Volts

VA (Watts)	TYPE	PRICE	Post
		£	£
12V	24V No. 242	1.58	0.34
0.5	0.25 111	1.38	0.34
1	0.5 213	1.74	0.47
2	1 71	2.30	0.47
4	2 18	2.96	0.56
6	3 70	4.18	0.56
8	4 108	4.56	0.64
12	5 72	5.20	0.72
16	6 116	5.51	0.72
20	8 17	7.00	0.80
20	10 115	10.42	0.88
30	15 187	13.25	1.01
40	20 232	14.85	0.80
60	30 226	16.83	0.80

## 30 VOLTS

AMPS	Ref. No.	Price £	Post £
0.5	112	1.90	0.47
1	79	2.40	0.56
2	3	3.50	0.56
3	20	4.50	0.64
4	21	5.15	0.72
5	51	6.40	0.72
6	117	7.16	0.88
8	88	9.55	0.95
10	89	9.87	0.95

## 50 VOLTS

AMPS	Ref. No.	Price £	Post £
0.5	102	2.58	0.47
1	103	3.48	0.56
2	104	5.03	0.64
3	105	5.81	0.72
4	106	7.58	0.88
6	107	12.30	0.95
8	118	13.20	1.13
10	119	17.02	D.A.

## 60 VOLTS

AMPS	Ref. No.	Price £	Post £
0.5	124	2.30	0.56
1	125	3.41	0.56
2	127	5.09	0.72
3	125	7.52	0.80
4	123	8.75	0.95
5	40	9.75	0.95
6	120	11.20	1.01
8	121	15.00	1.19
10	122	18.20	D.A.
12	189	18.50	D.A.

## AUTO TRANSFORMERS

VA (Watts)	Ref. No.	PRICE Cased £	Plugs 2 & 3 pin £	PRICE Open £	Post £
Tapped at 115, 220, 240 Volts					
20	113	3.85	0.20	1.71	0.47
Tapped at 115, 200, 220, 240 Volts					
150	4	6.38	0.20	4.12	0.56
200	65	7.04	0.20	4.95	0.64
300	66	8.00	0.20	5.81	0.72
500	67	10.99	0.20	8.85	0.88
750	83	13.82	0.85	10.80	0.95
1000	84	17.27	0.85	13.68	1.13
1500	93	21.87	0.85	18.31	0.80
2000	95	33.11	1.60	24.25	0.80
3000	73	47.94	2.10	35.10	0.80

## BRIDGE RECTIFIERS

ONE AMP	Price
50 P.I.V.	0.20
100 P.I.V.	0.20
200 P.I.V.	0.28
600 P.I.V.	0.30

FOUR AMP	Price
100 P.I.V.	0.55
200 P.I.V.	0.59
400 P.I.V.	0.65
600 P.I.V.	0.75

TWO AMP	Price
50 P.I.V.	0.35
100 P.I.V.	0.40
200 P.I.V.	0.45
400 P.I.V.	0.50

SIX AMP	Price
50 P.I.V.	0.65
100 P.I.V.	0.70
200 P.I.V.	0.08
400 P.I.V.	0.90

## POWER UNIT TYPE CC12-05



Output switched 3, 4.5, 6, 7.5, 9 and 12 Volts at 500 mA D.C. Operates from 240 V mains, suitable for Radios, Tape Recorders, Record Players, etc. Size 7.5 x 5.0 x 14.0 cm. Price £3.95 Post 25p.

## NEW! 2" AND 4" PANEL METERS

2"		4"	
SIZE: 60mm Wide x 45mm High x 40mm Deep.	Movement	SIZE: 110mm Wide x 82mm High x 43mm Deep.	Movement
0-50 micro A.	1R	0-50 micro A.	0ms
0-100 micro A.	1250	0-100 micro A.	1400
0-500 micro A.	580	0-1000 micro A.	170
0-1 mA	170	0-500 micro A.	200
0-5 mA	170	0-1 mA	200
0-10mA	6	0-5mA	200
0-30 mA	6	0-10 mA	6
0-100 mA	0.5	0-50 mA	0.5
0-500 mA	0.5	0-100 mA	0.5
0-1 AMP	0.5	0-500 mA	0.5
0-2 AMP	0.5	0-1 AMP	0.5
0-25 Volt	15K	0-25 Volt	15K
0-50 Volt	50K	0-50 Volt	50K
0-300 Volt	300K	0-300 Volt	300K
1" Meter	170	1" Meter	200
VU Meter	9250	VU Meter	5250

VU Meters are complete with detectors. Modern wide view. Price 2" £3.20 Post 10p. Price 4" £4.00 Post 10p. Lamps 60p per set.

## C1000 MULTI-METER

Compact General Purpose Multi Multimeter  
Input Resistance 1000 ohms per volt  
Ranges AC Volts 0-15 50 250 1000 Volts  
DC Volts 0-10 50 1000 Volts  
DC Current 0-1 mA 0-100 mA  
Resistance 0-150K ohms  
Size 80 x 21 x 30 mm  
Complete with Batteries, Test Prods. Instructions



Special price £3.30 Post 25p

## 1/4-WATT CARBON FILM RESISTORS

also available 1/4 watt at 70°C 12 range 10Ω-1MΩ. 5% tol above 470KΩ 10% tol. at 95p per 100.

## MINIATURE NEONS

6mm dia., 1.2mm length leads length approx. 20mm. Recommended ballast resistor 150K ohms for 240 Volt operation. Price Packet of 10 for 60p. Postage 15p.

PLEASE ADD VAT

Send 25p for Catalogue

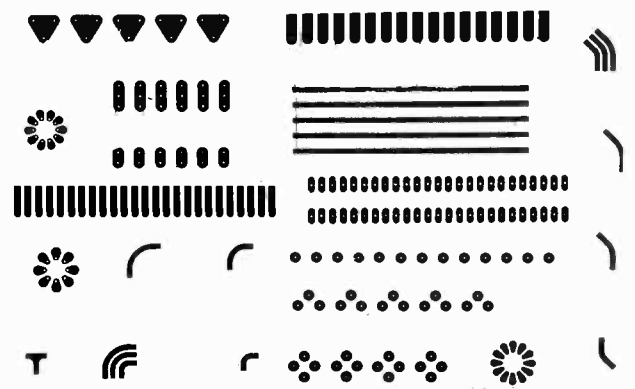
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(DEPT. WW9), SIMMONDS ROAD, WINGCHEAP  
CANTERBURY, KENT. Tel: (0227) 52436

NOW

# MAKE YOUR OWN PRINTED CIRCUIT BOARDS

£2.50 per set

IN PLANT OR AT HOME, SIMPLY RUB DOWN, ETCH AND WASH OFF. WE OFFER A COMPLETE SYSTEM OF ACID RESIST TRANSFERS THAT GIVES A PROFESSIONAL FINISH QUICKLY AND AT LOW COST.



LOOK

- ★ NO ARTWORK
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- ★ SAVE TIME
- ★ SAVE MONEY
- ★ GUARANTEED

Acid resistant transfers for direct application to P.C. Board. This is a new approach to printed circuit board manufacture, giving a professional finish with all details that an electronics engineer would require, including all drilling positions automatically marked. Ideal for single unit boards or small quantities. All at a very low cost - for example an average 6" x 4" layout would cost less than 30p. and the time taken under one hour, including etching to complete. The system is simple, briefly it consists of 10 sheets of self adhesive acid resistant transfers made in required shapes - i.e. edge connectors, lines, pads, dual in line I.C.'s 8-10-12, T.O.5 Cans, 3-4 lead transistors, etc., etc., which only require pressing into the required positions on the printed circuit board before etching.

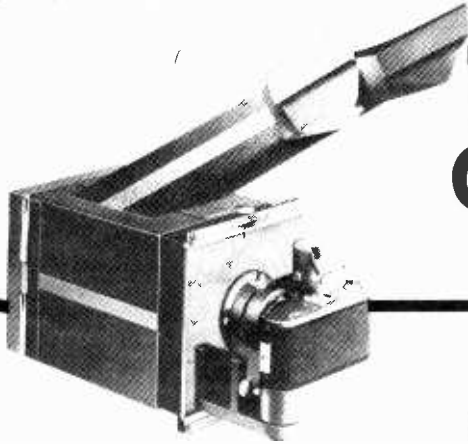
The printed circuit transfer system is a genuine offer to the public and industry. A full money back guarantee is sent with each order.

Complete system including post and VAT ..... £2.50

Overseas order £1.00 extra

Printed circuit board PCB transfer system patent applied for.

Send stamped addressed envelope for FREE sample and instructions.  
**P.M.S. NAMEPLATES. BROOK STREET, HIGHER HILLGATE, STOCKPORT, CHESHIRE**  
TELEPHONE NUMBER: 061-480-0959



# ROBOT Oscilloscope cameras

- \*Use economical 35mm film.
- \*Pulse operation up to 4 f.p.s.
- \*Optional large capacity film magazines.
- \*Clockwork or electrical operation.

More complete details available on request from:

## Telford PRODUCTS LTD.

WADSWORTH ROAD PERIVALE GREENFORD MIDDX. ENGLAND Telephone: 01-998 1011 Telex: 935524

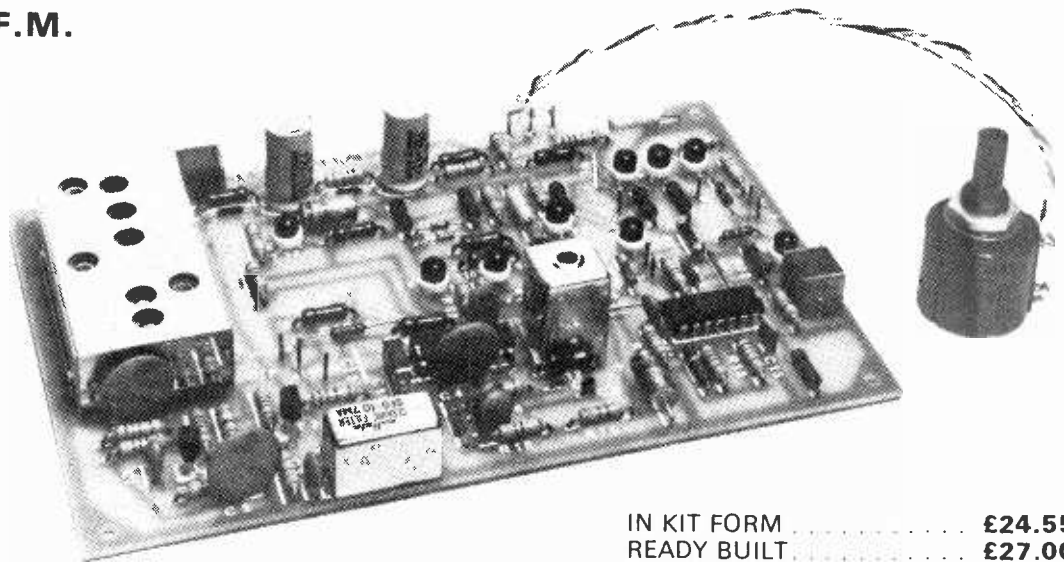
**DAVALL** A MEMBER COMPANY OF BENTIMA INDUSTRIES LIMITED

WW-016 FOR FURTHER DETAILS

## THE INSIDE STORY — 1 FOOLPROOF F.M.

Illustrated here is the heart of the F.M. tuner system which has set new standards of performance; standards which consider the needs of the user first, and then provides those needs with technically sound and well engineered design.

Features include a pre-aligned front end, integrated circuit i.f. amplifier, 3 stage ceramic i.f. filter, integrated mute system, varicap tuning by ten turn pot, plus 17 other semiconductors.



IN KIT FORM ..... £24.55  
READY BUILT ..... £27.00

Postage 30p UK + 25% VAT

Full details of our complete tuner kits and assembled modules available (s.a.e.) from:

How is it different? Well, to begin with the tuning is temperature compensated against drift, and provided with a powerful a.f.c. which holds stations firmly but does not prevent you tuning to a new programme. Then there is a single lamp tuning indicator allowing very accurate adjustment, and this same circuitry also mutes the audio output when stations are out of tune. In addition, a new system of interstation noise suppression is also included, to ensure that only wanted stations are heard and no spurious noises are produced, and this circuitry, in turn, extinguishes the tuning lamp so that it only indicates when a station is received.

All our kits are fully guaranteed, and backed by a complete after sales service, ensuring your satisfaction.

# Icon Design

33 RESTROP VIEW, PURTON, WILTS SN5 9DG

## FANTASTIC OFFER—DIGITAL CLOCK KIT SAVE £££s

- Fast building
- Easy to follow instructions
- No knowledge of electronics required
- The most comprehensive kit and instructions you have ever seen

NOW ONLY **£12.50**

+ £1.50 VAT & p&p

OR READY BUILT & FULLY TESTED

**£18** + £1.90 VAT p&p



**COMET CLOCK  
DATA**

Size 6¼ × 3 × 2½  
Mains Operation  
50/60HZ  
12/24 hour mode

KIT COMPRISES or separately at—

1 MOS Clock Chip 12-24 hr option	£ 1.95
4 0.63" LED Displays (latest HI BRI Type)	4.60
1 Segment Driver Chip	0.50
1 Pack Resistors, Caps., Transistors, switch	1.60
1 Double Sided Glass Fibre P.C. Board	0.95
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1 Circuit/Assembly Manual	0.50
1 Futuristically styled Case (state colour) Yellow, Orange, Red, Black, White, Mauve, Green, Blue	4.40

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## Pulse Electronics Ltd



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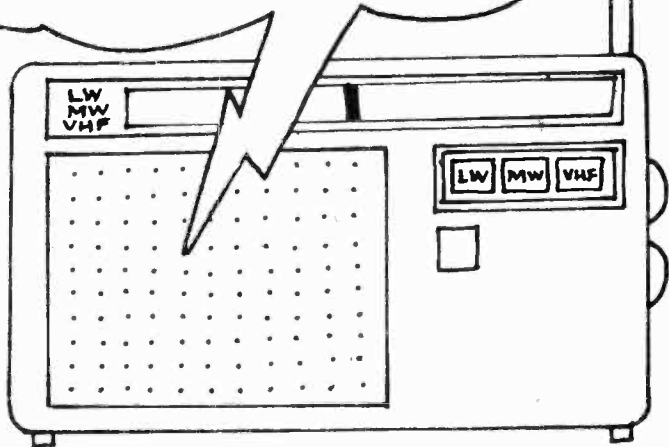
# NEW LOW COST TUNER DIODES

Ferranti now make high quality tuner diodes for domestic radio and TV applications. Low cost production quantities are available for immediate delivery.

ZC100 comes in the proven E-line pack that gives you reliability with economy. Selections on parameter tolerances and matched sets available on request.

Also in the series - Tuner diodes ZC700, 800 and 900 with different Q and tuning ranges to suit all needs.

Phone 061-624 0515 for prices, data and stock details or write to Ferranti Limited, Discrete Components Marketing, Electronic Components Division, Gem Mill, Chadderton, Oldham, Lancs., OL9 8NP



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Birmingham. 021-359 2410; London. 01-237 0404

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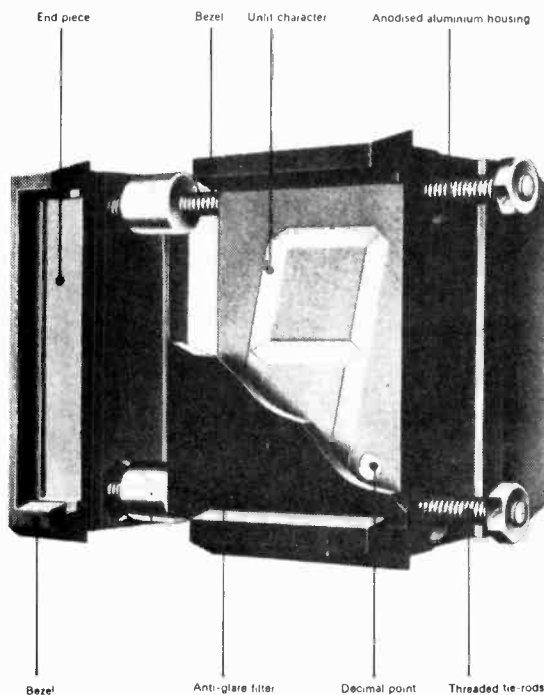
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**FERRANTI**  
semiconductors

FE 468

WW-078 FOR FURTHER DETAILS



## MODULAR DISPLAYS & COUNTERS AT NEW LOW PRICES!

The Spectra-Tek 2500 CLD is a modular solid-state counter with one inch high numerical display. Each module is self contained with counter, latch and driver IC's and provides one decade of display in seven segment form, together with a B.C.D. output. Since the units utilise standard TTL they are compatible with other logic elements to form complete counting and display systems with batching and totalising facilities. The 2500 D is a simplified version of the CLD without counter and latching circuits being driven from a B.C.D. input. The panel mounting modules can be assembled into multi decade arrays with end cheeks and red or amber polarising filters. These versatile modules have distinct advantages over the more conventional displays and counters:-

- ★ SPECIALLY AGED, LONG LIFE FILAMENT BULB DISPLAYS
- ★ LOW VOLTAGE DC OPERATION
- ★ TTL COMPATIBLE INPUTS AND OUTPUTS
- ★ EASY ASSEMBLY OF MULTI DECADE DISPLAYS
- ★ BANKING KITS AND FILTERS AVAILABLE FOR ANY NUMBER OF DIGITS

Up to and including December 31st, 1975 these units are available at the special low prices shown below. This represents up to a 40% saving. Offer subject to availability from current stock.

**electroplan**

P.O. Box 19, Orchard Road, Royston, Herts, SG8 5HH.

Telephone: Royston 41171 An Electrocomponents Group Company

### SPECIAL OFFER PRICE

2500 CLD - £9.99 + VAT per digit (electroplan order code (18-11))  
2500 D - £8.20 + VAT per digit (electroplan order code (18-22))

DELIVERY - SAME DAY DESPATCH BY POST

WW-090 FOR FURTHER DETAILS

# DEMA ELECTRONICS INTERNATIONAL

ELECTRONIC COMPONENTS DISTRIBUTOR FOR INDUSTRY AND HOBBYIST

MONTHLY SPECIALS - Free Data included on Calculator and Clock Chip.

CT 5001	40 Pin 12 Dig 4 Funct. Chain up Fix Dec Cal.	£ 1.49	3/3.95
CT 5002	Same as 5001 only Battery Operated	1.49	3/3.95
CT 5005	28 Pin 12 Digit 4 Function w/Memory	2.25	3/5.95
5314	Pin Clock Chip	3.45	3/8.95
ICL 8038	Funct. Gen. Volt Controlled Oscill. Sinc. Sq Tri Output Oscillator, Sine, Square, Tri Output 14 Pin	1.95	
1101	256 Bit Ram Mos.	1.25	3/2.95
1103	1024 Bit Ram Mos.	2.25	3/5.95
2102	1024 Bit Static Ram	3.50	
555	Timers £ 0.40 556 Dual £ 0.70		

TTL 7400 SERIES

7400	£ 0.11	7440	£ 0.11	7485	£ 0.85	74155	£ 0.59
7401	0.11	7441	0.60	7486	0.24	74156	0.59
7402	0.11	7442	0.55	7488	2.50	74157	0.70
7403	0.11	7443	0.75	7489	1.50	74158	0.70
7404	0.13	7444	0.75	7490	0.73	74160	0.85
7405	0.13	7445	0.70	7491	0.71	74162	0.85
7406	0.24	7446	0.85	7492	0.39	74163	0.85
7407	0.24	7447	0.75	7493	0.39	74164	0.25
7408	0.12	7448	0.69	7494	0.42	74165	1.25
7409	0.12	7450	0.11	7495	0.51	74166	1.15
7410	0.11	7451	0.12	7496	0.55	74170	1.65
7411	0.16	7453	0.12	74100	1.25	74175	0.85
7413	0.26	7454	0.12	74107	0.25	74180	0.85
7416	0.25	7460	0.11	74121	0.25	74181	2.95
7417	0.25	7470	0.25	74122	0.35	74182	0.85
7420	0.11	7472	0.21	74123	0.49	74192	0.90
7426	0.22	7473	0.26	74145	0.85	74193	0.90
7430	0.11	7474	0.26	74150	0.75	74194	0.95
7432	0.22	7475	0.37	74151	0.57	74195	0.80
7437	0.24	7476	0.26	74153	0.59	74198	1.70
7438	0.24	7483	0.65	74154	1.15	74199	1.70

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74H04	0.16	74H22	0.16	74H55	0.16	74H76	0.28
74H08	0.16	74H30	0.16	74H60	0.16		
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4007	0.29	4020	1.15	4050	0.48	4082	0.29
4008	1.30	4021	1.10	4066	0.75	4528	0.85
4009	0.49	4023	0.21	4068	0.29	4585	1.25
4010	0.49	4024	0.85	4069	0.29		
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932	0.10	937	0.10	946	0.10	963	0.10

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304	TO100	0.50	550	A DIP	0.55	748	V DIP	0.25
305	TO99	0.60	555	V DIP	0.45	5556 (1456)	V DIP	0.65
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	TO99	0.90	562	B DIP	2.55	75450	V DIP	0.45
309K	TO3	1.45	565	A DIP	1.45	75451	V DIP	0.45
311	V DIP	0.90	566	V DIP	1.50	75452	V DIP	0.45
320K	TO 3 NEG	5.2, 12.15	567	V DIP	1.60	75453	V DIP	0.45
		1.25	709	A DIP	0.22	75454	V DIP	0.45
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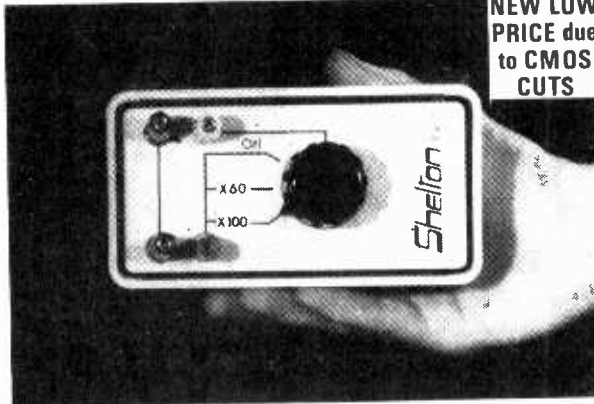
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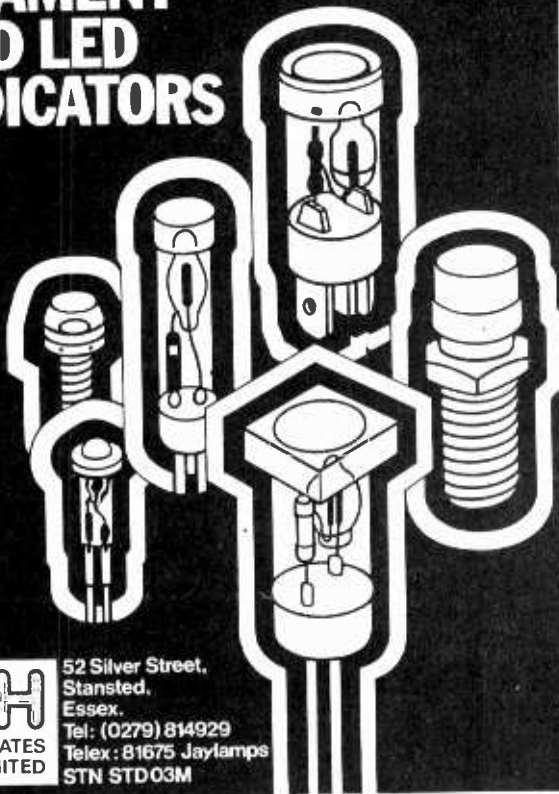
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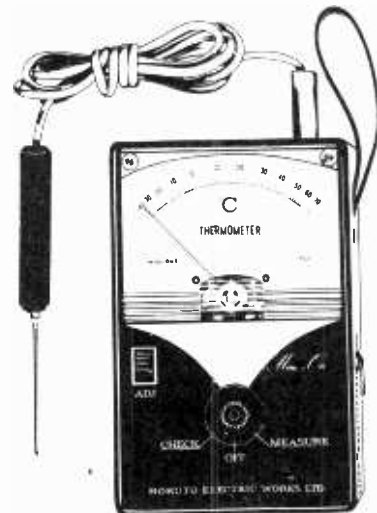


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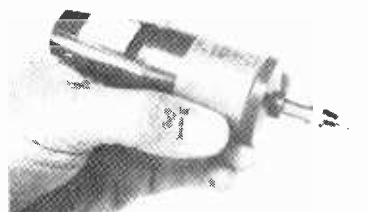
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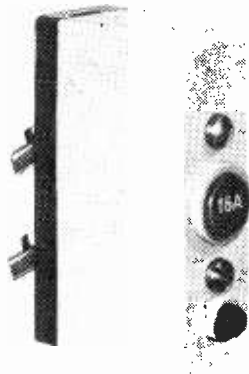
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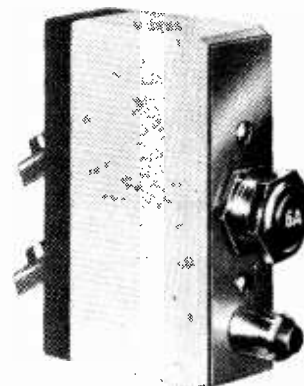
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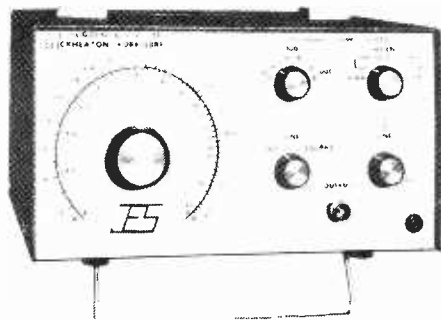
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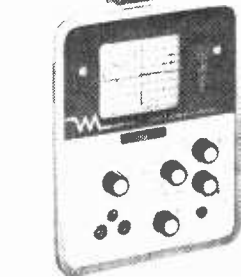
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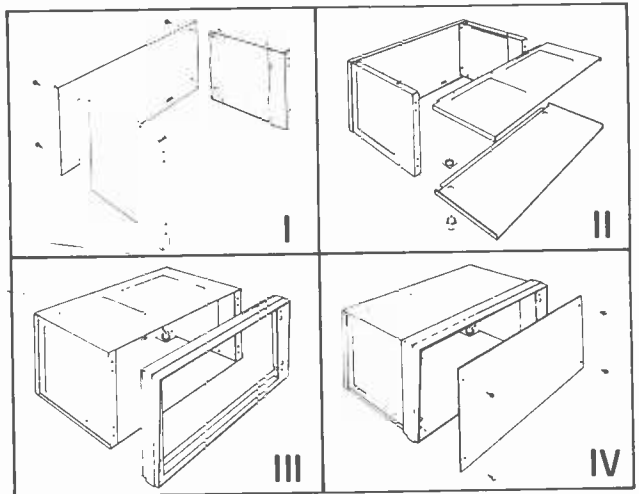
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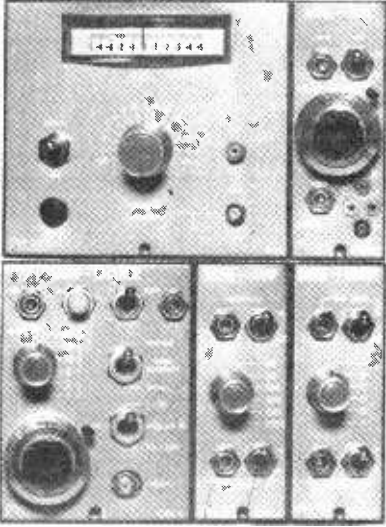
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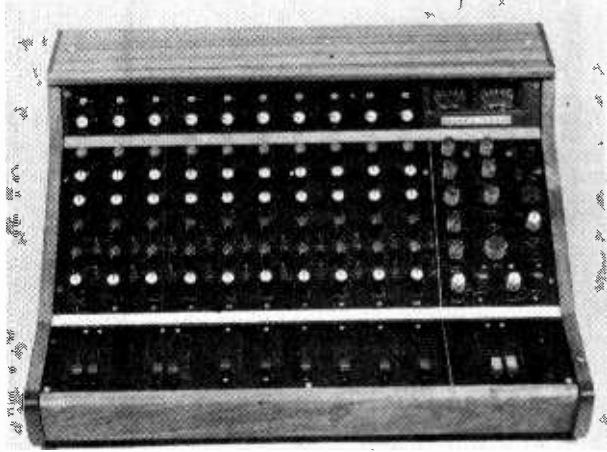
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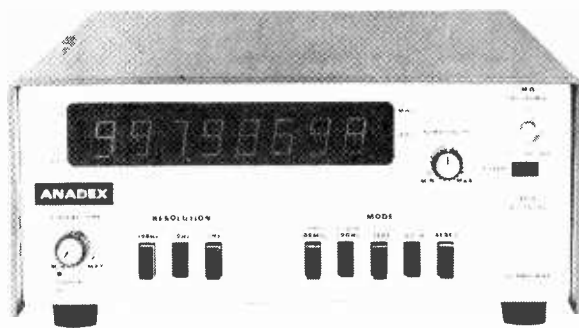
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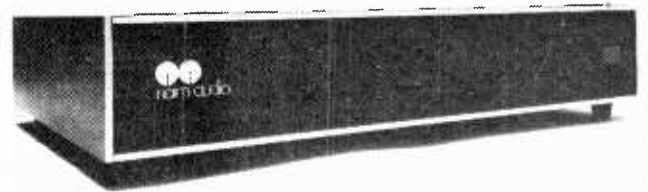
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Low cost slider faders by Ruf.



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WW—032 FOR FURTHER DETAILS

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With the AVO TT 169 in-circuit transistor tester. Go/No Go tests almost any transistor, diode or thyristor without de-soldering, without damage. Find out how it can save you time, save you money.

You'll find the price is no fiddle either. Contact your local wholesaler, or us.



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 Telephone: Dover (0304) 202620

THORN Thorn Measurement Control and Automation Division



WW—036 FOR FURTHER DETAILS



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The  
new  
Rank**

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**Versatile**

Meets in every respect all current specifications for measurement of Wow, Flutter and Drift on Optical and Magnetic sound recording/reproduction equipment using film, tape or disc

**High accuracy**  
with crystal controlled oscillator

**Simple to use**  
accepts wide range of input signals with no manual tuning or adjustment

**Two models available:**  
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CCIR 409-2 Specifications  
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For further information please address your enquiry to

Mrs B. Nodwell  
Rank Film Equipment, PO Box 70  
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## High Voltage Precision Resistors for Monitoring and Control

Constructed with high stability Micronox resistance films fired on to a solid cylindrical core, these high voltage resistors are ideal for use in high voltage power supplies and voltage control and monitoring applications where their temperature stability and long-term operating stability can provide immediate improvements in the specified performance of the equipment.

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The passivation layer on these micro-miniature chip resistors is more durable than the glass used to protect other thin film resistors and yet it allows perfect reliable bonding.

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- Power dissipation ¼-watt (250mw) when mounted.
- Networks comprising several resistors custom made.

Contact Sole U.K. Agents:

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WW-089 FOR FURTHER DETAILS

### SINCLAIR PROJECT 80

AFU	£8.31	FM Tuner	£14.91
Z40	£6.55	Stereo Decoder	£9.69
Z60	£8.31	Transformer for PZ8	£5.16
Q16	£9.71	Stereo 80	£14.91
PZ5	£6.21	Project 80S	£38.22
PZ6	£9.69	Project 80S5Q	£46.65
PZ8	£9.45	Proj 80 Quad. Decoder	£20.97

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IC20 10+10W stereo amp. kit with free booklet and printed circuit £8.50.  
PZ20 power supply kit for above £5.91.  
VP20 volume, tone control and preamp kit £6.20.

SEND S.A.E. FOR FREE DATA

### BATTERY ELIMINATORS

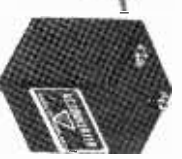
**6-WAY SPECIAL**  
The most versatile battery eliminator ever offered. Switched output of 3, 4½, 6, 7½, 9 and 12V at 500mA £5.45



**3-WAY MODEL**  
Switched output of 6, 7½ and 9V at 250mA with unique 4-way jack plug and socket output connector £3.55.



**RADIO MODELS**  
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9V £3.86  
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6+6V £4.43  
9+9V £4.43



**CASSETTE MAINS UNITS**  
7½V output complete with 5 pin DIN plug to run cassette tape recorders from the AC mains £4.61.

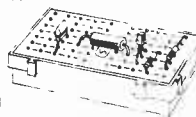
**HEAVY DUTY MODELS**  
500mA. British made to very high standards. Our best buy suggestion.  
6V £4.90. 7½V £4.90. 9V £4.90

**IC12 Amplifier**  
6W audio amp with free data and printed circuit £4.10.



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T-DeC £4.15  
µDeCA £4.55  
µDeCB £7.05  
IC carriers—  
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With socket £2.21  
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### SINCLAIR CALCULATORS

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Cam. Memory £14.10  
Scientific £14.10  
Oxford 100 £9.95  
Oxford 200 £15.90  
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WW-058 FOR FURTHER DETAILS

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- ★ 0.1% Accuracy
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## STEREO IC DECODER

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

**MOTOROLA MC1310P EX STOCK**  
**DELIVERY**  
**MC1310P SPECIFICATION**

Separation: 40dB 50Hz-15kHz  
I/P level: 560mV rms  
Input impedance: 50kΩ  
Distortion: 0.3%  
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**KIT COMPRISES FIBREGLASS PCB**  
(Roller tinned), Resistors, I.C., Capacitors,  
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**ONLY WHY PAY MORE?**  
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**RED** 29p  
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**LIGHT EMITTING DIODE**  
Suitable as stereo 'on' indicator for above

**MC1310P only £2.15 plus p.p. 10p**

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

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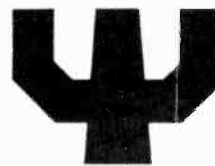
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# Low-cost phasemeter



Only £160

The A200 is an analogue phasemeter which directly displays the phase difference between two inputs - both input channels are carefully matched internally so that phase shift within the instrument is negligible. Lead/lag indicators automatically register polarity.

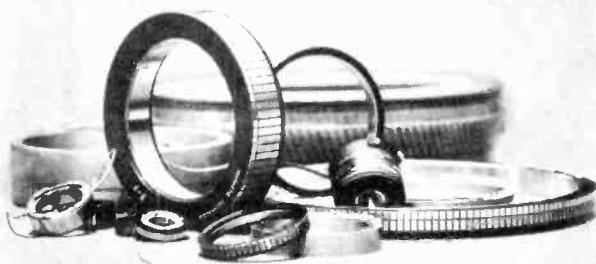


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WW-012 FOR FURTHER DETAILS

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Advanced Technology  
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DC Torque Motors and Tachometers

- ★ High performance, brush and brushless versions and complementary tachometers
- ★ 840 Standard Models ranging from 15 oz-in to 120 lb-ft
- ★ Military, Industrial or Space Qualified models are already used by most European Nations.

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Is able to offer a technical design service utilising these devices in control systems as well as supplying amplifiers, solid state synchro/resolver to digital converters, readouts and other servo control transducers.

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# ROGERS

## AUDIO TEST EQUIPMENT



A comprehensive, versatile range of test equipment primarily designed for the measurement of high quality audio equipment but with additional applications in the electronics industry in general. The equipment is of particular interest to the professional audio engineer, recording studios, broadcasting authorities and educational establishments

**DM344A Distortion Factor Meter.** Designed to make accurate and rapid measurements of total harmonic distortion generated within high quality audio amplifiers, recording and transmission equipment. **Selling Price: c/w Bench Case £225.00 + VAT.**

**S324 Low Distortion Oscillator.** Generates a pure sine wave and has been designed as a general purpose low distortion signal source. The primary application, used in conjunction with the DM344A, is the measurement of total harmonic distortion. **Selling Price: c/w Bench Case £94.00 + VAT.**

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**PS1A.** Regulated Mains Power Supply. **Selling Price: £22.50 + VAT.**



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Telephone: 01-697 8511 (3 lines)

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# 21<sup>st</sup> EXHIBITION



COMPONENTS  
MEASUREMENTS  
CONTROL  
REGULATION  
INSTRUMENTS  
SYSTEMS



BRUSSELS - HEYSEL  
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25<sup>th</sup> to 29<sup>th</sup> november 1975  
from 10 a.m. to 6 p.m.

Distributors of TOKO coils, tunerheads, filters for AM, FM etc.

## ambit INTERNATIONAL.

Ambit are the wireless specialists. We supply a comprehensive range of coils, filters, ICs, modules etc for AM/FM radio. We have systems for voltage tuned radio at ALL frequencies, available as components, kits, or ready built assemblies. A comprehensive folder of product information and prices is available for 40p., inc. PP. Alternatively, a complete shortform pricelist is available free of charge - to all requests accompanied by an SAE.

### Tuners, tunerheads, IF modules

**Larsholt 7252** tunerhead. 1uV for 26dB S/N. Scan, AFC, AGC, muting, dual MOSFET input 4 twin varicap tuned stages. A complete 88-108MHz receiver system for HiFi/Monitor uses. Built and tested .. £24.00

**Ambit ET8000**: As described for the ETI international FM tuner. A kit, with TOKO tuner, 3089/1310 IF and decoder, ceramic IF filters, PSU with stabilizer, pilot tone filter. Kit price (with EF5603) £28.00

**EF5600** tunerhead .. £10.00

**EF5603** tunerhead .. £9.05

**EC3302** tunerhead .. £5.00

Larsholt 8319 tunerhead £9.00

All the above are varicap tuned

**MT3302** FM tuner with AM gang capacitor and 3:1 drive (3 stage FM tuning) .. £5.00

**993090** deluxe MPX decoder - 40mV composite input, AF preamps, 19&38kHz filters. £7.60.

### Wireless system components.

Varicap tuning accessories:

WS150: 150mm WW slider pot for direct scale readout. £3.00.

9932: 6 preset 40 turn pots for fixed station selection. £3.40.

Edgewise meters for frequency, tuning, sig.strength. £2.50 ea.

(Includes 12v bulb at 50mA).

78series voltage regs for tuning voltage 12, 15, 18v @ 1A £1.55.

½A versions for 20, 24v £1.20.

**Varicap AM wireless systems:**

EC720: Ant, RF and Osc. tuned by MVAM varicap diode. IC signal processing system, ceramic IF filter. For ferrite rod or loop antenna. Kit .. £8.00

MVAM1 3x300pF varicap diode. £2.75, or MVAM2 2 diode version £1.05. (2% match)

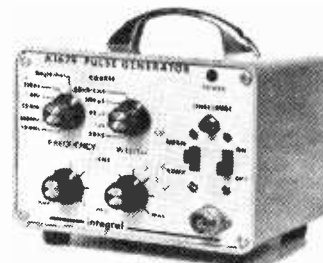
All prices exclude VAT. PP is 20p per order. Minimum invoice £7.50, min. cwo £2.

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PRESENT THE

### A1679 PULSE GENERATOR



Contains features previously found only on instruments FIVE TIMES the price.

- Wide Frequency Range — 10Hz to 10MHz.
- Wide Pulse Width — 50mS to 50nS.
- Single Shot Facility.
- Exceptionally Fast Rise and Fall Times.
- LED Indicator
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Taking advantage of integrated system techniques Integral Systems present one of the most versatile low cost pulse generators ever produced. Ideal for development, laboratory, amateur or educational requirements, it can be used for:

- checking ICs
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- pulse responses of amplifiers
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Price A1679 £36.00      A1679M £40.00  
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Manufactured by:

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WW-084 FOR FURTHER DETAILS

# Audio Laboratory Instruments

To expand the distribution of Audio Laboratory Instruments RADFORD are looking for new dealer/agents outside the United Kingdom. If you are a supplier of laboratory instruments to professional and industrial end users it could be to your advantage to learn more about RADFORD audio measuring equipment.


Write today for leaflets and details of franchised dealership.

Radford Laboratory Instruments Ltd  
Ashton Vale Road  
Bristol BS3 2HZ England


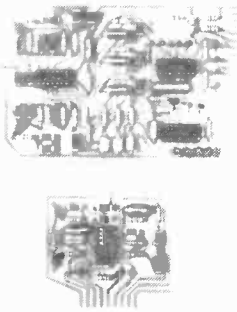


- LDO3. Low Distortion Oscillator**  
Frequency range: 10Hz – 100kHz.  
Distortion: Distortion less than 0.002% over audio band.  
Size: 17" x 7" x 8 3/4". £275.00
- LDO3B. Low Distortion Oscillator**  
As LDO3 but additionally fitted with output amplifier and transformer providing a 600 ohm floating balanced output.  
Unbalance: –80dB. 1kHz. –60dB 10kHz. £375.00
- DMS3. Distortion Measuring Set**  
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Size: 17" x 7" x 8 3/4". £225.00
- HSV1. High Sensitivity Voltmeter**  
Average reading: 10µV to 300V f.s.d. £125.00
- HSV2. High Sensitivity Voltmeter**  
True r.m.s. reading. 10µV to 300V f.s.d. £175.00
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Average reading: 10µV to 300V f.s.d.  
Includes Wide band, Audio band, IEC curve 'A' and CCIR weighting networks. Illustrated above. £150.00
- ANM2. Audio Noise Meter and High Sensitivity Voltmeter**  
As ANM1 but true r.m.s. reading. £200.00

WW—092 FOR FURTHER DETAILS



SQ IS A TRADEMARK OF CBS INC.

### SQ QUADRAPHONIC DECODERS

SQ the leading quadraphonic system designed by CBS engineers offers not only 4 channel ambiphony from the fast expanding range of SQ encoded discs but also immensely increased depth and fullness of sound from standard stereo recordings too.

Feed 2 channels (200-1000mV as obtainable from most pre amplifiers) into your choice of any of our 3 decoders and take 4 channels out with no overall signal level reduction. On the logic enhanced decoders Volume, Front Back, LF, RF, LR, RB and Dimension controls can all be implemented by simple single gang potentiometers - no need for exotic 4-gang units!

These state-of-the-art circuits used under licence from CBS are offered in kit form comprising first grade components only - fibre glass circuit boards of professional quality designed for edge connector insertion all resistors 2% metal oxide, all polystyrene and polycarbonate capacitors 5% or better and in decoder L2 ultra low noise (MPS A18-Q 5dB typ.) transistors used in each amplifying stage.

M1 Basic matrix decoder with fixed 10:40 blend 10 Resistors 14 Capacitors 1 Integrated Circuit Printed Circuit Board **£6.54**

L1 Full logic controlled decoder with wave matching and front back logic for enhanced channel separation using three specially designed integrated Circuits 24 Resistors 42 Capacitors 3 Integrated Circuits Printed Circuit Board **£19.80**

L2 More advanced full logic decoder with variable blend, extended frequency response increased front back separation 43 Resistors 44 Capacitors 3 Integrated Circuits 9 Transistors 6 Diodes Printed Circuit Board **£28.20**

All kits include IC sockets and construction notes. Prices include CBS licence fee.

Please write for further details in FREE LIST

United Kingdom Post Free Please add 25% VAT Overseas No VAT Please add (per kit) £2.00 p & p AIR MAIL or £1.00 p & p SURFACE MAIL

## AMBIENTACOUSTICS

PO BOX 3000  
ANDOVER, HANTS SP10 3EQ

WW—033 FOR FURTHER DETAILS

# RADFORD HD250

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**A new standard for sound reproduction in the home! We believe that no other amplifier in the world can match the overall specification of the HD250.**

- Rated power output: 50 watts av. continuous per channel into any impedance from 4 to 8 ohms, both channels driven.**
- Maximum power output: 90 watts av. per channel into 5 ohms.**
- Distortion, preamplifier: Virtually zero (cannot be identified or measured as it is below inherent circuit noise.)**
- Distortion, power amplifier: Typically 0.006% at 25 watts, less than 0.02% at rated output (Typically 0.01% at 1 KHz)**
- Hum and noise: Disc.—83dBV measured flat with noise band width 23 KHz (ref 5mV); —88dBV "A" weighted (ref. 5mv)**
- Line —85 dBV measured flat (ref 100v)  
—86dBV "A" weighted (ref 100v)**

Hear the HD250 at

## SWIFT OF WILMSLOW

Dept WW

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Mail Order and Personal Export enquiries: Wilmslow Audio, Swan Works, Bank Square, Wilmslow (Tel. 29599)

In stock: All Radford speaker drive units and crossovers, ZD22 preamp, Low Distortion oscillator LD03 and Distortion Measuring set DMS3.

WW—046 FOR FURTHER DETAILS

# Telequipment's new dual trace 10 MHz battery operated oscilloscope

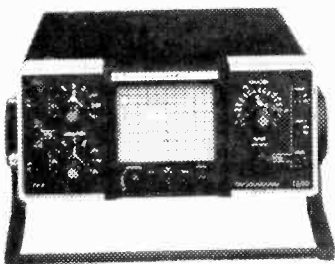


...and that's about the size of it

4 x 9 x 11 inches! Weight, less than 10lb!  
Price, only £275\*.

Small in all but specification, Telequipment pack into the tiny frame of the D32 features normally associated with instruments twice its size.

Easily carried on any assignment the D32 is probably the smallest and least expensive scope of its kind in the world.



\*Exclusive of VAT

Priced at £275\* (including re-chargeable batteries) this dual trace scope offers 10MHz bandwidth at 10mV/div sensitivity; automatic selection of chopped or alternate modes; automatic selection of TV line or frame displays; and the choice of battery or mains operation.

Size up the D32 for yourself and write or phone for a demonstration of this truly remarkable instrument now.

Telequipment gives you more scope for your budget

**TELEQUIPMENT**



Tektronix U.K. Ltd.,  
Beaverton House, P.O. Box 69, Harpenden, Herts.  
Telephone: Harpenden 63141 Telex: 25559

TQ14

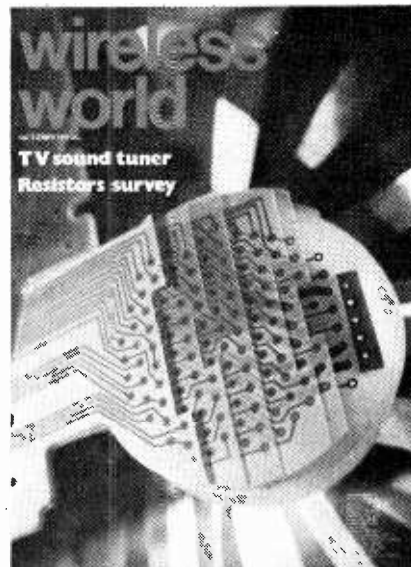
# wireless world

Electronics, Television, Radio, Audio

OCTOBER 1975 Vol 81 No 1478

## Contents

- 447 **Broadcasting and communications**  
448 **Television tuner design** by D. C. Read  
453 **Books received**  
454 **News of the month**  
    A telegram a second  
    Standstill brake tester  
    Breakthrough in quartz oscillators  
456 **Progress in multiphonic organs** by J. H. Asbery  
458 **Sixty years ago**  
459 **Facsimile scanner** by J. M. Osborne  
464 **Meetings**  
465 **Letters to the editor**  
    Wideband local networks  
    Controlling stage lighting  
    Peak-reading level indicator  
469 **Radio waves — what makes them go** by "Cathode Ray"  
473 **Circuit ideas**  
    Constant amplitude sawtooth generator  
    Thyristor protection circuit  
    Stereo rumble filter  
475 **Electronic circuit calculations simplified — 5** by S. W. Amos  
478 **H. F. predictions**  
479 **Transmitter power amplifier design — 2** by W. P. O'Reilly  
482 **Announcements**  
483 **Circards 25 & 26: RC oscillators** by J. Carruthers, J. H. Evans,  
    J. Kinsler and P. Williams  
486 **World of amateur radio**  
487 **Resistors** by R. A. Fairs  
493 **New products**  
496 **Real and imaginary** by "Vector"  
a75 **APPOINTMENTS VACANT**  
a94 **INDEX TO ADVERTISERS**



This month's front cover shows a multiple-layer printed circuit board made by BEPI (Electronics) Ltd. (Photographer Paul Brierley)

## IN OUR NEXT ISSUE

**Teletext decoder.** First in a series of articles on constructing a unit to show Ceefax/Oracle pages on a TV set

**Consultants — do they provide a worthwhile service?** A frank report based on investigations in the electronics industry

**Optical sensor ignition.** Contactless timing system for car c.d. ignition avoids deterioration of engine performance due to mechanical wear and play

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Telegrams/Telex. Wiworld Bisespres 25137 London. Cables. "Eithaworld, London SE1."  
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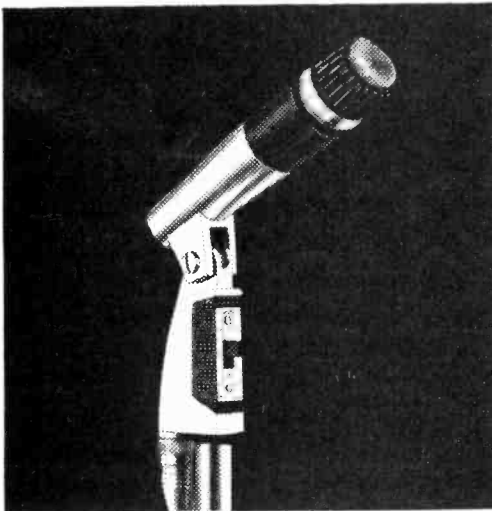
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SIXTY-FIFTH YEAR  
OF PUBLICATION





## Microphones matter most.



Never have so few words said so much about sound system installations. The truth is that a carefully chosen, top-quality microphone makes a measurable difference in sound system quality—regardless of the other components in the system. It is false economy at its worst to be a microphone miser. Install *Shure Unidyne* or *Unisphere* microphones—for installations with a marked superiority in voice intelligibility (and fewer service calls due to microphone problems). For the name of your local sound specialist, write:

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 Telephone: Maidstone (0622) 59881



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# wireless world

## Broadcasting and communications

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There is no doubt that broadcasting is becoming inextricably mixed up with telecommunications. This is largely in the sharing of the technical means, such as the electromagnetic spectrum for transmission and the coaxial cables for distribution. The actual function of broadcasting is on the whole separate from that of telecommunications, although broadcasting also conveys information and there may be some overlap in the future with such services as Teletext. An awareness of the engineering interdependence is probably what prompted the National Electronics Council to offer evidence to the Annan Committee, through a working party, on "... the future technological development of telecommunications and electronics services in the United Kingdom, as they affect broadcasting . . .", and its report\* is worth studying as an appraisal of the situation in a highly developed country such as the UK. It shows up some conflicts of interests, and different views on how things should be managed, between some of the organizations concerned, and recommends the setting up of a Telecommunications Council to be responsible for the integration of all telecommunication services.

The Post Office, with its monopolistic hold on telecommunications and the distribution of programmes, considers that to achieve economical operation there is a need for unification in meeting the needs of the public and that there should be a corresponding integration of the technical means for conveying information throughout the country. In practice this implies the "total systems approach" or "national electronics grid" that has been much under discussion – probably a wide-band v.h.f. and u.h.f. cable network, complementary to the broadcasting system, that would be capable of supplying a mixture of information services (some two-way) and television and sound programmes directly to people's homes.

One of the attractions of such a cable network is that it might take off some of the demands on the electromagnetic spectrum at present imposed by broadcasting and leave more space for such things as mobile communications (for which radio is the only possible medium). But it would be a vast and expensive network to set up and might take, according to some estimates, about 20 years to complete. Some objections from the cable television companies' point of view are made in a letter in this issue. The major problem, however, is that such a network would require long-term planning, and this implies some measure of inflexibility. How could we plan now for the information and entertainment requirements of, say, 20 years ahead? Society is changing rapidly and so is electronics and communications technology. There is a danger of being overtaken by events. Nobody knows this better than the Post Office, so it is to be hoped that in any large-scale plans for an integrated network they will succeed in keeping their engineering options as open as possible.

\*Published in the *National Electronics Review*, Vol. 11, No. 3, May-June 1975.

# Television tuner design

Gives quality sound as well as vision signals

by D. C. Read, B.Sc.

**Using a varicap u.h.f. front-end, this tuner design provides quality sound and vision outputs for connection to a separate sound reproduction system and to a monitor-type receiver. It provides a group-delay corrected signal and proper black-level registration. Sound information is removed prior to the video demodulator, overcoming the problem of sound and colour subcarrier interference. Two modifications, to be described in a subsequent article, enable it to be used with a conventional u.h.f. tuner and with a domestic-type receiver and the option of a simplified sound-only unit.**

Perhaps it is an unfair comment to say that sound has always been regarded as the Cinderella of the television world. But, certainly, set manufacturers have had good economic reason for getting the picture and the price right first; their customers demand it. The advent of colour also tended to push sound further down the priority list. Today's receivers are necessarily more complex, so that stability of operation and ease of control are harder to achieve at reasonable cost and in the achievement there is understandably little room left for more than the basic necessities of sound recovery.

With many households now equipped for hi-fi reproduction, however, and with integrated circuits more than adequate – and cheap enough – to provide the necessary extra circuitry, the essential ingredients for good-quality television sound reception are to hand; if we were to complete the earlier analogy, we might say that Cinderella's glass slipper is ready, waiting, and requires only the final fitting.

Considering the received signal itself, this carries a sound component which differs from the f.m. radio transmissions only in that there is (as yet) no provision for stereo and that the maximum deviation used is 50 instead of 75kHz; it is, therefore, reasonably 'hi-fi'. A further important point about the transmitted television sound signal, and one not generally known, is that for all the main U.K. stations, the two sets of information – vision and sound – are fed to separate transmitters and then combined for radiation from a common aerial. This reduces the risk of interaction between the two signals at the sending end and for the user to obtain the greatest benefit from such isolation, separate receiving chains might be

considered worthwhile. But such a provision would make station changing unnecessarily complicated and there are, in any case, certain advantages (mentioned later) to keeping part of the receiving system common to both signals.

The tuner design to be described has evolved from these thoughts. During many months of experiment, various circuits were tried until the right combination was found. The eventual outcome of these investigations shows refinements not only on the sound side but also to the video circuitry. Some of the changes to the vision circuits were necessary in support of the different sound-recovery arrangements being used, and some simply because improvement was called for, and could be obtained, by using with appropriate modification, circuits suggested in manufacturers' application notes and ideas culled from the technical press.

Accompanying these ideas was the purely practical intention to build a self-contained unit which could be installed in any convenient living-room position such as a book shelf and which would produce standard-level feeds: a 1-volt composite video signal for driving the decoder and display circuits of a conventional television receiver or monitor-type set, and a 0.5-volt r.m.s. audio signal.

The block diagram of Fig. 1 shows main circuit functions in the tuner, numbered and divided into the three principal sections. The following list, numbered for ease of reference to the diagram, gives brief outlines of these functions.

## Video, i.f. and r.f. circuits

1. The u.h.f. tuner used is the well-tried Mullard ELC1043 module which:

- employs varicap diode tuning (channels 21 to 69)
- has two r.f. stages with the aerial input stage untuned for optimum noise performance
- accepts a delayed a.g.c. voltage between 4 and 8 volts giving a control range of 40dB.

The carrier level at the first varicap tuned circuit is kept well below the intermodulation threshold. Excessive carrier levels in voltage-diode-tuned circuits can cause spurious phase modulation of the received signal. If simple synchronous demodulation is used, as in this tuner, the video is not affected but the recovered sound signal will contain unwanted in-band components which cannot subsequently be removed. (In more complex demodulators, such as those using a phase-locked-loop re-generated carrier for switching, phase modulation of the i.f. signal also affects the video.)

As a useful protection against temperature drift, the tuner module in this installation is mounted in the bottom corner of the circuit board away from heat-producing components. Other precautions have been taken to give good oscillator stability and the unit has operated satisfactorily in normal household use over long periods without a.f.c. connected.

An alternative version of the tuner has been built using a conventional mechanically-adjusted u.h.f. module instead of the varicap type. Apart from possible economic benefit to the constructor, mechanical tuners have some advantages in performance over their more modern counterparts. An important one is that they do not suffer from spurious f.m. sound-carrier phase modulation under the influence of the a.m. vision carrier in the way that



varicap tuners do with high r.f. level. Details of this option will be given subsequently.

2. The output circuit of the u.h.f. module forms part of the first of two band-pass coupled circuits which together give a well-defined i.f. characteristic with a shape nearly that of the required ideal (see Figs. 6 and 8).

3. The i.f. gain is provided by a single a.g.c. amplifier which, together with the following grounded-base stage, operates in a cascode-type configuration. Because the controlled transistor works between low impedances (it is fed from an emitter-follower stage), it gives maximum gain and a large control range which can be covered with negligible adverse effect on the i.f. response shape.

4. The second of the two band-pass coupled circuits surrounds the combined own-sound trap and sound carrier take-off circuit. Because separation and rejection are obtained here by means of inductive coupling and cancellation, there is little unwanted in-band loss for either carrier.

5. The Motorola MC1330 is a synchronous demodulator giving a

vision carrier rejection of at least 60dB and a conversion gain of about 35dB. Typical figures quoted give expected line linearity and differential gain of about 3%, and differential phase of 3° the performance realised here is of this order.

6. Instead of a 5.5MHz low-pass filter following the demodulator, two simple notch circuits – one each at the sound-carrier offset and twice colour-subcarrier frequencies – give sufficient protection against out-of-band interference. In practice, because of the high efficiency of the sound trap/take-off circuit mentioned in 4 above, the 6MHz trap has little work to do except during the temporarily disturbed conditions which can exist for short periods e.g. when first switching on the tuner. Additionally, the trap is included because its lower skirt completes the shaping of the video response, as will be illustrated later.

7. The correct trap-circuit termination is given by the following directly coupled amplifier which produces two outputs each of 4 volts pk-pk composite video. One of these feeds the a.g.c. circuit; the other is passed after impedance match-

ing to a two-stage group-delay corrector and thence to the video output amplifier. Direct coupling is used from the MC1330 demodulator onwards so that true-black-level registration can be achieved. For this reason, the directly-coupled stage mentioned above also provides a necessary d.c. shift so that signal blanking is at the required potential to suit following circuit conditions.

8. The tuner output circuit used will depend on the particular needs of a given installation. The complementary-pair amplifier shown in the full circuit diagram (see Fig. 2) provides one output at 75 ohms and one at higher impedance (about 270 ohms; this is specifically intended for a short link to the receiver decoder). If more than one 75-ohm output is required, larger transistors than those used in the suggested circuit will be necessary.

**Sound circuit**

9. From the sound take-off point, the 33.5MHz carrier is fed through a low-input impedance buffer stage to a band-pass pair filter and thence to a cascode amplifier which gives a gain of

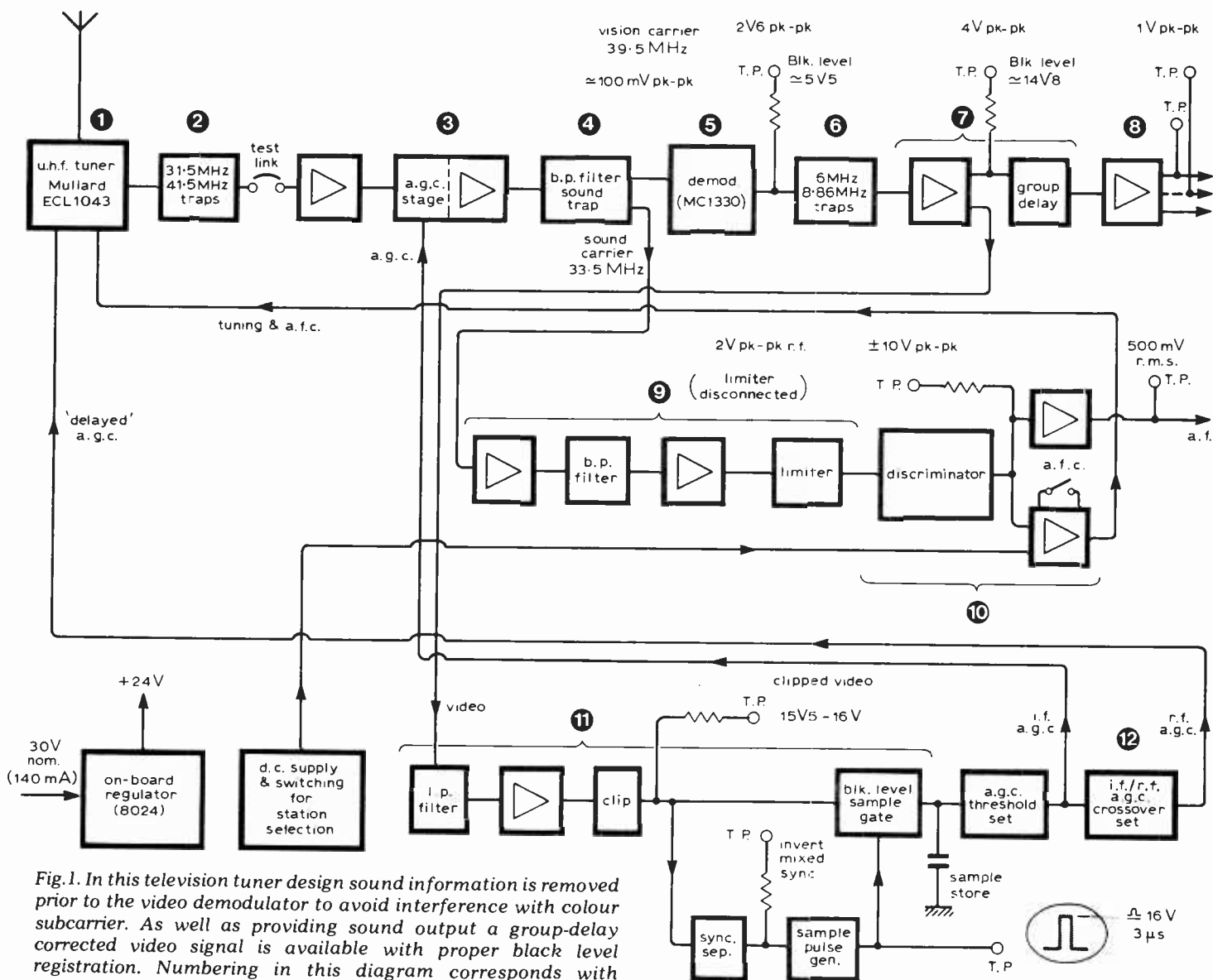
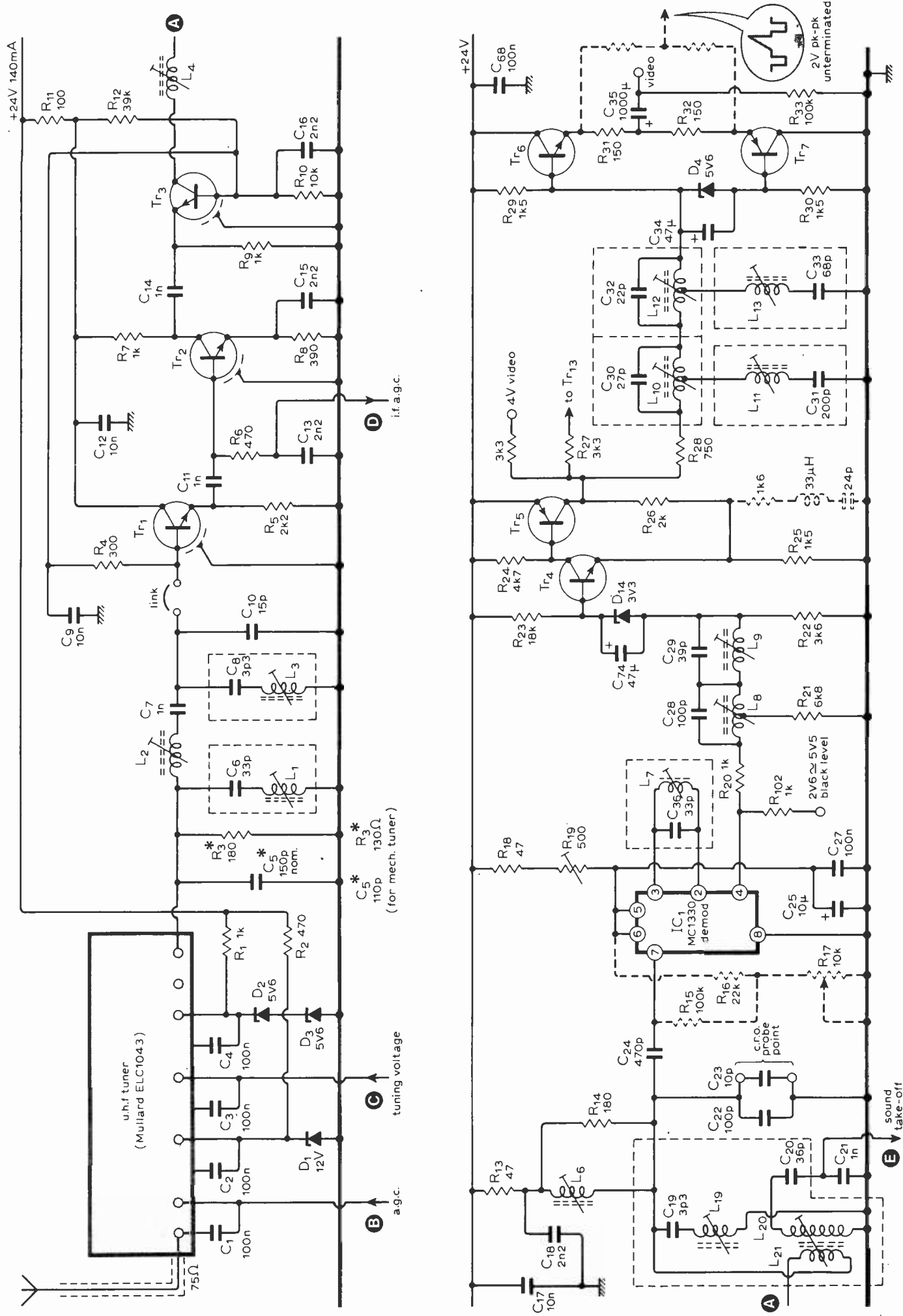


Fig. 1. In this television tuner design sound information is removed prior to the video demodulator to avoid interference with colour subcarrier. As well as providing sound output a group-delay corrected video signal is available with proper black level registration. Numbering in this diagram corresponds with numbers used in description.



