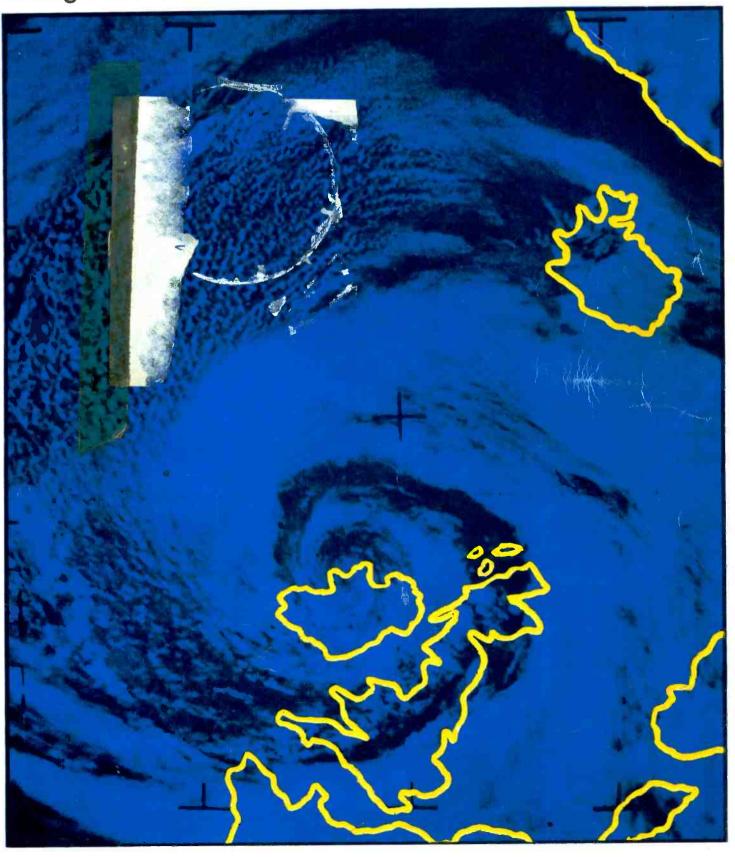
# WirelessWorld

Weather satellite receiver Making a turntable October 1971  $17\frac{1}{2}$ p



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# Taylor panel meters

are selected by equipment manufacturers everywhere.



### Vista Series

Popular, reliable panel maters with robust phenolic mouldings and scale lengths from 1½ in to 4½ in. This range combines compact functional styling with easy readability and excellent performance.

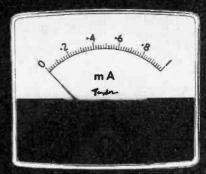
Machanically interchangeable with the Fyneline range.





### **Edgewise Series**

Here's the latest in the range of three Edgewise panel meters, the Model 330 with a 2½ in scale length. Ideal for today's crowded instrument panels, other scale lengths are 1½ in (Model 11) and 1¾ in (Model 220).



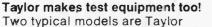
### **Fyneline Series**

Adaptable versatile series with scale lengths from 13/4 in to 41/2 in. Contemporary styling and clear shadow-free readings ensure maximum readability. This modern range maintains the Taylor reputation for reliability and sensitivity.

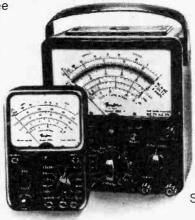
Taylor offers a comprehensive range of movingcoil and moving-iron panel meters. The movingcoil meters feature the proven Taylor centre-pole movement with practically friction-free operation, inherent magnetic shielding

and high torque/weight ratio. They are sensitive, accurate instruments that conform generally to BS 89/54 with contemporary

or conventional styling. Ask for the Panel Meter Shortform Catalogue.



Two typical models are Taylor
Model 88B, a robust, wide-range
multimeter with automatic cut-out and
polarity reversal facility, and the



popular Taylor Type 127A, a pocket-sized multimeter for the service engineer and hobbyist. Ask for the Instrument Shortform Catalogue.



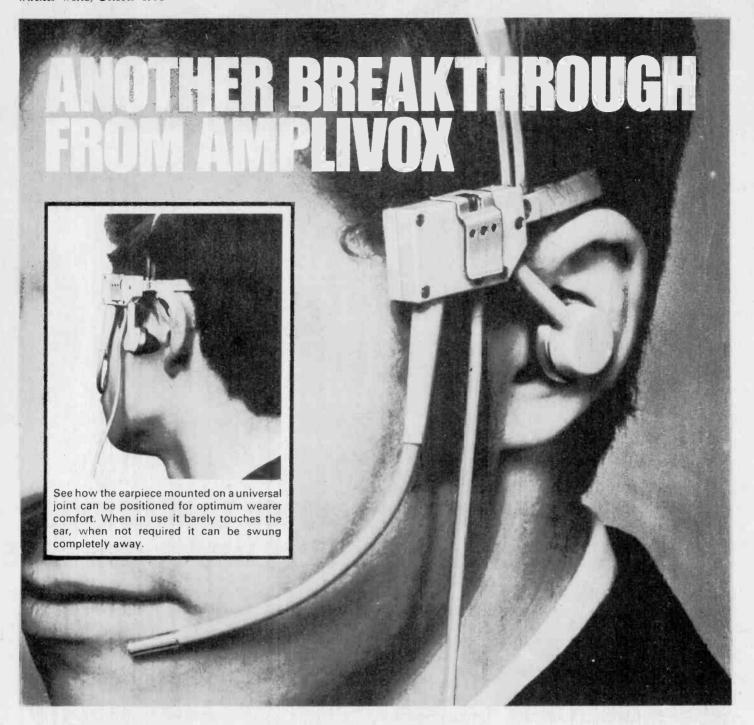
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WW-006 FOR FURTHER DETAILS

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The New Amplivox MINILITE – a break-through in super-lightweight headset design. MINILITE is feather light. No wearer fatigue. No wearer discomfort. New accoustic techniques have led to an earpiece that need barely touch the ear. So it's hygienic as well as comfortable. MINILITE is so light that it can be attached to the frame of a normal pair of spectacles. The telescopic 'Boom' is an accoustic tube that gives highest speech intelligibility. For all situations where the wearer has to use a headset continuously

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£2.75

# SK1 SOLDERING KIT

In rigid plastic "tool box" containing Model CN - 15 watts - 240 volts miniature iron fitted  $\frac{3}{16}$ " bit. Spare bits  $\frac{5}{2}$ " and  $\frac{3}{32}$ ". Reel of resin-cored solder, heat sink, cleaning pad, stand and booklet "How to Solder".



# SK2 Soldering Kit

In polystyrene pack, containing 15 watt miniature soldering iron, 240 volts fitted with  $\frac{3}{16}$ " bit, 2 spare bits  $\frac{5}{32}$ " and  $\frac{3}{32}$ ". Coil of resin-cored solder, heat sink, 1A fuse and bcoklet "How to Solder".

£2-40



Model CN 240/2 15 watts - 240 volts

£1.70

Fitted with nickel plated  $\frac{3}{32}$ " bit and packed in handy transparent box.



ES240 D 25 watt soldering iron

In transparent display pack, fitted with long life iron-coated bit  $\frac{1}{8}$ " diam.

Interchangeable spare bits  $\frac{3}{32}$ "  $\frac{3}{16}$ ",  $\frac{1}{4}$ " (extra) available. Improved design to ensure strong and reliable high speed iron. Heats up in 2 minutes.

**GSS Desoldering Tool** 

Model GSS with  $\frac{3}{32}$ " tip diameter

£4.67

De-soldering tool working on compressed air for industrial use with an air line or occasional use with foot pump.

Efficient, self-cleaning operation on Venturi principle. Split-second action.

Press valve control.

ESS Desoldering Tool

Model ESS with  $\frac{5}{3.2}$ " tip diameter

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Model ESS or GSS complete with foot pump

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Complete with 15 ft (4-50m) lead, 2 heavy gauge clips for instant connection to car battery and a guide 'How to Solcer'. Packed in strong plastic wallet



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Here are some outstanding ICs from the wide Plessey standard range.

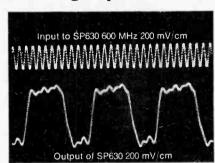
As European leaders in MOS and Bipolar technology

Plessey also offers you the most experienced

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proven by more than 400 successfully completed designs.

# **Ultra-High-Speed ECL Dividers**



WW-250 for further details.

SP602 ÷ 2 500MHz SP620 ÷ 5 400MHz SP630 ÷ 10 600MHz

These three circuits form part of an

expanding range of dividers. Power consumption from only 60mW.

Operating temperature from

-55°C to +125°C.

They are the only dividers available with full temperature range at this speed. Commercial and military applications are already nearing production.

# **Unique LSI Computing Circuits**

These DTL/TTL compatible circuits were initially developed for process control applications in ICI. Now generally available, they feature the following:

# SP520 5-Bit Reversible Gray Code Counter

A 5-bit up-down counter with non-overflow facility with both Gray and binary outputs. The Gray code o/p's can be inhibited—effectively open-circuiting. This makes them ideal for 'addressed parallel highway wired-OR applications'. Reset to zero facility is also provided.

# SP521 5-Bit Binary Rate Multiplier

Basically an arithmetic unit capable of multiplying

together a frequency and a binary number. Has two-phase capability, is infinitely cascadable and eliminates the need for capacitors and other components, all as a result of internal Gray code operation.

# SP522 Divider, Phase Lock and Comparator

Divides the master clock frequency (8F) by 8 giving two interlaced o/p's (1F). These can be used to clock the SP521. There is also an o/p at 2F. Locks the phase of any i/p signal to that of the master clock. Max. i/p frequency to phase lock circuit is 3.2F.

The comparator is a 5-bit up-down counter with reset facility to the central symmetrical state.

WW-251 for further details.

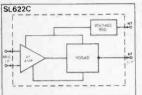
Quad decade	Device Number	Single or Quad Decade	Single or Dual Power Supply	BCD or Decimal Output	Current (I) or Voltage (V) Output	Carry Facility	Package
•	MP107B	S	S	BCD	V	<b>V</b>	10 lead TO.5
complements	MP108B	S	S	BCD	, 1	✓	10 lead TO.5
MOS counter	MP120B	Q	D	BCD	1	1	16 lead DIL
range	MP123B	S	D	BCD	V		10 lead TO.5
lange	MP124B	S	D	Decimal	V		16 lead DIL
11/11/ 050	MP125B	S	D	BCD	V	<b>V</b>	14 lead DIL
WW—252 for further details.	MP126B	S	D	Decimal	I		16 lead DIL
	MP127B	S	D	BCD	I	<b>V</b>	14 lead DIL

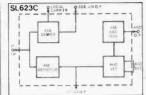


Plessey Semiconductors Cheney Manor, Swindon, Wiltshire Telephone: Swindon (0793) 6251 Telex: 44375

# **Detectors. Demodulators & AGC Circuits**

The SL622C, a microphone amplifier plus VOGAD and the SL623C, an SSB demodulator, low level AM detector and AM AGC generator are the latest additions to the successful range of SL600 communications circuits. This fully compatible series operates from a single power rail, has low power consumption, full AGC facilities and operates up to 140MHz.





WW-253 for further details.

# **1GHz Transistor Pair**

The SL360 is a monolithic matched pair of transistors capable of being used at frequencies up to 1GHz. The particularly good low current betas make this device suitable for a wide range of applications.

Typical characteristics:

a production diese		
BVCEO	15V	$(I_C = 10\mu A)$
h <sub>FE</sub>	65	$(V_{CE} = 2V, I_{E} = 5mA)$
f <sub>T</sub>	2.5 GHz	$(V_{CE} = 5V, I_{E} = 5mA)$
$f_T$		$(V_{CE} = 5V, I_{E} = 25mA)$
$V_{BE}(1) - V_{BE}(2)$	3mV	$(V_{CE} = 2V, I_{E} = 1mA)$
$h_{FE}^{(1)}/h_{FE}(2)$	1.1	$(V_{CE} = 2V, I_{E} = 5mA)$
V <sub>CE</sub> (Sat)	0.25V	$(I_F = 10\text{mA}, I_B = 1\text{mA})$

These characteristics make the SL360 an ideal element for the design and manufacture of more complex UHF circuits.

WW-254 for further details.

# Low Noise GaAs Microwave FET'S

Featuring high transconductance, low capacitance and operating frequency up to 4.5GHz.

10dB gain at 1GHz 4dB noise figure 5dB noise figure 8dB gain at 3GHz Ideal for use in low noise front-end amplifiers.

WW-255 for further details.

# **Television and Audio** Circuits

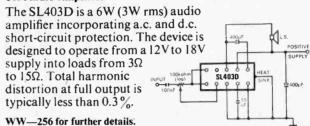
# Colour TV on 2 Chips

The SL435C and SL436B combined form the complete colour signal processing section of a colour television receiver (PAL system).

The following functions are incorporated:

Chroma amplification • PAL switch • Colour killer Gated burst amplifier with 45° switch Internal stabilisation • Reference amplifier Matrixing for red, green and blue outputs R-Y, B-Y balanced demodulator

### **6W Audio Amplifier**



# **OPTO Character Recognition**

The OPT6 is a linear array of 72 integrating elements designed for OCR, code recognition and position sensing applications where high data rates and high definition are required.

The 72 elements operate in current recharge mode and integrate for one line period. Two clock pulses and one data input pulse are required for scanning the shift register which will operate typically in the range 10KHz to 7MHz.

The  $0.2'' \times 0.08''$  chip is mounted in a  $\frac{3}{4}''$  glass windowed flat pack and dissipates about 300mW at maximum bit rate.

WW-257 for further details.

# **Product Summary**

If you would like details of the full range of Plessey IC's please ask for our Product Summary. This includes details of nearly 300 standard bipolar and MOS IC's, package diagrams, MOS logic diagrams and bipolar

WW-258 for further details.

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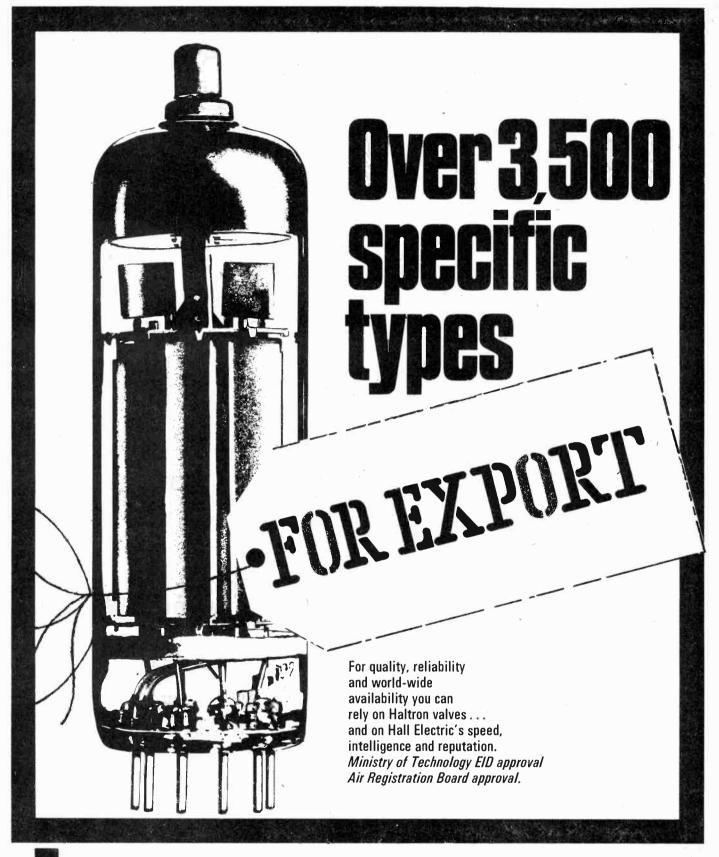
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Highly stable and tailored for today's technology, Erie Polycarbonates pack capacitance values from 0.1 to  $10\mu F$  into a slender, compact tube. Erie's unrivalled experience in processing and winding ultra thin dielectric film, results in ranges of 63V d.c. and 100V d.c. rating with a standard tolerance of  $\pm$  5%. Alternative tolerances of

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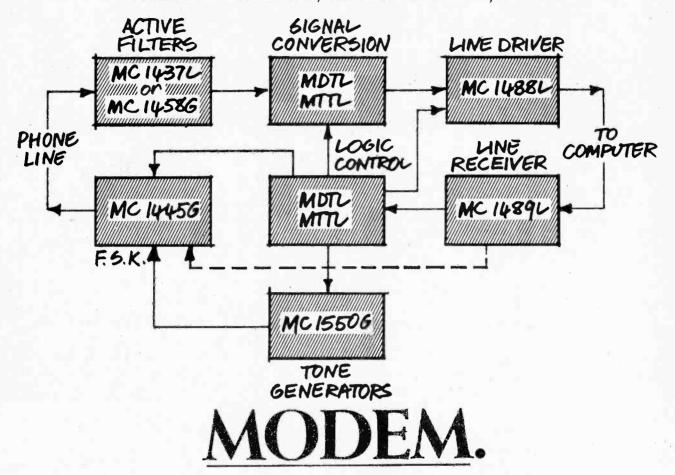
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The MC1445G is a dual-input, logic-controlled video switch that can connect either of two tone generators to an output line. It also has a low-impedance emitter-follower output stage.

# Tone generators.

The MC1550G is a high-frequency differential amplifier that makes an ideal, ultrastable oscillator with built-in bias circuitry at little more than the cost of a transistor.

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WW-019 FOR FURTHER DETAILS

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"Outstanding" is the word that sums up TRIO's 220-watt (Both channels at 8 ohms) KR-7070 auto tuning stereo receiver. It's full-balanced three-way tuning (auto, manual and remote) gives it immediate operating versatility. Also a 3-FET, 4-gang tuning condenser FM front end for distinctive FM reception. Over-all amazing selectivity with 4 IC's and crystal filter FM IF stages. Many exemplary extras throughout.

### SPECIFICATIONS OF KR-7070

- Continuous Power: 90/90 watts at 8 ohms
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- Usable Sensitivity (IHF): 1.5 µV
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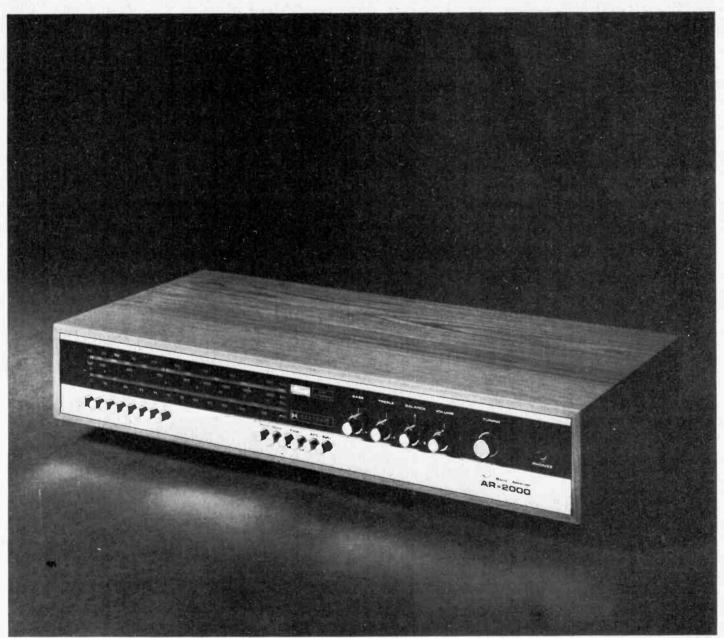
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# The problem-solvers.

Say hello to these nifty compacts from Sansui, and say goodbye to the problem of obtaining a quality receiver at a reasonable price.

These beauties have got what it takes, and you don't have to mortgage the farm to own one.

Let's start with the 300. 36 rousing watts. An expensive new FET frontend with 5-stage IF amplifier for superb FM sensitivity and selectivity. Wide linear scale FM tuning dial against a dramatic blackout window panel. Fully automatic AM/FM stereo switching, plus a new FM stereo noise canceler. The 300's power bandwidth is a wide 30 to 25,000Hz, and as for distortion, no problem. It's less than 1% at rated output. There's probably not another compact receiver in the world that offers so much for so little.

But the 200 comes close. Created especially for the person who's just beginning to get his feet wet in stereo appreciation, this handy little component is—at 13.2 lbs.—actually lighter than a good many conventional AM-only radios. Yet it pulls in rich FM stereo broadcasts as well, and does so with extraordinary clarity. Its many big receiver features include automatic FM stereo/mono switching, an FET FM frontend for rare sensitivity and selectivity, and a wide dial linear scale for the FM band. Its power bandwidth is a wide 30 to 25,000Hz, and distortion is limited to 1% or less.

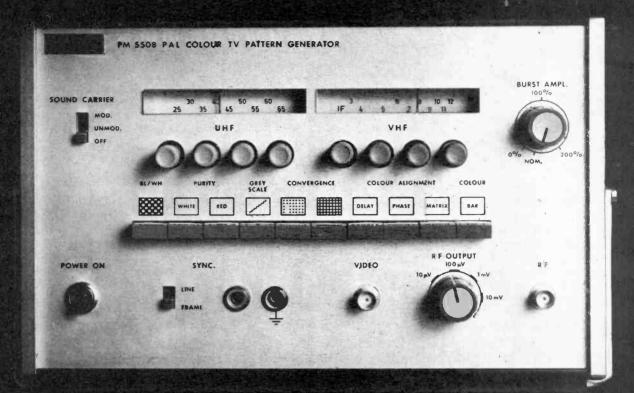
If you've been wrestling with the problem of obtaining a professional quality receiver at a price to suit your budget, stop in at your nearest authorized Sansui dealer and say hello to the problem-solvers.



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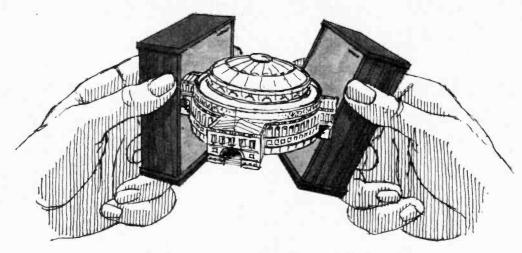


giving more information on the Phil ps PM 5508 PAL Colour TV Pattern Generator, the PM 3230 Oscilloscope and other radio and TV service equipment in the Philips range.

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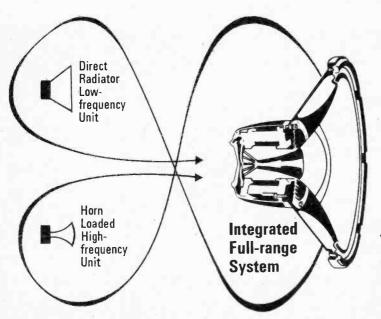
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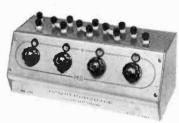
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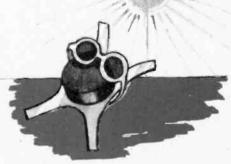
Includes more than 30 types of r.f. power semiconductor device for use from the lowest r.f. up to 1GHz. With c.w. power available from single devices ranging from 50W at h.f. to 20W at the highest u.h.f. Suitable for mobiles, base stations and pocket portables, because it's designed specifically for them.

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And that brings us to us.

Most you already know.
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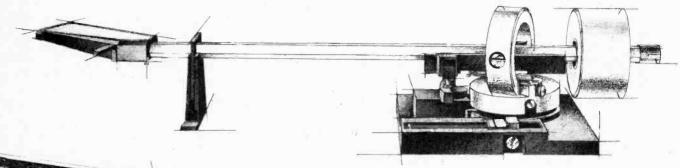


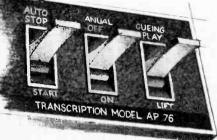
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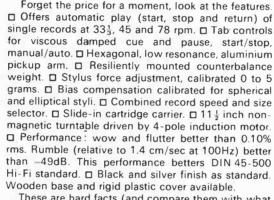
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# **The Garrard AP76** transcription quality deck gives you a good deal to think about:







These are hard facts (and compare them with what the competition offers). Add in true quality engineering and the reliability based on 50 years' leadership in record players.

Now look at the price-recommended at £27.85. Fully £10 cheaper than the good competitive decks having the same features. Only Garrard can do it - by long experience and their comprehensive production programme across a whole range of quality players.

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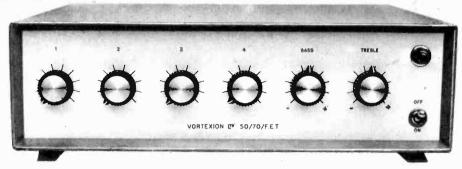
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# 50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 4-WAY MIXER USING F.E.T.S.

This is a high fidelity amplifier (0.3% intermodulation distortion) using the circuit of our 100% reliable 100 Watt Amplifier with its elaborate protection against short and overload, etc. To this is allied our latest development of F.E.T. Mixer Amplifier, again fully protected against overload and completely free from radio breakthrough.



The mixer is arranged for  $2-30/60\Omega$  balanced line microphones, 1-HiZ gram input and 1-auxiliary input followed by bass and treble controls. 100 volt balanced line output or  $5/15\Omega$  and 100 volt line.

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

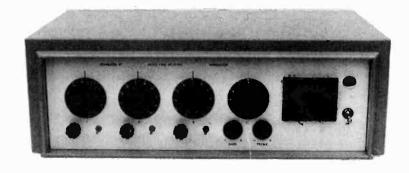
THE 100 WATT MIXER AMPLIFIER with specification as above is here combined with a 4 channel F.E.T. mixer,  $2-30/60\Omega$  balanced microphone inputs, 1-HiZ gram input and 1-auxiliary input with tone controls and mounted in a standard robust stove enamelled steel case. A stabilised voltage supply feeds the tone controls and pre amps, compensating for a mains voltage drop of over 25% and the output transistor biasing compensates for a wide range of voltage and temperature. Also available in rack panel form.

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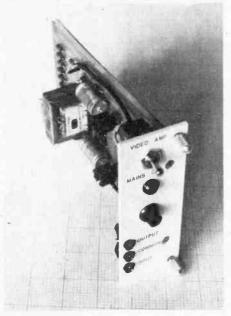
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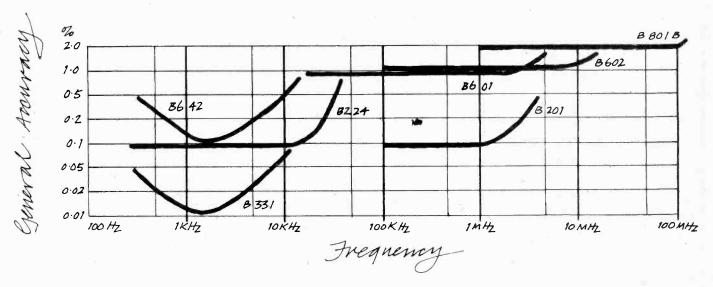
This range of bridges covers the audio, video and VHF bands.

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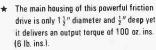
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Single conversion receiver for AM and FM with continuous coverage from 230MHz to 870MHz.

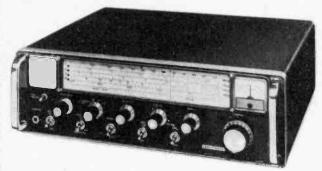
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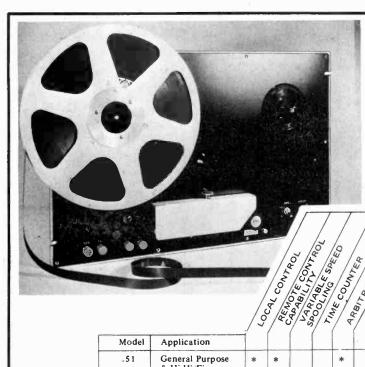
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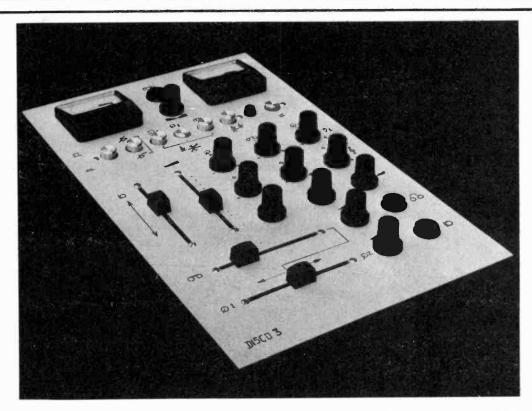
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.51	General Purpose & Hi-Hi-Fi	*	*			*		*	*	*				*	*	*	*	*	*	
.52	Recording Studio	*	*	*	*		*		*	*				*	*	*	*	*	*	
.53	Editing	*		*	*		*		*	*				*	*	*	*	*	*	
.54	Broadcast	*	*	*	*		*		*	*	*	*	*	*	*	*	*	*	*	
.5-5	Duplicating		*						*	*		l			*	*	*	*	*	
.56	Theatre Effects	*					*		*	*				*	*	*	*	*	*	
.57	Machine Control & Industrial		*						*						*		*	*	*	
.58	Long Play/Record		1											1		1		1	1	

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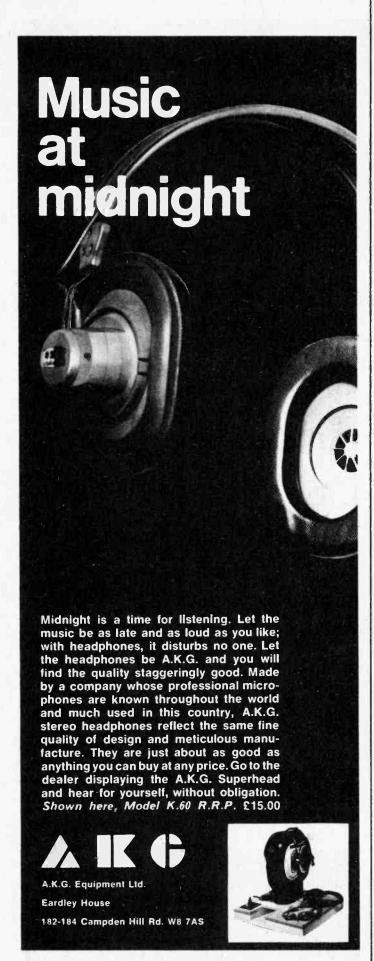
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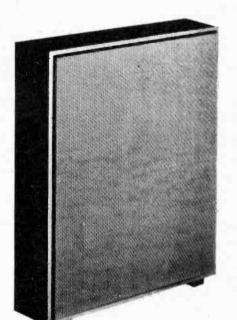
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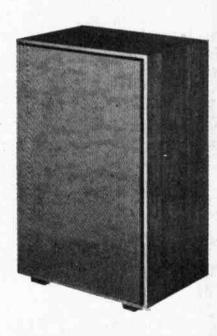
A 19" x  $12\frac{1}{2}$ " x  $8\frac{1}{2}$ " completely enclosed acoustically loaded cabinet housing a 9" graded melamine paper cone with siliconized cambric suspension giving a frequency response of 60Hz to 20KHz.

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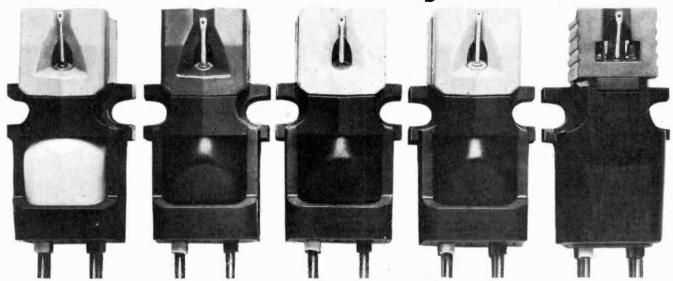


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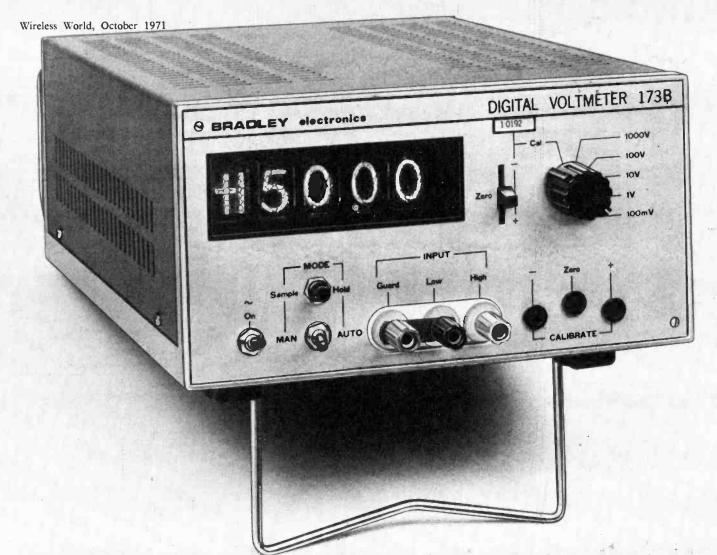
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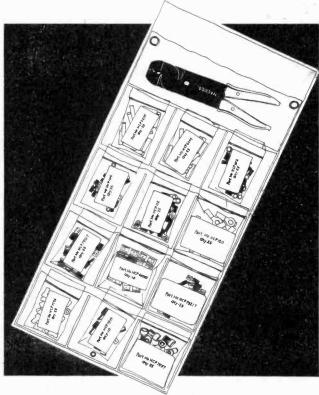
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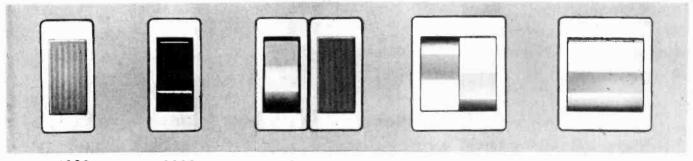


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1109

1100

1100/1109

**1100 twins** 

1110

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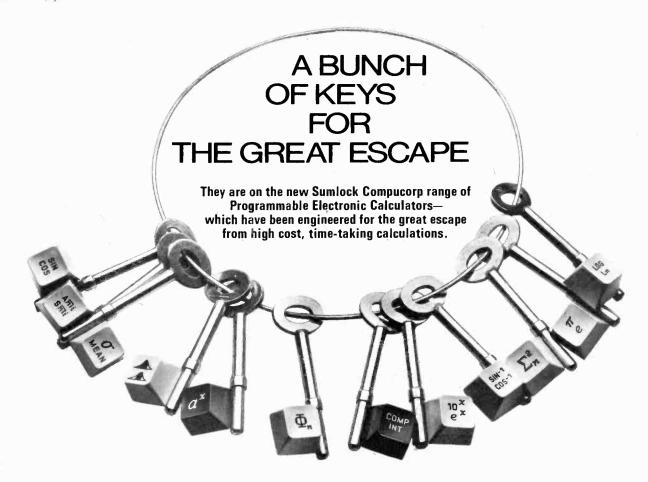
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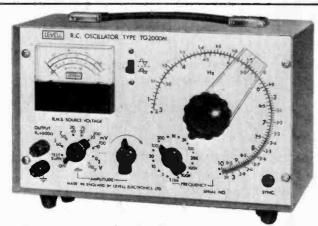
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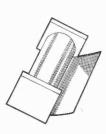
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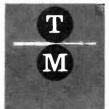
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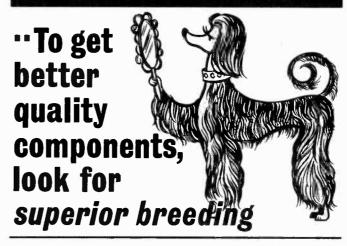
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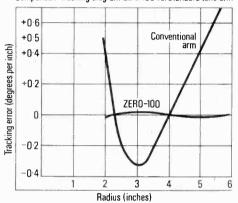


ZERO-100 S now the world's most advanced Hi-Fi deck as a single player. Garrard Zero-100, the new concept in transcription turntables is now in a new version.

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Comparison-tracking diagram Zero÷100 vs. Standard tone arm



Take a look at the diagram and you'll get an idea of the tracking accuracy. There are a whole lot of other features that go to make up the remarkable Zero-100. Magnetic bias compensation, which employs the principle that like poles repel each other. A shield can be moved between the magnets and, according to the setting of the shield, a controlled bias is exerted on the pickup arm. The scale is calibrated for both spherical and elliptical styli.

Since there are no moving parts or mechanical links between the pickup arm and compensator there is no friction, wear or distortion.

Precision stylus force adjustment, achieved by moving a weight along a 3-inch scale, is calibrated from 0 to 3 grammes in  $\frac{1}{4}$  gramme steps. Stroboscopic speed check, stroboscopic markings on the underside of the turntable are illuminated by a high intensity neon lamp and are viewed through a window in the base plate, enabling an immediate check to be made on turntable speed.

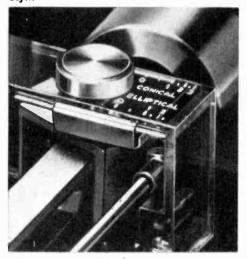
Fine speed control, giving a variation of  $\pm$  3% (a semitone in all), provides facility for adjustment of pitch. Tab controls give quick, easy operation of automatic, manual, reject, replay, cue and pause (fluid damped) and stop. The pivoting head at the start and end of a playing cycle. See the Zero-100 and the other models in the range at the Audio Fair, Olympia,

October 25-30.

Synchro-Lab motor. The Zero-100 is fitted with the Garrard Synchro-Lab motor, which combines the best features of both induction and synchronous motors, guaranteeing smooth running and constant speed.

Add to these features, performance figures such as: wow and flutter better than 0.1 r.m.s., rumble (relative to 1.4 cm/sec @ 100Hz) better than -51 dB and you'll see how it's easy to get enthusiastic about the remarkable Zero-100.

The pickup arm housing and assembly, showing the magnetic bias compensator calibrated for spherical and elliptical styli.



The extremely low friction which is essential to the concep of the Zero-100 tracking principle is achieved by the use of costly precision loaded ballbearings, and a free floating universal pivot. The low resonance pickup

3

arm is counterbalanced by a resiliently mounted weight and has precision gimbal type pivots for minimal friction.

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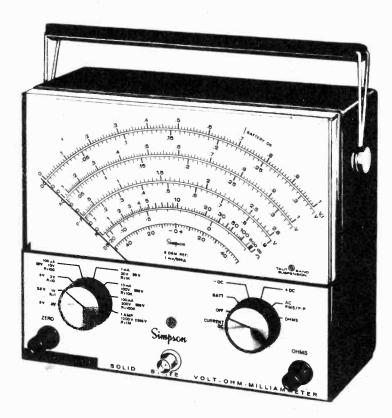
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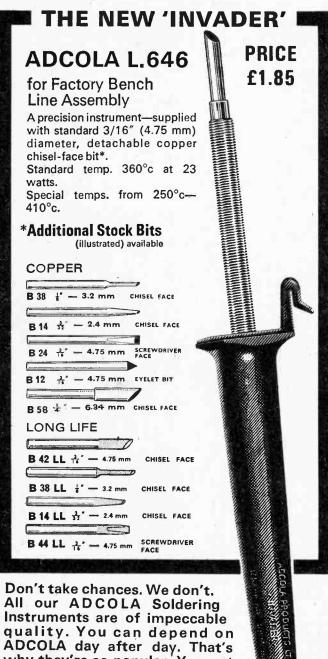


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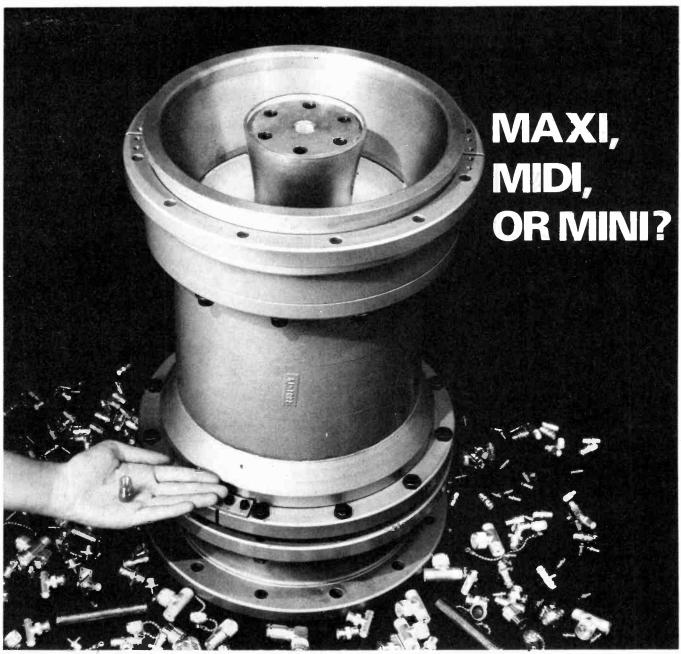


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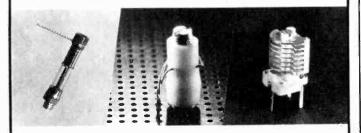
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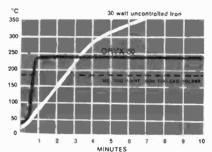
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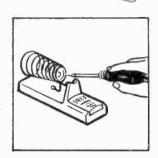


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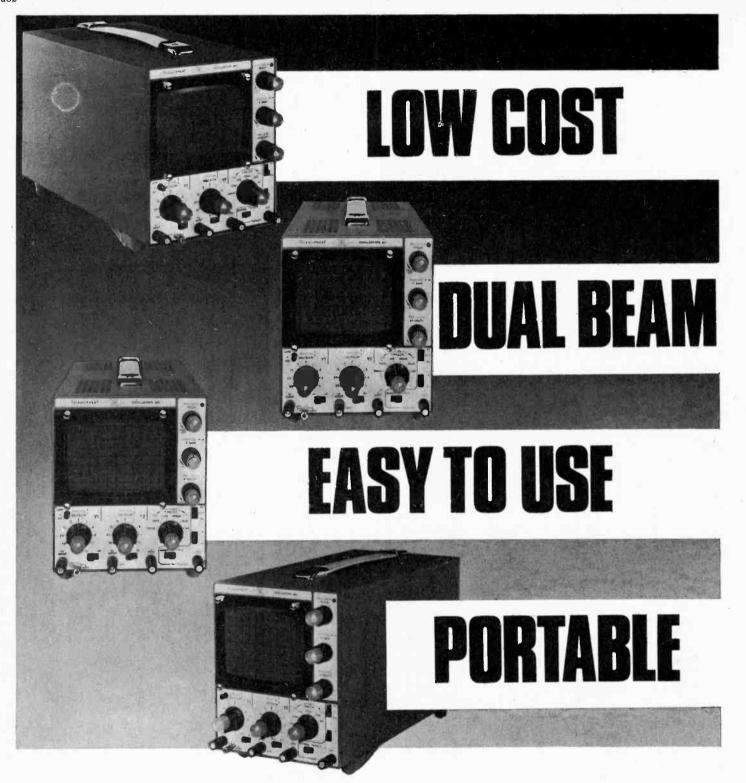
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# Wireless World

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Electronics, Television, Radio, Audio

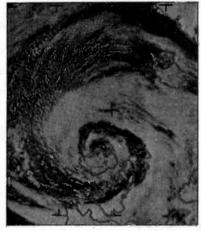
Sixty-first year of publication

October 1971

Volume 77 Number 1432

#### Wireless World Contents





Our cover photograph is a satellite weather picture, received by the weather satellite station at Ambassador College, St. Albans, showing a depression centred over the west coast of Ireland. The equipment used at the college is more complex, and hence gives better results, than the simple system described in this issue.

#### IN OUR NEXT ISSUE

Pickup arm for home construction. This design complements R. Ockleshaw's turntable in this issue. Detailed drawings show how to make and assemble the parts.

Electrostatic headphones—constructional details of a very high-quality constant charge push-pull design using easily obtained components.

Tape recording survey--progress report on tape quality, reel-to-reel and cassette recorders, and noise reduction systems.

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- A126 INDEX TO ADVERTISERS



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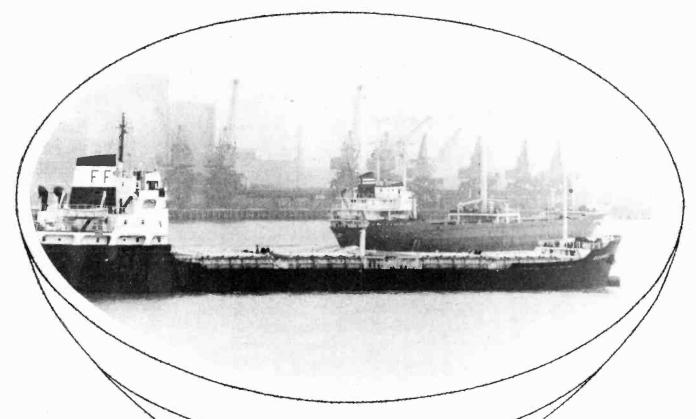
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# Wireless World

#### The Domestic Receiver Scene

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Traditionally our October issue must include a review of domestic receivers and this one is no exception. This tradition stems from the days when Radiolympia, usually held in the autumn, was the annual focal point of the British radio industry. Those hey days of the U.K. radio trade have long since passed and manufacturers now satisfy themselves, and presumably the traders, with a multiplicity of individual trade shows held in London hotels. Not so in Germany, however. Instead of the biennial national show, which was reintroduced a few years after the war, Germany has this year held its first international show. This, as did Radiolympia, had the unstinting support of the broadcasting organizations and the Post Office and the radio industry put on as big a show as ever—some individual companies taking the whole of one of the many halls at the exhibition centre in West Berlin. A staff report on the Berlin show, included in this issue, is devoted mainly to the subject of quadraphonic reproduction which stole the show.

Our review of domestic receivers on the U.K. market, this year surveys only television sets; there being little, if anything, new in sound receivers.

In this issue we also publish a letter from a reader who complains, as others have done from time to time, of the appalling lack of quality in the sound output of television receivers. He also mentions manufacturers' apparent disregard of the desire of many viewers to enjoy a standard of sound quality compatible with the vision quality and comparable with that of their audio equipment.

Designers, or perhaps more correctly the marketing men, have adopted the attitude that the audio output of a television receiver is secondary and, therefore, any cost pruning must be carried out in the audio circuits and the transducer.

No one is unmindful of the fact that television manufacturers are in business to sell sets at a profit and the pruning of what are considered non-essentials in order to market equipment at a competitive price is understandable. What we cannot understand is why set manufacturers, or at least most of them, do not cater for the discerning minority who would be willing to pay for something above average. As is well known, there are manufacturers who produce receivers in period cabinets, at a price, for those who want to camouflage the ubiquitous 'goggle box', but it is generally a standard chassis which is used and few, if any, make any pretence of giving a superior performance:

Our correspondent complains that the manufacturer—incidentally the one with the largest output of receivers in the U.K.—was unwilling to modify his set to provide an improved audio output. We can fully appreciate that to undertake such modifications for an individual set owner would be economically unacceptable—we would ourselves be shocked if we accurately calculated what it costs to answer an individual reader's technical enquiry let alone undertaking to modify equipment! What we cannot understand, however, is why provision is not made in at least some receivers for the audio output to be fed to a viewer's own audio equipment. We know there are problems of isolation etc, but they are not insurmountable.

We return to our opening remarks regarding the present state of the British radio and television industry. We believe it is the apathetic attitude of the industry which is responsible for the present recession and has opened the gates for the ever-increasing flood of imported equipment. The industry seems to rely on temporary boosts, such as that being given by colour television, to maintain its momentum. Something much more stable is required. Could not Britain's undoubted international reputation in the field of hi-fi be used on which to build a new image for the industry as a whole—high quality in sound and vision.

This new 'image' might provide the justification for reviving Radiolympia.

# Receiving Weather Pictures from Satellites

#### 1. A very simple receiving station

by J. M. Osborne\*

There are several American weather satellites in orbit and, at the time of writing, one is continuously transmitting weather pictures. It is possible for an amateur to receive these signals and make pictures from them.

There is no mystery about orbits as a brief description should make clear. Common sense and arithmetic should enable anyone to predict satellite transits for weeks ahead. The satellites which concern us are in simple circular orbits at a height of 1400 km above the surface of the earth. From Newton's Law of Gravitation it follows that the time to circle the earth at this height is 115 minutes.

A satellite will circle in the same plane

<sup>\*</sup> Westminster School

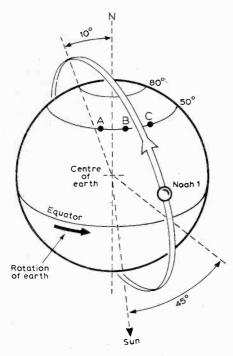


Fig. 1. The satellite's orbit shown relative to the earth. The orbit and the sun remain fixed while the earth rotates about its axis. As the satellite orbits every 115 minutes, a point on the earth's surface (London) moves successively from A to B and then C. From B the satellite is high to the east; from C high to the west.

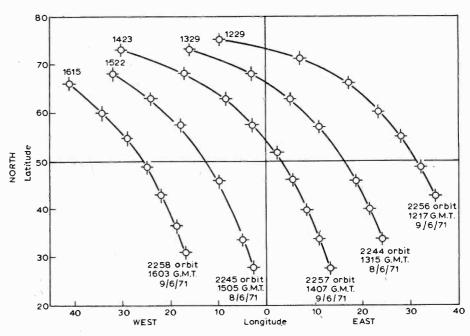


Fig. 2. The two orbits from Table 1 together with three orbits from the next day plotted at two-minute intervals which give an idea of where to point the aerial. The nearer the satellite the higher the aerial elevation needs to be.

indefinitely. The orbit has been chosen to make about 10° with the earth's axis of rotation. Hence the satellite crosses the equator at an angle of 80° and so reaches polar latitudes of 80° as shown in Fig. 1. As the earth rotates, each point on its surface between 80°N and 80°S will pass twice through this plane at the same time each day, e.g. once by day and once by night. In the example of Fig. 1 a point on the equator will cross three hours (45°) after passing the sun (after noon), that is 15.00 hr local time by the sun, e.g. 16.00 hr B.S.T. To within about 15 minutes this also holds for all points on the earth's surface between 50°N and 50°S.

A satellite is always somewhere on the circle of its orbit. Since 115 minutes per orbit is not an exact number per day, each day it will be at a different place in the orbit at the time the given point on the earth's surface passes through the plane. As an example let us consider London and a typical satellite NOAH 1 on 8th June 1971. At 11.26 hours the satellite crosses the latitude 52°N going north. As shown in Fig. 1 London at this time is in position

A. For an observer in London the satellite is below the eastern horizon. 115 minutes later, at 13.21 hours, the satellite will again be crossing latitude 52°. The earth having rotated 29° in the meantime (since it rotates 360° in 24 hrs), London will now be in position B in Fig. 1. For the observer the satellite is now high in the eastern sky moving from south to north and it will be above the horizon from about eight minutes before this time until about eight minutes later when it sets in the north.

115 minutes later, at 15.16 hours, the satellite will again cross latitude 52°N but by now London will be in position C in Fig. 1 and the satellite will be high in the western sky. A set of predictions for these two transits has been extracted from those prepared by the Radio and Space Research Station and is reproduced in Table 1. From these the latitude and longitude positions of the satellite have been plotted for an area corresponding to Europe (Mercator's projection) at two minute intervals in Fig. 2.

While an observer could never 'see' a satellite 1500 to 3000 km away, he can

receive signals from the satellite's  $5 \, W$  solar-powered v.h.f. transmitter. As the beam width of a simple aerial may be  $50^{\circ}$  tracking is not a critical process.

The two orbits discussed for 8th June were numbers 2244 and 2245 from launch. Also shown in Fig. 2 are orbits 2256 to 2258 on the following day. Orbit 2256 occurs 12 × 115 minutes after orbit 2244 and so on.

To generalize, this satellite will always move from south to north and be to the east of the observer between 12.00 and 14.00 each day and to the west between 14.00 and 16.00. Each day the transit will be about 1 hour (earlier or later) different from the day before. Assuming that one knows the time of crossing a given latitude, the track can be seen or interpolated on Fig. 2.

Everything said about the orbits applies to local time throughout the world. Furthermore the 80° inclination of the orbit (to the equator) is chosen because this results in a precession of the orbit of 1° per day; that is 360° or one revolution each year like the sun. So the times given apply to solar time throughout the year.

Pictures of the ground below the satellite are sent every few minutes by a slow-scan television system known as automatic picture transmission (a.p.t.). Each picture takes about three minutes to send at four lines per second. There is a short interval between pictures during which NOAH 1 sends infra-red pictures as it does also during the night. The pictures taken during orbits 2244 and 2245 are shown in Fig. 3. Each picture overlaps with its neighbours as can be seen on close inspection. As the camera is looking at a spherical earth and as the orbits converge towards the poles, the overlaps are not exact. By sticking the photographs together carefully, a best fit can be obtained as shown in Fig. 4. Europe from the Mediterranean to Scandinavia is clearly visible. Countries are often shown by cloud cover or snow on the mountains, but if the sky is clear coastlines can also be seen at lower contrast.

These pictures were taken with the very simple apparatus described in this article and are not of good quality due to receiver noise and low definition presentation. However, they might be good enough for an amateur weather forecaster. The block diagram is shown in Fig. 5. Working from left to right, the aerial is a home-made six-element Yagi for 137MHz, which is light enough to be held in the hand. A proper aerial for satellite tracking would be either a helical or a crossed Yagi to accept a rotating plane of polarization. However, a practised tracker using the portable aerial can rotate the aerial about its long axis at about a quarter of a revolution per minute to keep the signal strength meter reading maximum.

#### Aerial and receiver

I described a very simple aerial for satellite signal reception in the February 1971 issue of *The Short Wave Magazine*, essential details of which are reproduced in Fig. 6. Readers who require a full

constructional description should refer to the original article.

The receiver is a cheap domestic f.m. tuner, type TCC A1005, which has to be modified to cover 137MHz. The receiver

may be obtained from G. W. Smith Ltd for a little under £7. The modification consists of removing one turn from the r.f. and oscillator coils and removing 25% of the turns on the r.f. choke as shown in the

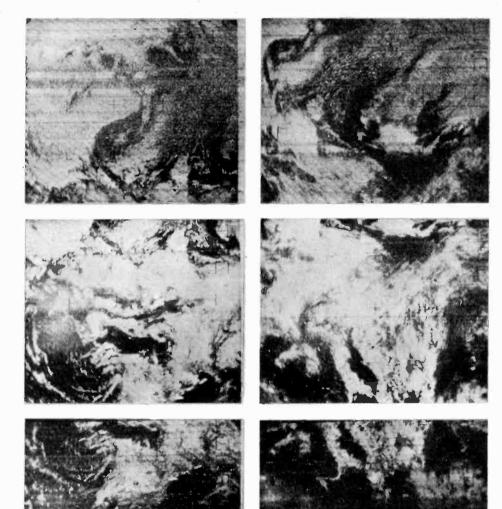


Fig. 3. Pictures taken, using the simple equipment described, during the orbits 2244 and 2245 tabulated in Table 1 and plotted in Fig. 2. They show, bottom right, the Nile delta and Italy; top right, Scandinavia and the Baltic; bottom left, Spain, Gibraltar and North Africa; and a practised eye could spot Scotland emerging from the cloud over the U.K. in the top left picture

**TABLE 1. Satellite Predictions** 

time azimuth		elevation	lat. N	long. E	height	range	
Orbit No. 224	14 date 8-6-71				kı	n	
13.15.1	125	12.3	33.73	23.99	1,472	3,419	
13.17.1	118.3	21.7	39.77	21.47	1,476	2,800	
13.19.1	106.3	33.4	45.76	18.58	1,480	2,271	
13.21.1	82.4	45.4	51.68	15.12	1,484	1,921	
13.23.1	43.4	48.3	57.49	10.78	1,488	1.858	
13.25.1	12.6	38.5	63.13	5.02	1,491	2.108	
13.27.1	357	26.2	68.47	356.81	1.493	2,579	
13.29.1	348.8	16	73.25	344.18	1,495	3,171	
Orbit No. 22	45 date 8-6-71	,			.,	7 -	
15. 8	183.8	14.4	27.65	357.5	1,467	3,265	
15.10	190.8	24.5	33.73	355.26	1,472	2.652	
15.12	203.7	37.3	39.77	352.74	1.476	2,135	
15.14	231.3	50.6	45.76	349.85	1.480	1,809	
15.16	276.8	52.1	51.68	346.39	1.484	1.783	
15.18	308	39.8	57.49	342.05	1.488	2,068	
15.20	322.6	26.6	63.13	336.29	1,491	2.559	
15.22	330.4	16.2	68.47	328.08	1,493	3,156	

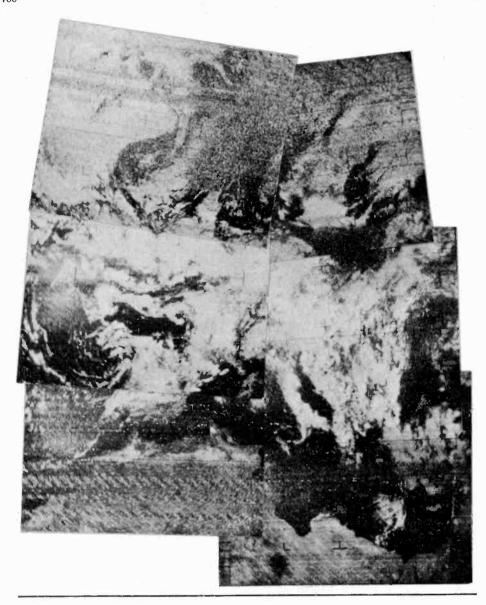


Fig. 4. The pictures of Fig. 3 overlapped to make a best fit mosaic, showing Europe and the Middle East from Suez to Iceland.

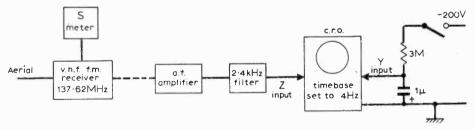
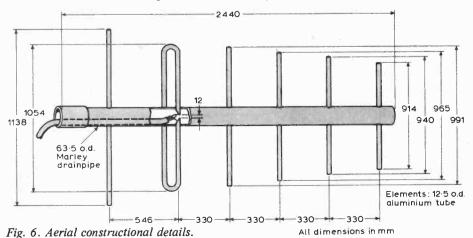


Fig. 5. Block diagram of the apparatus used for taking the pictures given in Figs. 3 and 4. The one-shot vertical sweep circuit is shown in full.



circuit diagram in Fig. 7. It is useful to have some way of checking that the frequency of the tuned circuits is correct and a dip oscillator is a useful tool for this purpose. The only satellite transmitting at present, ESSA 8, operates on 137.62 MHz. It is desirable to have this point marked on the dial with some precision, possibly by using harmonics of a crystal oscillator as markers. The satellite is in range for only fifteen minutes at a time so tuning cannot be left to chance. The discriminator in addition to demodulating the f.m. signal provides a signal-dependent voltage which is connected to a signalstrength meter. An AVO Multiminor on the 2.5V range or any 10k  $\Omega$ /V meter will do. It is an advantage to have a large scale instrument so that it can be easily

#### Oscilloscope Z modulation

seen by the person operating the aerial.

As implied, the picture information is conveyed by means of frequency modulation of the carrier so that its strength is independent of the varying range and attitude of the satellite. The modulation is carried out at a fixed frequency of 2.4kHz and this sub-carrier is easily recognized on the monitor speaker as an audible note. Its intensity, but not its frequency, fluctuates as the picture information is used to amplitude modulate the sub-carrier. A typical line of this amplitude modulated 2.4kHz sub-carrier is shown in Fig. 8. To improve the signal-to-noise ratio a tuned audio filter is used following the audio amplifier as shown in Fig. 9. This audio is sufficient to modulate the spot brightness on a standard school oscilloscope (Telequipment S51E). Because the cathode of the oscilloscope is at negative e.h.t. the Z modulation is applied via an internal capacitor. As d.c. coupling is not possible, the raw audio frequency is fed to the Z input, only the positive half of each cycle brightening the spot.

#### Line time-base and synchronization

The internal time-base of the oscilloscope can provide a 4Hz line sweep. It is just about possible to get recognizable pictures with a free running time-base and an example is given in Fig. 10. The white edge of the picture appears at random and wanders from line to line. There is no synchronizing in the picture signal and this raises the biggest technical problem for the amateur. The solution which I have adopted is to use a 100kHz quartz oscillator followed by i.c. dividers to produce a very stable 4Hz source of trigger pulses. These are injected into the Y input of the scope at the base of a 1 μ F capacitor and used to trigger the sweep as shown in Fig. 12, The inductance is in no way critical and a winding of a small a.f. transformer suffices. With the trigger control on the S51E set correctly perfect synchronization is possible.

The crystal clock consists of a 100kHz quartz crystal oscillator followed by an

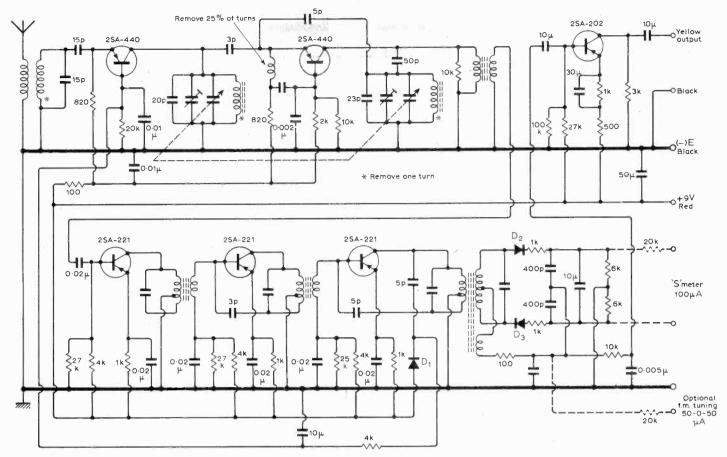


Fig. 7. The circuit diagram of the f.m. tuner showing how the S meter is connected and which coils to alter. Transistor types are given as a guide; alternative types may be fitted. Extra parts are shown dotted.

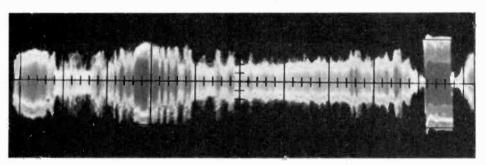


Fig. 8. An oscilloscope trace showing a typical line (250ms) of the amplitude modulation of the 2.4kHz subcarrier. The rectangular section near the end is the 12.5ms white edge of the picture.

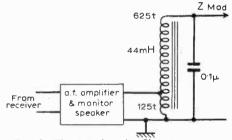
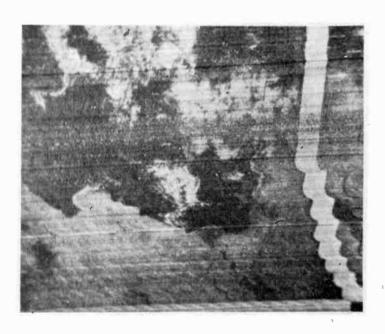
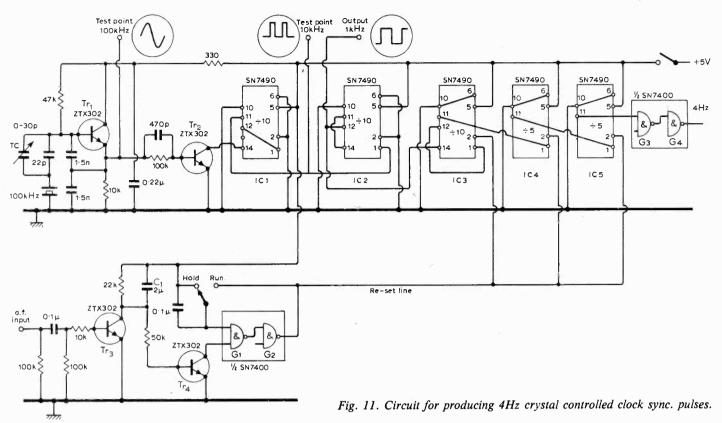


Fig. 9. The tuned audio filter is a simple device which steps up the signal voltage but, more important, gives considerable improvement in the signal-to-noise ratio.

i.c. divider chain (Fig. 11). The oscillator circuit is conventional but a high beta transistor should be selected for easy starting. The crystal frequency is adjusted by the trimmer TC. The simplest and completely effective calibration relies on the use of a radio with a long-wave band. This is tuned to the standard frequency 200kHz Radio Two transmitter. If the radio is placed near the crystal oscillator enough second harmonic exists to beat with the 200kHz signal. The trimmer is set to give one beat per second or better. The radio should be orientated to give a weak signal from the broadcast station. The receiver noise, as the a.g.c. operates on beats, and is helpful in making the final setting. A beat frequency of 0.2Hz is possible and the long term stability is probably better than 1 in 2 × 105. Once set the crystal clock needs no further attention. The second transistor is also a

Fig. 10. This shows the picture at the bottom right of Fig. 3 as it appears without synchronization and a free running time base. The white wavy line is the edge of the picture.





high beta type to switch the i.c. decade divider without noticably loading the crystal oscillator.

The divider chain provides outputs at 10kHz and 1kHz which may be used as test points or as frequency standards in other equipment.

A gate on the reset line of the counters is operated by the sync. pulse train which is transmitted before the picture information. This resets the divider to start in time with a gap in the pulse train (the gaps occur at 4Hz). Hence the first sync. pulse occurs in the next gap and, as the clock is accurate, the synchronization of the whole picture will be correct.

The starting procedure is as follows. Just before the sync train arrives the transmitter sends a few seconds' warning burst of a 600Hz tone. This warning that the picture is about to begin is easily recognized. The operator at this time throws the reset switch up, thus taking the reset line from all three dividers to the positive line. This sets and holds all counters to zero. At the end of the tone the sync. train arrives. The operator now moves the switch to the run position. In the meantime the signal arriving has charged  $C_1$  which holds  $Tr_4$  off so counting does not start. On the arrival of the next gap in the carrier  $C_1$  discharges and so switches on  $Tr_4$ . This puts the input 1 of gate 1 to ground causing the output of the gate to go positive. This causes the output of gate 2 to go down taking the reset line to zero and counting starts. The reset line also goes to input 2 of gate 1 thus holding the situation after the end of the gap and indeed indefinitely until the reset switch is next raised.

The line time-base is triggered by a negative-going pulse. This could be

obtained directly from the last divider. However, these dividers show a small step down in output voltage during the 'on' stage. This does not affect the logic but could conceivably produce a false negative trigger pulse. As a safety precaution the output is taken via the two remaining gates of the SN7400; as the final gate is either on or off no ambiguous pulses can occur.

#### Vertical time-base.

The frame time-base is a one-shot device and consists of two components only. A switch connects a  $1\mu$  F capacitor to a -200V supply via a 3M  $\Omega$  resistor. The Y input to the oscilloscope is arranged to give a 1V/cm sensitivity so that 10V across the capacitor gives full vertical deflection, this takes about 200 seconds and is adjustable by varying the supply voltage or the 3M resistor. It is

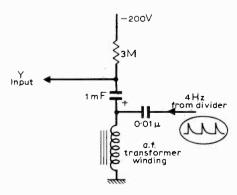


Fig. 12. The circuit used to introduce the synchronizing pulses from a quartz crystal clock into the Y input of the 'scope.

important to turn off the switch at the end of a sweep to avoid exceeding the working voltage of the capacitor. The circuit of the vertical time-base can be seen in both Figs. 5 and 12.

#### Photography

The slow scan picture can be seen on the screen of the oscilloscope and a general idea of the cloud cover in Europe could be estimated by watching the scan, line by line. Unless one has a very long-persistence screen, i.e. 3 minutes, it is necessary to integrate the picture by photography. The camera is focused on the c.r.t. with the shutter open while the picture is being made. Almost any camera will do but a supplementary lens is generally needed to focus down to 20cm. Almost any lens of about 20cm focal length will do and it can be held over the camera lens with insulating tape. The camera must be fixed in a rigid mount in front of the screen with the stop wide open, say f2.8, and the shutter on bulb. It is more convenient to black out the room than to exclude light from the camera and 'scope. One can have very subdued lighting while making the picture and so do the switching etc. and also see what is going onto the film. The camera used by the writer is a Kodak Retina employing Tri-X film.

An idea of the layout can be obtained from the photograph, Fig. 13. The camera faces the c.r.t. screen, the supplementary lens being held in a piece of wood just visible in front of the camera. Behind is the h.t. unit which supplies -200V d.c. adjustable, while in the foreground is the tuned filter passing the picture signal to the Z modulation on the 'scope.

One operator outside tracks the aerial

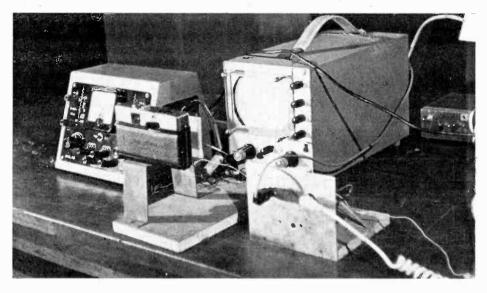


Fig. 13. The picture making end of the apparatus set up ready for use. The camera facing the screen is in the centre of the picture. To the right is the audio filter and to the left the 200V supply. The capacitor and resistor of the vertical sweep are attached to the Y input of the 'scope.

watching the S meter and monitoring the audio signal on a loudspeaker. The first audio amplifier and loudspeaker is seen near the feet of the operator in Fig. 14. Indoors, in a darkened room, the audio signal arrives via a screened cable, is amplified and fed to the 2.4-kHz filter and the 'scope Z input. The brightness control is set so that the sweep is just visible with no Z input. The modulation brings up the brightness to a value which will make an image on the film. The vertical deflection control is used to set the sweep at the top of the screen with the capacitor discharged.

A 3-second burst of a 600-Hz tone warns the operators that a picture sequence is about to start. The aerial operator concentrates on keeping the signal steady. The indoor operator switches on the vertical sweep and opens the camera shutter. At the same time phasing of the line sync. dividers is carried out as previously described. As soon as the picture finishes the shutter is closed and the vertical time-base switched off. The film is wound on ready for the next picture and the capacitor discharged through a  $1k\Omega$  resistor to bring the sweep back to the top of the screen. After the transit the film is cut off the cassette in a photographic darkroom and loaded into a tank, developed and printed in the usual way. A Polaroid camera can be used to give instant pictures.

My thanks are due to Dereck Slater, of Kettering Grammar School, for the original suggestion to use an S51E, to Geoffrey Perry of the same establishment for information on earlier satellites, to the Radio and Space Research Station at Slough for current prediction and the Met Office Tracking Station Operator for up-to-date information on new satellites and dead ones. My thanks also to the National Aeronautics and Space Administration of America, that mammoth organization capable of putting such

sophisticated machinery into orbit, who are still able and willing to send me information directly.

ESSA-8, the only satellite transmitting at present transmits on 137.62MHz and transits north to south in the mornings. We pass through the plane of the orbit around 11.00 hours. It operates in daylight only and sends a continuous note between pictures. Next month a more advanced station will be described.

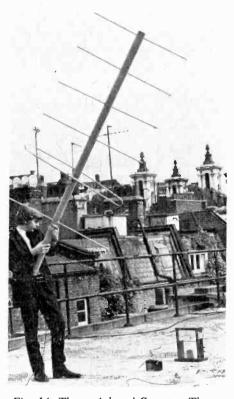


Fig. 14. The aerial and S meter. The coaxial cable leads to the aluminium box containing the receiver. The black box contains the first audio amplifier and monitor speaker.

Oct. 18-20

Lausanne)

Eurocon 71-I.E.E.E. Convention

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### **Conferences** and Exhibitions

LONDON R.H.S. New Hall Oct. 12-15 Engineering Inspection & Control Exhibition & Conference (Business Conferences & Exhibitions, Mercury House, Waterloo Rd., London S.E.1) Oct. 25-28 Olympia Research & Development Exhibition & Conference (R. W. Boardman (Exhibitions), 8 Leicester St., London WC2H 7BN) Oct. 25-30 Olympia Audio Fair (International Audio Festival & Fair, Dorset House, Stamford St., London S.E.1) **BRIGHTON** Oct. 19-21 Hotel Metropole Inter/Nepcon (P. G. Saville, 21 Victoria Rd, Surbiton, Surrey) BRISTOL Oct. 12-14 New Bristol Centre Electronic Instruments Exhibition (Industrial Exhibitions, 9 Argyll St., London WIV 2HA) MANCHESTER Oct. 5-8 City Hall MELEX-Manchester Electronics Exhibition (Industrial Exhibitions, 9 Argyll St., London WIV 2HA) NEWCASTLE Oct. 5-7 **Exhibition Centre Engineering Exhibition** (Engineering Industries Assoc., 15 Walker Tce., Prince Consort Rd., Gateshead-on-Tyne 8) OVERSEAS Toronto **Electrical & Electronics Conference** (Conference Office, 1819 Yonge St, Toronto 7, Ontario) Oct. 6-8 Washington Electronic & Aerospace Systems (M. B. Thorpe, Bell Aerospace, 1000 Connecticut Ave., Washington, D.C. 20036) Oct. 6-9 Mexico City Seminar on Telecommunications (J. Alberty, Siemens Mexicana, S.A., Poniente 116, 590, Col Industrial Vallejo, Mexico 16) Oct. 7 & 8 Montreal Video Cartridge, Cassette & Disc Player Systems (S.M.P.T.E., 9 East 41st St, New York, N.Y. 10017) Washington Oct. 11-13 Electron Devices
(I.E.E.E., 345 East 47th St, New York, N.Y. 10017) Oct. 11-13 One World of Microelectronics (International Society for Hybrid Micro-electronics, Suite 102, 1410 Higgins Rd, Park Ridge, Illinois 60068) Ljubljana Modern Electronics Exhibition (Gospodarsko Razstavisce, Ljubljana, Titova 50, Yugoslavia) Oct. 14-20 Düsseldorf Interkama (Dusseldorfer Messegesellschaft mbH-Nowea-4 Düsseldorf 10, Postfach 10203) Prague Audio, Video & Radio Exhibition (AVRO Praha '71, 10 Rimska, Praha 2) Oct. 18 & 19 Chicago Consumer Electronics Symposium (W. Luplow, Zenith Radio Corp., 1851 Arthur Ave., Elke Grove Village, Ill. 60007) Oct. 18-20 Chicago Fall Electronics Conference (I.E.E.E., 345 East 47th St, New York, N.Y.

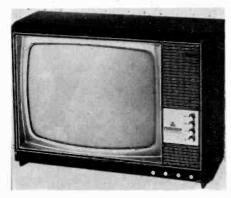
#### **Television Receiver Review**

#### Circuit developments in new sets

If one had to sum up the trend in television receivers since our last report (October 1970) one might reasonably say that it has been the year of the smaller set. Not small set, for these have been with us for a long time—the use of transistors and integrated circuits having made it possible to design neat mains/battery portable monochrome sets with screen sizes from 10in (Sanyo) down to 3in (Standard). It would seem that British and European tube and receiver manufacturers have decided that the 26in screen is about as large as they can go with the present technology, and are now concerned with fostering an apparent demand for lowerpriced receivers with smaller screens. (This demand may well have been started by the influx of the Japanese portables.) The 'smaller set' category might well be identified by a range of screen sizes of 17in (monochrome and colour), 15in (colour), 13in (monochrome only). Most of these receivers are described by their makers as 'portable', but some people might consider this applicable only to the smallest sets, which can be powered from batteries as well as from the mains.

Meanwhile existing designs of large (20in-26in) hybrid receivers have been continuing in production because they have been found successful both in price competitiveness and reliability. G.E.C., ITT-KB, Philips, Pye Group and Rank-Bush-Murphy are among the major groups which have reported 'no change'. A newcomer to Britain with hybrid receivers is Grundig, a firm which claims to be Germany's largest television set manufacturer. They have introduced three monochrome receivers and one 26in colour set, which uses integrated circuits for sound i.f. colour decoding and tuner stabilization.

Technically the most interesting of the smaller sets is the Sony 13-in colour receiver type KV-132OUB. This has a new type of tri-colour tube called the Trinitron which, as we reported in our March 1971 issue, p.108, uses, instead of a shadow-mask and phosphor-dot pattern, a metal plate with vertical slits and vertical phosphor stripes. The three electron beams emerge from a single electron gun in a 'horizontal-in-line' formation, as distinct from the triangular formation of a shadow-mask tube. Apart from this the receiver has a type of colour decoder which operates on



Example of this year's new sets—a Ferguson 17-inch colour receiver using the B.R.C. type 8000 chassis mentioned in the text.

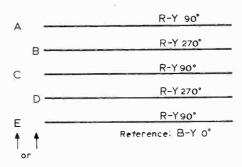


Fig.1. Successive lines of a television field, showing the phase of the R-Y colour information alternating between 90° and 270°.