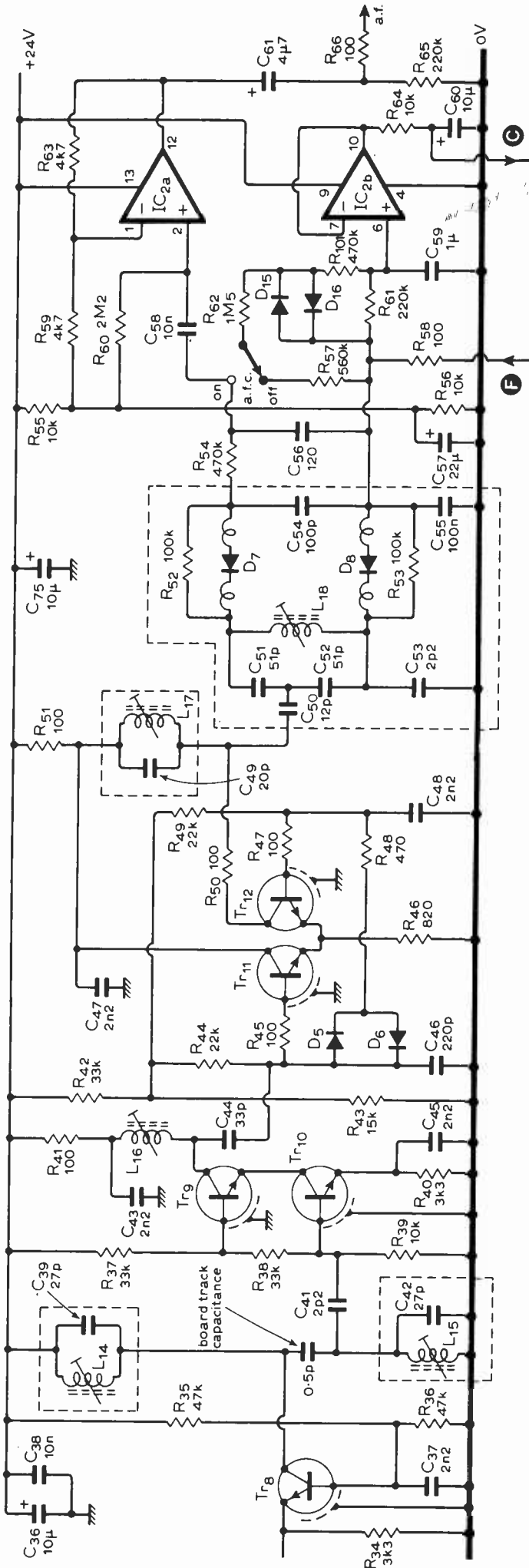
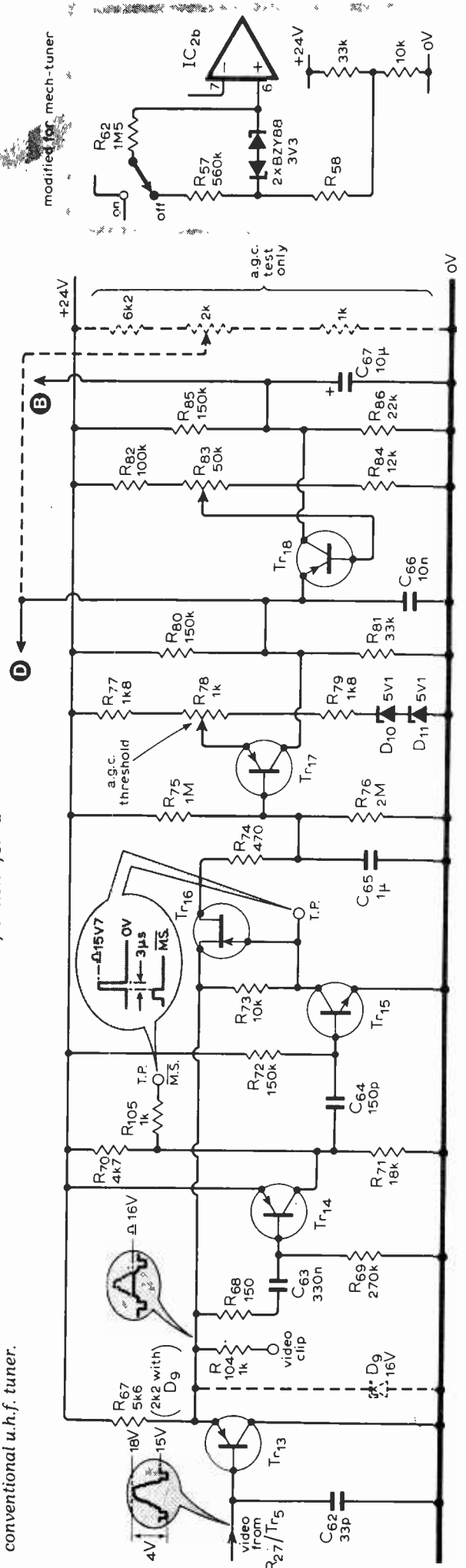
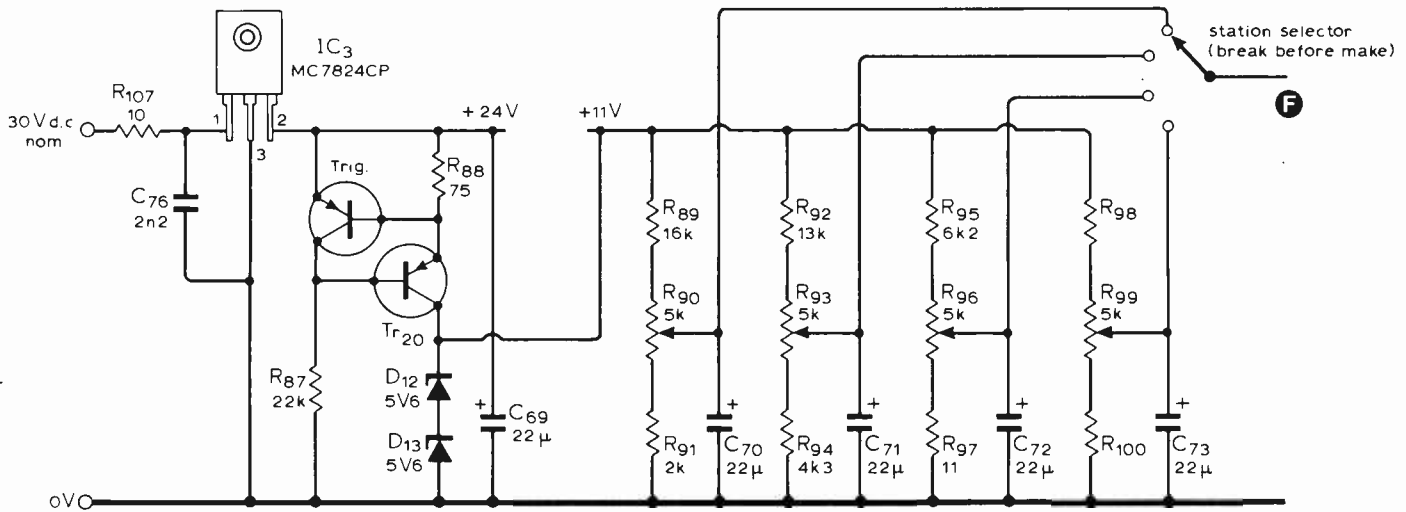


Fig. 2. Coil winding details and p.c. board diagram for this circuit will be given in a subsequent article together with performance details and a modification for a conventional u.h.f. tuner.





about 35dB. Response shaping is completed by two single-tuned circuits before the signal is applied to a long-tailed pair limiter. Only one stage of limiting is necessary because the transmitted sound and vision carriers are maintained at a fixed difference in level and therefore a.g.c. action on the vision is effective in keeping the sound carrier reasonably constant. This is the main reason for keeping the two carriers together in this part of the circuit where signal amplitude is relatively low.

10. The sound signal is recovered by means of a Foster-Seeley discriminator circuit using discrete components. In terms of the a.f. output from the discriminator, the circuit is 'floating' so that the d.c. off-tune error voltage also produced by the circuit can be added to whichever of the pre-set tuning voltages (developed elsewhere) has been selected and then returned to the u.h.f. tuner module as a combined a.f.c. station-change control feed.

#### A.G.C. circuit

11. The positive-going composite video feed obtained as outlined earlier is taken through a simple low-pass filter to remove high-frequency video, particularly the colour bursts. An emitter-follower buffer stage feeding a diode clipper slices the signal at a point just above blanking level. Two feeds of the resulting inverted mixed syncs are used; one is processed to generate a back-porch pulse which then operates a blanking-level sample-and-hold circuit carrying the other feed.

12. The remaining two stages develop the d.c. outputs with appropriate levels and time constants for gain control of the i.f. amplifier and the u.h.f. tuner module. The two stages include pre-set controls for adjustment of the main video output level and for selecting the r.f./i.f. a.g.c. crossover point.

#### Circuit description

A full circuit diagram of the tuner is given in Fig. 2; as in the outline of functions given above, for convenience the following detailed description is divided into the same three sections.

*Power supply arrangement for circuit of Fig.2 using varicap u.h.f. front end. Transistors Tr<sub>19</sub> and Tr<sub>20</sub> are BCY70 or 2N3906.*

#### Aerial input to video output

The Mullard ECL1043 front-end module is connected in a standard manner taking a 75-ohm aerial input and producing a 39.5MHz vision i.f. output with the sound carrier at 33.5MHz. The 12-volt d.c. feed to the r.f. stages is stabilized by a single zener whereas the oscillator supply is taken through a pair of 5.6-volt diodes which have a zero temperature coefficient and therefore give a measure of protection against frequency drift. Independent supply feeds are necessary because current consumption in the r.f. stages varies with a.g.c. action.

The module i.f. output circuit is combined with C<sub>5</sub> and L<sub>2</sub> to form a 'bottom-C' coupled pair of tuned circuits giving part of the i.f. pass-band shaping; a small amount of in-band slope correction is carried out by C<sub>7</sub>. Fig. 2 also shows a pair of conventional adjacent-channel traps at this point.

Emitter follower Tr<sub>1</sub> provides a low-impedance source of i.f. signal to the a.g.c. stage Tr<sub>2</sub> which feeds into the low-impedance offered by grounded-base amplifier Tr<sub>3</sub>. The circuit arrangement is the outcome of a considerable amount of experiment to overcome the problem of obtaining adequate i.f. gain and control range without the attendant change in pass-band response. Because of the wide difference in input loading given by transistors working variously between maximum and minimum gain, it has usually been necessary to swamp the changing impedance of an a.g.c. stage by means of surrounding fixed low impedances. But although this arrangement represents a fairly effective cure, it necessarily causes loss of overall i.f. gain and of control range (for maximally-flat signals).

In the circuit used here, Tr<sub>1</sub> provides a source of constant signal voltage, Tr<sub>3</sub> is

a 'virtual-earth' amplifier, so that Tr<sub>2</sub> and Tr<sub>3</sub> together effectively act as a cascode pair. Thus a higher maximum gain can be obtained from the combination and, as there is minimal signal voltage swing at the collector of Tr<sub>2</sub>, the effect of Miller feedback on this stage is removed. The output impedance of Tr<sub>3</sub> is then matched by the following band-pass circuit to give an overall maximum gain of 38dB and an optimum signal of 30 to 35mV r.m.s. at the MC1330 demodulator input. Similar results can be obtained from a dual-gate f.e.t. (e.g. the RCA 40673), but these components are fragile, and the more robust circuit used here was chosen in preference.

The form of the network which completes the i.f. band shaping is that of a 'bottom-L' coupled pair; in Fig. 2, L<sub>4</sub> with self and stray capacitance added to the output capacitance of Tr<sub>3</sub> represents the 'input' tuned circuit, and L<sub>8</sub> is the coupling component. There are no components representing the 'output' tuned circuit; this is because they were deliberately computed to zero and do not have practical existence.

The combined sound trap/sound take-off circuit comprises inductors L<sub>19</sub> to L<sub>21</sub> wound on a common former and capacitors C<sub>19</sub> to C<sub>21</sub>. This circuit is another departure from the conventional – again the result of development in devising a simple but effective way of achieving total sound channel separation so that there is minimum subsequent interaction between the two sets of information and little in-band loss for either.

Operation of the circuit is as follows. The series combination of C<sub>19</sub> and L<sub>19</sub> is tuned to 33.5MHz and therefore, in the normal sound-trap manner, offers a low-impedance shunt path to earth for i.f. signals at this frequency. Also, L<sub>21</sub> is coupled to L<sub>20</sub> which is tuned to 33.5MHz by C<sub>20</sub>/C<sub>21</sub> and thus acts as a 'suck-out' trap. The induced voltage is proportional to the by-passed sound carrier, which is then routed to the sound processing circuits to be described later. Note that the tuning capacitance for L<sub>20</sub> is split as shown in Fig. 2 to give a low-impedance source

**Semiconductor devices**

BF173	Tr <sub>1</sub> , Tr <sub>3</sub> , Tr <sub>8-12</sub>
BF167	Tr <sub>2</sub>
2N3904	Tr <sub>4</sub> , Tr <sub>6</sub> , Tr <sub>15</sub>
2N3906	Tr <sub>5</sub> , Tr <sub>7</sub> , Tr <sub>13</sub> , Tr <sub>14</sub> , Tr <sub>17</sub> , Tr <sub>18</sub> , Tr <sub>19</sub> , Tr <sub>20</sub>
2N3819	Tr <sub>16</sub>
IC <sub>1</sub>	MC1330
IC <sub>2</sub>	SN72747
regulator	MC7824
AAZ13	D <sub>5</sub> , D <sub>6</sub>
1N916	D <sub>7</sub> , D <sub>8</sub> , D <sub>15</sub> , D <sub>16</sub>
Zener diodes	— see Fig.2 for voltages

for the input to the sound i.f. circuit; the loss of signal voltage caused by the capacitor step-down is easily made up in the following amplifier which, of course, matches the low feeding impedance.

A 33.5MHz signal is also induced in L<sub>19</sub> where it is in phase opposition to the sound-carrier component of the total i.f. signal passing through this inductor and hence aids the action of the sound trap circuit already described. On tuning the two circuits, total phase cancellation can be achieved in the video path so that the combined effect is a notch in the overall response of at least 55dB at 33.5MHz.

Apart from the main function of producing good separation with negligible in-band loss, two further points of practical interest are illustrated by the way in which the circuit diagram and the assembly detail have been drawn.

First, L<sub>21</sub> is wound at the most 'earthy' end of L<sub>20</sub>, i.e. at the lowest voltage and impedance point as far as the sound carrier is concerned; this arrangement offers the best condition for maximum rejection. Second, two inductance tuning slugs are fitted into the common former and, as shown in the drawing, are positioned so that the one affecting L<sub>20</sub> and L<sub>21</sub> is screwed fully in to give maximum coupling between these windings, whereas only part of the slug for L<sub>19</sub> is enclosed by the winding — i.e. it is withdrawn towards the top of the former. In this way, the position of the L<sub>19</sub> slug determines the tuning frequency of the series circuit but has little influence on the degree of coupling between L<sub>19</sub> and L<sub>20</sub> which is then a function simply of the specified spacing between these two windings. The method of tuning adjustment for this circuit will be given in a later article together with other lining-up details.

(To be continued)

## Books Received

**Radio Servicing Pocket Book** by Vivian Capel. This is essentially a practical book for the radio service engineer and as a result much of the space is devoted to workshop planning and practice, test equipment, repair techniques, and fault diagnosis. The book contains information on aerials, car radios, interference and modern radio equipment but a section on some of the older radio sets likely to be encountered is included. A data section is also provided which contains useful formulae and tables together with a directory of over 140 manufacturers, importers, and service depots. Price £1.95. Pp. 230. The Butterworth Group, Borough Green, Sevenoaks, Kent TN15 8PH.

**The White Noise Book** — Multichannel communications systems and white noise testing by M. J. Tant. Multichannel f.d.m. systems have experienced a large growth in recent years and as a result this book has been published to aid the understanding of technologies associated with these systems, with particular reference to the practice of white noise testing. The history of f.d.m. is summarised and the various transmission techniques in cable and radio systems are described. The book then deals with current noise objectives for multichannel systems together with past and present recommendations for white noise testing. Price £2. Pp. 104. Publicity Department, Marconi Instruments, Longacres, St. Albans, Herts.

**Basic Electrical & Electronic Construction Methods** by G. M. Allen is a handbook intended for use in schools. The text provides comprehensive advice and guidance on a variety of construction methods and general principles for electronic projects. No electronic theory is dealt with but certain procedures affecting design and layout are discussed. The text is supplemented with diagrams, photographs, tabular information and covers circuits and symbols, components, electrical wiring, motors and solenoids, power supplies, testing, tools and techniques, concluding with a page of reference books. Price £1.80. Pp. 119. Heinemann Educational Books Ltd, 48 Charles Street, London W1X 8AH.

**Elements of Transistor Pulse Circuits** by T. D. Towers (second edition). This book is based on a series of articles which appeared in *Wireless World* 1964 by the same author. The text has been kept practical with a minimum of mathematics and is aimed at engineers or students with a limited knowledge of transistor pulse circuits. Chapters include linear pulse amplifiers, waveform shaping, blocking oscillators, gates, counter/timers and timebases. The book also incorporates a section on transistor and diode data. Price £3.50. Pp. 198. Butterworth & Co. Ltd., Borough Green, Sevenoaks, Kent TN15 8PH.

**Guglielmo Marconi 1874-1937** by Keith Geddes is a Science Museum booklet describing the life and times of the Italian pioneer. His early experiments with "Hertzian waves," which led to the first wire-less telegraphy system, are described as well as the formation of the Marconi Company and

the influence of the war years. The book concludes with an account of Marconi's last years in which he joined the Italian Fascist party, re-married and finally on 20th June 1937 died after several heart attacks. The booklet is well illustrated with photographs and is priced at 60p. Pp. 40. Her Majesty's Stationery Office, Atlantic House, Holborn Viaduct, London EC1P 1BN.

**Advanced Communication Systems** edited by B. J. Halliwell, comprises six chapters written by five independent authors. The aim of the book was to provide a comprehensive coverage and background to modern communication networks as well as systems of the future. Chapters are titled history and growth, f.d.m. systems, p.c.m. and digital networks, microwave radio systems, communication satellite systems and optical communication. Price £8.20. Pp. 276. The Butterworth Group, Borough Green, Sevenoaks, Kent TN15 8PH.

**Electronic Equipment Reliability** by J. C. Cluleyo. Attention to the reliability of electronic equipment has escalated during the past twenty years due to the development of more complex electronic systems and our increasing dependence upon them. This book provides an introduction to the subject and then deals with the mathematical background, reliability prediction, component failure data and finally a chapter on designing for reliability. Many of the calculations in the book involve simple application of the laws of probability statistics. These topics are summarised in an early chapter. Apart from this the only mathematics required are elementary algebra and integration. Price £2.50, paperback. Pp. 161. Macmillan, 4 Little Essex Street, London WC2R 3LF.

**What goes on in Telecommunications?** by Paul Roberson is an abridged story concerning the past, present and future of "at a distance" communications. The book adopts a non-technical explanation and is well illustrated with photographs making it suitable for budding Marconis and those with a general interest in telecommunications. Chapters include telegraphy, the telephone, radio, television and worldwide communications. The text concludes with a chapter on careers in telecommunications and sources of information. Price 90p. Pp. 80. Woodhead-Faulkner Ltd, 7 Rose Crescent, Cambridge CB2 3LL.

The OECD, Organisation for Economic Co-operation and Development, has just published **Energy Prospects to 1985** vol. I & II, an assessment of long-term energy developments and related policies. This report has been prepared by an inter-disciplinary team of OECD experts under the guidance of Professor Hans K. Schneider, Director General of the Institute for Energy Economics of the University of Cologne. Price \$11.25. Pp. 436. Her Majesty's Stationery Office, P.O.B. 569, London SE1 9NH.

**Towers' International Transistor Selector** by T. D. Towers gives tabular information on ratings, characteristics, package and lead identification, application, manufacturers, and equivalents of over 10,000 transistors. The transistors are a selection of current or popular obsolete types from the UK, USA, Japan and Europe. Price £2.95. Pp. 142. W. Foulsham & Co. Ltd, Yeovil Road, Slough SL1 4JH.

# News of the Month

## A telegram a second

Savings of over £1½M a year are expected by the Post Office from a new £4½M centre now open in London which automatically routes telegrams into and out of the United Kingdom. The largest telegram system of its kind in the world, the new London transmission centre handles a telegram each second of the working day. It directly links 13 international telegraph area offices in the UK, six in London and the others in Belfast, Birmingham, Bradford, Bristol, Glasgow, Liverpool and Manchester, with 67 countries using 77 different international routes. Telegrams may be sent through the centre anywhere in the world, either direct or by way of a distant terminal. As an example of how the centre operates, outgoing telegrams for delivery abroad are received at the 13 telegraph area offices in Britain from customers, mostly by telex or telephone, but also by hand or from the sender's local post

*Technical control position in the PO's new telegram retransmission centre (see news item) from which the operation of the processing computer can be supervised and controlled.*



office. Operators at the area offices forward them by teleprinter to the telegram retransmission centre. Here, a computer automatically checks that each telegram is in the correct internationally agreed format, works out the route it has to take to its destination (its memory holds 10,000 overseas destination towns for this purpose), extracts accounting and billing information, adds the destination indicator and then directs the telegram to the outgoing circuit for the destination office, all in under a minute.

The centre is equipped with three drum stores, each with a capacity of 2½M characters for use as brief memories, eighteen magnetic tape stores which will be used for recording telegrams and a variety of other functions plus 24 disc packs each with a capacity of 25M characters which are used for storing telegrams for rapid retrieval, the town name files, the registered telegraphic address and so on. Joint development work on the preparation of software for the system has been between the Post Office, Pye TMC and Philips.

## Integrated circuit in stitches

One of the latest domestic sewing machines introduced in the United States is controlled electronically by an m.o.s. l.s.i. system. This operates in conjunction with touch contact controls to replace up to 350 mechanical parts including the manual levers and dials conventionally used for the selection of the various machine functions. Pattern selection, for example, is effected simply by touching the relevant contact and the appropriate machine settings are then made automatically by the m.o.s. control system. This facility also allows one unit of a selected pattern to be sewn, after which the machine automatically stops. Machine settings under control of the device can also be made for selected stitch length and width and the fabric in use. The machine, called the Athena 2000, has been introduced by Singer in the United States and was developed by AMI Microsystems. A version of the machine for Europe is currently under development.

## Breakthrough in quartz oscillators

Quartz crystal controlled oscillators have been produced which have fundamental operating frequencies of 1GHz. This breakthrough has been achieved by using surface waves on quartz crystal substrates rather than bulk acoustic waves employed in traditional

crystal oscillators. Although the production process is technically advanced, the reduction in active multiplying and phase-lock loop circuits can produce substantial overall unit cost and size reductions. The claimed high spectral purity obtained by using the high fundamental frequency coupled with the overall ruggedness of the devices could permit their use in applications which cannot be undertaken by bulk crystals. The s.a.w. oscillator is capable of being frequency modulated making it suitable for telemetry. It is also expected to be applied in signal processing systems. Measurement of short term stability of the s.a.w. units have shown them to be comparable with bulk crystal oscillators, stabilities of 1 in 10<sup>9</sup> for a one-second time sample being obtained. The devices exhibit parabolic frequency/temperature characteristics and the zero frequency temperature coefficient point of these characteristics has been varied between -20° C and +70° C by using different cuts of quartz crystal.

Marconi Research Laboratories who have produced the oscillators had previously demonstrated the feasibility of using s.a.w. oscillators in the microwave range up to 720MHz. The laboratories are currently offering research samples for system evaluation purposes.

## Satellite interference suppressed

A new system for the suppression of unwanted signals which can interfere with transmission from communication satellites has been installed at the Satellite Earth Terminal Station, Goonhilly Downs, Cornwall. This station forms part of the INTELSAT satellite communications network which links virtually every major country in the world via satellites maintained in fixed positions over the Atlantic, Indian and Pacific Oceans. The Indian Ocean satellite appears at a low angle from Goonhilly, just above the horizon and the PO aerial working to it has to be aimed across France nearly in direct line with a French radio-relay station which transmits on frequencies in the 4,000MHz band which, unfortunately, can interfere with signals received from the satellite. During periods of anomalous propagation the power of the unwanted signals has sometimes exceeded the power of the wanted signals by as much as 30dB.

Under a preliminary study contract, Plessey proposed that the Post Office should consider use of a cancellation technique which had been used experimentally. This receives a significant level of the interfering signal only. By feeding a controlled amount of the signal from the auxiliary aerial into the main aerial receiver, the interference can be cancelled. This proposal was

acceptable to the Post Office and Plessey believe that this is the first time that such a system has been applied to civil radio communications and foresees considerable potential for its further application in all fields of communication where interference is a growing problem.

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## Standstill brake tester

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Coaxial displacement transducers are being used on a brake analyser which has been developed to test the braking system of motor vehicles. The analyser enables garage mechanics to simulate moving conditions without taking the car out of the workshop. This type of test is being stipulated by the Department of the Environment for vehicle examination and all garages undertaking this work should be equipped with such a device by the end of 1979. Two Pye Ether series PD20 co-axial displacement transducers are mounted either side of a roller which is free to rotate under no-load conditions, i.e. with the wheel of the car under test unbraked and the gears in neutral. The roller is driven by a separate motor and gear box. When the brakes of the car are applied the roller is brought to rest and the system collapses against a force retaining spring arrangement. The transducers compress and a direct reading of the brake force is read out on a meter. The equipment will also indicate other braking defects such as oval drums.

The transducer is a potentiometer type with versions having up to 12in of travel. It is designed for severe operating conditions such as those found in garage workshops and is available in a number of standard resistance values. The brake analyser was developed by Crypton Triangle.

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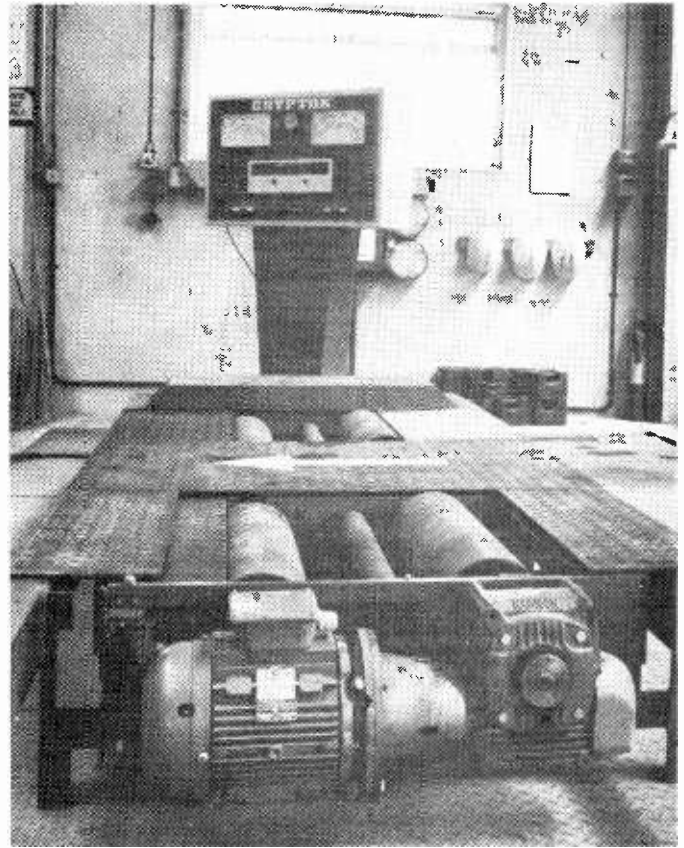
## Perth to Adelaide by microwave

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The 2,400km transcontinental 2GHz microwave-radio system between Perth and Adelaide is to be expanded to include the provision of additional telephone lines over the whole route which will effectively treble the telephone capacity of the system and also add a two-way television bearer over a section of the system. The route, which is equivalent to the distance between London and Moscow, crosses the continent between Northam, Western Australia, and Port Pirie, South Australia. As well as catering for through traffic between east and west, the system provides additional telephony circuits for towns and settlements along the route.

In this 60-hop system the low power-consumption of the 2GHz semiconductor equipment is particularly important since in many places there is no mains power supply and diesel fuel

*Crypton brake analyser before installation (see news item). At the bottom left-hand corner can be seen one of the Pye Ether coaxial displacement transducers.*



has to be transported up to distances of 650km. Power consuming air-conditioners have been eliminated at unattended repeater stations where the equipment is installed in a convection-cooled shelter which keeps the inside temperature within acceptable limits in spite of large diurnal variations outside of up to 22°C.

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## Colour TV deliveries down

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Deliveries to UK distributors of UK made and imported colour television receivers reached 88,000 in June, a fall of 49% compared with June 1974 (174,000), according to the latest statistics compiled by the British Radio Equipment Manufacturers' Association. This brought the total for the year to 824,000, a fall of 28% compared with the same period in 1974 (1,147,000). Of this total for the year, 123,000 were from abroad, which represents a 15% share of the market compared with 24% for the same period last year. Total monochrome television deliveries for June were 81,000, an increase of 47% compared with June 1974 (55,000) bringing the year's total to 448,000, an 8% increase on the same period last year.

## Briefly

**Incoming President of the IEE.** On Oct. 1st 1975, Mr Robert J. Clayton, CBE, MA will take office as President of the Institution of Electrical Engineers.

**Irish exhibit electronics.** Ireland's first electronics exhibition which is being presented under the title ITRON will take place at Dublin's Burlington Hotel Convention Halls from November 4-6 this year. Altogether it is expected that about 50 firms will be represented on the total exhibition area of 12,000 sq. ft.

**Delay on safety regulations.** The Electrical Equipment (Safety) Regulations 1975 were laid before Parliament on 21st August 1975 and are due to become part of the law of the land from that date. The date of effectiveness has, however, been delayed to 1st April 1976 with a further period of grace being given to manufacturers of electric light fittings, until 1st October 1976.

**IERE 50th anniversary.** The first meeting of the British Institute of Radio Engineers was held in Oct. 1925. The name was changed shortly afterwards to the Institute of Wireless Technology until 1941 when it merged with a smaller but similar organization and took the name of British Institution of Radio Engineers. The Institution was granted the Royal Charter in 1961 and in 1964 the title again changed to its present one of Institution of Electronic and Radio Engineers. Our congratulations and best wishes for the future.

**Cablevision goes commercial.** From September 1 1975 Sheffield and Greenwich local television stations are carrying advertising. This follows an announcement on July 23 that the British Relay organization which owns and operates Sheffield Cablevision, the largest of Britain's experimental community TV stations, has decided to take up the amended Home Office licence to carry advertising.

# Progress in multiphonic organs

## Use of more than one wave shape and more than one pitch

by J. H. Asbery, B.S.c., M.I.E.R.E.

Many constructors of electronic organs make the mistake of thinking that if the output from a waveform generator is taken to the correct filter the desired tone will result. This is far from the truth. For example, some generators produce a square waveform and some a sawtooth. A square waveform contains only odd harmonics. The open diapason sound requires a predominance of even harmonics. No filter will produce missing harmonics. For a second example, a sawtooth contains both odd and even harmonics. For the closed diapason sound and for the clarinet sound a predominance of odd harmonics is required. A filter which severely attenuates the 2nd, 4th, 6th etc. harmonics will also attenuate the 3rd, 5th, 7th etc. harmonics. The open diapason sound

cannot be produced from a square wave nor the closed diapason sound from a sawtooth. As well as the correct filter the correct input waveform is required.

In the more expensive organs a number of different waveforms are provided. In the medium priced organs the designer has to decide which waveform to use, as the price will not allow more than one. This restriction results in some tones not being provided.

In addition to different waveforms being provided, signals of different pitches for the same note are required to give the sound the "fullness" associated with organs. The most important additional pitch is one octave above the note being played. The second most important additional pitch is one octave

below the note being played, particularly at the lower end of the keyboard. A separate complete switching system is usually provided for each pitch.<sup>1</sup>

The first difference between a multiphonic<sup>2</sup> organ and a polyphonic<sup>1</sup> organ is that in a polyphonic organ the number of generators is related to the number of keys on the keyboard, typically 49, whereas in a multiphonic organ the number of generators is equal to the number of keys one wishes to press at one and the same time, typically six. This results in a substantial reduction of cost and time to construct.

The second difference is equally important. In a polyphonic organ the switching system is usually connected to the output of the generators, but in a multiphonic organ the switching sy-

*Fig. 1 (right). Circuits for adding and subtracting different waveforms produced by the waveform generator; also for frequency dividing and producing vibrato. The letters (a), (b) and (d) on the generator indicate the circuit positions of the waveforms (a), (b) and (d) in Fig. 2. On the extreme right are shown various stop filters.*

### Components list

#### Resistors — R

1	3k3 metal film	33	3k3
2	3k3 metal film	34	22k
3	500k 1%	35	22k
4	100k 5% carbon film	36	22k
5	10k 5% carbon film	37	10k
6	100k 1%	38	15k
7	100k metal film	39	47k
8	2k7 metal film matched set	40	22k
9	5k6 metal film matched set	41	1M8
10	100k 1%	42	15k
11	1k 5% carbon film	43	15k
12	1M 5% carbon film	44	22k
13	33k 5% carbon film	45	1M8
14	3k3 5% carbon film	46	100k
15	10k 5% carbon film	47	220k
16	470 ohm 5% carbon film	48	220k
17	15k 5% carbon film	49	47k
18	1k 5% carbon film	50	47k
19	2k2	51	470k
20	3k3 5% carbon film	52	470k
21	3k3 5% carbon film	53	220k
22	10k	54	1M8
23	10k	55	1M8
24	2k2	56	220k
25	68 ohm	57	220k
26	2k2	58	470k
27	10k	59	470k
28	10k	60	220k
29	10k	61	1M8
30	10k	62	470k
31	10k	63	470k
32	470k		

#### Capacitors — C

1	right hand side 100n	} polystyrene or polycarbonate matched sets
2	left hand side 400n	
2	70p	
3	220p	
4	220p	
5	1.5 $\mu$	
6	1.5 $\mu$	16 2.2n
7	1.5 $\mu$	17 100n
8	18n	18 2.2n
9	100n	19 2.2n
10	100n	20 330p
11	100n	21 2.2n
12	47n	22 2.2n
13	220n	23 18n
14	18n	24 220p
15	100n	25 18n

#### Integrated circuit

IC<sub>1</sub> op-amp 741

#### Variable resistors — RV

5 220k vibrato depth control  
6 50k melodic bass 16ft control

#### Transistors — Tr

1, 2 BC149  
3 BC307  
4, 5, 6 BC149  
7, 8 BC307  
9, 10 BC149

#### Inductors — L

1, 2, 3 600-700mH (Eagle LT700)

#### Preset resistors — RV

1 4k7 octave balance  
2 3k3 flute balance  
3 3k3 unison balance  
4 200 ohm vibrato loop gain

All components are available from J. H. Asbery; 87 Oakington Manor Drive, Wembley, Middx. Where component types are not specified, viz. all capacitors except C<sub>1</sub> and resistors R<sub>19</sub>, R<sub>22</sub> upwards, any type may be used.



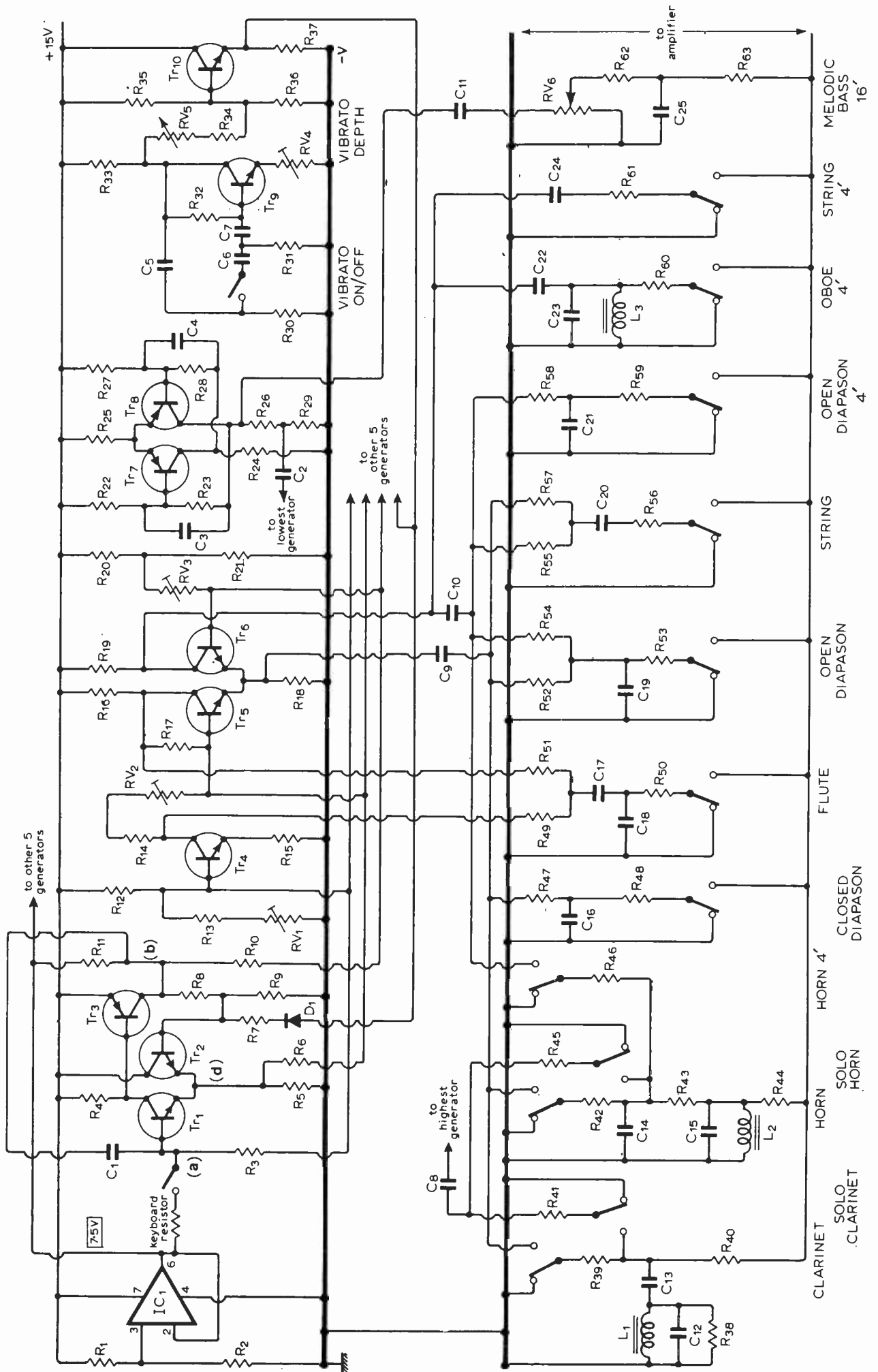
VIBRATO

DIVIDER FOR MELODIC BASS

MIXING AND SUBTRACTING

GENERATOR

HALF VOLTS UNIT



- CLARINET SOLO CLARINET
- HORN SOLO HORN
- HORN 4'
- CLOSED DIAPASON
- FLUTE
- OPEN DIAPASON
- OPEN DIAPASON 4'
- STRING
- STRING 4'
- OBEO 4'
- STRING 4'
- MELODIC BASS 16'

stem is connected to the input to the generators. The consequence of this is that if an extra waveform or extra pitch is required this can be added to an existing multiphonic organ without any extra switching.

#### Generating triangular waveforms.

$Tr_{1,2 \text{ \& } 3}$  and their associated components in Fig. 1 constitute a typical basic generator. The waveform on  $C_1$  is shown in Fig. 2(a) and the waveform on  $R_{11}$  is shown in Fig. 2(b). By subtracting 2(b) from 2(a) a triangle wave 2(c) results. This has low harmonic content and is suitable for driving the flute stop. A transistor is required to reverse one of these outputs to enable the subtraction to take place. To avoid loading the frequency determining components,  $C_1$  and the keyboard resistor, a buffer transistor is required. An economy can be made by combining these two functions in the one transistor,  $Tr_4$ . The result of subtracting a waveform we shall call A1 from waveform B1, waveform A2 from B2 etc. and adding the differences is the same as adding A1, A2 etc., adding B1, B2 etc. and subtracting the two totals. The outputs from all the generators can be added together by resistors and a single transistor used to subtract the totals. One transistor will

produce the new waveform, e.g. the triangle wave, for all the generators and hence for the entire keyboard.

**Generating sawtooth waveforms.** The waveform on  $R_5$  is shown as Fig. 2(d). By subtracting 2(d) from a half of 2(a) and a proportion of 2(b) the sawtooth 2(e) results. By changing the proportion of 2(b) the sawtooth 2(f) results. It can be seen that the frequency of 2(f) is twice the frequency of 2(b). This is equivalent to providing a second rank of generators at twice the pitch of the unison note, or one octave above unison, as well as providing the extra waveform, the unison sawtooth, from only one additional transistor.

**Pedal board and solo manual simulators.** A further advantage of the multiphonic organ compared with a polyphonic organ is that the lowest note played in the left hand side of the keyboard always comes from the same generator regardless of what the note is. To give extra body to the sound a conventional divider,  $Tr_7 \text{ \& } 8$ , can be connected to the "lowest note generator" to give pedal-board simulation. The pitch of this note will be one octave lower. Stops controlling this are conventionally labelled 16ft.

Similarly the highest note played in the right hand side of the keyboard is always from the same generator. The output from this can be controlled by separate stops and a two-manual solo and accompaniment arrangement simulated.

**Vibrato.** Any low frequency sinewave oscillator can be used to produce vibrato, such as the circuit of  $Tr_9$  and  $Tr_{10}$ . A diode  $D_1$  is required to apply the vibrato. Without this the vibrato increases the time of one half cycle and decreases the time of the other half cycle by about the same amount.

#### References

1. "Transistor electronic organ" by T. D. Towers. *Wireless World*, May 1966, pp. 219-224.
2. "Multiphonic organ" by J. H. Asbery. *Wireless World*, June 1973, pp. 303-305.

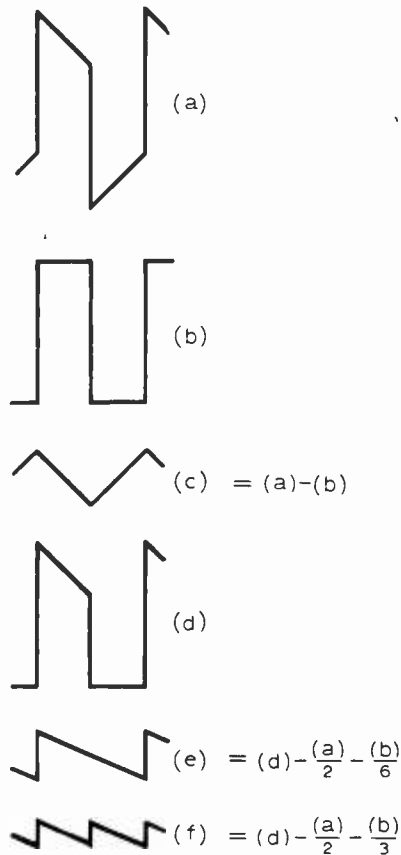


Fig. 2. Principle of combining different waveforms from the generator: (a) waveform on  $C_1$ ; (b) waveform on  $R_{11}$ ; (d) waveform on  $R_5$ . Triangle waveform (c) results from subtracting (b) from (a), while the sawtooth waveforms (e) and (f) result from the manipulations shown.

## Books Received

**Component technology and standardization** by the General Electric Co. (USA). This publication is three loose-leaf binders comprising 24 sections covering virtually every type of passive/active component used in the electronics industry. The information is presented in a standardised format and each component is described under 13 sections dealing with everything from cost factors to circuit applications. Although the manual was compiled by GEC the material was checked and revised by 43 electronics companies to produce an unbiased publication. The three binders, which are updated twice a year, have a total of 2,026 pages and represent one of the most comprehensive component encyclopaedias available to date. Price £197.80. London Information Ltd, Index House, Ascot, Berks SL5 7EU.

Gordon King has written two new books entitled **Colour Television Servicing** (second edition) and **The Audio Handbook**. Both publications are clearly written with many diagrams and photographs supplementing the text. The first book explains how a colour television system works and deals with each section of a receiver separately. Fault finding and servicing are described with circuit diagrams used wherever possible. At the end of the book there is a large fold-out fault-procedure chart arranged as coloured block diagrams with a cause and effect notation.

The second book explains the confused world of audio. Most aspects of the subject are covered including amplifiers, loudspeakers, headphones, f.m. radio, tape recording microphones and surround sound systems. Both books are priced at £4.90 and are available from Newnes-Butterworth, Borough Green, Sevenoaks, Kent TN15 8PH.

## Sixty Years Ago

In October, 1915, the generation of radio-frequency signals was still largely done by shock-excited LC circuits producing damped oscillations. There was considerable interest in the production of "single-frequency oscillations" and the British Association (Section G) meeting of September 10th was the occasion of a paper on the subject by Dr W. Eccles and A. J. Makower. — "Electric Oscillations in Coupled Circuits—a Class of Particular Cases". "The paper was of a highly mathematical character, and Dr Eccles apologised for presenting it to the Engineering Section of the Association. He pointed out, however, that the paper gave several formulae not to be found in text books, and he felt that these would be of assistance to designers of wireless telegraph installations. The investigations which formed the subject of the paper arose during an examination of the methods of coupling that might give rise to single frequency oscillations.

"Professor Gisbert Kapp, who was in the Chair, remarked that the author had judged the mentality of his audience rather too highly. He confessed that the subject was beyond him."

# Facsimile scanner

## Minimal-cost design for weather-satellite pictures

by J. M. Osborne

**A surplus windscreen wiper is pressed into service as a mechanical scanner for the reception of satellite weather pictures. The control and drive electronics are described and a description is included on an unusual method of synchronizing a d.c. motor with an a.c. signal.**

The mechanical-facsimile method of printing weather satellite pictures on special paper has obvious attractions over photographic techniques. Professional users, such as the Meteorological Office, normally use Mufax recorders, while amateurs have successfully devised and built drum recorders at a fraction of the cost of a Mufax machine. In general, definition and contrast are lower and mechanical problems are more difficult to solve and contain than electronic or photographic ones. However, as the NOAA satellite scan gives lower resolution than the earlier APT satellites<sup>1</sup> while still presenting the relevant meteorological information, the mechanical system is entirely adequate.

In essence, the satellite picture — like facsimile processes in general — involves a slow-scan raster. At slow speeds, mechanical raster systems compete favourably with the cathode-ray tube, both for transmission and reception. The Mufax machine scans a "spot" by means of a one-turn helix on a rotating cylinder pressing sensitive paper against a straight edge parallel to the axis, as shown in Fig.1(a). One revolution of the cylinder scans the point of contact across one line of the picture; it then starts the next line from the other end of the helix on the next revolution, the paper being moved forward at an appropriate "frame scan" speed. It would not be easy for amateurs to emulate this technique and an alternative scan is obtained by a stylus scribing on a paper-covered drum, as in Fig.1(b). This rotates at the line frequency, while the stylus moves slowly parallel to the axis, as in a screw cutting on a lathe. Again, the next line starts as one finishes.

The variable density of the scanned spot is achieved by using the picture signal to vary current through the paper used. In the Mufax, an electrochemical process is used; the paper passes

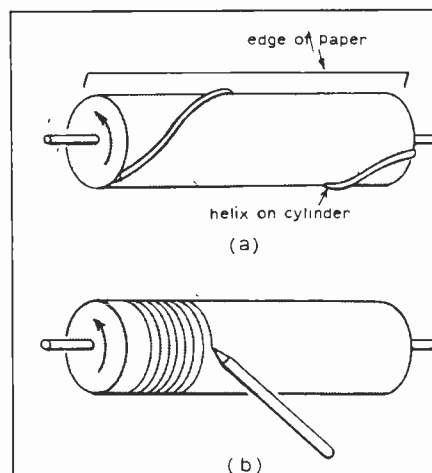
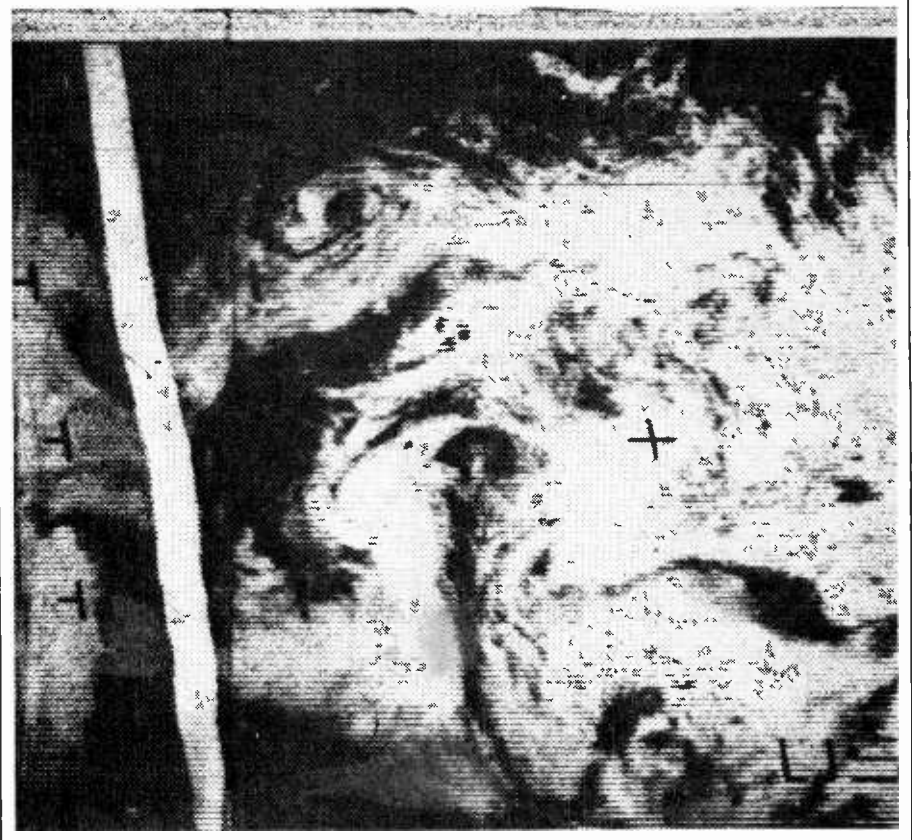


Fig. 1. An outline of the two mechanical scanning systems in use for facsimile recorders.

Fig.2. This photograph shows the quality obtainable on home made apparatus as outlined in Fig. 1(b). This is a picture taken from ESSA 8 by Mr J. A. Watts of Christchurch.



between the helix and the straight edge at a slow speed such that a series of close spaced lines (one per revolution of the helix) form the picture. The electrochemical paper is supplied damp and is fed from a humidity-sealed container, which poses a problem for the amateur. The rotating-drum method uses a dry white electro-sensitive paper<sup>2</sup> in which a current passing through a stylus marks the paper black. The current breaks down the white surface and partially exposes a black layer in the paper just below the surface. In this system a lead screw, or its equivalent, drives the stylus parallel to the drum axis at the frame scan speed. The picture, shown in Fig.2, from the ESSA 8 satellite was made by Mr Watts of Christchurch, Hants on his home made drum recorder.

A third mechanical scanner system occurred to me, while in a traffic jam on a rainy day. A windscreen wiper sweeps an arc of 100° or so at about 48 sweeps per minute, the NOAA satellite's line frequency. Now Fig.3 shows that the satellite line scan is based on a mirror rotating at 48 r.p.m. sweeping from horizon to horizon at right angles to the satellite orbit. Forward motion of the satellite provides frame scan. Since the active part of the line scan (horizon to horizon) occupies less than half the time for a revolution of the mirror, the flyback interval is greater than the line time. A stylus on the arm of a windscreen wiper will scribe an arc corresponding to a single scan line, leaving over 50% time for the flyback. It was this fact which made the windscreen wiper product possible.

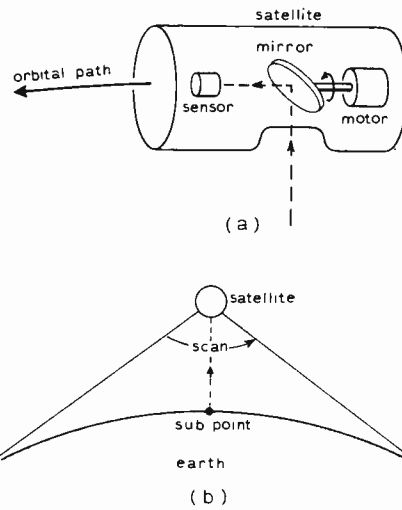


Fig.3. (a) shows diagrammatically the satellite's rotating scanning mirror; (b) shows the useful scanning angle swept by the mirror in the plane at right angles to the path of the satellite.

What follows shows that this concept is workable. Much can still be done to improve and extend this: some such suggestions will be mentioned later. While an extended period of operation should produce more interesting pictures, my object in presenting these preliminary results is twofold. Firstly, "projects" are never complete and are seldom suitable for direct copying. Secondly, the evidence supports an important general point about school projects. Except for those with considerable workshop facilities and advanced mechanical engineering faci-

lities, imaginative and creative project work is most practicable in electronics, leaving mechanical work to the adaptation of existing machines and materials. A mechanical approach to the problem might well have started with adapting synchronous motors to drive home-made mechanisms. This would have entailed far more time-consuming mechanical development, with, in my estimation, less chance of success. In this case, the "mechanics" are provided by a junk windscreen wiper assembly, "free for the taking" from a motor scrap yard, and standard "Handy Angle" components.

The most rewarding, yet in practical terms perhaps the most useless, result of this project has been the successful synchronizing of a d.c. motor. The idea and its execution is electrical. It is obviously necessary to get the right 48 r.p.m. line speed and equally obvious that the answer won't be in any standard text book on d.c. motors, or, at least, not in most of them<sup>3</sup>. Initially a simple scribe on the end of a wiper arm was lashed up using the wiper motor. This showed that a scan could be obtained, pulling the paper below the stylus by hand. Unless the motor speed could now be controlled to give a synchronised sweep of 48 r.p.m. there was no point in going on. The original hope had been that the motor speed could in some way be controlled by manually or electronically lining up sync pulses from the satellite signal with pulses generated by the sweeping arm. A possible source of the latter was from the "self parking" switch mechanism already built into the motor unit.

Fig.4. The square wave pulse drive for the armature enables the windscreen wiper motor to be driven synchronously.

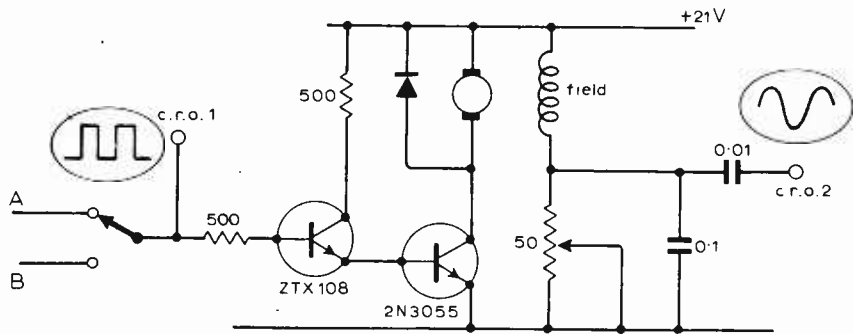
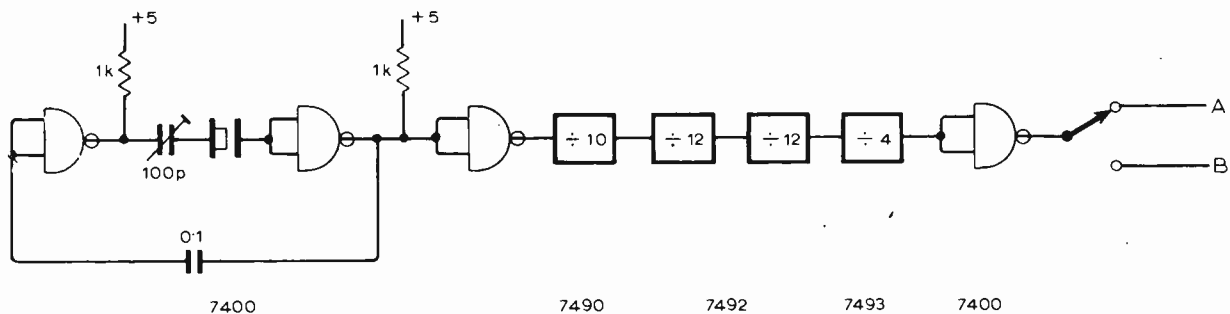


Fig.5. The quartz crystal oscillator and divider circuits to produce the required a.f. of 364.05Hz for synchronising the windscreen wiper motor.



A better idea developed when it was realised that in a commutator motor, the armature ripple superimposed on the direct current contained precise information, in the "ripple frequency", of armature and hence, sweep speed. This frequency is best observed across a speed control resistor in the field circuit. The armature a.c. ripple component is superimposed on the d.c. field current by transformer coupling between field and armature within the motor. While considering ideas of phase-lock loops, servo controls and the like, a simple experiment was first tried. A small-amplitude sinusoidal a.c. from a signal generator was fed in series with the armature d.c. supply. A weak tendency to "lock on" was observed when the ripple and generator frequency were sufficiently close. To exploit this phenomenon, a square wave drive was contrived (see Fig.4) to give the armature about twice the current for half the time. The armature torque remains about the same as for 12Vd.c. but the drive frequency takes significant control of the motor speed. Lock is held over substantial changes in field current. This may be observed by comparing the traces on a double beam 'scope from points CRO<sub>1</sub> and CRO<sub>2</sub> in Fig.4. The explanation of the phenomenon seems to lie in the armature segments acting like the teeth of a synchronous clock motor.

The next requirement was the precise frequency source to lock on to 48 r.p.m. By counting the commutator segments and gear ratios, the frequency was calculated on a pocket calculator to be 364.0519 Hz. (Not the most convenient figure, but hardly the fault of Lucas Ltd!) From a selection of quartz crystals and, again, with the aid of a pocket calculator<sup>4</sup>, the circuit of Fig.5 was arrived at. The crystal was marked 2096 kHz (1944). This vintage being demountable, it proved possible to grind it with fine carborundum and turps on plate glass to near 2097 kHz. The frequency was checked every 5 or 10 minutes during grinding by using the circuit of Fig.6<sup>5</sup>. After 30 minutes of grinding, the correct output count could be bracketed by adjusting the series trimmer. The l.f. source of Fig.5 is cheaper, simpler to construct, more versatile and more reliable than its predecessor, the electrically maintained turning fork. Using this source to drive the circuit of Fig.4, no problem was encountered in getting the synchronous 48 r.p.m. sweep, although the field current has to be adjusted to get the approximate speed before lock is obtained. As the motor warms up during the first five or ten minutes of running, further adjustment of field current is required to maintain lock. The scribing of picture information on to the paper depends on the choice of the sensitive paper. The paper used was surface conducting, Type SC41 (8½ in) supplied by Electrosensitive Coatings

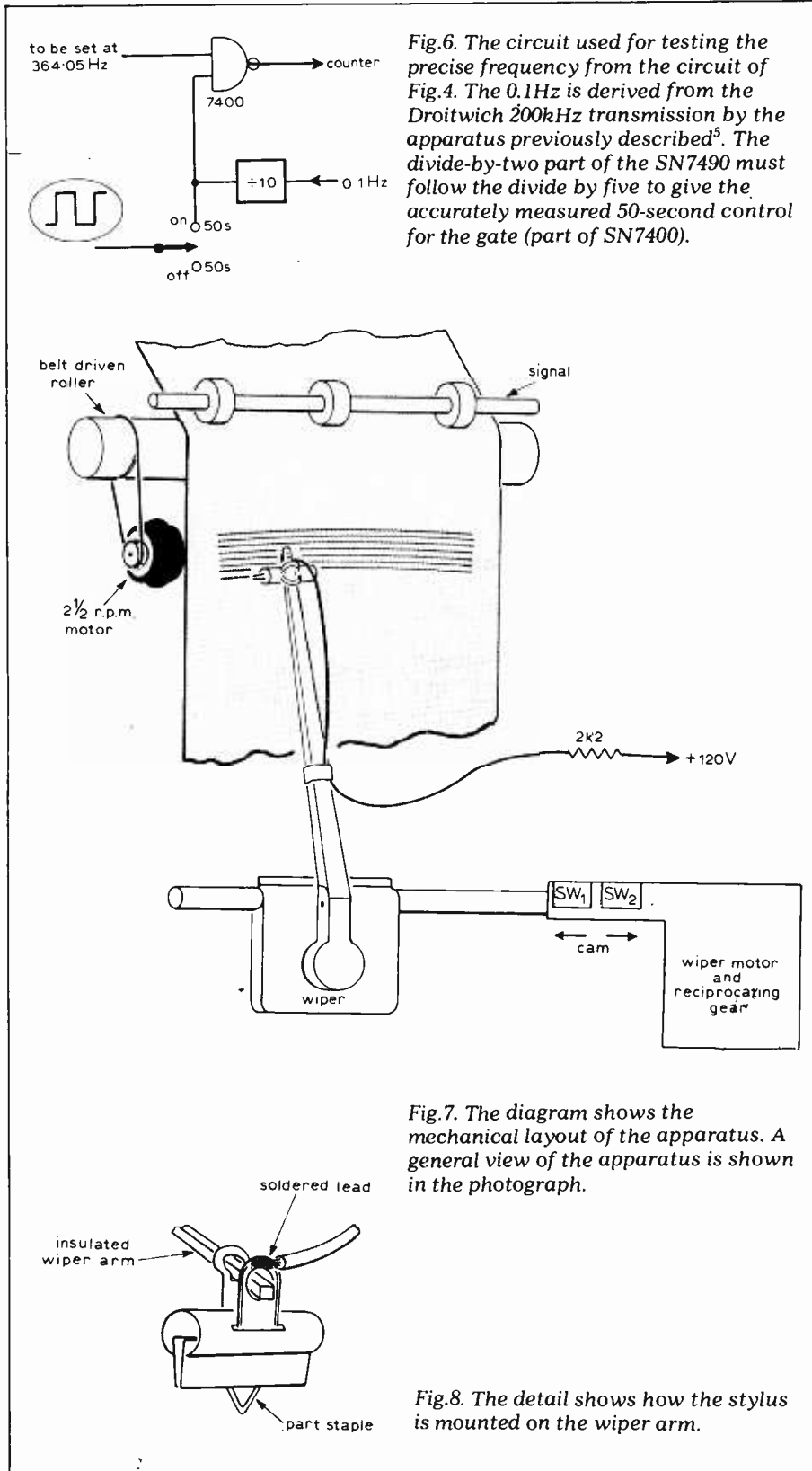


Fig.6. The circuit used for testing the precise frequency from the circuit of Fig.4. The 0.1Hz is derived from the Droitwich 200kHz transmission by the apparatus previously described<sup>5</sup>. The divide-by-two part of the SN7490 must follow the divide by five to give the accurately measured 50-second control for the gate (part of SN7400).

Fig.7. The diagram shows the mechanical layout of the apparatus. A general view of the apparatus is shown in the photograph.

Fig.8. The detail shows how the stylus is mounted on the wiper arm.

Ltd.<sup>2</sup> Three metal roller-skate wheels, loaded by gravity, make surface contact, as in Fig.7. The pen stylus is a "V" obtained by cutting in half a normal stationery staple. This is fixed by clipping into a small bulldog clip (see Fig.8), mounted on, but insulated from, the wiper arm. No wiper arm spring is used as the weight of the arm gives adequate stylus pressure. A current, up to 15 mA, is supplied to the pen from a

120 V neon-stabilized supply with a 2.2kΩ limiter. The current is controlled by a transistor between the rollers and ground. The transistor<sup>6</sup> has a high collector/emitter rating of 250V.

The audio signal is derived from the apparatus originally described in *Wireless World* Nov. 1971 page 539 Fig.20. Briefly, at the present time a NOAA satellite on 137.5 MHz f.m. broadcasts continuously a 2.4 kHz a.m. subcarrier

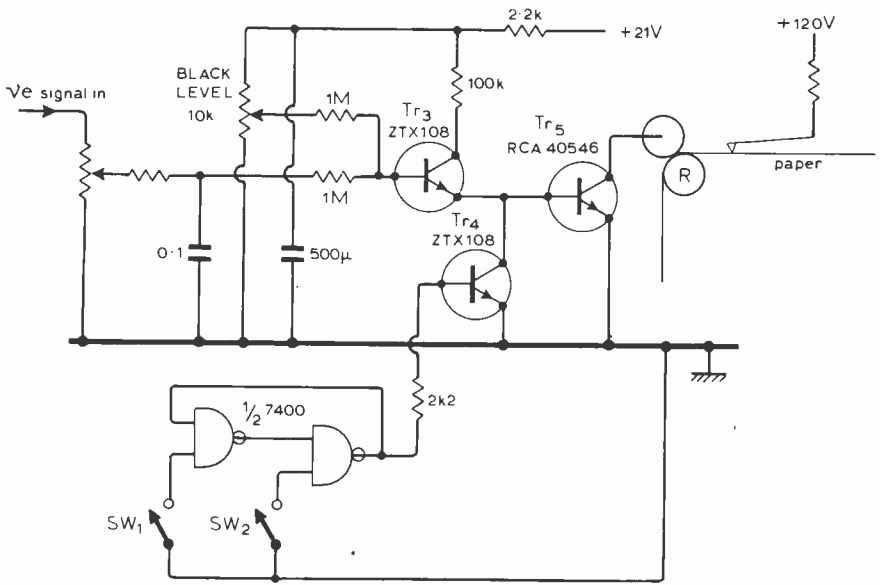


Fig.9. The circuit used to mark the sensitised paper with the signal from the satellite. SW<sub>1</sub> and SW<sub>2</sub> are microswitches operated by the "self parking" cam on the windscreen wiper motor assembly. They operate the 7400 latch circuit to blank the sweep in one direction while allowing the signal through in the other direction.

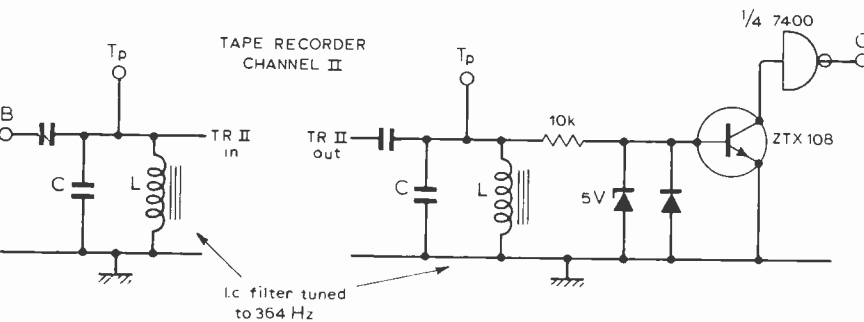
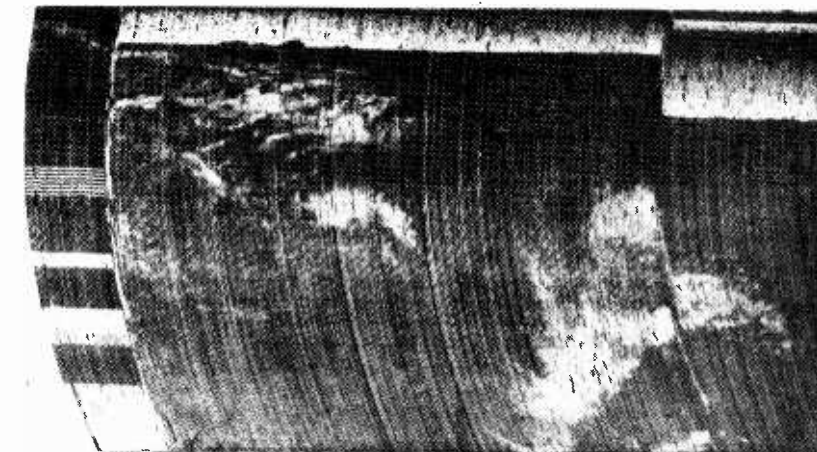


Fig.10. To interface the square wave pulses used for synchronising with the second channel on the tape recorder an LC circuit tuned to 364Hz is used. On record it filters the high harmonics, giving an approximate sine wave input to the recorder. On play-back the filter cleans up the signal before it is used to gate the 7400 to recover the square wave sync. Channel one is used to record the signal from the satellite for subsequent replay.

Fig.11. Part of a picture showing how phasing of the picture with the sweep of the wiper arm is achieved by deliberately throwing the motor off lock for brief intervals of a couple of seconds or so. Whether the motor runs fast or slow depends on the direction that the speed control is altered (see Fig.3).



with picture information of the cloud cover below plus various synchronizing pulses. The amplitude modulation of the 2.4 kHz a.f. subcarrier is demodulated to give a negative-going picture signal. Since each point of the earth passes through the plane of the orbit around 0945 and 1945 local time e.g. G.M.T. in the U.K. each day, two or three orbits are observable at just under 2 hour intervals, roughly between 0800 and noon each morning and again between 1900 and 2300 in the evening. The signal is used to drive the pen and mark the paper as shown in Fig.9. The 10kΩ bias potentiometer is set to give a full black line in the absence of a signal. The signal gain is then turned up to give full white (zero paper current) on cloud cover.

Blanking is achieved by grounding the base of Tr<sub>5</sub> through Tr<sub>4</sub>, which is switched by two gates of an SN7400 connected as a latch. Micro-switches are mounted on the wiper motor casing so that each is momentarily closed at the end of the travel of the cam mechanism. This cam mechanism already exists for providing the wiper self-parking facility. The switches cause latch up for one half of the sweep and so blank off the signal, but latch down and let the picture signal through for the return sweep. It should be mentioned that to avoid erratic scanning due to mechanical backlash, a long weak spring applies a permanent mechanical bias in one direction to the wiper arm. This spring stretches across the width of the baseboard just below the wiper arm to which it is attached by a string over a pulley fixed to the wiper motor casing.

Apart from running the motor in sync, the sweep must start as the signal line starts. So far no thought has been given to achieving this automatically. The motor is unlocked and allowed to run fast or slow by controlling the field current. By throwing the motor off lock for a few seconds at a time repeatedly, correct phasing can be obtained manually soon after the signal is acquired. A typical illustration of the consequence of this procedure is shown in the photograph Fig.11. In the NOAA 3 system an infra-red scan signal is transmitted during the visible flyback interval so either can be plotted by suitable phasing of the scan. The gain control has to be adjusted for suitable contrast which differs between the infra-red and visible scans.

A tape-recording of the signal is a very convenient technique for re-play to get both visible and infra-red pictures. Sync is obtained by recording the 364Hz on the second channel of the stereo recorder. The fundamental is filtered, on record and play-back, by the LC turned circuit as shown in Fig.10. By the nature of the satellite scan and the arc of the wiper sweep, two considerable sources of geometrical distortion are apparent. The arc distortion is minimised by reducing the throw of the

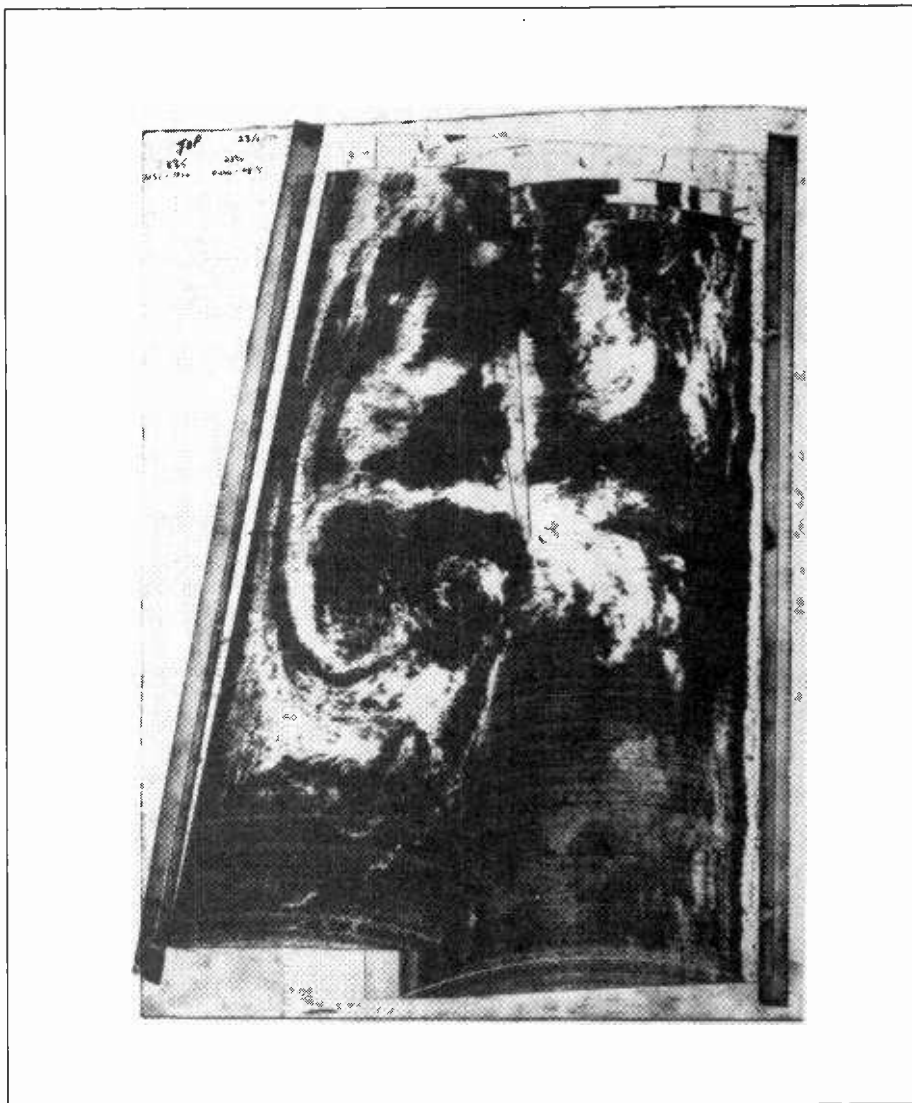
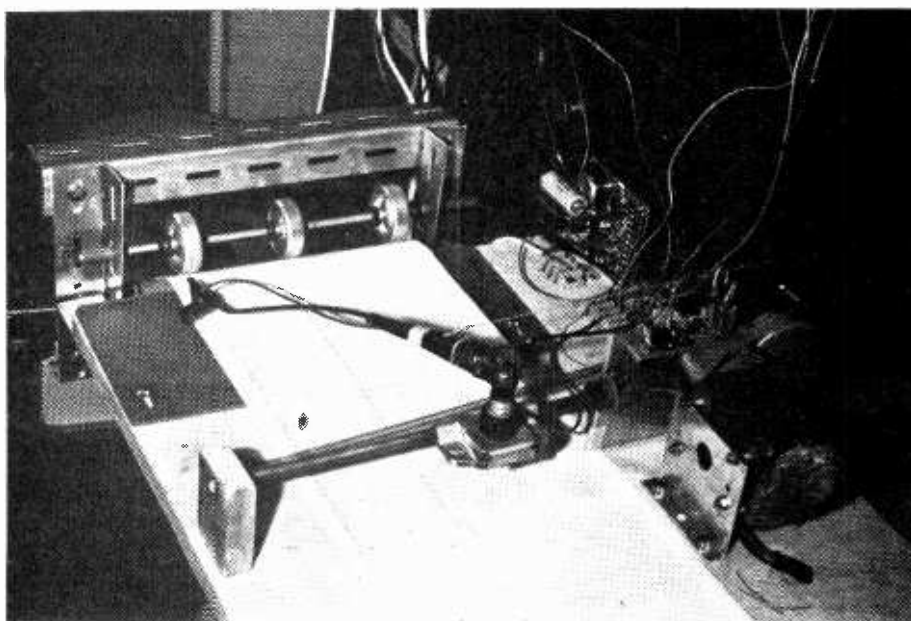


Fig.12. Pictures taken by the apparatus of two successive orbits of NOAA3. The overlap of cloud formation in the two pictures is not difficult to see.

Fig.13. A general view of the Facsimile project. Note the wiper arm, and contact rollers as shown in the top view layout of Fig.7 and the circuit of Fig.9. The circuitry of Fig.9 is mounted on a small aluminium plate in the top right corner of the photograph. The wiper motor is on the right.



reciprocating mechanism. This is achieved by resiting the big end bearing as close as convenient to the centre of the final drive wheel, resulting in an arc of  $36^\circ$ . In spite of distortion, the overlap between successive orbits is clearly demonstrable as seen in the photo Fig.12. If satellite predictions from the Appleton Laboratory, Radio & Space Research Station, Ditton Park, Slough, are available and if real time marks are put on the paper (or tape), the latitude and longitude can be deduced for points on the centre line of the picture.

The paper drive is obtained by turning the Handy Angle roller (R in Fig.9) by a belt drive from a  $2\frac{1}{2}$  r.p.m. synchronous motor (50p on the surplus market). The smallest available pulley was fitted to the motor spindle to drive the rubber belt (supplied as spares for a tape recorder). The resulting paper speed is about 50% too fast. The correct paper speed (to give an undistorted aspect ratio in the central region of the picture) can be calculated for a given pen speed taken at centre of the sweep. Firstly, we know the speed, say in km/s at which the satellite mirror scans the subpoint (see Fig.3(b)). At 48 r.p.m. and 1470 km high this is 7400 km/s. Next, we know the satellite subpoint speed – 5.8 km/s – from its period (115 minutes) and the circumference of the earth. This ratio, 1300, gives pen writing speed to paper speed. The pen writing speed can be deduced from the system geometry or more easily by feeding a known audio frequency signal to the pen and measuring the average dot spacing.

In conclusion, may I repeat, the project may never be concluded. The paper speed must be reduced and an automatic phasing devised. Perhaps then automatic start on receipt of the signal might be considered. This might be followed by two wipers, side by side, sweeping in opposition, printing both visible and infra-red pictures.

Acknowledgements are due to J. Campbell, of Westminster School, for designing the layout and building all but the electronics of the apparatus shown in the photograph; to Mr Eatwell of Sensitised Coatings Ltd for advice and samples of papers; to Mr J. A. Watts of Christchurch, Hampshire for the photograph; and to Mr D. B. Read of Bradfield College for suggesting the crystal oscillator circuit used in the circuit of Fig. 4.

#### References.

1. "Receiving weather satellite pictures", J. M. Osborne, *Wireless World*, 1971, October, page 464; November, page 537.
2. Paper supplied by Sensitised Coatings Ltd, Redlands, Coulsdon, CR3 2HT.
3. "Exciting Electrical Machines" by E. R. Laithwaite, Pergamon Press.
4. Letter to Editor, *Wireless World*, July 1974, 228.
5. "High standard low frequency source", J. M. Osborne, *Wireless World*, January 1973, p20, and "Applications" July, 1973, p316.
6. Transistor type RCA 40546 supplied by J. Birkett, 25 The Strait, Lincoln LN2 1JF.

# Meetings

## LONDON

1st IEE—Seminar on "High speed analogue to digital conversion" at 10.00 at Savoy Pl., WC2.

1st IERE—"Service experience with the Trident automatic flight control system" by S. J. Collins, R. Taylor and P. E. Ryan at 18.00 at 9 Bedford Sq., WC1.

2nd IERE — Development and evolution of colour television display systems" by Ir. P. G. J. Barten, at 18.00 at The London School of Hygiene and Tropical Medicine, Keppel St., WC1.

7th IEE—"Some developments in computer-aided information services for the blind" by Prof. J. L. Douce at 17.30 at Savoy Pl., WC2.

8th I.Phys.—"Teach In," on electronic components at 10.00 at Imperial College, SW7.

8th IERE—AGM and presidential address by HRH the Duke of Kent at 18.00 at The London School of Hygiene and Tropical Medicine, Keppel St., WC1.

9th IEE — "Computers in road traffic control," by D. C. Gazis at 17.30 at Savoy Pl., WC2.

9th RTS—"Underwater low-light television" by M. Johnson and C. Trapmore at 19.00 at Conference Suite, London Weekend Television, South Bank TV Centre, Upper Ground, SE1.

13th IEE—Discussion on "Development and application of high power transistors" at 17.30 at Savoy Pl., WC2.

13th IEE—Discussion on "Detectors for thermal imaging" at 17.30 at Savoy Pl., WC2.

14th Royal Soc.—Discussion on "Scientific results from the Ariel-5 satellite" at 10.00 at 6 Carlton House Terrace, SW1.

15th IERE—Colloquium on "Adaptive array processing" at 14.00 at 9 Bedford Sq., WC1.

16th IEE—Colloquium on "Microwave instrumentation" at 10.30 at Savoy Pl., WC2.

21st IERE/IEE—Colloquium on "Airborne computer systems" at 14.00 at 9 Bedford Sq., WC1.

21st IEE—"Telephone services in Japan" by Dr M. T. Hills at 17.30 at Savoy Pl., WC2.

22nd I.Phys—One-day meeting on "Molecular beam-surface interactions" at 10.00 at Imperial College, SW7.

22nd IEE—Colloquium on "Compact cassette systems for instrumentation" at 14.30 at Savoy Pl., WC2.

22nd IERE—Colloquium on "Training professional electronics engineers for tomorrow" at 14.30 at 9 Bedford Sq., WC1.

23rd RTS—"Teletext — the editorial angle" by Colin McIntyre, Geoffrey Hughes and Peter Fiddick at 19.00 at the Conference Suite, London Weekend Television, South Bank TV Centre, Upper Ground, SE1.

28th I.Phys — One-day meeting on "Acoustic emission" at 10.00 at the Geological Society, Burlington House, W1.

28th IEE—Colloquium on "Computer aided learning in secondary and further education" at 10.30 at Savoy Pl., WC2.

28th IEE—"Computer generated images" by Dr A. M. Spooner and P. M. Murray at 17.30 at Savoy Pl., WC2.

29th I. Phys—Half-day meeting on "Lasers in medicine" at 14.00 at the Geological Society, Burlington House, W1.

29th IEE—"Electronics and the aeroplane" by I. L. Davies at 17.30 at Savoy Pl., WC2.

30th IEE—Colloquium on "Reduced order models and their use in design of dynamical systems" at 14.30 at Savoy Pl., WC2.

## BATH

14th IERE/IEE—"Automobile electronics" by C. S. Rayner at 18.00 at Lecture Room 2E3.1, University of Bath.

## BELFAST

7th IERE—"Integrated circuit applications" by speaker from Texas Instruments at 19.00 at Cregagh Technical College, Montgomery Road.

## BLANDFORD

14th IERE/IEE/R. Sigs. Inst.—"Digital signal processing with application to speech and radar" by Prof P. C. J. Hill at 18.30 at School of Signals, Blandford Camp.

## BOLTON

29th Sept. IEETE/IEE — "The influence of TEC on electrical engineering education" by A. C. Normington at 18.15 at Bolton Institute of Technology, Deane Road.

## BRIGHTON

23rd SERT—"ITT 110 deg colour chassis" by A. E. Thomas at 19.30 at Brighton Technical College.

## BRISTOL

9th. IEE.— "Modern trends in hi fi" by J. Linsley Hood at 19.30 at Queen's Building, Bristol University.

## CAMBRIDGE

30th IERE/IEE—"Some aspects of modern loudspeaker design" by G. Bank at 18.00 at the University of Engineering Laboratories, Trumpington Street.

## CARDIFF

8th IERE—"Quadraphonic broadcasting" by J. H. Brooks at 18.30 at Dept. of Applied Physics and Electronics UWIST.

## CHATHAM

22nd IERE—"The semiconductor story" by Dr K. J. Dean at 19.00 at Medway and Maidstone College of Technology, Maidstone Road.

## CHELMSFORD

7th IERE/IEE—"Noise reduction in high quality audio" by K. J. Gundry at 18.30 at the Civic Theatre.

## COLCHESTER

16th IERE—"Fibre optics" at 19.00 at the University of Essex.

## COVENTRY

29th. IEETE — "The numerical control of machine tools" by M. S. Parkinson at 19.00 at Herbert Machine Tools Ltd, Edgwick Works.

## EVESHAM

16th IERE—"Charge-coupled devices" by E. W. Williams and Dr J. Mavor at 19.30 at BBC (Evesham) Club.

## FARNBOROUGH, Hants

30th IERE—"Electro-magnetic compatibility — a perspective" by L. J. Fountain at 19.00 at Farnborough College of Technology.

## HATFIELD

16th IERE—"Prospects for radio communications" by Prof W. Gosling at 19.45 at The Hatfield Polytechnic.

29th I.Phys. — One-day meeting on "Stress analysis — what should be taught?" at 10.00 at Hatfield Polytechnic.

## HULL

8th SERT "Oracle—broadcasting the written word" by D. Wood at 19.30 at Hull College of Technology.

## LEEDS

9th IERE/IEE—"Solar cells" by R. Davies at 19.00 at Leeds Polytechnic.

## LEICESTER

15th IERE.—"Electronic aids for medical studies" by Dr E. T. Powner and P. G. Best at 19.00 at Lecture Theatre "C" Chemistry Dept, Leicester University.

## LINCOLN

14th SERT—"Quadraphonics" by Dr K. Barker at 19.30 at the refectory, Lincoln Technical College.

## LIVERPOOL

15th IERE—"Electronics by numbers" by Dr K. J. Dean at 19.00 at Dept of Electrical Engineering and Electronics, University of Liverpool.

## LOUGHBOROUGH

15th SERT—"Digital techniques for television" by R. S. Roberts at 19.30 at room J001, Loughborough University of Technology.

## NEWCASTLE-UPON-TYNE

14th IERE.—"Frequency domain measurement" by R. S. Titmarsh at 19.30 at room J001, Theatre, Ellison Place.

## PORTSMOUTH

22nd IERE/IEE.—"Solid state transmitter power amplifier — modern design techniques" by R. O'Reilly at 18.30 at Portsmouth Polytechnic.

## PRESTON

29th Sept. IEETE — "Is your hearing reliable? — can you recognise hi-fi?" by T. G. Izatt at 19.15 at Preston Polytechnic, Corporation Street.

## READING

8th IERE—"Microprocessors — recent technological advances and applications" by N. Carruthers at 19.30 at Caversham Bridge Hotel, Caversham Road.

## REDHILL

8th. IEETE — "Special effects in television" by B. Wilkie at 19.30 at Redhill College of Technology, Gatton Point.

## SOUTHAMPTON

8th IERE/IEE — "Transistors by the million — high frequency technology with practical design" by J. H. Tuley at 18.30 at Lanchester Theatre, University of Southampton.

20th. IEETE — "The bionics of physical medicine" by Prof. T. Shelley at 20.00 at the Polygon Hotel, Cumberland Place.

## SWANSEA

30th IERE/IEE—"Computer graphics" by A. J. Davies at 18.30 at University College.

## SWINDON

21st. IEETE — "Ambisonic surround reproduction" by Prof. P. B. Fellgett at 19.30 at the Kings Arms Hotel, Wood Street, Old Town.

## TEDDINGTON

30th I.Phys—One-day meeting on "Vacuum standards and traceability of vacuum measurement" at 10.00 at the National Physical Laboratory.

## WEYMOUTH

16th IERE—"Processing techniques for the speech of divers breathing an oxy-helium gas mixture" by N. G. Kingsbury at 18.30 at South Dorset Technical College.

*Tickets are required for some meetings: readers are advised therefore to communicate with the society concerned.*

## Digital wristwatch

Mr D. D. Clegg, designer of the digital wristwatch published in our July and August issues, wishes to acknowledge the assistance with advice and components given to him by Motorola Ltd, Solid State Scientific, Inc., Photo-Etch Ltd, Brown Boveri Company and Mallory.



# Letters to the Editor

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## PERIL OF PUBLISHING

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I am in full agreement with the sentiments expressed in Mr Henniker's letter in the June issue regarding fearing to publish ideas for fear of having them destructively criticised. Perhaps some erroneous ideas do get published, perhaps some circuits are badly designed or "re-discoveries" of already discarded ideas. Publication of these ideas may still be justified if there is a possibility that they will stimulate someone with greater knowledge into thinking and into looking for a kernel of usefulness, rather than thinking and looking for a destructive criticism.

Perhaps some people would gain by reading Dr Edward de Bono's works on "lateral thinking." If my interpretation of the concept of lateral or non-Aristotelian thinking is correct its precepts are: observe from every viewpoint, look for alternative uses if it does not fit its stated use, do not discard until it is proven by all means to be of no use, now that you know it will not work can you conceive of an idea that will work? Basically, no data, idea or concept should be discarded until it is proven to be of no use even as a stimulant for further thought.

D. A. Bailes,  
London, S.E.5.

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## WIDE-BAND LOCAL NETWORKS

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If the Annan Committee says that the public ought to be allowed to enjoy the wider choice of entertainment and the vastly increased flow of information and education which cable television could bring them, then the government of the day will have to decide who is to be given access to the medium and who is to design and install the communication system.

The first question is not primarily a matter of engineering but it may

greatly affect the design of the system. One may hope, against all the odds, perhaps, that the aim will be to make the access to cable as free as it is to the printing press, so that anyone wishing to communicate with the public, who has the means to pay the distributor, is free to do so and free to set what price he likes on his publication. Some will offer it free because of the advertising it contains, some on a regular subscription basis; but others, and no doubt the great majority, on the logical and obvious basis of a separate price for each item like most ordinary economic transactions. This would be entirely in conformity with the principles enunciated by the Labour Party in "The People and the Media", thus:

"Seek, wherever possible, to move away from concentration of power over printing and broadcasting outlets and to decentralise responsibility and diversify outlets.

Make possible the widest practicable access to the media by community groups and by individuals.

Improve the opportunity to publish and broadcast a diversity of views so as to eliminate any risk that the system might lead to government or commercial censorship."

Nobody knows how many different simultaneous services the public will require or, still less, what they will be prepared to pay for, as they learn over the course of many years to make full use of the potential.

There will be two alternative ways of tackling the second question, the authoritarian or the pragmatic. In the authoritarian way "big brother" will try to decide on a fully integrated communication system capable of meeting all possible requirements and looking hopefully to the day when all signals are in digital form. "Big brother" will insist that the new system, whatever it is to be, must be applied universally so that nothing at all can be allowed to happen until its design is decided upon. That decision must be made in the face of continually changing requirements arising from practical experience in other countries and constantly changing estimates of the profitability of various services. Since the decision will set the form of the national telecommunications network for a long time ahead, "big brother" will take years to reach it and, being as fallible as the little brothers, will be just as certainly wrong. The pragmatic alternative is to harness the immense experience and entrepreneurial flair of existing cable operators and to allow them and any other competent parties to work out the right methods, both commercial and technical, for serving the public requirements in the market place.

The Post Office, with extraordinary folly, has asked the Annan Committee to accept the authoritarian way and has cast itself as big brother. The inevitable result will be that nothing will happen for years and, when it does, the decision

will be another disaster in the long series of over-ambitious proposals which come to nothing. The decision on electronic exchanges is the outstanding example of this. It was taken in the 1950s and has now disappeared out of sight in the mists of system X. Then there was the postal code to enable the electronic machines to sort right down to the postman's walk, announced several years ago and now virtually abandoned. There are many others only too well known to those whose fate it is to earn their living by supplying the Post Office with equipment to its ever changing requirements.

There is plenty in the Post Office evidence to Annan to support this contention. For example, it says "the means of taking responsible judgement on returns on investment are not yet to hand". It has the commercial success of the 1966 experiment by Pay-TV Limited in this country and the evident success and rapid growth of pay television in the USA to go on. What more does it want? Since the Post Office Act of 1969 it has had all the powers it needs to distribute sound and vision programmes of every conceivable kind on a pay television or any other basis; but it has done nothing, nothing at all except to install a few highly conventional communal aerial systems under contract to new town authorities.

It is also very clear from its evidence and other of its publications<sup>2</sup> in which numerous mutually exclusive technical proposals are mentioned, that, although much concerned with the virtues of standardisation in the abstract, it has no real idea of the standards which it would put forward for immediate adoption on a national scale. The scheme which it appears to prefer, a conventional v.h.f. trunk and branch network of a single coaxial cable with final distribution at u.h.f., has the wrong design objectives for the immediate future and, by reason of its limited capacity, cannot grow naturally into a full communication network enabling subscribers to have individual access to central audio-visual libraries or a full videophone service. The immediate design objectives are wrong; firstly, because pay television is left out of consideration and it is, of course, the only service likely to show an adequate return on investment in new cable networks. Secondly, it neglects the economy and rationality which can be achieved by including the home terminal as an integral part of the system. Of course, one must take into account the initial need for the system to serve, simply and cheaply, the conventional television receivers designed for off-air reception which exist in such large numbers; but to take as the primary objective that the cable system is to take the place of an aerial, particularly a u.h.f. aerial, is to accept severe and quite unnecessary restraints which stultify the design, reduce its flexibility and increase its costs. It is

clear that the Post Office is really quite well aware of the point from the reference in its submission to Annan to its future involvement in the technical specification of television receivers; but no doubt it is anxious not to stir up the opposition of the television set manufacturers and dealers and it does its best to cover it up.

For the last fifty years the Post Office has been considering its entry into the programme distribution business and, from time to time, making the decision to start. In practice, what it has done is to license private operators and this policy was quite effective since, until about ten years ago, this country led the world in cable services and would still do so if it were not for the appallingly severe restrictions imposed by grandmotherly governments in an effort to protect the monopolies of the established broadcasters. How much wiser it would be if the Post Office were to continue this policy of licensing others to operate; it could watch — or partake itself if it wished — while the best commercial and technical methods are evolved at other people's expense, while retaining overall control of the situation through its licence. When the time was ripe for standardisation, which it is certainly not today, the question of nationalisation might be considered and so might long-term licences to the operators on similar principles to those which now form a basis for the excellent telephone service enjoyed by the citizens of Hull.

As you said in the leading article in April, we are all agreed that the Post Office is the proper organization to handle the bulk transmission of signals of all kinds on the trunk routes between cities; but the arguments are overwhelming for a more adventurous and flexible approach to the local distribution of television programmes.

Ralph Gabriel  
Rediffusion Ltd  
London, SW1

#### References

1. Submission by the Cable Television Association of Great Britain to the Committee on the Future of Broadcasting, 1974.
2. "The Expanding Role and Integration of Telecommunications" by W. J. Bray, Director of Research, Post Office. Lecture first delivered at Eurocon '74, Amsterdam, on 25th April, 1974.

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## INSULATION TESTERS

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Referring to Mr Fox's letter "American Insularity" in the March issue, there are several aspects which deserve correction.

First, the instrument reviewed in *Electronics* was not "an ordinary hand-cranked Megger". Supporting literature indicates that it is identical to a Japanese-made instrument modelled on the lines of an obsolete Evershed product.

Second, Megger insulation testers are made solely by Evershed & Vignoles Ltd or under licence by our American associates, the James G. Biddle Co. The word "Megger" may be a generic term, but it has been a registered trade mark since 1903 and as such can be associated only with our products.

Third, the use of hand generator testers is by no means an out-moded practice. On a world-wide basis, there is clear evidence that the popularity of the electro-mechanical device is undiminished despite the technological achievements made in solid-state circuitry.

I trust that Mr Fox would not suggest that d.c. testing of a.c. installations as called for in IEE Regulations is equally ridiculous.

E. A. King,  
Evershed & Vignoles Ltd,  
Dover,  
Kent.

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## LOW-COST PRACTICE ELECTRONIC ORGAN

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My letter in the April issue gave rise to comments from several readers. Two manuals are preferred, though some would accept a single manual split at middle C. Some would accept one monophonic manual provided the other were polyphonic or had at least four selectable tuneable notes for chords. "Straight" organists need a 30- or 32-note radiating and concave pedal board to RCO dimensions, and this could well be monophonic. Reader K. Lawrence of Bristol has applied Asbery methods successfully, and points out that use of a monophonic or Asbery-type system affects the style of playing, e.g. exaggerated legato could lead to momentarily spurious results. As plenty of two-manual electronic instruments are on the market, but only one completely separate full-range electronic pedal board, I think a really cheap full electronic pedalboard would be worth developing, but this would take time and expense as some features still need consideration. For a monophonic board frequencies would range from approximately 262Hz to 698Hz (F), all calculations being based on A = 440Hz. This would give the 2ft pitch, dividers giving the 4, 8 and 16ft pitches. Three tone filters for stops might suffice, e.g. diapason, flute and reed, but these might need duplication to cover the full range. No conclusion can be reached about plastic pedals without actual trial. A phone jack for inaudible practice appears worthwhile, subject to the usual safety precautions. Spacing between the lowest manual and the pedalboard is important.

K. J. Young,  
Derby.

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## CONTROLLING STAGE LIGHTING

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The letter from Peter D. Hiscocks (August issue) concerning problems with triacs for stage lighting should be read by any amateur before even thinking of building stage dimmers. I should like to add a few thoughts based on many frustrating years with both triacs and thyristors in this country.

A stage lighting dimmer is a very different creature from the dimmer switch for the simple reason that its load is radically different — class T theatre lamps have substantially higher switch on surges, on a watt-for-watt basis, when compared with other lamps; and when T class lamps end their all too short lives they go with a far bigger wallop than an ordinary bulb! Therefore, a very substantial margin is needed between the steady current rating of the triac and the maximum load. I have found a ratio just above 3 to 1 sufficient, i.e. a 16-amp triac for a 1kW class T load; this will also allow the satisfactory use of relatively inexpensive Belling-Lee or Reyrolle fuses (provided of course that the triacs have a sufficiently high p.i.v. of at least 600V because the 240V supply is the r.m.s. value and its peak is 340V).

But at this point the British amateur must stop, for at the moment he cannot construct a 2kW dimmer — the most useful stage size — which he can completely rely on. A recently published design in a popular magazine actually suggested the use of a 15-amp triac to control a 3.25kW load — five minutes of a 2kW CP/12 lamp reduced that triac to a glorified nut and bolt. But given a 25- or 40-amp triac, and a maximum load of 2kW, the circuit would stand a fighting chance, and an 8- or 10-amp fuse could protect the device even from the death throes of the 2kW lamp. The catch is that in Britain, unlike Canada, these high power triacs are just not available to the amateur. Of course dimmers are made to handle 2 or even 2.5kW with little 16-amp triacs, and they employ very sophisticated trigger circuits and chokes (yes, even they are critical but they cost over £70 each. In France 25- and 4-amp triacs can be bought singly over the counter (at £12 each they are expensive, but then so too are the 16-amp devices at £5). Why can't these devices be made available to the amateur in Britain?

Now a final checklist for the would-be constructor of a stage lighting board. Can your dimmers

1. Maintain their maximum load at full setting for 4 hours and then smoothly fade down to true zero?
2. Withstand a direct short circuit or lamp blow?
3. Fade up smoothly from a true zero

without an irritating and, to the audience, distracting rush of light?

4. Withstand hot-patching — that is the addition of an extra load to a partially loaded dimmer?

5. Genuinely not interfere with radio reception and audio equipment in the area?

6. Fade without an undue buzzing sound from the chokes?

If your dimmers meet these demands, congratulations, they have every right to be in a theatre or hall; if not then relegate them to domestic service (though do try and meet condition 5 above) and start on the long road of saving for a professional board.

Paul M. Hodgson  
London, SW19

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## ELECTRONIC COMPONENT RETAILERS

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About five years ago we formed a buying group among the small electronic component retailers. The main object is to buy goods at cheaper prices by bulk buying. In addition, as we have nobody to represent us over such thorny questions as VAT we do this also. Our membership is at present twenty-five but for obvious reasons we would like to enlarge it. We have insufficient funds to advertise as our total revenue is derived from a modest £6 a year subscription.

I am confident there are several hundreds who would join us if they knew we existed.

If you think the continuance of the small electronic component retailer is a worthwhile object I wonder if you would be so kind as to give us a little publicity, perhaps by publishing this letter? Would those interested please write to me at the address below?

Alan Sproxton,  
c/o Home Radio (Components) Ltd,  
240 London Road, Mitcham,  
Surrey CR4 3HD (Telephone 01-648-8422).

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## ACTIVE NOTCH FILTERS

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In the article "Active notch filters" in the July issue, the author states that "No passive RC notch network, however complex, is capable of achieving  $Q_0$  higher than 0.9." This is presumably based on Ramachandran's theoretical limit<sup>1</sup> of  $\frac{1}{2}\sqrt{e}=0.8243$ , derived for a restricted form of response. However, the author has overlooked a subsequent contribution<sup>2</sup> which relaxes the conditions on the zero of the transfer function, thereby allowing transmission gains and enabling the maximum selectivity of an unbalanced RC network to reach a value of  $\frac{1}{2}e=$

1.359. Of course, this is still a low selectivity and extravagant in numbers of components; even a  $Q$  of 0.8875 requires as many as 31 passive components of large spread.

It is more practicable to resort to distributed RC null structures which, when exponentially tapered, can achieve gain slope and classical selectivities of 0.6585 and 0.860 respectively using only two integrated components. Higher  $Q$ s are possible by resorting to other inhomogeneities and configurations.

Finally, with regard to activated notch sections, it is worth mentioning the reduction in sensitivity to amplifier bandwidth afforded by more recent GIC-derived and allpass-pair circuits.

P. Bowron  
University of Bradford  
Yorkshire

### References

1. V. Ramachandran, "High selectivity passive resistance-capacitance null networks," *Proc. IEEE*, vol. 56, pp. 1237-1238, July 1968.
2. G. Wilson and P. Bowron, "The selectivity limit of lumped passive RC null networks," *Proc. IEEE*, vol. 60, pp. 911-912, July 1972.
3. P. Bowron and G. Wilson, "A selectivity comparison of the exponentially distributed and twin-T RC null networks," *AEU, Archiv fur Elektronik und Ubstrangangstechnik*, Band 27, pp. 505-510, December 1973.

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## ELECTRODYNAMICALLY INDUCED E.M.F.

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Concerning the question of measuring the voltage across aircraft wings, the suggestion by D. C. E. Todd and N. G. S. Taylor (Letters, July 1975) of employing ferromagnetic sheathing would, of course, work. The field across the wires could readily be reduced by a factor of a thousand or more with Mumetal sheathing, reducing the force on the electrons by the same factor.

However, two lengths of ordinary insulated wire would suffice to make the measurement. Pass each through the inside of the two wings; aircraft wings will provide little or no magnetic shielding and the full voltage developed across the wings will be measured between the inside ends of the two wires, which will be oppositely charged.

The e.m.f. generated will be quite significant; for example, at the latitude of the British Isles, with a 20-metre wing span and a speed of 220 m/s (500 m.p.h.) the e.m.f. will be about 26 volts, varying in proportion to speed. With aircraft in contact with beacons for half a transatlantic journey, however, the question is whether such a measurement would be more useful as a wind-independent measure of speed or as a measure of the variations in the Earth's field along the route.

C. S. Evans  
University of Reading

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## TRANSMISSION LINE IMPEDANCE

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In the April 1975 issue (Letters), after providing the graphical solution to the problem of finding the length and characteristic impedance of a loss-free, uniform transmission line which transforms a given complex impedance into another, Mr Day stated that the solution he gave "... must exist somewhere in the technical literature." In fact, Mr Day is correct — I have given the solution in 1960 in the *IEEE Trans. on Microwave Theory and Techniques*, vol. 8, p. 463, July, 1960.

P. I. Somlo  
National Measurement Laboratory  
CSIRO  
Sydney, Australia

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## MUSIC WITHOUT MOVEMENT?

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I wonder if Mr Young did any sums before he wrote to you ("Music without movement," Letters, August issue). Mine go something like this: For hi-fi performance a recorder should have, say, 15kHz bandwidth and 60dB signal/noise ratio among other things. These imply a sampling frequency of 32kHz and a resolution of 10 bits per sample, giving a data rate per channel of 320k bits/sec. Therefore to store a one hour stereo programme would require  $320,000 \times 3600 \times 2 = 2304$  megabits.

A look at the latest m.o.s. random access memory prices suggests that 0.05p/bit is a reasonable large quantity price, which gives a memory cost of £1,152,000! If one used type 2102 1-kbit m.o.s. r.a.m.s, which have a power consumption of 350mW each, the total power required for the memories would be 787kW (157,000 amps at 5V!).

Somehow, Mr Young, I don't think your solid-state tape recorder has been built just yet!

John C. Sager  
Ipswich  
Suffolk

We have received other letters making similar points.—Ed.

### Mr Young replies:

I had done some figuring, though admittedly some of my assumptions were a little different from those of Mr Sager.

I assumed a practical sampling rate of 20kHz, on the point that current hi-fi practice ignores waveform distortion above 10kHz. If you disbelieve this, try tape recording a 12kHz wave and observe the resultant waveform.

I also assumed mono. Would twice as many digits be needed for stereo? I think not. So, at 10 samples per data

point, this gives  $20 \times 10^3 \times 10 \times 3600 = 720$  megabits.

Since 1 megabit per  $\text{cm}^2$  is now a commercial viability, this means  $720 \text{cm}^2$  for a "feasible" (sic) one hour playback. Curiously, this is almost the same as one side of an l.p. record.

Cost? Admittedly computer quality comes high, but if storage recording for audio becomes the norm, prices would drop rapidly. If such a recorder exists, it will have been assembled from "reject" chips totally unsuited for calculations but perfectly satisfactory for audio purposes. Most of the cost is due to high scrap anyway.

Even now an equivalent to a "45" could be no larger than a cassette.

As for power consumption, only a tiny part of the array would be energized at any given moment. It may well be possible to run it off a battery. Certainly not kW!

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## DIGITAL FREQUENCY SYNTHESIS

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I read with interest in the May issue the article "Digital frequency-synthesis - a new approach" by D. C. Ayre and K. G. Woodard, and it occurred to me that an integrated circuit manufactured by Consumer Microcircuits Ltd may be of importance to those designing wide pull-in range frequency-synthesizers.

This i.c. (FX-401) covers a  $2 \times 10^4:1$  frequency range and has three outputs, input frequency high, low and inband. The high and low outputs are suitable for the coarse control of a voltage-controlled oscillator within a phase-locked loop and could bring the output frequency to within less than 1%. When the frequency was within this band the inband output would indicate approaching phase-lock and allow a conventional narrow band phase comparator (implying low residual f.m.) to complete lock, since the other two outputs would be off.

I will be pleased to arrange for a detailed datasheet to be sent to those interested.

George Bates,  
Consumer Microcircuits Ltd,  
Wheaton Road,  
Witham, Essex.

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## dB TO RATIO ON A CALCULATOR

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Recent correspondence in your columns on dB conversion on a slide-rule has been followed with deserved interest. There are, however, some of us who prefer to use an electronic calculator during the course of our work,

mainly because of its greater convenience and accuracy.

Although in recent months calculator prices have fallen considerably, very few of moderate price have an "antilog" key for base 10. This means that there is no direct, easy-flow way of converting decibels back to ratios. The answer to this problem is to be found in the following standard analysis:

$$\log_a x = \log_a b \times \log_b x$$

$$\text{If } a=e \text{ and } b=10, \text{ then}$$

$$\log_e x = \log_e 10 \times \log_{10} x = 2.302585 \log_{10} x$$

$$\text{Thus } x = \exp.(2.302585 \log_{10} x)$$

To convert decibels back to a voltage ratio:

$$\begin{aligned} \text{Ratio} &= \exp.(2.302585 \times \frac{\text{dB}}{20}) \\ &= \exp.(0.1151293 \text{ dB}) \end{aligned}$$

Thus, on a moderately-priced calculator, to convert dB to a voltage ratio, we enter the decibels, multiply by 0.1151293 and operate the  $e^x$  key.

It is hoped that this will usefully supplement the ingenious slide-rule method.

R. J. Isaacs,  
Clinical Research Centre, MRC,  
Harrow,  
Middlesex.

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## PEAK READING LEVEL METER

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We were most interested to read the article by S. F. Bywaters and J. E. West on the design of a peak reading audio level meter, published in the August issue. In view of our own experiences in designing and building similar meters for professional and commercial use, we would like to raise a number of points.

We were most surprised by the complexity and relatively high cost of the authors' design. With a small number of audio channels, where digital multiplexing does not offer a significant price advantage, we believe a wholly analogue display system to be preferable for several reasons. A resistive divider chain/comparator technique, for example, is cheaper, easier to calibrate, far more compact and generates less heat and electrical interference than a digital system. Analogue methods also allow the designer to vary the dB-increments along the scale, so that he may use 1 or 2 dB steps at the highest levels and 4dB steps at the bottom, for example. The temperature drifts of such an analogue system may be made negligible when compared with the capacitor, zener and clock frequency drifts inherent in the Bywaters and West circuit.

We were particularly concerned about the large amount of power dissipated in their design. Assuming a

single 20V power supply we calculated that the heat dissipation was about 16W, which is as great as a 20W/channel amplifier running flat out! We fear that constructors attempting this project may literally get their fingers burnt! As well as lowering overall reliability it is worth noting that high temperatures may reduce the light output of red l.e.d.s by as much as half for a temperature rise of 50°C. Although inconvenient, a separately derived 5V supply for the logic would help here. The power consumption could be further reduced by arranging the l.e.d.s in one or more series chains driven from current sources attached to the positive rail; changing the source current then varies the l.e.d. brightness in a predictable manner. If this modification were used the 74154 outputs could drive the 7407 buffers directly (7417s would have to be used for 15-30V rails), each buffer acting as a current sink to turn off the appropriate number of l.e.d.s in the chain. This would save four 7408s and 15 resistors per channel.

In spite of the lack of any disclosed specification it is clear that the meter does not meet the BBC specification ED1477 in several respects. Firstly, one cannot obtain a flat enough h.f. response from 748s used in precision rectifier circuits; instead high speed op-amps must be used, although a transistor/diode rectifier may be employed if care is taken to compensate for low level errors and drifts. Secondly, a moving coil meter has inertia (which a light column does not!) and to make a l.e.d. meter read the same as a p.p.m. on tone-bursts necessitates the use of a complex attack characteristic after the rectifier. If a simple attack time constant must be used then the best compromise is 4-5ms rather than the 2.2ms adopted by Bywaters and West.

In user trials of l.e.d. meters we have found that a combination of green l.e.d.s below 0dB and red above is the most acceptable format and that those l.e.d.s which indicate overload should be brighter than the rest. Luckily, because of the greater efficiency of most red l.e.d.s, this brightness difference may be automatically achieved by running them from the same current source as the green ones. We have also found it easier to use these meters vertically and to place them quite close together (typically 2 to 3 cm) in order to observe the channel balance most effectively. Happily this coincides with the cramped space available on most modern studio mixers, where modular l.e.d. meters show a considerable space saving when compared with conventional p.p.m.s or VUs.

John Dawson and Chris Evans  
Amplification & Recording  
Cambridge

A reply to this letter will be published later. - Ed.

# RADIO WAVES

## What makes them go

by "Cathode Ray"

Someone who read what I had to say in the September and October 1974 issues, on magnetism being a side effect of electricity (and it's nice to know that at least one person did so) asked me if I would care to go on and deal with electromagnetic waves, and in particular to derive from first principles their velocity and "the impedance of space."

There are three approaches to electromagnetic (or radio) waves. Those of you who are well versed in vector analysis and three-dimensional differential equations will no doubt follow in the footsteps of Clerk Maxwell, with the advantage over him of being able to see and hear the multifarious practical results now obtained with the waves that Maxwell predicted mathematically. Others will be content to enjoy those results, without any overwhelming urge to inquire into their theory. Members of these two classes may now disperse and employ their time more profitably elsewhere, as I am about to address myself exclusively to any who do wish to know what makes electromagnetic waves go, but lack the mathematical expertise needed for taking Maxwell's way.

Electromagnetic (e-m) waves consist entirely of electric and magnetic fields. Most of us are more at home with circuits, amps and volts than with fields. Transmission lines (or high-frequency cables) offer themselves as a bridge from one to the other. So let us adopt that way of approach to free-travelling e-m waves.

In ordinary circuits, resistance, inductance and capacitance are regarded as if they were confined to the places indicated by their symbols in the circuit diagram - the components. The rest of the circuit - the wiring - is there just for connecting up the components, and not for contributing any  $R$ ,  $L$  and  $C$  of its own. In so far as these qualities are inevitably present to some extent in the wiring, they are just unwanted complications which we hopefully neglect.

If transmission lines are regarded in this way, as they well might be by an electrician, they look like just wiring,

needed to connect units that unfortunately have to be installed at a distance from one another; the radio-frequency counterpart of the flex needed to connect the TV set to the mains socket. It is true that in both of these types of electrical link we would like the resistance to be small enough to neglect. If the resistance of the flex is enough to cause a noticeable loss of volts at the appliance, a heavier gauge of wire is indicated. Transmission lines, being in general much longer than flex leads, their resistance usually does cause appreciable loss en route. But at least they do not (as would too-resistive a flex) constitute a fire risk!

At the mains frequency the inductance and capacitance of a few yards of flex are truly negligible. But at the multi-million times greater frequency of the incoming signals, and with the greater length of the cable, one would quite rightly estimate that the capacitance between its two conductors would be very far from negligible, and perhaps expect this capacitance to be almost a short-circuit for the signals, allowing very little to reach the receiving end. But in spite of the two conductors being so close together - in the common coaxial type, one actually surrounding the other - so that the magnetic effects of currents in them tend to cancel out, there is enough inductance to have a profound effect. Just as the total capacitance is distributed in parallel all along the line (assumed to be uniform), so the total inductance is distributed in series. Electrically, the line can be represented as in Fig. 1,

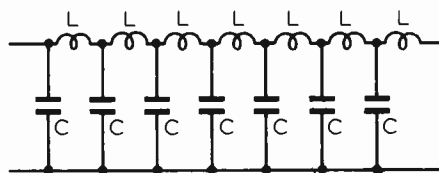


Fig.1 An ideal transmission line can be considered as a circuit in which the distributed capacitance and inductance are represented as a very large number of very small capacitors and inductors.

where  $L$  and  $C$  are respectively the inductance and capacitance per (very small) unit length of the cable.

Next, let us consider the effective resistance of the TV set or whatever the cable is feeding into,  $R$  in Fig. 2(a). It probably won't be a pure resistance, but it can always be made so by tuning; and that gets rid of one complication. Now we connect to it one of our very short unit lengths of cable, Fig. 2(b). It is so short that the series inductive reactance  $X_L$ , which is  $2\pi fL$ , is very small compared with  $R$ ; and the parallel capacitive reactance  $X_C$ , which is  $1/2\pi fC$ , is very large compared with  $R$ . That being so, the series capacitance  $C'$  in Fig. 2(c) is (near enough) electrically equivalent to  $C$  in (b) if its reactance,  $X_{C'}$  is equal to  $R^2/X_C$ . \*  $X_L$  and  $X_{C'}$ , being respectively positive and negative reactances, cancel out if  $X_{L'} = X_L$ . Fig 2(c), and therefore very nearly (b) also, is electrically the same as (a). For this to be true,  $R^2/X_C$  must be equal to  $X_L$ , so

$$R^2 = X_L X_C = \frac{2\pi fL}{2\pi fC} = \frac{L}{C}$$

$$\text{So } R = \sqrt{\frac{L}{C}} \quad (1)$$

Notice that frequency doesn't come into this at all, except that if it is very high

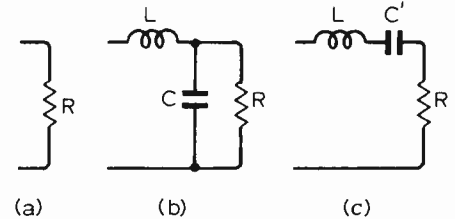


Fig.2 By selecting a suitable value of load resistance  $R$ , a pair of the small units of  $L$  and  $C$  in Fig.1 connected to it (b) can be made of no effect, because the series equivalent of  $C$  ( $C'$  at (c)) cancels out  $L$ . This process can be repeated until any length of line terminated by  $R$  is found to be equivalent, as an impedance, to  $R$  alone.

then  $L$  and  $C$  have to very small indeed to fulfil the condition that  $X_C \gg R \gg X_L$ .

The process of finding a Fig. 2(b) equivalent to (a) can then be repeated indefinitely, so that any length of cable terminated by a resistance is electrically the same as the resistance alone, provided that eqn.(1) is true, subject to the approximation we used. The smaller  $X_C$  and  $X_L$  are, the smaller is the error in assuming  $X_{C'} = R^2/X_C$ , so by making them smaller and smaller and increasing their number correspondingly, ultimately making Fig. 1 equivalent to a real cable, we can make the error as near zero as we like.

So to make a line or cable ideal for

\*Foundations of Wireless & Electronics, 8th edition, M. G. Scroggie; Sec. 8.16. See also Sec.16.2.

conveying radio signals from one place to another we have to ensure that its inductance and capacitance per unit length (not necessarily small at low frequency) are related to the load resistance  $R$  thus:  $R = \sqrt{L/C}$ .  $L$  and  $C$  depend on the cross-sectional dimensions of the cable, and there is only a limited range of practical values of these, so it is usual to fit  $R$  to them, rather than  $\sqrt{L/C}$  to  $R$ . The resistance  $\sqrt{L/C}$  is usually called the characteristic resistance of the cable and denoted by  $R_0$ . (It is also called characteristic impedance and denoted by  $Z_0$ ; this covers the fact that the effect of resistance of the line conductors introduces reactance along with  $R_0$ .) Owing to the way in which it was derived with the help of Fig. 2,  $R_0$  can also be regarded as the input resistance of an infinitely long line.

How does one find  $L$  and  $C$ ? Well, of course, they can be measured. Calculating them for practical lines and cables (parallel-wire or coaxial) is rather complicated. But although not a very practical form, there is no theoretical reason why a transmission line should not consist of two parallel metal strips as in Fig. 3. This is much easier for calculating  $L$  and  $C$  at least

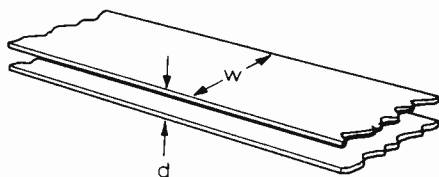


Fig. 3 A simple, if unusual, form of transmission line is a pair of parallel metal strips.

approximately, and, as we shall see, it is a very convenient form for studying the whole subject.

Although thinking a thing out from fundamental principles is usually harder work than remembering a handy formula or looking it up in a book, it should be worth it in this case. So we start with the standard definition of the capacitance between two conductors as the electric charge (positive on one conductor; negative on the other) per volt needed to put it there:

$$C = \frac{Q}{V} \quad (2)$$

(Until further notice I'm going to use the symbols  $C$  and  $L$  in a general sense; not per unit length as in Figs. 1 and 2.) And the inductance of a circuit or part thereof is defined as the voltage induced in it per amp-per-second variation in the current flowing through it:

$$L = \frac{V}{dI/dt} \quad (3)$$

Although defined thus, capacitance and inductance are really effects of electric and magnetic fields respectively, and we won't be able to get far without

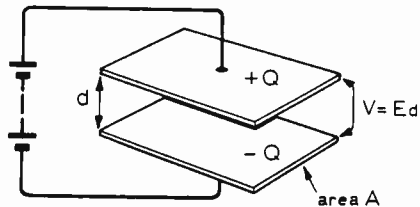


Fig. 4 A short length of the Fig. 3 type of line can be treated as a capacitor.

accepting that fact. Electric field is denoted by  $E$ , and is the voltage per metre between two points at different potential (Fig. 4). So

$$E = \frac{V}{d} \quad (4)$$

That connects with the  $V$  in (2). Associated with  $E$  is what is called electric flux density or displacement,  $D$ , which is equal to the charge on the plate per unit area:

$$D = \frac{Q}{A} \quad (5)$$

(This equation is a form of Gauss's theorem.)  $D$  and  $E$  are related to one another by a property of whatever material or non-material fills the space between the plates - its permittivity,  $\epsilon$ :

$$D = \epsilon E \quad (6)$$

So, substituting for  $Q$  and  $V$  in (2), from (4)-(6), we get

$$C = \frac{AD}{dE} = \frac{A \epsilon}{d} \text{ farads} \quad (7)$$

which I hope you will recognise as the well known formula for the capacitance of a parallel-plate capacitor in SI units. It would be very inaccurate for a capacitor like the one in Fig. 4 because there would be a lot of stray field besides that directly between the plates; this is usually referred to as edge effect, and is much less if (as in practice) the plates are very close together. Obviously we can apply (7) to calculating the capacitance between the strips in Fig. 3, per small length, or per metre, or for the whole

But now let us go back to inductance, eqn. (3). A coil has an inductance of 1 henry if 1 volt is induced in it when the current is changing at a steady rate of 1 amp per second. But what induces the e.m.f. is not the varying current itself but the varying magnetic flux due to the current and linked with the coil. In SI units the voltage induced is equal to the rate at which the flux is changing, so if 1 amp in the coil causes  $\Phi$  units of flux the inductance is equal to  $\Phi$ . In other words, the inductance is equal to the flux per amp:

$$L = \frac{\Phi}{I} \quad (8)$$

We can make a sort of coil of Fig. 3 if we short-circuit a length  $W$  at both ends and circulate a current  $I$  around this "coil". The flux passes through the

"core" of this coil and doubles back to complete a loop around the current, as indicated in Fig. 5 by only two dotted lines, which represent the continuous flux filling the whole core. Its conventional direction, for a clockwise current, is inwards as shown (corkscrew rule). The flux density, denoted by  $B$ , is equal to  $\Phi$  divided by the cross-sectional area  $A$  of the "window" inside the coil:

$$B = \frac{\Phi}{A} \quad (9)$$

This  $A$  is not the same as in (5) of course, but in this case is equal to  $Wd$ . The current itself is also involved because the magnetic field strength  $H$  inside the coil is equal to the encircling current per unit length of the  $\Phi$  path (Ampere's law):

$$H = \frac{I}{l} \quad (10)$$

But  $B$  and  $H$  are related to one another by a property of the material or non-material in which they occur - its permeability,  $\mu$ :

$$B = \mu H \quad (11)$$

So, substituting for  $\Phi$  and  $I$  in (8) we get

$$L = \frac{A \mu}{l} \quad (12)$$

Strictly, except where  $H$  is constant all the way  $l$  around its loop (which is very rarely)  $Hl$  in (10) must be  $\int H \cdot dl$ ;

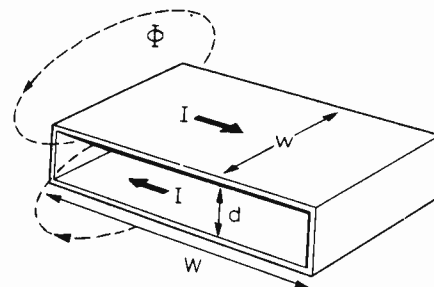


Fig. 5 By adding short-circuiting pieces at the ends, the bit of line in Fig. 4 can be made into an elementary coil.

but in Fig. 5 the external path of  $H$  (and  $\Phi$ ) is so much fatter than the internal one that, provided  $d/w$  is small, the only part of  $l$  that need be counted is the internal part,  $w$ . So approximately in this case.

$$L = \frac{A \mu}{w} \text{ henries} \quad (13)$$

This is analogous to (7), but we must remember that  $A$  means different things in (7) and (13). Incidentally, the approximation error ("end effect") in (13) due to  $w$  not being the whole path of  $B$  is analogous to the "edge effect" in (7); but whereas (7) gives too low a value for  $C$ , it should be fairly obvious that (13) gives too high a value for  $L$ .

Now at last we can combine (7) and

(13) to find approximately the characteristic resistance  $R_0$  of the Fig. 3 form of line. To simplify matters and get rid of the ambiguity of the symbol  $A$  we shall take a section of line 1 metre long, so that  $A$  in (7) is equal to  $w$ , and  $A$  in (13) is equal to  $d$ . If you object that 1 metre is not short enough to be valid in the argument based on Fig. 2, my reply is that it is good enough for relatively long waves (low frequencies) and to suit high frequencies you can reduce the scale. And if you point out that the line doesn't have short-circuits every metre along its length as in Fig. 5, the answer is that it doesn't need to, as current can flow freely along both strips, and is equal and opposite in them, just as in Fig. 5. So for Fig. 3, remembering that  $L$  and  $C$  are now per unit length again,

$$R_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{\mu d}{w} / \frac{\epsilon w}{d}} = \frac{d}{w} \sqrt{\frac{\mu}{\epsilon}} \quad (14)$$

The values of  $\mu$  and  $\epsilon$  for air are almost the same as for a vacuum,  $\mu_0$  and  $\epsilon_0$ , which are  $4\pi \times 10^{-7}$  and  $8.854 \times 10^{-12}$  respectively. So  $\sqrt{\mu/\epsilon} = 377$ . For example, if the width of the strips in Fig. 3 was 10 times their separation,  $R_0$  for this line would be  $37.7\Omega$  (approximately (owing to edge and end effects it would be rather less).

The  $R_0$  of a line or cable terminated by a resistance equal to  $R_0$  being equivalent to that same resistance so far as any generator connected to it is concerned,  $R_0$  is also the ratio of voltage to current at the point of connection and (as will be clear from the argument illustrated by Fig.2) at every point along the line, right up to the load. This is practically so even if the line loss moderately reduces the actual values of  $V$  and  $I$  between generator and load.

The fact that a low-loss line with suitably chosen  $L$  and  $C$  is electrically equivalent to the resistance connected to the far end does not, of course, mean that the generator signal arrives at the far end instantaneously. When the generator (such as an aerial) feeds the first positive half-cycle into its end of the line, it starts to charge the capacitance of that end, say one of the  $C$  units in Fig.1, but the current that tries to go on from there to charge the next unit is delayed by the first series inductance  $L$ . And so on. So the signal waveform travels along the line at a certain speed, rather like the wave one can make by wagging the end of a long stretched rope.

What speed?

We can look again at Fig.3 and, denoting the voltage and current at the start by  $V$  and  $I$  ( $V/I$  being  $R_0$ ) we calculate the charge on the upper strip (the lower one being assumed earthed) per unit length, from (2) and (7):

$$Q = CV = \frac{\epsilon w V}{d}$$

The current  $I$  along the line is the amount of charge passing any fixed point per second, so if we call the

velocity of the charge along the line  $v$ , we have

$$I = Qv = \frac{\epsilon w V v}{d}$$

therefore 
$$v = \frac{Id}{\epsilon w V} = \frac{d}{\epsilon w R_0}$$

and substituting from (14)

$$= \frac{1}{\sqrt{\epsilon \mu}} \quad (15)$$

In space, where  $\epsilon$  and  $\mu$  are  $\epsilon_0$  and  $\mu_0$ , this works out at nearly  $3 \times 10^8$  metres per second, which is the speed of light, usually denoted by  $c$ . Together with much other convincing evidence, this discovery led to the conclusion that light is electromagnetic, differing from radio waves only in its much higher frequency.

In air,  $\epsilon$  and  $\mu$  are very slightly greater than  $\epsilon_0$  and  $\mu_0$ , so the wave speed is very slightly (negligibly for most purposes) lower. But practical lines have to rely on solid insulating spacers with values of  $\epsilon$  several times greater than  $\epsilon_0$ , so the wave speed therein may be much less than  $c$ , and the wavelength along the line, at a given frequency, much less than in air.

Note that as  $V/I = R_0$  everywhere along the line, voltage and current are everywhere in phase, so they carry energy along the line, stored in the travelling electric and magnetic fields. Comparing Figs. (4) and (5) we see that these fields must be at right angles to one another and to the direction of wave motion. I don't want to get sidetracked here by the subject of polarization but just mention in passing that the direction of polarization is conventionally that of the electric field; vertical in Fig.3. That is why receiving dipoles for vertically polarized waves should be vertical. But e-m waves don't have to be like this, polarized in one direction ("linearly polarized"); they can be all mixed up.

Fig.6 shows diagrammatically the electric ( $E$ ) and magnetic ( $H$ ) field

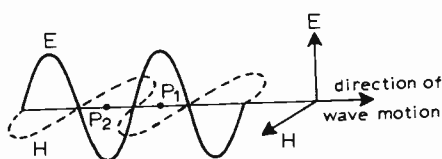


Fig.6 Plane, linearly-polarized electromagnetic waves consist of an electric field pattern, shown here in the vertical plane, accompanied by a similar magnetic field at right angles to it and to the direction in which the whole pattern is moving.

strengths in three-dimensional space between the conductors of a transmission line when vertically-polarized sinusoidal waves are going along it from left to right. If either  $E$  or  $H$  were reversed in phase, the waves would be going from right to left.

All this may be all very well, you may say, but when are we going to get free from lines and cables? How can the waves exist without charges or currents? Well, we know (I hope) that although each of the imaginary flux lines between the capacitor plates in Fig.4 begins on a positive charge and ends on a negative charge, and  $E$  is inevitably present around any charge, charges are not the only cause of  $E$ . The other cause is variation of a magnetic field (Faraday's law of e-m induction)\*. It happens in every power station and transformer. The basic principle of electric generators is  $V = Bvl$ ,  $V$  being the voltage generated in a straight conductor of length  $l$  cutting a magnetic field of flux density  $B$  at velocity  $v$ . But even if the conductor were not there the potential difference in space would be, and p.d. is a measure of the electric field between the ends of the length  $l$ , because over a length  $l$  it adds up to  $V$ . So a more fundamental equation is  $E = Bv$ . Or in terms of magnetic field strength  $H$ ,  $E = \mu H v$ .

But how does a magnetic field come into existence where there are no electric currents? Even the field around a permanent magnet is caused by electric currents on an atomic scale in the magnet material. We go back to eqn.(10) for the basic principle (Ampere's law). Put more correctly it says that the magnetomotive force (m.m.f.),  $\int H \cdot dl$ , is equal to  $I$ , the current enclosed by an  $H$  loop of length  $l$ . Now look at Fig.7, which shows a capacitor  $C$

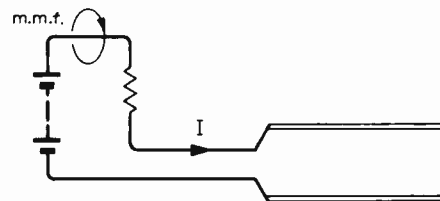


Fig.7 Although the space between capacitor plates carries no current in the ordinary sense, there is a "displacement current" which produces the same magnetomotive force around it as every other part of the circuit.

in process of being charged. The charging current is flowing in the direction conventionally shown by the arrow  $I$ , and of course is diminishing as time goes on. Exactly proportional to this current at all times, and numerically equal to it in SI units, is an m.m.f. everywhere around the current, indicated at one point in the circuit by a ring. The arrow head on this ring is conventionally related to the current arrow by the corkscrew rule. Having recapped on the familiar circuit situation, let us shift our attention to the space between the plates, which are

\*Discussed in "What is e.m.f.?", August 1974 issue.

wider apart than usual in order to make this easier.

It will be generally agreed that no current, in the ordinary sense, is flowing across the space between the plates. There is, as one would say, a break or gap in the circuit. But is there a gap in the m.m.f.? I've never done the experiment, but I'm sure that if a magnetic needle were to be suspended near the plates, with precautions to prevent it from being affected by the rest of the circuit, it would respond to this non-existent current. For I trust James Clerk Maxwell, who decided theoretically (and, for all I know without being able to look it up, experimentally) that there is indeed an m.m.f. around the space between the plates, caused by what he called *displacement current*. We have come across displacement already, in eqn.(5), as the electric flux density between opposite charges. The total displacement or flux over an area  $A$  is therefore  $AD$ , and, as (5) said, this is equal to  $Q$ , the total charge on either plate. The circuit current  $I$  is equal to the rate at which charge is moving along, but in the capacitor this charge is not moving along but is accumulating on the plates. However, it makes the displacement increase. The rate of increase of total displacement being equal to the rate of increase of charge, it is also equal to the circuit current,  $I$ . So if displacement current is defined as the rate of change of total displacement, it is always equal to  $I$ . So the m.m.f. ring around  $C$  is the same amount as around  $I$  anywhere else.

At a fixed point  $P_1$  in Fig.6,  $E$  is at this moment at a positive maximum and  $H$  likewise (if positive is towards us). At  $P_2$  they are both maximum negative. The rapid change from  $E$  at  $P_1$  to  $-E$  half a cycle later was supposed to be due to a negative charge on the upper metal strip being replaced by a positive charge, brought about by current along the strip between  $P_2$  and  $P_1$ . But if we remove the strips and join up the opposite  $E$  lines at  $P_1$  and  $P_2$  into complete loops as in Fig.8, the

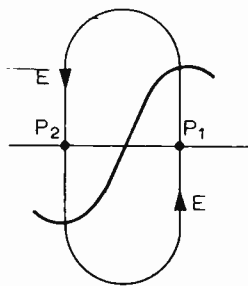


Fig.8 Although Fig.6 was based on the existence of electric charges moving along conductors (Fig.3), waves continue when the conductors are removed, because the fields join up to replace them, as for example this electric line of force at the  $P_1$ - $P_2$  section in Fig.6.

movement of this loop rightwards for half a cycle is accompanied by a displacement current in space where the conduction current used to be. This rapid change in displacement  $D$  causes a magnetic field  $H$  just as any ordinary current would. We have already noted that  $E=Bv=\mu Hv$ . Without going into the full derivation we can now be pretty sure (by the principle of duality I so often cite) that the counterpart is true:  $H'=Dv=\epsilon Ev$ . I have called the generated magnetic field  $H'$  to distinguish it from  $H$ , as in general the two are not necessarily equal. But for the two fields to keep one another going,  $H'$  must be equal to  $H$ , which in the first equation is equal to  $E/\mu v$ . Substituting this in the second, we get

$$\epsilon Ev = \frac{E}{\mu v}$$

$$\text{from which } v = \frac{1}{\sqrt{\epsilon\mu}} \quad (16)$$

which is the same as (15) derived from currents and charges.

Since e-m waves are thus able to get along quite nicely without currents and charges, what exactly is the role of the hardware, especially as its resistance weakens the waves by a few dB per 100 metres? The quick answer is that it guides them from  $A$  to  $B$ , when that is what is wanted rather than broadcasting. But how?

An air-cushion-shaped wave like Fig.8 has parts at top and bottom that are not wholly vertical. These will therefore expand upwards and downwards as well as forwards. In three dimensions it will expand sideways as well, and in fact all around. (The same applies to the magnetic field, not even suggested in Fig.8 but there in real waves.) If (say) an electric wave front expanding upwards hits a horizontal conducting surface, the field lines will not be at right angles to it. So they will have a component parallel to it, along the surface of the metal. But it is impossible for two points in or on a perfect conductor to be at different potentials. So where an electric field ends on a conductor the direction of the field must be wholly at right angles to the conductor.