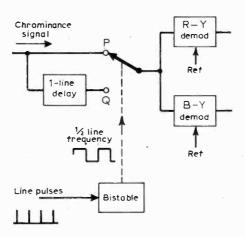


Fig.2. Basic principle of decoder used in Sony 13-inch colour receiver.

a different principle from that of a conventional PAL receiver and therefore, according to the manufacturers, does not infringe the AEG-Telefunken patents on PAL. (Sony do not have a licence from AEG-Telefunken to make PAL receivers.)

What in fact this decoder does is to convert the PAL chrominance signal available at the detector into an N.T.S.C. type of chrominance signal—that is, one without phase alternation line by line by the R-Y component. Thus the receiver does not make use of the essential feature which distinguishes the PAL system from N.T.S.C.—the cancellation of phase (and hence hue) errors introduced in the transmission path.

The phase reversal of the R-Y component on alternate lines of the transmitted signal is cancelled by the simple expedient of omitting the colour information in every other line of each field. Thus in Fig.1, if the R-Y information in lines A, C, E, etc., is omitted, the R-Y information in lines B, D, etc., is retained and always has the same phase angle (270°) with respect to the B-Yphase reference (0°). Alternatively, if the R-Y information in lines B, D, etc, is omitted, that in A, C, E, etc, is retained and again always has the same phase angle (90°) with respect to the reference. This process is achieved electronically by the system shown in Fig.2. An electronic switch is operated by a bistable circuit giving a square wave at half the line scanning frequency. Thus if the switch is in position P at the beginning of line A (Fig.1) the chrominance signal is passed directly to the R-Y and B-Y demodulators throughout line A. At the end of line A the bistable moves the switch to position Q, but the chrominance information transmitted during line B does not reach the demodulators because it is held back by the 64µs (one line period) delay unit. Instead, while the switch is at Q, the demodulators receive a delayed version of line A chrominance information. Before the line B chrominance information starts to emerge from the delay unit the electronic switch has moved back to position P where it remains for the duration of line C . . . and so on. In practice it does not matter which position the switch starts from when the set is turned on, the R-Y chrominance information will always have the same phase (permanently 90° or permanently 270°). The phase of the B-Y

component is not changed in the PAL transmitted signal, so this fixed phase information is passed to the demodulators in both positions, P and Q, of the electronic switch; but, as with the R-Y component, the demodulators receive the B-Y component directly when the switch is at P and then a delayed version of it when the switch is at Q. Thus the demodulators receive the chrominance information as transmitted only during alternate lines (e.g. lines A, C, E, etc.) and during the 'between' lines (e.g. lines B, D) they receive repeated versions of that information.

R-Y and B-Y demodulation is achieved in the normal way by synchronous detectors using local reference oscillators in phase quadrature operating at the colour subcarrier frequency. The phases of these reference oscillations are controlled by the colour sync bursts in the transmitted signal, and these swing  $\pm\,45^{\circ}$  in phase (with respect to the B-Y phase reference, 0°, plus  $180^{\circ}$ ), in synchronism with the R – Y component phase reversals. The controlling burst is used in the normal way for the B - Y reference oscillator, but because of the signal switching system described above the burst phase must be reversed for the R-Y reference oscillator on one line out of two to obtain the 90° shift in the mean burst phase. This is achieved by a further electronic switch, operated by the bistable, which switches in a phase inverter when the Fig.2 switch is at position P.

A simplified version of the actual circuitry is shown in Fig.3. It will be seen that the electronic switch in Fig. 2 is formed by two diodes which are turned on and off by positive and negative d.c. voltages from the bistable (the points equivalent to the switch terminals are shown at P and Q). The 220pF capacitors are simply to isolate the d.c. operating voltages from the previous signal paths. A similar two-diode circuit is used for switching the phase of the burst. As can be seen the 'phase inverter' referred to in the previous paragraph is obtained by means of a centre-tapped transformer, the two signal voltages between the c.t. and the secondary terminals being always 180° out of phase.

It would seem that the use of the non-PAL decoder has two main disadvantages. First, because of the omission principle of Fig.1, half of the transmitted chrominance information in the vertical direction is not displayed. (However, there is also a loss of vertical chrominance information in a standard PAL delay line decoder, because the colour information from any two adjacent lines is averaged by the action of the delay line.) Secondly, because the PAL signal is converted into an N.T.S.C. type of signal, hue errors introduced by phase shifts in the transmission path are not automatically cancelled (and in fact the Sony receiver is provided with a manual hue control for this very reason). On a 13-in screen the first disadvantage does not show up to any extent, but it will be interesting to see what is the picture quality of a forthcoming receiver using an 18-in Trinitron tube.

Another new colour receiver is the British Radio Corporation's type 8000

chassis, which has a 17-in (shadow-mask) colour tube. This set is interesting in a number of respects. First the price is below £200 (in fact £189.75); secondly it has an all solid-state circuit; thirdly the designers have dispensed with the e.h.t. voltage tripler used in most colour sets and reverted to an overwind on the line scanning transformer and single rectifier to provide the 21kV e.h.t. for the colour tube; fourthly the detector is a synchronous type instead of

the usual envelope detector, and finally the power supply uses a thyristor voltage stabilizer.

The makers have abandoned the e.h.t. tripler mainly on grounds of cost, thereby helping to keep the price of the set down. Although in the past overwinds for 20kV or more have been found prone to breakdown through shorting of turns, sometimes starting fires, the designers of the receiver state that they have achieved better relia-

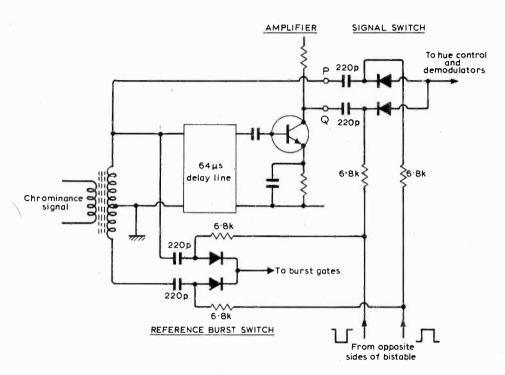


Fig.3. Simplified circuitry of the Sony colour decoder shown in Fig.2. The points P and Q correspond to the "switch contacts" P and Q in Fig.2.

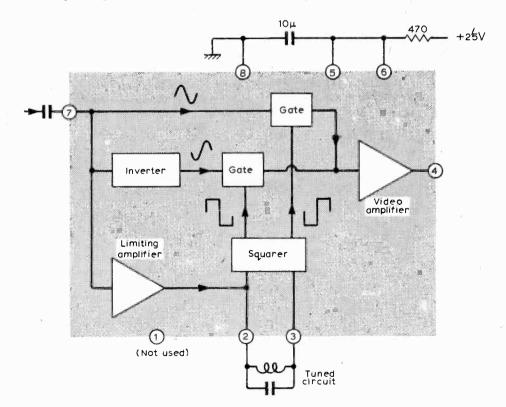


Fig.4. Functions and terminals of integrated circuit synchronous detector used in B.R.C. 17-inch colour receiver and Decca 12-inch monochrome set (Motorola MC133OP)

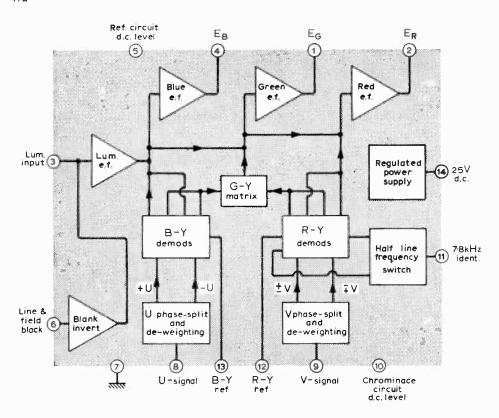


Fig.5. Functions and terminals of chrominance decoding integrated circuit (Motorola MC1327) used in B.R.C. and Decca 17-inch colour receivers.

bility by a winding technique involving impregnation with silicone rubber insulation. Decca, in their latest 17-inch colour receiver, the CS1730, have decided on an intermediate arrangement, by using a 10kV overwind and a voltage doubler. This doubler has selenium rectifiers and is housed near the bottom of the chassis to keep it cool.

A synchronous detector, operating at the low signal voltage of 50mV, is used in the B.R.C. set, and in a Decca monochrome receiver to be described later, because of its inherently high linearity in comparison with the simple diode envelope detector. The advantages of this high linearity include less need for sound trapping, less critical tuning and more stable i.f. performance at high receiver sensitivities,

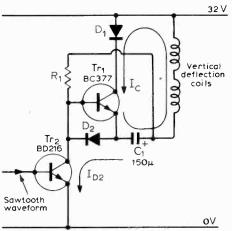


Fig.6. Simplified vertical deflection circuit of Decca 12-inch monochrome set.

as the i.f. and video gain partitioning can be re-apportioned to reduce the need for high gain at i.f. The synchronous detector is certainly more complicated, but it is available in integrated circuit form and so is not unduly expensive or difficult for the set maker to use. Fig. 4 shows the internal functions of the Motorola MC1330P used by B.R.C. and Decca. To provide the fixed local oscillation required for synchronous detection the incoming i.f. signal is passed through a limiting amplifier, removing the modulation, to an external tuned circuit (connected to terminals 2 and 3) which is tuned to the carrier frequency 39.5MHz. The resulting oscillation is applied to a squaring circuit which produces the square waves needed for opening and closing the gates. With the arrangement shown, two gates with an inverter in one signal path, the input signal is chopped at 39.5MHz and one half cycle is inverted. The result is a train of uni-directional, half-sinewave pulses proportional in amplitude to the carrier level and hence to the modulation. This is passed through a video amplifier within the i.c. and the result is an output (at terminal 4) with a d.c. component of about 7V and a video signal component of up to 4V peak-to-peak.

In the B.R.C. receiver the line timebase works at the high supply voltage (for transistor circuits) of 180V, and this allows a fairly simple regulated power supply to be used. In this a thyristor acting as a triggered switch is inserted between one mains input terminal and the 180V terminal to be voltage regulated. The time during the positive half cycle of the mains supply, when the thyristor is triggered is varied in accordance with the load on the regulated

supply, so that the energy removed by the load is balanced by the energy restored to the reservoir capacitor during the period of thyristor conduction. The time of triggering is determined by the rate of rise of ramp voltage across a capacitor, this rate being made a function of the output voltage of the supply.

In both this set and Decca's 17-inch colour receiver the chrominance decoding circuitry is greatly simplified by the use of an integrated circuit. This is the Motorola MC1327, and the functions it performs are shown in Fig.5. It accepts luminance and chrominance signals, the 4.43MHz reference oscillations for demodulation, the 7.8kHz identification signal and line and field blanking pulses. The chrominance signals are demodulated and matrixed so that the i.c. produces R, G and B signals.

Another new solid-state receiver is a 12-inch mains/battery monochrome set just introduced by Decca, the type MS1210. This receiver uses four integrated circuits: the MC1352 giving i.f. amplification and a.g.c., the MC1330 synchronous detection and video amplification, the TBA750 intercarrier sound detection and a.f. pre-amplification, and the TAA611B audio power amplification. The last two devices, in fact, provide the whole of the sound channel—no discrete active devices being used. The TBA750 intercarrier sound i.f., receives its input signal from the MC1330 vision detector via a ceramic filter. An interesting point about the power supplies is that a 120V rail required for the vision amplifier is obtained from a winding on the line output transformer.

An unusual circuit in the scanning section is the vertical deflection output stage. This is similar to a class B complementary symmetry output stage but does not in fact use a p-n-p power transistor, which would be unduly expensive to perform the functions required of it. Instead the output stage uses two ATES n-p-n transistors as shown in Fig.6, the lower one of which, the BD216, although it has a high breakdown voltage, is a low cost device. The two phases of the class B type of operation are: 1st phase, Tr, producing one half of the output waveform with  $Tr_2$ acting as its driver; 2nd phase, Tr2 alone producing the other half of the output waveform. The positive going ramp of the sawtooth waveform applied to the base of Tr<sub>2</sub> in both the phases produces an increasing collector current via  $R_1$ . This in turn causes the base current of  $Tr_1$  to fall,

 $I_b(Tr_1)=I_{Rl}-I_c(Tr_2),$ and hence the collector of  $Tr_1$  falls, going from a maximum to a minimum. The path of  $I_c$  is as shown by the loop. Eventually a point is reached when  $V_{be}$  of  $Tr_i$  goes negative, no further base current flows in  $Tr_1$  and  $D_2$  is now forward biased. This is the end of phase 1 and the start of phase 2 in which  $Tr_2$  acts on its own as the output transistor with  $R_1$  as its collector load; the waveform at the collector passing through  $D_2$ ,  $C_1$  and the vertical deflection coils. The sawtooth waveform applied to the base of  $Tr_2$  drops off rapidly at the end of the ramp, cutting off  $Tr_2$ , and as a result the back e.m.f. generated by the deflection

coils appears across  $Tr_{\frac{1}{2}}$ .

# Turntable Design for Home Construction

by R. Ockleshaw

In three articles the author describes a turntable, pickup arm and wow and flutter meter for home construction. The turntable, believed to be the first complete design for home construction and described in this issue, has a rumble level of -36dB relative to 1cm/s r.m.s. recorded velocity and peak wow and flutter of  $\pm 0.25\%$ . Ready-turned parts are available for those without access to a lathe. Detailed drawings show how the parts are made and assembled and the article also shows how the mechanical filtering system is derived. Cost of the turntable and pickup arm is between £20 and £25. The second article will describe the construction of the pickup arm and the third will show how to check turntable performance and describes a novel wow and flutter meter using a phase-locked loop.

Although several designs for pickup arms have been published, I do not know of a constructional project that included a turntable. Perhaps the reason for this is obvious—it is mechanics on the grand scale, not normally suitable for the amateur with a limited range of tools.

To produce certain parts for this project within a satisfactory tolerance a lathe has to be used, but I have been careful to ensure that lathe-work can be accomplished on medium-sized or even small machines, the type most likely to be available. Provided one has the basic ability to use a lathe, gaining access should be easy. Model societies may have one-almost certainly some of the members-local schools or colleges that run evening metalwork courses might be persuaded to allow the occasional use of a lathe, or may even encourage it. Those that do may charge a nominal fee. There are only three parts for which the use of a lathe is essential. Use of a lathe for certain other parts simplifies their manufacture, but if made by other means will only affect the finish and not the performance. (Ready-made turned parts can be obtained from the address given in the parts list.)

Filtering wow and rumble is discussed towards the end of this article where it may be better appreciated in the light of practical knowledge.

Styling is functional and in keeping with modern design, and performance, in relative terms, should satisfy all but the most critical. Although the design contains most features normally desired in a 'transcription' unit it is essentially simple both in concept and in detail.

The unit features a 10-in diameter machined cast-aluminium turntable driven by a self-starting synchronous motor through a resilient rubber belt. There is a choice of two speeds using a simple manual change. The matching pickup arm is protected against vibration and acoustic pick-up by integral mechanical filters. A

pickup-arm lowering device is featured. Provided instructions are followed, wow and flutter will be 0.5% pk-pk and rumble -36dB relative to a recorded velocity of 1cm/s r.m.s.

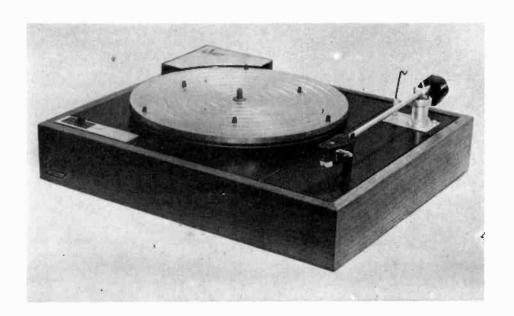
#### Construction

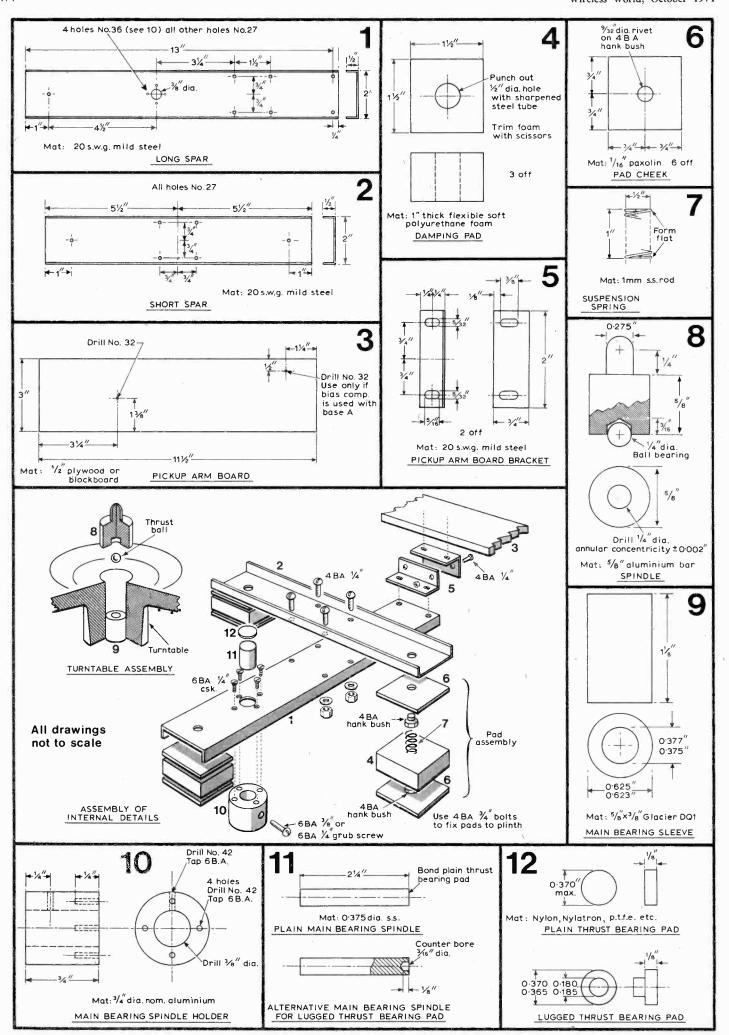
Motor board. The motor board should be to hand when assembling the plinth as it can be used as a jig to ensure that the plinth is square. Make from  $\frac{1}{2}$ -in plywood, or blockboard, the apertures being cut by jig-saw, coping saw, etc. In following the accompanying diagrams, note that the area around the aperture for the switch body is recessed to accommodate the switch mounting plate and screws. Veneer or paint the top surface. Other ideas are matt-black Formica, or if you paint the plinth, a contrasting colour. Finish also the exposed edge adjacent to the pickup-arm board.

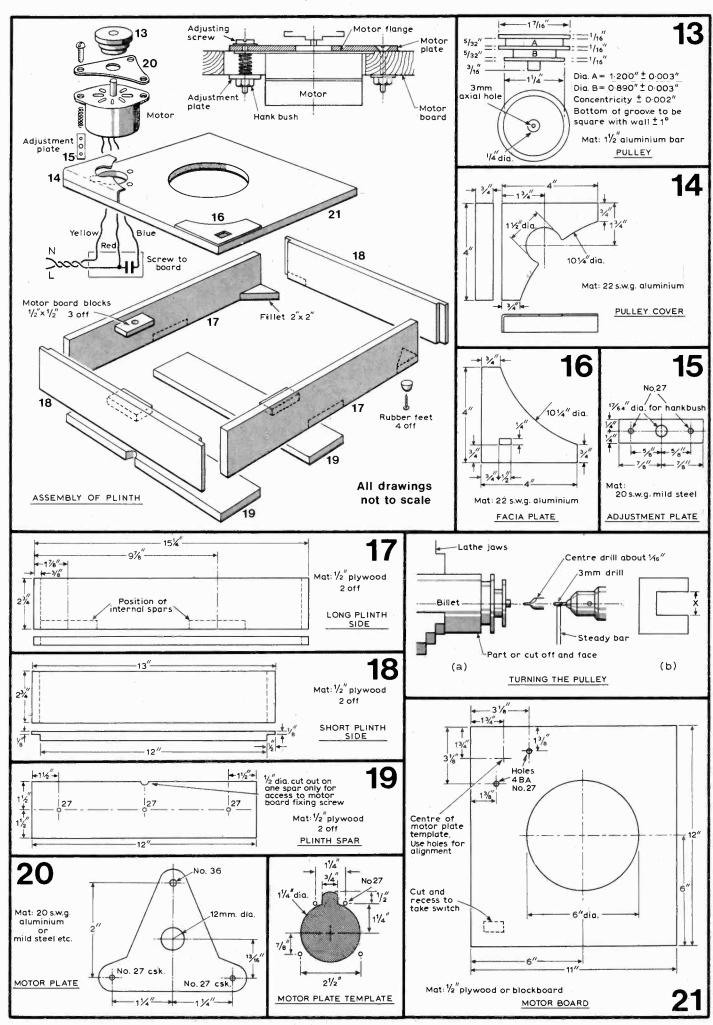
Plinth. Make the three duplicated parts in the plinth from  $\frac{1}{2}$ -in high-density plywood to the dimensions indicated and assemble as shown together with fillets and blocks. Use a good-quality synthetic glue (Evode Resin W, Cascamite, etc.) for the joints, these being held by veneer pins (use motor board as jig) while the glue sets. Rubber feet, obtainable from hardware or do-it-yourself shops, can be screwed or glued underneath. Finish as desired.

Next, make the motor plate, adjustment plate and pickup-arm board. Although a captive nut (hank bush) is specified for the adjustment plate, in practice a shakeproof washer and nut may be a useful alternative. Evostik impact adhesive can be used to fix the motor to the motor plate.

Turntable. The 3-lb turntable is a faceplate for an industrial sanding machine. It is produced by Picador Engineering Co. Ltd, a well-known firm of tool makers, and can be obtained through tool shops. It is essentially a sandcasting and may have slight casting flaws when received but these will be generally of little consequence. Complete the turntable by inserting the main bearing sleeve (see later) thrust bearing assembly (see later) and turntable mat. As a cheaper alternative to the mat, glue six rubber pips (mine came from a moulded rubber car mat) onto the turntable—preferably into drilled recesses.







(The inner three pips in the photograph are for 7-in discs.)

Main bearing spindle. Silver steel is supplied to a high degree of tolerance:  $\pm 0.0005$ -in of the nominal size. It is ground to this accuracy giving a finish considered more suitable for bearing surfaces than a turned one. After cutting to size, face the ends on a lathe. If a lathe is not available, rough file one end and grind with a rolling jig and oil stone.

Harden the spindle by heating to cherry red and then quenching in water. Polish with fine emery cloth and finally metal polish while rotating the spindle in the lathe or drill chuck. Carefully preserve the spindle surface prior to hardening as any attempt to remove blemishes by polishing may prove futile. These blemishes will cause excessive bearing wear. Round off top edges to prevent the bearing sleeve being scored when placing the turntable over it.

It is more important that the top surface of the nylon thrust-bearing pad is square than the top of the spindle. In this case bond the nylon thrust bearing pad to the top of the spindle with Araldite after hardening and grind square if necessary.

Main bearing sleeve. The main bearing sleeve is made from a p.t.f.e.-compound dry bearing material. This retains most of the desirable features of p.t.f.e. but is much easier to machine. The material is quite soft and convenient to use, if a trifle dirty, but care should be exercised to prevent bearing surfaces being damaged. This compound, in common with many plastics, has a high coefficient of linear expansion. Indeed, p.t.f.e. at 20°C exhibits a so-called phase change resulting in a sharp dimensional increase, which may be used to advantage. The bearing material is supplied as a tube with nominal  $\frac{3}{8}$ -in inside and <sup>5</sup>/<sub>8</sub> in outside diameter. As the inside hole is a little too small, use successive reamers to bore the material to correct size. Hold the reamers in a tail-stock chuck (the work in the main chuck of course) and rotate the work by hand or at least at a very low speed. Then carefully turn down the outside of the bearing sleeve to the correct size.

Fit the bearing sleeve into the turntable. At this stage the main bearing spindle may still not fit the hole or it may be too stiff. This may be because of the squeezing action of a tight fit of the sleeve into the turntable. In this case carefully run-through the reamer to bring it to the correct size. If the tolerance of the main bearing spindle is on the high side this still may not be sufficient to give a perfectly free-running bearing. (Test at normal room temperatures, not straight from the lathe or after being held in the hand.) To give increased bearing clearance place the turntable together with the fitted bearing sleeve in a refrigerator for a few minutes, followed by reaming. Use a reamer in reasonable conditionit is important that the surface should be free from scores. Always feed the reamer with a rotating action.

Thrust-bearing spindle. Construction of the thrust-bearing spindle is more straightforward. No tight tolerances apply except that it is as well to check that the spindle fits the hole in the middle of a new record as these rapidly wear. The thrust ball may be held in the assembly by overswaging with a centre punch or with Araldite. The thrust-bearing ball should rest on the exact centre of the nylon thrust bearing pad to reduce rumble. No difference in performance should result if this part is made in other materials, like nylon or p.v.c.

Long and short spars. Bend the two spars from 20-s.w.g. mild steel (galvanized or passivated if possible) to give adequate stiffness, If a bending machine is not available careful work with a mallet and vice should be adequate remembering that this part is unseen and finish is unimportant.

Pulley. The pulley is possibly the most difficult part to make. The tolerances given must be strictly adhered to if performance is not to be impaired. Measuring the internal diameter of the grooves when turning the pulley is facilitated by using a simple gauge (see drawing 'Turning the pulley'), the groove being too narrow for a normal micrometer. (Set dimension X with a template.) To start the hole in the pulley, use a centre drill and ensure the drill does not deviate inside the pulley by using a bar to steady the drill.

The pulley cover (drawing 14) can alternatively be made without the angled sides, instead using  $\frac{1}{2}$ -in thick wood for the two sides (as in the photograph). By making the height slightly greater than the pulley height, the  $1\frac{1}{2}$ -in dia. cut can be avoided.

Damped suspension pads. For the suspension pads, three springs are required, made by winding 13in of 1-mm silver-steel wire on a  $\frac{1}{2}$ -in dia. former. After removing from the former, even out the spring and form as shown. Compress with fingers until it 'bottoms'. After removing pressure it should be 1-in long. To give a clean  $\frac{1}{2}$ -in hole in the pads to take the springs, punch out using a sharpened piece of thin-walled  $\frac{1}{2}$ -in stainless-steel pipe (as used in the lifting device). Make the pads larger than necessary and trim on assembly. Use Evostik for bonding.

#### Assembly

Assemble the main bearing spindle with its bottom flush with its holder. Use the grub screw to lock it in place temporarily as adjustment will follow. Place the suspension cruciform comprising the long and short spars, with the pickup-arm board fixed by brackets, in the plinth before screwing on the motor board from underneath. Additional pad cheeks can be used

as packing to make the turntable top parallel with the motor board.

Assemble the bonded motor plate and motor to the motor board together with the adjustment plate and spring. (The spring must be strong enough to allow the end of the motor plate to rise above the board.) Screw the capacitor holder to the underside of the motor board.

Wire the motor to the switch before screwing the motor board to the plinth, earthing the motor casing. Assembling the pulley to the motor may require a little persuasion as it has been designed as an 'interference' fit. Heat the pulley in hot water for a few minutes—expansion should then allow a fit. Do not ream the hole to size and do not unnecessarily pull off the pulley once fitted as this may cause enlargement of the hole and consequent slipping. Lower or raise the main bearing spindle to align the top of the pulley with the top of the turntable.

#### Designing to avoid rumble

Rumble generally is generated by two sources in a turntable unit—the motor and turntable main bearing-and may be described as noise the spectral content of which lies within the range of about 10 to 200Hz. Apart from a comparatively small amount of noise due to mechanical displacement in the motor bearings, its contribution arises from 'stepping' or 'cogging'—the tendency to rotate in discrete steps rather than in a uniform way. If a synchronous motor is held loosely in the hand and allowed to rotate this 'cogging' vibration is felt quite strongly. Thus if the motor is coupled to the turntable it must always be through some kind of mechanical vibration filter-for example a resilient belt or rubber-tyred wheel.

Unfortunately it is more difficult to mechanically filter rumble generated by the turntable main bearing. This kind of rumble is generally random (except perhaps when the turntable is blessed with ball bearings) unlike the discrete motor vibrations that are related to mains frequency. It is caused by imperfections on the bearing surfaces.

#### Motor rumble

In this design, vibrations from the motor can be transmitted to the turntable by two paths—the drive belt and the motor mountings—and a mechanical filter is necessary in both paths (Fig. 1).

The electrical equivalent—Fig. 2—shows the motor as a two-dimensional

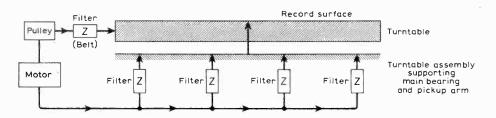


Fig. 1. Rumble from the motor is transmitted to the turntable by two paths (motor mounting and pulley) which must be separately filtered.

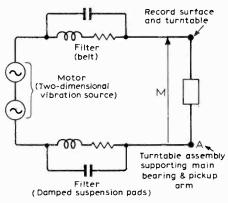


Fig. 2. Electrical equivalent of Fig. 1. Motor produces rumble through the belt in a lateral plane and through the mounting in a vertical plane. The lateral vibration can produce vertical vibration if the turntable is not stiff enough.

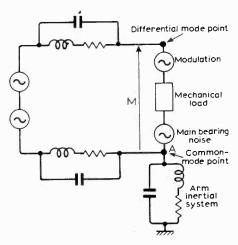


Fig. 3. Inertial grounding effect of pickup arm creates common and differential-mode points. Common-mode response can be eliminated by grounding point A.

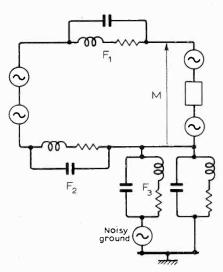


Fig. 4. Mounting a turntable unit on a 'noisy ground'—a non-rigid shelf for example—introduces noise and one solution is to use a 'lockable in transit' type of spring mounting for F<sub>3</sub>.

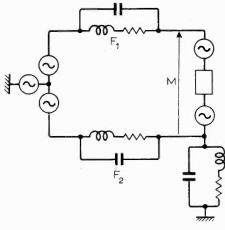


Fig. 5. In the belt-driven unit,  $F_2$  can be made effective enough to eliminate  $F_3$  and the motor casing can be grounded.

vibration source. Relative to the ground plane, vibration through the turntable mountings will be in a vertical plane while that from the belt will be predominately in a lateral plane. However, this lateral vibration can give rise to vertical vibrations if the turntable is not sufficiently stiff or adequately damped.

The main responses of a stereo cartridge will be at 45° to the plane of this vertical displacement and will thus reproduce a component of any vertical displacement relative to the pickup-arm mounting point. This is why it is always desirable to mechanically couple the pickup arm as close to the turntable as possible to reduce

as much as possible any differential movement.

But, however much we may reduce the differential displacement, the common-mode displacement may still have an effect on the pickup output because the pickup is essential an inertial system and will therefore have a common-mode response. What response it does have obviously depends on the design of the pickup arm.

We therefore should modify the electrical model to that of Fig.3 and it is obvious that any common-mode response can be eliminated by grounding (literally!) at point A. Unfortunately, if the ground is noisy due to the unit being placed on a shelf, then the pickup will produce an output in sympathy with the displacement. This is one common cause of acoustic feedback.

Many turntable units are grounded at this point but the manufacturers are always careful to ensure that effective filtering eliminates any displacement that might excite the common-mode response of the pickup arm Fig. 4.

The design of belt-drive units is not so mechanically restrictive as some jockeywheel-driven types, and allows the use of more efficient filters for  $F_1$  and  $F_2$  (Fig. 4)—the belt and turntable suspension pads respectively—and it becomes possible to combine  $F_2$  and  $F_3$  and ground the motor casing (mechanically). The resulting, chosen, arrangement is shown in Fig. 5.

#### Main bearing rumble

The prime cause of bearing rumble is imperfection of bearing surfaces. The

#### Parts List

All parts, including cover, for both pickup arm and turntable are available as raw materials or readyturned where appropriate from Longdendale Technological Products, Hadfield, Hyde, Cheshire.

Part	description/material	source
motor	Berger RSM 50/8	Longdendale Technological Products (LTP)
turntable	Picador 10-in sanding disc \(\frac{5}{8}\)-in shaft	most good tool shops
belt	rubber	LTP
main bearing sleeve main bearing spindle	Glacier DQ1 $\frac{5}{8} \times \frac{1}{8}$ in nom. $\frac{3}{8}$ -in dia. silver steel	Glacier Bearing Co. Ltd. sold in most tool shops & engineers' suppliers in 13-in lengths
suspension springs motor alignment spring	1-mm dia. silver steel $\frac{3}{4} \times \frac{1}{4}$ -in o.d.	LTP " "
damping pads	1-in thick polyurethane foam	upholstery dealers
long and short spars	20-s.w.g. mild steel	ferrous metal dealers
turntable mat	rubber	Metrosound, C. Watts radio hobby shops
pad cheeks	1-in Paxolin	radio hobby shops
pulley facia plate,	$1\frac{1}{2}$ -dia., 2-in long aluminium bar	non-ferrous metal dealers
pulley cover, motor plate, adjustable slate	20-s.w.g. aluminium	non-ferrous metal dealers
switch	2-pole c/o slider	Radiospares etc.
thrust bearing pad	$\frac{1}{4}$ -in dia. $\times \frac{1}{7}$ -in long nylon	LTP
thrust ball	i-in dia. ball bearing	cycle shops, motor accessory shops
spindle	$\frac{5}{8}$ -in dia. p.v.c. rod $\times$ $1\frac{1}{2}$ -in	LTP
main bearing spindle holder	$\frac{3}{4}$ -in dia. $\frac{3}{4}$ -in long aluminium rod	non-ferrous metal dealers

#### Miscellaneous

Captive nuts (hank bushes, six 4BA one 6BA), screws (six 4BA  $\frac{1}{4}$ -in cheesehead, four 4BA  $\frac{3}{4}$ -in countersunk head, four 6BA  $\frac{1}{4}$ -in cheesehead, six 4BA  $\frac{1}{2}$ -in cheesehead), nuts, rubber feet. From usual sources or LTP.

obvious approach is to make them as perfect as possible. This is quite reasonable but there is a limit and mechanical filtering techniques must be used to reduce the effect further.

It is well known that the less dense a material the greater is the attenuation to the passage of sound and noise. Here in lies the key. The bearings should be made of a material with a density that is as low as possible. The energy then generated, which can be quite high, suffers a great deal of attenuation in its passage to the stylus. The reproduction of rumble can also be affected by resonance phenomena in the pickup arm, about which more later.

Most modern plastics fall into the lowdensity category but not all are suitable bearing materials. Of those that are, nylon and p.t.f.e. are most common. Unfortunately p.t.f.e. is virtually impossible to machine, nylon is difficult but machinable, and p.v.c. while not an ideal material from the wear viewpoint is easier still to machine. Better still are some compound materials that have p.t.f.e. as a base. They retain all or most of the desirable properties but are easy to machine. They are known under proprietary names like Glacier DQ1, used in this design.

#### Wow and flutter

Wow is caused by slow variations in record speed, flutter by fast variations. Like rumble, it cannot be eliminated completely, merely reduced to an acceptable level. In the simple arrangement of a slow-speed motor directly driving a revolving turntable, wow and flutter could be caused by sticky main bearing, belt slip, motor cogging and pulley eccentricity. (Wow can also be caused by a badly eccentric or warped record but this is outside our control.) But note that only one of these points really indicates a design problem, that is motor cogging, and this is really tied up with rumble. If the belt is an efficient filter this source of flutter is eliminated.

The most usual way of preventing wow and flutter is to prevent the remaining three imperfections occurring due to bad manufacture, or dirt and grease being smeared on the belt, and to provide a turntable with a high inertia. Care must be taken that any turntable inertia is not overcome by too tight a coupling of the drive motor. This most certainly would occur if a synchronous motor was used with a rimdrive jockey-wheel system. The speed of a synchronous motor is fixed and does not depend on the load as with an asynchronous motor.

A second article will describe construction of a pickup arm.

### Correction

R. J. Ward, author of the article 'Swept-frequency audio oscillator' in the September issue, has asked us to point out that the 4.7-nF capacitor in Fig. 11 should be omitted. We regret omitting the label F, to correspond to E in the multivibrator of Fig. 5. There was a printer's omission on p.417-'Power supplies are required at +10V and -10V' should have appeared in the text gap.

## October meetings

#### LONDON

6th. IERE—"Components—past, present and future" by G. W. A. Dummer at 18.00 at London School of Hygiene, Keppel Street, W.C.1.
7th. RTS—"Satellite broadcasting" Part 1: Basic

satellite technology by G. Lewis at 19.00 at I.T.A., 70 Brompton Road, S.W.3.

12th. AES—"Developments in audio instrumentation" by J. Kuchn at 19.15 at the Mechanical Engineering Dept., Imperial College, Exhibition Road, S.W.7.

13th. IERE/IEE—"A blood analyser using the PDP-8/L" by E. T. Oram at 18.00 at 8-9 Bedford

Sq., W.C.1.
14th. SERT—"The BRC 8000 television receiver" by A. Martinez at 19.00 at I.T.A., 70 Brompton

18th. BCSR Statistical Soc.—Babbage memorial

lectures at 14.30 at I.E.E., Savoy Pl., W.C.2. 20th. IERE—"Application of satellite relayed communications to civil aviation and maritime use" by D. Hirst and J. D. Parker at 18.00 at 8-9 Bedford Sq., W.C.1.

21st. RTS-"Satellite broadcasting" Part 2: Satellite design by G. K. C. Pardoe at 19.00 at I.T.A., 70 Brompton Road, S.W.3. 27th. IERE—"Innovation in industry—a factor

for growth" by R. H. Jones at 18.00 at 8-9 Bedford Sq., W.C.1.

13th. IERE/RTS-"Colour film for television" by Dr. Boris Townsend at 19.30 at Robert Gordon's Institute of Technology, St. Andrews Street.

20th. IERE—"Hi-Fi tape recording" by R. West at 19.30 at Robert Gordon's Institute of Technology, St. Andrews Street.

13th. IERE—"Signal processing and computation using pulse rate techniques" by J. D. Martin at 18.00 at The University.

#### **BIRMINGHAM**

5th. IERE-"World competition in the electronics industry of 1970-a challenge for the engineer" by E. Jones at 19.15 at the Department of Electronic and Electrical Engineering, The University, Pritchetts Road.

21st. SERT-"Video tape, the manufacture and requirements" by R. Waldie at 19.30 at University of Aston, Gosta Green.