That being so, the wave front inside a transmission line must be a plane at right angles to the conductors and to the direction of wave travel. Which, not surprisingly, is why the waves are called plane waves. The conductors eliminate all field components of the waves that are not directly forward. (I have said nothing about the magnetic field, because it is obvious that if any part of the electric field is eliminated the corresponding part of the magnetic field has nothing left to keep it in existence.)

It is not essential to have two conductors for this guiding action; in certain circumstances an empty tube will do, called a waveguide. But that is

too long a story to start on now. If anyone asks me kindly I might tell it some other time. But I do just have room to fulfil my promise about the impedance of space. We found that a transmission line or cable that is loss-free and infinitely long has an input resistance that is

$$R_o = \sqrt{\frac{L}{C}} = \frac{d}{w} \frac{\mu}{\epsilon} \quad (14 \text{ again})$$

The awkward bit about being infinitely long can be got round by substituting any length you like provided that the far end is connected to a resistance equal to  $R_o$ , nobody will notice the difference at the input end because there won't be any difference there. If we imagine ourselves inside an enormous line of the Fig.3 type, looking towards the far end, we can consider one metre square of the cross section of space confronting us. By thus making  $d=w=1$  so far as the space is concerned, we get  $\sqrt{(\mu/\epsilon)}$  as the resistive impedance of space (since it is not concerned at all with the dimensions of the line). Let us call this resistance  $R_s$ . In fact, the line can be removed and, provided the waves stay plane, which they will then not do, but will very nearly do at a great distance from a radio transmitter, the same applies. We have already noted that the value of  $\sqrt{(\mu/\epsilon)}$  for empty space is  $377\Omega$ . Within dielectric materials  $\mu$  is hardly affected, but  $\epsilon$  will be greater, so the resistance of the material to plane waves will be less than  $377\Omega$ .

If we work back from  $R_s = \sqrt{(\mu/\epsilon)}$  by using equations (14), (4) and (10) (with  $l=w$ ) and  $R_o = \sqrt{L/C}$ , we get

$$R_s = \frac{E}{H}$$

which is analogous to

$$R_o = \frac{V}{I}$$

The dimensions are right, because  $E$  is in volts per metre and  $H$  is in amps per metre, and the metres cancel out.



# Circuit Ideas

## Constant amplitude sawtooth generator

This sawtooth generator is designed to give a constant-amplitude output over a range of frequencies when driven by an external periodic waveform. The ampli-

tude of the output is sensed and a corrective voltage is applied to the base of a transistor used as a constant-current source. The exponential current-voltage relationship of such a source renders it particularly useful for this purpose.

An MC3401P is the op-amp package used. This contains four single-supply internally-compensated amplifiers sharing common biasing circuitry, and operating over +5 to +18V. Each amplifier has a common-emitter type inverting input, and a current-mirror non-inverting input, often used to set quiescent output voltage.

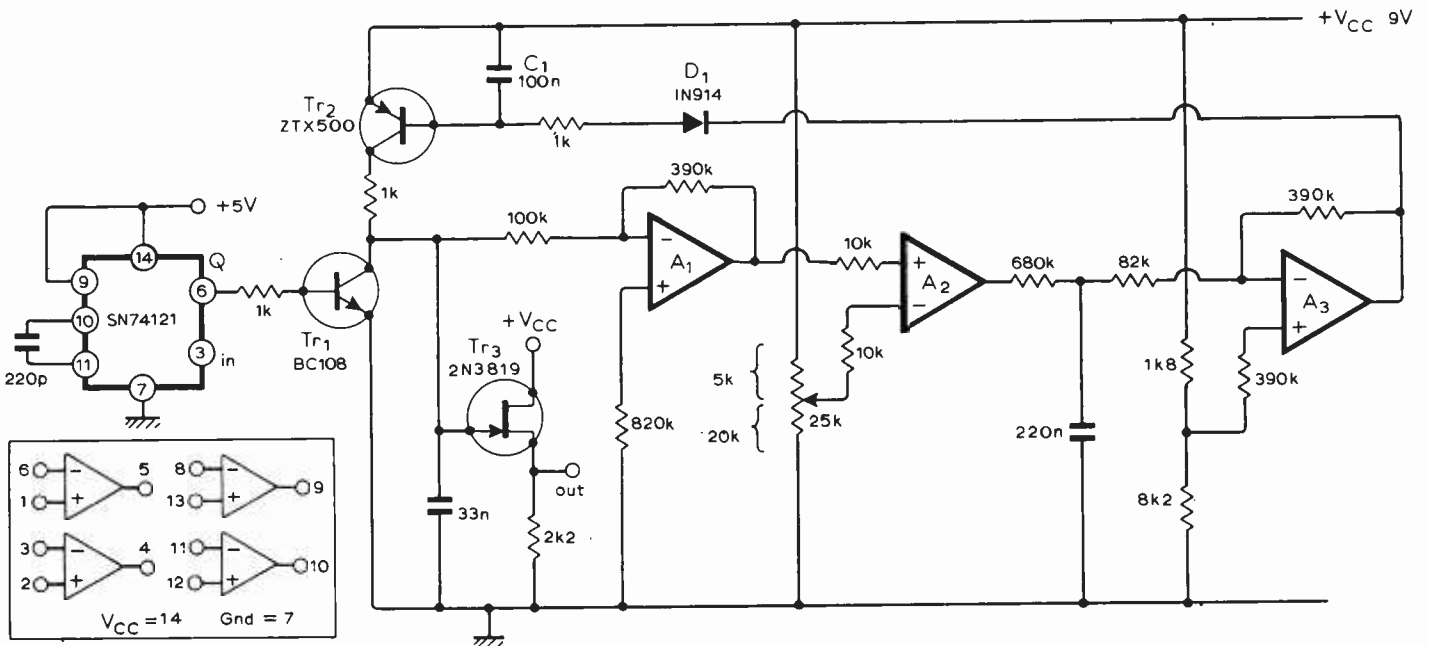
Transistors  $Tr_1$  and  $Tr_2$  form the basic sawtooth generator,  $Tr_1$  being driven on at the input frequency by a 300ns pulse. The resulting waveform is amplified by  $IC_1$  and fed to  $IC_2$  which acts as a comparator — the amplitude sensing element. The threshold is set by the 25k $\Omega$  potentiometer which should be adjusted for maximum output-ampli-

tude versus frequency linearity. Rectangular waves at  $IC_2$  output are filtered to give a control voltage; this is shifted in level by  $IC_3$  and  $D_1$  to meet the input voltage requirements of  $Tr_2$ . Capacitor  $C_1$  acts as a reservoir to smooth out any voltage fluctuations at  $Tr_2$  base during each cycle.

Values shown are for a range from 2kHz to 100kHz. If a faster response is desired it may be obtained by altering filter values at the expense of frequency range. An output appears at the source of  $Tr_3$ , and may be amplified to the desired value. For optimum stability, the power supply should be stabilized. The unit may be employed as a frequency multiplier by adding comparators set to fire at various ramp levels.

The pin diagram for the 14-pin d.i.l. version of the 3401 is shown. This device may be obtained from Jermyn, Sevenoaks, Kent.

J. N. Paine,  
Oxford.



## Thyristor protection circuit

When different pieces of equipment are being interconnected by a signal interface, the danger exists of high voltages appearing on the interface lines as the result of a malfunction. These can be dangerous, e.g. mains, or nuisance voltages which will damage delicate components. A protection circuit which will provide very little signal degradation is shown. The components may be selected to meet a wide variety of conditions. Suppose there is a voltage  $V_{AB} > 0$ . If  $V_{AB} > V_{D3} + V_{D1} \approx V_{D3}$  then thyristor  $SCR_1$  will latch and  $V_{AB}$  will reduce to  $\sim 1V$  within 1 to 2 $\mu s$ . If  $F_1$  is a suitable value it will blow, and isolation will result between  $AA'$ .

When  $V_{AB} < 0$  and if  $V_{BA} > V_{D4} + V_{D2} \approx V_{D4}$  then thyristor  $SCR_2$  will latch and  $F_2$  will blow. By suitable selection of  $Z_1$  and  $Z_2$  suitable voltages may be catered for.

Capacitors  $C_1$  and  $C_2$  guard against spurious triggering, or triggering on signal spikes transmitted through the diode capacitance, and  $D_1$  and  $D_2$

prevent forward voltage drops across  $D_3$  and  $D_4$ .

With the following values:

$Z_1, Z_2$  CV7144 10V zener

$D_1, D_2$  CV9637 small-signal silicon diode

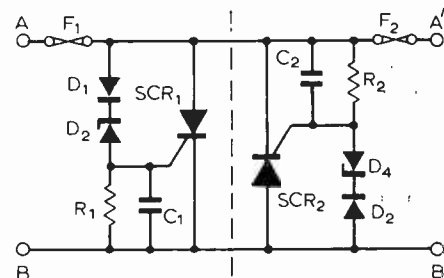
$R_1, R_2$  10k $\Omega$

$C_1, C_2$  0.047 $\mu F$

$Tr_1, Tr_2$  2N4147

the circuit will operate with pulses of 20ns with no noticeable degradation, and the circuit will latch if  $V_{AB}$  exceeds 11V.

Higher powered thyristors may be used where necessary with consequent slowing down of edges. Typical component cost is £1.10 for values as shown. S. G. Pinto,  
A. P. Bell,  
Ipswich.

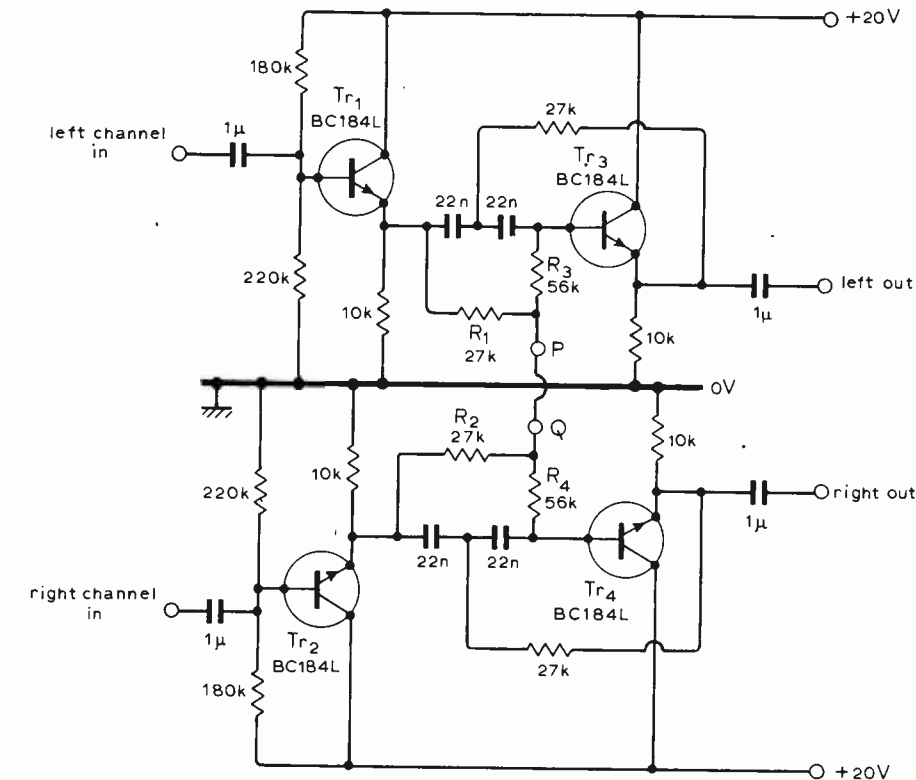


### Stereo rumble filter

On cheaper turntables and records audible rumble can extend to frequencies above 100Hz. This rumble can be resolved into mono rumble, corresponding to horizontal displacements of the stylus on the record, and stereo rumble, corresponding to vertical displacements. The last mentioned is disconcerting to the listener because it gives rise to out-of-phase loudspeaker signals. This is easily demonstrated by switching the amplifier from stereo to mono on a quiet passage of a mono record with the listener not equidistant from the loudspeakers. (I suspect that some surround-sound enthusiasts who feed difference signals into the rear speakers think that the stereo rumble is part of the ambience.)

Fortunately, as the human ear is not sensitive to directional information below about 400Hz, it is possible to remove the stereo (L-R) signal at low frequencies without losing stereo separation, thus also removing the stereo rumble, and reducing the total rumble. This is done by the circuit shown. Emitter followers feed two two-pole Sallen & Key high-pass filters, with 200Hz break-point frequencies and Butterworth characteristics, but with  $R_3$  and  $R_4$ , which would normally be joined to earth, connected together at the point P.

If identical signals are applied to the inputs (a mono signal), no current flows through P (P-Q acts as an open circuit), no filtering takes place, and the signals are unchanged. Resistors  $R_1$  and  $R_2$  provide low frequency paths around the capacitors and biasing to  $Tr_3$  and



$Tr_4$ . However, if signals of equal amplitude but opposite phase (a stereo signal) are applied to the inputs, then, by symmetry, the voltage at P does not vary, and P becomes a signal earth. The filters then attenuate the difference signal below 200Hz. The filter chosen gives 12dB attenuation at 100Hz, with channel crosstalk of -11dB at 500Hz rising to -31dB at 5kHz.

The author has used one of these filters for some time. With loudspeakers

there is an appreciable reduction of rumble without perceptible reduction of stereo separation. With headphones, there is an added bonus because the effective bass-blending of the circuit removes the highly unrealistic sensation of sometimes having bass in only one ear. The filter can be disabled by wiring a switch between P and Q.

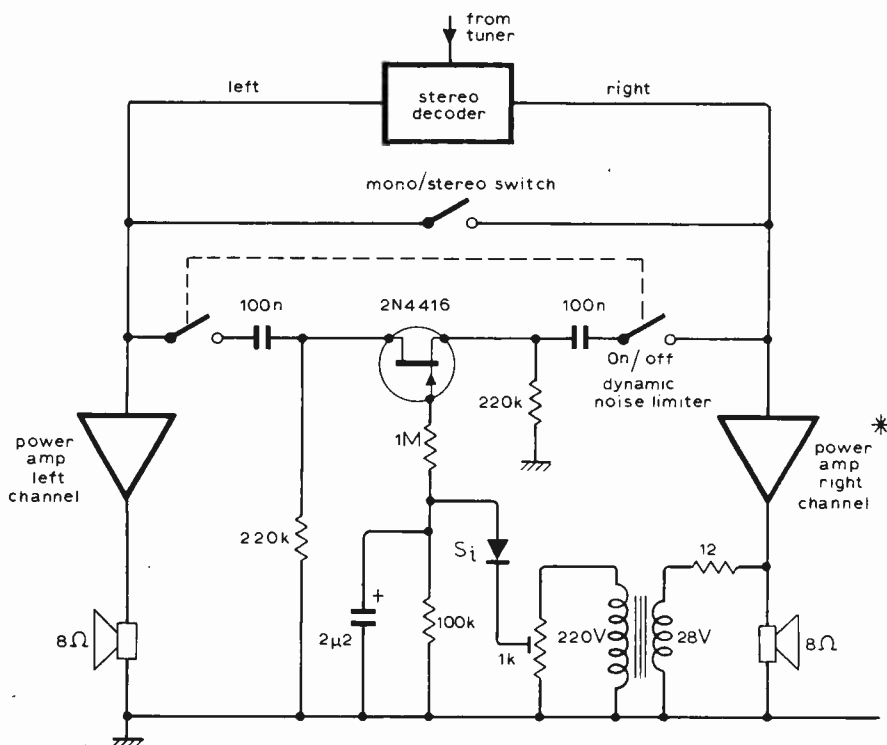
M. L. G. Oldfield,  
Dept of Engineering Science,  
Oxford University.

### Stereo dynamic noise limiter

Stereo reception of f.m. stations is often accompanied by a slight noise signal. This signal is only heard at weak passages; in this case a noise limiter will help to produce a pseudo-stereo sound, which has reduced noise.

In practice both audio channels are short-circuited, depending on the audio signal strength. The short circuit is realized by a field effect transistor 2N4417, whose gate is controlled by the output voltage. If this voltage is not sufficient to drive the f.e.t., an amplifier or transformer must be used.

J. W. Richter,  
Eindhoven.



(\* includes; volume, balance and tone controls)

# Electronic circuit calculations simplified

## 5 — RC combinations in a.c. circuits

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

This article is concerned with RC combinations in analogue or linear circuits. It shows how the values of resistance and capacitance required to give a particular type of frequency response can be simply calculated.

So far in the series we have used three formulae, namely  $I=V/R$  (Ohm's law),  $Q=It$  and  $C=Q/V$ . In this article we shall use a fourth formula, the expression for the reactance of a capacitor

$$\text{reactance} = \frac{1}{2\pi fC}$$

which shows that the reactance is inversely proportional to frequency and to capacitance.

**Fundamental frequency response of an RC circuit.** Fig. 1 shows a combination of series capacitance and shunt resistance commonly encountered in electronic circuits. Because the reactance of C is inversely proportional to frequency such a combination gives a response in which the loss increases as frequency decreases. It is possible for particular values of R and C to calculate the loss introduced by the circuit, and by repeating the calculation for a number of frequencies the response curve for the circuit can be deduced. This is, however, a laborious and unnecessary operation because the response can be calculated very simply as explained below.

At the frequency for which the reactance of C equals R, the loss of the circuit is 3dB. At double this frequency (i.e. one octave higher) the loss is 1dB and one octave higher still it is only 0.25dB. At half the frequency for 3dB loss (i.e. one octave below this frequency) the loss is 7.5dB and one octave lower still it is 12.5dB. A further halving of frequency increases the loss to 18dB and below this frequency the loss increase at the rate of 6dB per octave.

These loss figures are plotted against frequency in Fig. 2 which shows that the frequency response becomes at each end a straight line, a horizontal straight line at high frequencies and a straight line with a slope of 6dB per octave at low frequencies. These two lines, if extended to the centre of the diagram,

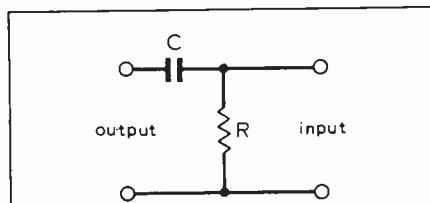


Fig. 1. Combination of series C and shunt R commonly encountered in electronic circuits.

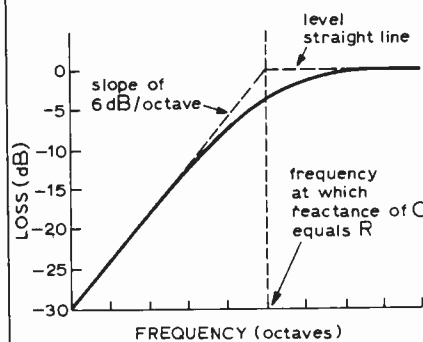


Fig. 2. Universal frequency response curve for all RC combinations.

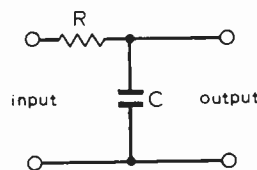


Fig. 3. Combination of series R and shunt C also commonly used in electronic circuits.

meet at the 3dB loss frequency, i.e. the frequency for which the reactance of C equals R. Thus if the 3dB loss frequency is known, it is possible to indicate it on graph paper and then to put in the straight line for zero loss and that for the 6dB-per-octave loss. With these as guides the response curve can now be drawn easily and rapidly yet with accuracy. Because of the low-frequency loss introduced by the circuit of Fig. 1, this is usually known as a bass-cut circuit.

If in the circuit of Fig. 1 the output is taken from across the capacitor instead of the resistor, the loss of the circuit is very low at low frequencies where the reactance of C is large but increases as frequency is raised. The loss is again 3dB at the frequency for which the reactance of C equals R, decreases to zero at lower frequencies and increases, reaching 6dB per octave, at higher frequencies. Such a response is usually described as a top-cut characteristic and the RC combination giving it is usually drawn in the form shown in Fig. 3. The frequency response is defined by precisely the same loss figures as for the network of Fig. 1 and the response curve is as given in Fig. 2 provided that frequency is taken as increasing from right to left. Once the 3dB loss frequency is known the response curve for the circuit of Fig. 3 can be rapidly drawn using the two straight lines as guides as for the circuit of Fig. 1.

The curve of Fig. 2 thus applies to all RC combinations and it gives the response no matter whether the RC combination is in the main path or the negative feedback loop. The curve is plotted from the figures 0.25dB, 1dB, 3dB, 7.5dB, 12.5dB, 18dB, 24dB, 30dB etc. which are the losses at octave intervals of frequency. These figures are extremely useful to the electronic engineer and are repeated in the accompanying table. What Calais was to Mary, this table should be to the electronic engineer! The usefulness of the table will now be illustrated by a number of practical numerical examples.

### Frequency response of RC circuit

Frequency for top-cut cct.	Frequency for bass-cut cct.	Loss in dB
$f/4$	$4f$	0.25
$f/2$	$2f$	1
$f'$	$f'$	3
$2f$	$f/2$	7.5
$4f$	$f/4$	12.5
$8f$	$f/8$	18
$16f$	$f/16$	24
$32f$	$f/32$	30
etc.	etc.	etc.
etc.	etc.	etc.

\* $f$  is the frequency for which the reactance of C equals R

**Coupling circuit.** Perhaps the most familiar application of the circuit of Fig. 1 is in coupling the output of one valve or transistor to the following stage. Fig. 4 shows the circuit in use between two f.e.t.s. If these form part of an a.f. amplifier then a uniform frequency response is required from the coupling circuit over the range say 30Hz to 15kHz. We can achieve this by arranging that the coupling circuit has a small acceptable loss, say 1dB, at the lower limit of the band. The loss will then be less at higher frequencies. It would be satisfactory, for example, if  $C_g R_g$  introduced 1dB loss at 30Hz. From the table or Fig. 2 we know that the loss will be 3dB one octave lower, i.e. at 15Hz, and this is the frequency at which the reactance of  $C_g$  is equal to  $R_g$ . A likely value for  $R_g$  is 1 megohm and from this we can calculate the value of  $C_g$  from the relationship:

$$\frac{1}{2\pi f C_g} = R_g$$

from which

$$C_g = \frac{1}{2\pi f R_g}$$

$$= \frac{1}{6.284 \times 15 \times 10^6} \text{ F}$$

$$= 0.01 \mu\text{F approx}$$

If there are many stages in an amplifying chain, each of the type shown in Fig. 4, then a loss of 1dB per stage at the low-frequency limit could be excessive and a lower loss should be arranged. For example a loss of 0.25dB per stage can be obtained by doubling the value of  $C_g$  (to  $0.02 \mu\text{F}$ ) or of  $R_g$  (to 2 megohms).

If, in the bias circuit for the f.e.t. the gate is connected to a potential divider across the supply, then the loss of the coupling circuit is 3dB at the frequency for which the reactance of the coupling capacitor is equal to the parallel resistance of the two arms of the potential divider. Some information on calculating this was given in an earlier part of this series.

If a bass cut is required,  $C_g$  can be made smaller. For example, if a loss of 12.5dB at 50Hz is required, Fig. 2 or the table shows that the loss will be 3dB two octaves higher, i.e. at 200Hz. A repeat of the above calculations shows that  $C_g$  should be 800pF if  $R_g$  is 1 megohm.

The circuit of Fig. 4 can also be used at radio frequencies, e.g. for coupling a tuned circuit to a valve or f.e.t., and a repeat of the above calculation for a frequency of say 1MHz shows that  $C_g$  should be less than 1pF! If however such a small value is used the coupling circuit would give a considerable loss because  $C_g$  forms with the input capacitance of the valve or transistor a capacitive potential divider (see Part 3). The input capacitance is likely to be many times 1pF and thus the potential divider gives a substantial loss. To minimise this effect  $C_g$  should be large compared with likely values of input

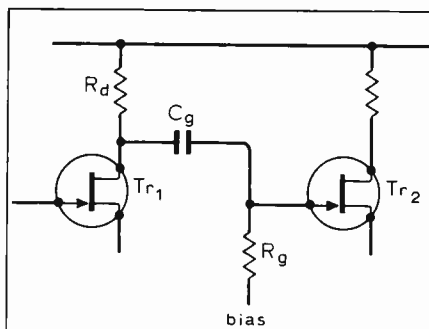


Fig. 4. The circuit of Fig. 1 used to couple two f.e.t.s.

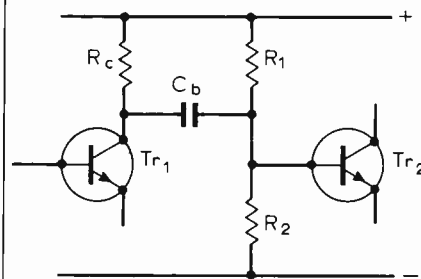


Fig. 5. The circuit of Fig. 1 used to couple two bi-polar transistors.

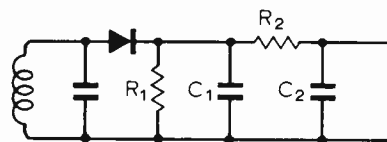


Fig. 6. The circuit of Fig. 3 used as an r.f. filter following a diode detector.

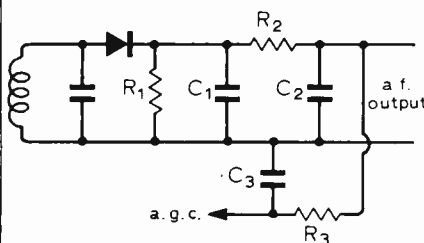


Fig. 7. The circuit of Fig 3 used as an a.g.c. filter following a diode detector.

capacitance: 100pF is a commonly-used value. Thus the type of calculation given above is confined to low frequencies at which the effects of input capacitance can be neglected.

Suppose now that  $Tr_1$  and  $Tr_2$  are bipolar transistors as shown in Fig. 5. The value of  $C_b$  required for an a.f. amplifier is quite different from those just calculated. The input resistance of a bipolar transistor is low (2 kilohms is typical for a collector current of 1mA) and the coupling circuit must be designed to ensure that as much of the output current of  $Tr_1$  as possible enters the base of  $Tr_2$ . The current leaving  $Tr_1$  collector splits at the junction of  $R_c$  and  $C_b$  and that which flows through  $C_b$  can

be assumed to enter  $Tr_2$  base. ( $R_1$  and  $R_2$  are usually large compared with  $Tr_2$  input resistance and so absorb very little of the signal current.) The current division at  $R_c C_b$  junction is analogous to the potential division in  $R_g C_g$  in Fig. 4. Thus  $R_c$  and  $C_b$  determine the frequency response of the coupling circuit in Fig. 5 and, as an approximation, we can say that the loss is 3dB at the frequency for which the reactance of  $C_b$  equals  $R_c$ , losses at other frequencies being, of course, as indicated in Fig. 2 or the table.

We saw in the section on resistive circuits that a likely value for  $R_c$  in a current amplifier is 18 kilohms and if the response is required to be 1dB down at 50Hz then the reactance of  $C_b$  should be 18 kilohms at 25Hz. This gives the value of  $C_b$  as

$$C_b = \frac{1}{2\pi f R_c}$$

$$= \frac{1}{6.284 \times 25 \times 18 \times 10^3} \text{ F}$$

$$= 0.35 \mu\text{F}$$

**R.F. filter circuit.** One application of the circuit of Fig. 3 is as a filter to attenuate r.f. signals in the output of an a.m. detector. A typical circuit is given in Fig. 6 in which  $R_1 C_1$  are the diode load components (see Part 4) and  $R_2 C_2$  form the r.f. filter.  $R_2 C_2$  should attenuate r.f. signals as much as possible but should not, of course, attenuate the upper audio frequencies significantly. In a medium- and long-wave receiver it would be satisfactory to make the attenuation 3dB at 5kHz: at this frequency therefore the reactance of  $C_2$  should equal  $R_2$ .

Before we can calculate  $C_2$ , however, we must know the value of  $R_2$ . If  $R_2$  is small  $C_2$  must be large and this would effectively increase the value of  $C_1$  causing possible distortion at the upper audio frequencies. On the other hand if  $R_1$  is large it forms with the following shunt resistor (normally the volume control) a potential divider with a large step-down ratio. A compromise value for  $R_2$  is 3 kilohms if  $R_1$  is 5 kilohms. We can now calculate  $C_2$  from the relationship

$$C_2 = \frac{1}{2\pi f R_2}$$

$$= \frac{1}{6.284 \times 5 \times 10^3 \times 3 \times 10^3} \text{ F}$$

$$= 0.01 \mu\text{F approximately}$$

**A.f. filter circuit.** Diode detectors are generally used as a source of a.g.c. voltage and this voltage should be free of r.f. and a.f. signals. The circuit of Fig. 3 is therefore used to attenuate these unwanted signals: a typical circuit is shown in Fig. 7 in which  $R_3 C_3$  are the a.g.c. filter components. A loss of at least 12.5dB is required at the low-frequency limit, say 50Hz. Thus, from Fig. 2 or the table, the 3dB loss frequency is 12.5Hz.  $R_3$  should be large enough not to

shunt the detector components seriously but low enough to provide effective base bias for the controlled transistors. A typical value for  $R_3$  is 15 kilohms and the reactance of  $C_3$  must equal this value at 12.5Hz. The value of  $C_3$  is thus given by

$$C_3 = \frac{1}{2\pi f R_3}$$

$$= \frac{1}{6.284 \times 12.5 \times 15 \times 10^3} \text{ F}$$

$$= 1\mu\text{F approximately}$$

**Top cut circuit.** A shunt capacitor such as C in Fig. 8 is often used to give top cut. Suppose, as a numerical example, a cut of 12.5dB is required at 10kHz. If  $Tr_1$  has a high input resistance (e.g. is an f.e.t. or an emitter follower) then the current leaving  $Tr_1$  collector effectively splits between  $R_c$  and C.  $R_1$  and  $R_2$  are normally large compared with  $R_c$ . Thus  $R_c$  and C determine the frequency response and Fig. 2 or the table can be used to determine the value of C in the usual way. The 3dB loss frequency is 2.5kHz and if  $R_c$  is 10 kilohms we have

$$C = \frac{1}{2\pi f R_c}$$

$$= \frac{1}{6.284 \times 2.5 \times 10^3 \times 10 \times 10^3} \text{ F}$$

$$= 0.007\mu\text{F}$$

The circuit of Fig. 8 is not of the L-shaped form of Fig. 3. In effect  $R_c$  and C are in parallel and are fed with current by  $Tr_1$ . Nevertheless Fig. 2 and the table still apply.

Suppose now that  $Tr_2$  is a common-emitter amplifier with a low input resistance, say 2,000 ohms. Current leaving  $Tr_1$  collector now splits between C and the input resistance of  $Tr_2$  so that this is now the RC combination which determines the frequency response. Since the input resistance is one fifth of  $R_c$  the value of C will be five times the former value to give the same frequency response. Thus C should now be 0.035 $\mu$ F.

**Top lift circuit.** As already shown the circuit of Fig. 1 gives a loss which increases at the rate of 6dB per octave as frequency is reduced. If, however, a resistor  $R_1$  is connected in parallel with C, as shown in Fig. 9, the loss of the circuit is limited to that of the potential divider  $R_1R_2$ . The frequency response of the circuit is now bounded by two horizontal lines as shown in Fig. 10. One line corresponds to zero loss and the loss to the loss of the potential divider  $R_1R_2$ . If the curve connecting the two lines corresponds to a low frequency, the circuit gives bass cut; if, however, it corresponds to a high frequency the effect of the circuit is to give top lift.

Suppose, for example, we want 12dB lift at 10kHz. 12dB corresponds to a voltage ratio of 4:1 and, as shown in Part 1,  $R_1$  should be three times  $R_2$  to

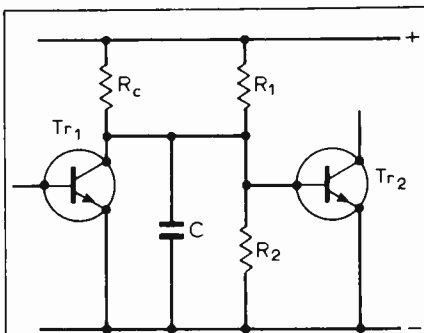


Fig. 8. Shunt capacitor C gives top cut.

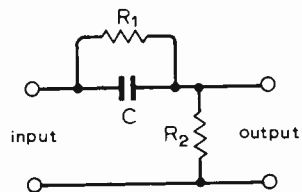


Fig. 9. Modification of the circuit of Fig. 1 to give top lift.

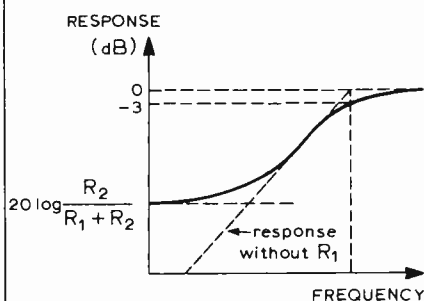


Fig. 10. Frequency response for Fig. 9.

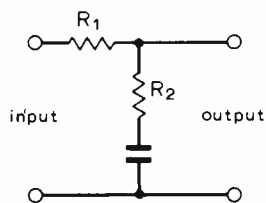


Fig. 11. Modification of the circuit of Fig. 3 to give bass lift.

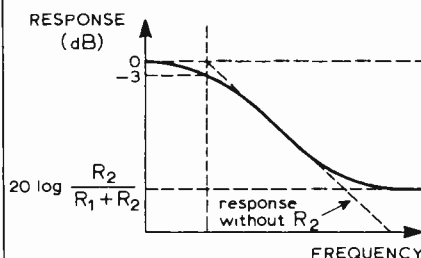


Fig. 12. Frequency response for Fig. 11.

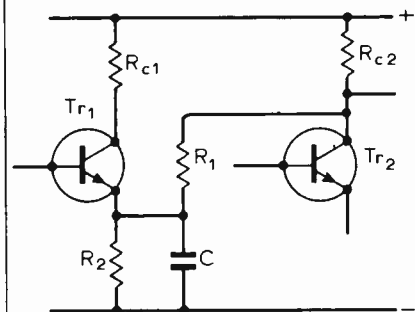


Fig. 13. RC circuit in feedback path of a voltage amplifier gives top lift.

give this ratio. Before the value of C can be calculated we must decide a value of  $R_1$  or  $R_2$  and the values to be assigned to these resistors are in practice dictated by the requirements of the circuit to which the network is connected. If  $R_2$  is connected to a high resistance e.g. the input of an emitter follower, then  $R_2$  could be 10 kilohms. This gives  $R_1$  as 30 kilohms. Provided  $R_1$  is large compared with  $R_2$ , the 3dB loss frequency is still approximately that for which the reactance of C is equal to  $R_2$  and this frequency should, from Fig. 2 or the table, be about 2.5kHz to give 12dB lift at 10kHz.

C is thus given by

$$C = \frac{1}{2\pi f R_2}$$

$$= \frac{1}{6.284 \times 2.5 \times 10^3 \times 10 \times 10^3} \text{ F}$$

$$= 0.0064\mu\text{F}$$

**Bass lift circuit.** The circuit of Fig. 3 gives a top cut characteristic and the loss increases at the rate of 6dB per octave as frequency increases. By including a resistor  $R_2$  in series with C as shown in Fig. 11 the maximum loss can be held to that of the potential divider  $R_1R_2$  as shown in the frequency response curve of Fig. 12. Such a characteristic would be described as top cut if it is located at the upper end of the audio band but as bass lift if located at the low-frequency end.

As a numerical example suppose a bass lift of 12dB is required at 50Hz. As before  $R_1$  must be three times  $R_2$  to give this degree of lift and the values of  $R_1$  and  $R_2$  will depend on the circuit to which these resistors are connected. Suppose the input of the network is required to be about 100 kilohms. Then  $R_1$  can be made 75 kilohms and  $R_2$  25 kilohms. Provided  $R_1$  is large compared with  $R_2$  the 3dB loss frequency is approximately that for which the reactance of C is equal to  $R_1$ ; a suitable frequency for this example is, from Fig. 2 or the table, 200Hz. C is thus given by

$$C = \frac{1}{2\pi f R_1}$$

$$= \frac{1}{6.284 \times 200 \times 75 \times 10^3} \text{ F}$$

$$= 0.011\mu\text{F}$$

**Negative feedback circuits.** The RC circuits of Figs. 1 and 3 give bass cut and top cut when used in the main path of an amplifier: when used in the feedback path they give bass lift and top lift. A typical example of an RC circuit in a feedback path is given in Fig. 13.  $Tr_1$  and  $Tr_2$  are cascaded common-emitter amplifying stages but, for simplicity, the coupling components are omitted. As shown in Part 1 the potential divider  $R_1R_2$  determines the voltage gain of the amplifier which is given approximately

by  $R_1/R_2$  provided  $R_1$  is large compared with  $R_2$ .  $C$  shunts  $R_2$ , reducing feedback at high frequencies and so giving a top lift characteristic. The frequency-response-determining components are thus  $R_2$  and  $C$  and their relative values can be calculated as shown earlier in this section. For example to obtain a lift of, say, 12.5dB at 15kHz the lift must be 3dB at 4kHz and at this frequency the reactance of  $C$  must be equal to  $R_2$ . A likely value for  $R_2$  is 500 ohms and thus  $C$  is given by

$$C = \frac{1}{2\pi f R_2}$$

$$= \frac{1}{6.284 \times 4 \times 10^3 \times 500} \text{ F}$$

$$= 0.08 \mu\text{F}$$

Another example of an RC circuit in a feedback path is given in Fig. 14. This is based on the circuit of Fig. 17 in Part 2. At low frequencies where the reactance of  $C$  is large, the feedback circuit consists effectively of the current divider  $R_1 R_2$  and the current gain of the amplifier is given approximately by  $R_1/R_2$  provided  $R_1$  is large compared with  $R_2$ . At high frequencies where the reactance of  $C$  is negligibly small  $R_1$  and  $R_3$  are effectively in parallel and their net resistance (call it  $R_1'$ ) is less than  $R_1$ . The current gain at these frequencies is  $R_1'/R_2$  which is less than  $R_1/R_2$ . Thus the low-frequency gain is greater than the high-frequency gain and the circuit can be used to give a bass-lift characteristic. For example suppose a lift of 12dB is required at 50Hz. For 12dB difference in gain  $R_1$  must be four times  $R_1'$  and this requires  $R_1$  to be three times  $R_3$ . So if  $R_1$  is 15 kilohms,  $R_3$  must be 5 kilohms. The frequency-response-determining components are  $R_3$  and  $C$ , and to give a

lift of 12dB at 50Hz the lift must be 3dB at 200Hz and at this frequency the reactance of  $C$  must equal  $R_3$ . Thus the value of  $C$  is given by

$$C = \frac{1}{2\pi f R_3}$$

$$= \frac{1}{6.284 \times 200 \times 5 \times 10^3} \text{ F}$$

$$= 0.17 \mu\text{F}$$

**Decoupling.** So far this article has been devoted to RC combinations in signal-frequency circuits but Fig. 2 has a common and essential application in good amplifier design which is not concerned with signal frequencies. This is its use as a decoupling circuit which is necessary in a multi-stage amplifier to avoid instability caused by the impedance of the power-supply circuit. A typical example of a decoupling circuit is shown in Fig. 15.

The decoupling circuit is required to introduce substantial attenuation at very low frequencies and the 3dB loss frequency must therefore be very low. As a numerical example let the 3dB loss frequency be 5Hz. A typical value for the resistance is 600 ohms (as shown in Part 1) and thus the reactance of  $C$  must be 600 ohms at 5Hz. From this information we can calculate  $C$  as follows:

$$C = \frac{1}{2\pi f R}$$

$$= \frac{1}{6.284 \times 5 \times 600} \text{ F}$$

$$= 50 \mu\text{F approximately}$$

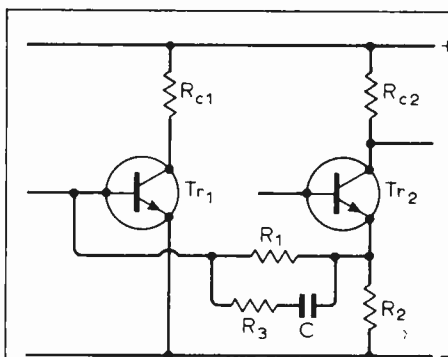


Fig. 14. An RC circuit in the feedback path of a current amplifier giving bass lift.

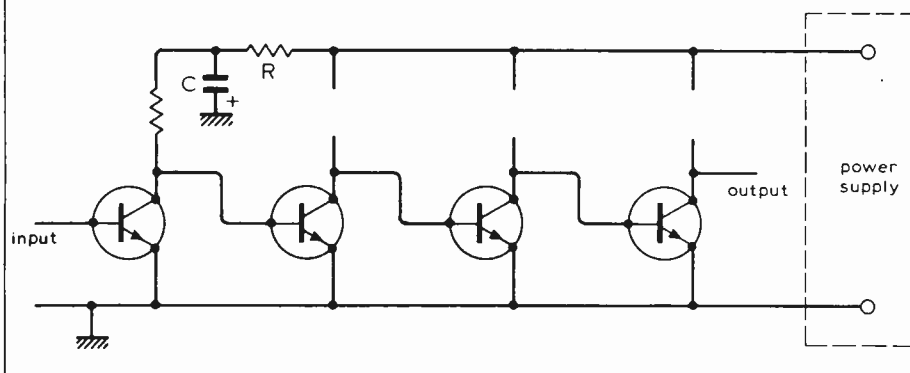
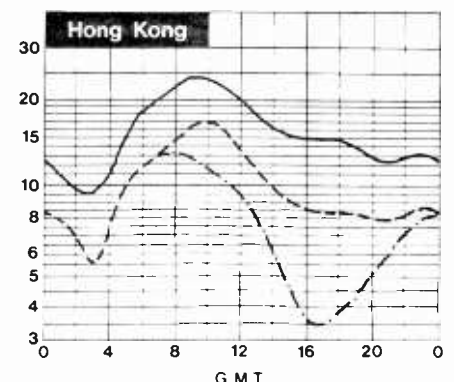
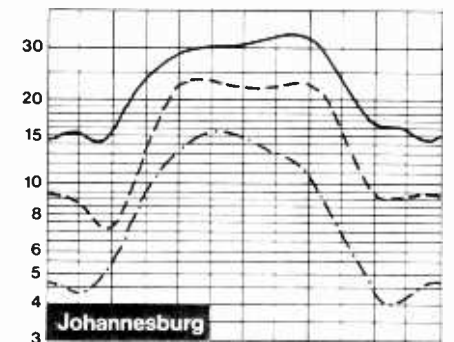
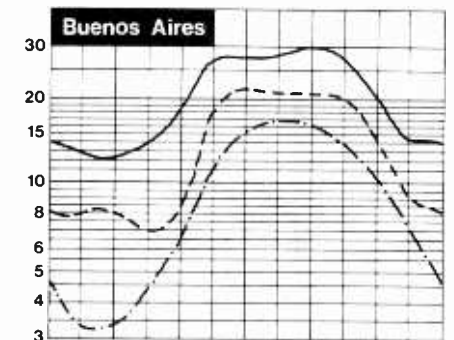
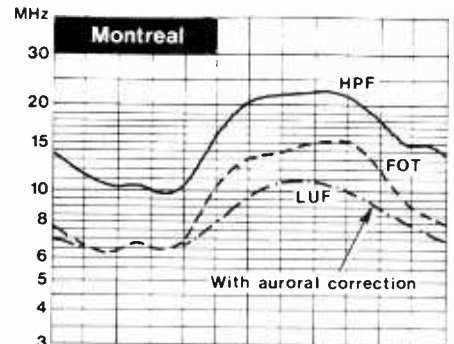


Fig. 15. Use of a decoupling network in a multi-stage amplifier.

# HF predictions

Circuit reliability is the product of the probability of ionospheric reflection and the probability of achieving a desired signal to noise ratio and is thus at a maximum somewhere between FOT and LUF. The term FOT, which is the French equivalent of OWF (optimum working frequency), is thus a misnomer since it relates only to skywave probability. However since LUF is dependent on many factors which cannot be generalised it is found satisfactory in practice to take FOT as being what it says it is.



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From Canada's largest manufacturer of video monitors, Bell & Howell present the extensive Electrohome range.

# Questions to ask before buying a video monitor

## It's an impressive number of models but what about the performance?

The performance/price ratio is equally impressive – perhaps the best in the CCTV business. More than 80% of the screen has a resolution capability greater than 1,000 lines and on the large monitors the minimum brightness in the white area is 130ft lamberts (under accepted test conditions). Other features include high video input impedance and external sync input.

## I need a large screen. For what application has Electrohome's 23 in monitor been designed?

The long-term reliability of the EVM23 and EVM23AG make either ideal for surveillance systems in banks, factories and department stores. They are equally at home in the message centres of the world's airports, in schools and broadcast studios. Both models have a durable outer casing and the EVM23AG has a special tube face to reduce reflections – important where lights or windows may reflect on to the screen. Lockable front panels make them ideal for unattended locations.

## What about mounting? I need the utmost flexibility.

There is no problem. Electrohome have wall and ceiling mount assemblies that allow a monitor to be swivelled or tilted about its centre of gravity. For mobile work like presentations and exhibitions there is an adjustable stand to support the EVM23 at four different heights – 63in, 55½in, 54in, and 46½in. If your requirement is for rack mounting versions, all sizes below 23in are available in rack mount options.

## How do I decide the screen size to suit my application and do Electrohome have a complete range?

Screen size depends largely on viewing distance and available space. If the minimum viewing distance is 10ft then you should use a large monitor – 17in or above. At closer distances or where space is limited a 9in or 11in screen may be more suitable. If you intend TV to teach or persuade, avoid the mistake of sacrificing visual impact for the sake of economy. Electrohome's range is one of the most comprehensive available with seven different sizes from 9in to 25in (two in colour).

## What facilities do Electrohome's small screen monitors offer?

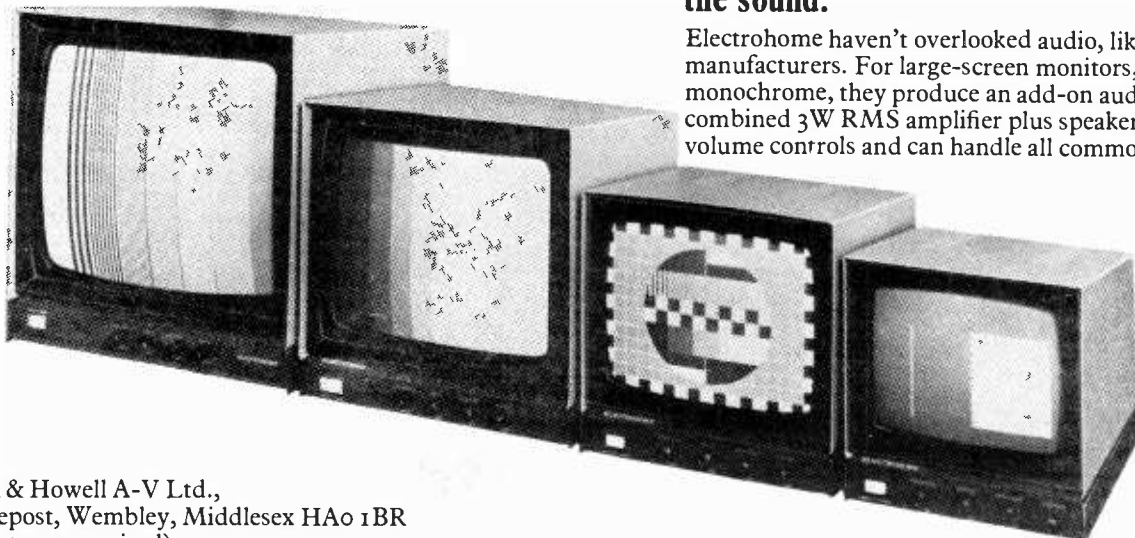
To complement this outstanding specification we have not forgotten the importance of switchable A-B inputs, switchable underscan, DC restoration and good geometry. Also the wide input sensitivity range and the input ground (which can be 'floated') will look after less favourable operating conditions. Input power requirement is also tolerant within 95–130V/185–265V, 50/60Hz.

## When should I use a colour monitor?

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# Specifications: the Electrohome monitor range from Bell & Howell

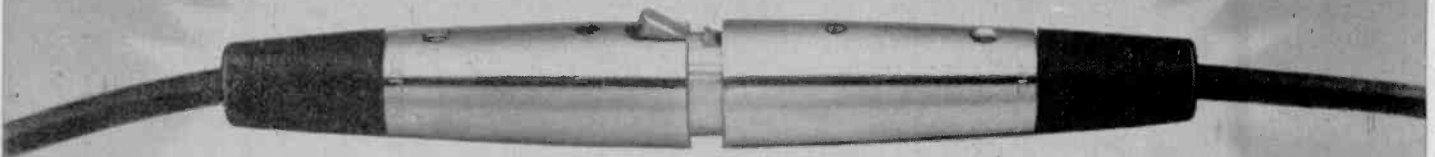
Models	Screen size	Specification	Individual features	
<b>EVM-910</b> (freestanding) <b>EVM-910R</b> (rack mounted) <b>EVM-910R2</b> (double rack mounted)	9in (21.7cm) 38in <sup>2</sup> (245cm <sup>2</sup> )	Input sensitivity 0.35V – 2V pp composite or separate sync. signal (sync. negative). Resolution in excess of 1,000 lines in central 80% of display area at 5ft lamberts; more than 860 lines at 30ft lamberts brightness; capability 55ft lamberts in white area of test pattern (23in monitor 150ft lamberts). EHT regulation, switchable scan size, DC restoration and 15Mhz bandwidth +3dB.	2 video inputs or 1 video blanked input plus sync.	
<b>EVM-1110</b> (free standing) <b>EVM-1110R</b> (rack mounted)	11in (26.3cm) 61in <sup>2</sup> (393.5cm <sup>2</sup> )			
<b>EVM-1410</b> (free standing) <b>EVM-1410R</b> (rack mounted)	14in (32.2cm) 82in <sup>2</sup> (529cm <sup>2</sup> )			
<b>EVM-1710</b> (free standing) <b>EVM-1710R</b> (rack mounted)	17in (41.3cm) 149in <sup>2</sup> (961cm <sup>2</sup> )			
<b>EVM-23</b>	23in (57.5cm) 282in <sup>2</sup> (1819.3cm <sup>2</sup> )			Lockable control cover
<b>EVM-23AG</b>	23in (57.5cm) 282in <sup>2</sup> (1819.4cm <sup>2</sup> )			Special tube face to reduce reflections. Lockable control cover
<b>ECV-19P</b> (colour)	19in (48.26cm) 185in <sup>2</sup> (1193.25cm <sup>2</sup> )	Input sensitivity 0.5V – 2V pp composite or separate sync. signal (sync. negative). D.C. restoration: keyed clamp back porch maintains black level shift to less than 2% of peak luminance from 10% to 90% APL. Colour temperature: 6500 K. Continuously adjustable to 9300 K.	Lockable control cover	
<b>ECV-25P</b> (colour)	25in (62.5cm) 315cm <sup>2</sup> (2032cm <sup>2</sup> )			
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<b>EWM-1</b>	Wall mount			
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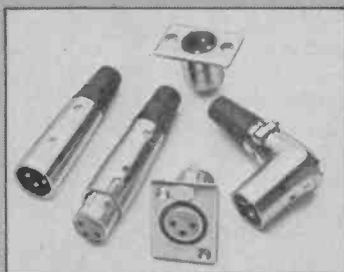
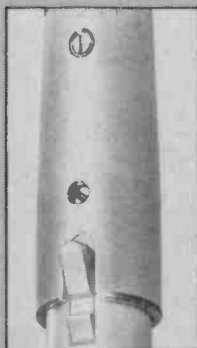


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# Transmitter power amplifier design — 2

## Design considerations for f.m., a.m., pulse operated and linear amplifiers for mobile radio

by W. P. O'Reilly, M.Sc., M.I.E.E.

*The Plessey Company Ltd*

In part 1 of this series on transmitter design power amplifiers were classified according to the type of modulation and the frequency band to be used. In part 2 the design of v.h.f. power amplifiers is considered with a discussion of some special design considerations for the four most commonly employed modulation processes.

### Power amplifiers for f.m.

The most common type of v.h.f. power amplifiers utilizes the common emitter configuration with Class C zero bias. The majority of power transistors are characterized for this mode of operation which is ideally suited to f.m. transmitters. The presence of only a single time-varying frequency in the f.m. signal means that the non-linearity of the input to output power characteristic is of no consequence since intermodulation distortion cannot be generated. The transistor may be operated into its saturation region and hence the maximum output power is much greater than could be obtained from the same device in a linear circuit. The saturated output power is given by:

$$P_{SAT} = 1.25 \left( \frac{V_{CC} - V_{SAT}}{2RL} \right)^2 \quad (1)$$

and using typical values of  $V_{SAT}$  for present day devices simplifies to

$$P_{SAT} \approx 0.4 \frac{V_{CC}^2}{RL} \quad (2)$$

The efficiency and power gain are higher if an output power approximately 20% less than  $P_{SAT}$  is acceptable.

### Power amplifiers for a.m.

These transmitters may be classified as either high level or low level modulation systems. In the former the audio frequency modulation is impressed upon the supply voltage to the output and driver stages of the power amplifier. The output stage is driven to voltage saturation so that the power output is determined by the instantaneous value of the supply voltage. In some amplifiers the supply voltage to earlier stages is modulated in the upwards

direction only in order to provide a greater increase in drive on peaks of modulation and compensate for the reduced gain of the output device as it nears current saturation. To achieve a depth of modulation approaching 100% the collector supply voltage must swing between zero and twice the average (or "carrier") voltage. Devices used for high level a.m. thus require a  $V_{CEO}$  in excess of twice the maximum "carrier" voltage. Devices having  $V_{CEO} \geq 35$  volts are generally selected for 12 volts nominal "carrier" supply.

The output power at the peak of the envelope is four times the carrier power

and to avoid excessive envelope distortion the output transistor must be capable of providing this power without heavily saturating. Fig.1 shows a typical load line under carrier and peak modulation conditions for an eight-watt carrier power design.

The modulation may be impressed upon the supply line by means of an audio power amplifier with an output transformer. The secondary of this is connected in series with the carrier supply line, or by a series regulator the reference voltage of which is made to vary with the modulating signal. The former solution is often bulky and expensive but can provide very high efficiency.

Low level modulation implies that the amplifier is fed with an already modulated drive signal. A linear amplifier is sometimes used, or, more commonly, a Class C amplifier with overall envelope feedback. The Class C amplifier would produce a distorted replica of the drive signal, but the output envelope is monitored by a detector and compared with the drive signal. The error signal so derived is used to pre-distort the drive signal so as to obtain an output with very little distortion. Using this technique very compact a.m. transmitters can be built with envelope distortion as low as 1% and efficiency approaching that of a high level modulation system. For these reasons this type of a.m. transmitter is rapidly gaining popularity.

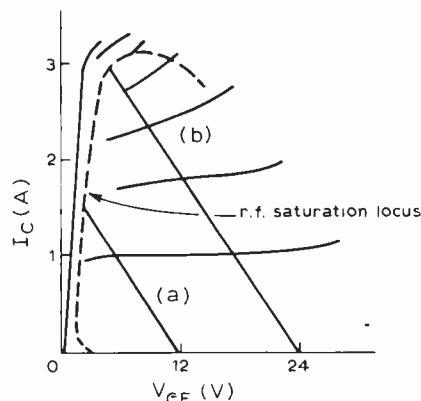


Fig. 1. Typical load line under carrier and peak modulation conditions for an eight-watt carrier power design (a) carrier conditions (b) peak modulation.

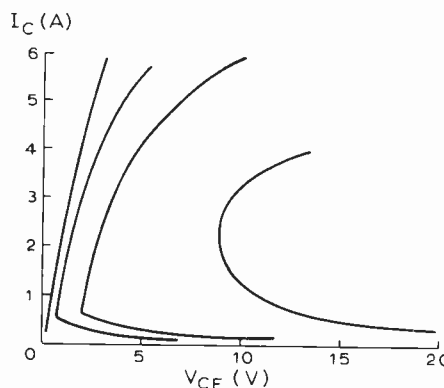


Fig. 2. Loci of constant  $f_T$  for a 100W power transistor.

### Pulse operated power amplifiers

When operated from the same supply voltage the pulsed output power capability of a transistor is only slightly greater than the f.m. or c.w. capability. This is because the limiting factors are current and voltage saturation of the transistor. Where the pulse duration is much shorter than the thermal time constant of the silicon chip and the duty cycle is sufficiently small to provide a very low average output power, some improvement results from running the transistor much cooler than it would be under c.w. conditions. Improvements of between 1 and 2dB have been reported.<sup>1</sup> The reduced

saturation voltage,  $V_{SAT}$  at low temperatures may account for much of the improvement.

A significant increase in output power is obtained if the transistor is operated from a higher supply voltage under pulsed conditions. Provided the duty-cycle and pulse width are suitably small a supply voltage approaching  $V_{CBO}$  may be used. Power transistors are not normally characterized for pulsed operation and the manufacturers should be consulted to determine the safe ratings for a particular application.

**Linear v.h.f. power amplifiers**

Linear high power amplification at v.h.f. using transistors is a relatively new concept and to date there are no power transistors specially characterized for this mode of operation above about 15W. Those which exist are generally intended for Class A operation in applications such as c.a.t.v. It is quite feasible to use certain devices which have Class C characterization in Class AB and to obtain very good linearity. Unfortunately, however, the majority of Class C devices do not give particularly good performance, and so it is as well to present a few notes which should help in selecting suitable devices:

- The maximum linear output in Class AB is usually about 20% to 35% of the Class C rating of the transistor.
- Transistors having high gain at the required operating frequency generally provide best performance in linear amplifiers but are less tolerant of load mismatch.
- If possible use the transistor at a slightly reduced supply voltage for improved ruggedness. 24- or 26-volts supply is ideal for 28-volt c.w. devices.
- Select transistor types showing least variation of  $f_T$  over the required operating loadline. Fig 2 shows contours of constant  $f_T$  for a v.h.f. power transistor rated at 100W c.w. in Class C. This device is ideal for linear operation and can supply up to 30W p.e.p. in the two-metre band with two-tone intermodulation products better than -30dB.
- A low impedance, temperature compensated bias network must be used. (The subject of biasing Class AB

amplifiers was discussed in part 1 of this series where some suggestions for suitable circuitry were made.)

- Provide an adequate heat sink. The gain obtained by Class AB operation at reduced output power is typically 4 to 6dB above the gain obtained in Class C at full rated output. The efficiency usually achieved, however, is much lower (typically 45 to 55%) and due allowance must be made in calculating the thermal performance of the heat sink. The linear power output falls with increased temperature and the reliability is greatly reduced.
- Note that transistors having the same type number from different manufacturers often have quite different performance in linear circuits

even though they may be similar in Class C performance.

In certain instances the linearity obtainable using Class AB operation is inadequate and Class A bias must be employed. Amplifiers capable of producing up to about 15W from a single device are feasible at the present time. Many devices designed for Class C operation will give very good performance in Class A provided the operating point is selected correctly. The following points should be given careful attention when designing this type of amplifier stage.

- The maximum supply voltage which a transistor should be operated from in Class A bias is:

$$V_{max} = \frac{V_{CEO}}{2} + V_{SAT} \quad (3)$$

A reasonable guide to the safe supply voltage is 18V for Class C 28-volt transistors and 8V for Class C 12-volt devices unless specifically quoted otherwise by the manufacturers.

- The maximum standing current is not usually limited by total dissipation or secondary breakdown considerations. Due to a phenomenon known as electro-migration the aluminium metalization which interconnects the cells of the transistor is gradually transported away from the contacts by a mechanism similar to electrolysis. The rate of erosion is a complex function of temperature and current density in the aluminium. To achieve a very high mean time to failure (m.t.t.f.) the transistor should be kept as cool as possible and very high standing currents must be avoided. As a general rule the power dissipated should not exceed 25% of the permissible power dissipation for Class C operation. If this rule is followed m.t.t.f. figures in excess of ten years can be obtained. Aware of the electro-migration problem - which becomes much more severe where very fine conductors must be used as in microwave transistors - some manufacturers are introducing gold metalization which offers a significant improvement over aluminium in its resistance to electro-migration, and in the near future as the problems of this new technology are solved we may expect v.h.f. transistors to use gold metalization and be capable of higher Class A power output.

- The input impedance in Class A is much lower than in Class C, and the manufacturer's data should not be used in design calculations unless the device is specifically characterized for ultra-linear operation.

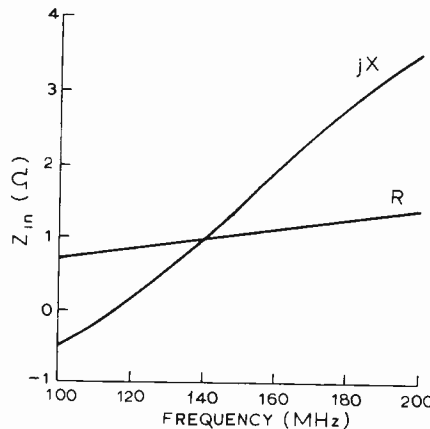


Fig. 3. Variation of input impedance with frequency for a typical 25W v.h.f. transistor.

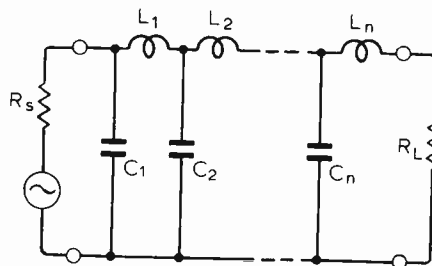
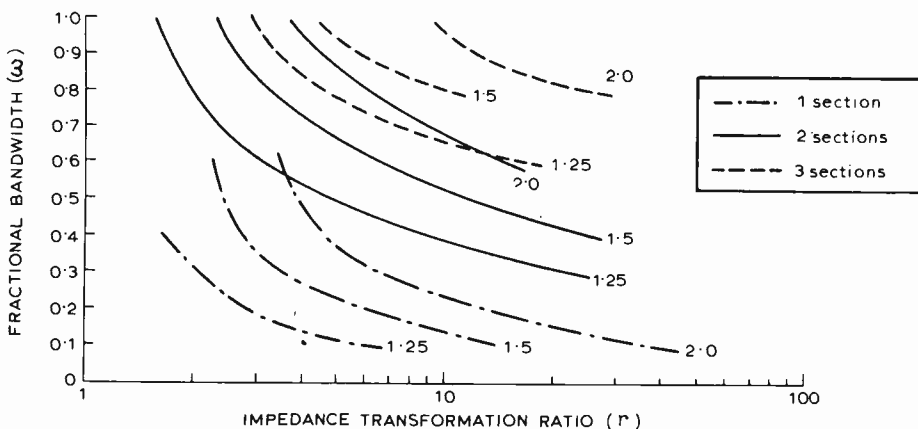


Fig. 4. Lumped element low-pass ladder matching network.

Fig. 5. Matching network (Fig. 4) bandwidth/impedance ratio for one, two- and three-section networks for different values of maximum v.s.w.r.



**Power transistor impedances**

One of the most critical factors in v.h.f. power amplifier design is the matching of the input and output impedances of the r.f. transistor to the source and load between which it must operate. The input impedance is generally low and complex while the required load is

determined by the operating supply voltage and output power, not by the output impedance of the transistor itself. Radio frequency power transistors are far from unilateral, the input and output impedances being functions of the load and source impedances respectively. For this reason it is advisable to measure the input impedance under actual operating conditions if the transistor is to be used at a power much below its rating or with a different class of bias, since the input impedance may then be quite different from the value quoted by the manufacturer.

Most v.h.f. power transistors have an output shunt capacitance of between 1.5 and 2.0 times the collector-base capacitance,  $C_{ob}$ . The optimum load admittance presents an equivalent inductive susceptance to resonate the output capacitance and a conductance determined by the required output power and class of bias. For maximum gain the input impedance must be conjugately matched by the source. In the case of a.m. transmitters, minimum envelope distortion is usually obtained by optimizing the input and output matching for maximum gain at the peak output power. Fig. 3 shows the variation of input impedance with frequency for a typical v.h.f. power transistor. The capacitance generally associated with the input of small signal transistors is swamped at v.h.f. by the inductance of the wire bonds and metalization of the base circuit. As a result, the input impedance passes through a resonance the frequency of which is lower for larger devices. It is the Q factor of the base circuit which presents the ultimate limitation to the maximum bandwidth over which the transistor may be matched.

**Matching networks**

The impedance transforming networks which are used to match the power transistor to its source and load generally fall into one of four main categories: transmission-line transformers; lumped element ladder networks; distributed networks; and a combination of these.

The design of broadband transmission-line transformers was discussed briefly in part 1 of this series and is well documented<sup>2</sup>. At v.h.f. octave bandwidths may be achieved without using ferrite cores. Suitable choice of core material may extend the frequency coverage to a decade or more. One serious limitation is that only impedance ratios of  $n^2$ , where  $n$  is an integer, can be obtained, and it is rare that an accurate match can be obtained between a transistor and its source without the use of additional components.

A very popular type of matching network using lumped elements – i.e. discrete capacitors and inductors – is the low-pass ladder of Fig. 4. The

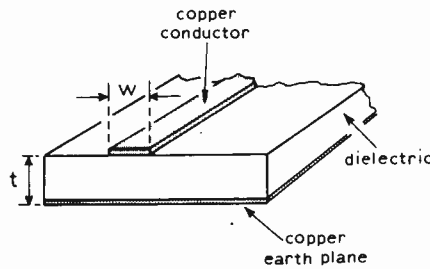


Fig. 6. Typical microstrip transmission line.

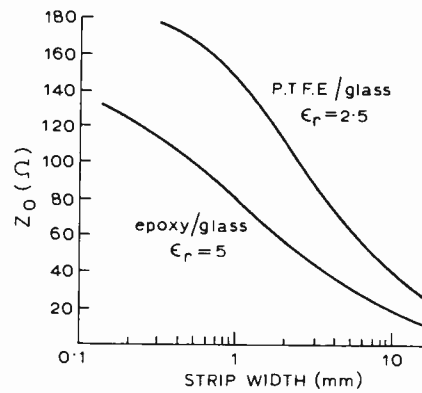


Fig. 7. Characteristic impedance of micro-strip on 1.6mm (1/16 in) 1oz copper clad p.c.b.

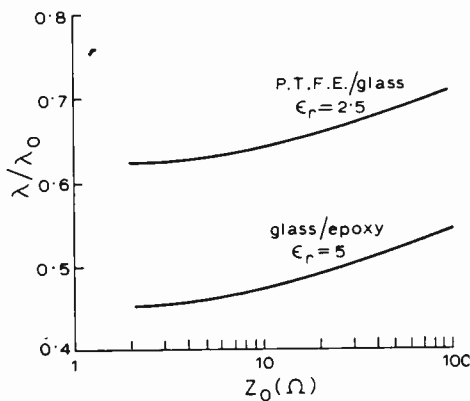


Fig. 8. Ratio  $\lambda/\lambda_0$  versus characteristic impedance for microstrip lines on 1.6mm substrate.

number of sections necessary to achieve the required impedance ratio and bandwidth may be determined from Fig. 5, in which curves for three values of voltage standing wave ratio have been prepared based on the work of Matthaei<sup>3</sup>. In practice due to component tolerances and especially the variation of input impedance between one sample and another of the same transistor type an input v.s.w.r. of less than 1.25 can rarely be achieved without individual adjustment of the matching components. The low-pass nature of these networks is useful in providing a degree of harmonic rejection. Lumped element networks can also be realised in high-pass or bandpass form if desired, and Motorola<sup>4</sup> have published tables of element values for various circuit configurations. For very wide band amplifiers the natural gain roll-off of the transistor may be

compensated by using networks having a matching accuracy which improves progressively through the frequency band. Tables of element values for 4, 5 and 6dB per octave slopes have been computed<sup>5</sup>. The slope is obtained by controlled reflective mismatch and as a result stages using such networks are best driven through unilateral coupling networks such as circulators or 3dB couplers.

In order to understand more fully the behaviour of distributed components it may be useful to summarize briefly the behaviour of an r.f. wave travelling along a transmission-line. Upon reaching the load the forward voltage wave,  $V_F$ , is partly absorbed by the load, the remainder of the power being returned as a reflected wave,  $V_R$ , towards the source. The two waves on the line interact to cause a standing wave pattern with voltage maxima of  $V_F + V_R$  at points on the line where the waves reinforce one another and minima of  $V_F - V_R$  at points of partial cancellation. The voltage standing wave ratio is

$$v.s.w.r. = \frac{V_F + V_R}{V_F - V_R}$$

$$= \frac{1 + V_F/V_R}{1 - V_F/V_R} = \frac{1 + |\rho|}{1 - |\rho|} \quad (4)$$

where  $\rho$  is the voltage reflection coefficient. At all points along a lossless line  $\rho$  is constant in magnitude and varies in phase

$$\rho = |\rho| \exp(j(\phi - 2\pi l/\lambda)) \quad (5)$$

where  $\phi$  is the phase angle of the reflection at the load and  $l$  is the distance along the line from the load. The impedance at any point on the line is related to the reflection coefficient, by

$$R + jX = \frac{1 - u^2 - v^2}{(1 - u)^2 + v^2} + j \frac{2v}{(1 - u)^2 + v^2} \quad (6)$$

From this relationship it may be seen that loci of constant values of  $R$  and circles on the  $P$  plane have centres  $(R/1 + R, 0)$  and radii  $1/1 + R$ . Similarly constant values of reactance,  $X$ , correspond to circles centre  $(1, 1/X)$  and radii  $1/X$ . The mapping of  $R$  and  $X$  on the  $\rho$  plane is called (after the inventor) the Smith Chart. Any point on the chart corresponds to both an impedance and a reflection coefficient. Impedances are normalized to the characteristic impedance of the line such that  $Z = 1 + j0$  corresponds to a matched load,  $P = 0$ .

The Smith chart, in either its impedance or admittance form, is an invaluable tool in the design of stripline components.

**Designing in microstrip**

Fig. 6 shows the construction of microstrip transmission lines. The field pattern on such lines is predominantly a transverse electromagnetic wave; that

is, the electric and magnetic fields are at right angles to one another and to the direction of propagation. Microwave integrated circuits use microstrip lines on high purity alumina substrates. The high relative permeability of alumina (typically  $\epsilon_r=9$ ) results in a small guided wavelength and so aids miniaturization. The very large alumina substrates which would be required at v.h.f. are not cost effective but microstrip techniques may still be used to advantage with conventional materials such as epoxy-glass or p.t.f.e. glass. Wheeler<sup>6</sup> has determined the relationship between substrate permeability, thickness, conductor width and line characteristic but the equations are tedious to solve for each application. Fig. 7 has been prepared so that conductor width may be readily determined for a particular characteristic impedance for the most popular thickness of printed circuit board (1.6 mm or  $\frac{1}{16}$  inch) and dielectric materials. Good quality epoxy-glass board may be used in most amplifier designs up to about 200MHz, above which frequency the loss may not be acceptable, while p.t.f.e.-glass is suitable for use up to several gigahertz. Fig. 8 shows the ratio of guided to free space wavelength for each of these materials as a function of characteristic impedance. Note that this ratio is not simply  $1/\sqrt{\epsilon_r}$ . This is because some of the field extends into the air above the line and thus travels at the free space velocity. On wider lines (those having lower characteristic impedance) an almost pure t.e.m. wave propagates and the velocity ratio approaches  $1/\sqrt{\epsilon_r}$ .

### References

1. RCA application note no. 3764.
2. Ruthroff, G. L., "Some transmission line transformers". *Proc. IRE*, Aug. 1959, pp.1337-1341.
3. Matthaei, G. L. "Tables of Chebyshev impedance - transforming networks of low-pass filter form", *Proc. IEEE*, Vol. 52, Aug. 1964, pp.939-963.
4. Motorola application report no. AN267.
5. Gibson, R.A. & Pitzalis Jr., O. "Tables of impedance matching networks which approximate prescribed attenuation", *Trans. IEE Microwave Theory & Techniques*, Vol. MTT-19, No. 4, April 1971, pp.381-386.
6. Wheeler, H. A., "Transmission line properties of parallel strips separated by a dielectric sheet", *Trans. IEEE, Microwave Theory & Techniques*, March 1965, pp.172-185.

(To be continued)

### Acknowledgement correction

The following acknowledgement should have been included at the conclusion of S. L. Silver's article "How speech can be compressed and expanded" in the September issue: "Copyright 1975 by Sagamore Publishing Company Inc. Reprinted by permission."

## Phase shift in loudspeakers

Recently several manufacturers have announced plans to market loudspeakers with phase shift taken as one of the design parameters. Loosely described as "linear phase" loudspeakers, these represent the practical evolution of engineering ideas which have been the subject of some controversy in the past. With this in mind *Wireless World* recently held a private conference, attended by 56 of the country's leading loudspeaker designers, to discuss the validity of the principles involved.

Papers were read, exploring various points of view, and some of these will appear as articles in *Wireless World*. In the discussion which ensued some new and interesting ideas were expressed, and a selection of these will appear in the letters columns in subsequent issues of the journal.

## Announcements

A conference on "Electronic Systems — Pilot 'A' Level" is to be held at The City University, St John Street, London EC1V 4PB on October 10th from 2.00 to 5.30 p.m. The aims are to describe the nature and content of the AEB "A" level syllabus in Electronic Systems and to make widely available the experiences of those schools teaching the course. Further information can be obtained from The Secretary, National Electronics Council, Abell House, John Islip Street, London SW1P 4LN.

"Electronic Calculators" and "Integrated Circuits" are two new short courses to be held at South London College commencing on Oct. 7 and Oct. 9 respectively. Applications should be made to the Senior Administrative Officer, South London College, Knight's Hill, London SE27 0TX.

The RAE classes which have previously been offered by Slough College of Technology will be taken over by the new Langley College of Further Education from September. The courses will continue to use accommodation at Slough College during the Autumn term. Full details of the courses can be obtained from E. C. Palmer, G3FVC, Langley College of Further Education, c/o Education Offices, 48 High Street, Slough, Berks SL1 1EN.

The Polytechnic of North London, Department of Electronic and Communications Engineering, Holloway, London N7 8DB is offering a range of courses on audio engineering and acoustics in 1975/76. For full-time students a new B.Sc degree in Electronics and Communications Engineering with audio engineering as a specialization starts this year. Part-time students can attend for one year on a course of Sound Studios and Recording. Fee for this course is £15 and it begins on October 28. Full details can be obtained from the Head of Department.

**Communication and its consequences** is an external studies course of nine lectures that has been organized at the University of Kent, Canterbury. The first talk will be at 7.00 p.m. on Oct. 16. The fundamentals of modern electronic communication systems and techniques will be discussed and demonstrated during the course. For further information contact Dr A. T. Barbrook, External Studies Office, Rutherford College, University of Kent.

Bedford Audio Club, 8 Emerton Way, Wootton, Beds, hold monthly meetings and are arranging a Winter programme and demonstrations. The club would be pleased to hear from enthusiasts in the area who wish to join or attend meetings.

The first class for the City & Guilds Radio Examination Course (No 765) to be held at the North and West Farnborough Further Education Centre, St Johns Road, Cove, Farnborough will be on Oct. 2nd, beginning at 7.30 p.m. There will also be a Morse Proficiency course beginning on September 29th at 7.30 p.m. at Oak Farm School, Farnborough, Hants.

Bury and Rossendale Radio Society will be holding RAE classes during 1975/76. The classes will be held at the Society HQ and full details of enrolment fees etc, can be obtained from Mr J. Marrow, 12 Halcombe Road, Tollington, Nr Bury, Lancashire.

A Radio Amateur Examination course will be held on Thursday evenings from 7.30 to 9.30 at the Technical College Annexe, Tamworth Road, Croydon, Surrey commencing on Oct. 2nd. Enrolment will be at the College Annexe on September 20th (10 a.m.-3 p.m.) or on the first evening. Further details may be obtained from P. L. A. Burton, Tel. 01-669 6700 (day) or Downland 51413 (evenings).

Two new companies have been set up to market Redac software and services in the German Federal Republic and the U.S.A. They are CADE, Laichingen, Nr Stuttgart and Redac Interactive Graphics Inc, Littleton, Mass., USA. Redac Software Ltd is the computer aided design division of the Racal Electronics Group.

On July 18, the share capital of Jaybeam Ltd, Moulton Park Industrial Estate, Northampton NN3 1QQ was transferred to Jones Stroud Ltd of Nottingham and consequently the Group of Companies is now a subsidiary of Jones Stroud (Holdings) Ltd.

A weekly bulletin which lists all published UK patents relating to electronics and associated technologies is available from PATINEL, 13 North Avenue, Gosforth, Newcastle upon Tyne NE3 4DT. The bulletin is despatched within one week of the original publication of the patents by the Patent Office.

Integrated Circuit Design Workshop is a weekly afternoon laboratory design course of 12 weeks duration beginning on November 12, 1975 at the North East London Polytechnic, Department of Electrical Engineering, Barking Precinct, Longbridge Road, Dagenham, Essex RM8 2AS, tel: 01-599 5141.

As from September 1st, D.D. Electronics, 42 Bishopsfield, Harlow, Essex becomes Rock Electronics operating from the same premises.

The Autumn lecture meeting of the Society of Cable Television Engineers will be held on Oct. 14 at 2.15 p.m. in the Faraday Room at the IEE, Savoy Place, London WC2, when EMI Sound & Vision Equipment Ltd present a paper on "Hybrid v.h.f. to u.h.f. Cable Television Systems".

The Library and Information Services, IEE, Savoy Place, London WC2R 0BL are offering a literature search service covering the fields of electrical and electronic engineering, computers, control engineering and physics. Costs to users vary according to search method and/or length of search. Short manual searches are free of charge and all manual searches are subject to a discount for Institution members. For more information contact Hugh Wilman, Head of Library and Information Services, tel: 01-240 1871.

# RC oscillators

Tested circuits for a wide variety of oscillators are given in sets 25 & 26 of Circards. This article summarizes the various kinds

J. Carruthers, J. H. Evans, J. Kinsler and P. Williams

*Paisley College of Technology*

Amplifiers oscillate; oscillators may not. These guiding principles have been developed and confirmed over many years of patient experimenting, not least during the preparation of Circards. Early versions of operational amplifiers were particularly critical of the source/load/supply impedances and were prone to oscillate at high frequencies unless carefully used. Early transistors had low values of current gain and cut-off frequencies making it difficult to produce controlled oscillations.

These properties point to a dividing line between oscillators and amplifiers with feedback viz that they are of the same kind, differing only in the quantity and nature of the feedback. The point can be illustrated by Fig. 1 in which an amplifier of gain  $A$  has a portion of its output voltage  $\beta$  subtracted from the signal at the input. The gain of the amplifier with feedback can be greater or less than  $A$ , and the output will in general differ in phase. For well-controlled characteristics, the phase-frequency response has to be such that the feedback does not become regenerative until the magnitude of the  $\beta A$  term is below unity.

Feedback theory is formally expressed in many different ways, but one graphical approach that is helpful is to consider the root locus (Fig. 2). The graph plots the locus of the system transfer function as the frequency varies. Points on the horizontal axis correspond to phase shifts of zero (to the right of the origin) and  $180^\circ$  (to the left). Points on the vertical axis represent phase shifts of  $+90^\circ$  and  $-90^\circ$ . The distance of a point from the origin represents the magnitude of the transfer function. Thus in many amplifiers the region of the locus near the horizontal axis would represent a very wide range of frequencies since the gain remains constant and the phase-shift is zero or  $180^\circ$  over this range.

An important point on this graph is the point  $1 \angle 0^\circ$ . A general criterion, due to Barkhausen, suggests that if the locus of the system response does not enclose this point then the loop may be safely closed and the feedback will not cause the amplifier to become unstable. An exceptional state of conditional

stability can result where the amplifier/feedback network has multiple reactive elements producing a complex locus which would enclose the point in the event of a fall in the magnitude of the gain.

When the locus passes through the point we have  $\beta A = 1 \angle 0^\circ$  commonly called positive feedback and this constitutes an oscillator of constant but undefined amplitude, i.e. the signal feedback is just sufficient to sustain the output unchanged and without the need for an input signal. Alternatively we may view it as an amplifier of infinite gain, the denominator of the expression,  $1 - \beta A$ , having gone to zero.

The inevitable small variations in  $\beta$  and  $A$  caused by temperature, supply or

load conditions as well as by long term drift in component values, cause the amplitude either to decay away ( $\beta A > 1$ ) or to increase ( $\beta A < 1$ ). The limit is set by non-linearities in the system either inherent to the amplifier or deliberately added externally in the feedback network(s). These reduce  $\beta A$  and the oscillations settle down to a stable situation in which the mean value of  $\beta A$  over the cycle is unity.

For good frequency stability a number of precautions have to be observed (1) the amplifier should have negligible or very closely controlled phase-shift at the frequency of oscillation. (2) Amplitude of oscillation should be controlled to minimize distortion, since harmonics are fed back to the

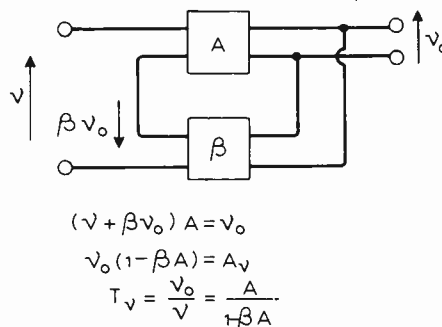


Fig. 1. A fraction of the output is added to the source at the input in deriving a standard form of the basic feedback equation. Positive feedback occurs when  $\beta A$  is positive.

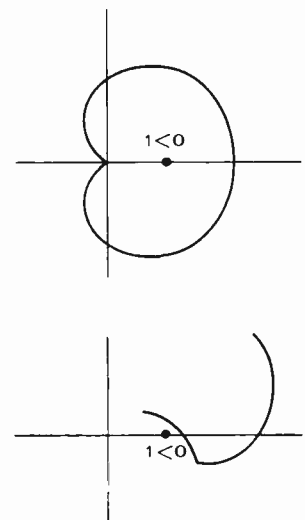
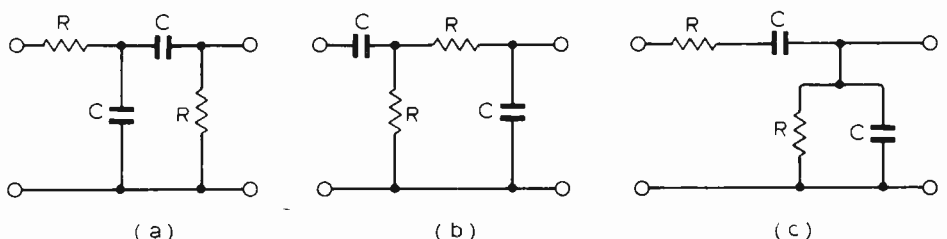


Fig. 2. If the in-phase and quadrature components of the overall loop gain are used as axes, the locus as the frequency is varied indicates the stability of the system.

Fig 3. These three networks have an identical transfer function and can be used interchangeably in oscillators.



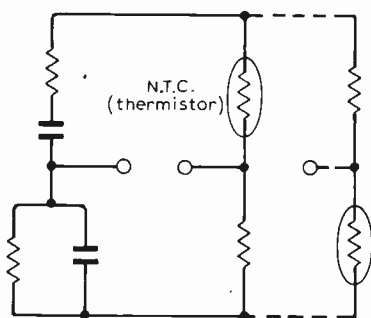


Fig. 4. Some oscillators use temperature-dependent resistors heated by the amplitude of the oscillation.

input and the resulting intermodulation reduces the frequency of oscillation below that predicted from the simple theory. (3) Input and output impedances of the amplifier must not load the RC networks significantly.

A major class of oscillators which includes the Wien bridge circuits, uses networks as in Fig. 3. Using equal values of  $R$ ,  $C$  throughout, the transfer function of each of these circuits is the same, with the output reaching a maximum of one third of the input when the phase shift is zero. Frequency is  $1/2\pi RC$ . Each can be used with an amplifier of gain  $+3$  to produce sustained oscillation. Many other combinations of these networks and amplifiers can be devised, by using current, transconductance and transresistance amplifiers.

Amplitude control may be via a gain-controlled amplifier whose gain is reduced as the output exceeds a given value, usually via a peak- or mean-rectifier and f.e.t. or similar controlled resistor. The classical solution is to use the RC network as part of a bridge

configuration with a high-gain amplifier monitoring the bridge unbalance. One of the bridge resistors is made amplitude sensitive, e.g. a filament lamp or thermistor arranged so that increasing amplitude of oscillation increases the amount of negative feedback thus stabilizing the oscillation amplitude Fig. 4.

These oscillators are controlled in frequency over a very wide range commonly by switching in pairs of capacitors as the coarse control or range-setting, with ganged resistors for fine control. The reverse is possible with high input-impedance amplifiers where high resistances allow the use of ganged tuning capacitors. Single-element control has obvious advantages of simplicity and economy, as well as the possibility of remote control via light dependent resistors and the like. Most solutions to this problem require a larger number of amplifiers to provide separate feedback paths by splitting the

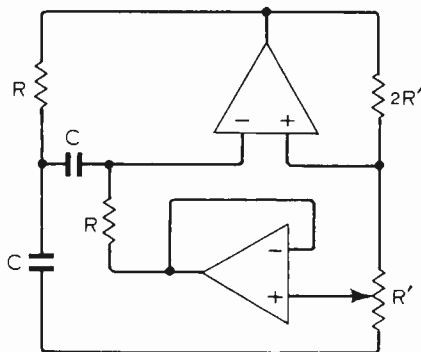


Fig. 6. Adding another amplifier at appropriate points in various oscillators allows a single control to change the frequency without varying loop gain.

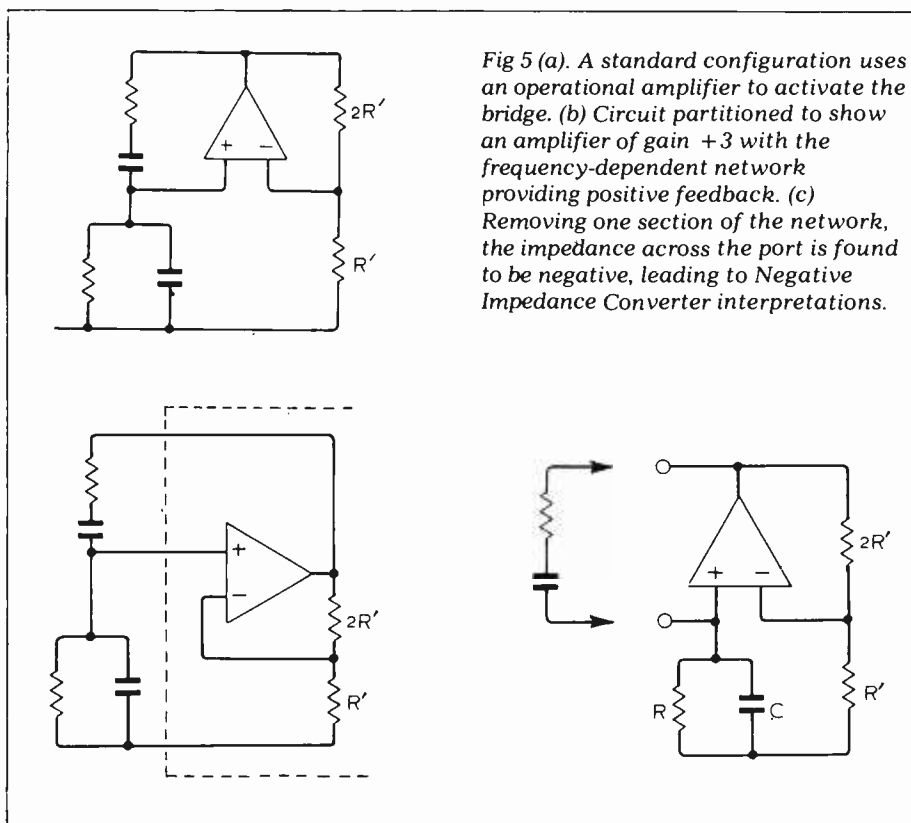


Fig 5 (a). A standard configuration uses an operational amplifier to activate the bridge. (b) Circuit partitioned to show an amplifier of gain  $+3$  with the frequency-dependent network providing positive feedback. (c) Removing one section of the network, the impedance across the port is found to be negative, leading to Negative Impedance Converter interpretations.

passive network in some way, and in addition there is an effective loss in  $Q$  of the system that results in increased distortion. One example out of many that have been designed is shown in Fig. 6. Frequency ranges of up to three decades have been reported, while the amplitude control mechanisms are similar to those above.

### T, phase-shift, and two integrators

Since both inverting and non-inverting amplifiers are obtainable, circuits can be designed in which the phase-shifts in the external networks are  $180^\circ$  and zero (or  $360^\circ$ ) respectively. An example of the former is the classical three section phase-shift circuit shown in Fig. 7. Using equal values of resistors and capacitors the network attenuation is rather large, the output being  $1/29$ th of the input at the frequency where the overall phase-shift is  $180^\circ$ . It is usually preferred to the alternative form using interchanged  $R$ s and  $C$ s, because the increased attenuation at high frequencies reduces the harmonic distortion and with it the corresponding shift in frequency.

If the RC values are scaled, then with  $n$  large each section can be analysed separately since the loading effects of the following section can be ignored. The phase shift of each section is then close to  $60^\circ$  at the critical frequency with a halving of the signal level. The amplifier then needs a voltage gain of  $-8$  but the demands on input and output impedances are more severe (the current that can be drawn from the network without loading it becomes very small while the current needed to supply it increases). Alternative methods are to separate the phase-shift networks, using one amplifier of gain  $-2$  between each section. Fig. 8 shows a related circuit that combines the gain and phase-shifting sections. Variants such as this are convenient for three-phase oscillators particularly as gain required from each stage is minimal.

A separate class of oscillators is based on null/notch/band-stop RC networks in which the signal transfer function tends to zero or a low value at a particular frequency (Fig. 9). These can give improved sharpness of tuning with lowered distortion, but interaction between the impedances can make them less tolerant of component drift. More important is the difficulty of tuning such circuits since several components need to be changed simultaneously. Separating the paths through these networks and driving them with individual amplifiers can allow control of the frequency without change in the amplitude condition.

There is a very close relationship between active filters and oscillators. They share common passive networks and in many cases one can be converted simply into the other by adjusting the damping factor (sharpness of tuning). A very important configuration which has wide application in both fields is the



two-integrator loop (Fig. 10). Well-known in analogue computing, it and its near relatives appear under a number of names including 'bi-quad,' 'triple,' 'state-space,' 'gyrator' etc. For ideal amplifiers the circuit Q is infinite without the need for positive feedback and it is particularly suited to the design of high-Q active filters by the addition of a small amount of negative feedback. In practice the net feedback will depend on internal phase-shifts as well as finite-amplifier gains, and both positive and negative feedback may be used to produce controlled oscillations.

If a single resistor or capacitor is varied then with ideal amplifiers, the circuit is still on the edge of oscillation, but the frequency at which oscillation can be sustained is varied. Single-element control of frequency is of considerable advantage in simplifying the construction of oscillators, since dual-gang controls are difficult to keep in a well-matched condition over a wide range. The feedback needed remains small under these conditions, being sufficient only to overcome amplifier imperfections and the finite Q of the capacitors.

Because the amount of feedback required is small it can be introduced via a clipping network that comes into action sharply at a particular amplitude without bringing in significant distortion. This gives instantaneous control of amplitude without the time delay due to heating effects with thermal control. In addition there are three separate outputs with 90° phase differences and the addition of another inverting amplifier gives the fourth phase if required. Again there are a number of combinations of amplifiers and network which share these desirable properties as in Fig. 11. In all of them there is a tendency to instability at high frequencies where the slew-rate limiting of the amplifiers produces a jump phenomenon that locks the oscillator into an output oscillation of higher frequency and uncontrolled amplitude.

Some of these networks are more usually interpreted as forms of impedance inverters/converters, in particular the gyrator, viz, a circuit that with a capacitor across one port synthesizes a purely inductive reactance across a second port. If that port has a second capacitor placed across it, a resonant circuit is established which sustains oscillation if a small amount of positive feedback is introduced. It is instructive to draw out the passive networks in such circuits since this clarifies the interrelationships between the various forms of oscillator and filter (Fig. 12).

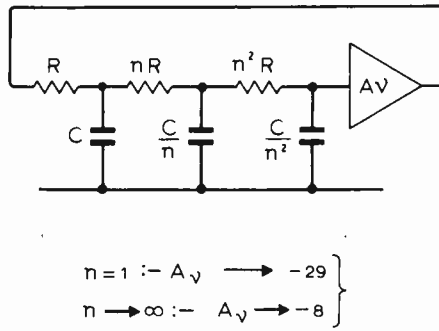


Fig. 7. If the impedances are graded to minimize loading of each section on the preceding one, each contributes 60° to the overall phase-shift at the frequency of oscillation.

Fig. 8. Three amplifier stages with defined gain/phase characteristics comprise a three-phase oscillator.

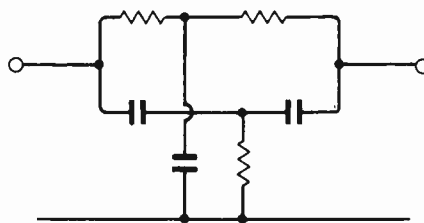
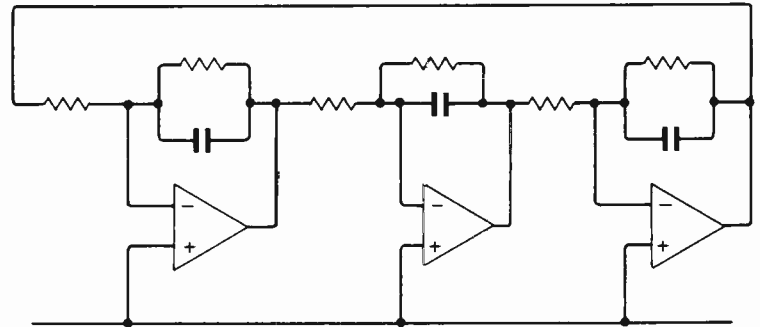


Fig. 9. T-networks can have zero-transmission at a particular frequency. Oscillators utilize positive feedback with the T-network in a negative feedback path.

Fig. 10. Two integrators plus an inverter form the nucleus of a number of oscillators and filters.

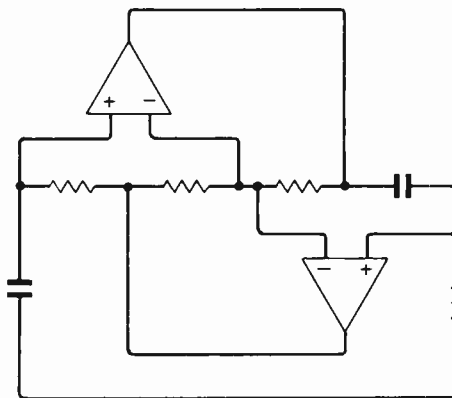
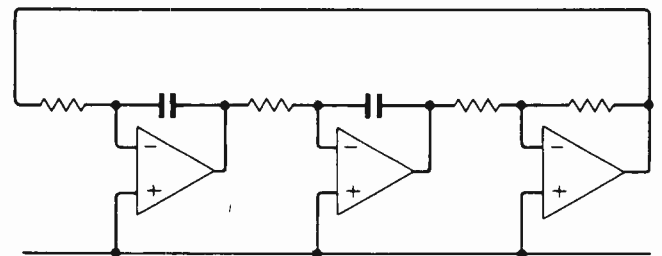
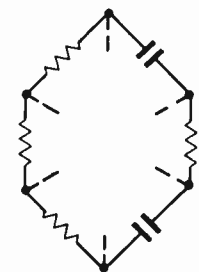


Fig. 11. Gyrators are a class of circuits that synthesize an inductive reactance from a capacitor. An oscillator results from resonating the reactance with a second capacitor.

Fig. 12. The previous two oscillators share a common passive network and can be shown to be functionally identical.



# World of Amateur Radio

## Typewriters rampant

Recently, on 3.5 MHz, I was in touch with Ian Trusson, G3RVM, near Swindon. A few minutes later, switching to 7 MHz, the next contact was with DL2QB in Cologne. Nothing very unusual about that — except for an interesting coincidence. Both of these c.w. stations, it transpired, were not using any of the usual forms of Morse key. Instead the operators were typing their messages on a typewriter keyboard — and electronics was doing the work of converting the letters into perfect international Morse. While still unusual enough to make two successive contacts surprising, this approach is clearly gaining ground. Although the keyboard encoders used by these stations were apparently home constructed, such equipments are now marketed. For example the DKB-2010 dual mode keyboard provides an output encoded either as r.t.t.y. (radio teleprinter) or c.w. and is claimed by Hal Communications Corporation as “one of the most sophisticated products ever offered to radio amateurs”. It permits r.t.t.y. at the various standard rates up to 100 words per minute (or optionally 132 w.p.m.) or c.w. between 8 and 60 w.p.m. Normally it is used with a 3-character memory, but 64-character memories are available.

Another use of electronic keyboards is reported by Richard Thurlow, G3WW. For several months he has been using one for slow-scan television (s.s.t.v.). His unit, the first in Europe, was constructed by Howard Watson, G3GGJ to a design by WoLMD, first demonstrated in the United States in 1973. Two Swiss amateurs and several others outside the USA are now using a commercial version of this design, made by Sumner Electronics.

Slow-scan continues to attract growing interest and a special s.s.t.v. convention is being organised by the British Amateur Television Club at Aston University, Birmingham on Saturday, October 11 (1000 to 1800 hours), open to all interested in the subject. One possible demonstration will be of a Robot slow-to-fast and fast-to-slow storage tube converter capable of giving a “frozen” s.s.t.v. picture on a

normal domestic TV set. Details and tickets (50p) from Mike Crampion, G8DLX, 16 Percival Road, Rugby CV22 5JS.

## A transatlantic link severed

With the death of 82-year-old Fred Schnell, W4CF (formerly W1MO etc) all three participants (Delroy, Schnell and Reinartz) on the first amateur two-way contact across the Atlantic in November 1923 are now with us only in memory. The significance of that historic contact was not just that it happened — but that it happened on about 100 metres, rather than the 200 metres on which all earlier amateur transatlantic tests had concentrated. It was this contact, more than any other single event, that started the rush to shorter wavelengths and so heralded the opening of the short waves.

Schnell was the original “traffic manager” of ARRL and a little later vividly demonstrated to the American navy the effectiveness of compact short-wave radio equipment during a famous voyage of the battleship *U.S.S. Seattle*. The British pioneer, Gerry Marcuse, G2NM, used to tell the story of how, during the time when he maintained regular contact with the Seattle in the Pacific, an American reporter woke him early one morning by throwing stones at his window. He had come to Caterham because of widespread disbelief in America that such communication was really possible and insisted on Marcuse obtaining from Schnell the answers to five questions. Marcuse successfully obtained these and the American returned to London to report to the United States that these incredible contacts were really happening!

## American opinions

The American Radio Relay League received no less than 56,000 replies to a detailed questionnaire seeking members' opinions on the FCC “re-structuring” Docket 20282. These replies provide perhaps the most detailed “snapshot” of opinions, activities and interests of amateur opinion ever compiled.

Almost half of the 56,000 were aged 50 years or over; only 11% less than 25; only 5% under 20. Half had taken out licences between 1950 and 1970; 18% before 1939; 19% since 1970. Almost half held the two most difficult-to-obtain licences; extra class (12%), advanced (36%). There was very strong support for the American system of “incentive” licensing which encourages amateurs to qualify for more difficult licences by offering extra privileges (81% either strongly agree or agree with this approach; only 10% oppose).

At present all classes of American licence impose a Morse code requirement (Technician and Novice classes at 5 w.p.m.) and the analysis shows that

generally American amateurs oppose the institution of a new “Communicator” class of licence for v.h.f.-only without a code requirement (51% disagree, 39% agree this would be a good way to bring in more amateurs).

And while most of those replying agree that there is a need to change the existing structure to encourage growth there is strong dislike of the idea of code-less licences with Novice-level technical requirement: 60% believing this would “bring in more undesirable than worthwhile new amateurs” compared with 26% who favour the idea. Almost exactly half disagree or strongly disagree with the suggestion that knowledge of Morse is not as important as it once was, compared with 43% who believe this to be true. But it is clear from the replies that American amateurs are not particularly knowledgeable about what happens in other countries: 64% replying “don't know” to the question whether other countries have issued no-code licences.

Some 39% of the 56,000 are active on h.f. only; 13% on v.h.f. only; 36% on both h.f. and v.h.f., giving a breakdown of 75% h.f. compared with 49% v.h.f.

One has the impression looking at the detailed analysis that amateur radio in the United States is an ageing hobby, still based primarily on h.f. and that the participants are aware of this and anxious to encourage growth among youngsters, but not at the risk of making fundamental changes to the hobby that has retained their interest over many years.

## Moonbounce

Moonbounce (EME) communication between G3LQR and ZE5JJ, Rhodesia was achieved first during pre-arranged tests this Spring. During EME tests arranged by the Stanford Research Institute using a 150ft dish aerial some 55 contacts were made on 144MHz and 11 on 432MHz. An s.s.b. moonbounce contact has been made between VK5MC and W8PKY on 144MHz, the Australian station using rhombic aerials. The French amateur F9FT has made moonbounce contacts with stations in Europe and North America on 432MHz.

## In brief

The annual Amateur Radio Retailers Association's “Fourth Midlands National Amateur Radio Exhibition” is at the Granby Halls, Leicester on October 30, 31 and November 1... Overall winner of the 1975 National Field Day was the Channel Contest Group and the leading single-station entry was once again the East Barnet Amateur Radio Contest Club with the Rascal group as second in this section. Band leaders were: 1.8MHz Mansfield; 3.5MHz Reigate; 7MHz Ariel; 14MHz Channel; 21MHz Glenrothes; and 28MHz Channel.

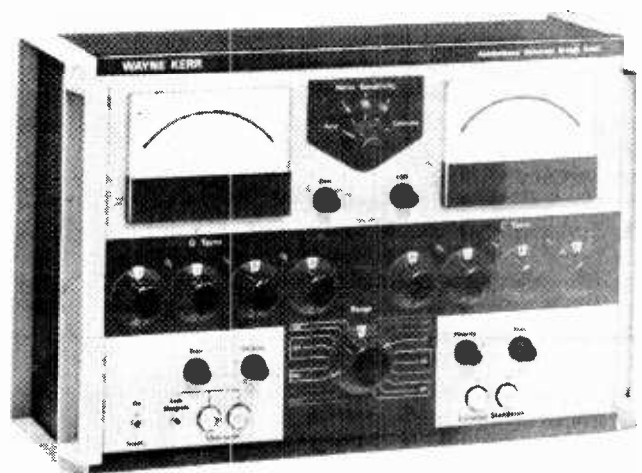
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Ranges for specified accuracy				
	0.1%	0.3%	0.1%	0.3%
C	100fF - 10 <sub>μ</sub> F	10 <sub>μ</sub> F - 10mF	1pF - 10 <sub>μ</sub> F	10 <sub>μ</sub> F - 10mF
G	1nΩ - 100mΩ	100mΩ - 1k	10nΩ - 100mΩ	100mΩ - 100Ω
L	1mH - 10kH	100nH - 1mH	1mH - 10kH	1 <sub>μ</sub> H - 1mH
R	10Ω - 1GΩ	1mΩ - 10Ω	10Ω - 100MΩ	10mΩ - 10Ω

NOTE: 0.1% accuracy relates to parallel component measurements above 10Ω impedance. 0.3% accuracy relates to series component measurements below 10Ω impedance.  
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# Resistors

## A survey of current resistor technology and applications

by R. A. Fairs, B.Sc.

Rank Radio International

**This survey, a sequel to "Capacitors" by the same author published in *Wireless World*, December 1974, describes the circuit analysis of simple equivalent circuits, the physics and significance of noise in resistors, the construction and properties of different resistor types and gives notes on their application. An applications chart relates the different properties and parameters.**

Resistors are the most commonly used components in electrical networks. Their presence in circuits is often taken for granted — a demand for a 470-ohm half-watt resistor is met by going to the appropriate box, selecting the component, placing it in circuit and usually forgetting about it.

Perhaps the first curious fact that would manifest itself to a newcomer to electronics would be the "odd" values that resistors take, for instance 4.7 and 680 ohms. These values are in answer to a problem. One requires to fill a certain band, say one to ten ohms with resistors manufactured to a particular tolerance in the most practical way. A good method is to use a logarithmic sequence (eqn. 1) which generates the E series of preferred values when Rn is rounded to two significant figures.

$$\epsilon \sqrt{10^n} = Rn \quad (1)$$

$$\epsilon = \frac{100}{t} (1 + 0.2)(0.8)^m \quad (2)$$

Where  $\epsilon = E$  number,  $n = \text{integer} \geq 0$  and in (2),  $t = \text{tolerance of resistors in percent}$ ,  $m = 0$  for  $5 \leq t \leq 20$  = 1 for  $0.5 \leq t \leq 2$ .

For 10% tolerance resistors equations (1) and (2) give the E.12 series of preferred values. For 5% tolerance

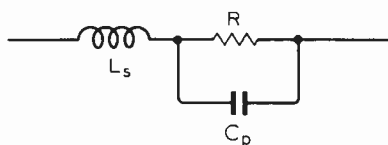


Fig. 1. Equivalent circuit for a resistor where  $L_s$  is the equivalent series inductance due to leads and construction,  $R$  is the apparent d.c. resistance and  $C_p$  is the parallel capacitance.

resistors the E.24 series result. The two series are shown schematically below where (3) is the E.12 series and (3) + (3a) is the E.24 series.

1.0	1.2	1.5	1.8	2.2	2.7	3.3	3.9	4.7	5.6
6.8	8.2								(3)
1.1	1.3	1.6	2.0	2.4	3.0	3.6	4.3	5.1	6.2
7.5	9.1								(3a)

### Equivalent circuit

By virtue of its construction, a practical resistor will include phenomena different from pure resistance. Fig. 1 shows an equivalent circuit for a resistor. If we take  $C_p$  as proportional to the magnitude of the resistor and constant along its body (to a first approximation) then we

$$Z = \left( \frac{1}{X_c} + \frac{1}{R} \right)^{-1} + X_l$$

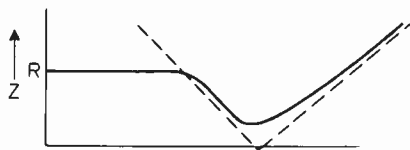


Fig. 2. Impedance of the equivalent circuit shown in Fig. 1.

have an impedance,  $Z$ , described by eqn. (4), and having the form of Fig. 2 when plotted against frequency,  $f$ , (on log-log graph paper).

$$Z = \left( \frac{1}{X_c} + \frac{1}{R} \right)^{-1} + X_l \quad (4)$$

From this we can make the following observations: for large  $R$  ( $> 500$  ohms)  $X_l \ll X_c$ ,  $Z \approx X_c$ . For small  $R$  ( $< 100$  ohms)  $X_l \gg X_c$ ,  $Z \approx R + X_l$ .

Some cancellation of  $X_l$  and  $X_c$  will occur if:

$$\frac{1}{X_c} \approx X_l, \quad X_l \gg \frac{1}{R}$$

For practical resistors (carbon composition type) variations of resistance with frequency are shown in Fig. 3.

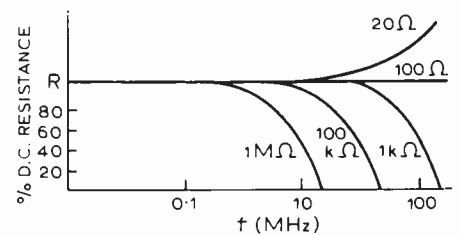


Fig. 3. Frequency characteristics for carbon composition types of resistor.

The curves shown are not entirely explained by eqn. (4). One may regard  $C_p$  as varying along the body of the resistor and not just as the simple sum of distributed capacitances. A more accurate interpretation of  $C_p$  is obtained by considering the body of the resistor as a distributed transmission line with capacitive and resistive elements\*. From this theory one may show that for each value of  $2\pi f$  there is a parallel combination of resistance  $R_{rf}$  and capacitance,  $C_{rf}$  which is an equivalent circuit for the resistor at a given frequency,  $f$ , provided the effects of inductance are negligible. In this case  $C_{rf}$  may change in sign as indicated in Fig. 4(a). The variation of  $R_{rf}/R$  is shown in Fig. 5.

Frequency effects are most pronounced in carbon composition and wire-wound resistors. In the latter type the variation of  $C_{rf}$  is extremely complex due to inductance effects which occur in the windings, however special winding techniques have been devised to improve the high frequency performance. Carbon film resistors have good stability at frequencies of 500MHz and over but in this instance mounting and connection become of importance.

\* Due to Howe 1933 (this theory also holds to some extent for film type resistors).

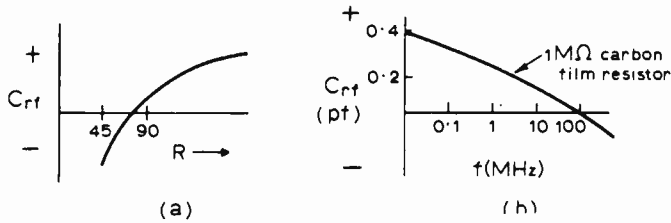


Fig. 4. Variation of  $C_{rf}$  with resistance at a fixed frequency.

Fig. 5. Variation of the ratio  $R_{rf}/R$  with resistance.

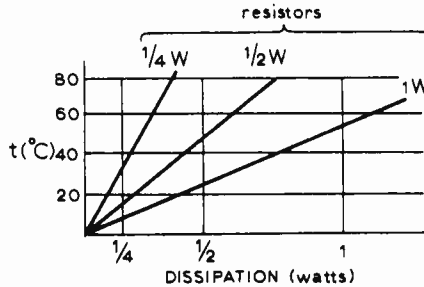
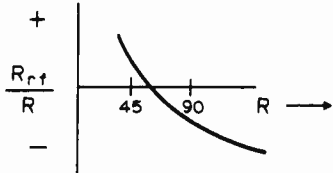


Fig. 6. Wattage curves for typical carbon film resistors.

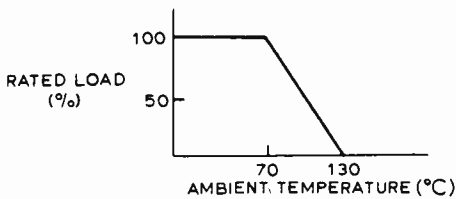


Fig. 7. Typical derating curve for a carbon film resistor.

The temperature at which a resistor is operated affects its stability (the ability of the resistor to keep to a particular resistance), and to a lesser degree its impedance characteristics. For resistance value a temperature coefficient (t.c.) is defined by:

$$t.c. = \frac{r \times 10^6}{R.t} = \frac{\text{change in resistance} \times 10^6}{\text{orig. resistance} \times \text{change in temp.}} = \alpha \text{ ppm}/^\circ\text{C where ppm} = \text{parts per million}$$

By defining the temperature coefficient in this manner it is independent of the units of resistance, and thus comparisons between resistors of differing magnitude may be made, as the change of resistance with temperature is rarely linear.

The wattage rating of a resistor is uniquely determined by the amount of power dissipated within it that creates a given long term stability of resistance value. The practical method of determining the wattage rating is to limit the body temperature to a certain quantity (see Fig. 6), but it is of importance that this will also depend on the ambient temperature of the surroundings, since this will affect the amount of heat transfer. For operation of resistors in high ambient temperatures a derating curve must apply; this curve is of the form shown in Fig. 7.

An excessive amount of power dissipated within a resistor causes violent

changes in resistance and ultimately thermal limitation occurs when the resistor breaks down.

For carbon film resistors definite observable changes manifest themselves during this type of overload. Firstly the resistor begins to emit a steady stream of smoke with a characteristic odour, it then glows cherry red and finally breaks down with three possible results: the resistor becomes open circuit, the resistor becomes short circuit or the resistor splutters hot carbon particles and eventually flames.

In practice the fact that the second case occurs means that detrimental effects could happen to other components (especially semi-conductors) in the circuit not necessarily responsible for the stress condition imposed on the resistor. Similarly, because of case three, components adjacent to the resistor may be permanently damaged by fire, and the risk of fire in the circuit as a whole is not to be dismissed lightly, particularly in consumer electronics.

For convenience it is desirable to select, where possible, a resistor which under extreme overload becomes open circuit and non-flammable.

In high resistance values there is a maximum permissible voltage which, rather than the maximum wattage, limits the use of a resistor. This is due to the dielectric of the resistor breaking down under the extreme electric fields created by the applied voltage. Local voids occur within the material and observable sparking becomes apparent in most cases.

### Pulse ratings

The response of resistors to transient effects is also of importance in circuit design. The same basic limitations of steady state conditions still apply here although the considerations are somewhat different.

In the transient case we have the form of Ohm's Law given by eqn. (5).

$$V^2 = W_p R \tag{5}$$

where:  $V$  = pulse voltage,  $W_p$  = peak wattage and  $R$  = resistance. The peak wattage is related to the maximum continuous wattage,  $W$ , by:  $W_p = W/ft$

where:  $f$  = frequency of the pulse and  $t$  = duration of pulse. Combining (5) and (6) we get

$$V^2 = \frac{WR}{ft} \tag{7}$$

From thermal considerations eqn. (7) suggests that there is no limitation on the pulse voltage, provided it is applied for a sufficiently short time. However, the reaction of the resistor to voltage stresses is almost instantaneous and there is a distinct stress region below which the resistor will not fail. Thus there is no gain achieved by pulsing the voltage.

Catastrophic failure by the spreading of voids in the material will increase with the frequency of the pulse since neutralization of the external field by space or surface charges cannot always take place (due to this being a time dependent process). Experience with the Corona effects in carbon film resistors limits the safe pulse voltage to twice the normal rated d.c. voltage.

### Noise considerations

Noise in an electrical circuit is an unwanted parameter. Being by far the most worrisome factor, resistors must be selected to give the lowest possible noise for a given application. Metal oxide resistors can be used at the input of audio amplifiers to promote low noise performance, if cost is not a prime consideration.

An intrinsic property common to all types of resistor is the generation of noise due to thermal agitation (Johnson Noise,  $J$ ). In any resistor we have three types of transport phenomena, viz: (a) random motion of free electrons, (b) thermal motion of molecules and (c) electron drift current due to the p.d. across the resistor. In order that the laws of physics be satisfied, equilibrium between (a) and (b) must exist. This causes a noise voltage,  $e$ , whose magnitude is (intuitively) dependent on temperature and the magnitude of the resistance to be superimposed on (c).

An exact expression for Johnson Noise has been given by Nyquist, i.e.,

$$e^2 = 4KRT.\delta f \tag{8}$$

where:  $K$  = Boltzmann's constant

$= 1.38 \times 10^{-23} \text{WK}^{-1}$ ,  $T$  = temperature in degrees kelvin (K),  $R$  = resistance in ohms,  $\delta f$  = bandwidth of measuring equipment (Hz),  $\bar{e}$  = mean noise voltage (volts).

Carbon composition resistors also exhibit noise due to the current flowing through the resistor. In this instance the noise is generated by random changes in the constituent material caused by the current flow. This noise (see appendix), termed current noise,  $E$ , is different in character from Johnson Noise,  $J$ , in the following ways:  $E^2 \propto \log(f_2/f_1)$  where  $f_2 - f_1 = \delta f$  (for  $\delta f = \text{const } E \propto 1/f$ );  $E^2 \propto V$  where  $V$  = direct voltage across resistor; and  $E \gg J$  (see Fig. 8).

It should also be mentioned that low noise in resistors can be obtained by operating the component well below its rated wattage (see Fig. 9). The noise figures for resistors are quoted in  $\mu\text{V}/\text{V}$  or in dB referred to a fixed figure (usually  $1\mu\text{V}/\text{V}$ ); a comparison between types is given in the Applications Chart.

**Solderability**

Solderability can, by virtue of overheating, cause a change in resistance. In miniature resistors the change can be excessive if the soldering

time is not limited. Soldering time can be shortened by the cleaning of soldering surfaces (particularly important for resistors that have been in stock). The tinning of leads will also reduce the soldering time, and the latter can often be seen to have been done by the manufacturer if the leads have a bright, clean appearance. A soldering time of two seconds at a temperature of  $240^\circ\text{C}$  is a maximum for flow soldering. For hand soldering, fifteen seconds at the same temperature is a safe maximum for the component.

The most important considerations in choosing a resistor for particular applications are: rated wattage, working voltage and resistance value; frequency characteristics and noise; environmental conditions (temperature and humidity considerations) and stability; physical size and cost.

It should be noted that a manufacturer cannot achieve a specific life or failure rate, but is able by quality of materials to ensure that the resistor is not subject to any known wear-out mechanism. Information such as resistance drift with respect to applied load, ambient temperature and time will be important in circuit application and thus individual manufacturers' data must be consulted.

A survey of the various types of fixed resistors now follows.

**Carbon composition resistors**

Carbon composition resistors were used extensively in the radio and television industries for power ratings of up to two watts during the valve era, and to some extent in the early days of transistors. Commercially the resistors were cheap and hence the detrimental effects of poor stability, large temperature coefficient, and high noise levels were to some degree offset.

The construction of carbon composition resistors falls into two basic types. In the first (uninsulated) the resistive element consists of finely ground carbon particles dispersed by a refractory filling, and bonded together with a synthetic resin binder. The resultant black powder (whose proportion of constituents determines the value of the resistance) is then compressed into shape and solidified in a kiln. The end connections are made by either forcing a metal end cap onto the carbon rod (Fig. 10) or by spraying the ends with metal and the leads soldered (Fig. 11). Alternatively the enlarged ends of the connecting leads may be moulded directly into the carbon rod.

The second type of resistor (insula-

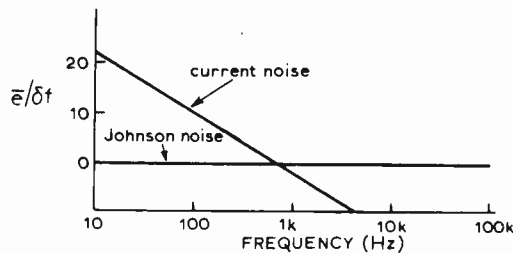


Fig. 8. Comparison of Johnson and current noise for carbon composition resistors.

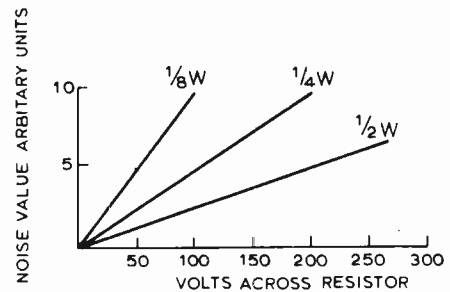


Fig. 9. Noise figures for carbon film resistors of differing wattage.

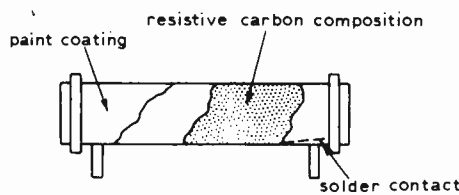


Fig. 10. Carbon composition resistor with the end connections made by forcing a metal end-cap onto the carbon rod.

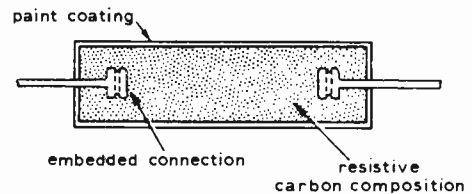


Fig. 11. Carbon composition resistor with the end connections made by spraying the ends with metal and the leads soldered.

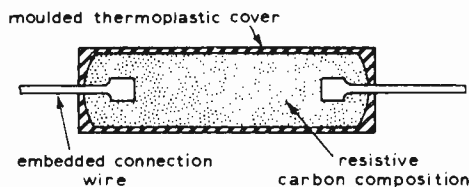


Fig. 12. Insulated carbon composition resistor construction.

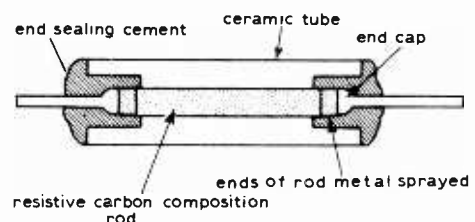


Fig. 13. Assembly of a ceramic tube type insulated carbon composition resistance.

ted) is constructed by encapsulating the carbon rod in either a thermoplastic insulation (Fig. 12), a moisture resistant silicone lacquer, or a ceramic tube. With the latter, construction is by placing the rods in ceramic tubes and fitting brass caps over the copper sprayed ends, which are then cemented with a moisture resistant cement. A typical assembly is shown in Fig. 13. Another method of constructing an insulated composition resistor is by dispersing the carbon granules and filler in a varnish which is applied to a glass tube. Leads are then projected into the tube and the whole assembly encapsulated by a moulded case.

The uninsulated form of carbon composition resistors are smaller than the insulated type for a given wattage. This is due to their open construction permitting good heat dissipation. However due to the necessity of preventing short circuits to adjacent components the insulated type of composition resistor is more widely used.

Carbon composition resistors have a large voltage coefficient which means that there is a change in resistance due to the applied voltage. This coefficient is insignificant in film types. Failure in composition resistors is rarely catastrophic, but on account of a large negative temperature coefficient the hotspot of the resistor is at the centre and will exhibit failure if overloaded by way of a reduction in resistance value in the first instance.

Abnormally high noise is generally due to poor terminations on the end cap which causes poor contact with the resistive element. Microphony may also be caused by the modulation of the noise voltage on the signal passing through the resistor.

The demand of transistor circuits caused high stability resistors to become dominant in electronics. On account of the initial investment of continental designers in their use of carbon film resistors during the post war boom in consumer electronics, manufacturing techniques caused the price gap between carbon composition and film to narrow and it is chiefly this reason that has caused carbon film resistors to be widely used in many branches of electronics.

### Carbon film resistors

In a cracked or pyrolytic film resistor a hydrocarbon vapour at a temperature of about 1000°C is decomposed onto a ceramic rod to produce a thin carbon film. The thickness of the film is a compromise between good electrical properties and detrimental temperature effects as indicated by Fig. 14.

The inherent value of the resistor is increased by spiralling the film to form a long continuous path thus yielding a typical gain in resistance value of 10-10000. The final resistor is thus compact in size and values of up to 10<sup>8</sup>ohms can be obtained.

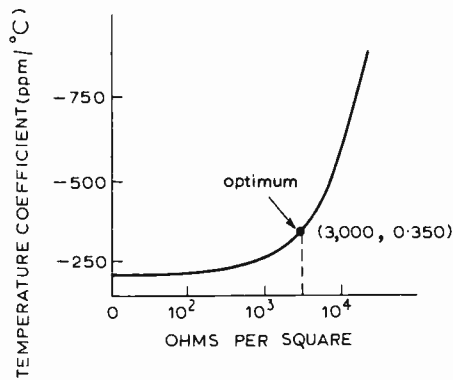


Fig. 14. Variation of the temperature coefficient with resistivity (thickness of carbon film).

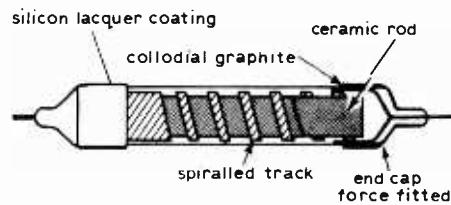


Fig. 15. Construction of a carbon film resistor.

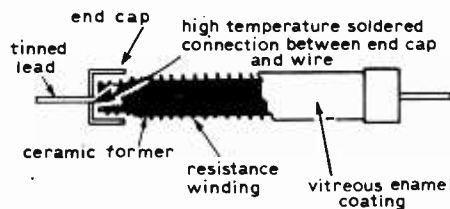


Fig. 16. One construction example of wirewound resistor.

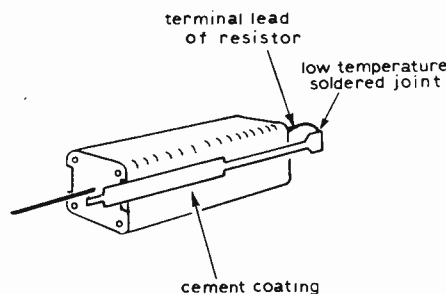


Fig. 17. Fusible type wire wound resistor.

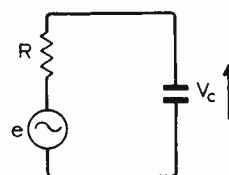


Fig. 18. Equivalent noise circuit where  $e$  is the noise voltage generator,  $R$  is a noiseless resistor and  $C$  is the parallel capacitance.

Terminations may be metal end caps pressed over the carbon film, or alternatively the ends of the ceramic rod may be metallized and the leads soldered to them. Owing to the delicate nature of the carbon film, protection against moisture and handling is necessary, hence apart from enclosing the resistive element in a ceramic or glass tube numerous varnishes are applied.

Construction of a carbon film resistor is shown in Fig. 15, and it is noted that this figure is representative of all types of film resistors as are the noise and failure considerations that follow.

The noise,  $n$ , in carbon film resistors is much less than in their composition counterparts. Its general properties are summarised by eqn. 9.

$$\begin{aligned} \text{(i)} \quad n &= f(v, l/t) \\ \text{(ii)} \quad n &\propto l/t^2 \end{aligned} \quad (9)$$

where  $v$  = voltage stress,  $t$  = thickness of film and  $l$  = length of film.

Typical noise figures are given in the application chart. Carbon film resistors are available in ratings of up to two watts, and in the latter case may be flameproofed for safety.

Failure is more common in the higher value resistors and is often caused by irregularities in the spiralled track and film. In the former a shallow groove causes an intermittent bridge between tracks whilst a deep groove will produce isolated sections of film along its edge resulting in instability and noise.

Of particular interest in carbon film resistors is the dependence of the temperature coefficient of resistance (t.c.r.) on the resistance value and rated wattage of the resistor due to the amount of effective carbon film involved in constructing the resistor. This is another instance where manufacturer's data is to be consulted.

### Metal oxide film resistors

The resistive film for these resistors is formed by the chemical reaction of aqueous stannic chloride on a glass or ceramic rod at red heat. A resulting hard glass-like oxide varying in thickness between 10<sup>-9</sup> and 10<sup>-7</sup> metres is produced. This oxide film is electrically conducting and inert to common chemicals. Its resistivity (typically 10<sup>3</sup>ohm/sq.) and temperature coefficient of resistance (usually  $\pm 250$ ppm/°C) may be modified by the addition of small amounts of antimony or boron added to the original chloride solution.

The final resistance value of the film is adjusted by cutting a helix along the ceramic rod. Terminations are similar to those of carbon film resistors but with more attention paid to detail to improve noise and reliability considerations. Encapsulation of the resistive element is usually by means of a suitable epoxy.

The noise and t.c.r. vary little with the value of the resistor and are a good deal lower than in carbon film types. The t.c.r. may be either positive or negative



**Application chart**

	carbon comp.	carbon film	metal oxide	metal glaze		metal film	wirewound	
				service	commercial		commercial	precision
Resistance range ( $\Omega$ )	10-22M	1-10M	10-150k	10-150k	10-150k	100-1M	100-1M	10-500k
Selection tolerance (%)	5-20	5	1-5	0.5	1	0.2-1	5-10	<0.5-0.1
Max d.c. voltage (V)	500	500	500	350	350	350	dependent on type	350
Insulation resistance ( $\Omega$ )	$10^4$	$10^7$	$10^8$	$10^9$	$10^9$	$10^9$	$10^7$	$10^9$
Voltage coefficient (ppm/V)	3000	100	negligible	negligible	negligible	negligible	negligible	negligible
Average size (length $\times$ diam) (mm)	15 $\times$ 6	10 $\times$ 3	7 $\times$ 2.5	7 $\times$ 2.5	7 $\times$ 2.5	7 $\times$ 2.5	dependent on type	on type
Cost	low	low	fair	fair	fair	fair	fair	high
Noise ( $\mu$ V/V)	3	0.15	0.03	0.4	1.0	0.015	negligible	negligible
Average frequency range (MHz)	$\sim$ 10	$\sim$ 50	$\sim$ 50	$\sim$ 50	$\sim$ 50	$\sim$ 50		
Stability after 1000 hours (%)	<20	<1	<0.5	<0.5	<1.0	<0.2	<2	<0.05
Max operating temp (ambient + load)	110	150	150	95	120	150	350	150
Temperature coefficient* of resistance (ppm/ $^{\circ}$ C)	<1200	250-1200	50-250	100	100	15-100	<200	<5
Max wattage (W) at surface temp of 70 $^{\circ}$ C	2	2	10	1	5	1**	50	1**

\* Absolute value.

\*\* High power types also available.

due to the semi-conducting nature of the oxide film. Most resistive films used in the construction of resistors are semi-conductive; the limit of precision in the composition of the film results in the t.c.r. being a positive or negative quantity for a given value and type of resistor.

Metal oxide resistors are used in circuit applications where stability and low noise are of importance. There is an increasing tendency to use metal film types.

Another application of metal oxide film is in power resistor developments. In this instance tolerance is typically 5% and the resistors are coated with a non-inflammable silicon cement and exhibit fusing characteristics. The considerations of cost and stability render this component competitive. High power types (up to 5000W) are also produced.

**Metal film resistors**

The film used in these resistors is achieved by the vacuum evaporation of nickel chromium alloys (surface resistivity  $10^3\text{ohm/sq.}$ ) or by the chemical deposition of nickel alloys (surface resistivity  $10^5\text{ohm/sq.}$ ) onto a cylindrical ceramic substrate. The metal film is eroded rapidly in humid conditions with a light d.c. load, and for this reason the resistive element is protected by encapsulation in one of the three following ways: lacquering and encapsulation in a moulded plastic case, sealing in a resin filled tube and lacquering and hermetic sealing in a ceramic tube with soldered ends.

The general construction of metal film resistors is similar to the types of film resistor already discussed, the difference being that the terminations may be made via forced metal caps which are in good contact with the resistive element by vacuum deposited terminating bands. Current noise level of metal film resistors is determined only by the cut of the helical groove (c.f. appendix). The t.c.r. may be as low as  $\pm 20\text{ppm}/^{\circ}\text{C}$ . The stability of metal film is good; results in

laboratory test conditions have given failure rates of 0.0012% for 1000 hours of life test.

From these considerations metal film resistors are becoming widespread in military and scientific applications where reliability and close tolerance are of importance. Power types are also available.

**Metal glaze resistors (cermet)**

In these resistors an organic suspension of metal and glass particles is applied to a ceramic rod and fired. As a result a thick resistive film remains on the rod. The firing process causes the ceramic to fuse with the thick film, thus the type of ceramic used influences the physical properties of the resistive element. Unsuitable thermal characteristics of the ceramic rod will cause an expansion effect with the film, as in a bimetallic strip of two dissimilar metals.

The construction of metal glaze resistors is similar to film resistors and shown in Fig. 15. The resistive film can be varied from  $10\text{ohm/sq.}$  to  $10^6\text{ohm/sq.}$  depending on the glaze used. An excess of glass in the suspension causes the metal particles to be disjointed, and hence produces a high but uncontrollable resistance.

Due to the high initial firing temperature, metal glaze resistors may be run at high temperatures and loads, in this instance conduction of heat away from the resistive element is via the terminations and the ceramic rod.

The noise level of metal glaze resistors is intermediate between film resistors and carbon composition. The t.c.r. is low ( $\pm 100\text{ppm}/^{\circ}\text{C}$ ) and stability is excellent on account of the body temperature of the resistor being low for the amount of power dissipated.

**Wirewound resistors**

In resistors of this type a length of resistance wire is wound on a bobbin (usually ceramic) and its ends anchored to terminal leads. A coating or case protects the wire from damage or corrosion. A suitable wire for general pur-

pose wire wound resistors is nickel chromium since it has good stability, a low t.c.r., and a high operating temperature. Encapsulation of the wirewound resistive element may be by cement, lacquer or vitreous enamel. Open wound resistors may be used in high power applications.

General purpose wirewound resistors are supplied to tolerances of 5% and 10% with wattage ratings of up to 50 watts. In the latter case a cement coating is used for the lower wattage types (up to 20 watts) which is not impervious to moisture but has the advantage of cheapness.

Vitreous enamelled types are usually of 5% tolerance but a 0.1% tolerance may be selected. Excellent protection against moisture is afforded by the vitreous enamel, and one general example of construction is shown in Fig. 16. In precision resistors the resistance wire is Eureka, which has a low t.c.r., but a relatively low operating temperature. In this case certain variations exist, viz: hermetic sealing in an oil filled tube, sealing in a ceramic tube, moulded plastic casing, and various kinds of lacquer. In the latter, protection against moisture is satisfactory but the working temperature is limited to around 170 $^{\circ}$  C.

In the use of wirewound resistors particular care must be taken concerning the high ambient temperature from affecting surrounding components. Power resistors of tubular construction convect heat through the hole. The operating temperature of the resistor may be used to effect a fusible resistor an example of which is shown in Fig. 17.

Frequency characteristics of wirewound resistors may be improved by special winding techniques, such as winding in anti-phase. Exact analysis of the effects encountered is impossible due to the number of variables, e.g., physical size, wire size differences, spacing etc. At around 2.5MHz low value resistors become capacitive so non-inductive windings are not of value.

Failure in wirewound resistors may be due to the following: (1) in high value resistors the wire may be blemished, (2) in vitreous enamel types expansion differences between the ceramic substrate and the enamel coating may cause cracking and penetrating of moisture, (3) corrosion of the wire due to d.c. load conditions can induce an excess of alkali in the enamel.

In order to eliminate (2) in their precision wirewound resistors, one manufacturer uses the same material for encapsulation as for the bobbin.

### Special types

High value resistors are composed of a carbon composition film resistive element in an evacuated glass envelope, the assembly strongly resembling a glass thermistor. Values of resistance up to  $10^{13}\Omega$  may be obtained.