#### BOLTON

14th. IERE—"Computer-aided design" bv E. Wolfendale at 18.15 at the Institute of Technology, Deane Road.

#### BOURNEMOUTH

5th. SERT/IEETE—"Radar ornithology—the engineer's point of view" by H. R. J. Smith at 19.45 at College of Technology, The Lansdowne.

21st. SERT-"Curve tracers" by R. Watson at 19.30 at the Polytechnic, Ashley Down.
27th. IERE—"The continuing education and

development of professional engineers" by Dr. K. G. Stephens at 19.00 at The Polytechnic, Ashley Down.

#### CAMBRIDGE

28th. IERE—"The problem of addressing new display materials" by A. Colchester at 18.30 at the University Eng. Labs., Trumpington St.

#### CARDIFF

6th. SERT-"Demonstration and lecture on the Sony Trinitron television tube" at 19.30 at Llandaff Technical College, Western Avenue.

20th. IEETE—"Electronic variable speed drives"

by C. J. Teece at 19.30 at University of Wales Institute of Science & Technology, Cathays Park.

#### CHATHAM

28th. IERE-"Electronic video recording and reproduction" by B. T. Pickstock at 19.00 at Medway College of Technology.

#### **CHELMSFORD**

13th. IERE—"Comparison of p.c.m. and f.d.m./f.m. microwave radio relays" by S. G. Allen at 18.30 at the Civic Centre.

#### COVENTRY

28th. IERE-"Reliability" by R. C. Winton at 19.15 at Lanchester Polytechnic.

7th. IEETE-"Technician engineers and technicians—their role, their status, their future" by E. A. Bromfield and "The Engineers Registration Board and composite register" by M. W. Leonard at 19.00 at the University, Fulton Bldg.

13th. IEETE-"Modern telecommunications" at 19.30 at University Science Labs, South Rd.

#### EDINBURGH

6th. IERE—"The development of a colour TV service" by J. Dunlop at 19.00 at Carlton Hotel, North Bridge, 1

12th. IEE—"Setting up an educational micro-electronics laboratory" by N. Milne at 18.00 at Carlton Hotel, North Bridge, 1.

7th. IERE-"The development of a colour TV service" by J. Dunlop at 19.00 at The Institution of Engineers and Shipbuilders, 183 Bath Street, C.2.

11th. IEE—"Setting up an educational micro-electronics laboratory" by N. Milne at 18.00 at The Institution of Engineers and Shipbuilders.

22nd. IERE-"Fibre optics in telecommunications" by Dr. N. Chown at 19.30 at Harlow Technical College.

12th. IERE—"Finance and engineering" by J. Cuckney at 19.00 at the Department of Electrical Engineering and Electronics, The University.

13th. IERE-"Electronics in Medicine" by Dr. D. W. Hill at 19.00 at the Department of Electrical Engineering and Electronics, The University.

#### MANCHESTER

21st. SERT-"Pulse width modulation" and demonstration of IVC colour video recorder by A. Parkinson at 19.00 at Renold Building, U.M.I.S.T., Sackville St.

#### MIDDLESBROUGH

26th. SERT-"Philips solid-state colour receiver" by N. Cunniff at 19.30 at Cleveland Scientific

NEWCASTLE-UPON-TYNE
6th. SERT—"Engineering development in colour TV" by K. R. Harris at 19.15 at Charles Trevelyan Technical College, Maple Terrace.

13th. IERE—"A new look at data logging" by Kinnear at 18.00 at Ellison Building, The Polytechnic, Ellison Place.

#### READING

21st. IERE—"Developments in transistor circuit design" by Prof. E. A. Faulkner at 19.30 at The University, Whiteknights Park.

#### SOUTHAMPTON

20th. IERE—"The design and application of digital filters" by Dr. D. R. Wilson, D. R. Corrall and B. D. Dollimore at 18.30 at Lanchester Theatre, The University.

#### STEVENAGE

20th. IEETE-"Electronics usages in commercial vehicles" at 19.30 at College of Further Education, Monkswood Way.

### **SWANSEA**

20th. IERE—"Replanning aspects of medium-wave broadcast service" by Dr. R. C. V. Macario and J. F. Craine at 18.15 at Department of Applied Science, University College.

19th. IERE—"Hi-Fi tape recording" by R. West at 19.30 at Thurso Technical College.

# Digital TV Synchronizers and Converters

# Advantages of field storage technique for synchronizing different picture sources and for standards conversion

by S. M. Edwardson\*, M.I.E.E., and A. H. Jones\*, B.Sc.

One of the ways in which the presentation of television programmes has improved in recent years is that, as far as possible contributions from a multiplicity of picture sources are now arranged to be synchronous. One reason for this is to provide an uninterrupted train of synchronizing pulses so that viewers are not disturbed by frame 'roll-overs' or other momentary synchronization defects when changes are made between different sources. Continuity of the synchronizing pulses is important to the broadcaster as well, particularly when the programme is being recorded on video tape, because the subsequent replay from a video tape machine can be seriously disturbed for several seconds following any discontinuity in the recorded synchronizing pulse train. A further advantage of synchronous sources is that special effects are possible, such as the so-called 'split-screen' technique (in which a single picture contains simultaneous contributions from two or more sources). In addition, source synchronism enables programme makers to wipe, mix and dissolve rather than simply cut between different sources.

When the different television sources are all located within a single building there is no great difficulty in achieving synchronism, since they all can be fed from a common pulse generator and, by adjusting the timings of the pulse feeds to individual sources, precise and virtually permanent synchronism of the video signals is obtained. This is not possible, however, when some sources are remote.

This article considers the ways used by broadcasters to achieve synchronism between relatively remote television sources. Emphasis is placed upon the most modern method—the field-store synchronizer—and the practicality of making a relatively cheap, high-performance version using digital techniques. The article also considers the application of such techniques to standards converters.

Existing methods of source synchronization used by the B.B.C. fall into three main categories.

Genlock. Here the signal from the remote source is regarded as the 'master' signal and the synchronizing pulses at the

\* B.B.C. Research Department.

studio centre are adjusted automatically to synchronize with the pulses of the master. This is simple and convenient, but has the disadvantage that the synchronizing operation must be carried out slowly to avoid disturbance to viewers' receivers and other apparatus. Furthermore, only one remote source at a time can be used as master and it is necessary to use signals from a local source (e.g. a studio) for a period, while re-locking to a further remote source is carried out.

Natlock.† Here the central source (e.g. B.B.C. Television Centre) is the master, to which all other contributing sources are locked<sup>3</sup>. At the master, the phase of the synchronizing signals from one (or more) remote sources is compared with that of the master and digitized correction signals are fed back to each remote source so as to bring and maintain them in synchronism. The whole network is highly stable and uses narrow-band audio circuits for the correction signals.

The field-store synchronizer. This is essentially a variable video delay interposed in the path of a television signal, the value of delay being such that the output signal is in precise synchronism with a master signal. Precise synchronism between two television signals is achieved when the phases of their field synchronizing pulses, line synchronizing pulses and colour subcarriers are the same. Where a difference in frequency (changes of these phase relationships with time) exists between the television signal to be synchronized and the master signal, the delay in the synchronizer steadily increases or decreases to maintain synchronism; ultimately, the delay reaches a maximum or minimum value, at which point it is reset, to repeat its cycle of variation. A convenient value of maximum delay is equal to the duration of one field; thus, when the cycle of variation is repeated, one television field is omitted or duplicated according to the direction of delay variation. An interesting effect occurs in a field-store synchronizer when the cycle repeats, since the picture information carried by the train of cutput

 $\uparrow$  The National Slavelocking System used by the B.B.C.

www.americanradiohistory.com

television fields, normally 'odd, even, odd, even, etc.' becomes, for example, 'odd, even, odd, odd, even, etc'. Two fields of the same kind, with regard to picture content, then occur successively and the output picture is seen to move vertically or 'hop' by one picture-line spacing. A hop in the other direction takes place at the next re-cycling. This effect is found in practice to be not very obvious and, in the majority of synchronizing applications, occurs only very rarely.

Only one field-store synchronizer exists at present and is in service at the B.B.C's Television Centre in London. Its variable delay is formed from a switched cascade of ultrasonic delay-lines similar to those in an electronic field-store standards converter—in fact, this synchronizer is a modified standards converter. Fig. 1 indicates one of the ways in which it is used

#### Applications of synchronizers

PAL to PAL synchronization is the most common use of a synchronizer within the United Kingdom, where a colour television signal from a remote source is synchronized to, say, the signals at the studio centre. In most respects PAL to-PAL synchronization presents the simplest problem, because of the tight tolerance to which the subcarrier and scanning frequencies are held (±0.45 part per million when the PAL signals originate in other countries using the PAL system). SECAM-to-PAL synchronization particularly useful when importing signals from SECAM countries because, after processing by the synchronizer and transcoding, the signal conforms to the PAL specification in all respects, despite the wide range of scanning frequencies that the SECAM specification permits.‡

The synchronization of monochrome signals creates a special problem despite the simpler nature of the signals to be handled. The wide range of scanning frequencies likely to be encountered with imported monochrome signals can exceed the capacity of the present synchronizer

 $<sup>\</sup>ddagger$  French exported SECAM signals are held to a tolerance of  $\pm$  0.5 part per million, this helps a great deal but would nevertheless result in a non-standard, transcoded PAL signal, unless a synchronizer were

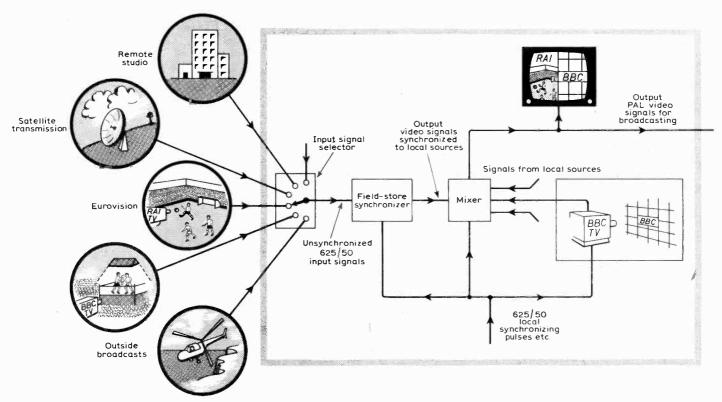


Fig. 1. Action of field-store synchronizer.

 $(\pm 400 \text{ parts per million})$  and an optical standards converter must, at present, be used to achieve synchronism. Future non-optical synchronizers will occasionally be required to handle wide-tolerance monochrome signals. It was mentioned earlier that a vertical hop occurs every time the synchronizer's delay system re-cycles and, for input signals with scanning frequencies differing greatly from those of the output signal, hopping would occur very frequently and would be subjectively annoying. To handle such signals, therefore, additional storage capacity equal to one television field might be required, so as to ensure the emergence of an undisturbed train of 'odd, even, odd, even, etc.' fields from the synchronizer." In this case re-cycling would occur half as frequently and a complete picture (i.e. two fields) would be omitted or duplicated each

#### Pros and cons of synchronizers

The field-store synchronizer has the advantages that a television source can be synchronized without disturbing the synchronizing pulses of the master station and without using feedback to the point of origination. It provides a continuous train of output synchronizing pulses (even with no input signal) and it permits rapid 'cutting' from one remote source to another, producing a correct output within a small fraction of a second of the arrival of a new input signal. The ability to synchronize without feedback particularly valuable when overseas sources are considered.

A disadvantage of the synchronizer arises from the fact that it operates by delaying the video signal and hence can cause video-signal distortions whereas, in the cases of Genlock and Natlock, synchronism is achieved through operations on only the synchronizer at present in service with the B.B.C., the distortion is small but is not imperceptible—an important consideration for a device intended to be used frequently in the television broadcasting chain.

Digital techniques now offer a solution to the problem of video distortion, as well as having other important advantages.

It is well known that the information contained in any analogue signal can be conveyed by sampling the signal at at least twice the highest frequency present; the magnitude of each of the samples may be sent as a binary number which is described by the presence or absence of

each of a group of pulses. Fundamental work on the application of pulse-code modulation4 to broadcast-quality colour television signals has concluded that a sampling frequency of three times the colour subcarrier frequency (i.e. about 13MHz) should be used and that each of the samples should be described by eight binary digits, corresponding to 256 equispaced quantizing levels; this leads to a serial bit-rate of about 100M-bits per second. However, the serial digit stream may be subdivided so as to use a number of parallel channels working at a correspondingly reduced bit-rate. It is possible, for example, to use 8 channels working at about 13M-bits per second, or 24 channels working at about 4M-bits per second. This subdivision transforms the digital signal into a form in which it can be processed by readily obtainable integrated circuits and storage devices. The advantages of digital processing are high accuracy and reliability, immunity to noise

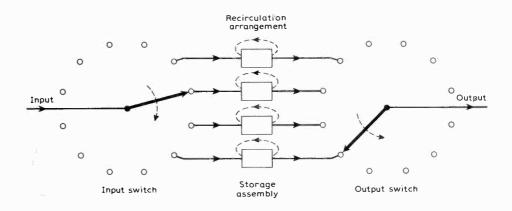


Fig. 2. Basic form of digital field store synchronizer.

<sup>\*\*</sup> The 'hop' could also be removed by simpler means, but at the expense of impaired vertical resolution.

and interference, with freedom from drift and from the necessity for careful setting-up and adjustment.

This last advantage makes digital processing particularly attractive for those parts of the television signal in which complicated processing is carried out. Experimental digital line-store converters have already been built5 and it is reasonable to expect the practical application of digital processing to field-store synchronization and standards conversion. The costs involved in applying digital techniques have fallen in recent years to the extent that a digital solution to a requirement can now often compete, on economic grounds, with the analogue equivalent. It is estimated that the cost of a future digital field-store synchronizer will be appreciably less than that of the corresponding analogue equipment.

#### Methods of digital synchronization

Present-day analogue synchronizers make use of ultrasonic delay-lines for signal storage. These lines have the property that a signal inserted into them emerges at the output terminal after a specified time interval. For synchronization, and a number of other applications, however, it would be preferable to use devices into which 'blocks' of signal may be written and stored for a variable interval depending on the relative phasing of the input and output synchronizing pulses. Fortunately, the storage devices used in digital systems are generally of this type and their application to the television synchronization problem, in place of delay-lines, leads to a considerable simplification in the ancillary circuits.

Thus with a storage system consisting of a series of 'pigeon-holes', which can be filled and emptied as required, it is possible to envisage field-store synchronizer whose basic form is shown in Fig. 2.

The storage assembly is subdivided into a number of individually accessible units; these may have any convenient size, but it is desirable that the information contained in a television field should be accommodated within a whole number of units. The total capacity of the storage assembly must be at least equal to that required for one television field.

Writing and reading from the storage units is effected by means of the input and output switches shown diagrammatically in Fig. 2. The stores are emptied in sequence via the output switch which is controlled by the output synchronizingpulse train. The input switch is controlled by the input synchronizing pulses and directs each block of information to the storage unit to which the output will be connected when that particular information is required; the stores are controlled by input clock-pulses during writing and by output clock-pulses when reading. The reading process is preferably made non-destructive (perhaps 'read-restore' action), the stored information remaining available until replaced by the writing-in ('overwriting') of new information.

By this overwriting technique it is

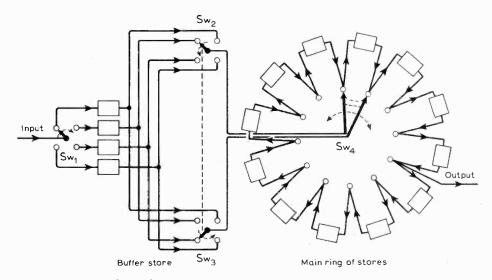


Fig. 3. Alternative form of synchronizer.

possible to deal with non-synchronous cuts in the input signal without causing any visible disturbance at the output.\* If the position on the raster of the beginning of a new signal were known, say by indicating the 'line-number' to the input switching system, the signal could immediately be routed to the appropriate store location. In practice, this cannot occur and it will be necessary to arrest the writing process until the first of the new field-synchronizing pulses arrives; in this case, that part of the input signal which was written into the stores during the field immediately preceding the cut would be repeated at the output. If the writing process were stopped altogether, say by the removal of the input signal, the output would produce a stationary picture.

In general, however, the input and output switches provide access to the storage units in an orderly sequence but, of course, at slightly different rates. Now digital storage arrays are generally constructed in such a way that the writing and reading processes are carried out by the same circuits. Thus writing and reading cannot take place simultaneously in any one storage unit, if the two clock rates are different, as indeed they may have to be in a synchronizer.

This restriction can be overcome by incorporating more storage units than are necessary to accommodate only the information corresponding to a field. Then if, say, writing 'catches up' with reading, the reading switch can be arranged to omit a field. If reading catches up with writing, the reading switch will correspondingly cause the previous field to be repeated. This process is identical to the delay re-cycling process mentioned earlier. In practice, it may be advantageous to use a number of extra storage units sufficient to provide backlash; in this way frequent vertical picture hops may be avoided in the circumstances when the phase difference between the input and output signals wanders about zero.

At present, the obvious choice of storage device for a synchronizer of this type is the m.o.s. dynamic shift-register. This device will not store information reliably for more than a short time interval, but this problem can be overcome by recirculating the information within each storage unit, at either input or output clock rate, during the interval between writing and reading. Another way of coping with the problem posed by dynamic registers is to cycle the information through the storage units connected as a ring. If this were done under the control of, say, the output clock it would be possible to derive the output from a fixed point in the ring of stores, with the signal inserted at an appropriate point. In this form, the ring may be regarded as a tapped delay with the addition of a recirculation path to allow for the repetition of information when required. A subsidiary buffer store would be required at the input, however, so that new information could be inserted into the appropriate point of the ring at the appropriate time, under the control of the output clock pulses. This leads to arrangements of the type shown in Fig. 3. Each of the storage units comprising the buffer store on the left-hand side of this diagram has a capacity equal to that of each of the units in the main ring of stores. Sw, directs input information into the buffer store as it arrives; this process is, of course, clocked at input rate. The reading of the buffer store and all subsequent switching and clocking operations are locked to the output standard. Sw<sub>2</sub> and Sw, are ganged; their purpose is to provide access, during the period of each signal block, to information that has been written into the buffer and is ready to be transferred to the ring. During any one such period, signals flow down one or both, or neither of the two wires leading to Sw<sub>4</sub>. The wipers of Sw<sub>4</sub> are ganged and are positioned, at the beginning of each signal block, to feed information into the appropriate (adjacent) pair of terminals on the ring so as to replace the signal block(s)

<sup>\*</sup> This assumes that the fact that a cut has been made is conveyed to the synchronizer; if not then, between the time of the cut and the appearance of the next field synchronizing pulse at the input, information may be displayed in the wrong position on an otherwise standard output raster.

that would, otherwise, have circulated through that particular section of the ring. Information is discarded or repeated at the output when the wipers of Sw4 move past the output connection. The size of the buffer store, and the motion of Sw, and Sw, may be arranged so that frequent discarding and repeating of information is avoided when the input and output synchronizing waveforms are hovering near synchronism. If the main ring holds only one field, ancillary circuits can be connected at the output to ensure that the output signal is presented in correct phase during successive fields.

Other arrangements can be envisaged; for example, it would be possible to connect the input signal to the main storage ring, with a subsidiary buffer store at its output. The final choice of block diagram will depend on detailed design considerations.

Complications arise when field-store synchronization is attempted with a storage capacity limited to about one television field. The properties of a PAL colour signal are such that an 8-field cycle is involved; this arises because of the interlaced fields, the V-axis (PAL) switching at half-line frequency, and the arithmetical relationships between the colour subcarrier and the scanning switching sequence will be wrong. During the development of the present-day synchronizer, various methods of overcoming this problem were examined and the method finally adopted was to change, when necessary, the synchronizer, delay by one complete television line so as to bring the V-axis switching sequence into This method, known 'line-slipping', results in a picture that has been moved bodily up or down by one line and means that a further loss of one line of video information can occur; this was considered less serious than the degradation of picture quality which would accompany alternative solutions. It is likely that a similar method will be necessary in a digital synchronizer.

#### Extension to field-store conversion

A field-store converter is required to produce an output signal whose field phasing is constantly varying relative to the input. A field-store synchronizer must, of course, be capable of dealing with such variations. However, in the case of the converter, the variation is much more rapid, and the conversion process, in general, also involves a change in the number of lines per picture. These requirements may be satisfied by

Recirculation arrangement 0 0 Input Output Interpolator 0 0 0 0 0 Ω Storage Input switch Output switch

Fig. 4. Extension of Fig. 2 to provide facilities for field-store standards conversion.

frequencies. Each of the eight fields is separately identifiable and a synchronizer would, ideally, have a storage capacity sufficient for eight fields, in order to match precisely any incoming field to one from the master signal; even the synchronization of monochrome signals ideally requires two-field storage. There is no need, however, for such storage capacity in practice since the difficulties can be overcome without serious penalties. There are two main effects involved.

First, when the timing of the input signal requires that 'odd' fields at the input be displaced to become 'even' fields at the output, or vice versa, picture information will be absent from half of one television line at the bottom or top of the output picture.

A second, and more serious, problem arises in connection with the polarity of the V-axis (PAL) switching. Once the corresponding lines of the nearest incoming field have been aligned, there is a 50% chance that the polarity of the PAL

arrangements similar to those given in Figs 2 and 3 with the addition of circuits that interpolate between a number of input lines (possibly derived from successive input fields) to produce information suitable for display on the output raster, together with the additional storage capacity required for interpolation.

Fig. 4 is an extension of Fig. 2 to provide these extra facilites. In this example the interpolator takes information from one line in each of two successive fields, and the two output switch wipers are driven accordingly. The total storage capacity required would somewhat exceed that corresponding to two fields. Circuits already developed, could be used to carry out the processing required in a digital interpolator of this type.

The presence of the colour subcarrier complicates the interpolation process, however, as it does for analogue field-store standards conversion. A problem arises because the phase of the colour subcarrier changes from line to line and field to field in a manner which can prevent information being taken directly from different lines and fields of the signal. Analogue standards converters avoid this difficulty by using an intermediate system of colour signal coding, rather like N.T.S.C., having a specially chosen colour subcarrier frequency which is an integral multiple of the input line frequency. This means that, for a given colour, the phase on any line of any field is always the same and interpolation is thereby simplified. It is possible that a similar kind of intermediate colour system may be necessary in digital field-store standards converters.

#### Acknowledgements

The authors wish to acknowledge the contributions and help received from their colleagues in the B.B.C. Research Department; they also wish to thank the Director of Engineering of the B.B.C. for permission to publish this article.

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#### Communication 72

This is the title of an international radio and data transmission conference being organized for 13th-15th June next year in the Metropole Convention Centre, Brighton. It is being jointly sponsored by Electronics Weekly and Wireless World and will provide a meeting ground for the manufacturers and users (both military and civil) of communications equipment. A steering committee including representatives of Government Departments, the industry and user organizations has been set up and a call for papers will be issued shortly.

Considerable interest has already been shown by manufacturers in the supporting international exhibition which has the backing of the Electronic Engineering Association and is being organized by P. Gordon Saville, 21 Victoria Rd., Surbiton, Surrey. Present plans provide for about 150 stands.

Since PAL switching occurs at half-linefrequency rate, the opposite switching polarity must always exist on adjacent lines.

# Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

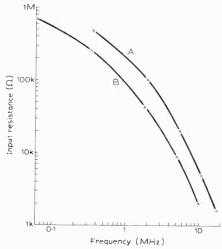
#### Dual-trace oscilloscope unit

I would like to comment on some of the points made by W. T. Cocking in his article 'Dual-trace Oscilloscope Unit'.

A continuously variable gain control I consider unnecessary and I do not use it on an ordinary oscilloscope in which the gain varies in steps of 1:2:5:10. On the other hand, I would not consider the purchase of an oscilloscope which lacked direct coupled amplifiers. There are rare occasions when the a.c. and d.c. components differ so much that I have to put a dry battery in series with the input, but this is acceptable for experimental work.

Most people believe that the input resistance of an oscilloscope is about  $1M\Omega$  shunted by a capacitance of 30 to 50 pF because this is stated in the instruction manual. In fact this is true only at low frequencies. At high frequencies the shunt resistance falls to perhaps  $2k\Omega$ . This may not be important when used with switching circuits but it will probably be disastrous if connected across the tuned circuit of an oscillator.

The graph shows the resistive component of the input impedance measured with a Q meter. Above 100kHz the resistance is inversely proportional to the square of the frequency. The resistance will vary slightly from one attenuator position to



Input resistance of oscilloscopes. (A) Advance OS2100 (transistor amplifier); (B) Telequipment D53, amplifier C2 (valve).

another but the two curves are representative. One oscilloscope (B) uses valve amplifiers and the input resistance varies only slightly when the mains supply is switched off. There are series resistances such as grid stoppers in the input attenuator and these probably cause the very low equivalent shunt resistance. Measurements were made with short (approx. 6 inch) wires between oscilloscope and Q meter.

I must emphasise that the graphs do show the shunt resistance. They are not curves of capacitive reactance.

M. D. SAMAIN, University of Salford.

#### The author replies:

The points about gain control and a d.c. response are surely personal ones. I am used to a continuous gain control and would not willingly do without one. On the other hand, I have rarely found any use for the d.c. input of an oscilloscope.

I am most interested in the figures for the input resistance of oscilloscopes at high frequencies. I made a rough measurement on an oscilloscope at 10MHz and found the resistance to be of the order of  $7k\Omega$  only. The c.r.o. so loaded a tuned circuit, however, that the resulting Q was too low to measure accurately with the meter available and I would not rely on my figure to better than  $\pm 50\%$ ! It does, however, give confirmation of a low input resistance at high frequencies.

The suggestion that it is caused by the use of series stopping resistors is probably the chief cause. At 10 MHz,  $22 \Omega$  in series with 30 pF has a parallel equivalent of  $12.8 \text{k}\Omega$  in shunt with 30 pF. W. T. COCKING.

#### Television sound quality

I recently purchased a new 24-inch single-standard TV set. I have subsequently found that although the picture quality is very good the sound is dreadful, speech quite frequently being unintelligible and music invariably not worth listening to. When I complained to the retailer I was told that the poor sound was common to most sets and was due to the fact that the manufacturers had provided more for the money on the vision side. I said that the sound

quality was as important as the visual quality to my enjoyment and that I was prepared to pay either to have the sound taken through my high-fidelity amplifier and speaker system, or, alternatively to buy an entirely separate tuner to use with my high-fidelity system. I was told that they were forbidden by the manufacturers to do the former (it was done on a previous TV set), and that there was no such thing as a separate tuning unit for TV sound.

I then communicated with the manufacturer (B.R.C.) pointing out that the sound quality was much worse than on one of their own portable transistor sets I had bought for a little over £20. They said that they were sure my TV set was faulty and should be returned to their factory. I perforce went through the lengthy procedure of doing this, at the same time stating that I would much rather put the sound through my other equipment either from the TV set or a separate tuning unit, or failing that, and since the set was being returned to them anyway, would willingly pay anything within reason for them to fit a better quality amplifier and/or speaker. In the event they insisted that none of these things was possible and returned my set with a note that a capacitor had been changed.

The quality of the sound reception is minimally improved but remains quite unacceptable by any reasonable standard.

In common with many other families, we use our television set for more hours of the week than either the radio or record player. Despite the fact that I have very expensive equipment for sound reproduction, I am obliged to tolerate sound on our major source of entertainment which spoils our pleasure in the programmes. Although I am prepared to spend whatever additional money is necessary to obtain good sound quality I am told that this is not available at any price.

R. SEAR, London N.W.3.

#### **Optimum scale integration**

In 'News of the Month' in your July issue (page 340) you comment on the use by Plessey of the term 'Optimum Scale Integration'.

When designing complex linear integrated circuits - for example colour processing systems – the limit to the amount that may be integrated is rarely set by chip size. The factors controlling chip complexity are usually stability (when high gains are involved) and overall system price - bearing in mind that the cost of an integrated circuit increases very rapidly with the number of external connections that are made to it. A digital system may well have less connections if it is integrated on a single huge l.s.i. chip than on several smaller chips but the same does not apply to linear systems, which need coupling, decoupling and tuning, most of which are accomplished with non-integrated components.

Thus, several years ago, Plessey Microelectronics coined the term 'optimum scale integration', or o.s.i., to describe the integration of linear systems into the most economic number of functions per chip. It was a contrast with digital l.s.i. where the most economic number of functions per chip is usually the largest.

JAMES M. BRYANT, Plessey Company, Components Group, Swindon, Wilts.

In reply:

Mr. Bryant quite rightly points out that the problems of designing linear and digital i.cs are different but to imply that digital i.cs do not have to be optimized is stretching things a bit. Minimizing the number of interconnecting leads can be done only if the chip is being designed for a particular system. In most cases the chips (digital) are intended as building bricks in some system to be designed by the customer and not known to the i.c. manufacturer. Digital i.cs, like most other manufactured products, are the result of a process of optimization and compromise. The term o.s.i. seemed to stem from the need to make the devices sound different for publicity purposes-hence our quip.-

# The asymmetric long-tailed pair

The long-tailed pair is, arguably, the most versatile basic circuit scheme ever conceived—all credit to the perceptive genius of A. D. Blumlein—and the advent of monolithic silicon integrated circuit technology, with its active device oriented circuit design philosophy, has vastly extended its use. So far, however, attention has concentrated on the 'symmetric' longtailed pair, i.e. a balanced scheme in which the active devices are made, intentionally, as near-identical as possible. As far as I am aware no attention has been paid to the case where the devices are intentionally fabricated with a significant, controlled, asymmetry, i.e. the asymmetric long-tailed pair. It is the purpose of this letter to point out briefly, the possible advantage of such a configuration; in the case discussed here bipolar junction transistors are dealt with.

Consider the circuit of Fig. 1 in which transistors  $Tr_1$  and  $Tr_2$ , made in close

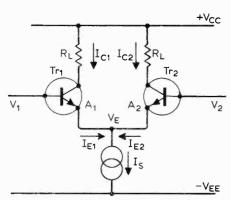


Fig. 1. Basic long-tailed pair.

proximity on the same semiconductor wafer, have emitter areas  $A_1$ ,  $A_2$  units respectively. If, (i) the saturation current density of the emitter base junctions of both devices is  $J_o$ , (ii) operation is at a current level  $\Rightarrow I_{CBO}$  (typically  $< \ln A$ ), and (iii) the common-base d.c. current gain of each device is  $\alpha$ , then

$$I_{C1} = \alpha I_{E1} = \alpha A_1 J_o \exp \{ (V_1 - V_E)/V_T \}$$

$$I_{C2} = \alpha I_{E2} = \alpha A_2 J_o \exp \{ (V_2 - V_E)/V_T \}$$
(2)

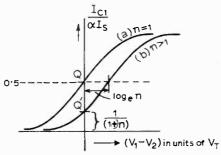


Fig. 2. Long-tailed pair transfer characteristics.

where  $V_T$  = thermal voltage =  $KT/q \approx 25$  mV at  $T = 300^{\circ}$  K.

Furthermore,  $I_S = I_{E1} + I_{E2}$  (3) Routine algebraic manipulation of (1), (2), (3) gives,

$$(I_{C1}/\alpha I_S) = 1/[1 + n \exp\{-(V_1 - V_2)/V_T\}]$$
(4)

where  $n = (A_2/A_1)$ . A similar expression holds for  $(I_{C2}/\alpha I_S)$ .

A more convenient form of (4) is,  $(I_{C1}/\alpha I_S) =$ 

$$1/[1 + \exp\{(V_{os} - V_1 + V_2)/V_T\}]$$
 (5) in which,

 $V_{OS} = V_T \log_e n$  (6) Equation (5) is sketched in Fig. 2. Curve (a) corresponds to n=1 (symmetric case): curve (b) corresponds to n>1 (asymmetric case). Clearly the effect of area difference is to shift the transfer characteristic parallel to itself along the horizontal axis by the amount of the offset voltage,  $V_{OS}$ . (In the intentionally symmetric case there is always the possibility of some undesired small offset voltage because of fabrication tolerances: thus a 2% area difference between  $Tr_1$ ,  $Tr_2$  yields, via (6),  $V_{OS} = 0.5 \,\mathrm{mV}$ ).

For the linear amplification of small signal voltages bipolar with respect to a specified reference level  $V_2$  a symmetric scheme is suitable. With the quiescent point at Q the transfer characteristic is substantially linear for  $\Delta V_1 = \pm V_T$ . Suppose, however, that it is required only to amplify signals positive going with respect to  $V_2$ . In such a case the choice  $n \neq 1$  would appear preferable: in fact, the input signal range for linear amplification is extended by a factor of 2 if the transistors are designed so that,

$$V_{OS} = V_T \log_e n = V_T \tag{7}$$

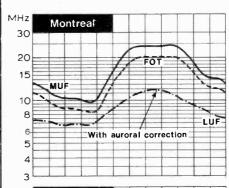
or,  $n \approx 2.7$ .

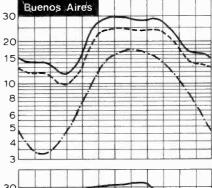
For this condition the quiescent point is Q'. Obviously, the configuration is equally suitable for the amplification of negative going signals only if they are applied to the base of  $Tr_2$ .

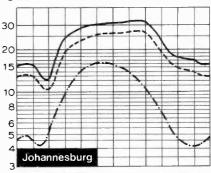
B. L. HART, London E. 15.

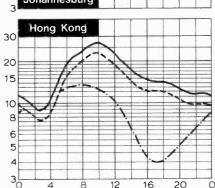
## H.F. Predictions— October

Path MUFs are determined by the twocontrol-point method of calculating MUFs for 4000km range from each terminal along the great circle between them and taking the lower value as the MUF for the path. When the terminals are widely separated in latitude the MUF difference can be considerable, for example on Hong Kong/ London during 00.02 to 00.04 G.M.T. it is 23MHz. Operation above path MUF is often observed under these conditions accompanied by a change in direction of arrival away from the great circle bearing towards the equator. Similar effects, due to ground reflection scattering and ionospheric layer tilts, are observed on many long-distance circuits and have diurnal and seasonal variations.









## News of the Month

#### New radio-telescope

A detailed design for a radio-telescope, to be known as the Mark VA, is to be commissioned by the Science Research Council at a cost of some £250,000. In 1967 the Council announced two preliminary design studies for a large steerable radio-telescope to be operated by remote control from the Nuffield Radio Astronomy Laboratory of Manchester University, at Jodrell Bank. The new design announced by the Council will carry these preliminary studies a stage further and lead to the consideration of tenders for construction of all the major components of the telescope in about a year's time. The Engineering Division of the United Kingdom Atomic Energy Authority Reactor Group will be the S.R.C's agent; Husband and Company, of London and Sheffield, will be the consulting engineers. The specification is for a telescope of about 114m aperture, with a solid membrane, the elements of which can be adjusted by remote control during operation. The membrane will be carried on a large steel structure pivoted in elevation on bearings carried on a beam supported from a reinforced concrete turntable. It is planned that the site of the telescope, if approved, will be at Meifod in Montgomeryshire in Wales. If constructed the Mark VA would operate at wavelengths down to a few centimetres and be used in conjunction with the existing Mark I, currently being repaired and modified, to form an interferometer with a base-line some fifty miles long.

#### Automatic buoy

Europe's first fully-automatic unmanned navigational buoy has replaced the Shambles lightship off Portland Bill, Dorset. Lanby (large automatic navigational buoy) has just undergone a year of intensive testing which followed its delivery by the manufacturers, Hawker Siddeley Dynamics, to Trinity House. The buoy consists of a main light beacon 12m above sea level which can be seen for sixteen miles and a powerful fog signal which can be heard more than three miles away. At a later date radar and radio beacons may be fitted, and there is provision for accommodating meteorological or oceanographic data-reporting equipment if required. The automatic operation of the buoy and its power

supplies, three 5kW diesel-powered generating sets, is monitored every thirty minutes by a shore station via a radio telemetry link. Should any failure occur, standby services operate automatically, and indication of the fault is relayed to the shore station. Shore control can carry out 40 separate checks on the equipment and can control 22 different operations. It is estimated that the buoy will cost 90% less to operate than the £29,000 per year required to keep a light vessel at sea.

#### Small airfield 'control tower'

A compact equipment (NP8) designed by Rohde & Schwarz for small airfields is not only an accurate direction finder but also provides two-way v.h.f. communication on any one of up to six channels. A technique known as the wide aperture Doppler method is used for the direction finding process.

The pilot of an aircraft wishing to land at an airfield equipped with the NP8 selects the airfield approach frequency on his normal v.h.f. transmitter and calls the control tower. The NP8 receives the signal and provides the controller with a digital indication of the airfield's bearing from the aircraft (QDM) to within one degree and also gives a rough indication (within 10°) of the aircraft's bearing from the airfield (QDR). The controller also hears the transmission and reply using the NP8's transmitter.

The direction finder aerial consists of 16 dipoles arranged in a circle of 3.3m diameter which are electronically commutated at 170Hz and simulate a single aerial rotating around a circle of 3.3m diameter. The communications aerial is a single dipole mounted at the centre of the 16 d.f. dipoles.

The outputs of the two aerial systems are fed to two separate receivers which have a common crystal-controlled local oscillator. The output of the communications receiver is detected and used to feed an audio amplifier and speaker. It is also used to compensate for frequency differences between transmitter and receiver and to prevent an f.m. signal from upsetting the d.f process by comparing the communications receiver output with the d.f receiver output to obtain a correction signal.

The d.f. receiver's output is frequency modulated by a 170Hz signal which is

caused by the 'rotation' of the aerial relative to the aircraft's transmitter and has a phase which when compared with the original 170Hz commutating signal yields the bearing of the aircraft.

The phase shift of the bearing signal is averaged over a period of 180 simulated aerial rotations before being displayed but for a very short transmission a bearing indication is available after 36 rotations.

# Naval gun used to produce ferrite parts

New ferrite components are being developed at the Billericay factory of Marconi Communication Systems using an unusual production process. The basis of the new process is a 6-inch naval gun with the barrel cut short and sealed. Soft rubber moulds, containing powdered ferrite material from which all the air has been evacuated, are immersed in a hydraulic fluid in the gun barrel, and the breach of the gun is closed. The fluid is then pumped up to a pressure of over 15 tons per square inch, and the powder is forced into a solid block inside the moulds. Since the pressure is applied evenly in all directions by the fluid in the gun barrel, the compressed powder is almost completely free from stresses which might distort the block of ferrite in the furnace.

The ferrite is then fired at a high temperature in an electric furnace, during which time it becomes nearly molten, and shrinks by one fifth of its size. At the end of the process the component is hard enough to cut glass, and is accurate in size to within 0.5%. This unusual method of compressing ferrite powders eliminates lengthy cutting and grinding operations, which normally have to be carried out using diamond cutting tools on the finished ferrite blocks. It also saves a considerable wastage of off-cut material, which cannot be re-used after it has been fired. In the case of the more expensive ferrites, this saving can be considerable.

#### I made it myself

The communications division of Motorola have taken a step in the right direction by adding an important commodity to one of their radio paging receivers. Each receiver is assembled, tested and packed by one assembly technician. Gone is the production line where each worker did the same job over and over again with little idea of what the final product looked like. The assembly workers are now completely involved. They are responsible for the quality and reliability of the receivers they have each made and an extra something is added which is called pride in one's work. A signed note with the receiver tells the customer who made it.

The receiver in question, called the Pageboy-2, uses only 80 components (if a hybrid i.c. can be called a component) and makes the one-person production technique possible. Motorola are so pleased with the results of the exercise they are now looking at other areas where the idea could be applied.

# Quadraphony and Home Video steal the Berlin Show



The 27th German-based radio and television exhibition, held this year in Berlin (Aug. 27-Sept. 5), was international for the first time. So we are justified in presenting some developments from outside Germany this time. The enlarged exhibition area held 263 exhibitors, with nearly half from countries other than Germany. There were 14 British manufacturers represented, 20 from the U.S.A. and 38 from Japan. Main developments were in quadraphonic sound systems and home video equipment.

#### Four-channel systems

There was a lot to see in four-channel equipment. If you're confused by what's happening in four-channel sound systems, we don't blame you. The situation is confusing because of the variety of systems and in particular a lack of agreement about which to use for what purpose. The jargon doesn't help the outsider to four-channel thinking either.

As well as the basic four-channel arrangement of four microphones feeding four speakers independently ('4-4' system) there are simulated systems—which can be merely ambience-enhancing techniques—for creating four speaker signals from two channels ('2-2-4' system) and '4-2-4' systems for processing four-channel information over two-channel links (e.g. discs). Then there is the question of what to do about compatible tapes, discs and broadcasts for four channels of information (at least ten systems have been proposed for broadcasting).

Some are tempted to dismiss it all as commercial gimmickry, if not trickery, but out of all this comes a theme we have heard before with mono vs stereo and monochrome vs colour television—those who have heard the better four-channel systems say they don't want to go back to conventional stereo.

Ambience is what is mostly lost through stereo reproduction, and is the reverberant sound of the playing room which arrives later than the direct sound and with an almost random directionality. To get an impression of this one has to perceive sound in the listening room on the same basis as in the original room. To do this

means arranging to get sounds in the room which follow on from the original sound in an incoherent way but at the same time do not reduce the stereo directional property. Using the findings of Haas (which incidentally related to speech pulses) it is maintained that delays of about 1 to 30ms do not reduce directionality-the first-heard sound locating the source—and the delayed pulses merging to reinforce the first sound (provided the level difference is less than 10dB). Thus it has been proposed to introduce delays (of around 10ms) between front and back speakers (in a two-channel stereo system), arranging the back speakers to get the best ambience effect-level with the ears. Getting these delays can be inconvenient because of the delay mechanism needed, e.g. displaced tape heads, sound propagation tubes, etc. The alternative of using four appropriately spaced microphones can achieve the required delay, but requires the co-operation of the recording director and a 4-2-4 system. Consequently simpler ways of achieving an ambience effect have and are being adopted.

The Körting Multisound 600, Siemens RS172 and RS302, a unit by Audioson, and the Elac 3400T are based on the old argument that the difference between two stereo channels carries reverberant sound (which is less masked than in the sum signal) and can be used to reproduce an enhanced reverberation effect. Körting use a differential amplifier to produce antiphase difference signals,  $(\pm I-R)$ , which are fed through separate amplifiers to two rear speakers. The 180° phase difference is intended, the makers say, to prevent a sound image being formed midway between the rear speakers. But the effect of this may be disturbing to some in a similar way to the effect of anti-phase speakers in a conventional stereo setup, and can give reduced l.f. response through cancellation. Although these two signals could be provided more economically using either one extra amplifier with antiphase speakers or by matrixing the L and R signals, Körting -in common with many other manufacturers of such black boxes-are anticipating availability of four-channel discs or tapes.

Pioneer equipment shown had two modes of operation—one using a matrix for fourchannel discs (coded stereo discs) and one using a phase difference circuit for ordinary stereo discs. The phase difference method provides a differential L-R signal for the rear speakers with a  $90^{\circ}$  phase difference to provide a diffused rear sound source. The matrix mode is intended to be used with coded discs, i.e. two-channel discs derived from four main microphone channels. The Sansui QS-500 also includes a matrix and it is interesting that makers have decided to adopt a particular kind of matrix before there is any agreement on what system will eventually be used for disc coding.

The Sansui equipment is unique in that it includes phase modulators to give a presence effect which acts on each of the rear channels to give 'randomly' varying phase differences between 0 and 180°. Both rear channel signals, derived by matrixing, are phase shifted prior to this phase modulation—the specification shows 90° at 300Hz for the left and 90° at 600Hz for the right. The significance of these frequencies is not explained.

A '4-2-4' system proposed for use with such units has a four-microphone arrangement feeding a linear matrix coder to produce two channels from the four. The resulting left channel output comprises mainly signals from the left front and back microphones together with a difference signal from the right front and back microphones, and conversely for the right output. These two composite signals can then be applied to a stereo disc cutter in such a way as to rotationally modulate the groove by appropriate choice of coefficients in the matrix, rotation of the cutter x-y axes corresponding in theory to 'panning' a sound source around 360°.

In practice of course the cutter—or pickup stylus—is not physically rotated, the desired effect being achieved by giving suitable coefficients to the cutter signals. When the matrixed or 'coded' signals are retrieved from a disc, and 'de-matrixed' it turns out that when, say, the left front microphone only is providing a signal, three speakers are energized, the left front with a full signal and the two adjacent speakers with a signal 3dB down. As it stands, this system is clearly not a 'discrete' system, and it would seem there is a reduction in front left-right separation.

But it is argued that most programmed material would not demand four discrete channels. When discrete reproduction is important it is possible to apply gain control to the two flanking channels to reduce their effect using circuitry which recognizes the appropriate kinds of signals. This basic idea, similar to that of Scheiber, is the basis of a variety of commercial fourchannel playback units, including those by Pioneer, Sansui, Electro-Voice. Lafayette.

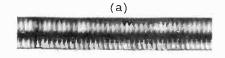
While it may be true that conventional stereo discs can be reproduced with added realism, such a coded disc will not be very compatible-a two-channel stereo setup will have reduced separation. Also, to improve this front right-left separation means an expensive decoder because of the need for additional gain control circuitry. As a centre-back signal corresponds to a vertical stylus motion, this would be lost when playing such a disc in the mono mode. A way round this is to provide a 90° phase difference (actually  $\pm 45^{\circ}$ ) between the two composite channels and thus their sum is equal to the square root of the sum of the squares of the two signals, thus giving mono compatibility.

Bauer\* has pointed out that there is directional ambiguity as a result of using a one-dimensional matrix i.e. one in which the output signals are linearly related to the input with real coefficients, claimed to be overcome in the CBS system by using a two-dimensional matrix with complex coefficients-see later.

One method of putting four channels of information onto a disc is the modulated subcarrier technique used by the Victor Company of Japan. In this a matrix produces the signals  $L_F + L_B$ ,  $L_F - L_B$ ,  $R_F + R_B$ ,  $R_F - R_B$ . The two difference signals are separately angle modulated onto a subcarrier of 30kHz with a total passband of 20-45kHz. (Difference signals below 800Hz are frequency modulated and above 800Hz are phase modulated onto the carrier.) The two sum signals are then added, so the two composite signals (representing the left channels and the right channels) are modulated onto the disc groove in the normal way. Fig. 1(a) shows a typical groove modulation. The level of the modulated difference signals is kept to 20dB less than the maximum level of the sum (audio) channels. By this means crosstalk figures of 20dB (both front-to-back channels) and 25dB (both left-to-right channels) are obtained.

This kind of system was investigated by CBS—except that the carrier was at 22kHz with an a.m. upper sideband extending to 38kHz-but a number of snags were found. So that the stylus can trace the finer groove modulations the base-band signal has to be reduced in level resulting in a 6 to 8dB drop in s/n ratio in the stereo mode. Also there are difficulties in tracking which would mean restricting the inner groove radius to about 15cm. Then there is the cost of pickups designed for use up to 40kHz.

The system eventually adopted by CBScalled SQ (stereo/quadraphonic) and re-



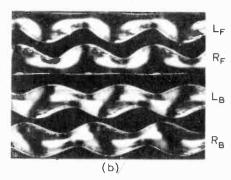
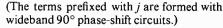


Fig. 1. Grooves of four-channel discs using subcarrier technique (a) and using CBS matrix technique (b).

cently demonstrated in London as well as in Berlin-uses a linear matrixing technique which gives improved performance in some respects over other matrixing methods. Starting with the disc cutter, the method of getting the additional directional information onto the disc is similar to the system already discussed. The front signals are as for a conventional stereo disc. The left back channel is associated with a clockwise circular motion in the groove and the right back channel with an anti-clock wise motion. The left back signal is applied equally to both groove walls with a 90° phase lag on the right, and the right back signal is applied equally with a 90° phase lead on the right. The back channels are thus orthogonal-as are the front channels-signals in one back channel being unaffected by a signal in the other back channel. Thus, in theory, infinite separation is available between the front pair and the back pair of channels. (Not so between the left and right pairs, where separation can be as little as 3dB.) Equal front signals give a lateral groove modulation, equal back signals give a vertical modulation and a source at other points around a microphone square would give elliptical modulation. Fig. 1(b) shows four 45-45 grooves with modulation by each channel. The 90° phase difference between the two wall modulations is clearly seen.

The matrixing process has the following

relation: 
$$L = L_F + aR_B - jaL_B$$
 and  $R = R_F - aL_B + jaR_B$  where  $a = \sin 45^\circ = \cos 45^\circ = \frac{1}{2}\sqrt{2} = 0.707$ .



In the 'de-matrixing' process (Fig. 2) the outputs will be:

$$L_F' = L_F + aR_B - jaL_B$$

$$R_F' = R_F - aL_B + jaR_B$$

$$L_B' = L_B - aR_F + jaL_F$$

$$R_B' = R_B - aL_F - jaR_F$$

Thus the front-left speaker, for example, produces no front-right signal, but has an in-phase back-right component and a backleft signal shifted in phase by  $-90^{\circ}$ . By inspection of the other equations it can be seen the front and back pairs have the theoretically infinite separation while front signals are transferred with reduced amplitude in the rear and vice versa. High front separation is most useful for maintaining compatibility with two-channel stereo equipment and is a distinguishing feature of the system-Fig. 3(a). This figure also shows the signal amplitudes resulting from a front left signal in the other systems for comparison at (b). (It is achieved at the expense of slightly more power being radiated from the opposite direction of the dominant sound source than in the system using all real coefficients in the matrix-Fig. 3). Using a different kind of matrix with the system will reduce separation and alter sound distribution.

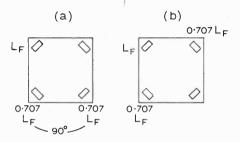


Fig. 3. Speaker outputs when a front-left microphone only is energized using the CBS matrix method (a) and typical output using other matrices (b).

In the example of Fig. 3(a), the rear signals have negligible effect on perceived direction, only contributing to the total loudness. The human hearing system favours sounds from the front, and as sounds for the back reach the ear largely by reflection (in a room) and are therefore delayed, the Haas effect prevents any effect of reflected sound on directionality. This rule doesn't seem to apply when the back

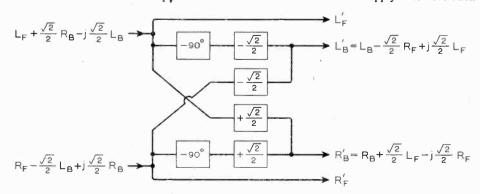


Fig. 2. Simplified decoder matrix used in CBS SQ system using wideband 90° phase-snift circuits. Modified form of matrix can give improved separation between centre front and back signals at the expense of left-right separation.

<sup>\*</sup> Letter to the editor, J. Audio Eng. Soc. vol.19 1971 pp.315/6.

signals are dominant. In the case of a back left signal, the signals in the front speakers are in quadrature and it has been shown that the image from two such signals is displaced toward the leading signal (front left). It turns out that this is at about the same angle as the perceived sound from the back speaker-which is about  $\frac{1}{3}$  of the angle between two speakers. (Perceiving incoherent stereo signals from behind narrows the separation angle.) So the front image tends to 'blend' with the back image, and because the back signal is the stronger the sound is perceived from the back. A feature of the system is that the same effect occurs if the listener turns round and faces the back.

When playing a four-channel disc on a two-channel system, the sounds corresponding to equal signals in quadrature are shifted towards the leading phase speaker. Thus a back left signal appears displaced toward front left, which helps to convey some sense of identification between the four and two-speaker reproductions.

The reduced-amplitude (or 'side-effect') signals are perceived when a listener turns through 90°, reducing apparent front-back separation. A refinement to the system therefore is to use controlled-gain amplifiers in each of the four channels, whose action is to attenuate the side-effect signals whenever they have equal amplitudes and a 0, 90 or 180° phase difference in adjacent channels. (Gain of the remaining two amplifiers is correspondingly increased to maintain constant power.) Given such a system, performance is claimed to be virtually identical to that of the original master tape.

CBS say that the first quadraphonic discs—about 20 titles—will be released in the U.S.A. in November, costing about \$1 more than two-channel discs. Sony are the first licensee for hardware outside the U.S.A. and showed two decoders at the exhibition. They are expected to be available in Europe early in 1972, when no doubt CBS will start pressing discs in the U.K. Cost of decoders is expected to range from about £20 for a matrix-only type to around £60 for a model with gain control circuitry. Other manufacturers and record companies are being licenced in Europe, and we expect announcements to be made later this year.

#### Home video

The Philips VCR video cassette recorder had its premiere at the exhibition. Demonstration models using this system (under licence) were seen on a number of stands-Bosch/Blaupunkt, Loewe Opta, Grundig, Nordmende and Philips-and other companies have also agreed to use the system, including Telefunken, Saba, Lenco, Zanussi (Italy), Revox and Thorn. A feature of the VCR machines is the inclusion of a u.h.f. receiver, enabling broadcasts to be recorded independently of the playback receiver. On some models, a timer is included to operate the recorder at a preselected time. Philips machines are expected to cost about £290 and are now planned to be marketed in April or May 1972. Despite the wide agreement on the VCR system for the PAL system, there still does not appear to be a standard for N.T.S.C., 60Hz areas. In Japan and the U.S.A. ten different tape systems have been announced.

Most of the proposed domestic video machines are running behind schedule—our table (page 529 November 1970 issue) showing dates of introduction of the competing systems is now out of date. The Teldec video disc is now expected in 1973 and problems with RCA's Selectavision mean that a launch date cannot be given.

Nordmende demonstrated their CCS Super 8-mm film system. Like the EVR system this uses the flying-spot technique to convert film pictures for display on a television receiver.

The most interesting system technically is the video disc, and the colour version of the Teldec (Telefunken-Decca) video disc player was demonstrated for the first time. To get picture information onto a disc with a reasonable playing time clearly needs a revolutionary technique not only in pickup design but also in getting the required information density. Information theory shows that for a 3-MHz bandwidth with a signal-to-noise ratio of 40dB, a channel capacity of 4  $\times$   $10^7$  bit/s is required, which amounts to a storage density of 500,000 bit/mm<sup>2</sup> at 1500 rev/min-two orders of magnitude greater than a microgroove disc!

To get this kind of density means that normal lateral groove modulation is out of the question and constant-width grooves are used less than  $8\mu m$  wide. The sound and picture information is frequency modulated onto a carrier of between 3 and 4MHz, with a ratio of minimum to maximum wavelength of 1:2.66. The signal is cut into the 150° grooves in hill and dale fashion. In retrieving this modulation from the disc the wave crests are impressed against the piezoelectric pickup (fixed in relation to the groove, thus avoiding the problem of pickup inertia) by an air film no greater than 50µm (see illustrations in "The video disc" by J. C. Gilbert, Wireless World vol.76 1970 pages 377/8). Pickup output is proportional to wavelength, and as the disc is rotating at constant speed, the wavelength-frequency 'constancy' varies as the pickup traverses the disc because of increase in groove velocity. The resulting fall in output is equalized prior to demodulation and subsequent u.h.f. modulation. Pickup response is limited to about 5MHz by a resonance which occurs when the acoustic half-wavelength in the transducer is comparable with its dimensions. Transducer mass and compliance of the elastic mounting give a low-frequency resonance at about 100kHz. This allows a pickup-arm bandwidth of five to six octaves to be achieved, presumably necessary because of the low modulation index, producing sidebands outside the deviation band.

The big question is how has colour been added to this system? Teldec engineers argued that vertical resolution is unnecessarily high and to match the

horizontal resolution, considerably less than 625 lines per frame can be used. Hence, the red, green and blue picture content is recorded in sequence, so that red information is given every three lines. On playback, delay elements are used so that all three signals are available at the same time. This mixing process is used only for low-frequency picture information—up to 1MHz—so sharpness is not lost. Only two kinds of disc are necessary, a 1500 rev/min type for 625 lines, 50Hz and a 1800 rev/min type for 525 lines, 60Hz. Differences within the 625-line standard are catered for in the processing circuitry.

Although playing time per disc is short, about 5min, cartridges have been developed to take a stack of discs, which are automatically removed from their covers. Both monochrome and colour versions of the equipment are now scheduled for marketing in 1973.

#### Tape noise reduction

Philips showed a prototype cassette 'hi-fi' recorder (model N2510) whose performance is claimed to meet DIN45 500 standards. Using high-coercivity-tape cassettes, improved magnetic heads and their dynamic noise limiter technique (see Wireless World July 1971 issue pp.339/40) it is scheduled for release mid-1972.

While in Berlin we thought we would follow up a rumour that three Japanese companies—Sony, Matsushita (National) and Victor—had jointly developed a rival to the Dolby system. Sony dissociated themselves from this and said they were still negotiating with Dolby.

National, who have been using a noise reduction circuit on their cassette tape recorders (rather like the Sanyo type), claim to have developed a new 'double-ended' system, i.e. one which requires signal processing prior to recording. According to National literature, they obtain a 6-dB improvement in signal-to-noise ratio with this and together with their 'noise-free device' single-ended circuit they claim an overall improvement of 20dB! It seems they have not yet decided whether to market this, one governing factor being development of the Philips system. They have also been involved in discussions with Dolby Laboratories over the B-type system.

The Victor company (Japan) claim to have a system competitive and compatible with the Dolby system-their published curves in fact are identical to Dolby's-without patent infringement. A possible reason for the emergence of these other systems may be the royalty price Dolby is asking. According to Dolby Laboratories it has recently been reduced to about four pence per processor as a result of an increased number of licensees. There are now 63 licensees of consumer Dolby products, including 22 in the USA. 13 in Japan and 12 in the U.K. Latest cassette machines seen using the Dolby system are made by Hitachi and Sansui.

# **Dual-trace Oscilloscope Unit**

## 3. Bipolar transistors

by W. T. Cocking\*, F.I.E.E.

The two previous parts of this article have dealt with the requirements for a dual-trace oscilloscope unit and have discussed in detail the design of an amplifier incorporating a field-effect transistor for its input stage. It was shown that the main practical difficulty with an f.e.t. arises out of the very large tolerances on this type of semiconductor. Additionally, however, there is a lack of definite information on the temperature coefficient. In view of the gain control requirements, this makes it impossible to be sure that a design is satisfactory without lengthy tests on a great many f.e.ts.

It is a fact that the provision of a continuous control of gain is a major design problem. It was clear from the start that the most satisfactory solution would probably be to use a differential amplifier with the gain control resistor connected between the two emitters. This is a well-known circuit, but for good maintenance of the balance it requires complete symmetry. This means, in particular, that as far as d.c. is concerned everything connected between one base and the bias source must be duplicated between the other base and its bias source.

This virtually rules out the use of the f.e.t. as an input device, for a matched pair would be required to achieve the necessary symmetry and with their normal large tolerances this is more easily specified than secured. How then otherwise can we achieve an adequately high input resistance? It must be around 5  $M\Omega$  as a minimum and is better 10  $M\Omega$ , so that it causes negligible error by its shunting effect on the  $100~k\Omega$  resistor which is supposed to define the input resistance.

An emitter-follower has an input resistance of approximately  $h_{fe}R_E$  and a typical transistor, such as the BC107, has a minimum  $h_{fe}$  of about 100. To obtain an input resistance of 10 M $\Omega$ , therefore, an emitter load of 100 k $\Omega$  is needed. Now the input resistance of a differential stage is unlikely to be much more than 10 k $\Omega$ , so a second emitter follower is needed. A second stage with an emitter load of 1 k $\Omega$ , will have an input resistance of 100 k $\Omega$  to form the emitter load of the first stage.

Thus, a preliminary check indicates that a double emitter follower is needed to

According to the text-books the input resistance of the double emitter follower is lower than one expects because the input resistance of  $Tr_2$  is shunted by the collector-emitter differential resistance of  $Tr_1$  (Fig. 1.) Further, it is usually advised that a coupling resistor be connected from the emitter of  $Tr_1$  to  $-V_{CC}$ , which provides a further reduction of the emitter load. The reason for providing this coupling resistance is to ensure that  $Tr_1$  is not cut-off by the  $I_{CO}$  of  $Tr_2$ . This is possible even with silicon transistors under some conditions.

However,  $I_{CO}$  is unlikely to exceed 0.05  $\mu$ A even at high temperature and the trouble is most simply avoided by making  $I_{B2}$ , and hence  $I_{C1}$ , large in comparison. The BC107

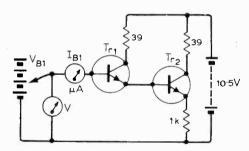


Fig. 1. Circuit for measuring the input current-voltage relation for a double emitter follower.

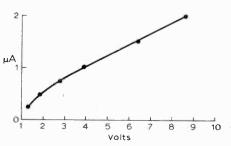


Fig. 2. Plot of current-voltage for the circuit of Fig. 1.

is rated for an  $h_{FE}$  of 110 to 450. In the worst case, if  $I_{C2}$  is at least 3 mA,  $I_{B2}$  is not less than 3/450 = 0.00665 mA =  $6.65 \mu$ A, and this is adequately large in comparison with any likely value of  $I_{CO}$ . A current of 3 mA or more is also desirable to minimize the risk of the emitter follower cutting off on negative-going signals. There is always shunt capacitance to any coupling and it cannot change its charge instantly.

In order to assess the input resistance we need to know the collector a.c. resistance of  $Tr_1$  at a collector current of the order of  $6-30 \mu A$ , the latter figure being appropriate for  $h_{FE2} = 110$ . The published transistor data is of no help here and so we resorted to experiment. We rigged up the circuit shown in Fig. 1 using a pair of 2N3706 transistors. These are not the most suitable, for they have a minimum  $h_{FE}$  of only 30, but they happened to be at hand. We varied the base bias in steps and noted the base current and plotted the figures as a curve (Fig. 2). Above about 8.6 V the base current rose very rapidly because of the approach of  $Tr_1$  to saturation. For  $V_{B1}=8.6\,\mathrm{V},\ I_{B1}=2\,\mu\mathrm{A}$  and for  $V_{B1}=2.8\,\mathrm{V},\ I_{B1}=0.75\,\mu\mathrm{A}$ ; thus, the a.c. input resistance is

$$(8.6-2.8)/(2-0.75) = 4.63 \text{ M}\Omega.$$

Similar measurements with a pair of BF194 transistors gave a resistance of  $7.2 \text{ M}\Omega$ . This showed it to be practicable to obtain an adequately high input resistance from a double emitter follower.

The general form of the circuit follows almost automatically and is shown in Fig. 3. Transistors  $Tr_1$  and  $Tr_2$  form the input emitter follower;  $Tr_3$  and  $Tr_4$  are the differential pair; and  $Tr_5$  and  $Tr_6$  are a duplicate emitter follower. The output stage is  $Tr_8$  with  $Tr_9$  to switch it on and off. Because the base voltage of Tr<sub>8</sub> is much lower than the collector voltage of Tr3, the p-n-p stage  $Tr_7$  is interposed. It also enables a shift control to be provided which does not affect the gain. This is  $R_8$ acting as a variable resistance. The free end is connected into the other amplifier so that the component acts as a differential shift control, moving one trace upwards and the other downwards at the same time. This is necessary because independent shift controls can lead to grossly incorrect bias on

 $Tr_8$ . The bias supplies for  $Tr_1$  and  $Tr_6$  are obtained from  $R_2$  and  $R_3$  which are fed

obtain the required input impedance, and for symmetry, it must be duplicated on the other side of the differential amplifier. This solution thus requires rather a large number of transistors. This was why initially we investigated other arrangements and we returned to it only when we found those other arrangements to be unsatisfactory for gain control.

<sup>\*</sup> Editor-in-chief, Wireless World

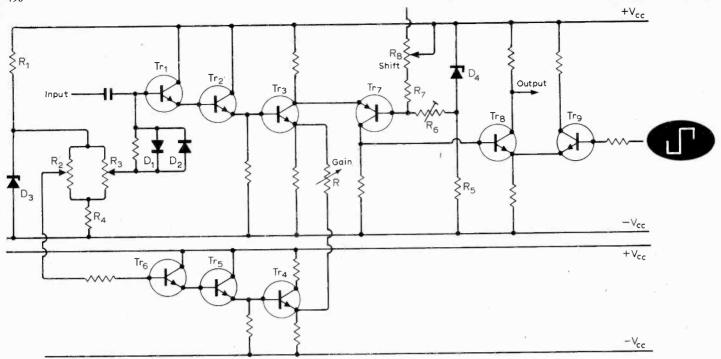


Fig.3. Basic circuit of amplifier.  $Tr_3$  and  $Tr_4$  form a differential amplifier with the gain-control resistor R between the emitters.  $Tr_1$  and  $Tr_2$  have a high input resistance, so that the actual input resistance of the amplifier is defined by  $R_{B1}$  (see text for explanation of the terminology).  $Tr_5$  and  $Tr_6$  are a duplicate emitter follower and are necessary only to preserve the balance of the differential stage.  $Tr_7$  is used primarily to give a change of d.c. level between  $Tr_3$  and  $Tr_8$  but it also enables 'shift' to be obtained without affecting gain.  $Tr_8$  is the output stage which is switched on and off by  $Tr_9$ .

from the zener diode  $D_3$ . Stabilized bias supplies are essential unless the main supply is stabilized; even if it were, the bias supply resistors would have to be of  $\pm 1\%$  tolerance. In practice,  $R_3$  is adjusted to bring the voltage across  $R_{E3}$  to a design value and then  $R_4$  is adjusted for zero voltage across R;  $R_7$  is adjusted with  $R_{10}$  at its mid position for a design value of  $V_{C7} = V_{B8}$ .

Before proceeding further, it may be as well to clarify the nomenclature and conventions used. To simplify the diagram base, emitter and collector resistors are not labelled in Fig. 3; they are all  $R_B$ ,  $R_E$  or  $R_C$  with a numerical subscript for the particular transistor to which they belong. Thus,  $R_{E3}$  is the resistor between the emitter of  $Tr_3$  and  $-V_{CC}$ . The resistor between the collector of  $Tr_3$  and  $+V_{CC}$  can be designated as  $R_{C3}$  or  $R_{E7}$  as desired; similarly, the one between the collector of  $Tr_7$  and  $-V_{CC}$  can be called  $R_{C7}$  or  $R_{B8}$ .

For n-p-n transistors, all voltages which have a single letter subscript (e.g.,  $V_B$ ,  $V_E$ ) have also a numerical subscript to indicate the particular transistor, and the voltages are measured with respect to  $-V_{CC}$ . If measured with respect to some other point, there is a double letter subscript. Thus  $V_{C8}$  is the collector voltage of  $Tr_8$  with respect to  $-V_{CC}$ ;  $V_{CE8}$  is the collector voltage with respect to the emitter of  $Tr_8$ .

In the case of p-n-p transistors, the voltages are normally measured with respect to  $+V_{CC}$ . They should, therefore, strictly have a minus sign, but this is inconvenient.  $V_{C3}$  is the collector voltage of  $Tr_3$  and is also clearly the emitter voltage of  $Tr_7$  with respect to  $-V_{CC}$ . However,  $V_{E7}$  is the emitter voltage of  $Tr_7$  with respect to  $+V_{CC}$ . Collector voltage  $V_{C3}$  is positive,

 $V_{E7}$  is actually negative (because of the different point from which it is measured) but is referred to here without the minus sign.

After this explanation, we can return to Fig. 3. The diodes  $D_1$  and  $D_2$  are essential protective devices. They ideally have no effect on the normal signal performance. Their purpose is to prevent damage to the equipment if the probe is accidentally connected to a high voltage. We take this high voltage to be the supply mains, which can reach ±360 V peak. For 10:1 input attenuation of the probe and  $R_{B1}$  together, the probe resistance is 900 kΩ and even without the diodes the maximum input to Tr<sub>1</sub> is ±36 V peak. With the diodes, the base voltage of Tr<sub>1</sub> is limited to at most a volt more than the diode return voltages. Because of component tolerances a close control of voltages is impracticable and it is necessary to design so that safe conditions exist throughout the amplifier, not merely in the first stage. In particular,  $V_{EBO}$  for any transistor must not exceed 6 V for the BC107 type.

In the development, we naturally omitted  $D_1$  and  $D_2$  initially and we rigged up the circuit of Fig. 3 on the bench to check its performance. This did, in fact, prove admirable. We found it readily possible to obtain a-6 dB bandwidth of 10 MHz, a gain of 10 times, a gain control range of 3.5:1, and good stability of the d.c. balance. Although not perfect, this last was far superior to that of any other circuit tried. When we came to add protective diodes, however, we found that  $Tr_3$  and  $Tr_7$  were in some danger and we had to do some redesign to avoid this. This is why we now take them into account from the beginning.

Before considering the design in detail,

it is advisable to be clear about a few important facts about transistors. The first is that for d.c.  $V_{BE}$  is virtually a constant except for tolerances and temperature. For the BC107 it is 0.55 to 0.7 V as a manufacturing tolerance, and it decreases with rising temperature at the rate of  $2 \text{ mV}/^{\circ}\text{C}$ . For the BC157 p-n-p transistor  $V_{BE}$  is 0.6 to 0.75 V and decreases in magnitude at  $2 \text{ mV}/^{\circ}\text{C}$ .

Because of this, when there is appreciable external emitter resistance, the emitter voltage bears an almost constant relation to the base voltage. It is a very low impedance point. In Fig. 3, for example, if  $V_{B7}$  is fixed,  $V_{E7}$  is also fixed at a magnitude lower by  $V_{BE7}$ . This means that the total current in  $R_{C3}(R_{E7})$  is constant; therefore, if  $I_{C3}$  increases  $I_{C7}$  decreases by the same amount.

For a.c., the internal differential resistance of the base-emitter junction must sometimes be taken into account. This is designated  $r_e$  and has the rough value of  $26/I_c$  ohms with  $I_c$  in mA. It is usually additive to the external emitter resistance  $R_E$  and we shall call  $r_e + R_E$  the total effective emitter resistance  $R_e$ . The voltage amplification is then  $R_C/R_e$  and the input resistance measured between base and earth is  $h_{fe}R_e$ .

The maximum normal output required from  $Tr_8$  (with  $Tr_9$  off) is 1 V peak-to-peak. With two traces on the c.r.o. fully separated it can be only one-half of this. To allow a large factor of safety for drift and to obtain good linearity we shall design for an output of 2 V peak-to-peak. We previously chose  $R_{C8} = R_{E8} = 330 \Omega$  on the grounds of nominally unity gain and the required frequency response. We also decided on  $V_{B8} = 2.7 \text{ V}$ .

Deducting  $V_{BE8}$  (= 0.55 to 0.7 V),  $V_{E8}$  is 2 to 2.15 V. The collector current (assuming the base current to be negligibly small in comparison, as is usually the case) is  $V_{E8}$  divided by  $R_{C8}$ , which is 330  $\Omega$  nominal. With a  $\pm 5\%$  tolerance, the resistance lies between the limits of 314 and 347  $\Omega$ . Therefore, the limits on collector current are 2/0.347 = 5.75 mA and 2.15/0.1314 = 6.84 mA.

The internal emitter resistance  $r_{e8}=26/I_C$  and so ranges from  $3.8~\Omega$  to  $4.5~\Omega$ . From the signal point of view, this plus  $R_{E8}$  equals  $R_{e8}$ , the effective total emitter resistance, which is thus 318.5 to  $350.8~\Omega$ . The collector resistance  $R_{C8}$  is also nominally  $350~\Omega$ , but ranges from 314 to  $347~\Omega$ . Now  $R_{e8}$  and  $R_{C8}$  are uncorrelated and the limits are with one high and the other low. Therefore, the voltage amplification  $R_{C8}/R_{e8}$  is 347/318.5=1.09 to 314/350.8=0.895.

The input resistance is

$$h_{fe8}R_{e8} = 125 \times 0.3185 = 40 \text{ k}\Omega$$

as a low limit with  $h_{fe}=125$ . In fact,  $h_{fe}$  may be as high as 500 for the BC107 transistor, so the input resistance may be as high as  $160 \, \mathrm{k}\Omega$ . We can do nothing to prevent this variation, but we can make its effect trivial by making  $R_{C7}$  small compared with its lowest value. As we shall see later,  $R_{C7}$  is  $1.2 \, \mathrm{k}\Omega$ . With a  $\pm 5\%$  tolerance its value is  $1.16 \, \mathrm{to} \, 1.26 \, \mathrm{k}\Omega$ . Now  $1.16 \, \mathrm{k}\Omega$  shunted by  $40 \, \mathrm{k}\Omega$  is  $1.13 \, \mathrm{k}\Omega$  and  $1.26 \, \mathrm{k}\Omega$  shunted by  $160 \, \mathrm{k}\Omega$  is  $1.25 \, \mathrm{k}\Omega$ . These are the values which should strictly be taken in assessing the gain of the  $Tr_3$ ,  $Tr_7$  combination. The maximum error caused by ignoring it is only 3%, however.

The calculations for  $Tr_8$  have been given in detail to illustrate the method employed. The same procedure is followed for the other stages but it would be tedious to give it in full. The results only are, therefore, summarized in Table 1.

In general, we need not in this case calculate  $V_{CE}$  nor the collector dissipation, because they are so far below the limits that it is unnecessary. However, as an example, we shall do so for  $Tr_8$ . We assume

$$V_{cc} = 12 \text{ V} \pm 1.5 \text{ V},$$

making  $V_{CC}=10.5$  to 13.5 V. From the point of view of  $V_{CE}$ , the worst case is when  $R_C$  and  $R_E$  are off tolerance in the same direction. The collector-emitter circuit resistance is thus 628 to 694  $\Omega$  and  $I_{C8}$  is 5.75 to 6.84 mA so that the voltage drop is 5.75 × 0.694 = 3.89 V to  $6.84 \times 0.628 = 4.3$  V.

The currents and voltages are taken this way because low current results from high resistance and *vice versa*. The minimum  $V_{CE}$  is thus  $10.5-4.3=6.2\,\mathrm{V}$  and the maximum is  $13.5-3.89\approx9.5\,\mathrm{V}$ . The collector dissipations are  $6.2\times6.84=42.5\,\mathrm{mW}$  and  $9.5\times5.75=54.6\,\mathrm{mW}$ . The latter is not necessarily the maximum dissipation, but in this case it probably is. It is so far below the limit of 400 mW for the transistor that we need not worry about it.

The figures are for continuous operation. However,  $Tr_8$  is switched on and off for equal periods. As a result, the mean current and the mean dissipation are one-half of the above figures.

Table 1

	Low	Normal	High	
V <sub>BB</sub>	_	2.7	_	V
VBEB	0.55	0.625	0.7	V
V <sub>E8</sub>	2	2.075	2.15	V
/ <sub>C8</sub>	5.75	6.27	6.84	m.A
r <sub>e8</sub>	4.5	4 14	3.8	Ω
Ř <sub>e8</sub>	318-5	334-1	350-8	Ω
$R_{ca}$	314	330	347	Ω
A <sub>8</sub>	0.895	0.985	1.09	
R <sub>c7</sub>	1.14	1.2	1.26	kΩ
107	2.15	2.25	2:37	mΑ
$V_{E3} = V_{E4}$	_	2.7		V
$V_{B1}$ and $V_{B6}$	4.35	4.575	4.8	V
$R_{F3}$ and $R_{F4}$	2.09	2.2	2.31	ķΩ
I <sub>c3</sub> and I <sub>c4</sub>	1.17	1.23	1.29	mΑ
Ř <sub>C4</sub>	1.14	1.2	1.26	kΩ
$I_{C4}R_{C4} = V_{B10}$	1.34	1.475	1.63	V*
/ <sub>c3</sub> +/ <sub>c7</sub>	3.32	3.48	3-6	mΑ
R <sub>C3</sub>	446	470	494	Ω
V <sub>E7</sub>	1.485	1.64	1.78	V.
V <sub>BE7</sub>	0.6	0.675	0.75	V
V <sub>87</sub>	2.085	2.515	2.53	V.
r <sub>e7</sub>	12.1	11-6	10.95	Ω
r <sub>e3</sub> and r <sub>e4</sub>	20.1	21 · 1	22.2	Ω
V <sub>B10</sub>	1.35	1.48	1.63	V*
V <sub>E10</sub>	0.75	0.8	0.88	٧.
1c10+1cm	1.52	1.7	1.97	mΑ
/ <sub>C10</sub>	0.26	0.284	0.358	mΑ
611	1.162	1.416	1.71	mΑ
R <sub>C11</sub> _	1.425	1.5	1.575	kΩ
I <sub>C11</sub> R <sub>C13</sub>	1.66	2.12	2.7	V
V <sub>C11</sub>	2-41	2.92	3.58	V*
V <sub>CE11</sub>	11.09	9.08	7.12	V

<sup>\*</sup>Voltage below +V<sub>cc</sub>

Our next concern is the input capacitance  $Tr_8$ . The stage gain is about unity, so the portion of the input capacitance due to Miller effect is only twice  $C_{bc}$ . Because of  $R_{E8}$ , the portion caused by  $C_{be}$  will be only a small fraction of  $C_{be}$ . Values of these elements are not quoted for the BC107. Nor is  $C_{ce}$  for the BF157 used for  $Tr_7$ . We have to guess that the total capacitance across  $R_{C7}$  is unlikely to exceed 5 pF.