Ceramic carbon resistors are able to withstand high voltages (typically 25kV) and are used as current limiting resistors in voltage multiplier circuits in television sets. Standard resistors are constructed as precision wirewound types, the wire used being manganin. A small adjusting resistor in parallel with the main resistive element gives trimming of the exact value. The range of ohmic value is between  $10^{-4}$  and  $10^3\Omega$ .

Precision power resistors (0.5%) may be constructed by mounting a suitable wirewound resistor or power metal film resistor in an extruded aluminium casing. With additional heat sinking this type of encapsulation is capable of dissipating 200 watts.

Recent developments in resistors include the encapsulation of an array of high stability resistive elements (15% to 2% tolerance) in a dual-in-line package similar to the micro-circuits already available. One immediate advantage here is that in low power applications repetitive resistors such as in current limiting for I.e.d. displays, assembly and overall cost are reduced.

Two types of resistive ink are used in the manufacture of resistor arrays giving rise to the terms plane film (sometimes referred to as thin film) and thick film.

In plane film types two inks are principally used, nickel/chromium (t.c.r. 30ppm/ $^{\circ}$ C) and tantalum/aluminium (t.c.r. 150ppm/ $^{\circ}$ C). The substrate is alkali free glass and the method of manufacture is by vacuum deposition. The geometry of resistors is achieved by selective etching which may be laser trimmed. Evaporated gold film is used for the patterns of the conductors, external connection being by soldering or thermocompression. Encapsulation may be d.i.l. or in an inert gas filled metal can.

Thick film types are constructed in a similar manner to plain film. The ink used is the same as for metal glaze resistors and this consists of an organic suspension of metal or metal oxide with

fine glass powder. The ink is screen printed onto the ceramic substrate, dried and then fired, insulating pastes are applied next and are in turn dried. Three or four printings may be required to build up the resistive network and the complete assembly (including terminal leads) is then passed through a furnace under a controlled process as some reaction with the ink may occur. In thick film circuits encapsulation is in d.i.l. form. Whole circuits including small capacitors may be designed into the package and most manufacturers offer a design service. The tolerance of the resistors produced may be as low as 2%.

### Further reading and acknowledgement

Many manufacturers provide excellent information on fixed resistors, among those of particular interest are technical literature by Mullard, ElectroSil, VTM, Allan Bradley, Utronix, Dale, Welwyn, and ITT.

A short list of further reading and references includes:

1. Dummer, Fixed Resistors, Pitman, 1956.
2. Dove, K. L. Metal Glaze Resistors, *Wireless World*, June 1970.
3. Dearden, J. Development of oxide film resistors, *Electronic Components*, Vol. 9, No. 2.
4. Boswell, D. & Russel, R. F. Thick and thin film resistors: performance and reliability comparison. *Microelectronics*, Vol. 1, No 1.
5. Browning, J. Film Resistors, *Electronic Components*, Vol. 16, No. 2.
6. B.S.9000 for methods of test and interpretation of information and results.

The author wishes to thank Rank Radio International for permission to publish this article, and in particular Mr. G. Botwright for his help with its preparation.

### Appendix

#### Noise in resistors

The noise voltages that appear across the terminals of any resistor are attributed to the random motion of free electrons in the material of the resistance. Electrons in a conductor are free to move by virtue of their thermal energy, and at a given instance more electrons may be directed toward one terminal of the resistor than the other. The result is a small p.d. across the resistor, and this p.d. will fluctuate as the electrons move.

Since the noise voltage across the resistor fluctuates randomly, it has Fourier components covering a wide range of frequencies. It is thus convenient to specify the noise voltage in terms of bandwidth as given by eqn. (8), viz:

$$\bar{e}^2 = 4KRT\delta f \quad (A1)$$

Eqn. (A1) may be derived as follows: consider the equivalent circuit shown in Fig. 18. We have:

$$V_c^2 = \frac{e^2}{1 + (\omega RC)^2} \quad (A2)$$

The condition of Fig. 16 is completely

determined by  $V_c$ . In thermodynamic terms the circuit is a system with one degree of freedom. According to the equipartition theorem in thermodynamics the total energy of the capacitor must be equal  $1/2KT$ , thus:

$$1/2KT = 1/2CV_c^2 = \int_0^{\infty} \frac{e^2 df}{1 + (\omega RC)^2} \quad (A3)$$

The integration extends over all frequencies  $f$  due to the random nature of the noise. Assuming that the noise voltage is independent of frequency, we have:

$$KT = Ce^2 \int_0^{\infty} \frac{df}{1 + (\omega RC)^2} = e^2/4R$$

i.e.  $e^2 = 4RKT$  (A4)

Eqn. (A4) shows that the noise voltage of resistances is independent of frequency, and accordingly, is termed "white" noise in analogy with the uniform spectral distribution of white light energy. This noise in resistors is also called Johnson or Nyquist noise after its discoverers. For a given bandwidth,  $\delta f$ , eqn. (A4) assumes the form of eqn. (A2).

Noise voltages in excess of Johnson noise are observed experimentally in certain resistances when a direct current is present. Although the physical origins of this additional noise are uncertain, an empirical expression for the effect is given by (c.f. eqn. (8)):

$$\bar{e}^2 = \alpha \frac{I^2}{f} \delta f \quad (A5)$$

where  $\alpha$  = constant (dependent principally on the geometry and material of the resistor),  $I$  = d.c. current and  $f$  = frequency.

The magnitude of the noise shown by eqn. (A5) (termed current noise,  $E$ ) varies markedly with the material of the conductor and its physical form. It is entirely absent in metals and hence is not observed in wirewound resistors. Composition resistors generate a large current noise due to the intergranular contacts in such resistors as shown by Fig. 8 in the main article.

### Peak-reading level indicator

The following notes are related to "Peak-reading audio level indicator," August issue. The value of  $R_{11}$  quoted in the components list applies to  $R_{11}$  connected to  $Tr_3$  gate and  $R_{16}$  in Fig. 3. The second resistor marked  $R_{11}$  connected to  $Tr_3$  source and  $C_8$  should be  $47k\Omega$ . The latter  $R_{11}$  is that mentioned on p.357, column 3. Left-hand side of the logic equation (p.359, column 3) should be  $Y_r$  not  $X_r$ . On page 360,  $VR_2$  should be  $R_{13}$ . Under the heading of "Construction" the second sentence should begin "Three types of board were used" not "Three boards were used." Finally, in Fig. 10 a diode 0A202 should be included connected from the inverting input of the second op. amp. to the base of the 2N2905 transistor.

# New Products

## Low profile i.c. socket

Known as the Ultra Low Profile Socket, this i.c. socket is available in 6, 8, 14, 16, 18 and 22 pin, 0.3in pitch versions. When fully inserted, the i.c. is 0.16in from the p.c.b. Contacts first grip the flat of the i.c. pin and also make contact with the wider surface area at the top, reducing contact resistance to typically 6mΩ.

The socket conforms to the vibration requirements of BS2011 and DEF5011, and beneath the socket are four 0.02in

high feet acting as a moisture barrier, thus conforming to the BS9500 specification for i.c. sockets. Jermyn Manufacturing, Sevenoaks, Kent.

**WW 301 for further details**

## Cooling fans

Designed for forced cooling applications where space is at an absolute premium, the Rotron Piccolo fans are 80mm square by 38mm deep. From 9 to 13 litres per second of air flow are provided by the fans which are double insulated and protected.

Versions are available with either sleeve bearings for use up to 55°C, or ball bearings for use up to 75°C. Both versions can be supplied with either 115V or 240V motors. G.D.S. Sales Ltd, Michaelmas House, Salt Hill, Bath Road, Slough, Bucks.

**WW 302 for further details**

## Vibration analyzer

A Mark 2 version of the VM3C portable vibration analyzer is being offered by Vibro-Meter Ltd. Designed for use, even in hazardous environments, with signal

supplied from both piezo-electric and magnetic transducers, the read-out may be made in one of three modes. These are velocity, displacement or acceleration, shown as a deflection on a built-in meter.

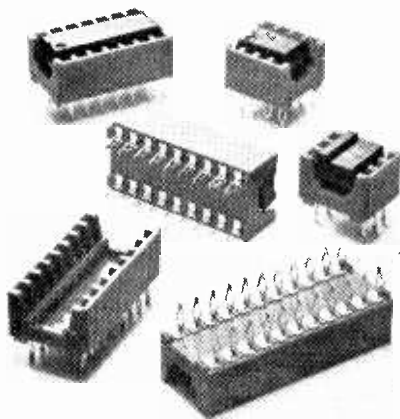
Narrow band analysis is possible using the variable filter which ranges from 10Hz to 10kHz. Powered from mains or internal, re-chargeable Ni-Cd batteries the unit is 300mm × 130mm × 310mm. Vibro-Meter Ltd, Newby Road, Hazel Grove, Stockport, Cheshire.

**WW 303 for further details**

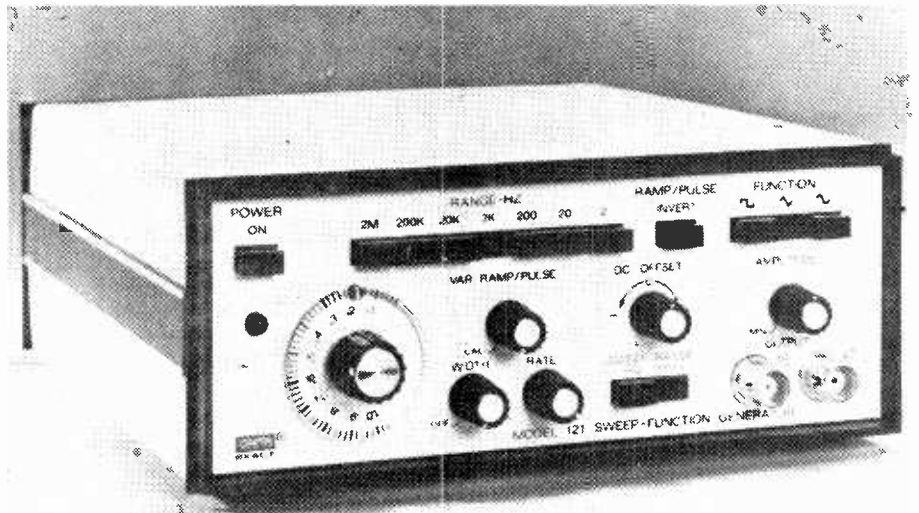
## Sweep/function generator

The model 121 Exact is a portable swept function generator with a frequency range from 0.002Hz to 2MHz and a range of waveforms with variable time symmetry. Outputs may be sine, square or triangle and have a swept range from zero to 1000:1 with a sweep rate continuously adjustable from 1ms to 10s.

Two output levels are available, 20V pk-pk open circuit, dropping to 10V pk-pk into 50Ω, and 632mV pk-pk open circuit, dropping to 316mV pk-pk into



**WW 301 for further details**



**WW 304 for further details**



**WW 303 for further details**



**WW 302 for further details**

50Ω. An invert switch is provided to reverse the polarity of the pulse and ramp outputs, a  $\pm 10V$  of d.c. offset and an external frequency control socket. The sweep waveform is available from a rear mounted socket. Price is £155, or the model 121A, with a 20dB step attenuator, is available at £195. Dana Electronics Ltd, Collingdon Street, Luton, Beds.

**WW 304 for further details**

## Static meter

With static becoming a serious problem in industry and the medical world, the model 703 non-contact static meter from 3M Nuclear Products can be useful to examine suspect surfaces.

It can be set to read at distances of 2, 6 or 12 inches and will detect potentials from 50V to 2000kV. The meter is battery operated from two 9V dry batteries, giving up to 100 hours continuous service.

The instrument operates on the principle of the discharge of a metal sensor plate in the muzzle, using a weak beta ray source. The small current thus generated is measured by means of an amplifier connected to the meter. The value and polarity of the charge is indicated.

A free "static analysis service" is also offered on industrial premises. Product Public Relations, 3M United Kingdom Ltd, 380 Harrow Road, London W9 2HU.  
**WW 305 for further details**

## Test set

A hand-held test set designed for fault-finding in data transmission systems, has been announced by IAL Data Communications. The Data Monitor Set PDMS 9801 shows, on a "go-no go" basis, the signal states on the ten most frequently used data and control circuits of a CCITT V24 interface. It is Post

Office approved for connexion to their modems and other approved modems in series with the modem-to-computer interchange cable.

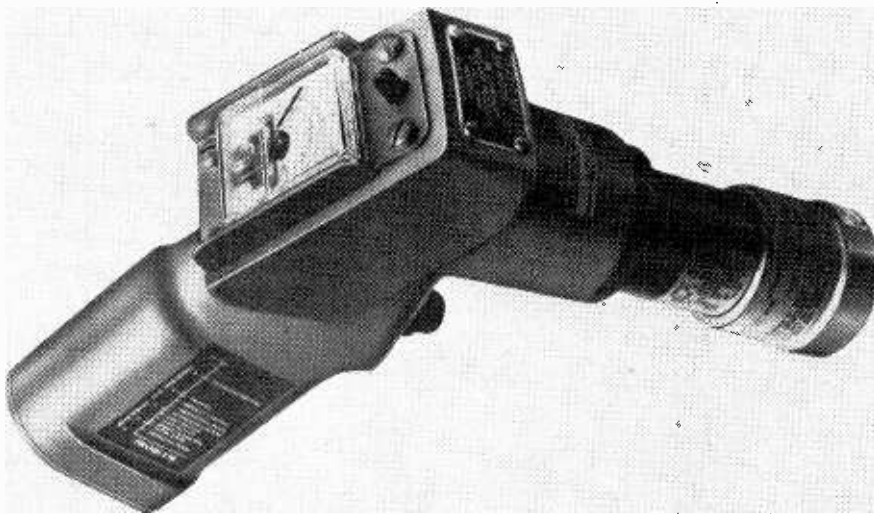
The test set imposes negligible loading on the system being tested and is powered by readily available dry cells. International Aeradio Ltd, Aeradio House, Hayes Road, Southall, Middx.

**WW 306 for further details**

## Multipurpose instrument

Digital is a precision voltage and current generator, v.o.m. and constant voltage or current power supply. Designed to provide a calibration source for d.c. instrumentation or other equipment, it offers five functions and 25 ranges.

An 8mm, 3½-digit l.e.d. display indicates the instrument's output which can be from 10μV to 100V at up to 100mA or 10nA to 100mA at up to 100V.



**WW 305 for further details**



**WW 306 for further details**



**WW 307 for further details**



**WW 308 for further details**

It will also measure external voltages or currents of a similar range and additionally measure resistance from 10m $\Omega$  to 100k $\Omega$ . Delresistor Ltd, 21 Windsor Street, Uxbridge, Middx.

**WW 307 for further details**

## Standard frequency receiver

One of a range of frequency standards manufactured by R.C.S., the type 103 receiver operates from the Droitwich signal and provides two outputs at 3V pk-pk square wave into 300 $\Omega$ , of 10MHz and 1MHz.

The short-term stability is 1 part in 10<sup>8</sup> and the long term stability, that of Droitwich itself. Manual controls are eliminated by the use of an automatic lock taking up to 20s from switch-on to operate.

A remote ferrite rod assembly is supplied for use as an aerial and the power requirements for the receiver are

220/250V, a.c. 50-60Hz. R.C.S. Electronics, National Works, Bath Road, Hounslow, Middx.

**WW 308 for further details**

## Portable tachometer

The Philips PR 9131 is a portable tachometer for direct measurements between 1 and 9999 r.p.m. An extension of the range above this is obtained by contactless measurement, from 100 to 999,900 r.p.m.

Accuracy is claimed to be  $\pm 0.2\%$  ( $\pm 1$  digit) of the true speed, the display being a 4 digit l.e.d. indicator. Power is provided from either mains or battery, the latter giving 180 minutes continuous use. Recharging takes approximately 10 hrs.

Price with case and accessories, but without batteries is £295. Pye Unicam Ltd, York Street, Cambridge.

**WW 309 for further details**

## Frequency synthesizer

Additional components are being offered to extend the range of the basic WJ-1250 modular synthesizer by Watkins-Johnson. These consist of a chassis (WJ-1253A) which can house up to three WJ-1251 r.f. sources, with automatic interfacing with the WJ-1250 microwave synthesizer main frame.

Two double-band r.f. sources using fundamental y.i.g.-tuned oscillators, one of which (WJ-1251-7) provides from 8 to 18GHz at 5mW (min), the other supplying 20mW (min) from 1 to 4GHz.

Various options and auxiliary modules are also available. Watkins-Johnson International, Shirley Avenue, Windsor, Berks.

**WW 310 for further details**

## Soldering iron

A 24V soldering iron suitable for continuous production usage has been introduced by Light Soldering Developments. Called the Conqueror, it weighs 35g and is supplied with a range of five bits from 1.6mm to 6.3mm and a spiral spring holder mounted on a Bakelite base. The base is fitted with a wiping sponge and can be fitted directly onto many existing 24V power units. Light Soldering Developments Ltd, 97-99 Gloucester Road, Croydon, Surrey

**WW 311 for further details**

## Injection moulded capacitors

High humidity protection is claimed for the 8017 series of capacitors from Advance Filmcap. The process eliminates voids occurring in normal resin encapsulation and ensures the accurate central location of the axial leads.

The range of values available matches the existing Filmcap polycarbonate and polyester ranges and has received British Post Office approval. Advance Components Ltd, Rhosymedre, Wrexham, Denbigshire.

**WW 312 for further details**

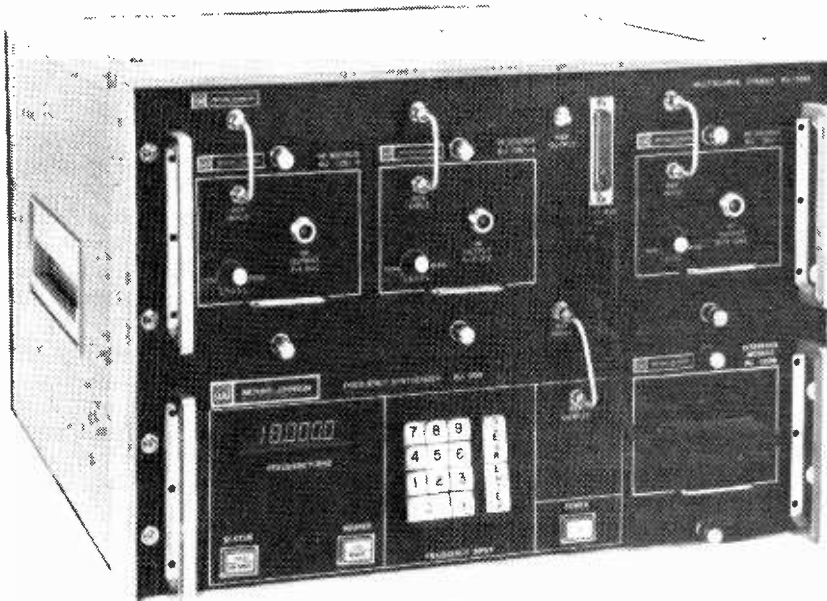
## Etch and wash unit

This is a heated p.c.b. processing tank with a spray wash bath, designed as a bench top unit 16 x 22 x 20ins. Heating and agitation is by a patented integral wall heater with air agitation. The wash tank contains two spray bars.

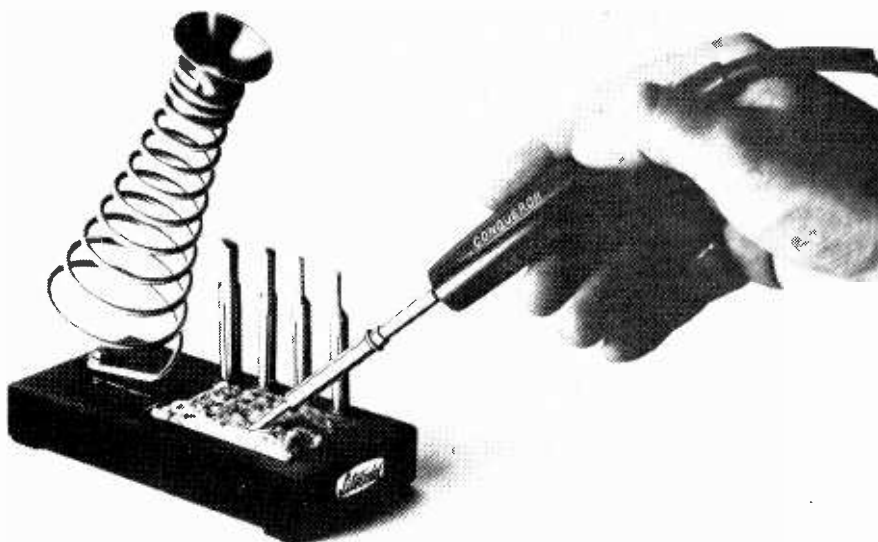
All controls, thermostat and air pump are part of the units which only require connection to the 240V mains supply, mains water and drainage.

Other units with develop, etch, tin or strip tanks each combined with a wash tank are available. Circuitape Ltd, 33 New Street, Aylesbury, Bucks.

**WW 313 for further details**



**WW 310 for further details**



**WW 311 for further details**

# Real and Imaginary

by "Vector"

## ON COMMITTEES

There's this friend of mine, see, who's the proud father of a seven-year-old son. One day, junior returns from school bursting with excitement and announces that his class is working on a new project, to wit, the manufacture of a papier-maché cow. You know — wire netting framework and that kind of lark. Pa, suitably impressed, asks questions, and in particular what son's contribution is going to be.

"Well, actually," says junior, voice trembling with pride, "teacher's appointed me chairperson of the crumpled horn committee!"

In these troubled times it's reassuring to know that our educational system is solidly behind us, nurturing our tender plants so that in the fullness of time the young idea will emerge completely meeting-orientated and ready to pull their full weight in British Industry.

I feel sorry for our forebears. I just don't know how they managed to cope in the B.C. (Before Committee) era. For, incredible as it may seem, Graham Bell, Edison, Marconi *et al.* seemed to have functioned on a bull-at-a-gate, suck-it-and-see basis and entirely without benefit of committees. That they got anywhere at all can only be attributed to beginner's luck. Fluking their way through, you might call it.

Yes, it's a great pity that the old-timers hadn't latched on to the committee approach, which, as all thinking men agree, was the greatest single invention since the wheel and girls. For, properly employed in industry, it confers two major boons; it's an almost foolproof safeguard against getting the sack and it creates an intense eager-beaver atmosphere without actually getting anything done.

Consider the instance of Bludswet and Teeres Ltd, electronic equipment manufacturers in a smallish way of business. In days of yore if one of their engineers had an idea (and they sometimes did) he'd wheel it along to the Chief Engineer. If the Chief liked it, he'd say go ahead and if it, subsequently proved to be a success — well, Chief Engineers were paid to spot winners. If

it didn't, another C.E. was appointed sharpish. Each position of high responsibility carried a built-in chopper; that was what it was all about.

How primitive! Thank goodness we have none of that barbarism nowadays! In the interim period Bludswet and Teeres have prospered and now constitute a democracy by committee. Their Research Dept. dream up an idea and, after lots of meetings, pass it to Development who hold a lot more and tag every electron involved so that they'd know it again if they met it in the street. The prototype is then processed through various channels and is eventually offered to the Commercial Manager; by this time it's not nearly such an original idea as it once was because a lot of water has gone under the bridge and those fiendish Japanese are believed to have got something similar up their kimonos.

In short, the new equipment is a dodgy potato and the Commercial Manager has been too long in the business to stick his neck out. So he sets up a committee of senior executives to brood over the project and eventually to advise him on a straightforward digital yes-no basis.

Naturally, they do nothing of the sort. They have serious responsibilities like week-end cottages, cabin cruisers and Mercedes cars to think about and they know just as much about hedging bets as the Commercial Manager. So they promptly appoint another set of committees at the next level below them. Thus, if we start off with a top-brass committee of ten (a reasonable figure) and each of these appoints a coven of similar size to advise him on his own peculiar interests in the equipment, we already have 110 good men and true involved in committee work.

But that's only the start. The lower (but still quite senior) stratum have no intention of facing a firing squad either, so they in turn delegate subordinates to . . . but I needn't go on because you know the picture anyway. And naturally, everybody on a committee has to hold a prior meeting with a few immediate colleagues in order to establish what he's got to say at the meeting. So, in no time at all, half the personnel at Bludswet and Teeres are involved in reporting to somebody or other. There are steering committees, whose members are specially selected for their complete lack of a sense of direction, and there are also things called working parties. Nobody has yet discovered what a working party is supposed to do. Nevertheless, momentous issues are being solved all the time. Somewhere in the morass a sub-committee has been haggling for months as to whether the chassis should be stoved in baby blue or a crackle finish.

The immediate consequence of decision-by-committee is that a mass of paper ascends to high heaven and flutters down to the IN-trays beneath. These memoranda require the utmost

care and deliberation in their composition; they must be verbose enough to impress the committee conveners but at the same time they mustn't actually say anything; particularly anything that could be construed as a recommendation one way or another. This continuous interdepartmental to-and-froing of memos has been unkindly described as a closed oscillatory circuit using paperwork coupling.

But at long last the moment of truth can no longer be delayed and, from the information dredged up, the Commercial Manager reluctantly decides that the new equipment shall go into production. The lengthy business of tooling up, buying in components and producing working drawings begins, and, of course, this necessitates a whole lot of new committees. Then, just after the point of no return, those perfidious Japs, who have no sense of the correct procedures, bring out something better on immediate delivery. But do heads roll at Bludswet and Teeres? They do not. The buck is passed down and down and you can't sack a committee complex consisting of half the factory, with at least three trade unions behind them.

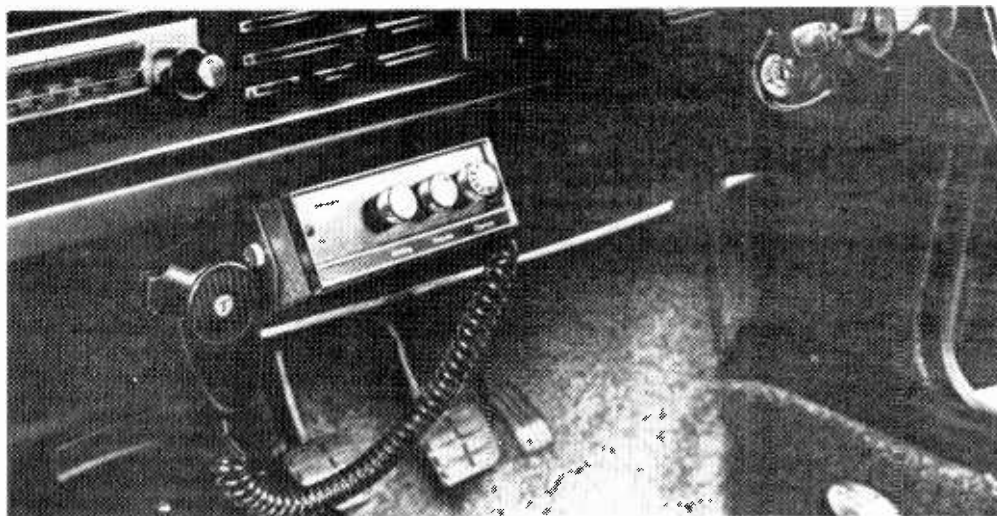
There are, broadly speaking, two distinct categories of meeting-attenders. There are the dedicated committee-men and those who have been co-opted protestingly from their lawful occasions to pronounce judgement on a technical issue. The latter are the sacrificial lambs who can (and assuredly will) be put on the altar should appeasement be demanded from on high.

Professional committee men come in various types. There is the Chairman, born with an agenda in his hand, who has an inexhaustible fund of Rabelaisian anecdotes with which to jolly the meeting along but who is known to have the ear of Sir upstairs, so watch it. Then there are at least two members of any given meeting who like to hear the sound of their own voices and are adepts at saying nothing at interminable length. There is Terribly Ernest, a junior executive from Trends and Tendencies Department; it is his first meeting and he's anxious to make a good impression upon his seniors.

Another well-known frequenter is Humpty Dumpty, so adept at sitting on the fence. There's the Doodler who spends the meeting sketching positions from the Kama Sutra on his pad. And then there's the Ancient, in his prime when the new-fangled triode was ousting the crystal detector; nobody is at all sure who he represents. He just sits in dour silence until the meeting's over and then totters off to a blue movie. And then there's — but you know them, anyway.

Meanwhile, back on the Works Floor the machines are on short time and the pound's taken yet another turn for the worse. H'm; it looks as though we'd better convene another meeting.

# The Dymar 971 radiotelephone.



So many savings, you'd think your accountant had designed it.

Dymar's 971 mobile radiotelephone offers fleet operators a whole series of super-saving features –

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● **Rugged construction.** The 971 is built to take the knocks, and has proved it over hundreds of thousands of miles of overseas operation. Should something go wrong, instant testing is also a simple plug-in operation. You save, again, on equipment down-time.

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● **Economy pricing.** 971 prices come as a pleasant surprise in these days of rising costs – the final argument to convince your accountant, or bank manager.

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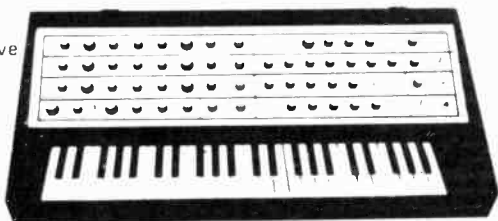
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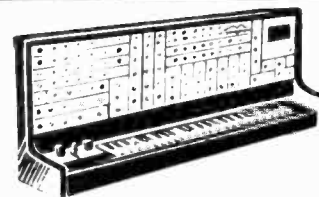
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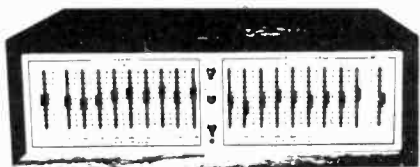
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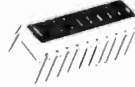
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CD4008AE	£1.75	£1.46	£1.17	7408	16p	13p	11p	709 (TO-99)	45p	CA3065	£1.60	MC1468G	£2.18	TAA300	£2.16
CD4009AE	Use	CD4049		7409	16p	13p	11p	710 (8 pin dip)	39p	CA3075	£1.64	MC1495L	£4.24	TAA310A	£1.87
CD4010AE	Use	CD4050		7410	16p	13p	11p	710 (TO-99)	39p	CA3078	£1.26	MC1496C	96p	TAA320	£1.44
CD4011AE	23p	19p	15p	7413	29p	24p	20p	711 (14 pin dip)	44p	CA3080	59p	MC1302P	£1.50	TAA370	£2.43
CD4012AE	23p	19p	15p	7417	27p	22p	20p	720 (A.M. Radio)	£1.76	CA3097E	£1.86	MC3401P	74p	TAA550	79p
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CD4014AE	£1.75	£1.46	£1.17	7427	27p	22p	18p	741 (8 pin dip)	36p	CA3401E (LM3900)	68p	MFC6030A	79p	TBA120S	£1.25
CD4015AE	£1.75	£1.46	£1.17	7430	16p	13p	11p	741 (10 pin dip)	43p	CA3600E	£1.44	MFC6070	£1.66	TBA231	£1.02
CD4016AE	69p	56p	46p	7432	27p	22p	18p	741 (TO-99)	36p					TBA281 (723)	£2.59
CD4017AE	£1.75	£1.46	£1.17	7437	27p	22p	18p	741 (14 pin dip)	£1.04	CT7001	£5.34	MM5314	£4.80	TBA500Q	£3.16
CD4018AE	£2.51	£2.09	£1.67	7441	75p	62p	50p	747 (14 pin dip)	£1.04	LM301 S (TO-99)	65p	MM5316	£9.99	TBA520Q	£3.85
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CD4020AE	£1.97	£1.64	£1.31	7445	85p	71p	57p	748 (TO-99)	46p	LM301A S (8 pin dip)	59p	NE561B	£5.06	TBA540C	£3.72
CD4021AE	£1.75	£1.46	£1.17	7447	95p	83p	67p	748 (14 pin dip)	49p	LM308 T (TO-99)	57p	NE565N	£2.96	TBA550Q	£5.29
CD4022AE	£1.83	£1.53	£1.22	7447A	95p	83p	67p	753 (IF M. Int. I.F.)	£1.08	LM308 S (8 pin dip)	92p	NE568V	£2.63	TBA920Q	£4.71
CD4023AE	23p	19p	15p	7448	85p	71p	57p	75491	88p	LM308 T (TO-99)	57p	NE567V	£2.63	TBA990Q	£4.71
CD4024AE	£1.26	£1.05	£0.84p	7470	30p	25p	20p	75492	£1.10	LM308 S (8 pin dip)	92p	NE555V	73p	TCA270Q	£5.24
CD4025AE	23p	19p	15p	7472	25p	21p	17p	Regulators 100 mA		LM308 T (TO-99)	57p	NE555V	73p	TCA760	£2.16
CD4026AE	£2.79	£2.33	£1.86	7473	30p	25p	20p	78105WC (TO-92)	60p	LM308 T (TO-99)	57p	NE555V	73p	TCA800Q	£7.04
CD4027AE	98p	82p	65p	7474	32p	26p	21p	78112WC (TO-92)	60p	LM308 T (TO-99)	57p	NE555V	73p	TCA830S	£7.24
CD4028AE	£1.53	£1.28	£1.02	7475	47p	39p	31p	78115WC (TO-92)	60p	LM308 S (8 pin dip)	92p	NE555V	73p	TCA940	£2.25
CD4029AE	£1.12	£1.76	£1.41	7476	34p	28p	23p	Regulators 100mA		LM308 S (TO-99)	57p	NE555V	73p	TDA1054	£1.50
CD4030AE	71p	59p	47p	7482	75p	62p	50p	78105WA (TBA625A) 90p		LM308 S (TO-99)	57p	NE555V	73p	TDA1200	£2.43
CD4035AE	£1.75	£1.46	£1.17	7485	£1.30	£1.09	87p	78112WA (TBA625B) 90p		LM308 S (TO-99)	57p	NE555V	73p	TDA1405	80p
CD4040AE	£2.01	£1.68	£1.34	7486	32p	26p	21p	78115WA (TBA625C) 90p		LM308 T (TO-99)	57p	NE555V	73p	TDA1412	80p
CD4042AE	£1.49	£1.24	99p	7489	£3.56	£2.80	£2.10	Regulators 500mA		LM308 T (TO-99)	57p	NE555V	73p	TDA1415	80p
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CD4050AE	69p	58p	46p	7491	65p	55p	45p	78M12HC	£1.35	LM339	£2.25	NE546A	£1.16	TDA2020	£3.75
CD4051AE	£2.78	£2.32	£1.85	7492	57p	46p	36p	78M15HC	£1.35	LM339	£2.25	NE555V	73p	ULN2111A	£1.52
CD4052AE	£2.78	£2.32	£1.85	7493	49p	40p	32p	78M18HC	£1.35	LM339	£2.25	NE560B	£5.06	ZN414	£1.26
CD4056AE	£2.12	£1.76	£1.41	7495	67p	55p	45p	78M24HC	£1.35	LM339	£2.25	NE568B	£5.06		
CD4060AE	£2.51	£2.09	£1.67	7496	£1.08	89p	72p	Regulators 1A		LM372N	£2.99	NE568V	£2.63		
CD4066AE	£1.13	94p	75p	74100	£1.08	89p	72p	7805KC (TO-3)	£2.09	LM373N	£2.71	NE568V	£2.63		
CD4068AE	28p	24p	19p	74107	35p	28p	22p	7808KC (TO-3)	£2.09	LM380	£1.25	NE568V	£2.63		
CD4069AE	28p	24p	19p	74107	35p	28p	22p	7812KC (TO-3)	£2.09	LM381	£1.85	NE568V	£2.63		
CD4070AE	28p	24p	19p	74121	34p	28p	23p	7815KC (TO-3)	£2.09	LM382	£1.66	NE568V	£2.63		
CD4071AE	28p	24p	19p	74122	47p	39p	31p	7818KC (TO-3)	£2.09	LM383	£1.66	NE568V	£2.63		
CD4072AE	71p	59p	47p	74141	76p	63p	53p	7824KC (TO-3)	£2.09	LM384	£1.66	NE568V	£2.63		
CD4081AE	28p	24p	19p	74145	68p	58p	48p	(ICL8038	£3.52	LM384	£1.66	NE568V	£2.63		
CD4082AE	28p	24p	19p	74154	£1.75	£1.48	86p	AY-1-0212	£6.93	LM384	£1.66	NE568V	£2.63		
CD4085AE	£1.28	£1.06	85p	74174	£1.00	83p	67p	AY-1-5051	£1.44	LM384	£1.66	NE568V	£2.63		
CD4086AE	£1.28	£1.06	85p	74180	£1.06	88p	71p	AY-5-1724	£3.95	LM384	£1.66	NE568V	£2.63		
CD4093AE	£1.56	£1.20	£1.04	74181	£3.20	£2.50	£1.90	AY-5-3500	£6.59	LM384	£1.66	NE568V	£2.63		
CD4099AE	£2.95	£2.46	£1.96	74192	£1.35	£1.14	90p	AY-5-4007	£7.94	LM384	£1.66	NE568V	£2.63		
				74193	£1.35	£1.14	90p			LM384	£1.66	NE568V	£2.63		
				74196	£1.64	£1.34	99p			LM384	£1.66	NE568V	£2.63		

### SIEMENS LCD's

LIQUID CRYSTAL DISPLAY complete with socket and removable reflective backing. Ref. AN4132R 13mm character height. Can be directly driven by National Semiconductor Alarm Clock chip MM5316. £13.99



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NEW LED Linear Cursors each device contains 10 light emitting diodes in a 20pin dual in-line package. Ideal for solid state analogue meters or dials. Type 101 RED. £2.26

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**2N5777**  
V<sub>ceo</sub>. V<sub>ceo</sub> 25v. V<sub>ebo</sub> Bv  
V<sub>ceo</sub>. V<sub>ceo</sub> 25v. V<sub>ebo</sub> Bv  
I<sub>he</sub> 2500. I<sub>c</sub> 250 mA **35p.**

### I.C. SOCKETS

Dual in-line		TO8	
Pins			
9	14	15	24
15	18	24	28
16	20	30	36
20	24	30	36
24	28	36	44
28	32	36	44
32	36	44	48
36	40	48	52
40	44	48	52

### L.E.D.'s

Free snap-on plastic retainer

0.125" dia. lens (TIL209)	0.16" dia. lens	0.2" dia. lens (MLED 350)	0.25" dia. lens
1p	10p	10p	10p
15p	10p	15p	15p
15p	20p	20p	20p
20p	20p	20p	25p
20p	20p	20p	25p
25p	20p	20p	25p
25p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p
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30p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p
30p	20p	20p	25p

Low Cost Red GaAsP Motorola MLED 500 in a TO92 package 15p

NEW Opto-isolators (IL1) (N25 or TIL116) 6 pin industry standard package 2.5KV isolation £1.66

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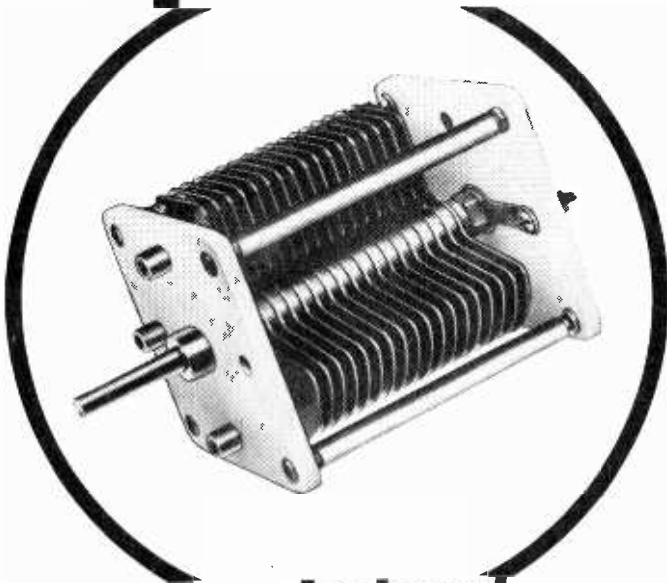
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- All UK small package orders will go first class mail.
- Minimum postage & packing charge will increase to 20p.

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	COMMON ANODE P.H. Dec. Pr.	COMMON ANODE L.H. Dec. Pr.	COMMON ANODE - 1 Dec. Pr.	COMMON CATHODE R.H. Dec. Pr.	Our Price
RED	DL707R	DL707	DL701	DL704	£1.82
GREEN	MAN51	MAN52	MAN53	MAN54	£1.82
RED	MAN71	MAN72	MAN73	MAN74	£1.82
YELLOW	MAN81	MAN82	MAN83	MAN84	£1.82
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GREEN	XAN51	XAN52	-	XAN54	£1.49

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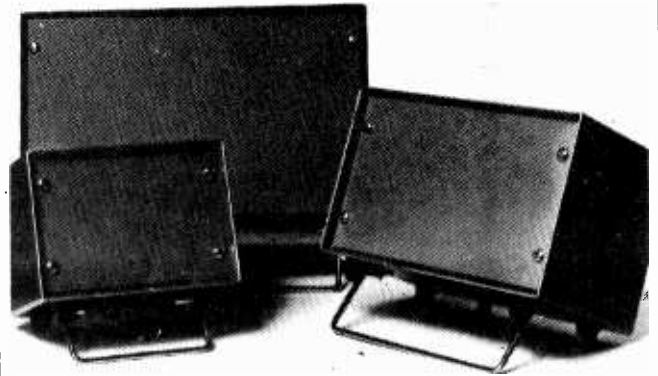
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# OLSON

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Standard minicases are made from 20g. mild steel sheets zinc-coated and finished in silver grey hammer-tone stove enamel. Front panels made from 18g. steel, finished in light grey high gloss enamel.

Type	Overall Dimension			Case no vents	Case with vents	Chrome leg
	Width	Height	Depth			
21	6½"	4½"	4½"	—	<b>3.92</b>	<b>0.90</b>
22	8½"	5½"	5½"	—	<b>4.40</b>	<b>0.90</b>
23	10½"	6½"	6½"	—	<b>5.25</b>	<b>0.95</b>
24	12½"	7½"	7½"	—	<b>5.74</b>	<b>0.95</b>
25A	6½"	4½"	4½"	<b>3.80</b>	<b>4.28</b>	<b>0.90</b>
25B	6½"	4½"	6¼"	<b>4.00</b>	<b>4.48</b>	<b>0.90</b>
26A	8¾"	5¾"	6¼"	<b>5.37</b>	<b>5.85</b>	<b>0.95</b>
26B	8¾"	5¾"	8¼"	<b>5.62</b>	<b>6.10</b>	<b>0.95</b>
27A	12¼"	7½"	5½"	<b>5.75</b>	<b>6.35</b>	<b>0.95</b>
27B	12¼"	7½"	8"	<b>6.35</b>	<b>6.95</b>	<b>0.95</b>
28A	14"	10½"	6½"	<b>6.95</b>	<b>7.55</b>	—
28B	14"	10½"	8½"	<b>7.55</b>	<b>8.15</b>	—
29A	10"	4"	6"	<b>4.85</b>	<b>5.33</b>	<b>0.95</b>
29B	10"	4"	8"	<b>5.15</b>	<b>5.63</b>	<b>0.95</b>
30A	12"	5"	6"	<b>5.25</b>	<b>5.85</b>	<b>0.95</b>
30B	12"	5"	8"	<b>5.56</b>	<b>6.16</b>	<b>0.95</b>
31A	14"	6"	6"	<b>5.75</b>	<b>6.35</b>	<b>0.95</b>
31B	14"	6"	8"	<b>6.05</b>	<b>6.65</b>	<b>0.95</b>
61	15½"	7½"	9½"	—	<b>8.75</b>	—
62	17½"	8½"	9½"	—	<b>10.15</b>	—
63	16½"	9½"	9½"	—	<b>10.15</b>	—
64	15½"	7½"	12½"	—	<b>10.15</b>	—
65	17½"	8½"	12½"	—	<b>11.60</b>	—
66	16½"	9½"	12½"	—	<b>11.60</b>	—

Types 21, 22, 23 and 24 are finished in olive green hammertone with front panels in light straw gloss enamel. Fitted with ventilated rear panels only. No louvres in the base.

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# JOY KIT

<p><b>KAMODEN 360 MULTIMETER</b> High sensitivity DC 100ohm/V AC 10ohm/V 5% mirror scale, overload protected. Ranges: 0.5/1/5/50/250/1000V DC, 5/10/50/250/1000V AC. Current: 0.01mA/0.1/5/50/500mA/10A. Resistance: 0.1/1/10/100 ohms. DC input: 0.1/1/10/100 ohms. -20 to +62dB. Battery operated. Size: 180 x 140 x 80mm. Supplied complete with test leads etc. <b>OUR PRICE £18.90</b> P/P &amp; Ins 60p</p>	<p><b>KAMODEN TT35 TRANSISTOR TESTER</b> High quality instrument to test reverse leak current and DC current. Amplification factor of NPN, PNP, diodes, transistors, SCR's etc. 4" square clear scale meter. Operates from internal batteries. Complete with instructions, leads carrying handle. <b>OUR PRICE £18.90</b> P/P &amp; Ins 60p</p>	<p><b>TE22 SINE SQUARE WAVE AUDIO GENERATOR</b> Sine 20cps to 200kHz on 4 bands. Squares 20 cps to 30 kHz. Output impedance 500 Ohms. 200/250V AC operation. Supplied brand new guaranteed, with instruction manual and leads. <b>OUR PRICE £26.90</b> P/P &amp; Ins 60p</p>	<p><b>SUPERB QUALITY LOW PRICES AUDIOTRONIC DIGITAL CLOCK RADIOS</b></p> <p><b>ADC22</b> 24-hour clock radio covering MW FM wave bands. 180-minute sleep timer. Choice of Grey or White cabinet. <b>OUR PRICE £17.50</b> P/P &amp; Ins £1.00</p> <p><b>ADC33</b> Deluxe 24-hour clock radio covering MW FM wavebands. 180-minute sleep timer. Buzzer alarm. Tone control. <b>OUR PRICE £19.95</b> P/P &amp; Ins £1.00</p>	<p><b>MINIATURE ORGAN MUSIC MASTER AM100</b></p> <p>Spanning nearly two octaves, including semi-tones This instrument will give hours of enjoyment to all the family. Beautifully finished. The keyboard range can be adjusted to be in tune with any instrument. Operates from internal 9V battery. Fitted with on-off switch, vibrato switch, earphone socket and external 9V D.C. socket. (Size 228mm x 127mm x 64mm) <b>OUR PRICE £9.95</b> P/P &amp; Ins 50p</p>	<p><b>FREE CATALOGUE</b></p> <p>LASKYS 32 PAGE CATALOGUE AND PRICE LIST absolutely free and available from all stores or by post (see coupon below). This exciting catalogue provides a comprehensive selection from the largest Hi-Fi Retailer in Europe - a MUST for every Hi-Fi and electronics specialist.</p>																
<p><b>Model HT100B4 MULTIMETER</b> Overload protected, shock proof circuits. 9.5" Mirror with mirror scale. Sensitivity 100kV. Polarity change. Ranges: 0.5/2/5/1/50/250/500/1,000 Volts DC, 2.5/10/50/250/1,000 Volts AC. DC resistance 0-20/200k/2/20 Meg. ohms. DC current: 0.1/250uA/1/2.5/25/250 uA. AC current: 0-10A -20 to +62dB. Operates from 2 x 1.5V batteries. Size: 180 x 134 x 79mm. <b>OUR PRICE £21.50</b> P/P &amp; Ins 60p</p>	<p><b>S100TR MULTIMETER TRANSISTOR TESTER</b> 100,000opv. Mirror scale. Overload protection. 0.86/1/2/0.6/3/12/30/120/500V DC. 0.6/3/10/30/120/500V AC. Sensitivity 0.1/2/60uA/1/2/30mA/0.1/2A DC. 0.01/0.2 MFD. Transistor tester measures Alpha, Beta and ICO. Complete with instructions, batteries and leads. <b>OUR PRICE £22.65</b> P/P &amp; Ins 60p</p>	<p><b>SINCLAIR DM2 DIGITAL MULTIMETER</b></p> <p>Will measure AC and DC volts, AC and DC current, and resistance in a total of 20 ranges. The large light emitting diode display will read up to 1998 and automatically indicate polarity. Indication of positive and negative overload is also provided. The instrument is fitted with a combined carrying handle and bench stand and sockets are provided for the connection of an external power supply.</p> <p>DC VOLTS 1, 10, 100V, 1000V AC VOLTS 1, 10, 100V, 1000V DC CURRENT 1mA, 10mA, 100mA, 1000mA AC CURRENT 1mA, 10mA, 100mA, 1000mA RESISTANCE 1k, 10k, 100k, 1000k <b>OUR PRICE £63.70</b> P/P &amp; Ins 50p</p>	<p><b>AUDIOTRONIC HEADPHONES</b></p> <p><b>LSH20</b> Individual volume controls Mono/stereo switch 40-19,000 Hz 8 ohms <b>OUR PRICE £6.25</b> P/P &amp; Ins 50p</p> <p><b>LSH30</b> Individual tone and volume controls Mono stereo switch 30-20,000 Hz 8 ohms <b>OUR PRICE £8.95</b> P/P &amp; Ins 30p</p> <p><b>LSH40</b> Two-way speaker system Individual volume controls 20-20,000 Hz 8 ohms <b>OUR PRICE £10.75</b> P/P &amp; Ins 30p</p>	<p><b>AUDIOTRONIC AH101 Stereo Headphone Amplifier</b></p> <p>All silicon transistor amplifier operates from magnetic ceramic or tube inputs with twin stereo headphone outputs and separate volume controls for each channel. Operates from 9V battery. INPUTS: 5mV and 100mV. OUTPUT: 50mV per channel. <b>OUR PRICE £10.65</b> P/P &amp; Ins 30p</p>	<p><b>FREE CATALOGUE</b></p> <p><b>HIGH QUALITY CONSTRUCTION KITS</b></p> <p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>																
<p><b>MODEL C7080EN</b> Giant 6" mirror scale, 20,000 opv. 0/0.25/1/2.5/5/10/50/250/1000/5000V DC. 0/0.25/1/2.5/5/10/50/250/1000/5000V AC. 0.5/5uA/1/10/100/500uA/10mA DC. 0/2k/20k/20 Meg. -20 to +50dB. <b>OUR PRICE £21.50</b> P/P &amp; Ins 60p</p>	<p><b>C15 PULSE OSCILLOSCOPE</b></p> <p>For display of pulsed and periodic waveforms in electronic circuits. VERT. AMP Bandwidth: 10MHz. Sensitivity at 100kHz V/M/5mm: 0.1-25. HOR. AMP Bandwidth: 500kHz. Sensitivity at 100kHz V/M/5mm: 0.3-25. Preset triggered sweep 1-3000uSec. Free running 20-200 kHz in fine range. Calibrator pops 220 x 360 x 430mm. 115-230V AC. <b>OUR PRICE £47.50</b> P/P &amp; Ins £1.50</p>	<p><b>ARF 300 AF/Rf SIGNAL GENERATOR</b></p> <p>All transistorised oscillator, battery operated. AF sine wave 18Hz to 220 kHz. AF square wave 18Hz to 100kHz. Output Square/Sine wave 10V. RF: 100kHz to 200MHz. Output 1V maximum. 220/240V AC operation. Complete with instructions and leads. <b>OUR PRICE £40.50</b> P/P &amp; Ins 60p</p>	<p><b>T.T.C. SPRITE STEREO HEADPHONES</b></p> <p>Feather weight 15oz) Dynamic stereo headphones providing high quality reproduction at a budget price. Soft removable ear pads and adjustable headband. Speaker size 28mm Impedance 8 ohms. Frequency response: 30-13000Hz <b>OUR PRICE £2.40</b> P/P &amp; Ins 30p</p>	<p><b>SAVE £9.35</b></p> <p><b>ELIZABETHAN DCR26 DIGITAL CLOCK RADIO</b></p> <p>A smaller than usual digital clock AM/FM radio, measuring only 8 1/2 x 3 1/4 x 4 1/2". The DCR is finished in simulated teak veneer and is fitted with a pre-set sleep timer switch that will turn on the radio at the precise time chosen (Mains operation) List Price £24.25 <b>OUR PRICE £14.90</b> P/P &amp; Ins £1.35</p>	<p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>																
<p><b>KAMODEN 72.200 Multitester</b></p> <p>High sensitivity tester, 200,000 opv. Overload protected. Mirror scale. Ranges: 0/0.6/3/3/30/120/600/1200V DC. 0/3/15/30/150/300/1500/3000V AC. 0.1/0.5/5/50/500uA/5M 500 Megohms <b>OUR PRICE £24.30</b> P/P &amp; Ins 60p</p>	<p><b>U4341 Multimeter &amp; Transistor Tester</b></p> <p>27 ranges, 16,700opv. Overload protected. Mirror scale. Ranges: 0.1/0.5/5/50/150/300/900V DC. 1.5/7.5/30/150/300/750V AC. Currents: 0.06/0.6/6/60/600mA DC. Resistance: 0-20/200k/2/20 Meg. ohms. 0.1/2A/20A AC. Battery operated. Supplied complete with probe, leads and steel carrying handle. Size: 215 x 90mm. <b>OUR PRICE £11.85</b> P/P &amp; Ins 60p</p>	<p><b>TRANSISTORISED I.C.R. AC BR 8 MEASURING BRIDGE</b></p> <p>A new portable bridge offering excellent range and accuracy at low cost. Resistance 6 ranges 0.1 ohm-11.1 megohm + 1% Inductance 6 ranges 1 microhenry-111 henries + 2% Capacity 6 ranges 10pf-1110 mfd + 2% Turns Ratio 6 ranges 1:1 1000:1 11100:1 1% Bridge Voltage at 1,000cps Operated from 9-volt battery. 100 micro amp meter indication. Size 74 x 5 1/2 x 2. <b>OUR PRICE £29.70</b> P/P &amp; Ins 60p</p>	<p><b>WALKIE TALKIES SKYFON NV7</b></p> <p>Super low cost transmitter/receivers 100MW with call buzzer and on-off volume control. 7 transistors. Telescopic rod antenna. <b>OUR PRICE £43.60</b> per PAIR P/P &amp; Ins 60p NOT LICENSABLE IN THE U.K.</p>	<p><b>SAVE £14.00</b></p> <p><b>ELIZABETHAN 8/LZ-1</b></p> <p>8 Track Stereo Player. Home 8 Track player with automatic and manual programme change and illuminated channel indicators for use with your hi-fi system. Size 7 1/2" x 12" D x 2 1/2" H. List Price £28.90 <b>OUR PRICE £14.90</b> P/P &amp; Ins £1.35</p>	<p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>																
<p><b>SWR METER Model SWR3</b></p> <p>Handy SWR meter for transmitter antenna alignment, with built-in field strength meter. Accuracy 5%, Impedance 52 Ohm. Indicator 100uA DC. Full scale 5 section collapsible antenna. Size 145 x 55 x 60mm. <b>OUR PRICE £4.55</b> P/P &amp; Ins 60p</p>	<p><b>MODEL TE20 RF SIGNAL GENERATOR</b></p> <p>Six bands, 120kHz-260MHz. Dual output RF terminals. Separate variable audio output. Accuracy ± 2%. Audio output to 8V. Power requirements: 105-125V, 220-240V AC. Size 193 x 265 x 150mm. Complete with test leads etc. <b>OUR PRICE £20.45</b> P/P &amp; Ins 60p</p>	<p><b>SINCLAIR Project 80 Modules</b></p> <p>240 Power Amp £5.60 P/P &amp; Ins 15p 260 Power Amp £6.95 P/P &amp; Ins 15p Stereo 80 Pre. Amp £13.10 P/P &amp; Ins 15p Active Filter Unit £7.40 P/P &amp; Ins 15p FM Tuner £13.10 P/P &amp; Ins 15p Stereo Decoder £8.60 P/P &amp; Ins 15p P25 Power Supply £4.55 P/P &amp; Ins 10p P26 Power Supply £8.40 P/P &amp; Ins 10p P28 Power Supply £7.90 P/P &amp; Ins 10p Transformer for P28 £5.10 P/P &amp; Ins 10p</p>	<p><b>HANIMEX HDC 1900 DIGITAL ALARM CLOCK</b></p> <p>240V operation with large clear numbers, night light and snooze switch. Attractively finished in white and silver. <b>OUR PRICE £8.10</b> P/P &amp; Ins £1.00</p>	<p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>	<p><b>FREE CATALOGUE</b></p> <p><b>HIGH QUALITY CONSTRUCTION KITS</b></p> <p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>																
<p><b>MODEL TE15 GRID DIP METER</b></p> <p>Transistorised. Operates as Grid Dip. Oscillator, Absorption Wave Meter and Oscillating Detector. Frequency range 440kHz-290MHz in six coils. 500uA meter. 9V battery operation. Size: 180 x 80 x 40mm. <b>OUR PRICE £18.90</b> P/P &amp; Ins 30p</p>	<p><b>LB4 TRANSISTOR TESTER</b></p> <p>Tests PNP or NPN transistors. Audio indicator. Operates on two 1.5V batteries. Complete with instructions etc. <b>OUR PRICE £4.85</b> P/P &amp; Ins 20p</p>	<p><b>AUDIOTRONIC LOW NOISE CASSETTES</b></p> <table border="1"> <thead> <tr> <th>TYPE</th> <th>5</th> <th>10</th> <th>25</th> </tr> </thead> <tbody> <tr> <td>C60</td> <td>£1.70</td> <td>£3.24</td> <td>£7.65</td> </tr> <tr> <td>C90</td> <td>£2.45</td> <td>£4.59</td> <td>£10.80</td> </tr> <tr> <td>C120</td> <td>£2.95</td> <td>£5.59</td> <td>£13.22</td> </tr> </tbody> </table> <p>P/P &amp; Ins 4p each 3 10p 4 and over 15p</p>	TYPE	5	10	25	C60	£1.70	£3.24	£7.65	C90	£2.45	£4.59	£10.80	C120	£2.95	£5.59	£13.22	<p><b>ORDER BY POST</b></p> <p><b>TO LASKYS CUSTOMER SERVICES DIVISION</b> Audiotronic House, The Hyde, London NW9 6JJ. Tel: 01-200 1321</p> <p>Please send me the following items</p> <p>Name _____</p> <p>Address _____</p> <p>Signature _____</p> <p><b>TOTAL PURCHASE PRICE</b> _____ (inc. P/P &amp; Ins)</p> <p>Please send me your Free 32 page Hi-Fi catalogue price list <input type="checkbox"/> I enclose cheque <input type="checkbox"/> postal order <input type="checkbox"/> money order <input type="checkbox"/></p> <p>I wish to pay by Barclaycard/Access and my number is _____</p>	<p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>	<p><b>FREE CATALOGUE</b></p> <p><b>HIGH QUALITY CONSTRUCTION KITS</b></p> <p><b>ALL PRICES REDUCED TO CLEAR</b></p> <p><b>LIMITED STOCKS</b> AT Oxford Street, 42 &amp; 257 Tottenham Court Road, 1, 2, Fleet Street, 311 Edgware Road, CROYDON BIRMINGHAM KINGSTON LEICESTER NORTHAMPTON SOUTHOLD TUNBRIDGE WELLS WOLVERHAMPTON branches or by Mail/Order</p> <p>All kits are complete with comprehensive easy to follow instructions and covered by full guarantee. Post and Packing Ins. 15p per kit.</p>
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<h3>TMK 200 MULTIMETER KIT</h3> <p>Build yourself a quality 20000 opv multimeter and save money. Complete kit with meter scale, movement and rotary range selector ready mounted in cabinet. All parts, batteries, test prods and instructions. Ranges: 0/0.6/6/30/120/600/1200V DC. 0/6/30/120/600/1200V AC. Current: 0/0.6/6/60/600mA. Resistance: 0/10/100K/1/10 Meg ohms. Decibels -20 to +63dB. Size: 90 x 150 x 35mm</p> <p><b>OUR PRICE £9.65</b> P/P &amp; Ins 30p</p> 	<h3>TMK MODEL TW50K</h3> <p>46 ranges, mirror scale. 50kΩ/V DC 50kΩ/V AC. DC Volts: 0.125/0.25/1.25/2.5/5/10/25/50/125/250/500/1000. AC Volts 1.5/3/5/10/25/50/125/250/500/1000. DC current 25/50uA/2.5/5/25/50/250/500mA/5/10A. Resistance: 10k/100k/1 Meg/10 Meg ohms. -20 to +81.5dB.</p> <p><b>OUR PRICE £13.50</b> P/P &amp; Ins 60p</p> 	<h3>Model HT100B4 MULTIMETER</h3> <p>Overload protected, shock proof circuits. 9.5uA Meter with mirror scale. Sensitivity 100kV. Polarity change switch. Ranges: 0.5/2.5/1/50/250/500/1000 Volts DC. 2.5/10/50/250/1,000 Volts AC. DC resistance 0—20/200k/2/20 Meg. ohms. DC current: 0/10/250uA/2.5/25/250mA/10A. AC current: 0—10A. -20 to +62dB. Operates from 2 x 1.5V batteries. Size: 180 x 134 x 79mm.</p> <p><b>OUR PRICE £21.50</b> P/P &amp; Ins 60p</p> 	<h3>U4341 Multimeter &amp; Transistor Tester</h3> <p>27 ranges. 16,700 opv. Overload protected. Ranges: 0.3/1.5/6/30/60/150/300/900V DC. 1.5/7.5/30/150/300/750V AC. Current: 0.06/0.6/6/60/600mA DC. 0.3/3/30/300mA AC. Resistance: 0.06/0.6/2/20/60/200k ohms/2 Mohms. Battery operated. Supplied complete with probes, leads and steel carrying case. Size: 115 x 215 x 90mm.</p> <p><b>OUR PRICE £11.85</b> P/P &amp; Ins 60p</p> 	<h3>SINCLAIR DM2 DIGITAL MULTIMETER</h3> <p>Will measure AC and DC volts, AC and DC current, and resistance in a total of 20 ranges. The large light emitting diode display will read up to 1999 and automatically indicate polarity. Indication of positive and negative overload is also provided. The instrument is fitted with a combined carrying handle and bench stand and sockets are provided for the connection of an external power supply.</p> <p><b>OUR PRICE £63.70</b> P/P &amp; Ins 50p</p> 
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<h3>U4324 MULTIMETER</h3> <p>High sensitivity. 20,000 opv. Ranges: 0.5/1.2/3/12/30/60/120/600/1200V DC. 3/6/15/60/150/300/600/900V AC. Current: 0.06/0.6/6/60/600mA/3A DC. 0.3/3/30/300mA/3A AC. Resistance: 25/50 ohms/0.5/5/50/500k ohms/5 Mohms. Decibels: -10 to +12dB. Size 167 x 98 x 63mm. Supplied complete with test leads, spare diode and instructions.</p> <p><b>OUR PRICE £10.60</b> P/P &amp; Ins 60p</p> 	<h3>MODEL 500</h3> <p>30,000 opv with overload protection. Mirror scale. 0/0.5/2.5/10/25A 100/250/500/1000V DC. 0/2.5/10/25/100/250/500/1000V AC. 0/50uA/5/50/500mA. 12A DC. 0/60k/6 meg/60 megohms.</p> <p><b>OUR PRICE £15.05</b> P/P &amp; Ins 60p</p> 	<h3>MODEL C7080EN</h3> <p>Giant 6" mirror scale. 20,000 opv. 0/0.5/2.5/10/50/250/1000/5000V DC. 0/2.5/10/50/250/1000/5000V AC. 0/50uA/1/10/100/500mA/10A DC. 0/2k/200k/20 Meg. -20 to +50dB.</p> <p><b>OUR PRICE £21.50</b> P/P &amp; Ins 60p</p> 	<h3>S100TR MULTIMETER TRANSISTOR TESTER</h3> <p>100,000 opv. Mirror scale. Overload protection. 0/0.12/0.6/3/12/30/120/600V DC. 0/6/30/120/600V AC. 0/12/60uA/12/30mA/6/12A DC. 0/10k/1 Meg/100 Meg. -20 to +50dB. 0.01-0.2 MFD Transistor tester measures Alpha, Beta and ICO. Complete with instructions, batteries and leads.</p> <p><b>OUR PRICE £22.65</b> P/P &amp; Ins 60p</p> 	<h3>TE-200 RF SIGNAL GENERATOR</h3> <p>Accurate wide range signal generator covering 120 kHz-500 MHz on 6 bands. Directly calibrated. Variable R.F. attenuator audio output. Xtal socket for calibration. 220/240V a.c. Brand new with instructions. Size 140mm x 215mm x 170mm.</p> <p><b>OUR PRICE £24.30</b> P/P &amp; Ins 60p</p> 
<h3>U91 Clamp VOLT AMMETER</h3> <p>For measuring AC voltage and current without breaking circuit. Ranges: 300/600V AC. Current: 10/25/100/250/500A. Accuracy 4%. Size 283 x 94 x 36mm. Complete with carrying case, leads and fuses.</p> <p><b>OUR PRICE £15.10</b> P/P &amp; Ins 60p</p> 	<h3>U4317 MULTIMETER</h3> <p>High sensitivity instrument for field and laboratory work. Knife edge pointer. 80mm. mirror scale. Overload protection. Ranges: 100mV/0.5/2.5/10/25/50/100/250/500/1000/250/500/1000V AC. Current: 50uA/0.5/1.5/10/50/250mA/1.5A DC. 0.25/0.5/1.5/10/50/250mA/1.5A AC. Resistance: 0.5/10/100/200 ohms/1/3/30/300k ohms. Decibels: -5 to +10dB Battery operated. Size: 210 x 115 x 90mm. Supplied in carrying case complete with leads.</p> <p><b>OUR PRICE £18.35</b> P/P &amp; Ins 60p</p> 	<h3>KAMODEN 72.200 Multitester</h3> <p>High sensitivity tester. 200,000 opv. Overload protected. Mirror scale. Ranges: -0/0.6/3/30/120/600/1200V DC. 0/3/12/60/300/1200V AC. 0/6uA/1.2mA/120mA/600mA/12A DC. -20 to +63dB. 0/2k/200k/2 Meg/200 Megohms.</p> <p><b>OUR PRICE £24.30</b> P/P &amp; Ins 60p</p> 	<h3>C15 PULSE OSCILLOSCOPE</h3> <p>For display of pulsed and periodic wave-forms in electronic circuits. VERT. AMP. Bandwidth: 10MHz. Sensitivity at 100kHz VRMS/mm: 0.1-25; HOR. AMP. Bandwidth: 500kHz. Sensitivity at 100kHz VRMS/mm: 0.3-25 Preset triggered sweep 1-3000uSec. Free running 20-200 kHz in nine ranges. Calibrator pips. 220 x 360 x 430mm. 115-230V AC.</p> <p><b>OUR PRICE £47.50</b> P/P &amp; Ins 1.50</p> 	

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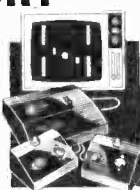
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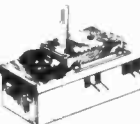
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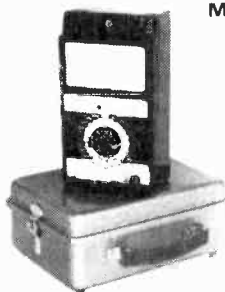
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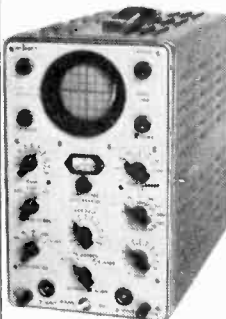
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SN7423	0.29	0.25	0.22
SN7425	0.28	0.25	0.22
SN7426	0.28	0.25	0.22
SN7427	0.26	0.25	0.22
SN7428	0.39	0.38	0.37
SN7430	0.14	0.13	0.12
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ZN1308	0.47	ZN5296	0.48	BC149B	0.16	BF196	0.13	TIP35A	2.90
ZN1711	0.46	ZN5457	0.49	BC157A	0.15	BF197	0.15	TIP36A	3.70
ZN2102	0.60	ZN5458	0.46	BC158A	0.16	BF198	0.18	TIP42A	0.90
ZN2147	0.78	ZN5459	0.49	BC167B	0.15	BF244	0.21	TIP3055	0.96
ZN2148	0.94	ZN6027	0.45	BC168B	0.15	BF257	0.47	TIP3055	0.96
ZN2218A	0.22	ZN128	0.73	BC169B	0.15	BF258	0.53	TIS43	0.28
ZN2219A	0.26	ZN140	1.00	BC182	0.12	BF259	0.55	TX300	0.13
ZN2220	0.25	ZN141	0.81	BC182L	0.12	BFS61	0.27	ZTX301	0.13
ZN2221	0.18	ZN200	2.49	BC183	0.12	BFS98	0.25	ZTX500	0.15
ZN2222	0.20	40361	0.40	BC183L	0.12	BFR39	0.24	ZTX501	0.13
ZN2369	0.20	40362	0.45	BC184	0.13	BFR79	0.24	ZTX502	0.18
ZN2646	0.55	40406	0.44	BC184L	0.13	BFX29	0.30	1N914	0.07
ZN2904	0.22	40407	0.38	BC212A	0.16	BFX30	0.27	1N3754	0.15
ZN2905	0.25	40408	0.50	BC212LA	0.16	BFX84	0.24	1N4007	0.10
ZN2906	0.19	40409	0.52	BC213LA	0.16	BFX85	0.30	1N4148	0.07
ZN2907	0.22	40410	0.52	BC214LB	0.18	BFX88	0.25	1N5404	0.22
ZN2924	0.20	40411	2.00	BC237B	0.15	BFY50	0.25	1N5408	0.08
ZN2926G	0.12	40594	0.74	BC238C	0.15	BFY51	0.23	AA119	0.25
ZN3053	0.25	40595	0.84	BC239C	0.16	BFY52	0.205	BA102	0.25
ZN3054	0.60	40636	1.10	BC257A	0.16	BRV39	0.48	BA145	0.18
ZN3055	0.75	40673	0.75	BC258B	0.16	ME0402	0.20	BA154	0.12
ZN3391	0.28	AC126	0.20	BC259B	0.17	ME0412	0.18	BA155	0.12
ZN3392	0.15	AC127	0.20	BC301	0.34	ME4102	0.11	BB103B	0.23
ZN3393	0.15	AC128	0.20	BC307B	0.17	MJ480	0.96	BB104B	0.45
ZN3440	0.69	AC151	0.27	BC308A	0.15	MJ481	1.20	BY126	0.12
ZN3442	1.40	AC152	0.49	BC309C	0.20	MJ490	1.06	BY127	0.15
ZN3638	0.15	AC153	0.35	BC327	0.23	MJ491	1.45	BY211	0.51
ZN3702	0.12	AC176	0.30	BC328	0.22	MJ2955	1.00	BY212	0.61
ZN3703	0.13	AC187K	0.35	BCY70	0.17	MJE340	0.48	O447	0.08
ZN3704	0.15	AC188K	0.40	BCY71	0.22	MJE370	0.65	O481	0.08
ZN3706	0.15	AD143	0.68	CCY72	0.15	MJE371	0.75	O490	0.08
ZN3708	0.14	AD161	0.50	BD121	1.00	MJE520	0.60	O491	0.08
ZN3714	1.38	AD162	0.50	BD123	0.82	MJE521	0.70	WO21A200	0.32
ZN3716	1.80	AF106	0.40	BD124	0.67	MJE2955	1.20	BY164	0.57
ZN3721	2.20	AF109	0.40	BD131	0.40	MJE3055	0.75	ST2 diac	0.20
ZN3737	2.65	AF115	0.35	BD132	0.50	MP8113	0.47	40669	1.00
ZN3789	2.06	AF116	0.35	BD135	0.43	MPF102	0.39	TIC44	0.29
ZN3819	0.37	AF117	0.35	BD136	0.47	MPSA05	0.25	C106D	0.65
ZN3820	0.64	AF118	0.35	BD137	0.55	MPSA06	0.31	ORP12	0.60
ZN3904	0.27	AF124	0.30	BD138	0.63	MPSA55	0.31		

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\*We incorporate the Quilter modification which is most important as it reduces distortion and increases the bass and treble control range.