When considering the output stage  $Tr_8$  in Part 1 we found that the combination of 330  $\Omega$  and 55 pF gave a response down by 3·61 dB at 10 MHz. For the same response here with 5 pF,  $R_{C7}$  can be

$$330 \times 11 = 3,630 \,\Omega.$$

For  $R_{C7} = 1.5 \,\mathrm{k}\Omega$ , the response will be  $-0.87 \,\mathrm{d}\mathrm{B}$ ; for  $1.2 \,\mathrm{k}\Omega$  it will be  $-0.6 \,\mathrm{d}\mathrm{B}$ . This is, therefore, the sort of value which we should use on a frequency response basis, and is so low in comparison with the input resistance of  $Tr_8$  that we can forget the latter.

From the point of view of frequency response the lower the value of  $R_{C7}$  the better, but there is clearly not much advantage in making it less than  $1.2\,\mathrm{k}\Omega$ . For a required gain, say,  $10\,\mathrm{times}$ ,  $R_{E7}/R_{e3}\approx 10$ , making  $R_{e3}=120\,\Omega$  for  $R_{C7}=1.2\,\mathrm{k}\Omega$ . The input resistance of  $Tr_3$  is  $h_{fe}R_{e3}$  and this must be large compared with  $R_{E2}=1\,\mathrm{k}\Omega$ . We have thus to strike a balance between frequency response and a large enough input resistance for  $Tr_3$ . With  $h_{fe}=125$ , the input resistance is  $125\times0.12=15\,\mathrm{k}\Omega$  which is certainly large compared with  $1\,\mathrm{k}\Omega$ . As  $h_{fe}$  varies so much, it may actually be four times as large.

Before deciding on  $1.2 \,\mathrm{k}\Omega$  for  $R_{C7}$  we have to check that  $I_{C7}$  will be sufficient to handle the signal. The current is

$$I_{C7} = V_{B8}/R_{C7} = 2.7/1.26 = 2.15 \,\text{mA}$$

minimum with a high tolerance resistor. For a 1 V peak signal, the signal current will be 1/1.26 = 0.794 mA. There is thus adequate signal-handling capacity and we

can decide definitely to make  $R_{C7} = 1.2 \text{ k}\Omega$ .

The next step is to estimate the gain of the input emitter follower  $Tr_1$  and  $Tr_2$ . We saw earlier that for the required input resistance  $R_{E2}$  must be about  $1~\mathrm{k}\Omega$  and that  $I_{C2}$  should be something like  $3~\mathrm{m}A$ . Taking these figures,  $r_{e2}=26/3=8\cdot6~\Omega$ . The gain of  $Tr_2$  is thus  $1000/1008\cdot6\approx0.99$ . Now  $Tr_1$  works into a load  $h_{fe}$  times as great and has  $1/h_{FE}$  times the current;  $h_{fe}$  and  $h_{FE}$  are usually similar in magnitude, although not necessarily equal. It follows that the gain of  $Tr_1$  will be about the same as that of  $Tr_2$  and the overall gain about 0.98.

Since the gain of  $Tr_8$  is 0.895 to 1.09, the overall gain apart from  $Tr_3$  and  $Tr_7$  is 0.879 to 1.07. We require the overall gain to be 10 times, therefore  $Tr_3$  and  $Tr_7$  together must provide an amplification of 9.35 to 11.4 times. This gain is actually

$$\frac{R_{C7}}{R_{e3}} \cdot \frac{R_{C3}}{R_{C3} + r_{e7}}$$

Here  $r_{e7}$  is the internal emitter resistance of  $Tr_7$  and depends on  $I_{C7}$ ; it is given in Table 1 and is around 11  $\Omega$ . The requirement for  $R_{C3}$  is that it be very large compared with  $r_{e7}$ , but not so large that it drops too much voltage with  $I_{C3}$  and  $I_{C7}$  in it. A value of 470  $\Omega$  suggests itself. If  $I_{C3}$ , which we do not yet know, is about the same as  $I_{C7}$ , the drop will be about 2.1 V, which seems reasonably low. The factor

$$R_{C3}/(R_{C3}+r_{e7})$$

is thus about 470/481 = 0.975. It is not worth while here to bother taking tolerances into account. We now find that  $R_{C7}/R_{e3}$  must be 9.62 to 11.7.

Before we can proceed further we have to consider the input conditions and, in particular, how we can protect the amplifier against an accidental overload. As mentioned earlier we are taking the maximum input at the probe to be  $\pm 360 \, \text{V}$ . The probe resistance is  $900 \, \text{k}\Omega$  and so the maximum possible overload current is  $0.4 \, \text{mA}$ . At this current, the forward drop of a diode is unlikely to be more than  $1 \, \text{V}$  at most and is more probably  $0.5-0.6 \, \text{V}$ . If the diodes are unbiased, as shown in Fig. 3, they will limit the input to  $Tr_1$  to  $\pm 1 \, \text{V}$  about its bias voltage. This will certainly do no harm in the early stages.

Now the normal maximum signal at the output is 0.5 V peak and with a gain of 10 times this becomes 0.05 V at the input. The gain control range is 3.33:1 minimum and so to obtain full output at low gain, the input must be  $0.05 \times 3.33 = 0.167 \text{ V}$  peak. The diodes are in shunt with  $R_{B1}$  and must have a resistance very large in comparison if the input resistance is to be well-defined by  $R_{B1}$ . This resistance should be  $20 \text{ M}\Omega$  per diode when forward biased by 0.167 V, the peak signal.

The normal diode data does not help in selecting a suitable type, nor in deciding whether bias is necessary or not. The BZY145 appears to be suitable but it is necessary to resort to experiment. A trial quickly showed bias to be essential. This raises problems of how to obtain it. Trial showed about 0.5 V back bias to be sufficient.

It is practicable to connect one diode

between the base of  $Tr_1$  and  $-V_{CC}$ . On overload  $V_{B1}$  will then be taken to -0.5 V or thereabouts. This will cut-off  $Tr_1$ ,  $Tr_2$  and  $Tr_3$ , but this need not harm any of these three transistors. We cannot, however, safely return the other diode to  $+V_{CC}$ , for this will result in  $V_{B1}$  reaching about  $V_{CC}+0.5$  V on overload. At least  $Tr_1$  will saturate and probably  $Tr_2$  also. There is a a probability that the base current would be dangerously high.

We now assume that the back bias on the diode should not be less than 0.5 V. If we use a BZY88/C5V6 zener diode for  $D_3$  its voltage will be 5.3 to 6 V. If the diode is returned to this,  $V_{B1}$  must not exceed 4.8 V for 0.5 V or more back bias on the diode. With maximum tolerances on  $V_{BE}$  for  $Tr_1$ ,  $Tr_2$  and  $Tr_3$ ,  $V_{E3}$  must be at least 2.1 V lower. Thus,  $V_{E3} = 4.8 - 2.1 = 2.7 \text{ V}$  as a maximum. It is a coincidence that this is the same as  $V_{B8}$ , but a convenient one if it is otherwise satisfactory.

For a forward voltage drop of 0.5 V,  $V_{B1}$  will rise to 5.8 to 6.5 V above— $V_{CC}$  depending on the zener used. With low tolerance  $V_{BE}$ ,  $V_{E3}$  will rise at most to 6.5-1.65=4.85 V.

Tests which were later carried out with  $V_Z = 5.6 \, \mathrm{V}$  and  $V_{B1} = 4.7 \, \mathrm{V}$  ( $V_{E3} = 2.7 \, \mathrm{V}$ ), which corresponds to a back bias of 0.9 V on the diode, were quite satisfactory. It was noticed that changing the diode bias affected the frequency compensation of the probe appreciably. This is to be expected because diode capacitance changes with voltage. The practical variations, however, are caused by tolerances and are taken up by initial adjustments. The main changes in the life of the equipment are caused by temperature and are likely to be very small.

When the equipment was completed, the adequacy of the protection was tested by connecting the input across the 240-V supply mains. Naturally, nothing on the equipment was earthed. No harm whatever resulted. Having thus chosen

$$V_{E3} = V_{E4} = 2.7 \text{ V},$$

we can proceed to design the Tr<sub>3</sub> stage. The first thing to notice is that if signals are applied in the same phase to  $Tr_3$  and  $Tr_4$ , there is ideally no current in R and R does not affect the gain for these signals. Such signals are those resulting from the effects of temperature on  $Tr_1$  to  $Tr_6$ . The in-phase gain is approximately  $R_{C7}/R_{E3}$  and can be made less than unity if  $R_{E3}$  is greater than  $R_{C7}$ . However, for fixed  $V_{E3}$ ,  $I_{C3}$  falls as  $R_{E3}$ is increased and it must be large enough to handle the signal. We previously found the signal current in  $R_{C7}$  to be 0.79 mA and allowing for the small loss in the coupling to Tr<sub>7</sub> we can take it as being 0.8 mA in  $Tr_3$ . The collector current of  $Tr_3$  should thus be 1.2 mA or more for reasonable linearity. This means that  $R_{E3}$  should not exceed  $2.25 \text{ k}\Omega$ . We thus choose  $2.2 \text{ k}\Omega$  for  $R_{E3}$  and, (Table 1)  $I_{C3}$  is 1.17 to 1.29 mA.

We have now chosen the main circuit values except for the gain control R. Before we do this, which is a little complicated, let us check the overload conditions after the first stage. It is quite possible to have a condition in which the first stage is safe, but some later stage is not.

On overload,  $V_{B1}$  goes to a maximum of +6.5 V or a minimum of -0.5 V. In the first case  $V_{E3}$  rises to a maximum of 6.5-1.65=4.85 V and if R is small it pulls the emitter of  $Tr_4$  up to almost the same voltage. Now  $V_{B6}$  will be at its normal 4.38 to 4.8 V and V  $_{B4}$  will be 3.25 to 3.4 V, therefore  $Tr_4$  will be cut off. Considering R as negligibly small, we then have

$$V_{E3} = V_{E4} = 4.85 \,\mathrm{V}$$

with an emitter load comprising  $R_{E3}$  and  $R_{E4}$  in parallel. This is  $1.1 \text{ k}\Omega$  nominal,  $1.045 \text{ k}\Omega$  minimum. Therefore,

$$I_{C3} = 4.85/1.045 = 4.64 \text{ mA max}.$$

Because  $I_{C3}$  increases above its normal value,  $I_{C7}$  will decrease. The increase of  $I_{C3}$  is 4.64-1.17=3.47 mA at most, while  $I_{C7}$  is 2.37 mA (a little more because of shift conditions yet to be discussed). It follows that  $Tr_7$  will be cut-off and  $V_{B8}$  will be zero. The drop across  $R_{C3}$  will be

$$4.64 \times 0.494 = 2.3 \text{ V}$$

and so the IR drops of Tr3 will be

$$4.64 + 2.3 = 6.94 \text{ V},$$

making  $V_{CE} = 9.5 - 6.94 = 2.56 \text{ V}$  as a minimum. Thus  $Tr_3$  will not saturate and this makes the calculations valid ones. It is clear also that  $Tr_4$  will not have excessive reverse base-emitter bias. It is well under the 6 V limit.

To make everything safe all we have to do is to ensure that  $Tr_9$  cannot pull the emitter of  $Tr_8$  more than 6 V above  $-V_{CC}$ .

Now consider a negative overload. This takes  $V_{B1}$  to about -0.5 V and  $Tr_1$ ,  $Tr_2$  and  $Tr_3$  are cut off. If there is no  $R_{E1}$ , as in Fig. 3, the potential of the emitter of  $Tr_1$  and base of  $Tr_2$  is indeterminate. It is wise, therefore, to fix it at  $-V_{CC}$  by a resistor of  $1 \text{ M}\Omega$  or so. With  $Tr_3$  cut-off,  $Tr_7$  acts as a common-emitter stage with  $R_{C3}$  as its emitter resistor. As  $V_{B7}$  has its normal value, so will  $V_{E7}$  have a normal value. Therefore, the total current in  $R_{C3}$  does not change, but  $I_{C7}$  rises to the normal  $I_{C3} + I_{C7}$ , or 3.6 mA maximum. This increases  $V_{B8}$  to 4.55 V maximum, and so  $V_{E8}$  is 0.55 V less, or 4 V.

An additional shift of  $\pm 0.5$  V is required on  $V_{B8}$  and  $V_{E8}$ , which makes the maximum emitter voltage of  $Tr_8$  4.5 V. When  $Tr_9$  has its base at  $-V_{CC}$ , this is reverse base-emitter bias on  $Tr_9$ . It is under the 6 V rating and so is safe.

We can now return to consider the gain control. We require a minimum range of 3.33:1 and a gain of 9.62 to 11.7 times. With low tolerance  $R_{C7}$  is 1.14 k $\Omega$  and  $R_{e3}$  must be  $1140/11.7 = 97 \Omega$ ; with high tolerance it must be  $1260/9.62 = 131 \Omega$ . To reduce the gain to 1/3.33, these values must be 3.33 times or  $323 \Omega$  to  $437 \Omega$ .

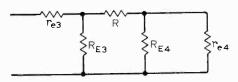


Fig. 4. This shows the equivalent circuit of the emitter circuit of  $Tr_3$ .

Now  $R_{E3}$  is the complex network shown in Fig. 4. As  $r_{e3}$  and  $r_{e4}$  vary only by  $\pm 1 \Omega$ , it is good enough to take  $r_{e3} = r_{e4} = 21 \Omega$  constant. The elements apart from  $r_{e3}$  must thus be 77 to 111  $\Omega$  and 303 to 417  $\Omega$ . Since  $R_{E4}$  is  $2.2 \text{ k}\Omega$  it can be neglected as a shunt on  $r_{e4}$  of 21  $\Omega$ .

The required figures are thus to be given by  $R_{E3}$  and  $R+r_{e4}$  in shunt; whence

$$R + r_{e4} = \frac{R_{E3}R'}{R_{E3} - R'}$$

where R' is the required resistance. Working this out for  $R_{E3} = 2.09 \text{ k}\Omega$ , we get for  $R + r_{e4}$ ,  $80 - 117 \Omega$  and  $355 - 522 \Omega$ ; with  $R_{E3} = 2.31 \text{ k}\Omega$ , we get  $79.6 - 116.5 \Omega$  and  $348-509 \,\Omega$ . Deducting  $r_{e4}=21 \,\Omega$ , we get for R,  $59-96 \Omega$  and  $334-501 \Omega$  in the first case, and  $58.6-95.5 \Omega$  and  $327-488 \Omega$  in the second. It is thus clear that R can consist of  $100 \Omega$  and  $500 \Omega$  variable resistors in series, one as a preset to fix the maximum overall gain at unity, and the other as a panel gain control. Variable resistors usually have a tolerance of  $\pm 10\%$ , so the maximum values may be only 90  $\dot{\Omega}$  and 450  $\Omega.$  The latter is a little low, but if we include a 22  $\Omega$ fixed resistor we have for the preset a minimum range of 22-112  $\Omega$  and the minimum required values of 58.6 Ω plus the 450 Ω of the gain control gives  $508.6 \Omega$ which is greater than the maximum of 501  $\Omega$ needed.

We shall not here go into detail about the bias networks. They are straightforward and the only difficult thing is to obtain the required range of control, despite tolerances, with standard value components. Two controls are provided for  $Tr_7$ ;  $R_6$  is a preset which is adjusted to bring  $V_{BB}$  to  $2.7 \, \mathrm{V}$  with the shift control  $R_8$  at its mid-setting. The required output shift is  $\pm 0.5 \, \mathrm{V}$  to separate the traces fully. At the base of  $Tr_7$  it is under  $\pm 0.2 \, \mathrm{V}$  because it is subject to the gain of  $Tr_7$  as a base-input amplifier, which is about  $2.5 \, \mathrm{times}$ .

It will be realized that d.c. shift is permissible in spite of a.c. coupling to the oscilloscope because the switching process breaks up the different levels on the two output stages into a square wave which is passed by the a.c. coupling. Nothing has so far been said about temperature and we shall now deal with this.

It is very laborious to do this taking all tolerances into account and, in any case, we have not sufficient information to do it accurately. We take all transistors as having a temperature coefficient of 2 mV/°C which acts to increase the collector current. At 5.6 V, the zener diode  $D_3$  will have a coefficient of  $-0.2 \text{ mV/}^{\circ}\text{C}$ . The mean value of  $V_{B1} = V_{B6}$  is 4.575 V (Table 1). This is 4.575/5.6 = 0.816 of the zener voltage and the effective temperature coefficient of  $V_{B1}$ and  $V_{B6}$  is  $-0.2 \times 0.816 = -0.163 \,\text{mV/°C}$ The combined coefficients of  $Tr_1$ ,  $Tr_2$  and  $Tr_3$  are 6 mV/°C and so the coefficient of  $V_{E3}$  is  $6 - 0.163 = 5.837 \text{ mV}/^{\circ}\text{C}$ . Both sides of the differential amplifier are alike and so it is the same for  $V_{E4}$ . At all temperatures, therefore,  $V_{E3}$  and  $V_{E4}$  move together and there is no current in R. Balance is maintained. Notice, however, that this demands equal temperatures and temperature coefficients on the two sides, and this may not be achieved in practice.

Because there is no current in R, the effective gain for temperature effects is not the signal gain of  $R_{C7}/R_{c3}$  but

$$R_{C7}^*/R_{E3} = 1200/2200 = 0.545.$$

This is a very great advantage of the differential stage; the gain for in-phase signals can be small while the gain for push-pull or single-sided inputs can be large. The effective temperature coefficient, due to the circuits prior to  $Tr_7$ , at the base of  $Tr_8$  is thus  $5.84 \times 0.545 = 3.18 \,\mathrm{mV/^{\circ}C}$ . In  $Tr_3$ , an increase of temperature increases the current, but this reduces the current in  $Tr_7$  and so a negative sign is required, to make the voltage at  $Tr_8$  base  $-3.18 \,\mathrm{mV/^{\circ}C}$ .

Now in  $Tr_7$ , the temperature coefficient of  $V_{BE7}$  is  $2 \text{ mV}/^{\circ}\text{C}$  acting to increase  $I_{C7}$  and so acting at the base of  $Tr_8$  in opposition to the previous one. If  $D_4$  is a 4-7 V zener its temperature coefficient is  $-1.55 \text{ mV}/^{\circ}\text{C}$ . The normal value of  $V_{BE7}$  is 2.515 V (Table 1). The bias reduction factor is 2.515/4.7 = 0.535 and so the effective temperature coefficient of the zener diode at the base of  $Tr_7$  is

$$-1.55 \times 0.535 = -0.83 \text{ mV/}^{\circ}\text{C}.$$

This acts to reduce the collector current and so the total effective temperature coefficient of  $Tr_7$  referred to its base is  $2-0.85 = 1.15 \text{ mV}/^{\circ}\text{C}$ .

This is subject to the gain of the stage, which is 1200/470 = 2.55 times, making the contribution of  $Tr_7$  at the base of  $Tr_8$   $1.15 \times 2.55 = 3.05$  mV/°C. Combined with the -3.18 mV/°C from the early circuits the total resultant is -0.13 mV/°C. Virtually, therefore, we have a nominally zero temperature coefficient at the base of  $Tr_8$ . This is partly a happy chance, but only partly, for although we have not mentioned it, we chose a zener voltage for  $D_4$  which would lead to a temperature coefficient suitable for theoretical overall cancellation. Of course,  $Tr_8$  itself has the usual 2 mV/°C coefficient affecting its collector current.

The tolerances on the zener temperature coefficients are actually quite large. However, the major factors in achieving a low overall coefficient remain. These are the differential stage which attenuates rather than amplifies the combined coefficients of the early stages and the fact that  $Tr_7$  temperature coefficient acts in opposition. We have not worked it out in detail, but in the worst case we should not expect the coefficient at the base of  $Tr_8$  to exceed  $\pm 3 \, \text{mV/}^\circ\text{C}$ , which we consider to be reasonably small.

The switching process prevents 'internal sync' from being used. For the Marconi Instruments oscilloscope used in development the minimum signal at up to 1 MHz for 'external sync' is 0·2 V peak. The normal maximum output for fully-separated traces is 0·25 V peak. Clearly a sync output signal of around 1 V is desirable. An additional sync amplifier with a gain of about four times is needed.

Ideally, the collector loads of  $Tr_3$  and  $Tr_4$  do not affect the balance of this stage. In practice, they have some small effect.  $Tr_3$  has a very low impedance load to a.c.

for it is mainly the emitter input resistance of  $Tr_7$ , about 11  $\Omega$ . This is important in that signal voltages on the collector of  $Tr_3$  are negligible and Miller effect is absent, which keeps the input capacitance of  $Tr_3$  low.

In the interests of simplicity we have chosen to make  $R_{C4}$  give about the same voltage drop as  $R_{C3}$  and it turns out that this requires  $1.2 \,\mathrm{k}\Omega$ , so that the signal on the collector of  $Tr_4$  is of the same amplitude as that on the base of  $Tr_8$ . As Table 1 shows the IR drops in the collector of  $Tr_4$  are a little lower than those in the collector of  $Tr_3$  (compare  $V_{E7}$  with  $V_{B10}$ ). The amplifier which follows is of the type described in Part 2, but using a p-n-p transistor followed by an n-p-n, and its circuit is shown in Fig. 5.

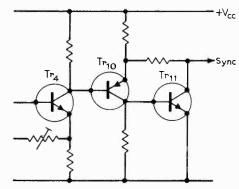


Fig. 5. An extra two-stage amplifier is used and fed from Tr<sub>4</sub> to provide a greater output than the main amplifier and one which is isolated from the switching signals for synchronizing the oscilloscope timebase.

Values of  $V_{E10}$  and  $I_{C10}+I_{C11}$  are readily found and appear in Table 1. If  $R_{C10}=2.2\,\mathrm{k}\Omega$  and  $V_{BE11}=0.625\,\mathrm{V}$ , the current in  $R_{C10}$  must be

$$0.625/2.2 = 0.284 \,\mathrm{mA}$$

and, neglecting the base current, this is  $I_{C10}$ , whence  $I_{C11} = 1.7 - 0.284 = 1.416$  mA. The remaining figures are worked out in Table 1.

It is now necessary to consider what happens on a severe overload. In one sense of overload  $Tr_4$  is cut-off. Then  $V_{B10}$  is zero and both  $Tr_{10}$  and  $Tr_{11}$  are cut-off, and no harm is done. In the other sense,  $Tr_3$  is cut-off, so effectively  $Tr_4$  has normal bias to keep  $V_{E4}=2.7$  V, but the effective emitter resistance is  $R_{E4}/2$ , or 1.045 to 1.16 k $\Omega$  and it passes 2.33 to 2.59 mA. The drop across  $R_{C4}$  is then 2.66 to 3.39 V. Therefore,  $V_{B10}$  can be 3.39 V below  $+V_{CC}$ . In the worst case with  $V_{BE10}=0.6$  V,  $V_{E10}$  must be 2.79 V below  $+V_{CC}$  and the current in  $R_{C10}$  can be 2.79/0.146=6.25 mA.

Let us assume that  $Tr_{11}$  saturates, so  $V_{CE11} = 0.2 \text{ V}$ . Then with  $V_{CC} = 10.5 \text{ V}$  the drop across  $R_{C11}$  must be

$$10.5 - 0.2 - 2.79 \approx 7.5 \text{ V}$$

and the current in it may be only

7.5/1.575 = 4.76 mA.

This leaves a balance of

6.25 - 4.76 = 1.49 mA

for  $I_{C10}$ . Now  $V_{BE11}$  will change but little and so the current in  $R_{C10}$  will not change much, so the difference

$$1.49 - 1.16 = 0.33 \text{ mA}$$

must be  $I_{B11}$ .

With  $V_{CC} = 13.5$  V, the drop across  $R_{C11}$  is 10.5 V, and the current in it can be 7.35 mA. This is greater than the 6.25 mA total in  $R_{C10}$  and so in this case  $Tr_{11}$  will not saturate. In either case, the conditions seem safe ones.

We have still to consider the possibilities of danger arising in the connections to the oscilloscope, the attenuator details and, of course, the switching waveform generator. Space prevents their discussion here, and these matters will be deferred to Part 4.

## Announcements

For the fourteenth year a 27-lecture evening course on colour television engineering is being held at the Polytechnic of North London, Holloway N.7, beginning on 4th October. Fee £6. a good fundamental knowledge of monochrome techniques is assumed.

A post-graduate evening course entitled Integrated Circuit Electronics (Application Techniques) is to be held at North East London Polytechnic commencing 21st October. Details from The Registrar, Faculty of Engineering, North East London Polytechnic, Longbridge Rd, Dagenham, Essex RM8 2AS. Fee £5.

The following weekly evening courses are to be held at Hendon College of Technology, The Burroughs, London N.W.4. Electronics for non-electrical engineers, 16 meetings commencing 12th October; the construction and operation of digital computers, 16 meetings commencing 13th October; and hi-fi sound reproduction, 9 meetings commencing 11th October.

Two ten-evening courses entitled 'Basic Electronics' are to be held at Twickenham College of Technology, commencing 14th October this year and 13th January 1972. Fee £10 per course. Further details from Twickenham College of Technology, Egerton Road, Twickenham, Middx.

An evening course of eight lectures on microelectronic design techniques will be held at Enfield College of Technology, Queensway, Enfield, Middx. commencing 5th October. Fee £6.

The Plessey Company Ltd have acquired the instrument landing systems interests of Standard Telephones and Cables Ltd which will consolidate Plessey's activities in the navaids field.

Marconi International Marine Co. Ltd are to supply a complete v.h.f. radiotelephone network to link the ferries, pier offices and head office of the Caledonian Steam Packet Co. Ltd of Gourock, Renfrewshire. The system comprises 18 Corvette 20S v.h.f. radiotelephone transceivers and a 20W v.h.f. base station.

Standard Telephones and Cables Ltd have been awarded orders by the British Post Office to the value of £400,000, for installation of eight TXE2 electronic telephone exchanges.

F.W.O. Bauch Ltd, 49 Theobald Street, Boreham Wood, Herts, announce that hiring facilities are now available for the ARP 2600 electronic music synthesizer. The rate is £25 per day including instruction which takes place on the Bauch premises.

FR Electronics, Wimborne, Dorset BH21 2BJ, have announced a marketing and technical collaboration agreement with Hathaway Instruments Inc., of Colorado, U.S.A.

# International Audio Fair

## Olympia, October 26th-30th

On this page is a list of product names which will be seen at the Audio Fair, and a list of the 20 lecture demonstrations arranged as last year but taking place in a specially built 'hi-fi theatre' on the second floor of the Empire Hall.

Wireless World will be sponsoring five events—four lectures and one recital

of recorded music.

The lectures will be further explorations of ever-important questions relating to audio engineering, and may well help in establishing a more honest connection between engineering specifications and the listening experience.

The recital (4 p.m. on the Saturday) will consist of selected gramophone recordings played over a pair of small corner-horn loudspeakers based on a design published in Wireless World last year. The Fair is open from 10 a.m. to 9 p.m. each

### Lecture demonstration programme

#### Tues. 26th Oct.

- 2 p.m. Acoustics of rooms by Roger Driscoll
- 4 p.m. Processing of gramophone records
- by E. B. Pinniger 6 p.m. The musical value of synthesizers by Tristram Cary (W.W. presentation)
- 8 p.m. Live, recorded, dead or alive? by Adrian Hope

#### Wed. 27th Oct.

- 2 p.m. Producing classical recordings by Christopher Bishop
- 4 p.m. Tape troubles by H. W. Hellyer
- 6 p.m. The progress of sound reproduction by Ralph West (W.W. presentation)
- 8 p.m. Women and Hi-Fi. (A bird's eye view 'brains trust'!)

### Thurs. 28th Oct.

- 2 p.m. The development and practical use of dynamic and electrostatic headphones by Howard Souther
- 4 p.m. Loudspeakers-why the weakest link? by Arthur Bailey (W.W. presentation)
- 6 p.m. An eccentric look at the record repertoire by Donald Aldous
- 8 p.m. Silence and music by R. Berkovitz

#### Fri. 29th Oct.

- 2 p.m. Multi-channel recording by Robert Auger
- 4 p.m. Record rejuvenating by A. C. Griffith
- 6 p.m. Design problems in audio amplifiers by J. L. Linsley Hood (W.W. presentation)
- 8 p.m. 'Feed-back chat'. (A 'brains trust')

#### Sat. 30th Oct.

- 2 p.m. Audio tape cassettes and cartridges by Walter Woyda
- 4 p.m. Recital of recorded music (W.W. presentation)
- 6 p.m. From all directions. Microphone problems discussed by R. H. Fisher

Readers who hope to attend one or more of the Wireless World presentations may care to send questions on the subjects to be explored. A selection of queries received will be put to each lecturer at the end of his discourse. Submissions should be brief, preferably broadly based, and addressed to The Editor, Wireless World, Dorset House, Stamford St., London S.E.1.

On the Wireless World stand at the Fair will be working demonstrations of audio equipment built to designs published in the journal. It is planned to interconnect the various items and provide a rank of good quality headphones for the use of visitors.

AKG Agfa-Gevaert

Akai Amstrad Audio Technica

BSR MacDonald Bang & Olufsen

BASF Bell & Howell (AR) Bib Brahms/Medway

Bush (Arena) Celestion

Decca Dynatron Radio

**Enquiry Recorder Systems** 

Ferguson Ferrograph

Garrard Goldring Goodmans

Grosvenor Grundig

HMV Hacker Harman-Kardon Heathkit

Howland-West

KEF

Keletron Kellar

Koss Lansing Leak

Luxor MB Mikrofonbau

Marconiphone Markovits Metrosound Musonic

National Panasonic

Nivico Onkyo

Ortofon Paddock Tidy Recorders

Philips Pickering Pioneer **Precision Tapes** 

Pve Quad

> R.C.A. Reslosound

Rota Rotel

SMF STE-MA Sansui Sanyo

Scotch Sennheiser Sharp

Shure Sinclair Sonotone

Sony Stax Tandberg

Tannoy Telefunken Thorens

Trio Uher

Unlimited Sound

Wharfedale

Wien

# Field-sequential Colour Television Receiver

## 2—Circuit details

by T. J. Dennis, B.A.

The automatic phase control system used for synchronizing the rotation of the colour wheel is straightforward in operation. Its circuit is shown in Fig. 1. The design finally adopted is heavily dependent on the motor used and the torque it is required to produce; that shown here should be used only as a guide.

The prototype motor came from a piece of domestic equipment, and was intended for series operation from a.c. mains. Access to field and armature windings separately was obtained, and tests showed that the motor would produce adequate torque at 1000r.p.m. with 12V on the field winding and 19V on the armature, at 600 and 200mA respectively. The control circuit  $(Tr_{6-11})$  was therefore designed to give the latter output voltage for an input at the base of  $Tr_s$  of 6 volts. Silicon diodes  $D_{5-7}$  are voltage droppers, giving a total drop of approx. 2 volts.

In operation either field sync or flyback pulses (negative going) trigger the emitter-coupled astable (1)\*, consisting of  $Tr_1$  and  $Tr_2$ , at 16.75Hz. The emitter-coupled variant was chosen as it enables large mark-space ratios to be obtained, and gives a current output which can be heavily loaded without affecting frequency.

The negative going output pulse of approx. 8ms duration is fed to a phase splitter (6) consisting of  $Tr_3$  and  $Tr_4$ . Complementary transistors are used to ensure that when the output is on 'sample' both are saturated, with the result that the pulses fed to the four-diode discriminator (7) through  $R_{13}$  and  $R_{14}$  are truly symmetrical. The negative edge of the pulse from  $Tr_4$  is also used elsewhere in the system.

The pick-up coil  $L_1$  (12) should consist of 500-1000 turns of 28 gauge enamelled wire wound on a U-shaped limb. Construction is not critical, provided a peakpeak output of at least 1V is obtained. The actual magnitude (in fact dV/dt on the edges) of the voltage affects the gain of the system, and therefore its transient response: excessive amplitude will cause hunting, while a low level will result in a weak and sloppy phase lock.

In operation, the output from  $L_1$  is taken in series with a variable d.c. from  $R_{22}$ 

for speed control to emitter follower  $Tr_5$ , which provides a low impedance feed to the discriminator.

On receipt of the 8ms gating pulses, all four diodes of the discriminator conduct, and by balanced bridge action a path exists between  $Tr_5$  emitter and  $Tr_6$  base. Over a small number of cycles,  $C_8$  charges to the potential of  $Tr_5$  emitter, and preserves it—more or less—over the non-sampling period of 52ms. This is because the input impedance of the next emitter follower,

 $Tr_6$ , is very high (approx.  $600k\Omega$  assuming  $Tr_6$  beta = 50, which gives an 8% loss over 52ms). A further emitter follower,  $Tr_7$ , reduces again loading effects on  $C_8$ .

Next come the voltage adjusting diodes, followed by a voltage amplifier with gain 2, whose main purpose is to provide the working voltage for the motor armature plus the  $V_{be}$  drops of the three impedance-reducing emitter followers,  $Tr_{9-10-\&-11}$ . As  $Tr_{11}$  has to handle appreciable current, particularly on starting, a 2N3055 is used.

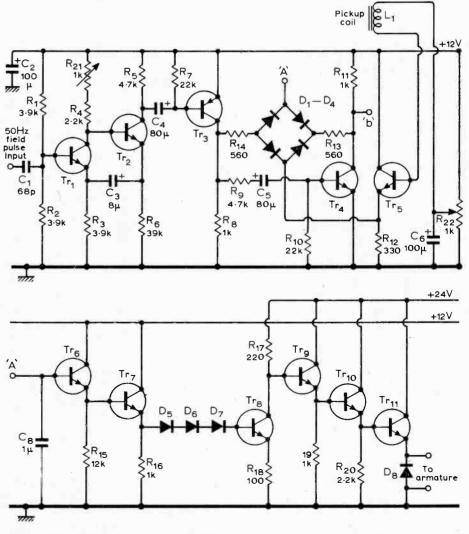


Fig. 1. Motor control system. Motor field winding is connected across 12V.  $Tr_1$ ,  $Tr_2$ ,  $Tr_4$ ,  $Tr_6$ ,  $Tr_7$ ,  $Tr_9$ , ZTX300;  $Tr_3$ , ZTX500;  $Tr_5$ ,  $Tr_8$ ,  $Tr_{10}$ , 2N697;  $Tr_{11}$ , 2N3055;  $D_1-D_7$  1N914;  $D_8$ , BY100.

<sup>\*</sup>Numbers in brackets refer to the block diagram of Fig. 1, Part 1.

Colour switching circuits

The gating pulses generator consists of

three identical monostable multivibrators,

the circuit of the first being shown in Fig. 2

(2R). On receipt of a negative edge from

Diode  $D_8$  is essential to suppress the negative voltage transients which will appear across the largely inductive armature at switch-off.

It should be pointed out that the above circuitry is suitable only for relatively small motors driving colour wheels of the simple type described last month. Once the diameter of the disc becomes much greater than, say, 15 inches, windage accounts for a considerable power loss, and a larger motor is required. The problem was overcome in the case of the writer's 23in. wheel by the use of a d.c. shunt-wound motor, intended for 220V at 0.5A. This is supplied

with 300V for its field, while the armature is fed from a typical variable seriesregulated feedback-stabilized high-voltage power supply. The lower limb of the voltage controlling potentiometer on this unit is replaced by a pentode valve whose grid is fed directly from  $Tr_8$  collector, Fig. 1. Adjustment of  $R_{22}$ , and the cathode resistor of the pentode enables a mean output of 160 volts to be obtained, which will run the motor at 2000 r.p.m. Coupling to the colour wheel shaft is effected by means of a 2:1 reduction belt drive.

The low level parts of the a.p.c. system are retained unchanged.

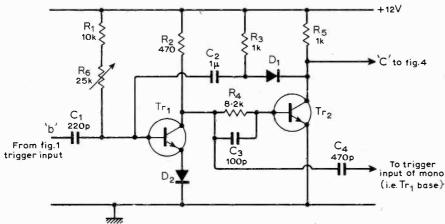


Fig. 2. Red gating pulse generator. Tr<sub>1</sub>, Tr<sub>2</sub>, ZTX300; D<sub>1</sub>, OA91.

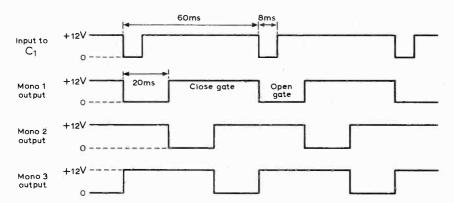


Fig. 3. Ideal monostable outputs.

TR<sub>4</sub>, Fig. 1, the circuit produces complementary pulses at its outputs, of width dependent on the time constant of  $R_6 + R_1$ and  $C_2$ . Variable resistor  $R_6$  is adjusted to obtain pulses of as near as possible 20ms. Diode  $D_1$  is included to sharpen up the trailing edge of the negative going output from Tr2, which would otherwise be partially exponential as  $C_2$  would have to recharge, once Tr<sub>2</sub> turns off after the quasi-stable period of 20ms, through  $R_5$ . This task is now performed by  $R_3$ ,  $D_1$ being immediately cut off by the positive excursion of  $Tr_2$  collector.

> The trailing edge of the positive pulse from  $Tr_1$  collector is differentiated by  $C_4$ and used to trigger the following monostable, which in turn, on completion of its 20ms pulse triggers the third, the resulting waveforms being as shown in Fig. 3. The next input edge then appears at  $Tr_1$  base, and the sequence is repeated.

> Fig. 4 shows the circuit of one of the three gate units and the output circuitry.

The colour difference inputs come directly from the collectors of the first stage amplifiers of the May 1969 W.W. article, Fig. 1. These amplifiers are operated at full gain, independent gain control being provided at the gate inputs.

Emitter follower  $Tr_1$  is mounted on the decoder board with  $R_{19}$  on a small panel nearby, as are the other two colourdifference gain controls. Its main purpose is to isolate the matrixing stages. As the d.c. levels of the decoder outputs are rather high, 12V zener diodes provide a suitable drop. The amplitude controlled input is a.c. coupled to emitter follower Tr, which sets up the correct mean d.c. condition for the gate proper,  $Tr_3$  & 4 and provides a lowimpedance source.