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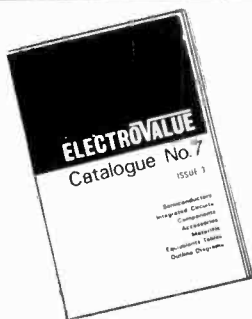
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### TRIACS

<b>1.6AMP PLASTIC TO5</b>	<b>6AMP ISOLATED TAB</b>	<b>10AMP ISOLATED TAB</b>
NAS0161 W 100v .21	NAS0651W 100V .46	NAS1001W 100V .63
NAS0161X 100V .26	NAS0651X 100V .44	NAS1001X 100V .60
NAS0162W 200V .30	NAS0652W 200V .58	NAS1002W 200V .78
NAS0162X 200V .28	NAS0652X 200V .56	NAS1002X 200V .74
NAS0164W 400V .40	NAS0654W 400V .84	NAS1004W 400V 1.09
NAS0164X 400V .38	NAS0654X 400V .80	NAS1004X 400V 1.04
NAS0166W 600V .55	NAS0656W 600V 1.05	NAS1006W 600V 1.34
NAS0166X 600V .52	NAS0656X 600V 1.00	NAS1006X 600V 1.28
<b>3AMP "CLIPPED TAB"</b>	<b>8.5AMP ISOLATED TAB</b>	<b>16AMP ISOLATED METAL</b>
NAS0301W 100V .30	NAS0851W 100V .52	NAS1601W 100V .90
NAS0301X 100V .28	NAS0851X 100V .50	NAS1601X 100V .82
NAS0302W 200V .36	NAS0852W 200V .67	NAS1602W 200V .95
NAS0302X 200V .34	NAS0852X 200V .64	NAS1602X 200V .88
NAS0304W 400V .52	NAS0854W 400V .97	NAS1604W 400V 1.40
NAS0304X 400V .50	NAS0854X 400V .92	NAS1604X 400V 1.32
NAS0306W 600V .70	NAS0856W 600V 1.20	NAS1606W 600V 1.85
NAS0306X 600V .66	NAS0856X 600V 1.14	NAS1606X 600V 1.75

Devices with Internal Trigger have "W" suffix. "X" denotes Standard Triac.

### THYRISTORS

<b>1.6AMP MIN. TO5</b>	<b>4AMP ISOLATED TAB</b>	<b>6AMP ISOLATED TAB</b>
NAS006P 50PIV .25	NAS106P 50PIV .26	NAS206P 50PIV .37
NAS006Q 100PIV .28	NAS106Q 100PIV .30	NAS206Q 100PIV .42
NAS006R 200PIV .31	NAS106R 200PIV .36	NAS206R 200PIV .50
NAS006S 400PIV .40	NAS106S 400PIV .52	NAS206S 400PIV .77
NAS006T 600PIV .52		
<b>8AMP ISOLATED TAB</b>	<b>16AMP ISOLATED TAB</b>	
NAS306P 50PIV .41	NAS806P 50PIV .50	
NAS306Q 100PIV .47	NAS806Q 100PIV .58	
NAS306R 200PIV .59	NAS806R 200PIV .73	
NAS306S 400PIV .85	NAS806S 400PIV 1.15	

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152	250	9.83	73
153	350	11.88	73
154	500	13.65	91
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156	1000	29.15	8RS
157	1500	33.23	8RS
158	2000	37.07	BRS

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70	5 3	4.12	45
08	8 4	4.56	45
72	10 5	5.14	53
116	12 6	5.52	53
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187	30 15	13.59	83
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Ref. No.	AMPS	£	P&P
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79	1.0	2.40	38
3	2.0	3.49	38
20	3.0	4.53	45
21	4.0	5.13	53
51	5.0	6.41	53
117	6.0	7.16	60
88	8.0	9.87	67
89	10.0	9.90	73

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Ref. No.	AMPS	£	P&P
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103	1.0	3.38	38
104	2.0	4.68	45
105	3.0	5.81	53
106	4.0	7.60	67
107	6.0	12.10	67
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**60 VOLT RANGE**  
 SECONDARY TAPS  
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Ref. No.	AMPS	£	P&P
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126	1.0	3.41	38
127	2.0	5.08	45
125	3.0	7.52	60
123	4.0	8.75	67
120	5.0	9.75	73
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131	8.0	15.00	BRS
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66	300	"	5.82	53
67	500	"	8.82	67
84	1000	"	13.68	91
93	1500	"	18.11	BRS
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Ref.	mA	Volts	£	P&P
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212	1A1A	0-6-0-6	1.84	30
13	100	9-0-9	1.41	13
235	330.330	0-9-0-9	1.56	19
207	500.500	0-8-9-0-8-9	1.92	30
208	1A 1A	0-8-9-0-8-9	1.30	38
236	2C0.200	0-15-0-15	1.43	19
214	3C0.300	0-20-0-20	1.93	30
221	700(DC)	20-12-0-12-20	2.17	38
206	1A 1A	0-15-20-0-15-20	3.46	38
203	500.500	0-15-27-0-15-27	3.00	38
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AC154	0.22	BC212L	0.16	MJE3055	0.80	2N753	0.55
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AC176	0.15	BC337	0.15	NKT221	0.17	2N1309	0.25
AC179	MP	BC211	0.28	NKT224	0.15	2N1754	0.20
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AC177	0.26	BD132	0.40	NKT278	0.15	2N2933	0.16
AC178	0.26	BD131	MP	OC22	0.50	2N2924	0.18
ACY17	0.28	BD132	0.75	OC28	0.50	2N2925	0.15
ACY18	0.22	BD139	0.70	OC35	0.45	2N2926G	0.14
ACY19	0.22	BD140	0.70	OC36	0.55	2N2926Y	0.12
ACY20	0.20	BD243	0.85	OC44	0.17	2N2926R	0.11
ACY21	0.18	BD244	0.85	OC45	0.14	2N2926B	0.11
ACY27	0.20	BF167	0.24	OC70	0.11	2N2926B	0.11
ACY28	0.22	BF181	0.33	OC71	0.11	2N3053	0.19
AD140	0.53	BF182	0.40	OC72	0.15	2N2054	0.50
AD142	0.53	BF183	0.40	OC81	0.17	2N3055	0.50
AD149	0.55	BF194	0.12	OC87	0.28	2N3702	0.12
AD161	0.43	BF195	0.30	OC201	0.12	2N3703	0.12
AD162	0.43	BF196	0.15	OC202	0.27	2N3704	0.14
AD161	MP	BF197	0.16	OC203	0.29	2N3705	0.13
AD162	0.85	BF200	0.50	OC204	0.28	2N3707	0.14
AF115	0.26	BF274	0.39	OC445K	0.20	2N3710	0.10
AF116	0.26	BF274	0.39	SG5269	0.15	2N3711	0.10
AF124	0.33	BF299	0.28	SG5269A2	0.14	2N3713	0.20
AF125	0.31	BF284	0.33	SG5269A4	0.15	2N3094	0.33
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BC143	0.30	BSY40	0.31	V10/50	0.40	2N4291	0.22
BC147	0.10	BSY41	0.31	Z1116	0.75	2N4293	0.19
BC148	0.10	C111	0.50	ZTX107	0.12	2S322	0.48
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BC157	0.11			ZTX502	0.17	2S745	0.45
<b>DIODES</b>				<b>I.C.s &amp; 74 SERIES</b>			
AA119	0.06	BY100	0.16	OA200	0.07	IN4002	0.05
2/AA119	0.09	BY127	0.12	OA202	0.07	IN4003	0.05
AAZ15	0.11	BY164	0.38	IN3A4	0.08	IN4004	0.06
BA90	0.10	BYX38/300	0.08	IN202	0.08	IN4005	0.07
BA111	0.18	BZ213	0.46	IN252	0.10	IN4006	0.08
BA112	0.18	BZ295	0.15	IN914	0.06	IN4007	0.09
BAX78/1	0.10	OA10	0.12	IN1124	0.09	IN4148	0.04
BAY31	0.14	OA47	0.10	IN3064	0.10	IN4244	0.07
BAY74	0.12	OA81	0.08	IN4001	0.05	IS3036A	0.15
<b>ZENER DIODES</b>		<b>ZENER DIODES</b>		<b>ZENER DIODES</b>		<b>ZENER DIODES</b>	
400mW 2-33v ALL 0.9 each		1Wat 15 & 2-33v ALL 0.19 each					

### JET'S SUPER BARGAIN PACKS

No.	Qty.	Contents	Price
J1	1	Pre-amp component kit plus data	0.85
J2	3	Transistors AF115 new and marked	0.65
J4	4	Transistors 2N726 new and marked	0.85
J5	8	Zener Diodes top hat type 75 volt	0.85
J7	50	Metres con/wire mixed colours	0.85
J8	25	Metres con/wire 4 Metres 60/40 solder	0.85
J9	100	Resistors HI/STAB 1/2w mixed values	0.85
J10	100	Resistors HI/STAB 1/4w mixed values	0.85
J11	250	Resistors mixed values	0.85
J14	100	Capacitors miniature mixed values	0.85
J15	5	Terminal blocks brand new 12 way	0.85
J15	10	switches 5 push to make 5 off/on	0.85
J18	12	Standard crocodile clips	0.85
J19	12	Screwdrivers 5 inches long	0.85
J20	1	Pack nuts & bolts self tappers, etc., etc	0.85
J22	20	Volume controls lin & tog mixed values	0.85
J23	75	5yn/rubber grommets mixed sizes	0.85
J25	20	Screw on rubber feet 1/4inch dia approx	0.85
J26	1	Pack marker sleeve mixed colours & sizes	0.85
J27	5	lengths ferrite rod mixed flat & round	0.85
J28	20	tag strips assorted lengths	0.85
J29	4	Micro switches brand new	0.85
J31	20	Preset pots lin & tog mixed	0.85
J32	20	Capacitors can type mixed values	0.85
J33	50	Ceramic plate capacitors mixed values	0.85
J34	1	Pack copper clad bakelite board	0.85
J35	20	Fuse holders mixed	0.85
J36	8	Metres multi-core solder 60/40 22swg	0.85
J37	10	3 5mm Jack sockets chrome	0.85
J38	8	Sockets 5 pin & 2 pin	0.85
J39	2	Relays 12 & 24 volt	0.85
J40	1	Pack of component boards ICs Transistors etc	0.85

**J PACKS ONLY ADD 10% TO TOTAL ORDER PLEASE FOR POST & PACK**

**PAPST TAP MOTOR 220v 50Hz £2.50 p&p 25p**  
**AMPLIFIER 12 volt 500 mW £1.00 p&p 10p**  
**TELEPHONE DIALS BRAND NEW £1.00 p&p free.**  
**P.A.R. BISTABLE RELAY LATCHING 24v DC C/O CONTACTS 0.55.**  
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**SWITCH 4 POLE 2 CHANGE/OVER IS STILL AVAILABLE ONLY £1.50**  
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**E.H.T. POWERUNIT.** 110/240v 50Hz giving 5Kv. at 50mA. METERED OUTPUT. £18.50. P.P. £1.50

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 8 1/2 x 6 x 1/16 inch, 3 for 75p. P.P. 25p  
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**GARRARD PLINTH & COVER.** For "Zero-100" etc beautifully finished in brushed aluminium and black with hinged smoke/grey perspex lid £9.75 P.P £1  
**24v. A.C. RELAY (PLUG-IN).** 3 pole c/o 75p. P.P. 15p. 2-pole change over 55p. P.P 15p  
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**MINIATURE "ELAPSED TIME" INDICATORS.** (0-5000 hours), 45 x 8mm 75p.

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**H.D. ALARM BELLS.** 6in Dome, 6/8v DC £2.75. P.P 97p

**TELEPHONE DIALS (new) £1. P.P 15p**  
**EXTENSION TELEPHONES** (Type 706). Various colours. £3.95. P.P. 75p  
**RATCHET RELAYS** (310 ohm). Various types £1.20. P.P 20p  
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 Single 2 x 4 c/o Locking 50p. P.P 10p Bank of 4—2 x 4 c/o each switch (one biased). £1.20. P.P 15p

**MULTICORE CABLE.** 6-core (6 colours) 14/0078 Screened P.V.C 22p per yard. 100 yards at £16.50. P.P 2p a yard. 7-core (7 colours) 7/22mm Screened P.V.C 22p per yard. 100 yards £16.50. P.P 2p per yard 30-core (15 colours) 25p per yard 100 yards £20. P.P 2p per yard  
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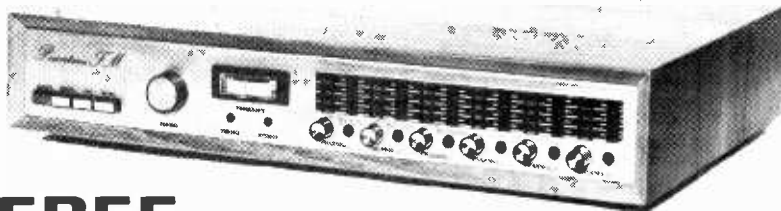
**OVERLOAD CUT-OUTS.** Panel mounting (1 1/4 x 1 1/4 x 1/2in). 800 M/A 1.8 amp -10 amp. 45p. P.P 5p.

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<b>ADVANCE TRANSFORMERS "VOLSTAT".</b> Input 242v A.C. <b>C.V.50.</b> 38v. at 1 amp; 25v. at 100 m/a. 75v. at 200 m/a. £2.50. P.P 65p. <b>C.V.75.</b> 25v. at 2 1/2 amp. £3. P.P. 75p. <b>C.V.100.</b> 50v at 2 amp. 50v. at 100 m/a. £3.75. P.P. 75p. <b>C.V.250.</b> 25v at 8 amp. 75v at 1/2 amp £6.50. P.P. £1 50 <b>C.V.500.</b> 45v. at 3 amp; 35v at 2 amp £10. P.P £1 75 <b>H.T. TRANSFORMER.</b> Prim 110/240v Sec 400v 100 m/a. £2.50. P.P 65p. <b>L.T. TRANSFORMER "TOROIDAL".</b> Prim 240v Sec 30v at 1/2 amp. Size 3 in. dia thick. £1.65. P.P. 20p <b>L.T. TRANSFORMER.</b> Prim 240v Sec 27-0-27 at 800 m/a 7.5 amp £2.25. P.P. 50p	<b>L.T. TRANSFORMER.</b> Prim 110/240v Sec 0/24/40v 1 1/2 amp (Shrouded) £1.95. P.P 50p. <b>L.T. TRANSFORMER.</b> Prim 200/250v Sec 20/40/60v at 2 amp (Shrouded) £3. P.P 50p <b>L.T. TRANSFORMER (H.D.).</b> Prim 200/250v Sec 18v at 27 amp; 40v at 9.8 amp. 40v at 3.6 amp 52v at 1 amp 25v at 3.7 amp £17.50. P.P £2 50 <b>L.T. TRANSFORMER.</b> Prim 240v Sec 16-0-16v at 2 amp £2. P.P 50p. <b>L.T. TRANSFORMER PRIM.</b> 120-0-120v Sec 12v at 1 amp 70p. P.P 20p. <b>L.T. TRANSFORMER PRIM.</b> 240v Sec 18v 1 amp £1. P.P 20p	<b>POWER UNIT (TRANSFORMER/RECTIFIER).</b> Prim 240v output 17 1/2v (unsmoothed) at 1 amp £1.85. P.P 45p <b>L.T. TRANSFORMER ("C" CORE).</b> 200/240v Secs 1.3-8-9v All at 1.5 amp 50v at 1 amp £2.50. P.P 50p <b>L.T. TRANSFORMER ("C" CORE).</b> 200/240v. Secs 1.3-9-27v All at 4 amp £4. P.P. 50p. <b>L.T. TRANSFORMER ("C" CORE).</b> 200/240v Secs 1.3-9-27v All at 10 amp £7.50. P.P £1.50 <b>L.T. TRANSFORMER ("C" CORE).</b> 200/240v Secs 1.3-9-20v. All at 4 amp £5.50. P.P 75p. <b>L.T. TRANSFORMER ("C" CORE).</b> 120/120v Secs. 1.3-9-9v All at 10 amp £6.50. P.P 75p <b>L.T. TRANSFORMER ("C" CORE).</b> 110/240v. Secs. 1.3-9v 10 amp 35v 1a 50v 750 M/A. £6.50. P.P 75p
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Pack	Price
1 Fibreglass printed circuit board for front end, 1 F strip, demodulator, AFC and mute circuits	£2.15
2 Set of metal oxide resistors, thermistor, capacitors, cermet preset for mounting on pack 1	£4.80
3 Set of transistors, diodes, LED, integrated circuits for mounting on pack 1	£6.25
4 Pre-aligned front end module, coil assembly, three-section ceramic filter	£8.80
5 Fibreglass printed circuit board for stereo decoder	£1.10
6 Set of metal oxide resistors, capacitors, cermet preset for decoder	£2.60
7 Set of transistors LED, integrated circuit for decoder	£3.45
8 Set of components for channel selector switch module including fibreglass printed circuit board, push-button switches, knobs, LEDs preset adjusters, etc.	£8.30

Pack	Price
9 Function switch, 10 turn tuning potentiometer, knobs	£5.30
10 Frequency meter, meter drive components, fibreglass printed circuit board	£8.60
11 Toroidal transformer with electrostatic screen, Primary: 0-117V-234V	£4.45
12 Set of capacitors, rectifiers, voltage regulator for power supply	£2.95
13 Set of miscellaneous parts, including sockets, fuse holder, fuses, inter-connecting wire, etc.	£1.50
14 Set of metal work parts including silk screen printed fascia panel, acrylic silk screen printed tuning indicator panel insert, internal screen, fixing parts, etc.	£6.50
15 Construction notes (free with complete kit)	£0.25
16 Teak cabinet	£9.85
One each of packs 1-16 inclusive are required for complete stereo FM tuner.	
Total cost of individually purchased packs	
	£76.85



**NOVEL STEREO FM TUNER**

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

STYLED TO COMPLEMENT THE WORLD-WIDE ACCLAIMED LINSLEY-HOOD 75W AMPLIFIER

**THE FM TUNER KIT YOU HAVE WAITED FOR!**

for further information please write for FREE LIST

**FREE** TEAK CASE WITH FULL KITS

KIT PRICE only **£66.75** carriage free (U.K.)

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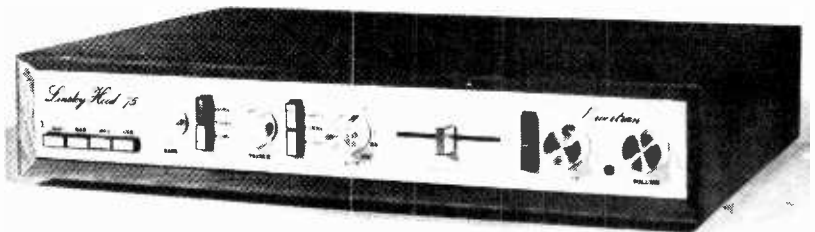
MORE ON NEXT PAGE!

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**DESIGNER APPROVED KIT**

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

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



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

**FREE** TEAK CASE WITH FULL KITS  
KIT PRICE only **£62.40** carriage free (U.K.)

Pack	Price
1 Fibreglass printed-circuit board for power amp.	£0.85
2 Set of resistors, capacitors, pre-sets for power amp.	£1.70
3 Set of semiconductors for power amp. (now using BDY56, BD529, BD530)	£6.50 £0.80
4 Pair of 2 drilled, finned heat sinks	
5 Fibreglass printed-circuit board for pre-amp.	£1.30
6 Set of low noise resistors, capacitors, pre-sets for pre-amp.	£2.70
7 Set of low noise, high gain semiconductors for pre-amp.	£2.40
8 Set of potentiometers (including mains switch)	£2.05
9 Set of 4 push-button switches, rotary mode switch	£3.70
10 Toroidal transformer complete with magnetic screen/housing primary: 0-117-234 V, secondaries: 33-0-33 V, 25-0-25 V.	£9.15

Pack	Price
11 Fibreglass printed-circuit board for power supply	£0.65
12 Set of resistors, capacitors, secondary fuses, semiconductors for power supply	£3.50
13 Set of miscellaneous parts including DIN skts, mains input skt, fuse holder, inter-connecting cable, control knobs	£4.25
14 Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£6.30 £0.30 £9.85
15 Handbook	
16 Teak cabinet	
2 each of packs 1-7 inclusive are required for complete stereo system	
Total cost of individually purchased packs	
	£72.25

V A T Please add 25%\* to all U.K. orders

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U.K. ORDERS — Carriage free (MAIL ORDER ONLY)  
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#### SS103

Compact I.C. amp. 3 watts R.M.S. Single channel (mono). On P.C.B. size 3 1/2" x 2". Needs 10-20V supply. **£1.75**

#### SS103-3

Stereo version of above. (Two I.C.s.) **£3.25**

#### NEW! SS105 Mk. 2

A compact all-purpose power amp. Size 3 1/2" x 2". Useful 5w output (mono) into 3Ω using 12V. Excellent value. Two 20w at 12V 4 p.a. **£2.25**

#### SS110 Mk. 2

Similar in size to SS105 but will give 10w output into 4Ω using 24V (mono). Two in stereo give first-class results, suitable for many domestic applications. **£2.75**

Now — the SS120 gives 20w V.M.S. into 4 ohms from 34V. Size 3 1/2" x 2" **£3.00**

#### SS140\*

Beautifully designed. Will give up to 40w R.M.S. into 4Ω. Excellent S.N.R. and transient response. Fine for P.A., disco use, etc. Operates from 45V DC. Two in bridge formation will give 80w R.M.S. into 8Ω **£3.75**

### PRE-AMP/CONTROL MODULES

#### SS100

Active tone control to provide Bass and Treble (stereo). With full instructions. **£1.60**

#### SS101

Pre-amp for stereo ceramic cartridges, radio and tape. **£1.60**

#### SS102

Pre-amp for low-output stereo magnetic cartridges, radio and tape. **£2.25**

### BUILD A STEREO F.M. TUNER WITH THESE MODULES

#### SS201

Front End assembly. Ganged tuning with well engineered slow-motion geared drive in robust housing. A.F.C. facility. Requires 7-10V. Excellent sensitivity. 88-108MHz. **£6.25**

#### SS202

I.F. Stage (with I.C.). Designed to use with SS201 uses I.C. Carefully checked before despatch. For 9-16V. **£5.25**

#### SS203

Stereo Decoder. Designed essentially for use with SS201 and SS202, this excellent decoder can also make a stereo tuner of almost any single channel FM tuner. Supplied ready aligned. A.L.E.D. can easily be fitted. 9-16V **£5.62**

### SAVE £5 ON THE S/S TUNER

By buying Units SS.201, SS.202 and SS.203 together, the price is £12.12 — a genuine saving of £5 on this very efficient tuner. **£12.12**



**3 SPECIAL OFFERS**

**LM 380 AUDIO IC** (Marked SL60745). Brand new and to spec. 3 watts R.M.S. out. With data **£1.00**

**2 X SN 7490.** Brand new I.C. to spec. decade counters. **£1.00**

**3 X SN 7400 Quad 2** input Nan gate ICs **50p**

## NEW RANGE TRANSISTOR & COMPONENT PACKS

### TP SELECTION

- TP5** 20 Transistors. PNP Germanium. Red Spot A F.
- TP6** 20 Transistors. PNP Germanium. White spot RF.
- TP7** 1 2N174 150w 80Vce Power Transistor. with mounting assembly.
- TP19** 100 diodes, mixed Germanium, Gold-bonded, etc. Marked/Unmarked.
- TP23** Twenty NPN Silicon uncoded T05. Similar to BFY50/2, 2N696, 2N1613, etc. Complementary to TP24.
- TP24** Twenty PNP Silicon. uncoded T05. Similar to BFY64, 2N2904/5.
- TP29** 8 power diodes 400V. 1.25A Silicon FST 3/4.

### UT SELECTION

- UT1** 50 PNP's Germanium, AF & RF.
- UT2** 150 Germanium diodes, min. glass.
- UT4** 100 Silicon diodes, min. glass. similar to IN914, IN916.
- UT5** 40 250mW Zener diodes OAZ 240 range, average 50% good.
- UT7** 30 Silicon rectifiers 750mA, mixed voltages. Top Hats, etc.
- UT9** 40 NPN Silicon planers. Similar to 2N3707-11 range. Low noise amps.
- UT12** 25 2N3702/3 Transistors. PNP Silicon, Plastic to 92.

### CP SELECTION

- CP1** Mixed bag of capacitors — Electrolytic, Paper, Silver Mica (Approx. 150 — sold by weight).
- CP2** 200 (approx.) Resistors, various types, values, watts. (Sold by weight.)
- CP3** 40 Wire-wound resistors, mixed.
- CP4** 12 pots — pre-set, w/wound, carbon, dual, with/without switches — all mixed.
- CP7** Heat sinks, assorted. To fit SO-2 (OC72) TO-1 (AC128), etc.

### SUNDRY

**P.I PAK** — Approx. 170 short-lead semi-conductors and components. PNP, NPN, diodes, rectifiers, etc. on ex-computer panels. At least 30% factory marked. Some data supplied. **50p.**

UHF 625 line tuner, rotary. **£2.50.**

Rev Counter (for cars) (8%). **£1.00.**

Books by Bernard's Publications, Newnes-Butterworth's, etc.

**ALL ABOVE PACKS — 60p EACH. TP Tested & Guaranteed. UT Untested, unmarked. CP Components.**

### CAPACITOR DISCHARGE IGNITION KIT

Simple to assemble and fit. Improves car performance, saves on fuel. P/P 30p. **£7.50\***

### BI-PRE-PAK X-HATCH GENERATOR MK. 2



Four-pattern selector switch  
3" x 5 1/4" x 3"  
Ready-built and tested  
In kit form **£9.93\***  
**£7.93\***

*Please add 33p for postage and packing.*

Is invaluable to industrial and home user alike. Improved circuitry assures reliability and still better accuracy. Very compact, self-contained. Robustly built. Widely used by TV rental and other engineers. With reinforced fibreglass case, instructions, but less batteries. (Three U2 type required.)

### TV SIGNAL STRENGTH METER\*

Complete kit as described in "Television" £19.50 plus 40p for P&P

### SS300 POWER SUPPLY STABILISER

Add this to your un stabilised supply to obtain a steady working voltage from 12 to 50V for your audio system, workbench, etc. Money saving and very reliable. **£3.25\***

### PLASTIC POWER TRANSISTORS

40 WATT SILICON*					
Type	Polarity	Gain	VCE	Price	
40N1	NPN	15	15	20p	
40N2	NPN	40	40	30p	
40P1	PNP	15	15	20p	
40P2	PNP	40	40	30p	
90 WATT SILICON*					
Type	Polarity	Gain	VCE	Price	
90N1	NPN	15	15	25p	
90N2	NPN	40	40	35p	
90P1	PNP	15	15	25p	
90P2	PNP	40	40	35p	

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# QUALITY AMPLIFIER KITS by POWERTRAN ELECTRONICS

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<b>60V REGULATED POWER SUPPLY</b>	
Pk. 1 F/Glass PCB	£0.75
Pk. 2 Resistors, capacitors, pots	£1.40
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<b>BAILEY-BURROWS PRE-AMP</b>	
Pk. 1 F/Glass PCB	£2.05
Pk. 2 Resistors, capacitors, pre-sets, transistors	£4.95

Pk. 3R Rotary potentiometer set	£1.60
Pk. 35 Slider potentiometer set (with knobs)	£2.70

### STUART TAPE RECORDER

A set of three printed-circuit boards has been prepared for the stereo integrated circuit version of this high-performance *Wireless World* published design.

TRRP Pk. 1 Reply amplifier F/Glass PCB	£0.90
TRRC Pk. 1 Record amp./meter drive cct. F/Glass PCB	£1.40
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For details of component packs for this design please write for free list.

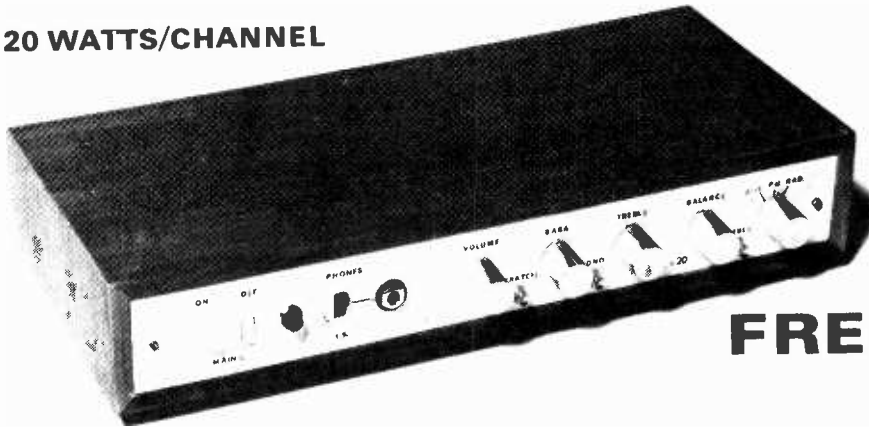
## TOROIDAL T20 + 20

Developed from the famous Practical Wireless Texan

Designed by Texas engineers and published in a series of articles in *Practical Wireless*. The TEXAN was a remarkable breakthrough in delivering true Hi-Fi performance at exceptionally low cost. Now further developed to include a true Toroidal transformer, this slimline integrated circuit design, based upon a single F/Glass PCB, features all the normal facilities found on quality amplifiers, including scratch and rumble filters, adaptable input selector and headphones socket.

Pack	Price
1 Set of all low noise resistors	£0.95
2 Set of all small capacitors	£1.50
3 Set of 4 power supply capacitors	£1.40
4 Set of miscellaneous parts including DIN sockets, fuses, fuse holders, control knobs, etc.	£1.90
5 Set of slide and push-button switches	£1.20
6 Set of potentiometers and selector switch	£2.00
7 Set of all semiconductors	£7.25
8 Special Toroidal Transformer	£4.95
9 Fibreglass PC Panel	£2.50
10 Complete chassis work, hardware and brackets	£4.20
11 Preformed cable/leads	£0.40
12 Handbook	£0.25
13 Teak Cabinet	£4.50

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2N5477 £0.45	BC182L £0.10	MC1310 £2.90	SL3045 £1.60	<b>FILTERS</b>
2N5459 £0.45	BC184L £0.11	MC1351 £1.05	SN72741P £0.40	FM4 £0.80
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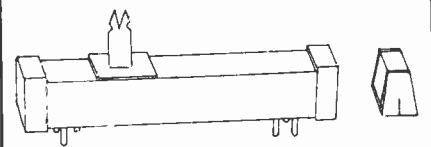
### ACTIVE FILTER CROSSOVER

An essential and critical component in a high-quality speaker system is the crossover unit conventionally comprising of a series of passive networks which unfortunately, though introducing reactive impedances between the amplifier and the speakers, result in the loss of the advantage of high amplifier damping factor and renders the speakers prone to overshoots and resonances. An elegant solution to this problem, described by D. C. Read in *Wireless World*, involves the use of a series of active filters splitting the output of the pre-amplifier into three channels, of closely defined bandwidth, each of which is fed to the appropriate speaker by its own power amplifier. A design for a suitable 20-watt amplifier, based on a proven Texas circuit, was also described by Mr Read. The printed-circuit board for this has been designed such that three amplifiers may be stacked and mounted together on a common heat sink to achieve a conveniently compact module.

<b>ACTIVE FILTER</b>	<b>READ/TEXAS 20w amp.</b>	<b>POWER SUPPLY</b>
Pack 1 Fibreglass PCB (accommodates all filters for one channel) £1.05	Pack 1 Fibreglass PCB £0.70	FOR 20W/CHANNEL STEREO SYSTEM
2 Set of pre-sets, solid tantalum capacitors, 2% metal oxide resistors, 2% polystyrene capacitors £4.20	2 Set of resistors, capacitors pre-sets (not including O/P coupling capacitors) £1.10	Pack 1 Fibreglass PCB £0.50
3 Set of semiconductors £2.65	3 Sets of semiconductors £2.40	2 Set of rectifiers, zener diode, capacitors, fuses, fuse holders £2.60
2 off each pack required for stereo system	6 off each pack required for stereo system	3 Toroidal transformer £4.95
	4 Special heat sink assembly for set of 3 amplifiers £0.85	
	5 Set of 3 O/P coupling capacitors £1.00	
SUITABLE ALSO FOR FEEDING ANY OF OUR HIGH-POWER DESIGNS	2 off packs 4, 5 required for stereo system	<b>MORE KITS ON PAGE 57</b>

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### RECORD PLAYBACK TAPE HEADS

Individual prices of these are  
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 Erase heads are also available separately —  
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**£1.85.**  
 ALL PLUS 25% VAT.



### DRILL CONTROLLER

**NEW 1KW MODEL**  
 Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by finger-tip control. Kit includes all parts, case, everything and full instructions. £2.50 plus 45p post & VAT. Made up model also available. £3.50 plus 55p post & VAT.

### NEED A SPECIAL SWITCH

Double Leaf Contact. Very slight pressure closes both contacts. 12p each. Plastic pushrod suitable for operating. 10p each, 10 for 68p.

### 1 R.P.M. MOTOR + GEAR BOX

Made by the famous Chamberlain & Hookham Ltd. These could be made to drive clock or similar. Really robust, reliable unit. Price **£1.50 + 30p post & VAT**

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Six speeds are available 500, 850 and 1,100 r.p.m. and 8,000, 12,000 and 15,500 r.p.m. Shaft is 3/4 in. diameter and approximately 1 in. long. 230/240v. Its speed may be further controlled with the use of our Thyristor controller. Very powerful and useful motor, size approx 2 in dia x 5 in long. Price **£1.40 + 45p post & VAT**

### SLIDE SWITCHES

Slide Switch, 2-pole changeover panel mounting by two 68.A screws. Size approx 1 in x 1/4 in, rated 250V lamp, 15p + 7p post & VAT. **Sub Miniature Slide Switch.** DPDT 19mm (3/4 in approx.) between fixing centres. 28p each + 9p post & VAT or 10 for **£1.90.** SP Change over spring return 250v 1 amp 25p + 8p post & VAT.

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Push button gives 10 variations as follows: (1) continuous hot water and continuous central heating (2) continuous hot water but central heating off at night (3) continuous hot water but central heating on only for 2 periods during the day (4) hot water and central heating both on but day time only (5) hot water all day but central heating only for 2 periods during the day (6) hot water and central heating on for 2 periods during the day time only — then for summer time use with central heating off (7) hot water continuous (8) hot water day time only (9) hot water twice daily (10) everything off.

A handsome looking unit with 24 hour movement and the switches and other parts necessary to select the desired programme of heating. Supplied complete with wiring diagram. Originally sold, we believe, at over **£15** — we offer these, while stocks last at **£6.95** each, VAT & Postage 85p each.

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**THIS MONTH'S SNIP**  
 Smiths 24 hr. timer heart, really the "Autoset" without its plastic case. This is a 24 hr. twice on, twice off, clock switch which will repeat until re-programmed. Switches rated at 15 amps. Limited supplies — **£3.95** each + VAT & post 55p.

**12 VOLT 1 1/2 AMP POWER PACK**  
 This comprises double wound 230/240v mains transformer with full wave rectifier and 2000 mfd smoothing. Price **£3.75** plus VAT & post £1.  
**Heavy Duty Mains Power Pack.** Output voltage adjustable from 15-40V in steps — maximum load 250W — that is from 6 amp at 40V to 15 amp at 15V. This really is a high power heavy duty unit with dozens of workshop uses. Output voltage is very quick — simply interchange push on leads. Silicon rectifiers and smoothing by 3,000mfd. Price **£10.50** plus £1.25 VAT & post.

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9v	3.5 amp	2.50
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12v	1 amp	1.00
12v	1 amp	1.50
12v	1 amp	1.50
18v	2 amp	2.25
24v	3 amp	3.50
24v	50mA	1.20
12 0:12v	50mA	1.20
6 0:6v	1/2 amp	1.50
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 Designed to operate transistor sets with amplifiers. Adjustable output 6v, 9v, 12 volts for up to 500mA (class B working). Takes the place of any of the following batteries. PP1. PP3. PP4. PP6. PP7. PP9 and others. Kit comprises: main transformer, rectifier, smoothing and load resistor, condensers and instructions. Real snip at only **£1.50.** VAT & Postage 60p.

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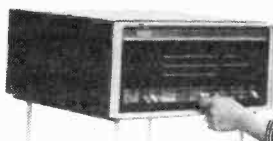
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## PAPER TAPE PUNCHES & READERS

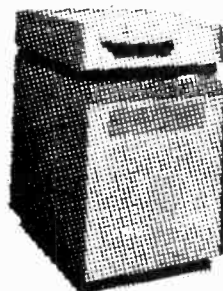


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 Mounted on printed circuit board (non-coded). 53 character keys + 10 instruction keys and 2 space bars. Layout can be re-arranged as required. Ideal for prototypes and special applications. Hall-effect switches. Power requirement + 5V 420 mA. Price **£20.00 (P&P £1).**

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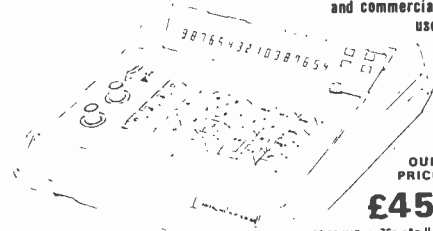
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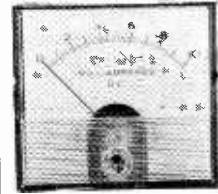


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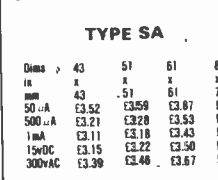
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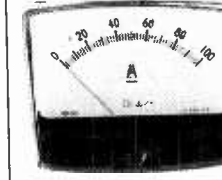
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in	x	x	x	x	x
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1mA	£3.27	£3.44	£3.64	£4.53	£5.23
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Dim's	43	51	61	82
in	x	x	x	x
mm	43	51	61	78
500µA	£3.52	£3.59	£3.67	£4.12
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1mA	£3.11	£3.18	£3.43	£3.72
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AC126	25p	BC185	35p	BFY10	35p	OC75	25p	IN4005	12p	2N2926	13p	2N4062	12p
AC127	25p	BC198E	27p	BFY44	50p	OC76	25p	IN4007	16p	2N3055	50p	2N4286	25p
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AC188	27p	BC213L	12p	BFY53	25p	OC87	25p	2N696	25p	2N706A	10p	2N4290	25p
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AC198	25p	BC214L	15p	BFY90	65p	OC170	30p	2N708	15p	2N707A	12p	2N4871	35p
AC199	25p	BC219	15p	BSV45B	85p	OC171	30p	2N929	22p	2N3702	12p	2N4873	£1.80
AC20	25p	BC239	15p	BSV68	40p	OC200	60p	2N930	20p	2N3705	12p	2N4903	£1.80
AC201	25p	BC300	30p	BSW63	65p	OC201	60p	2N930	20p	2N3707	12p	2N5063	£1.20
AD140	60p	BC301	30p	BSW68	80p	OC202	75p	2N1132	25p	2N3708	12p	2N5191	96p
AD142	60p	BC302	30p	BSX21	25p	TP29A	45p	2N1302	30p	2N3709	14p	2N5192	£1.20
AD161	45p	BC303	40p	BY127	20p	TP30	55p	2N1303	30p	2N3710	14p	2N5194	£1.10
AD162	45p	BCY31	55p	BY164	65p	TP31A	57p	2N1304	30p	2N3772	1.60	2N5195	£1.40
AF114	25p	BCY32	95p	IS100	15p	TP32A	69p	2N1305	30p	2N3776	1.20	2N5245	46p
AF115	25p	BCY33	60p	IS103	15p	TP33A	£1.00	2N1306	30p	2N3784	30p	2N5295	55p
AF116	25p	BCY34	65p	MJ340	50p	TP34A	£1.40	2N1307	30p	2N3787	1.50	2N5451	45p
AF117	25p	BCY38	95p	MJ481	95p	TP35A	£3.20	2N1308	30p	2N3794	30p	2N5458	35p
AF118	50p	BCY39	65p	MJ2801	£1.25	TP41A	70p	2N1309	30p	2N3819	35p	2N5458	35p
AF124	30p	BCY55	£1.50	MJ2801	£1.95	TP42A	85p	2N1613	30p	2N3820	55p	2N5457	35p
BF239	60p	BCY70	20p	MJ340	50p	TP42A	85p	2N1711	30p	2N3823	70p	2N5458	35p
BA102	30p	BCY71	20p	MJ370	75p	TP29B	54p	2N1890	60p	2N3866	85p	2N5459	40p
BA112	50p	BCY72	20p	MJ371	90p	TP30B	60p	2N2146	15p	2N3905	55p	2N5490	55p
BA114	16p	BD121	75p	MJ520	65p	TP31B	65p	2N2147	90p	2N3905	55p	2N5490	55p
BA155	16p	BD123	85p	MJ2955	£1.20	TP32B	77p	2N2160	80p	2N3906	25p	2N5555	65p
BA156	15p	BD124	70p	MJ3055	75p	TP33B	£1.06	2N2217	25p	2N4014	80p	2N5777	40p
BC107	15p	BD131	95p	MM1									

# SERVICE TRADING CO

## RELAYS

### SIEMENS PLESSEY, etc. MINIATURE RELAYS

1	2	3	4	1	2	3	4	
52	4-8	2c/o	70p*	700	16	24	4 M2B	60p*
56	5-9	6 c/o	80p*	700	16	24	4 c/o	80p*
185	8-12	6 M	80p*	1250	18	36	2 c/o	60p*
230	9-18	2 c/o HD	80p*	2500	36	45	6 M	60p*
430	15-24	4 c/o	80p*	2500	31	43	2 c/o HD	60p*
700	12-24	2 c/o	60p*	9000	40	70	2 c/o	60p*
				15k	85-110	6 M		60p*

(1) Coil ohms; (2) Working d.c. volts; (3) Contacts; (4) Price HD=Heavy Duty. All Post Paid. (\*Including Base)

### OPEN TYPE RELAYS

- 6 VOLT D.C.** 1 make con. 35p. Post 15p
- 9 VOLT D.C. RELAY** 3 c/o 5 amp contacts 70 ohm coil 75p. Post 15p
- 12 VOLT D.C. RELAY** 3 c/o 5 amp contacts 120 ohm coil 75p. Post 15p
- 24 VOLT D.C.** 3 c/o 600 ohm coil 75p. Post 15p
- 2 HD c/o 700 ohm coil 75p. Post 15p
- 4 c/o 300 ohm coil 85p. Post 15p

### ENCLOSED TYPE RELAYS

- 24V D.C. 3 c/o 75p. Post 15p Base 15p
- 24 VOLT A.C.** Mfg. ITT 3 h.d. c/o contacts 55p. Post 15p. Base 15p extra.
- 55 VOLT A.C.** 3 heavy duty c/o contacts. Price 55p. Post 15p. Base 15p.
- 100 VOLT A.C.** 2 c/o sealed type octal base 75p. Post 15p. Base 15p.
- 240 VOLT A.C. RELAY** 240V. A.C. heavy duty 3 c/o contacts. Price 75p. Post 15p. Octal base 15p extra

- 220/240 VOLT A.C. RELAY** 3 c/o 5 amp cont. Sealed M.f.g. ISKRA £1.25. Post 15p. Base 15p extra.
- ARROW 230/240V AC** 2 c/o 15 amp contacts. Amp connectors. £1.00. Post 15p
- 110 VOLT A.C.** 2 c/o 20 amp. £1.25. Post 15p
- CLARE-ELLIOT Type RP 7641 G8** Miniature relay. 675 ohm coil. 24 volt D.C. 2 c/o. 70p. P.P.

MANY OTHERS FROM STOCK, PHONE FOR DETAILS

### PRECISION CENTRIFUGAL BLOWERS



Mfg. by Smiths Industries. Miniature model. Series SF/200. Size 95mm x 82mm x 82mm. Aperture 38mm x 31mm. 12 c.f.m. £2.75 Post 25p

Mfg. by Airflow Developments Ltd. Precision made continuously rated, smooth running. 230/240v A.C. motor. 80 c.f.m. As illustrated but with round aperture. £6.50. Post 50p.

Mfg. by Woods. Extremely powerful. 220/250v A.C. 0.3 amp. 2,700 r.p.m. continuously rated. Capacitor start. Cast construction. Aperture 66mm x 50mm O/A 200mm. £12.00. Post £1.00

### 230V FAN ASSEMBLY



Continuously rated, removable aluminium blades. Price £1.25. Post 25p. VAT 25%

### SUB-MINIATURE REED RELAY 3-9 VOLT D.C.



Single make, size 1 1/4" x 3/4" x 3/4". OUTSTANDING VALUE ONLY £1.00 for six. £1.50 for ten. Post 15p. (Min. order six)

### LATCHING RELAY

Twin latching relay. flip-flop 2c/o each relay. Mains contacts. 115 volts A.C. or 50 volt D.C. operation or 240 volts A.C. with 2.5k resistor. 85p. Post 15p



### COIN MECHANISM (Ex-London Transport)

Unit containing selector mechanism for 1p, 2p & 5p coins. Micro switches, relays solenoid-operated hopper. 24 volt D.C. Precision built to high standard. Incredible VALUE at only £2.50. Post 70p. VAT 25%.

### 230-250 VOLT A.C. SOLENOID

Similar in appearance to illustration. Approximately 1 1/2 lb. pull. Size of feet 1 1/8" x 1 1/8". Price £1.00 Post 15p



### SOLENOID HEAVY DUTY MODEL

230/250v A.C. Approx. 14lb. pull, 4" long x 2 1/2" wide x 3" high. £2.50. Post 30p

### 24 VOLT DC SOLENOIDS

UNIT containing 1 heavy duty solenoid approx 25 lb. pull at 1 in. travel, 2 solenoids of approx. 1 lb. pull at 1 in. travel, 6 solenoids of approx. 4 oz. pull at 1 in. travel. Plus 1 24V D.C. 1 heavy duty 1 make relay. Price: £2.50. Post 75p. ABSOLUTE BARGAIN.

### 600 WATT DIMMER SWITCH

Easily fitted. Fully guaranteed by makers. Will control up to 600 watts of all lighting except fluorescent at mains voltage. Complete with simple instructions. £2.75. Post 25p

1000 watt model	£4.00. Post 25p
2000 watt model	£8.00. Post 30p

### VARIABLE VOLTAGE TRANSFORMERS

- Carriage extra
- INPUT 230 v. A.C. 50/60
- OUTPUT VARIABLE 0/260 v. A.C.
- BRAND NEW. All types.
- 200W (1 Amp) ..... £10.00
- 0.5 KVA (Max. 2 1/2 Amp) ..... £11.50
- 1 KVA (Max. 5 Amp) ..... £16.50
- 2 KVA (Max. 10 Amp) ..... £30.00
- 3 KVA (Max. 15 Amp) ..... £33.00
- 4 KVA (Max. 20 Amp) ..... £60.00
- (max. 37.5 Amp) ..... £102.50
- 1 Amp OPEN TYPE (Panel Mounting) ..... £10.00



### LT TRANSFORMERS

- 0.6, 12 volt @ 10 amp. £5.60 Post 70p
- 0.10, 17, 18 volt @ 10 amp. £7.90 Post 70p
- 0.6, 12 volt @ 20 amp. £9.00 Post 70p
- 0.12, 24 volt @ 10 amp. £9.20 Post 70p
- 0.4, 6, 24, 32 volt @ 12 amp. £9.90 Post 70p
- 0.6, 12, 17, 18, 20 volt @ 20 amp. £10.40 Post 70p

### AUTO TRANSFORMERS

Step up step down 0 115 200 220 240 volts. At 75 watt £2.64. Post 40p. 150 watt £3.50 Post 50p. 300 watt £6.20 Post 60p. 500 watt £9.20 Post 75p. 1000 watt £12.00 Post 90p.

## STROBE! STROBE! STROBE!

- ★ FOUR EASY TO BUILD KITS USING XENON WHITE LIGHT FLASH TUBES, SOLID STATE TIMING + TRIGGERING CIRCUITS, PROVISION FOR EXTERNAL TRIGGERING. 230-250v. A.C. OPERATION.
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- ★ RANGE OF THREE OTHER STROKE KITS FROM STOCK. FROM £5.30 to £22.00 S.A.E. (Footscap) for details.
- ★ \*\*\*\*\*
- ★ BIG BLACK LIGHT 400 Watt Mercury vapour ultra violet lamp. Extremely compact and powerful source of u.v. Innumerable industrial applications also ideal for stage display, discos etc. P.F. ballast is essential with these bulbs. Price of matched ballast and bulb £21.00. Post £1. Spare bulb £8.00. Post 40p.
- ★ \*\*\*\*\*
- ★ BLACK LIGHT FLUORESCENT U.V. TUBES 4ft. 40 watt £5.50 (cellars only). 2ft. 20 watt £4.25. Post 40p. For use in span bin fitting. MINI 12in. 8 watt £1.60. Post 25p. 9in. 6 watt £1.30. Post 25p. Complete ballast unit and holders for either 9" or 12" tube. £1.70. Post 25p. (9in. x 12in. measures approx.)
- ★ \*\*\*\*\*
- ★ U.D.I. SINGLE CHANNEL. 750 watt MANUAL/AUTO DIMMER 750W Solid State Fader, with three functions. Manual fade, Auto fade-up, Auto fade-down. Automatic cycling up and down. Functions selected with 'three position' rocker switch. Two ranges of cycling for 'Flashing' or 'Slow blending'. Ready built module 6" x 3" glass fibre board incorporating 10 amp TRIAC. Two or more modules for top quality colour blending and flashing effects. PRICE £15.00. Post 45p.
- ★ \*\*\*\*\*

### SQUAD LIGHT



A new conception in light control. Four channels each capable of handling 750 watts of spotlights, noodlights, or dozens of small mains lamps. Seven programs all speed controlled plus flash modulation, effectively giving 14 different displays. Makes sound-to-light obsolete. Completely electrically and mechanically noise free. Can be used on same circuit as radio mikes or sensitive amplifiers. A whole new range of lighting effects possible with astounding results. Already in use in London's foremost theatres, night clubs and discos. Conforms to all R.F.I. tests, including Common Market regulations. Supplied in tough, well designed case with embossed front panel. Price only £60.00. Post 60p. S.A.E. (Footscap) for further details.

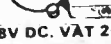
### 'GENTS' 6" ALARM BELL

200/250 volt AC/DC. Brand New. Price: £5.00. Post 60p (Illus.) VAT 25%



### 'STC' 6" RED ALARM BELL

Brand New. Price: £4.00. Post 50p. 24/48V DC. VAT 25%



### INSULATION TESTERS (NEW)

Test to I.E.E. Spec. Rugged metal construction, suitable for bench or field work, constant speed clutch. Size L. 8 in., W. 4 in., H. 6 in., weight 6 lb. 500 VOLTS 500 megohms £30.00. Post 80p. 1000 VOLTS 1000 megohms £36.00. Post 80p.



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### METERS NEW



90mm Diameter. Type 65C5. 2A D.C. M/C. 5A D.C. M/C. 10A D.C. M/C. 20A D.C. M/C. 50A D.C. M/C. Type 62T2. 1A A.C. M/I. 20A A.C. M/I. 300V A.C. M/I. ALL ABOVE £2.50. Post 20p. Type 65L5. 300V A.C. R/M/C. £2.75. Post 20p

64mm x 56mm RECTANGULAR Type B5C1. 5A D.C. M/C. 20A D.C. M/C. Type 85L1. 5A A.C. R/M/C. 10A A.C. R/M/C. 300V A.C. R/M/C. All at £3.00. Post 20p

### 'CARTER 230 VOLT A.C. GEARED MOTOR



230/240 volt A.C. smooth, powerful, continuously rated. Two types: 32 r.p.m. or 110 r.p.m. Either type £4.50 post 50p.

### REVERSIBLE MOTOR

General Electric. 230v A.C. 1,600 r.p.m. 0.25 amp. Complete with anti-vibration mounting bracket and capacitor. O/A size 110mm x 95mm. Spindle 5/16" dia. 20mm long. Ex-equipment tested. £3.00. Post 50p.

### 20 r.p.m. GEARED MOTOR

230/240 volt 20 r.p.m. motor £1.00 Post 15p

### BODINE TYPE N.C.I. GEARED MOTOR



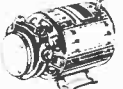
(Type 1) 71 r.p.m. torque 10 lb. in. Reversible 1/70th h.p. cycle 38 amp. (Type 2) 28 r.p.m. torque 20 lb. in. Reversible 1/80th h.p. cycle 28 amp. The above two precision made U.S.A. motors are offered in as new condition. Input voltage of motor 115v A.C. Supplied complete with transformer for 230/240v A.C. input. Price either type £6.25 Post 65p. or less transformer £3.75 Post 50p. These motors are ideal for rotating aerials, drawing curtains, display stands, vending machines, etc. etc.

### BENDIX MAGNETIC CLUTCH



A superb example of electro-mechanics! The main body is in two sections. The coil section is fixed and has a 3/8in. sleeve. The drive section rotating on the outer perimeters. The uniting plate has 3/8in. ID bearing concentric with main section and 18-tooth cog wheel. When energized transmission is extremely powerful, 24V d.c. at 240 MA. OUR PRICE JUST £2.50 Post 30p

### ROTARY VACUUM AIR COMPRESSOR AND PUMP



Carbon vane, oilless, 100/115v A.C. 1/12 h.p. motor, 50/60 cycle 2875/3450 r.p.m. 20" vacuum. 1.25 c.l.m., 10 p.s.i. (approx. figures). New unused surplus stock, with elect. connection data. Fraction of maker's price. £12.00. Post 50p. Suitable transformer £3.50. Post 50p.

### UNISELECTOR SWITCHES - NEW

4 BANK 25 WAY FULL WIPER 25 ohm coil, 24v. D.C. operation £6.90. Post 30p. 6 BANK 25 WAY FULL WIPER 25 ohm coil, 24 v. D.C. £7.90. Post 30p. 8 BANK 25 WAY FULL WIPER 24 v. D.C. operation £9.50. Post 40p.



### TIME SWITCH

'Horstmann' Type VMK II Time Switch. 200/250 volt pre-set time 30 amp contacts. 35 hour spring reserve in case of power failure. Day omitting device. Fitted in heavy high impact case, with glass observation window. Built to highest Electricity Board spec. individually tested. Price £7.75. Post 50p. (Total inc. VAT £8.91)



### A.C. MAINS TIMER UNIT



Based on an electric clock, with 25 amp single pole switch, which can be preset for any period up to 12 hrs. ahead to switch on for any length of time, from 10 mins. to 6 hrs. then switch off. An additional 60 min. audible timer is also incorporated. Ideal for Tape Recorders, Lights, Electric Blankets, etc. Attractive satin copper finish. Size 135 mm x 130 mm x 60 mm. Price £2.00. Post 40p. (Total inc. VAT & Post £2.59)

### PROGRAMME TIMERS

230/240 Volt A.C. 15 RPM Motors. Each cam operates a c/o motor switch. Ideal for lighting effects, animated displays etc. Ex-equipment tested. Similar in illustration. 2 cam model 15 r.p.m. £2.00 post 35p. 4 cam model 15 r.p.m. £2.50 post 35p. 8 cam model 20 r.p.m. £4.75 post 40p. 8 cam model, each cam fully adjustable. 6 r.p.m. M.f.g. by Magnetic Devices. £7.50. Post 35p.



### POWER RHEOSTATS

new ceramic construction, vitreous enamel embedded winding, heavy duty brush assembly, continuously rated. 25 WATT 10 25 100 150 250 500 1k 1.5k 2.5k ohm. £1.70 Post 15p. 50 WATT 1.5 10 25 50 100 500 1k ohm £2.10. Post 20p. 100 WATT 1/10 25/50/100/250/500/1k/1.5k/2.5k/5k ohm £3.30. Post 25p. Black Silver Skirted knob calibrated in Nos. 1-9. 1 1/2 in. dia brass bush. Ideal for above Rheostats, 22p ea.

### TRIAC

Raytheon Tag symmetrical Triac. Type TAG 250/500V. 10 amp. 500 p.i.v. Glass passivated plastic triac. Swiss precision product for long-term reliability. £1.00 Post 10p. Inct. data and application sheet. Suitable Diac. 18p

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ECH81 0.35	E290 0.45	PFL36 0.83	UF89 0.50	6ESGT 0.75	30C17 1.00	6062	CV133	CV3991	EF56	OZ4
ECH84 0.50	EY50 0.90	PL38 0.85	UL41 0.85	6F23 0.90	30C18 0.90	6063	CV135	CV3998	EF60	OZ4A
ECL30 1.40	ECL80 0.60	PL81 0.55	UL84 0.50	6J5G 0.45	30F5 1.00	6064	CV136	CV4001	EL91	PT15
ECL82 0.42	ECL82 0.42	PL82 0.50	UY41 0.55	6J5GT 0.55	30FL1 1.00	6065	CV137	CV4002	EN30	QA2400
ECL86 0.55	H63 0.75	PL83 0.50	VP4B 1.25	6K6GT 0.80	30L15 0.95	6067	CV138	CV4003	EN31	QA2403
ECL88 0.55	HL41DD 0.70	PL84 0.50	VR75/30 0.55	6K8GT 0.50	30L12 1.00	6072	CV139	CV4004	EN32	QA2406
EF37A 1.20	HN309 1.50	PL504 0.85	VR105/30 0.40	6Q25 2.50	30P19 0.95	6073	CV140	CV4005	EN91	QA2404
EF39 0.40	KT66 2.85	PL508 0.90	VR150/30 0.50	6Q7GT 0.43	30PL1 0.95	6074	CV141	CV4006	ESU74	QA2406
EF40 0.50	KT81 (7C5) 1.30	PL509 1.55	Y63 1.25	6G6T 0.50	30PL13 1.10	6080	CV173	CV4007	ESU76	QA2406
EF45 1.50	KT88 3.25	PL801 1.00	Y63 1.25	6J5G 0.50	30PL14 1.10	6082	CV177	CV4008	ESU77	QA2406
EF48 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6083	CV180	CV4009	ESU77	QA2406
EF49 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6084	CV182	CV4010	ESU77	QA2406
EF50 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6085	CV187	CV4011	ESU77	QA2406
EF55 1.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6086	CV188	CV4012	ESU77	QA2406
EF58 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6087	CV190	CV4013	ESU77	QA2406
EF60 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6088	CV191	CV4014	ESU77	QA2406
EF65 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6089	CV192	CV4015	ESU77	QA2406
EF68 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6090	CV193	CV4016	ESU77	QA2406
EF69 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6091	CV194	CV4017	ESU77	QA2406
EF70 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6092	CV195	CV4018	ESU77	QA2406
EF71 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6093	CV196	CV4019	ESU77	QA2406
EF72 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6094	CV197	CV4020	ESU77	QA2406
EF73 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6095	CV198	CV4021	ESU77	QA2406
EF74 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6096	CV199	CV4022	ESU77	QA2406
EF75 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6097	CV200	CV4023	ESU77	QA2406
EF76 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6098	CV201	CV4024	ESU77	QA2406
EF77 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6099	CV202	CV4025	ESU77	QA2406
EF78 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6100	CV203	CV4026	ESU77	QA2406
EF79 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6101	CV204	CV4027	ESU77	QA2406
EF80 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6102	CV205	CV4028	ESU77	QA2406
EF81 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6103	CV206	CV4029	ESU77	QA2406
EF82 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6104	CV207	CV4030	ESU77	QA2406
EF83 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6105	CV208	CV4031	ESU77	QA2406
EF84 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6106	CV209	CV4032	ESU77	QA2406
EF85 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6107	CV210	CV4033	ESU77	QA2406
EF86 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6108	CV211	CV4034	ESU77	QA2406
EF87 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6109	CV212	CV4035	ESU77	QA2406
EF88 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6110	CV213	CV4036	ESU77	QA2406
EF89 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6111	CV214	CV4037	ESU77	QA2406
EF90 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6112	CV215	CV4038	ESU77	QA2406
EF91 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6113	CV216	CV4039	ESU77	QA2406
EF92 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6114	CV217	CV4040	ESU77	QA2406
EF93 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6115	CV218	CV4041	ESU77	QA2406
EF94 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6116	CV219	CV4042	ESU77	QA2406
EF95 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6117	CV220	CV4043	ESU77	QA2406
EF96 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6118	CV221	CV4044	ESU77	QA2406
EF97 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6119	CV222	CV4045	ESU77	QA2406
EF98 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6120	CV223	CV4046	ESU77	QA2406
EF99 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6121	CV224	CV4047	ESU77	QA2406
EF100 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6122	CV225	CV4048	ESU77	QA2406
EF101 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6123	CV226	CV4049	ESU77	QA2406
EF102 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6124	CV227	CV4050	ESU77	QA2406
EF103 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6125	CV228	CV4051	ESU77	QA2406
EF104 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6126	CV229	CV4052	ESU77	QA2406
EF105 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6127	CV230	CV4053	ESU77	QA2406
EF106 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6128	CV231	CV4054	ESU77	QA2406
EF107 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6129	CV232	CV4055	ESU77	QA2406
EF108 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6130	CV233	CV4056	ESU77	QA2406
EF109 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6131	CV234	CV4057	ESU77	QA2406
EF110 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6132	CV235	CV4058	ESU77	QA2406
EF111 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6133	CV236	CV4059	ESU77	QA2406
EF112 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6134	CV237	CV4060	ESU77	QA2406
EF113 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6135	CV238	CV4061	ESU77	QA2406
EF114 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6136	CV239	CV4062	ESU77	QA2406
EF115 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6137	CV240	CV4063	ESU77	QA2406
EF116 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6138	CV241	CV4064	ESU77	QA2406
EF117 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6139	CV242	CV4065	ESU77	QA2406
EF118 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6140	CV243	CV4066	ESU77	QA2406
EF119 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6141	CV244	CV4067	ESU77	QA2406
EF120 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6142	CV245	CV4068	ESU77	QA2406
EF121 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6143	CV246	CV4069	ESU77	QA2406
EF122 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6144	CV247	CV4070	ESU77	QA2406
EF123 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6145	CV248	CV4071	ESU77	QA2406
EF124 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6146	CV249	CV4072	ESU77	QA2406
EF125 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6147	CV250	CV4073	ESU77	QA2406
EF126 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6148	CV251	CV4074	ESU77	QA2406
EF127 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6149	CV252	CV4075	ESU77	QA2406
EF128 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6150	CV253	CV4076	ESU77	QA2406
EF129 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6151	CV254	CV4077	ESU77	QA2406
EF130 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6152	CV255	CV4078	ESU77	QA2406
EF131 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6153	CV256	CV4079	ESU77	QA2406
EF132 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6154	CV257	CV4080	ESU77	QA2406
EF133 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6155	CV258	CV4081	ESU77	QA2406
EF134 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6156	CV259	CV4082	ESU77	QA2406
EF135 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6157	CV260	CV4083	ESU77	QA2406
EF136 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6158	CV261	CV4084	ESU77	QA2406
EF137 0.50	KT88 3.25	PL802 1.25	Y63 1.25	6J5G 0.50	30PL14 1.10	6159	CV262	CV4085	ESU77	QA2406
EF138 0.50	KT88 3.25	PL802								

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Large table of electronic components including resistors, capacitors, and transistors with various part numbers and prices.