When the gate is closed,  $Tr_3$  base is forward biased through  $R_8$  from the relevant monostable, now in its stable state. The bias of approx 1mA is suffi-

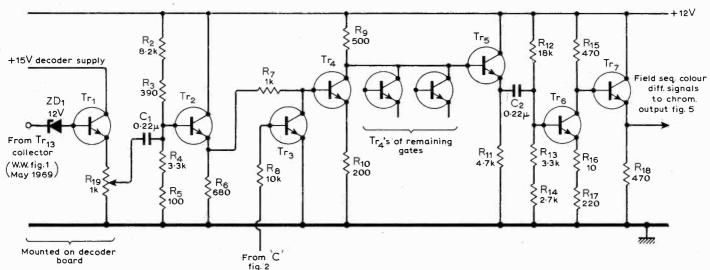


Fig. 4. Colour gating circuitry (only R - Y gate shown in full). Tr<sub>1</sub>, Tr<sub>2</sub>, Tr<sub>3</sub>, Tr<sub>4</sub>, Tr<sub>6</sub>, ZTX300; Tr<sub>5</sub>, Tr<sub>7</sub>, 2N697.

cient to cause  $Tr_3$  to bottom, with its collector load of  $R_7$  fed from a 2.7V source. The base of  $Tr_4$  is thus clamped at zero volts and the transistor is cut off. No signal can then reach the common load  $R_9$ . Once the monostable changes to its 20ms quasi-stable state,  $Tr_3$  is cut off, and  $Tr_4$  behaves as a conventional series feedback amplifier, with collector load  $R_9$  and theoretical gain 2.5.

It should now be clear how the complete system operates: the  $Tr_3$ s are switched off in turn, enabling the required colour difference signal to appear at the output.

Theoretically there should be no change in the d.c. level at  $Tr_5$  emitter as colour changeover occurs, as the gate circuits are identical. However, some differences are unavoidable due to component tolerances. Small potentiometers of the order of 100 ohms can be included in the d.c. setting bias chains at the inputs, and adjusted for minimum pedestals on the output waveform with no signal input.

An effect which will almost certainly occur is that due to incorrect setting of the pulse width controls in the monostables. This results in a positive or negative pulse at  $Tr_5$  emitter according as the total period of the monostables is less than or greater than 60ms. The pulse will occur between the completion of one colour sequence and the initiation of the next; its effect may be eliminated by ensuring that the period is slightly too long, when the negative pulse is inverted twice, by  $Tr_6$  and the valve chrominance output stage, to cause beam cutoff at the c.r.t. grid.

Long term stability of the monostables has proved sufficient for the application, provided a stabilized power supply is used; logic circuits to generate the gating pulses were considered, but rejected in favour of the simplicity of the above arrangement.

Fig. 5 shows the chrominance output circuit to drive the c.r.t. grid and is based on that of the June 1969 W.W. article, Fig. 1. The choice of valves is purely because they were to hand. An ECL84 or PCL84 could replace either.

The chief modification is in the facility for varying the clamping potential of the triode for brilliance control by means of  $R_9$ , this system has proved more efficient in operation than that described in the relevant W.W. article, and enables a conventional 'video amplifier' to be used in the luminance channel.

The luminance output stage is the original monochrome circuit with the addition of the luminance delay line. Fig. 6 shows the circuitry round the latter.

Transistor  $Tr_1$  is a phase splitter, with  $1k\Omega$  collector load to match the delay line impedance. Chrominance is taken from the emitter circuit, which includes a 4.43MHz trap, L,  $C_2$ . Video is also taken from this point to the additional sync separator providing PAL switching pulses and timing for the burst gating pulse.

Losses in the unit are counteracted by inclusion of networks  $R_4$ ,  $C_3$  and  $R_{11}$ ,  $C_6$  which adjust the gains of the two amplifiers. D/C. restoration is provided at the video amplifier grid by  $C_7$ ,  $R_{12}$  and  $D_1$ .

The circuit of Fig. 6 was inserted directly in the feed to the v.f. output stage of the monochrome receiver after the existing 6MHz sound take-off coil.

#### Auxiliary sync separator

It is not feasible to use the existing receiver sync separator in place of what is to be described, since the pulses extracted therefrom carry the 600ns delay imposed by the luminance delay line.

Fig. 7 shows the complete burst-gating pulse generator, used to operate a four-diode bridge placed in series with  $C_7$  and  $Tr_3$  base of Fig. 2, W.W. April 1969.  $P_3$  is then connected to a decoupled potential divider at approx 4 volts. Capacitor  $C_9$  is then connected to the  $C_7$  side of the bridge.

Referring to Fig. 7,  $Tr_1$  is an inverting amplifier feeding the sync separator proper,  $Tr_2$  & 3. Transistors  $Tr_4$  and  $Tr_5$  constitute a monostable giving a pulse (of width sufficient to encompass the colour burst) triggered from the trailing edge of the line sync pulse. This pulse is amplified to 15V, and phase inverted twice to provide gating current for the burst gating bridge.

The negative pulse at  $Tr_9$  emitter is also used for triggering the PAL bistable in the decoder, and gating *out* the burst at  $D_1$  of Fig. 1, W. W., May 1969.

#### Power supplies

For simplicity it was decided to operate all solid-state sections of the system from rail voltages of 12 and 24V, deriving all other levels from these as required.

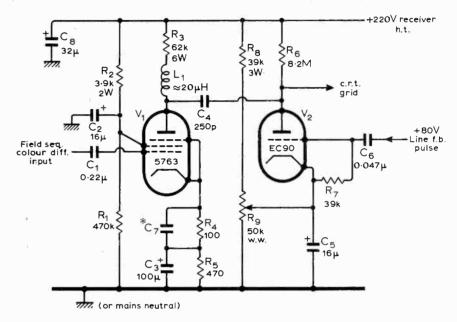


Fig. 5. Colour difference output stage. The +80V line pulse can be obtained from a winding of about six turns of p.v.c. insulated wire on the line output transformer.  $*C_7$  should be adjusted for optimum frequency response.

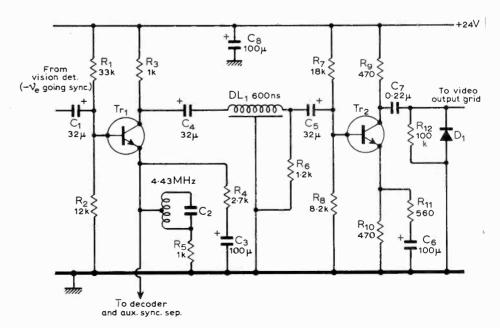


Fig. 6. Luminance delay line. Tr<sub>1</sub>, ZTX300; Tr<sub>2</sub>, 2N697; D<sub>1</sub>, 1N914.

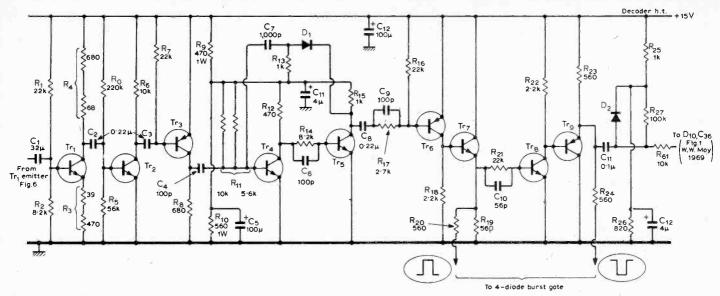


Fig. 7. Auxiliary sync separator and burst gating pulse generator.  $Tr_1$ ,  $Tr_2$ ,  $Tr_4$ ,  $Tr_5$ ,  $Tr_8$ , ZTX300;  $Tr_3$ ,  $Tr_6$ , ZTX500;  $Tr_7$ , 2N697;  $Tr_9$ , MM1614;  $D_1$ , 1N914;  $D_2$ , OA91.

The basic voltages came from two 12-V series stabilizers, in series and fed from isolated windings on one transformer.

Fig. 8 shows the circuit, based on a Ferranti 'E-line' transistors application report, of one of the supplies; it is conventional in form, the output voltage sets itself to that defined by the zener voltage plus the  $0.7VV_{be}$  of  $Tr_1$ .

Transistor  $Tr_5$  is a crude, but adequate, current limiter operating at approx 2.1A; i.e., that current required to drop 0.7V across 0.33 ohm. The 2N3055  $(Tr_4)$  must be mounted on a suitable heat sink.

The +15V supply for the decoder is derived from the +24V rail by a third series stabilizer, identical to that of Fig. 8, but with the omission of  $Tr_4$ ,  $Tr_5$  and  $R_4$ .  $ZD_1$  (now a 15V specimen) and the load are connected to the emitter of  $Tr_3$ .

The +20V supply for the decoder was obtained from a single 20V zener fed via a  $470\Omega$  resistor from +24V.

The -20V necessary for the colour difference amplifiers and other parts of decoder circuit presented some problems, however. The rather complex solution of Fig. 9 was finally adopted. It consists of an astable multivibrator running freely somewhere below line frequency, its complementary outputs being buffered by two emitter followers,  $Tr_3$  and  $Tr_{45}$ from a pair of peak rectifying circuits,  $D_{5-8}$ . The circuit provides a no-load output of 24V, the internal impedance being set by the  $560\Omega$  emitter loads of  $Tr_3$  and  $Tr_4$ . No physical zener series resistance is therefore provided for  $ZD_1$ , which stabilizes the output at -20V: the demanded current is approx 3mA.

#### Setting-up

The basic assumptions made here for setting-up are that the constructor has access to a double-beam oscilloscope and a reliable source of colour difference signals, as well as line flyback, composite video and field sync.

(1). The master astable,  $Tr_1$  and  $Tr_2$  of

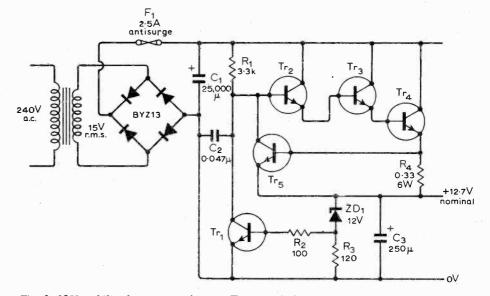


Fig. 8. 12V stabilized power supply. Tr<sub>1</sub>, Tr<sub>5</sub>, ZTX300; Tr<sub>2</sub>, Tr<sub>3</sub>, 2N697; Tr<sub>4</sub>, 2N3055.

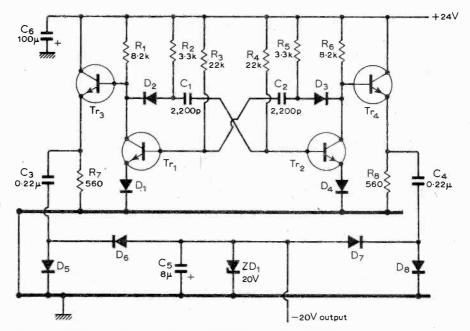


Fig. 9. -20V power supply.  $Tr_1$ ,  $Tr_2$ , ZTX300;  $Tr_3$ ,  $Tr_4$ , 2N697;  $D_{1-8}$ , OA91.

Fig. 1 must be set to divide by three the incoming 50Hz field frequency. Operation in a division mode depends on the amplitude of the sync pulse used, and this should be adjusted experimentally to obtain the maximum range on  $R_{21}$  within which the division ratio is maintained. The input pulses must also be entirely free from line frequency transients, which will seriously impede synchronization.

The best method is to take the separated field sync pulse from the monochrome set used through a simple RC low-pass filter to a limiting amplifier, thence (negative

going) to the astable.

(2). Check that  $Tr_3$  and  $Tr_4$  produce positive- and negative-going 8ms 12V pulses respectively at their collectors, and that both transistors remain saturated during the pulse period.

(3). With  $R_{22}$  set to give 6V at  $Tr_5$  base, check the voltage at  $Tr_7$  emitter, where it should be approx 3.9V. Also check that this voltage varies with variation of the

setting of  $R_{22}$ .

(4). Having previously tested the motor under operating conditions for the voltages required for running at 1000 r.p.m., make suitable variations in  $R_{17}$  and  $R_8$ , and the presence or absence of  $D_{5.7}$  to obtain the required armature voltage at  $Tr_{11}$  emitter. Note 1. A rheostat can also be included in series with the field winding if necessary, but remember that a reduction in field current, while increasing the speed of an ideal shunt wound motor, also increases the armature current proportionately. Torque remains constant.

Note 2. The velocity of the motor can best be determined by making use of the waveform from  $L_1$ . Trigger the oscilloscope from the  $16\frac{2}{3}$ Hz pulses from the master astable (itself running correctly) and display them on one trace. The second trace carries the coil waveform which is visually compared in period and phase with the 60ms of the

timing trace.

(5). With  $L_1$  disconnected and  $R_{22}$  slider (Fig. 1) connected directly to  $Tr_5$  base, adjust  $R_{22}$  until the motor runs as nearly as possible in synchronism (using the method of Note 2.).  $L_1$  should then be brought into circuit, when the motor phase should move to a locked position after a few damped oscillations. If oscillations continue experiment with the gain of the control circuit, and the value of  $C_8$ . A convenient means of reducing the effective gain is to move the pickup coil away from the rotating magnet.

(6). The angular position of the magnet relative to the coil must be adjusted to ensure that the correct coloured filter is moving past the c.r.t. at the correct time. A rough positional guide is to place the bar magnet so that one of its ends points to an angular position on the wheel just ahead of the commencement of the first colour in the sequence, which in the prototype is the

red. See also step 13.

(7). Adjustment of monostable periods. With one trace of the oscilloscope displaying at least three field flyback or sync pulses, and the other the quasi-stable period of the first monostable, trigger the 'scope on the 16<sup>2</sup><sub>4</sub>Hz pulses.

Adjust  $R_6$ , Fig. 2, until the pulse period of the monostable is equal to that between two field sync pulses.

Check that the second monostable is being triggered reliably by the trailing edge of the first, and repeat the adjustment for width. If triggering is unreliable or absent, increase the value of  $C_4$  to 560pF.

The 'scope should then be reconnected to display the first monostable output on trace (1) and the third on trace (2). Trigger from the trailing edge of the first monostable output. Adjust the period of the third monostable so that it overlaps with the beginning of the next sequence by an amount not greater than the field blanking period of the incoming video. This ensures that there is no interference with the picture between sequences.

(8). With the decoder switched on, and the transmitter carrying colour bars, check that the waveforms at the emitters of the  $Tr_2$ 's transistors (Fig. 4) for R-Y, B-Y and G-Y are as they should be, and not distorted or clipped, up to full settings of the saturation control on the decoder, and  $R_{19}$ .

During this test, the free ends of the  $R_8$ s should be taken to +12V to ensure

that all gates are cut off.

(9). Connect the  $R_8$ s of the three colour gates to the relevant monostable outputs and with the  $R_{19}$ s at minimum, check the waveform at  $Tr_5$  emitter for pedestals as colour change-over occurs; this is apart from the negative pulse which will be obtained between sequences if the monostables have been set up as above. If marked pedestals are obtained, suitable adjustments should be made to the bias chains at the  $Tr_2$  bases.

(10). With the  $R_{19}$ s at full gain and a moderate saturation adjustment, the 'scope being triggered from a line frequency source, check the waveform at  $Tr_7$  emitter, where all three colour difference signals should be visible simultaneously, with a marked flicker.

(11). With the input to  $C_1$ , Fig. 5, disconnected, check the operation of  $R_9$  as a brilliance control with +80V line-flyback

clamping pulses on  $V_2$  grid.

(12). Check the operation of the luminance delay line circuit, Fig. 6, and that the video waveform is not clipped by  $Tr_1$  or  $Tr_2$  when contrast is high. With the 'scope input on d.c., check that the waveform is being d.c. restored correctly by  $D_1$ .

(13). Connect  $C_1$  of Fig. 5 to  $Tr_7$  emitter, Fig. 4, when coloured areas of the picture will flicker with an intensity proportional to their saturation. View the picture through the locked colour wheel, when if colours are incorrect (e.g., blue faces), re-check step 6 and reverse the connections to the pickup coil. Once the wheel is in roughly the correct phase, make fine adjustments of the relative angular positions of magnet and coil. The direction of movement necessary will become apparent through experience or common sense.

(14). With the decoder saturation control set to give a reasonable signal output, preferably with colour bars, adjust the  $R_{19}$ s of Fig. 4 to obtain colours which 'look' right. These adjustments are uncritical and straightforward.

It is best to have the saturation control high and the  $R_{19}$ s low rather than viceversa, as this arrangement ensures a good s/n ratio in the displayed colour picture. (15). If the circuit of Fig. 7 is incorporated in the decoder, the operation of the sync separator,  $Tr_2$  and  $Tr_3$ , should be checked to ensure that line pulse output continues independently of picture content. Trouble will occur if  $Tr_1$  clips the incoming waveform on highlights, with the result that burst gating pulses are lost.

The gain of  $Tr_1$  has to be a compromise, in that it must provide adequate gain for clean sync separation on low contrast settings, but must not clip when contrast

is high.

(16). The only problem likely to be encountered in setting-up the power supplies is with Fig. 9. Astables of this type sometimes fail to start oscillating on switch-on, since a stable state exists with both transistors saturated. This effect was encountered when the prototype was powered from two 12-V car batteries, the astable being started then by shorting one of the bases of  $Tr_1$  or  $Tr_2$  to earth. The effect does not occur with the mains power supplies of Fig. 8.

#### **Conclusions**

These articles have been written to present sufficient information on a field sequential colour TV system built by the writer to enable interested readers to do the same.

Although quite a considerable amount of circuitry is involved, none of it is particularly critical in design or construction, and is no doubt amenable to criticism, modification and improvement.

The only specialized electronic components required are the two delay lines, and the 4.43MHz crystal for the decoder.

The filters were purchased as  $21 \times 49 \times 0.01$  in sheets (smaller areas are available) from Rank Strand Electric, Ltd., of 250 Kennington Lane, London, S.E.11, and are their "Cinemoid" stage lighting filters, numbers 6, 20 and 39, primary red, green and blue. This size cost 63p per sheet.

Perspex sheet is obtainable from any good builders' merchant, and can sometimes be cut to shape on request. Suitable motors were, in the author's case retrieved from the yard of a local scrap dealer.

The basic monochrome receiver used was a home-built affair, which, however, contains commercial u.h.f. tuner and i.f. plus sound and vision output units.

It is suggested that the monochrome receiver be used initially with its existing c.r.t., and a simple colour wheel, to gain experience of the behaviour of the system, before the necessary tube replacement and remounting is carried out for a larger spiral wheel. Suitable small 110° tubes are the A28-14W, giving an 11in picture, or any portable set tube. These will take the existing scan coils without modification, although width, and e.h.t. may need adjustment.

Thanks are due to the Department of Electrical Engineering Science at the University of Essex, particularly Dr. J. A. Turner.

# **Electronic Building Bricks**

## 16. The Quantizer

by James Franklin

Signals originating from analogue transducers-such as a television camera or an electrical strain gauge-sometimes have to be converted, for information processing purposes, into digital form. This means that the successive values of the signal become represented by numbers (Part 4), which might be decimal, binary or based on any other radix. We have already met the idea of considering a signal as a sequence of separate values (Part 2) and the use of this concept for measuring information (Part 15).

Now a practical requirement of an analogue-to-digital converter is that it needs a certain amount of time to produce each number. Electronically each number is represented by a pattern, either in time (e.g. a sequence of pulses), or in space (e.g. an array of on/off states of electronic switches), and some interval of time, however small, is necessary to enable each pattern to be formed and distinguished from those preceding and following it. Clearly such a converter cannot operate directly on an analogue signal, which is a continuously varying quantity (i.e. has infinitely small time intervals between successive values). The best that can be done, to keep the digital representation as close as possible to a continuously varying quantity, is to convert values of the signal to numbers at a very high rate—say a million conversions per second. In practice we use the rate necessary for the job.

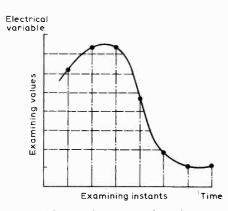
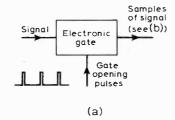


Fig. 1. Showing how a signal can be examined at regular intervals of time (indicated by dots on graph) or regular intervals of the variable which constitutes the signal.



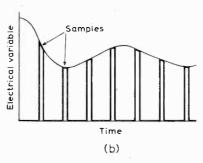
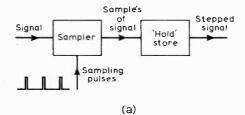


Fig. 2. Quantization by sampling, using an electronic gate (a) which is opened and closed to the signal by short duration pulses. The resulting output waveform is shown by the thick line in



Stepped signal Electrical variable (b)

Fig. 3. Quantization by the 'sampleand-hold' method. The 'sampler' in (a) is an electronic gate as in Fig. 2. The resulting output (b) is a series of steps roughly following the original signal.

What this is depends on the accuracy of digital representation of the signal we need for a particular application. Any clock using an escapement mechanism does not indicate time continuously but it is near enough to continuous for most human purposes.

Thus the continuously varying signal must be examined at intervals. This examination could be at regular intervals of time or at regular intervals of value, e.g. voltage, of the signal (in which case the time intervals will be irregular). Both methods are illustrated in Fig. 1. This general process is known as quantization, because what was originally continuously varying is now represented as a series of discrete quantities, or quanta.

Two methods of achieving quantization of a signal are shown in Figs. 2 and 3. In Fig. 2(a) the signal is passed through an electronic 'gate' which is opened for short periods by regularly occurring pulses (from an electronic 'clock' or oscillator). What emerges from the gate, shown in (b), is a train of pulses of different amplitudesthin 'slices' or 'samples' of the original signal. These samples may be usable as such in information processing equipment even though the tops of the pulses are sloping. If not-perhaps because the samples are of too short duration-the method shown in Fig. 3(a) may be used. Here the signal waveform is sampled as before but the initial value of each sample is stored\* until the next sample is taken. Thus the information available from the store is in the form of a series of steps roughly following the graph of the original analogue signal, as can be seen in (b). This is known as the 'sample-and-hold' method.

How accurately the quanta-the samples in Fig. 2 or the steps in Fig. 3-follow the original signal graph depends on the fineness of quantization, that is, the time intervals or value intervals between samples. We have already discussed this idea in terms of the number of levels required for measuring the information in a signal in bits (Part 15). Generally speaking it is more difficult and costly to sample rapidly than to sample slowly, so engineers use the slowest rate of sampling that will define the signal to the accuracy they need for a particular purpose. To obtain the maximum possible accuracy of signal definition the sampling rate required is given by a simple formula based on mathematical analysis† of the shape of the signal graph.

One example of the use of quantizers is in an advanced type of telephone trunk transmission system now being introduced in various parts of the world. This is called pulse code modulation and it requires that the voice signals be quantized to enable them to be coded into digital

e.g. as charge in a capacitor

<sup>†</sup>Fourier analysis of the signal into component sinewaves. For full accuracy of definition the sampling rate must be at least twice that of the highest frequency sinewave that is a component of

# **Elements of Linear Microcircuits**

## 12: Television receivers

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

In the 1960s transistors ousted valves from most circuit positions in domestic television receivers and now we are seeing linear microcircuits in their turn displacing transistors.

Although the U.S.A. has led the world in development of military and industrial i.cs, Western Europe has led in consumer i.cs (at least in monolithics, since in hybrids Japan has forged ahead). In Europe the main stream of i.c. development for television receivers has come from Western Germany with devices from Valvo (Philips), Siemens, Telefunken, and Intermetall (I.T.T.). Plessey in the U.K., S.G.S. in Italy and Secosem in France have also entered the field, while across the Atlantic Motorola, R.C.A., Texas Instruments and Fairchild are active.

To date the different semiconductor manufacturers have tended to adopt different approaches to partitioning the television receiver for linear i.c. substitution. As a result, second source supplies are not usually available to the set maker.

Good receiver partitioning aims at using the advantages of monolithic techniques up to a point where the replacement cost of any microcircuit is not prohibitive. A single microcircuit covering all the electronics of the receiver is possible but economically prohibitive. It looks as if the number of microcircuits in a receiver will ultimately settle at between four and eight.

Until now linear i.cs have been most widely used in the sound channel, the post-video-detector signal processing, and the colour decoder. Limited frequency, voltage and power handling capabilities have restricted their applications in other areas. Your understanding of the problems of the change-over to i.cs might well be helped by a study of my book 'Transistor Television Receivers' (Iliffe Books, 1963).

#### Sound channel

A natural development of the early op-amp linear i.c. was an amplifier microcircuit which gave the typical 66dB voltage gain needed in an f.m. intercarrier sound i.f. strip (200kHz bandwidth round

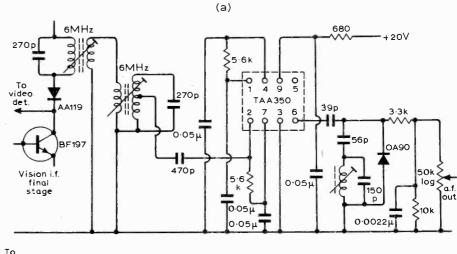
6MHz). The Mullard TAA350, with four current-driven, balanced, long-tail pairs giving efficient limiting and high a.m. rejection, was an example of this.

Fig. 1 (a) is a practical circuit (from the Pye 691 single-standard 625-line colour chassis) using the TAA350. The input is from an AA119 intercarrier sound detector via two 6MHz tuned circuits. Output is via an OA90 sound detector to a volume control and an a.f. amplifier.

It is relatively easy to integrate a detector stage into a monolithic amplifier, and we find many commercial examples of

this such as the Mullard TAA380, Plessey SL432A and Telefunken TAA930. All the basic f.m. detector types (discriminator, ratio, quadrature, differential peak, pulse counting and phase locked loop) have been tried. Anyone interested in the merits (or demerits) of the different detector systems should consult 'A Comparison of Integrated-circuit Television Sound Systems by L. Blaser and D. Long in *I.E.E.E. Transactions on Broadcast and Television Receivers*, Feb., 1971, Vol. BTR-17, No. 1, pp. 35-43.

The long-tail pair makes it simple to



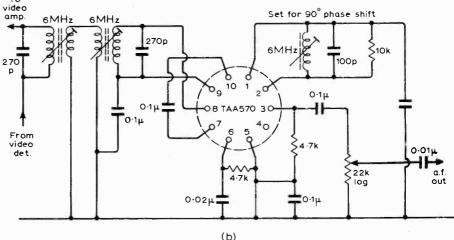


Fig. 1. Typical sound channel microcircuits. (a) Connections used with the Mullard TAA350 amplifier-limiter; (b) use of the TAA570 with integral detector.

<sup>\*</sup> Newmarket Transistors Ltd

vary voltage gain by varying the d.c. bias voltage on the base of one of the transistors of the pair, and we find a group of amplifier-limiter-detector i.cs with a d.c. volume control facility that enables the volume control potentiometer to be located some distance from the microcircuit. Typical of this type of i.c. are the Mullard TAA450 and TAA570 (Plessey pin-compatible SAA570), Siemens TBA120, and SGS TBA261. Fig. 1 (b) shows how the TAA570 has been used in the Pye 169/769 monochrome (625-line only) television chassis. Sound i.f. input comes via two 6MHz tuned circuits from the video detector, detection is by a single-tuned quadrature detector, and the audio output drives a two-stage valve amplifier. (The remote d.c. volume control available at pin 4 of the TAA570 has not been used in this case.)

Extra transistors are easy to fabricate in monoliths, so that the next development was to add an audio pre-amplifier stage to the limiter amplifier. This extra stage you will find in the Mullard TAA640, TAA750 and TBA480, and in the RCA3065.

Two audio stages (a pre-amplifier and driver) appear in such amplifier-limiter microcircuits as the SGS TBA581 (to drive class AB complementary transistor power output stages) and TBA591 (for class A transistor or valve output).

All the intercarrier sound i.cs described above require some form of external audio amplifier to complete the drive to the loudspeaker. These outboard audio amplifiers are still usually discrete transistor or valve designs, but microcircuit versions are available.

Monolithic audio amplifiers up to 3W output are now fairly common. Typical

examples are the Telefunken TAA900 (2W) and SGS TAA621 (3W). By suitable heat-sinking, conventional monolithic designs can be pushed up to 5W, and we are already seeing new designs (e.g. from Sony) capable of 20W r.m.s. output.

Thick film add-on audio power amplifiers from 3-50W output are now produced by many Japanese firms such as Mitsubishi, N.E.C., Sanken, Sanyo and Toshiba, and will compete strongly with monoliths.

One interesting development that seems to point the way to the final solution to integrating into a single package the whole intercarrier sound channel is the SGS monolith TBA631, which combines the functions of limiter-amplifier, detector and 3W audio amplifier into a single chip with an integral heatsink.

#### Jungle chips

The post-video-detector circuitry of the television receiver has received much attention from i.c. manufacturers. It has been found possible to integrate in one chip the following video signal processing functions: video pre-amplification, keyed a.g.c. detection, a.g.c. amplification for both tuner and vision i.f. control, noise cancellation for a.g.c. and sync. circuits, sync. separation, automatic horizontal sync. and, finally, vertical sync. pulse separation. This video signal processing i.c. is variously known as the 'signal processing circuit' or, affectionately and obviously, as the 'jungle chip'.

The best known example is the Mullard TAA700 (now superseded by the

The TAA700 is designed for TV receivers equipped with transistors or valves in the deflection and video output stages, with n-p-n transistors in the tuner and i.f. amplifier, and with negative modulation. It works on a nominal 12V d.c. supply rail.

set out in detail here but Mullard can

supply data to prospective users.

## Sound/vision i.f.

Sound/vision i.fs present special problems in applying i.cs because the first i.f. stage must have a.g.c., and the requirement for many tuned bandpass and rejector circuits has tended to give the monolithic i.c., for sound/vision i.f. only applications, no advantage over discrete transistor assemblies. Away back in 1967 Fairchild brought out the  $\mu$  A 717 for just such a purpose, but it was never widely adopted at least on this side of the Atlantic.

An i.c. combining the sound/vision i.f. amplifier with some later stages of the receiver can, however, make integration an economic proposition. One interesting example of this is the RCA CA3068 shown in section block diagram in Fig. 2.

The CA3068 provides a high gain (75dB typical) 45MHz wideband i.f. amplifier with 50dB a.g.c., a video detector, a 12dB video pre-amp., an impulse noise limiter, keyed a.g.c. with noise immunity, delayed a.g.c. for the tuner, buffered automatic fine tuning for varicap tuner control, separate sound i.f. amplification, sound carrier detector, 4.5MHz sound intercarrier pre-amplifier and isolated zener reference diode for regulated voltage supply. The connection diagram of Fig. 2 illustrates the simplicity of use of this i.c., particularly when the needs of the serviceman are remembered.

Another interesting approach to sound/vision i.f. microcircuitry was described in 'A Thick-film Television Video I.F. Amplifier Using Compatible Components' by R. Weber and J. Prabhakar in I.E.E.E. Transactions on Broadcast and Television Receivers, Nov. 1967, Vol.BTR13, No.3, pp.7-12. In this, thick film techniques were used with printed capacitors and surface mounted toroidal coils, both capacitors and coils being adjustable on test by abrasive (powder jet blast) techniques. While this approach has not been widely adopted, it has attractions because it can produce a pre-aligned plug-in i.c. requiring no adjustment by the set maker or serviceman.

#### Tuner

The frequencies (up to 900MHz) handled by the tuner are well beyond current monolithic i.c. capabilities. Hybrid (thick or thin film) techniques show some promise as explained in 'The New Thick-film Hybrid Integrated Circuit Module for V.H.F. Television Tuners? by K. Williams in I.E.E.E. Transactions on Broadcast and Television Receivers, July, 1968, Vol. BTR-14, No. 2, pp. 111-115. Plugged into the appropriate passive tuning networks, the resultant i.c. provides

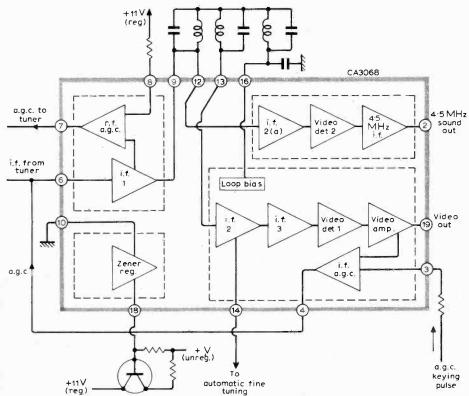


Fig. 2. Combined sound/vision i.f. microcircuit type CA3068.

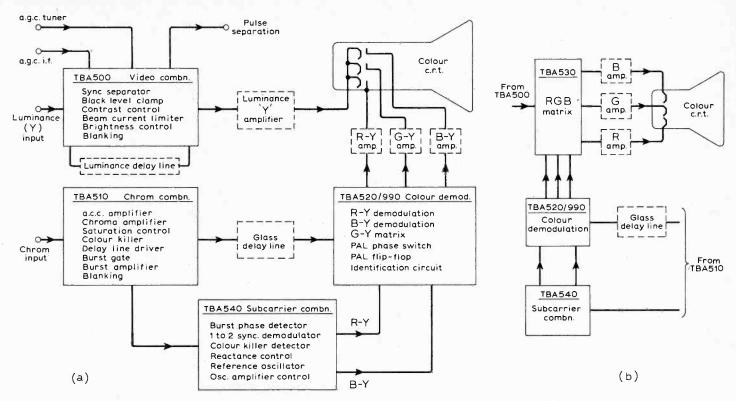


Fig. 3. Using the Mullard TBA500 series in colour receivers. (a) Colour difference arrangement; (b) RGB drive.

all the active circuitry for a v.h.f. tuner which is competitive with discrete device assemblies on the score of both performance and cost.

Most new European television receivers are now varicap-tuned, and although it has not been possible to produce a commercially viable tuner i.c., several firms have produced a self-contained voltage regulator i.c. to provide the very stable 30V or so required for varicap tuning. Typical of these is the Mullard TAA550 and Telefunken TBA940.

#### Colour television receivers

Some of the microcircuits described earlier, such as the tuner-varicap regulated supply, the sound/vision i.f., the sound channel, and the video processing jungle i.c., can be used in monochrome or colour sets. But a special breed of microcircuits has also been developed for colour signal processing.

There are several different approaches to the problem of handling colour signals with i.cs. The Mullard set of i.cs consists of the TBA500 video combination, TBA510 chrominance combination, TBA520 (TBA990) colour demodulator, TBA530 RGB matrix and TBA540 colour subcarrier combination. Space prevents a full description here of the internal circuitry and design problems of this family which is constantly being updated. However, for conventional colour difference drive to the c.r.t. grids, a practical system uses four of the i.cs . . . the TBA 500, 510 520 and 540 . . . . as shown in Fig. 3(a). Essentially, the luminance (Y) input to the TBA500 (which could come from the TAA700 described earlier) is amplified, delayed and fed into the Y amplifier to drive the c.r.t. cathodes. The TBA510 takes the chrominance input, centred about 4.43MHz, separates off the chrominance (R-Y. B-Y) information and feeds it via a 64 s glass delay line to the colour synchronous demodulator, TBA520. At the same time it isolates the 4.43MHz colour subcarrier information and feeds it to the TBA540 where it controls the 4.43MHz crystal carrier reinsertion local oscillator to produce a correct phase and frequency output to feed the synchronous demodulator TBA520, also taking into account the

PAL phase reversal on alternate lines. In the TBA520, the demodulated R-Y and B-Y inputs are combined (matrixed) to give a G-Y signal. The three colour-difference signals are then fed through separate discrete-component amplifiers to the c.r.t. grids.

Where an RGB drive to the separate c.r.t. cathodes is desired, the fifth i.c. of the set, the TBA530 is interposed between the luminance and colour-difference outputs on the one hand and the c.r.t. RGB drive amplifiers on the other as shown in Fig. 3(b).

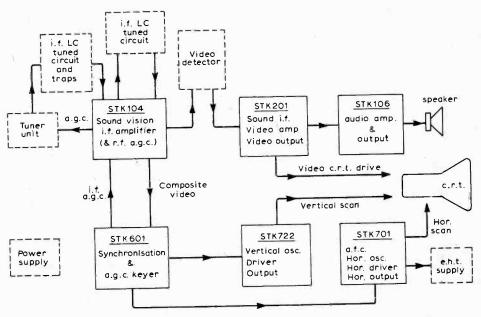


Fig. 4. Six thick film hybrid microcircuits from Sanyo provide most of the circuitry for this 17in receiver.

Interesting alternative approaches to colour signal processing can be found in 'Integrated M.T.O.S. Circuits for Colour TV Applications' by M. M. Mitchell and W. Sheets in *I.E.E.E. Transactions on Broadcast and Television Receivers*, July, 1968, Vol. BTR-14, No. 2, pp. 28-33, and in 'Colour Command—A Digital Method for Extracting the Colour Information from the N.T.S.C. Signal' by R. Weber and T. T. Fu in the same journal, July 1968, Vol. BTR-14, No. 2, pp. 52-57.

Going back to Fig. 3, it will be seen that the drive circuits to the c.r.t. are discrete component, transistor or valve. Thick film hybrids are now available to replace these, as for example in the 'Accucircuit' plug-in microcircuits produced by RCA.

#### Future of i.cs in television receivers

Monolithic i.cs predominate in the microcircuits for TV receivers described so far, but thick-film hybrids are beginning to offer strong competition. Fig. 4 shows in block form the use of six thick-film i.cs

which provide most of the circuitry for a 17in v.h.f. receiver designed by Tokyo Sanyo Ltd. Using an insulatedmetal-substrate, Sanyo can meet the high voltage and power requirements of output stages without separate amplifiers. As a result, the count of 25 transistors, 246 other parts and 553 solder joints for conventional discrete assembly is reduced to 6 i.es, 58 other parts and 198 solder joints. For fuller discussion, you should consult 'Development of All-i.c. 17in Black-and-white Line-operated TV Receiver' by Sadao Kondo, et. al. in I.E.E.E. Transactions on Broadcast and Television Receivers, May, 1971, Vol. BTR-17, No. 2, pp. 98-104.

The shape of things to come can also be seen in the Matsushita (Panasonic) pocket-size receiver using eight thick film hybrids providing the functions sound i.f. and detector, audio and a.g.c., vision i.f., video detector and amplifier, sync. separator and a.f.c., vertical deflection, horizontal deflection and power supply filtering.

Finally we can expect to see a mixing of i.c. technologies as foreshadowed in a colour TV design developed at the Kansai Electronic Industry Development Centre in Japan and organized by five TV manufacturers, seven component producers, four universities and two institutes in the Osaka area. While the design uses a discrete u.h.f. tuner, the v.h.f. tuner uses a thin film r.f. amplifier and a monolithic mixer/oscillator. The 3W audio amplifier is monolithic, as are the vertical and horizontal oscillators. In the colour section, thick film is used for the chrominance bandpass amplifier, the chrominance demodulators, the matrix pre-amplifier and the subcarrier reactance oscillator, with monolithics for the colour killer, and colour burst amplifier. Both thick and thin film are used in the colour phase detector circuit.