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Table listing electronic components including diodes (PCL86, PCL805), transistors (2B01U, 2900T), and other parts.

Table listing electronic components including diodes (6A8K, 6A8L), transistors (6A8M, 6A8N), and other parts.

Table listing electronic components including diodes (6A8P, 6A8Q), transistors (6A8R, 6A8S), and other parts.

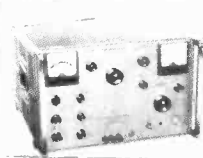
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Unit Oscillator 121B-A **P.O.A.**  
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### HEWLETT PACKARD

U.H.F. Signal Generator 614A 900-2100MHz 1% Accuracy. Output 0.1 $\mu$ V-0.2V into 50 ohms. Modulation: CW/Int. or EXT. FM & Pulse S.H.F. Signal Generator 618C 3.8-7.6GHz  $\pm$  1% 50 ohms **£550**  
Signal Generator 608B 10-400MHz 0.1 $\mu$ V-0.8V **£195**  
Signal Generator BU8E **£625**

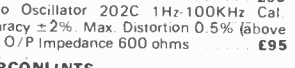
Signal Generator 612A 450MHz-1230MHz Internal & Ext. A.M. 50 ohms **£495**  
Audio Oscillator Type 201C 20 Hz-20 KHz 0-40 dB in 10 dB steps. Distortion less than 0.5%. Also 200 CD & 200B **£95**

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**MARCONI INSTRUMENTS.**



Phase/AM Signal Generator TF 2003 0.4-12 MHz. Bargain price - super condition **£150**

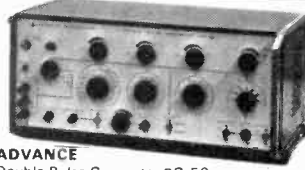
FM/AM Signal Generators  
TF995A **£185**  
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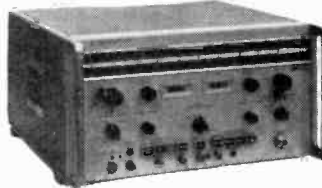
## PULSE GENERATORS



### ADVANCE

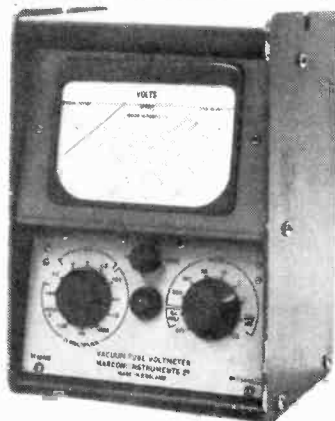
Double Pulse Generator PG 56 Pulse Amplitude 0.1V-10V. Sq. wave 0-10V. Rise Time 10nsec. (typically) **£87.50**  
Pulse Generator PG 55 **P.O.A.**  
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Sweep Oscillator 692D 2-4GHz **£495**  
Sweep Oscillator 693B 4-8GHz **£495**

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Sensitive Valve Voltmeter TF 1100 **£85**

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VTVM 400L Logarithmic version of 400D. Reads RMS value of sine wave. Log. voltage scale 0.3 to 1 & 0.8 to 3. Linear dB scale. Input Impedance 10Mohms **£90**

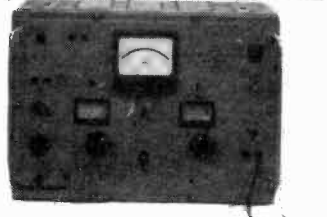
PHILIPS  
L.F. Millivoltmeter GM 6012 **£65**  
H.F. Millivoltmeter GM 6014 **£55**  
D.C. Microvoltmeter GM 6020 **£60**

ADVANCE  
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Megger 250V **£20**  
Battery Megger 500V **£37**

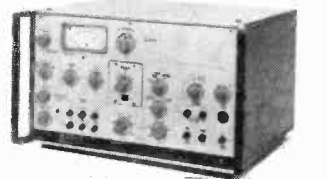
## TELEPHONE TEST EQUIPMENT



Siemens Level Meter 3D 335 10KHz-17MHz. Complete system by Siemens comprising: 3W 518 Level Oscillator, 3D 335 Level Meter, 3W 933 Sweep Attachment, 3D 346 Screen Level Tracing Receiver **P.O.A.**  
Siemens Level Meter 3D 332 0.3-1200KHz. Level Oscillator 3W 29. 0.3-1200KHz **P.O.A.**

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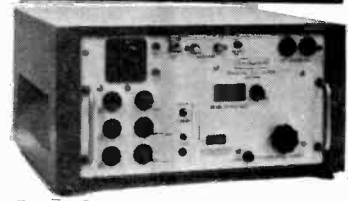
B 7971. Displays alphabet & 0-9 numerals **99p**

## OSCILLOSCOPE TEST EQUIPMENT



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## MISCELLANEOUS



Transfer Oscillator Type 7580HB by Beckman. DC-15GHz with counter, 7.5MHz-15GHz without counter. Sensitivity 100mV (R.M.S.)  
**MARCONI**  
Distortion Factor Meter TF 142F Fundamental Freq. Range 100Hz-8KHz. Dist. measurement ranges 0-5% & 0-50% **£60**  
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Low Freq. Decade Oscillator OS 103.3 **P.O.A.**

EKCO INSTS (Nucleonics)  
Rate meter N 600B **P.O.A.**  
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Level Measuring Set 74307A **P.O.A.**

RADIOMETER  
1MHz Capacitance Comparator Type CMB 11bS2 **P.O.A.**

BELL  
Gaussmeter 120 **P.O.A.**

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Microwave Link Analyser 3701/02/03 **£2000**  
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Trolley for 175A scope **£50**  
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P.R.D. **P.O.A.**

Noise Generator 904A **P.O.A.**  
TELEMAX-SOUTHERN  
TD1 Freq. Meter/Generator. 10KHz-3000 MHz **P.O.A.**

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Manuf	Type	Turns	Value	Price
Relcon	0705/1001/A	5	100 ohm	<b>£1.75</b>
Relcon	0705/05/F11	5	200 ohm	<b>£1.75</b>
Beckman	7246/5019	10	50 ohm	<b>£2.00</b>
Bourns	35005-2-500	10	50 ohm	<b>£1.95</b>
Bourns	35005	10	1K	<b>£2.00</b>
Beckman	A/S303	10	5K	<b>£1.00</b>
Beckman	72212/5	10	10K	<b>£2.00</b>
Relcon	0710-1-1-001A	10	10K	<b>£2.00</b>
Beckman A		10	20K	<b>£3.00</b>
Borg	KS1302512	10	20K	<b>£2.00</b>
Beckman	7223	10	50K	<b>£3.50</b>

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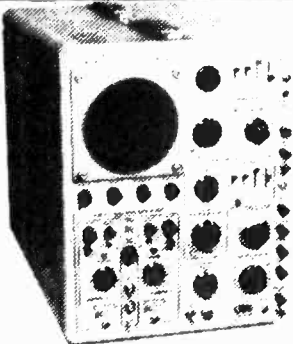
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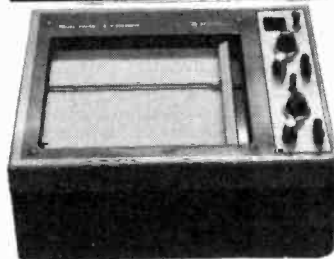
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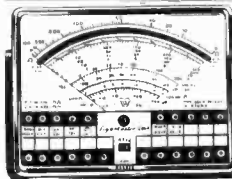
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MEASURES ONLY  
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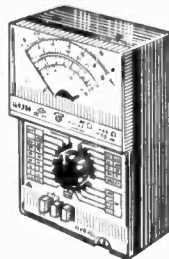
PRINTED CIRCUIT BOARD IS REMOVABLE WITHOUT SOLDERING

Volts d.c. 6 ranges: 100mV, 2V, 10V, 50V, 200V, 1,000V (20kΩ/V) 2% precision on d.c. and a.c.  
Volts a.c. 5 ranges: 1.5, 10V, 50V, 250V, 1,000V (4kΩ/V)  
Amp. d.c. 6 ranges: 50µA, 500µA, 5mA, 50mA, 500mA, 5A  
Amp. a.c. 5 ranges: 250µA, 2.5mA, 25mA, 250mA, 2.5A  
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## RECORDERS

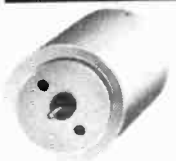
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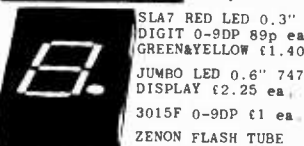


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**INSULATION TEST SET:** 0-10 kV negative, earth with amplifier provision for checking ionisation. 110/230v a.c. input. S/hand, good cond. £35 + £1 carr.  
**BRIDGE MEGGER:** 250V. (Evershed Vignoles) series 2. £30 each. Carr. £1.  
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**CRYSTAL TEST SET TYPE 193:** used for checking crystals in freq. range 3000-10,000KHz. Mains 230V 50Hz. Measures crystal current under oscillatory conditions and the equivalent resistance. Crystal freq. can be tested in conjunction with a freq. meter. £25. Carr. £1.50.

**SOLARTRON VARIABLE POWER UNIT S.R.S. 1535:** 0-500 volts at 100 mA and 6.3 volts C.T. 3 amps d.c. 110/250 volts a.c. input. £18.50. Carr. £1.50.

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**NOISE FIGURE METER TYPE 113A** (Magnetic AB, Sweden): Complete with Noise Source 121 and 122. £125. Carr. £1.  
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**RHODE & SCHWARZ HF MILLIVOLTMETER:** 30Hz-30MHz Type UVH, 1mV-1V in 7 ranges, 220V. £75 each. Carr. £2.  
**PHILIPS VALVE VOLTMETER TYPE GM6014:** 1-300mV in 6 ranges, 70-20dB, probe 1000Hz-30MHz, 300mV maximum. £35 each. Carr. £1.

**CT343 VALVE VOLTMETER:** in ruggedised steel case. Range 1.2mV to 400V. 6 ranges indicated on 3" meter. 230v a.c. input. £25. Carr. £2.

**UHF MICROWAVE MILLIWATTMETER TYPE 14:** Direct reading, can be used to measure power from 100MHz upwards. F.S.D. on 4in. scale meter 2.5mW. £40 each. Carr. £1.  
**MARCONI HF SPECTRUM ANALYSER OA. 1094/3:** Further details on request. £250 each. Carr. £5.

**Q METER:** 30MHz-200MHz. £55. Carr. £1.  
**AVO TRANSISTOR ANALYSER CT.446:** £35. carr. £1.50.  
**ALL CARRIAGE QUOTES GIVEN ARE FOR 50-MILE RADIUS OF LONDON ONLY.**

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**TF-1278/1 TRAVELLING TUBE WAVE AMPLIFIER:** £25. Carr. £2.  
**BPL A.C. MILLIVOLTMETER TYPE VM.348-D Mk. 3:** 2 millivolts-2 volts, 6 ranges. £30. Carr. £1.  
**WAYNE KERR WAVEFORM ANALYSER A.221:** Low scale 0-1200 c/s. High scale 1-20 Kc/s. 600 ohms. Harmonic level is 0-55 dB in 12 steps. £75. Carr. £1.50.

**SPECTRUM ANALYSER TYPE MW.69S** (Decca): Further details on request. £200.

**MARCONI DUAL TRACE UNIT TM-6456:** £30. Post 60p.  
**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 — 40-400 pulses per sec. Pulse Width — 0.5-10 microseconds. Timing — Undelayed or delayed from 3-300 microseconds from external or internal pulse. Output — 1 milliwatt max., 0 to -127 dB variable. Output Impedance — 500. Price: £120 each + £2 carr.

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- check tape switch for encoded monitoring in three-head machines

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- regulated power supply components
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Additional items required .....

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AC134	0.15	BC182	0.15
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AC154	0.20	BC187	0.29
AC156	0.20	BC207	0.11
AC157	0.25	BC208	0.12
AC158	0.20	BC211	0.15
AC159	0.20	BC212	0.13
AC167	0.20	BC214L	0.17
AC168	0.25	BC225	0.26
AC169	0.15	BC226	0.36
AC176	0.20	BC301	0.28
AC177	0.28	BC302	0.25
AC178	0.29	BC303	0.37
AC179	0.29	BC304	0.37
AC180	0.20	BC440	0.31
AC180K	0.30	BC460	0.37
AC181	0.20	BCY30	0.25
AC181K	0.30	BCY31	0.27
AC187	0.23	BCY33	0.22
AC188	0.22	BCY34	0.28
AC188K	0.32	BCY70	0.15
ACV17	0.26	BCY71	0.20
ACV18	0.20	BCY72	0.15
ACV19	0.20	BCZ10	0.20
ACV20	0.20	BCZ11	0.26
ACV21	0.20	BCZ12	0.26
ACV22	0.17	BD115	0.63
ACV23	0.19	BD116	0.81
ACV28	0.19	BD121	0.61
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ACV30	0.36	BD124	0.70
ACV31	0.29	BD131	0.51
ACV34	0.21	BD132	0.61
ACV35	0.21	BD133	0.67
ACV36	0.29	BD136	0.41
ACV40	0.18	BD137	0.46
ACV41	0.18	BD138	0.46
ACV44	0.38	BD139	0.58
AD130	0.39	BD140	0.61
AD140	0.49	BD155	0.81
AD142	0.49	BD175	0.61
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AD149	0.51	BD177	0.67
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AD161 & AD162 (MP)	0.69	BD180	0.71
AD162 (MP)	0.69	BD185	0.67
AD170	0.51	BD186	0.67
AD174	0.25	BD187	0.71
AD175	0.25	BD188	0.71
AD176	0.25	BD189	0.77
AD177	0.25	BD190	0.77
AD178	0.36	BD195	0.87
AD179	0.36	BD196	0.87
AD180	0.36	BD197	0.87
AD181	0.36	BD198	0.87
AD182	0.36	BD199	0.87
AD183	0.36	BD200	0.87
AD184	0.36	BD201	0.87
AD185	0.36	BD202	0.87
AD186	0.36	BD203	0.87
AD187	0.36	BD204	0.87
AD188	0.36	BD205	0.87
AD189	0.36	BD206	0.87
AD190	0.36	BD207	0.87
AD191	0.36	BD208	0.87
AD192	0.36	BD209	0.87
AD193	0.36	BD210	0.87
AD194	0.36	BD211	0.87
AD195	0.36	BD212	0.87
AD196	0.36	BD213	0.87
AD197	0.36	BD214	0.87
AD198	0.36	BD215	0.87
AD199	0.36	BD216	0.87
AD200	0.36	BD217	0.87
AD201	0.36	BD218	0.87
AD202	0.36	BD219	0.87
AD203	0.36	BD220	0.87
AD204	0.36	BD221	0.87
AD205	0.36	BD222	0.87
AD206	0.36	BD223	0.87
AD207	0.36	BD224	0.87
AD208	0.36	BD225	0.87
AD209	0.36	BD226	0.87
AD210	0.36	BD227	0.87
AD211	0.36	BD228	0.87
AD212	0.36	BD229	0.87
AD213	0.36	BD230	0.87
AD214	0.36	BD231	0.87
AD215	0.36	BD232	0.87
AD216	0.36	BD233	0.87
AD217	0.36	BD234	0.87
AD218	0.36	BD235	0.87
AD219	0.36	BD236	0.87
AD220	0.36	BD237	0.87
AD221	0.36	BD238	0.87
AD222	0.36	BD239	0.87
AD223	0.36	BD240	0.87
AD224	0.36	BD241	0.87
AD225	0.36	BD242	0.87
AD226	0.36	BD243	0.87
AD227	0.36	BD244	0.87
AD228	0.36	BD245	0.87
AD229	0.36	BD246	0.87
AD230	0.36	BD247	0.87
AD231	0.36	BD248	0.87
AD232	0.36	BD249	0.87
AD233	0.36	BD250	0.87
AD234	0.36	BD251	0.87
AD235	0.36	BD252	0.87
AD236	0.36	BD253	0.87
AD237	0.36	BD254	0.87
AD238	0.36	BD255	0.87
AD239	0.36	BD256	0.87
AD240	0.36	BD257	0.87
AD241	0.36	BD258	0.87
AD242	0.36	BD259	0.87
AD243	0.36	BD260	0.87
AD244	0.36	BD261	0.87
AD245	0.36	BD262	0.87
AD246	0.36	BD263	0.87
AD247	0.36	BD264	0.87
AD248	0.36	BD265	0.87
AD249	0.36	BD266	0.87
AD250	0.36	BD267	0.87
AD251	0.36	BD268	0.87
AD252	0.36	BD269	0.87
AD253	0.36	BD270	0.87
AD254	0.36	BD271	0.87
AD255	0.36	BD272	0.87
AD256	0.36	BD273	0.87
AD257	0.36	BD274	0.87
AD258	0.36	BD275	0.87
AD259	0.36	BD276	0.87
AD260	0.36	BD277	0.87
AD261	0.36	BD278	0.87
AD262	0.36	BD279	0.87
AD263	0.36	BD280	0.87
AD264	0.36	BD281	0.87
AD265	0.36	BD282	0.87
AD266	0.36	BD283	0.87
AD267	0.36	BD284	0.87
AD268	0.36	BD285	0.87
AD269	0.36	BD286	0.87
AD270	0.36	BD287	0.87
AD271	0.36	BD288	0.87
AD272	0.36	BD289	0.87
AD273	0.36	BD290	0.87
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AD280	0.36	BD297	0.87
AD281	0.36	BD298	0.87
AD282	0.36	BD299	0.87
AD283	0.36	BD300	0.87
AD284	0.36	BD301	0.87
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AD288	0.36	BD305	0.87
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AD292	0.36	BD309	0.87
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AD295	0.36	BD312	0.87
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AD297	0.36	BD314	0.87
AD298	0.36	BD315	0.87
AD299	0.36	BD316	0.87
AD300	0.36	BD317	0.87
AD301	0.36	BD318	0.87
AD302	0.36	BD319	0.87
AD303	0.36	BD320	0.87
AD304	0.36	BD321	0.87
AD305	0.36	BD322	0.87
AD306	0.36	BD323	0.87
AD307	0.36	BD324	0.87
AD308	0.36	BD325	0.87
AD309	0.36	BD326	0.87
AD310	0.36	BD327	0.87
AD311	0.36	BD328	0.87
AD312	0.36	BD329	0.87
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AD323	0.36	BD340	0.87
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AD328	0.36	BD345	0.87
AD329	0.36	BD346	0.87
AD330	0.36	BD347	0.87
AD331	0.36	BD348	0.87
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AD342	0.36	BD359	0.87
AD343	0.36	BD360	0.87
AD344	0.36	BD361	0.87
AD345	0.36	BD362	0.87
AD346	0.36	BD363	0.87
AD347	0.36	BD364	0.87
AD348	0.36	BD365	0.87
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AD350	0.36	BD367	0.87
AD351	0.36	BD368	0.87
AD352	0.36	BD369	0.87
AD353	0.36	BD370	0.87
AD354	0.36	BD371	0.87
AD355	0.36	BD372	0.87
AD356	0.36	BD373	0.87
AD357	0.36	BD374	0.87
AD358	0.36	BD375	0.87
AD359	0.36	BD376	0.87
AD360	0.36	BD377	0.87
AD361	0.36	BD378	0.87
AD362	0.36	BD379	0.87
AD363	0.36	BD380	0.87
AD364	0.36	BD381	0.87
AD365	0.36	BD382	0.87
AD366	0.36	BD383	0.87
AD367	0.36	BD384	0.87
AD368	0.36	BD385	0.87
AD369	0.36	BD386	0.87
AD370	0.36	BD387	0.87

## \* 74 SERIES T.T.L. I.C.'s

BI-PAK STILL LOWEST IN PRICE. FULL SPECIFICATION GUARANTEED. ALL FAMOUS MANUFACTURERS

Type	Quantities			Type	Quantities		
	1	25	100+		1	25	100+
7400	0.14	0.13	0.12	7486	0.32	0.31	0.30
7401	0.14	0.13	0.12	7489	3.70	3.47	3.24
7402	0.14	0.13	0.12	7490	0.60	0.58	0.56
7403	0.14	0.13	0.12	7491	1.02	0.97	0.93
7404	0.14	0.13	0.12	7492	0.69	0.68	0.69
7405	0.14	0.13	0.12	7493	0.89	0.86	0.89
7406	0.36	0.31	0.29	7494	0.79	0.78	0.69
7407	0.36	0.31	0.29	7495	0.79	0.78	0.69
7408	0.23	0.22	0.21	7586	0.89	0.86	0.90
7409	0.23	0.22	0.21	74100	1.39	1.34	1.30
7410	0.14	0.13	0.12	74104	0.56	0.54	0.51
7411	0.23	0.22	0.21	74105	0.56	0.54	0.51
7412	0.28	0.25	0.24	74107	0.41	0.39	0.37
7413	0.30	0.29	0.28	74110	0.56	0.51	0.46
7416	0.28	0.27	0.26	74111	0.83	0.81	0.78
7417	0.28	0.27					

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**AL 60**

**ONLY £3.95**

**50w. PEAK (25w. R.M.S.)**

● Max Heat Sink temp 90°C ● Frequency Response 20Hz to 100K Hz ● Distortion better than 0.1 at 1KHz  
 ● Supply voltage 15-50 volts ● Thermal Feedback ● Latest Design Improvements ● Load — 3, 4, 5 or 16 ohms ● Signal to noise ratio 80dB ● Overall size 63mm x 105mm x 13mm. Especially designed to a strict specification. Only the finest components have been used and the latest solid state circuitry incorporated in this powerful little amplifier which should satisfy the most critical A.F. enthusiast.

## STABILISED POWER MODULE SPM80

SPM80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watt (r.m.s.) per channel simultaneously. This module embodies the latest components and circuit techniques incorporating complete short circuit protection. With the addition of the Mains Transformer BMT80, the unit will provide outputs of up to 1.5 amps at 35 volts. Size: 63mm x 105mm x 30mm.

These units enable you to build Audio Systems of the highest quality at a hitherto unobtainable price. Also ideal for many other applications including:—Disco Systems. Public Address Intercom Units, etc. Handbook available 10p.

**TRANSFORMER BMT80 £2.60**

**PRICE £3.00**

## STEREO PRE-AMPLIFIER TYPE PA100

Built to a specification and NOT a price, and yet still the greatest value on the market, the PA100 stereo pre-amplifier has been conceived from the latest circuit techniques. Designed for use with the AL50 power amplifier system, this quality made unit incorporates no less than eight silicon planar transistors, two of these are specially selected low noise NPN devices for use in the input stages.

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

**£13.20**

### MK 60 AUDIO KIT

Comprising: 2 x AL60, 1 x SPM80, 1 x BTM80, 1 x PA100, 1 front panel, 1 kit of parts to include on-off switch, neon indicator, stereo headphone sockets plus instruction booklets.

COMPLETE PRICE: £27.55 plus 45p postage.

### TEAK 60 AUDIO KIT

Comprising: Teak veneered cabinet size 16 1/4" x 11 1/4" x 3 3/4", other parts include aluminium chassis, heatsink and front panel bracket, plus back panel and appropriate sockets, etc.

KIT PRICE: £9.20 plus 45p postage.

## STEREO 30 COMPLETE AUDIO CHASSIS

**7 + 7 WATTS R.M.S.**

The Stereo 30 comprises a complete stereo pre-amplifier, power amplifiers and power supply. This with only the addition of a transformer or overwind, will produce a high quality audio unit suitable for use with a wide range of inputs, i.e. high quality ceramic pickup, stereo tuner, stereo tape deck, etc.

Simple to install, capable of producing really first-class results, this unit is supplied with full instructions, black front panel, knobs, mains switch, fuse & fuse holder and universal mounting bracket, enabling it to be installed in a record plinth, cabinets of your own construction or the cabinet available.

Ideal for the beginner or advanced constructor who requires Hi-Fi performance with a minimum of installation difficulty. Can be installed in 30 mins.

**PRICE £15.75** Plus 45p postage & packing

**TRANSFORMER £2.45** plus 45p postage & packing **TEAK CASE £3.65** plus 45p postage & packing

## AL 10/AL 20/AL 30

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

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

**AL10 £2.30, AL20 £2.65, AL30 £2.95**

### SPEAKERS

E.M.I. LEK 350 Loudspeakers Enclosure kit in teak veneer, including speakers. Rec. retail price £4.50 per pair.

OUR SPECIAL PRICE ONLY £27.75 per pair P&P £3 WHILE STOCKS LAST!

### HEADPHONES

4-16 ohms impedance frequency response 20 to 20,000 Hz stereo/mono switch and Volume Control £4.55

### FRONT PANEL

FOR PA100. Attractive matt silver. Finish with black trim and lettering. Adds that professional touch £1.10 only.

### M.P.A.30

Enjoy the quality of a magnetic cartridge with your existing ceramic equipment using the new Bi-Pak M.P.A.30 which is a high quality pre-amplifier exist for the use of ceramic cartridges only.

Used in the construction are 4 low noise, high gain, silicon transistors and it is provided with a standard DIN input socket for ease of connection.

Supplied with full, easy to follow instructions.

**PRICE £2.65**

### STORAGE-CARRY CASES

**RECORD CASES**  
 7 in E.P. 18 3/8th in. x 7 in x 8 in (50 records) \*£2.48  
 12 in L.P. 13 3/4 in x 7 3/8th in x 1 1/2 in (50 records) \*£3.30

**CASSETTE CASES**  
 Holds 15. 10in x 3 3/4 in x 5in. Lock and handle \*£1.50

**8-TRACK CARTRIDGE CASES**  
 Holds 14. 13in x 5in x 6in. Lock and handle \*£2.20  
 Holds 24. 13 3/8th in x 8 in x 5 3/8th in Lock and handle \*£3.20

### CARTRIDGES

ACOS GP91-1SC	200mV at 1.2cm/s/sec	£1.11
GP93-1	280mV at 1cm/sec	£1.43
GP96-1	100mV at 1cm/sec	£2.31
J-2005	Crystal/Hi Output	£0.97
J-2010C	Crystal/Hi Output Compatible	£1.11
J-2006S	Stereo/Hi Output	£1.52
J-2105	Ceramic/Med Output	£1.81
J-2203	Magnetic 5mV/5cm/sec including stylus	£4.78
J-22038	Replacement stylus for above	£2.88
AT-55	Audio-technica magnetic cartridge 4mV/5cm/sec	£3.06

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**STEREO FM TUNER**

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MARCONI TF801B/2S. 10-480 mHz £225.  
MARCONI TF144H 10kHz-72 mHz P.O.A.  
ADVANCE SG63D. AM/FM 7.5-230mHz £125.  
RACAL/AIRMEC 201A. 30kHz-30mHz. As new. P.O.A.  
ADVANCE SG21 VHF Square-wave generator 9kHz-100mHz. £25.

## OSCILLOSCOPES



TEKTRONIX 661 Sampling scope with 4S1 & 5T1A plug-in units. 3GHz. £200.  
TEKTRONIX 545A with CA unit. DC-30mHz. Price only £295.00  
TEKTRONIX 531 DC-15mHz with L type plug-in  
TEKTRONIX 535 DC-15mHz with L type plug-in  
TEKTRONIX 545B DC-30mHz with 'CA' plug-in.  
TEKTRONIX 585A. DC-80mHz with type 82 plug-in.  
TEKTRONIX 654B. Storage oscilloscope.  
TEKTRONIX 502. 200uV. Sens. X-Y.  
TEKTRONIX C27 Polaroid Camera. Series 125 with 560 series adapter.

## MISCELLANEOUS TEST EQUIPMENT

MARCONI TF1400S double pulse generator with TM6600 S secondary pulse unit. £105.  
MARCONI TF791D deviation meter. 4-1024mHz. 0-100kHz deviation.  
MARCONI 455E Wave Analyser £120.  
MARCONI TF2600 Valve Voltmeter 1mV-300V. Excellent. £75.  
ROHDE & SCHWARZ USVD calibrated receiver 280-940mHz (4600mHz).  
ROHDE & SCHWARZ A.F. Wave Analyser type FTA 0-20kHz plus log/lin AF meter incorporated. Excellent condition.  
ROHDE & SCHWARZ URV milli-voltmeter BN10913 (late type) 1mV-10V. With 'T' type insertion unit. free probe and attenuator heads. 1kHz-1.600mHz. £175.  
COSSOR 1453 True RMS milli-voltmeter. Excellent. £75.  
AIRMEC TYPE 210 modulation meter. Excellent condition.  
ROHDE & SCHWARZ "SCR" V.H.F. Signal Generator 1000-1900 mHz  
ADVANCE type SG68 low distortion A.F. oscillator. 1.5 Hz-150kHz. Sine and square wave. Battery operated. £75.  
MARCONI type TF936 Impedance Bridge. £85.00.  
GERTCH Phase Angle V. Meters. Range 1mV-300V, in 12 ranges.  
SOLARTRON oscillator type CO 546. 25Hz-500kHz. £30.00.  
GAMBRELL Precision 4 Decade Resistance Box. 1-11, 110 ohms £24.50.

### BOXER INSTRUMENT FANS

Dimensions 4.5 x 4.5 x 1.5 ins. Very quiet running. precision fan specially designed for cooling electronic equipment, amplifiers etc. For 110V. AC operation—(practise is to run from split primary of mains transformer or use suitable mains dropper). CC only 11 Watts. List price over £10 each. Our price, in brand new condition, is £4.50.

### POWER SUPPLIES

WEIR Electronics modular unit. Model OCAR. Regulated & stabilised. 0-7V @ 2A. £9.50.  
APT regulated, stabilised power packs of computer quality. 240V input. 20VDC O.P. variable at 10A. Also 10V variable at 7.5A. Uses best quality output transistors. New condition. Both models £18.50.

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BNC plugs 50Ω. 30p. BNC sockets 50Ω. 25p. N. Type plugs 50Ω. 50p. Burndept plugs. 40p. Burndept sockets. 40p. Miniature PYE. 20p. Miniature sockets. 20p.  
All connectors are brand new. Immediate delivery. Please add appropriate postage.

AEI miniature uniselectors. Type 2200C. 3 banks. 1 bridging, 2 non-bridging wipers. 12 positions. Coil resistance 50 ohms. Complete with bases. Brand new. £4.50 each.  
20-way BPO Jack strips to accept 316 type Jack plugs. Also quantity of 316 plugs available. All good condition.

**PLEASE ADD 8% V.A.T. TO THE TOTAL AMOUNT WHEN ORDERING. INCORRECT AMOUNTS WILL CAUSE DELAY IN DESPATCH. THANK YOU.**

### AVO VALVE TESTERS

Brief-case type 160. Full working condition throughout. £65.

**AERIAL CHANGE/OVER RELAYS**  
of current manufacture designed especially for mobile equipments, coil voltage 12v., frequency up to 250 MHz at 50 watts. Small size only, 2 in. x 1/2 in. Offered brand new, boxed. Price £1.50, inc. P.&P.

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**WESTREX PAPER TAPE PUNCHES.** 8 Hole. Late model contained in noise reducing cabinets. As new. £105.00.

E.M.I. oscilloscopes model WM16 with type 7/1 W.B.A. plug-in unit. Supplied in perfect condition complete with trolley. £125.00.

**HEWLETT PACKARD/BOONTON TYPE 8900B**  
Peak-power calibrator. Measures true peak power ±6 db absolute. Frequency range 50-2000mHz. RF power range 200mW peak, full-scale. RF Impedance 50 ohms. P.O.A.

**MARCONI TF995A2/M AM/FM R.F. SIGNAL GENERATORS.** 1.5-220mHz. 0-100kHz Deviation. 1μV-100mV output. Sold in excellent condition. P.O.A.

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CD4013AE 0.46	CD4031AE 1.01	CD4049AE 0.46	CD4071BE 0.18	CD4510BE 1.26
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CD4015AE 0.83	CD4033AE 1.14	CD4051AE 0.77	CD4073BE 0.18	CD4512BE 1.93
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**BUILD A SIMPLE CLOCK**  
5LT01 4 digit 0.5" display + AY51202 new clock IC + suitable transformer: all for **£13.10.** (Only other components needed are 20 R's, 5 C's, 6 D's, 3 Sws)

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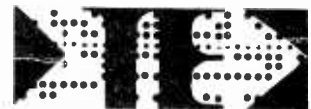
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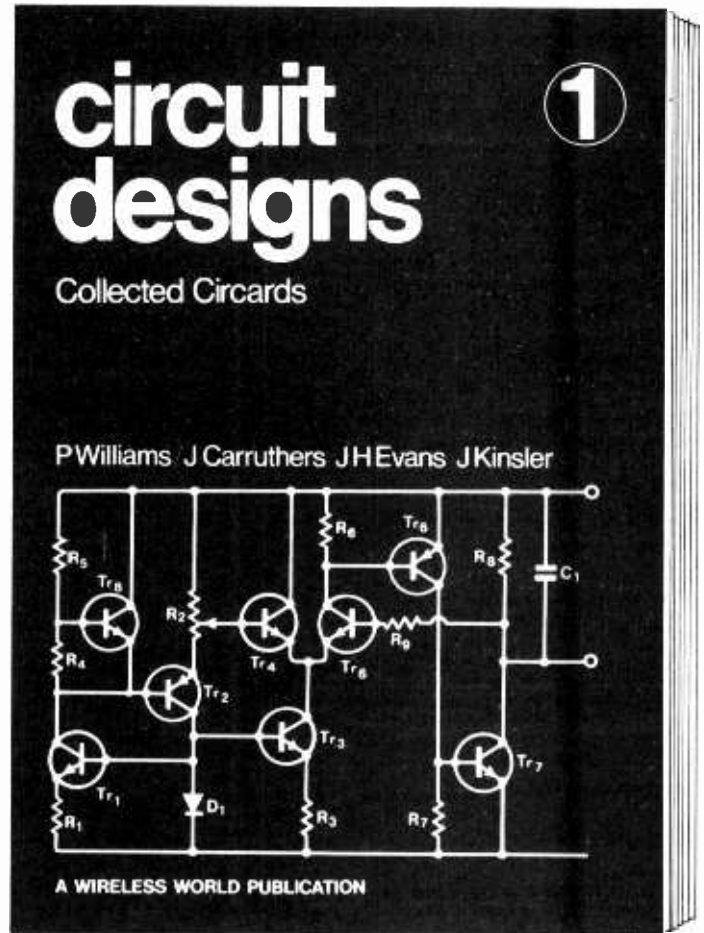
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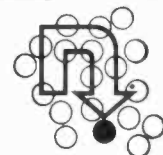
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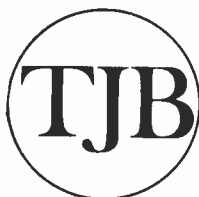
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The company operates a free life assurance plan and contributory pension scheme.

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**TIM HOLL  
Director of Acoustics  
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for Spain

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NORTRON, Fernando el Católico 63, Madrid 15, Spain. Attention of the Engineering Manager, and state phone number and suitable hours to be contacted.

(4924)

## ELECTRONIC ENGINEERING STAFF

## TWO ELECTRONIC ENGINEERS

are required by EMI Electronics, Electron Tube Division, Ruislip, Middx.

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The second vacancy exists in the Equipment Section for an electronics engineer to undertake electronic equipment design and subsequent development through to small scale production. The equipment may incorporate photo-electric devices and it would be necessary for him to investigate some of the mechanical, thermal and optical aspects of the design.

The candidates should preferably have an Honours Degree but applicants with other qualifications and some experience would be considered.

Personal interviews arranged by telephone at a time to suit your convenience or call for immediate interview 9 a.m. - 11 a.m. or 2 p.m. - 4 p.m.

Telephone Mrs. E. A. Crossman, Personnel Department, EMI Electronics Ltd., Bury Street, Ruislip, Middx. Ruislip 30771.

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c. £3,600 London, SE1

A Technical Author is required to join a small team of authors in the Development Department of Cable and Wireless Limited (location: Southwark, between Waterloo and London Bridge). Current involvements include message switching systems (telegraph), telex, data communications and airport traffic control equipment.

The successful applicant would be responsible for compiling Customer handbooks and must therefore combine a good electronic engineering background with the ability to interpret circuit diagrams, and to transfer the information into a logical and readable form, in lucid English. A knowledge of logic and linear circuitry and previous experience of technical writing are essential.

Qualifications should be preferably HNC (Electronics) or City and Guilds Final Telecom. Technicians Certificate standard, but other applicants will be considered if their experience is suitable. Starting pay around £3650 per annum according to qualifications and experience, on career salary scale.

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Personnel Officer (Recruitment),  
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Theobalds Road,  
LONDON, W.C.1.  
01-242 4433 Extn. 211

4948

## SOUND SYSTEMS ENGINEER

for Spain

NORTRON, the leading Spanish designers and manufacturers of TV, FM and Sound Broadcasting equipment, require a SYSTEMS ENGINEER with not less than 4 years' experience in multichannel Mixer Desks and with good knowledge of the Broadcasting industry.

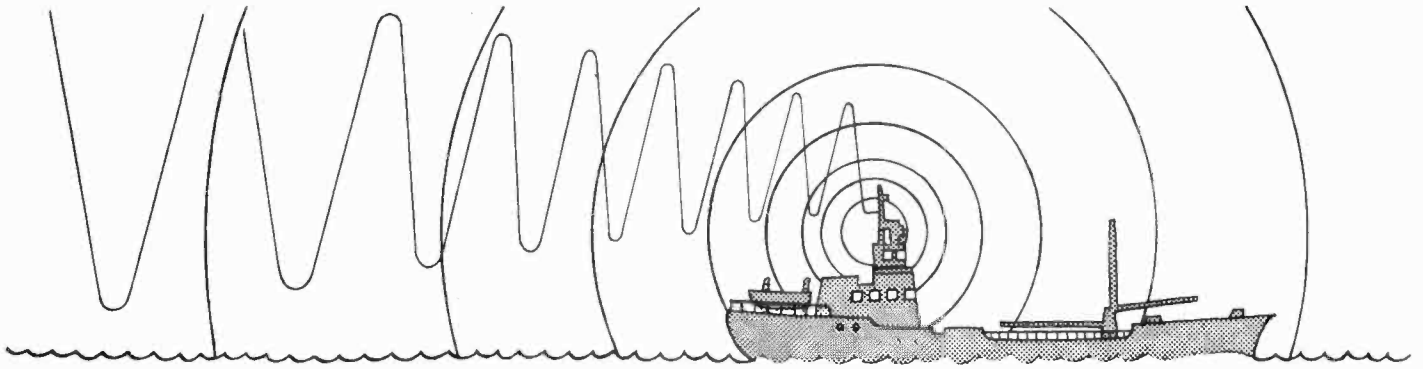
The post is based in Madrid, Spain, and attracts a substantial salary and full relocation expenses.

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NORTRON, Fernando el Católico 63, Madrid 15, Spain. Attention of the Engineering Manager, and state phone number and suitable times to be contacted.

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according to age. You'll also receive an allowance for shift duties which at the maximum of the scale averages £900 a year and there are opportunities to earn overtime. There's a good pension scheme, sick pay benefits and prospects of promotion to senior management.

Right now we have vacancies at some of our coastal radio stations, so if you're 19 or over, write to: ETE Maritime Radio Services Division (R/B/10), ET 17.1.1.2., Room 643, Union House, St. Martins-le-Grand, London EC1A 1AR.

Post Office Telecommunications

93

### ELECTRONIC ENGINEERS

Applications are always invited from Engineers with a background of test and R and D. Bias to Avionics systems.



Technical Reserves  
362 Euston Road  
London, NW1  
Tel: 388 1609

(4944)

### MEDICAL ELECTRONICS

Technician / Academic (non-tutorial). Salary not less than £2,511 rising possibly to £6,050, plus London Weighting.

Applications invited from graduates preferably with industrial experience, to work in new Medical, School & Teaching Hospital as part of team evaluating drugs under laboratory and clinical conditions. Successful applicant to operate and maintain wide range of electronic monitoring equipment including colour TV. **Research interest in design fields encouraged.**

Apply: The Secretary, Dept. of Pharmacology, Charing Cross Hospital Medical School, Brandenburgh House, Fulham Palace Road, London, W6 9HH.

(4927)

## Opportunities for Electronics Engineers

To change to wider fields of electronics — join the EMI Service Team at Hayes.

Vacancies exist on repair and calibration of a wide range of electronic test gear including oscilloscopes, DVMS, pulse generators, power supplies etc.

### Also

Servicing and commissioning closed circuit television equipment including cameras, VTRs, Monitors etc.

Applicants should have at least 5 years practical experience.

These positions offer varied and interesting work. Attractive starting salaries, subsidised lunches, 4 weeks holiday and excellent sick pay and pension schemes.

For further details telephone or write to: - M. Ford, 01-573 3888, Ext. 2167, EMI Service, 254 Blyth Road, Hayes, Middlesex.



The international music, electronics and leisure Group.

(4926)

## British Relay Communication and Call Systems - Speech and Visual

We are acquiring an increasing volume of business in this field including many very long term contracts, and we are seeking to expand the range of our activities. Consequently, we have immediate requirements for engineers with good practical experience and ability in any of the following aspects of the work:—

System Design  
Planning and Estimating  
Project Control  
Installation Supervision  
Test and Commissioning

Duties are varied and interesting, with frequent opportunities for travel, and for acquiring experience in new fields. Enquiries and application for interviews will be treated in strict confidence, and should be sent to:—

### BRITISH RELAY TV

The General Manager,  
British Relay  
(Electronics) Limited,  
41 Streatham High Road,  
London SW16 1EP  
Tel. 01-677 9681.

(4937)

## ELECTRONIC DEVELOPMENT ENGINEER

Do you have an H.N.C. Technician's qualification?  
Have you obtained a five-year apprenticeship and  
mechanical experience?

Are you interested in joining a "high-powered" team?

If so, we have the job for you —

Our Research and Development staff need an engineer to assist in the design and development of high power electronic X-ray supplies (including the redesigning of conventional X-ray power supplies), test equipment and general laboratory duties.

The engineer must be able to work under minimum supervision and high voltage engineering and transformer design would be an advantage to applicants. This is a senior staff position and carries an appropriate salary level.

If you would like an interview, please contact:



The Personnel Officer  
Pantak (EMI) Ltd.  
Vale Road  
Windsor  
SL4 5JP  
Telephone: Windsor 60306

4946

### LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

#### ELECTRONICS TECHNICIAN

Applications are invited for a post in the Department of Engineering Production. Duties include the setting up and maintenance of a range of instrumentation for experimental work in the Department's laboratories. The person appointed would be expected to give assistance to projects in the form of development and construction of electronic equipment and devices. There would be an opportunity to gain experience in the fields of control engineering, numerically controlled machine tools, and application of computers in Production Engineering.

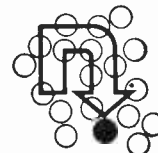
Education to ONC/OND or City and Guilds Intermediate Certificate standard and experience, including apprenticeship, of at least ten years required.

Salary on Grade 5 scale: £2,439-£2,895 per annum.

Applications in writing or by telephone for application form to: **Administrative Officer, Department of Engineering Production, University of Technology, Ashby Road, Loughborough, Leics., LE11 3TU. Telephone Loughborough 63171, ext. 323.**

(4935)

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01-629 0501

4947

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Experienced Language Laboratory Technician required. Salary on scale £2013-£2343 or £2247-£2628 plus £260 London Allowance, according to age and experience. Applications stating training and experience, together with the names and addresses of two referees should be sent to the Personnel Officer (WW) as soon as possible, from whom further details may be obtained.

(4920)

**It's the  
Engineers  
on the  
ground  
who  
keep the  
aircraft  
flying**

**MARCONI  
ELLIOTT  
AVIONICS**

A GEC-Marconi Electronics Company

With the increasing sophistication of today's aircraft, the role of the Service and Test Engineer on the ground is of the utmost importance if the electronic systems and equipment are to be kept at a high level of efficiency.

We are engaged in an expanding programme of work covering the provision of spares and the repair, maintenance and overhaul of airborne electronic equipment, and we need Service and Test Engineers to work on a variety of British and American equipment, both in the aircraft and in the workshop.

The work calls for a sound knowledge of radio and electronics theory, preferably coupled with a recognised qualification and at least two years' experience in servicing or maintaining complex electronics equipment, including complete fault diagnosis using sophisticated test gear. Training will be given to suitable less experienced engineers.

The Company offers excellent salaries together with all the benefits of working for a highly progressive company within a major electronics group. The Unit provides first-class working conditions and is conveniently located in pleasant surroundings with close easy access to the M1.

Write with details of experience to Mrs. L. J. Elborn, Marconi-Elliott Avionic Systems Limited, 22-26 Dalston Gardens, Stanmore, Middlesex HA7 1BZ.  
Tel: 01-204 3322.

(4936)

**CHAILEY HERITAGE  
CHILDREN'S HOSPITAL**

**ELECTRONICS/  
TECHNICIAN**

A new post in the Experimental Workshop, Chailey Heritage Children's Hospital, Lewes, Sussex, to assist with research on equipment for physically-handicapped children. Required: experience in electronic circuitry and instrumentation and fundamental knowledge of measurement and data acquisition techniques. Qualifications: ONC, HNC, HND, or appropriate degrees, plus experience. Salary: £3558-£4581 p.a. Whitley Council conditions of service.

Phone (Newick 2112) or write to Mr. N. D. Ring (Technical Director) for further details. Applications by October 3rd.

4959

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**KINGSTON POLYTECHNIC  
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The Senior Technician will deal mainly with servicing of equipment in the Closed Circuit Television Unit. Knowledge of colour circuitry-helical scan VTRs and video cassette systems essential. Candidates should have HNC or final C&G Electronic Servicing or equivalent.

Salary grade T2/3 £2529-£3282 + £261 London allowance.

Application forms from Assistant Registrar  
Kingston Polytechnic

Penrhyn Road, Kingston upon Thames KT1 2EE. 01-549 1366

4966



**R & H APPLIED DYNAMICS  
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For installation and maintenance of hybrid computers and interactive computer display systems. Previous experience in similar systems desirable but not essential. Adaptability and ability to work on own initiative more important. Attractive salary and a company car will be offered to suitable applicant who will work from home with occasional calls to base in Worthing.

Please write for Application Form, or telephone:

**R&H Applied Dynamics  
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Tel. Worthing (0903) 205995**

4940

## AIRFIELD NAVAIDS AND RADAR TRAINING COURSES

### for well paid overseas posts

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Suitable applicants who have had several years' experience in this field will be given additional training at our own college of engineering.

#### AR5/SSR: commencing 4th November

Experienced Radar Tech./Engineers for training on airport surveillance radar and sophisticated secondary radar systems.

Applicants will have had several years' practical experience in maintenance of radar systems together with a good knowledge of digital techniques. Experience on small computers would be an advantage.

Formal qualifications to HNC standard (or C and G final telecomms) or several years' experience of in-depth maintenance of modern radar systems.

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The commencing salary is c. £4500 p.a., free of local income tax. Additional benefits include free furnished accommodation, generous leave, excellent contributory pension scheme.

Write or telephone now for application form to:

John Nisbet, Recruitment Officer, International Aeradio Limited, Aeradio House,

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4850

## Technical Writers and Authors

£2,500-£3,750  
South East

For a major British electronics company, exporting 60% of its products, with wide experience in commercial and military fields. It is a leader in radar simulation, nuclear power simulation and key-to-disc systems.

The Technical Writers and Authors will prepare maintenance and operational manuals for the above.

Candidates need at least two years' experience and must be able to express themselves clearly. Ex-Service personnel with electronics teaching/writing experience will be considered. Salaries to match qualifications and experience, company benefits and help with removal expenses.

Telephone: Vernon Wells, Brighton (0273) 23431, or write to PER, 53 West Street, Brighton BN1 2RL.

4941

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WITWATERSRAND, JOHANNESBURG

## RESEARCH ELECTRONICS ENGINEER

Applications are invited from suitably qualified persons for a vacancy in the Electronics Workshop of the Nuclear Physics Research Unit.

The duties encompass the maintenance and repair of existing electronic units associated with all aspects of the Unit's research interests as well as the design and construction of new equipment.

The salary scale attached to the post is R6300 x 360 — R9180.

An applicant not meeting the required standard of qualification and/or experience may be offered the appointment on a lower salary scale.

The University offers generous leave, medical aid and pension facilities, and an annual vacation savings bonus. The policy of the University is not to discriminate in the appointment of staff or the selection of students on the grounds of sex, religion, race, colour or national origin.

Applicants should apply in writing giving full personal and career details, including the names and addresses of three referees, to the Registrar, University of the Witwatersrand, Jan Smuts Avenue, Johannesburg 2001, South Africa, with whom applications should be lodged not later than 29th October, 1975. A copy of the application should be sent to the London Representative, University of the Witwatersrand, 278 High Holborn, London W.C.1.

4953

## ENGINEERS for DEVELOPMENT and PRODUCTION

Grampian, a member company of the Telephone Rentals group, are engaged in the manufacture of a wide range of professional and industrial audio and telephone equipment, both electronic and electro-acoustic. The equipments are for both outright sale and long-term rental contract. In order to ensure the reliability necessary for such applications we carry out many operations in-house not often grouped within a single company. This means that our engineers have greater freedom of specification and a wider field of involvement than they might otherwise achieve.

If you are interested in accepting the challenge of one of these positions and you have relevant experience and qualifications please telephone Mr. G. Turner on 01-894 9141, or write for application form to:

**Grampian**

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The Hanworth Trading Estate  
Hampton Road West, Feltham, Middlesex TW13 6EJ

4945

**ELECTRONICS TECHNICIAN** aged 20-30. We are a small Company situated in S.W. London. We require a technician to join our young electronics team working on professional audio equipment. He will be responsible for the alignment, testing and maintenance of digital, analogue and audio circuitry, and should have some practical experience in one of these fields. The company operates a profit sharing scheme. Telephone Mr. Evans at 01-542 1171. (4869)

**TELEVISION TECHNICIANS** wanted for Middle East position. Five years heavy maintenance required. Send resumes and copies of certificates to Box WW 4851.

University of Oxford  
Department of Biochemistry

## RESEARCH ASSISTANT IN ELECTRONICS

Applications are invited for the post of Research Assistant to help with the development and construction of a 470 MHz magnetic resonance spectrometer. The successful candidate will work in a small research group headed by Dr. R. E. Richards and will be involved in the UHF, digital and audio fields. Whilst expertise relevant to one of these areas would be an advantage, the post is probably most suited to a person wishing to gain experience on a broad front by participation in an exciting project, which is a leader in its field. The salary for the post, which is funded for a maximum of three years by the Science Research Council, will be in the range £2439 to £3594 p.a., starting salary depending on age and experience. Candidates must have a degree or equivalent qualifications, and applications, giving full details and including the names and addresses of two referees, should be sent by 30th October to: The Administrator, Department of Biochemistry, South Parks Road, Oxford OX1 3QU.

4939

**INSTRUMENT TECHNICIANS**, can you offer an interesting, worthwhile and rewarding employment to a recently qualified Instrument Technician with City & Guild (275). Industrial measurement P. control certificate. Who is prepared to work non standard hours. If required with a U.K. based company. Then please contact WW, Box 4965, for further details.

**MARINE ELECTRONIC FIELD** installation engineers able to install and service radars, R/T, auto-pilots, instrumentation, D.F.s, etc., around the country and abroad. Mechanical engineering ability is necessary. A first-class standard of work without supervision is a must. Candidates must live in or around London. Clean driving licence and references required. Apply in writing to: Telesonic Marine Ltd., 243 Euston Road, N.W.1. (4849)

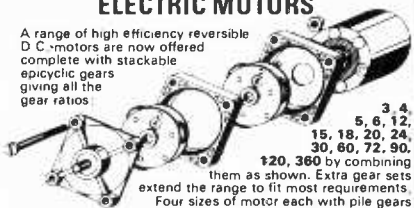
**STUDIO IN KENSINGTON AREA** requires JUNIOR TECHNICIAN (18-22 years) to assist with maintenance and tape editing. Contact Graham Stephens, 108 Cromwell Road, London SW7. Tel. 01-370 1442. (4887)

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Suggested applications. Laboratory equipment, stirrers, pump drives, servo systems, positioning of aerials, dampers, doors, power for models, trains, boats, drills, cutting wheels etc. SAE for DATA SHEETS. All prices are inclusive in U.K.

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Applicants must possess experience in running a consumer service operation for a large Company and the knowledge of audio and T.V. servicing is particularly relevant.

Conditions of service and benefits are first class.

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The Boots Company Ltd.,  
Station Street, Nottingham NG2 3AA.

(4938)

## LINK



## DEVELOPMENT ENGINEER (VIDEO)

to join our R and D team working on design and development of TV studio broadcast equipment. Our products range from amplifiers and coders to broadcast standard colour cameras.

You should be about 24-28 with a good degree or HND and you must have at least two years' experience since qualifying. A background within television or communications would be ideal but is not essential.

We are a young Company with full order books for both home and export markets. Our factory in Andover is in an attractive area of rural Hampshire close to several main towns. Housing is both easier and cheaper than London. In addition to a good salary we also offer free life and health insurance, pension scheme, of course, subsidised canteen and assistance with relocation costs where necessary.

Either telephone Mic Comber at Andover 61345 (reverse charge if you wish) or write with brief details so that we can send you an application form.

## LINK ELECTRONICS

Walworth Industrial Estate,  
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4919  
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All 240V input, voltages quoted approx. RMS

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**N-TYPE PLUGS** 50ohm, 60p each.

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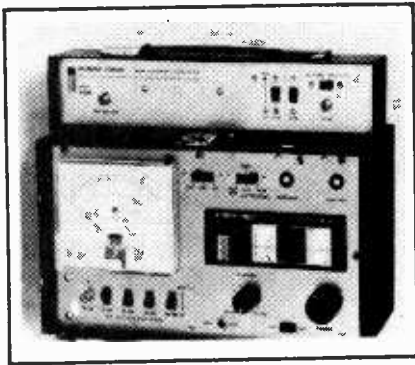
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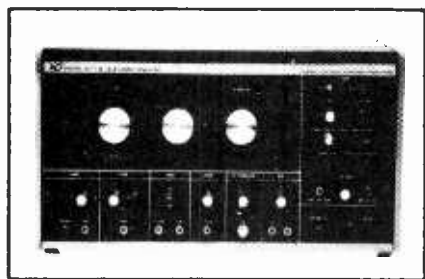
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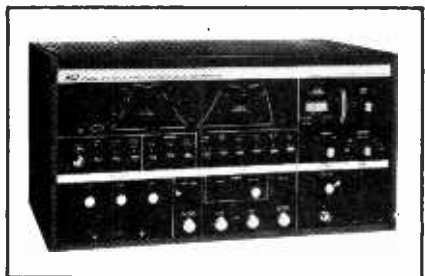
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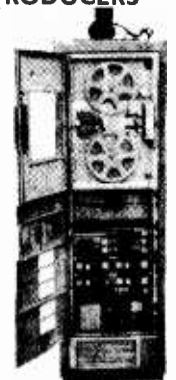
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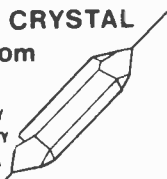
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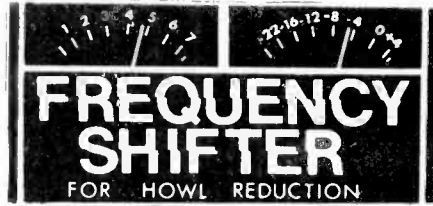
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## INDEX TO ADVERTISERS

Appointments Vacant Advertisements appear on pages 75-87

PAGE		PAGE		PAGE	
Aero Electronics Ltd.	26, 28	Grampian Reproducers Ltd.	14	Q-Max Electronics Ltd.	27
Alice Broadcasting (Stancoil Ltd.)	12	Greenwood Electronics Ltd.	2	Quality Electronics Ltd.	26
Ambientacoustics	33			Quartz Crystal Co. Ltd.	90
Ambit International Ltd.	32	Harmsworth Townley & Co. Ltd.	Readers Card		
Amtron (U.K.) Ltd.	27	Harris Electronics (London) Ltd.	16, 25	Radford Audio Ltd.	20
Antex Ltd.	37	Harris P.	91	Radford Laboratory Instruments Ltd.	33
A.S.P. Ltd.	21	Hart Electronics	54	Radio Shop, The	55
Aspen Electronics Ltd.	29	Heath (Gloucester)	4	Ralfe, P.	72
Audio Amateur	92	Henry's Radio Ltd.	51	Rank Film Equipment	30
Avo Ltd.	5, 29	Hi-Fidelity Designs	89	Rastra Electronics Ltd.	53
		I.L.P. (Electronics) Ltd.	8	R.C.S. Electronics	10
Bamber, B. Electronics Ltd.	86	Icelectrics Ltd.	31	Replecomps Ltd.	88
Barr & Stroud	6	Icon Design	22	R.E.W. Audio Visual Co.	92
Barrie Electronics Ltd.	55	Industrial Tape Applications Ltd	17	R.I. Audio	10
Bauch, F. W. O. Ltd	40	Integral Systems	32	Rilton Electronic Ltd.	26
Bell & Howell Ltd.	38, 39	Integrex Ltd.	11	Rogers Developments (Electronics) Ltd.	31
Bentley Acoustic Corp. Ltd.	65			Rola Celestion Ltd.	47
B.H. Component Factors Ltd	50	Jackson Bros. (Ldn) Ltd.	46	R.S.T. Valves Ltd.	64
Bias Electronics Ltd.	18	J.H. Associates Ltd.	25		
Bi-Pak Semiconductors Ltd.	70, 71	J.E.T. Electronics	56	Salon de L'Interelectronique	32
Bi-Pre Pak Ltd.	58	J. J. Lloyd Instruments Ltd.	3	Samsons (Electronics) Ltd.	62
Bridge Electronics	93			S.C.S. Components	93
Broadfields & Mayco Disposals	92	Keytronics Ltd.	92	Semiconductor Supplies	Loose Insert
Brooks & Green Ltd.	30			Service Trading Co.	63
Bull, J., Electrical Ltd.	60	Laskys	48, 49	Servo Data Ltd.	31
		Levell Electronics Ltd.	1	Servo & Electronics Sales Ltd.	61
Cambridge Learning	9	Light Soldering Developments Ltd.	12	Shelton Instruments Ltd.	25
Chiltmead Ltd.	73, 92, 94	Linstead Electronics	15	Shure Electronics Ltd.	36
Chromasonic Electronics	45	Longs Ltd.	24	Sintel	72
City Audio	54	Lynx (Electronics) London Ltd.	52	Sowter, E. A., Ltd.	92
Colomor (Electronics) Ltd.	65			Special Product Distributors Ltd.	24
Computer Sales & Services	60	Macinnes Labs. Ltd.	19	Strumech Eng. Ltd.	27
Crofton Electronics Ltd.	64	Magnetic Tapes Ltd.	29	Sugden, J. E. & Co. Ltd.	26
C.T. Electronics Ltd.	62	Manners, K. T. Design Ltd.	28	Surrey Electronics	93
		Maplin Electronic Supplies	44	Swanley Electronics Ltd.	30
Decon Laboratories Ltd.	10	Marco Trading Co.	91	Swift of Wilmslow	33
Dema Electronics International	24	McKnight Crystal Co.	92		
Direct Electronics Ltd.	93	McLennan Eng. Ltd.	18	Technomatic Ltd.	52
Dolby Noise Unit	69	Marconi Instruments Ltd.	cover ii	Teleprinter Equipment Ltd.	72
Doram Electronics Ltd.	7	Marshall, A. & Sons (London) Ltd.	54	Telegroup Products (Tektronix U.K.) Ltd.	34
Drake Transformers Ltd.	14	Meteronic Ltd.	27	Teleradio Special Products	92
Dymar Electronics Ltd.	43	Mills, W.	68	Telford Products Ltd.	22
		Modern Book Co.	91	Time Electronics Ltd.	30
ECM (Europe) Electronics Ltd.	42	Morhan Exporting Corp.	90	Trampus Electronics	68
East Cornwall Components	50	Multicore Solders Ltd.	cover iv	Turner Electronics	27
Edicron Ltd.	20				
Eddystone Radio Ltd.	4	Naim Audio	29	Vero Electronics	42
Electronic Brokers Ltd.	66, 67			Vitavox	18
Electro Systems & Timing Co.	28	OCLI Optical Coatings Ltd.	15		
Electroplan	23	Olson Electronics Ltd.	46	Wayne, Kerr, The, Co. Ltd.	41
Electrovalue	55			West Hyde Developments Ltd.	92
Empire Exporters Inc.	91	Patrick &innie	56	Whiteley Electrical Radio Co. Ltd.	17
English Electric Valve Co. Ltd.	20	PMS Nameplates	21, 92	Wilmslow Audio	90
Euro-Circuits	92	Powertran Electronics	57, 59	Wilkinson, L. (Croydon) Ltd.	64
Europhonic	28	Precision Petite Ltd.	25	Wireless World Circuit Designs	74
		Prosser Scientific Instruments	31		
Farnell Instruments Ltd.	13	Pulse Electronics Ltd.	22	Z. & I. Aero Services Ltd.	19, 51
Ferranti Ltd.	23	Purnell Book	Loose Insert	Zettler GmbH	16
Ferroglyph Professional Recorder Co. Ltd.	Cover iii	Pye Unicam Ltd.	13		
Ferroglyph Co. Ltd.	16				
Fi-Comp Electronics	30				
Fisher, Harold (Plastics) Ltd.	90				
Fisher, Harold (Plastics) Ltd.	92				
Fraser-Manning Ltd.	29				
Future Film Developments Ltd.	29				
Fylde Electronics Laboratories Ltd.	28				

# Ferrograph Professional Studio 8 Console



Full logic control. Tape motion sensing. Two speeds. Servo-controlled capstan. Constant tape tension. Direct-reading tape timer (minutes and seconds). Three editing modes. Provision for synchronisation, remote control and remote display panel. Available for line-in/line-out or with mixing and monitoring facilities. IEC or NAB equalisation. Full or

half-track mono, dual track or stereo. Easy access for maintenance. Also available in transportable and rack-mounted versions.

For full details contact Ferrograph Professional Recorder Company, 442 Bath Road, Slough SL16BB. Telephone Burnham (06286) 62511. Telex 847297. Cables Britferro, Slough.

# Ersin Multicore- the international solder

## Ersin Multicore 5-Core Solder

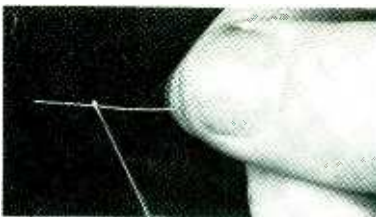
The proved superiority of ERSIN Multicore Solder for over thirty years is due to many factors. We have specialised throughout this period in the manufacture of cored solders. Consequently our research and manufacturing staff have been able to devote all their energies to the development of Multicore Solders. All alloys are of highest purity, carefully formulated and checked.

Our unsurpassed ERSIN flux is rigorously tested before and after it is incorporated in the solder wire. Our five separate cores of flux ensure flux continuity, leave only an ultra-thin layer of solder separating flux from work for instant wetting and provide a more accurate ratio of flux to solder. It is therefore possible to

use less solder and obtain greater reliability.

Our Quality Control at all stages of manufacture is guaranteed and recorded by the batch number on every reel.

## Needle fine gauges



In addition to our standard range of wire diameters (10-22 swg: 3.2-0.7 mm) supplied on 2½ kg and ½ kg reels we also mass-produce needle-fine gauges (24-34 swg: 0.56-0.23 mm) on 250 g reels for microminiature soldering applications—still with 5 Cores of flux.

## Savbit Solder

One of our most popular special ERSIN Multicore Solder alloys is SAVBIT alloy. Compared with ordinary tin/lead solders it dramatically reduces the erosion of soldering iron bits, copper wires and printed circuit conductors. It also saves costs and increases reliability. SAVBIT alloy containing 5-Cores ERSIN 362 flux has received special Ministry approval—under DTD. 900/4535 for Military applications.



Sectioned iron-plated bit, after 40,000 simulated operations using 60/40 Solder.



Sectioned iron-plated bit, after 40,000 simulated operations using SAVBIT Solder.

## ALLOY

Composition (nominal major elements)	Grade	Melting Temperature		Specification
		Solidus °C	Liquidus °C	
50/33/17 Sn/Pb/Cd	TLC	145	145	DIN 1707
62/36/2 Sn/Pb/Ag	LMP	179	179	DIN 1707
62/35.7/2/0.3 Sn/Pb/Ag/Sb	Sn62	179	179	QQ-S-57 1E
63/36.7/0.3 Sn/Pb/Sb	Sn63	183	183	QQ-S-57 1E
60/40 Sn/Pb	K	183	188	B.S. 219
60/39.7/0.3 Sn/Pb/5b	Sn60	183	188	QQ-S-57 1E
50/50 Sn/Pb	F	183	212	B.S. 219
50/49.7/0.3 Sn/Pb/Sb	Sn50	183	212	QQ-S-57 1E
50/48.5/1.5 Sn/Pb/Cu	Savbit 1	183	215	DTD 900/4535 DIN 1707
45/55 Sn/Pb	R	183	224	B.S. 219
40/60 Sn/Pb	G	183	234	B.S. 219
40/59.7/0.3 Sn/Pb/Sb	Sn40	183	234	QQ-S-57 1E
30/70 Sn/Pb	J	183	255	B.S. 219
20/80 Sn/Pb	V	183	275	B.S. 219
15/85 Sn/Pb	—	225	290	—
Pure Tin	P.T.	232	232	B.S. 3252
95/5 Sn/Sb	95A	236	243	B.S. 219
5/93.5/1.5 Sn/Pb/Ag	H.M.P.	296	301	B.S. 219



For full information on these and a Selector Guide to other MULTICORE products please write on your Company's letterhead direct to:

**Multicore Solders Limited**, Maylands Avenue, Hemel Hempstead, Hertfordshire HP2 7EP.  
Tel: Hemel Hempstead 3636 Telex: 82363