Development is now so rapid that a pundit in the U.S.A. has been quoted as going on record that in five years time 75% of the circuitry of the televison set will be integrated in only three i.cs.

# **Personalities**

Professor J. F. Coales, O.B.E., M.A., appointed president of the I.E.E. for 1971/2, is professor of engineering, Cambridge University, where he has been in charge of post-graduate studies in control engineering since 1952. Professor Coales, who is 64 and a graduate of Sidney Sussex College, Cambridge, held various appointments in the Admiralty Department of Scientific Research and Experiment from 1929 until 1940 when he took charge of the development of naval gunnery radar. Six years later he became research director of Elliott Brothers Ltd where he stayed until his academic appointment at Cambridge.

R. H. Barker, Ph.D., F.I.E.E., deputy director of the Royal Armament Research and Development Establishment, is the 1971/2 chairman of the Control and Automation Division of the I.E.E. Dr. Barker, a physics graduate of University of Hull, joined Standard Telephones and Cables as a physicist in 1938 and from 1941 to 1954 worked at the Signals Experimental Establishment (later the Signals Research and Development Establishment). He was made assistant director, Ministry of Supply, with responsibilities for airborne radar, navigational aids, maritime devices and air communications in 1954. Three years later he became superintendent of research at the

Signals Research and Development Establishment and in 1959 was appointed deputy director of the Central Electricity Research Laboratory. Dr. Barker was technical director of R. B. Pullin & Company from 1962 until his appointment to his present position in 1965.

Peter E. Trier, M.A., M.I.E.R.E., director of Mullard Ltd, is the new chairman of the Electronics Division of the I.E.E. Mr. Trier, who is 52, graduated at Trinity Hall, Cambridge, and was on the staff of the Admiralty Signal and Research Establishment from 1941 until he joined the Mullard Research Laboratories in 1950. He became manager of the laboratories in 1953 and a director in 1957. His inaugural lecture, on October 20th, is on computeraided design in electronics.

R. M. Hill, Ph.D., F. Inst. P., who was at one time head of the Electronics Department at the Electrical Research Association, Leatherhead, and is now reader in physics at Chelsea College of Science and Technology, is to supervise an investigation being undertaken at the College on conduction mechanisms in thick films. The work, for which a grant of £18,000 (renewable annually over three years) has been made, is being carried out on behalf of the Ministry of Defence (Aviation

Supply). Dr. Hill, who is 38 and a graduate of the Royal College of Science and Technology, Glasgow, spent three years in Australia in the Commonwealth Scientific and Industrial Research Organisation and a further year as research fellow in the Clarendon Laboratory, Oxford, before joining the E.R.A. Electronics Department in 1962 as deputy head.

G. W. Mackenzie, M.I.E.R.E., has become chief engineer, B.B.C. Regions, in succession to J. D. MacEwan, B.Sc., F.I.E.E., M.I.E.R.E., A.Inst.P., who was recently appointed chief engineer, radio broadcasting. Mr Mackenzie joined the B.B.C. in 1941 and from 1954 until 1969 was on the staff of the Engineering Training Centre, latterly as head of technical operations section. Since September 1969, he has been in Northern Ireland, first as head of engineering and later head of programme services and engineering.

William A. Kinsman, F.I.E.E., is appointed managing director, Thorn Radio Valves & Tubes Ltd, and Thorn Colour Tubes Ltd. Until recently Mr. Kinsman was managing director of the Pressed Glass Division, Pilkington Brothers Ltd. At his own request, C. C. McCallum, who is 61, has relinquished the post of chief executive of both companies and will be retiring from full-time activities at the end of March 1972. After that, he will continue to serve on the boards in a part-time capacity. J. C. King, F.I.E.R.E., and G. P. Thwaites, B.Sc., F.I.E.E., F.I.E.R.E., have

been appointed to the board of Thorn Radio Valves & Tubes Ltd., and Mr King, who has been engineering manager (products development), assumes the responsibility of general manager.

Arthur E. Crump, who has contributed several articles to W.W., and A. G. Witts, B.Sc., have formed Custom Electronics (Poole) Ltd whose first product is a logic probe which can also be used as an analogue comparator and spike detector. Mr. Crump, who is managing director, was instrumentation manager at CETA Electronics and formerly principal engineer on remote control systems at Plessey Automation. Mr. Witts was also at CETA where he was responsible for design and production engineering, and previously was in the research laboratory of Plessey Automation.

E. Marland, F.I.E.E., has joined Dubilier Ltd as managing director in succession to J. H. Cotton, M.B.E., who has retired after over 40 years with the company. Mr. Marland was previously managing director A. H. Hunt (Capacitors) Ltd and a director of Erie Technological Products Ltd. The company has also announced the appointment of B. V. Sargent to the board as marketing director. He joined the company 14 months ago as marketing manager having previously held executive positions with Electrosil, M.E.C. and Plessey. The other members of the board, of which S. Soames became chairman earlier in the year on the retirement of F. J. Hurn, are R. Davidson, B.Sc., M.I.E.E., chief engineer and technical director, and G. W. Wilks.

# New from Ferrograph

# For the maintenance of professional recording equipment.

Now, for the first time, all the major parameters of a magnetic recording system can be measured on a single, inexpensive instrument. The Ferrograph RTS1 Recorder Test Set.

Consisting of 4 basic sections—variable frequency audio generator, millivoltmeter with associated attenuator, peak-to-peak wow and flutter meter, and distortion measuring network—this instrument will measure frequency response, distortion, crosstalk, erasure, input sensitivity, output power and signal/noise ratio.

Completely solid state and lightweight, it may be used in the field as well as the laboratory,

operating on voltages of 100-120, 200-250 volts at 50 or 60 hz.

It is developed specially for those people who have to operate, maintain or service all types of tape recorders, sound-on-film equipment and audio apparatus.

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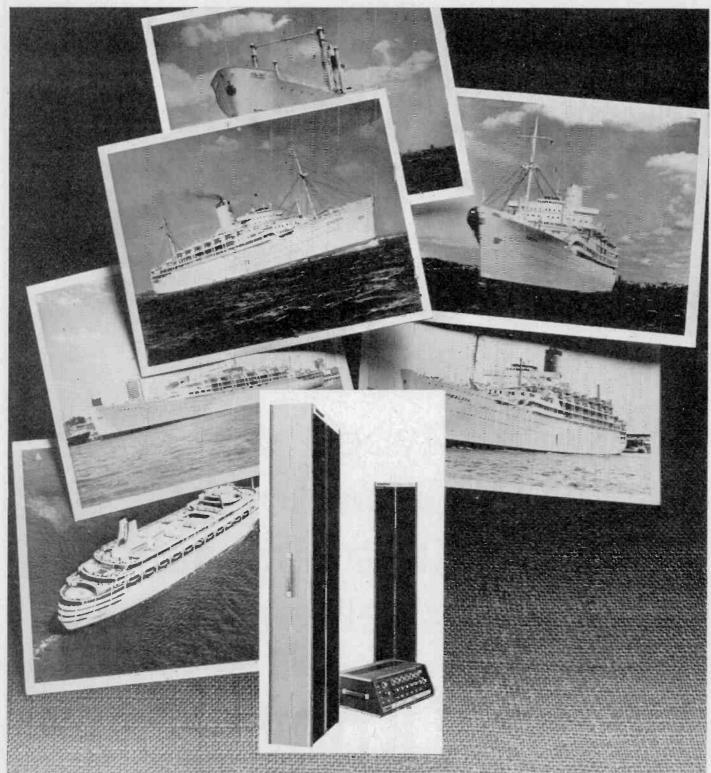
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## **New Products**

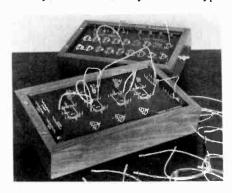
#### **CCTV** camera

A solid-state television camera for closed circuit operation is now available from the Industrial Imports Division of Dodwell & Co. It can be connected directly to a domestic television set which is then used as a monitor. Automatic light compensation for varying light levels between 50 and 8000 lux provides stable operation over the range of 50 to 500 lux minimum. Type 7735A vidicon used in the camera has a resolution of 500 lines, and random interlace scanning is provided. The output signal is composite video/r.f. modulated at 1.5V peak-to-peak into  $75\Omega$ . Horizontal frequency is 15.75Hz, and the vertical frequency 50/60Hz. Ambient operating range is 32° to 104°F. A 220V, 50/60Hz operating voltage is required with a power consumption of 12.5VA. Weight is 6.8lb and the dimensions are  $86 \times 241 \times 137$  mm. Price £101.90. A range of lenses is available. Remote control pan, tilt and zoom facilities can be provided. Viewing monitors are also available. Dodwell & Co. Ltd., Industrial Imports Division, 18 Finsbury Circus, London EC2M 7BE.

WW326 for further details

#### Logic tutors

A Combinational Logic Tutor from Limrose Electronics uses i.cs to provide a selection of AND, OR, NAND and NOR gates, together with input switches and output indicators, in a compact unit. Also new is the Sequential Logic Tutor designed for painless teaching of the principles of 'sequential' circuits such as binary and non-binary counters and shift registers. Both synchronous and asynchronous types



of sequential circuits can be constructed on this unit. The unit also uses integrated circuits and consists of a selection of J-K flip-flops, NAND gates, a low-speed clock unit and a manual pulse generator. The outputs of the flip-flops are permanently connected to logic indicator lamps to continuously monitor their logical states. In both units, all electronic components and integrated circuits are mounted behind the front panel. This results in a 'student-proof' design which cannot be easily damaged mechanically or electrically in normal usage. Prices from £23.50. Limrose Electronics Ltd, Lymm, Cheshire.

WW327 for further details

## Recorder with extra low tape speed

A multi-channel communications recorder which can record for 72 hours continuously on 31 separate channels simultaneously, is one of three new machines available from Pye TVT. Manufactured by Philips, the recorders are claimed to be the first to employ a standard tape speed of 15/32 i.p.s. Tape heads are of Ferroxcube, and there is a self-adjusting tape guide system. Three basic versions of the recorder are: (a) for 31 simultaneous channels on 1 intape; (b) for 15 simultaneous channels on  $\frac{1}{2}$  intape; and (c) for 7 simultaneous channels on  $\frac{1}{4}$  in tape.

Each version is fitted with twin tape decks. A third deck can be added to 15- and 31-channel installations. An edge track is used to record a time reference signal as well as a pilot signal. The complete installation is normally housed in a standard 19-inch rack and has lockable glass fronted doors. Pye TVT Ltd, Coldhams Lane, Cambridge CR13III

WW 324 for further details

#### Digital audio delay system

The Gotham Delta-T 101 digital audio delay system converts audio information into digital form, stores it in this state and retrieves it at some later time controlled by switches on the front panel. Since there is no decay of the digital data while in

storage, the delayed outputs maintain identical signal quality for all settings of the delay selector switches. The Delta-T101 is available as a single channel device, with the amount of time delay selectable in 5ms steps up to a maximum of 40ms. Additional plug-in output taps, up to a maximum of five, may be added at any time. Each of these will have its independent delay selection switches as well as a by-pass switch. Seven additional delay cards of 40ms each may also be plugged into the frame to bring the unit up to its maximum 320ms delay capability. Overall timing is controlled by a stable crystal oscillator. Integrated circuit operational amplifiers are used in the analogue portions of the unit. Except for the input and output transformers, direct coupled circuits are used with resultant intermodulation and harmonic distortion under 1%, even at maximum signal levels. Frequency response is 20Hz-12kHz ± 2dB. Power requirement: 115/ 230V, 50/60Hz (100W max.) Size: standard 19in rack panel, 7in high and 17in behind panel. Gotham Audio Corporation, 2 West 46th Street, New York, N.Y. 10036, U.S.A.

WW316 for further details

#### Heat conducting compound

Thermaflow 2001 from Jermyn can be applied as a thin film between a heat dissipating device and heat sink to reduce the thermal resistance by as much as 50%. Electrically non-conductive, the compound will withstand a temperature of 200°C for 24 hours with a volatility of only 1%. The



compound is available in disposable syringes containing 14g (A30S— $52\frac{1}{2}p$  each), and in jars containing 140g (A30J—£1.6 $2\frac{1}{2}p$ ). Jermyn Industries, Vestry Estate, Sevenoaks, Kent.

WW311 for further details

#### Tape noise reduction unit

The Dolby B tape hiss reduction system is now available from Kellar Electronics in the form of the KDB1 noise reduction unit. Its use as a record and replay tape signal processor results in 10% less tape hiss than the recorder would normally produce. This is achieved, it is claimed, without affecting frequency response or adding distortion. Such a system will make a large difference to cassette  $(1\frac{1}{8} \text{ i.p.s.})$  and  $3\frac{1}{4} \text{ i.p.s.}$  reel-to-reel machines when reproducing a wide



range of frequencies and dynamic levels. Inputs are 25 mV into  $20 \text{k} \Omega$  (record) and 25 mV into  $30 \text{k} \Omega$  (replay) for outputs of 580 mV. Channel separation is quoted as 50 dB at 1 kHz and s/n ratio (including hum) better than 70 dB referred to 580 mV unweighted. Operation is from the a.c. mains. Price £49.50. Kellar Electronics Ltd, 6 Bycullah Avenue, Enfield, Middlesex.

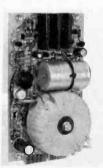
WW318 for further details

#### Miniature resistors

A range of carbon film resistors, type Rsx 00 intended for miniaturized equipment, is available from Steatite Insulations. Each resistor measures only 0.7mm dia.  $\times$  2.5mm long. Values are from  $10\Omega$ —4.7M $\Omega$ , with tolerances of  $\pm$  10% and  $\pm$  20%. Steatite Insulations Ltd, Hagley House, Hagley Road, Birmingham 16. WW317 for further details

## Power supply for logic circuits

IC100 miniature power supply from Coutant supplies an output adjustable between 5 and 6V at 1A. Over-voltage protection set at 6.8V is included, along with re-entrant circuitry for overload protection. Change in output is 0.02% for a  $\pm$ 10% input voltage change, and load regulation changes 0.1% (output voltage) for a no-load to full-load change. Ripple on the output is less than 1.5mV peak-to-peak and the unit operates over a temperature range of 0 to 55°C with a temperature coefficient of 0.03% change in output voltage for each °C change in ambient temperature. A.C. input is 100 to 132 or 200 to 264V. The unit measures 80  $\times$ 133





× 42mm. Connection to equipment is either by printed circuit edge connector or by 4mm fixing screws and soldered connections to turret lugs. Price is £14.50. Coutant Electronics Ltd, 3 Trafford Road, Reading RG1 8JR.

WW309 for further details

#### Swift digital tester

An 'in-house' need for a quick and simple means of testing logic circuit cards led to the design of this general purpose digital test set by the Test Systems Division of Honeywell. The equipment has its limitations and is mainly intended for tests on combinational circuits, but in certain circumstances sequential circuits can be accommodated. Testing is carried out by comparing a suspect circuit with a known good circuit. The 'master circuit' card is



plugged into a socket on the front panel. For 'one off' tests a patch panel is used to connect the d.c. power supplies and the test set outputs to the logic card inputs. All unspecified pins are assumed by the machine to be outputs. The suspect circuit card is plugged into a second socket on the front panel. The machine applies every possible binary combination to the card inputs and compares all the outputs of the two cards. If a difference occurs the sequence is stopped and a GaAs lamp display shows at which output pin an error was detected. The machine can be restarted if required whereupon it will cycle through the remaining tests. When a number of identical cards have to be tested, the patch cords can be replaced by a pre-wired plug which fits into a front panel socket. Cards to be tested can have up to 28 inputs and output fault patterns are indicated on a bank of 64 GaAs lamps. Various adaptors are available enabling different sized cards and single integrated circuits to be

tested. Tests are carried out at a rate of one per  $\mu$ s and input and outputs are 5V t.t.l. Price is £890. Honeywell Ltd, Test Systems Division, Eton Rd, Industrial Estate, Hemel Hempstead, Herts. WW301 for further details

#### Schottky barrier diode

Schottky barrier diode, type BAV46 from Mullard, has been developed for use in Doppler radar systems requiring a diode that has a low flicker noise at frequencies close to the carrier frequency, and a high conversion efficiency with or without d.c. bias when driven by low-level signals from the local oscillator. The overall noise figure is typically 10dB at 1kHz from the carrier frequency. Under typical operating conditions, forward current would be  $30\mu$ A and the r.f. level  $1\mu$ W at 9.375GHz. Its conversion efficiency is typically  $1\mu A/\mu W$ . When operated as a microwave video detector with a forward bias current of 50µA and a video amplifier bandwidth of 2MHz, the BAV46 has a tangential sensitivity of -52dB and X-band frequencies (7-12 GHz). The device can be mounted across an X-band waveguide. If required, it can be supplied with a reversible end collet, type 56321, that makes the diode then conform to the DO-22 outline. The encapsulation is hermetically sealed. The operating temperature range is -55 to +150°C. Mullard Ltd, Mullard House, Torrington Place, London W.C.1. WW308 for further details

#### Lightweight headset

A micro-miniature headset from Amplivox Communications, and called the Minilite, has an adjustable earphone housing which enables the user to receive incoming signals with the earphone unit resting lightly against the ear. The earphone housing is adjustable in all directions to enable the earphone to operate as a miniature speaker without physical contact. The housing rotates through 180° to enable the headset to be used on left or right ears. An acoustic tube-type microphone is used



which has telescopic adjustment for length, and also rotates for correct positioning near the mouth. The whole assembly is supplied complete with a new type of integral sliding headband. The headset can alternatively be mounted on spectacles. Weight with headband is 43.7g. Amplivox Communications Ltd., Beresford Avenue, Wembley, Middx, HAO 1RU.

WW333 for further details

## High performance 42-track data recorder

An instrumentation tape recording system from SE Labs, designated SE data Series 5000, employs an eight-speed bi-directional tape transport, with a low mass integral capstan/motor assembly in a phase-lock servo. Arms produce sufficient tape tension around the capstan to dispense with pinch-rollers. These arms also act as sensors for the positional servo system controlling supply and take-up motors. Record and reproduce data amplifiers are common to all configurations of the Series 5000. Direct and f.m. modules are interchangeable. The direct reproduce module accepts up to eight plug-in equalizers which are switched automatically when the tape speed is changed. The f.m. system operates without adjustment in I.R.I.G. low, intermediate and wideband group 1 modes with eight-speed automatic switching. Flat amplitude or optimum transient filter response is selected manually by the position of the plug-in filter with respect to its socket. The 42-track recording heads of the 5000C maintain intertrack spacing at 3.81cm +  $2.54\mu$ m  $(1.5000in \pm 0.0001in)$  and gap scatter 2.5 m (100 in). The basic price of the system is about £7,000. SE Laboratories (Engineering) Ltd, North Feltham Trading Estate, Feltham, Middx.

WW334 for further details

#### Reel-to-cassette duplicator

Series 235CS-1 reel-to-cassette duplicating system made by Telex, of Minneapolis, and available in the U.K. from Avcom Systems, comprises an open reel master transport and cassette slave modules. Frequency response is 30Hz -10kHz  $\pm 3dB$  at  $1\frac{7}{8}$  i.p.s, and t.h.d. less than 1% at 1kHz at '0' VU at  $7\frac{1}{2}$  i.p.s. Bias frequency is 300kHz. Wow and flutter is given as 0.25% r.m.s. Crosstalk rejection at 1kHz: half track, two-channel, 50dB; quarter track, twochannel, 30dB stereo channel separation: and quarter-track four-channel, 30dB stereo-channel separation, with 45dB for adjacent stereo programmes. Signalto-noise ratio is within 3dB of master tapes. All mechanical movements are solenoid controlled with operation from the master transport by momentary contact push buttons. Equalization for various combinations of tape speeds can be pre-set by clearly



identified controls. This system, with six slaves, will produce 84 C-30 cassettes per hour. A typical duplication station, with six slaves, is priced at £1,295. Avcom Systems Ltd, Newton Works, Stanlake Mews, Stanlake Villas, London W12 7HA.

WW 320 for further details

#### 25MHz storage oscilloscope

Oscilloscope type 2200 from Advance has a main frame with three operating modes: normal, with P31 phosphor; variable persistence; and store. A stored trace can be retained almost indefinitely and even displayed after the instrument has been switched off for a period. A range of plugin X and Y modules are available for this new main frame:—

OS2001Y Single trace unit.

OS2007Y Dual trace unit—with a sensitivity of 10mV/cm from d.c. to full bandwidth.

OS2004Y High gain differential unit—bandwidth d.c. to 2MHz—sensitivity 50uV/cm.

OS2001X X amplifier unit-for X-Y operation.

OS2003X Standard timebase unit.

OS2005AX Sweep delay unit-sweep speeds 19 ranges from 200ms/ cm to 40ns/cm.

OS2006X Wide range/delay timebase unit—sweep speeds in 23 ranges from 2s/cm to 20ns/cm in 1.2.5.

Advance Electronics Ltd, Raynham Road, Bishop's Stortford, Herts. WW312 for further details

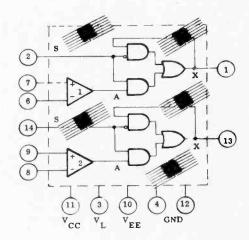
#### Range of trimmer pots

The Contelec T-84 series of single-turn, humidity-proof trimmers from Kynmore has a power rating of 0.5W at 70°C, with

an operating temperature range -55 to  $+150^{\circ}\mathrm{C}$ . Size is TO-5. The standard version of the series has a dial printed on the top of the case, and an arrow on the adjuster, giving the location of the wiper on the track. Contacts are of precious metal. Solder pins are nickel- and gold-plated. Stops are provided at each end of travel. Screwdriver adjustment provides the electrical settings. The resistance range is from  $10\Omega$  to  $20\mathrm{k}\Omega$ . Special resistance values and close tolerances are available to order. Kynmore Engineering Co. Ltd., 19 Buckingham Street, London W.C.2. WW 307 for further details

#### Dual voltage comparator f.e.t.

A high-speed (90ns delay) dual-channel voltage comparator f.e.t. type L132, for analogue-to-digital conversion, has been announced by Siliconix. The device comprises two isolated comparison channels, each with a separate strobed latch on the output. Each latch is a t.t.l. type circuit, capable of driving t.t.l. inputs. The latch can change state only when the strobe is raised to the 1 level. Amplifier



comparison input error is 2mV. Common mode range is  $\pm$ 5V. Typical input current is  $3\mu A$ , and differential input voltage 10V maximum. Supply current is 10mA maximum. The device is available as L132 CL in a TO-86 flat pack or L132 CK in a TO-116 dual in-line package. Siliconix Ltd., Saunders Way, Sketty, Swansea, SA28BA.

WW305 for further details

## Capacitance and inductance meters

Model C1, capacitance meter, available from Sintrom Europe, has a measuring range of 0 to  $30\mu F$  in twelve ranges. The ranges are in a 1-3-1 sequence with 100pF full scale as the lowest range. Nominal full-scale accuracy is 1%. The maximum voltage seen by the capacitor is 11V d.c.



Model L1, inductance meter (illustrated), has a measuring range of  $100\mu H$  to 100H in twelve ranges. Nominal accuracy is 1% for inductances with a Q greater than 10. The voltage across the inductor is 50mV to reduce errors due to core magnetization. The instruments, made by Russell Laboratories in the U.S.A., are available in the U.K. from Sintrom Europe Ltd, 2 Arkwright Road, Reading RGS OLS. WW304 for further details

#### Magnetic recording head

The Y28 recording head from Marriott Magnetics has been designed to meet the requirements of multi-track applications for use with standard recorded 8-track stereo cassettes. It has a rear plug suitable for interchangeable replacement with the standard of plug adopted in America. Outer dimensions of the head have also been standardized to facilitate interchangeability with other types. The head has a thick outer case of mumetal, and internal screening provides channel separation of 55dB. It is designed for a track width of 0.020in and is based on the X type using a · nickel-silver headface.



#### Specification:

Inductance at 1kHz 400mH  $\pm 20\%$  resistance (d.c.) 450 $\Omega$  impedance at 1kHz 2600 $\Omega$  track spacing, centre-centre 0.127in

Output from Ampex ref. type 01-31331-01 120 $\mu$ s (uncompensated) 500Hz (reference level) 0.55mV  $\pm$  2dB 1kHz (-10dB) 0.23mV  $\pm$  2dB 7.5kHz (-10dB) greater than + 1dB

The outputs of channel pairs are quoted as within 2dB of each other at any frequency in the range 100Hz to 7.5kHz.

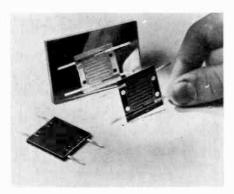
above 1kHz level

Output from own recording using 3M175 tape at  $3\frac{3}{4}$  i.p.s.

WW 319 for further details

#### U.H.F. quadrature coupler

The outputs of several devices may be combined, transmission continuity retained and mismatches isolated using the quadrature coupler type MIC 5830-31 3-dB from Motorola. Mismatch problems are overcome because the application of a reflected signal at either of the output ports of the coupler results in signals at the input port attenuated by 20dB. Insertion loss is as low as 0.25 to 0.30dB, phase balance ±1.5° to 3.0°, amplitude balance 0.5 to 0.7dB, and the v.s.w.r. is 1.2:1. Transmission capability is maintained should one of a number of combined output r.f. transistors fail. Usable frequency ranges are 225-



400MHz, and 450-512MHz. The stripline devices are  $31.8 \times 31.8 \times 3.6$ mm and are constructed from sealed fibreglass board. Price under £10 each. Motorola Semi-conductors Ltd, York House, Empire Way, Wembley, Middx.

WW 321 for further details

#### **Double balanced mixers**

Two sub-miniature double balanced mixers, types 1759 and 1760, from Hatfield Instruments occupy approximately one eighth of a cubic inch. The units can be used over the frequency range 100kHz to 500MHz (1759) and 10kHz to 150MHz (1760). Separate port earths are provided to reduce problems associated with common earth currents. Types 1759 and 1760 are priced at £19.80 each. Hatfield Instruments Ltd., Burrington Way, Plymouth, Devon. PL5 3LZ.

WW 303 for further details

#### Metal-oxide resistors

Metal-oxide films resistors, type WK, from Steatite Insulations are available horizontally or vertically preformed, with resistance values ranging from  $1\Omega$  to  $100 \mathrm{k}\Omega$ , with standard 2% and 5% tolerances. Temperature coefficients are either 200 or 400 p.p.m. Three body sizes are available: WK5, 6mm dia.  $\times$  16mm long; WK8, 9mm dia.  $\times$  20mm long; WK83, 9mm dia.  $\times$  32mm long. Power ratings at 70°C are 1.5, 4 and 6 W respectively. Steatite Insulations Ltd, Hagley House, Hagley Road, Birmingham, 16.

WW310 for further details

## Marine communication receiver

Receiver HR 600-601/602 manufacturered in America by National Radio Company is available in the U.K. from Ericsson Marine. The main frame of the receiver contains all the signal path circuits—from aerial inputs to line and speaker audio outputs, including aerial attenuator, slot filter assemblies, frequency converters, i.f. amplifiers, i.f. filters, a.m. and product detectors and audio amplifiers. The main frame also includes a frequency synthesizer for first mixer injection, a beat-frequency oscillator and can operate from 115-230V a.c. 47-420Hz. Two frequency-control plug-in units are available, and when augmented by one of these units, the receiver is capable of operating at any frequency between 10kHz and 30MHz in a.m., c.w., s.s.b. and f.s.k. modes. Crystal filter i.f. bandwidths are automatically matched to the reception mode selected. A wide range of accessories will be available. Ericsson Marine, Crown House, London Road, Morden, Surrey.

WW328 for further details

## World of Amateur Radio

#### Impact of integrated circuits

Amateurs in many parts of the world are now developing and describing constructional projects based on the use of linear and digital integrated circuits. One notes especially the wide use of the Plessey SL-600 series, the CA types (RCA) and the high-gain Motorola balanced mixer type MC1596G for communications receivers and compact transceivers. The advantages of the SL621 a.g.c. generator have crossed the Atlantic, and is used, for example, in a recent 3.5-MHz receiver described in Ham Radio by the Canadian amateur Paul Hrivnak, VE3ELP, in conjunction with such linear devices as the SL610 r.f. amplifier, the MC1596G and the General Electric PA237 a.f. amplifier plus discrete field-effect transistors for the oscillators.

Crystal calibrators and digital frequency meters are using digital t.t.l. devices including the popular SN7490N decade dividers. Digital logic is also being used in electronic keyers and automatic senders. Also attracting increasing attention are the sophisticated integrated-circuit phase-locked loop synchronous demodulators such as the Signetics NE561 and NE565 (M565N) devices. The CA302A is proving useful as a combined speech amplifier and balanced modulator for s.s.b. generation and also as a linear amplifier providing up to about 1W p.e.p. output to drive a valve power amplifier.

#### A case for more power?

One of Britain's leading h.f. long-distance operators, Dr John Allaway, G3FKM, recently voiced the growing feeling that the maximum power limits of the British amateur licence need to be up-dated.

Since 1946, except for occasional special tests, the power limits imposed on all British stations have been 150W d.c. input for c.w. or a.m. operation or 400W peak envelope power output for s.s.b. (A3A or A3J) on the majority of bands. Most amateurs would agree that these limits are, in themselves, reasonable (although it is puzzling why s.s.b. should be given more power than c.w.). These powers permit regular DX operation with or without high-gain beam aerials.

The present problem is that much amateur DX operating is of a competitive nature: the rarer contacts tend to go to the stations which can put the strongest signals into the distant country. In these circumstances, the top power permitted in other European countries becomes of importance to British amateurs-and, in this respect, there is little doubt that Dr Allaway has grounds for asking for the subject to be reconsidered. Looking through recent pages of my log book, I find that more and more high power operation is being permitted in Europe (the limit in North America has always been 1kW). I have worked West German c.w. stations using 250, 500 and 750W, Swedish stations up to 500W, Swiss 400W, Polish 250W, French 175W, Italian 300W, many Russians using 200W, while the operator of a Hungarian club station recently gave his power as 1kW.

It must be admitted that it is widely believed that a number of British stations are using more than their permitted power (these operators may not be pleased to learn that in some regions the Post Office has restarted routine inspections). Much of the popular factory-built equipment has to be 'throttled back' to get down to the British power limits. It would surely be better to issue licences for higher power than to tolerate some amateurs obtaining an advantage by disregarding the licence terms. So while the majority of British amateurs would be happy to continue with present limits if only other European amateurs were similarly restricted, there is likely to be a growing desire that Minpostel should look again at the power restrictions.

#### 70th anniversary of transatlantic radio

Plans are afoot to mark the 70th anniversary of the spanning of the Atlantic by Marconi (12th December 1901). These may include an international get-together of radio amateurs connected by history or location with the early days of radio. A special station, using the call VB1MSA, is reported to have begun operation in Newfoundland and is active on 3.5, 14 and 21 MHz. In this country, the event is

being organized by the Cornish Amateur Radio Club (in whose county the 1901 transmitter was set up), and among those who have promised support is the Derby society, which, as the country's oldest radio society, is planning to run a demonstration station during the weekend December 11-12.

## Death of a noted blind amateur

The death took place during August of a well known sightless amateur-James Illingworth, G3EPL, of St Bees, Cumberland. A former headmaster, he had held his licence for several years when, in 1956, he lost his sight. After only a short break he returned to his amateur operating and for many years has been a notable example of what can be done by the keen amateur to overcome physical handicaps, as well as encouraging other handicapped people to find satisfaction in this hobby. In 1963, Illingworth became the recipient of a Mullard Award, the citation for which recorded: "The courage which he has shown in overcoming his handicap has been a source of inspiration to amateurs everywhere. By his knowledgeable advice and persistent encouragement over the air, he has helped many other amateurs to modify and improve their own equipment."

#### In brief

A little-noted decision of the recent I.T.U. Geneva space conference (WARC-ST) may have a greater impact on amateur radio than the actual space allocationsthis was the overwhelming rejection of a proposal by Argentina to reduce from 144 to 50 MHz the frequency above which licences may be issued without a c.w. test. . . . There was a record attendance of some 2500 at the R.S.G.B. 1971 Mobile Rally at Woburn Abbey . . . . A joint entry by the Surrey Radio Contact Club and the Croydon R.S.G.B. group (stations G3BFP/P and G6LX/P) gained the overall victory in the 1971 National Field Day, runners-up being Norfolk Amateur Radio Club. Stockport Radio Society won the Bristol Trophy for the leading single-station entry. Altogether 118 local clubs and groups competed, an increase of 14 on 1970. . . . A 144 MHz station, G3UGF/MM, is regularly active from the East Coast coastal tanker, Esso Inverness. ... JY6RS is the station of the Royal Jordan Amateur Radio Society. . . . P. J. Smith, G3XJE, of Peterhouse, Cambridge, would welcome reports of long-delayed echoes (see 'W.o.A.R.' last month) as part of new Cambridge University research into this phenomenon. Reports should give delay period, strength of echo, date and time of observation, frequency of signal and any possible frequency shift of the echo. . . . The 70 MHz beacon station, ZB2VHF, at Gibraltar is again in operation and has been received in the U.K. . . . The prefix 8Q6 is now being used in the Maldive Islands.

PAT HAWKER, G3VA

## Circuit Ideas

## Variable astable multivibrator

The circuit was devised to fulfil the following requirements:

- (a) Square wave generation in the range 1-30Hz.
- (b) Operation from a 5V supply and t.t.l. compatibility.

To obtain a wide frequency variation the conventional timing resistors of a multi-

available and the rise time of both outputs when driving a single t.t.l. load was measured to be 25ns.

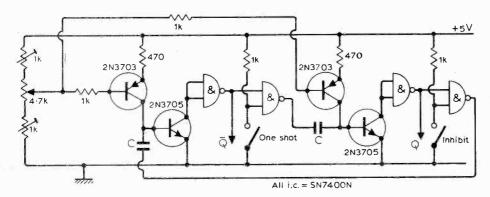
When the inhibit line is switched to earth the oscillator stops. If the single shot button is then pressed a single square wave is generated at the normal output only. If the single shot button is operated when the oscillator is running this merely produces an inhibit function.

None of the components is at all critical.

be a 20pF trimmer. An OA202 is used in place of a 'varactor'. An inverse polarizing voltage of 4V is about optimum and is obtained from a potential divider across the supply. To prevent shunting of v.h.f. voltages by the signal generator the modulating signal is applied to the diode via a 5µH miniature choke, and the collector end of the tuning circuit is connected to the diode by a capacitor of a value sufficiently small to 'block' currents at audio and somewhat higher frequencies. The components are mounted on a small piece of Veroboard having widely spaced strips of short length (to avoid undue self capacitance). This in turn is mounted on sheet aluminium bent to provide screening and to which earthy points are connected.

To check the functioning of the oscillator a low-voltage rectifier voltmeter, fitted with point contact diodes, may be connected through a small capacitor to a tapping on the tuning coil. Alteration of the collector/emitter capacitor will affect the amount of oscillation. Amplitude modulation may be achieved by applying the modulating voltage to the base of the transistor.

W. H. H. KELK, Farnborough, Hants.



vibrator were each replaced by a p-n-p transistor whose currents are controlled by the linear single gang potentiometer. It was found possible to get a frequency variation of 500:1 by this method. The pre-set resistors were adjusted to get the required frequency range of 1-30Hz. With this coverage the relationship between frequency and rotation of the potentiometer is virtually linear. The prototype would oscillate in any frequency band between 0.167Hz and 350kHz by choosing suitable values of capacitor. At 0.167Hz C= $33\mu$ F (tantalum) and at 350kHz C =5000pF. The upper limit could probably be appreciably increased by using fast switching transistors, and selecting components to suit them.

The second requirement was met by using a quad two-input NAND as a twin 360° inverter. This considerably reduced the rise and fall times and enabled the incorporation of inhibit and single shot facilities as described later. The n-p-n transistors acted as current sinks for the NANDS.

The circuit proved very satisfactory for symmetrical square waves and for mark-space ratios of up to 10:1. Normal (Q) and complementary  $(\overline{Q})$  outputs are

The supply should be 5V  $\pm$  0.5V and for maximum frequency stability should be stabilized.

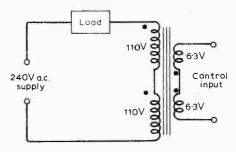
C. C. WARD, University of Exeter.

#### Simple v.h.f./f.m. oscillator

A 2N2926 yellow-spot transistor oscillates readily in the circuit shown. The tuning coil consists of four turns of 16 s.w.g. tinned copper wire and is 0.4in dia. by 0.4in long. The variable capacitor can

Variable power source using magnetic amplifier

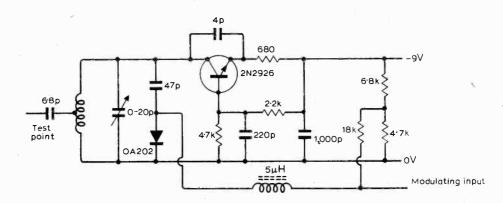
Two mains transformers with 110V taps can be connected in series and in phase on the mains side, and in series but out of phase on the l.t. side, to provide a variable voltage supply. The l.t. windings are fed



with a d.c. control of 1-3V, derived from a separate transformer. The amplifier can be used to supply a further transformer (as load) to provide a variable voltage supply. W. B. PICKLES,

St. Albans,

Herts.



## Literature Received

For further information on any item include the appropriate WW number on the reader reply card

#### **ACTIVE DEVICES**

A folder is available from Sintrom Electronics Ltd, 2 Arkwright Rd, Reading, Berks., which contains data on analogue-to-digital converters, a fast follow-and-hold amplifier, eight-channel multiplexers and a range of operational amplifiers all manufactured by the Dynamic Measurements Corp., of Massachusetts ...... WW401

British Brown-Boveri Ltd, Albany House, 41 High St, Brentford, Middlesex, have published a catalogue 

MCP Electronics Ltd, Alperton, Wembley, Middlesex HAO 4PE, have sent the following literature to us which describes products distributed by them:

BF377/378. Data sheet dealing with transistors manufactured by Telefunken intended to replace the BFY90. Static characteristics are identical but the gain bandwidth product is 1.3GHz at 5V and 25mA. The 800MHz noise factor at 5V and 2mA is 5.5dB (200MHz, 2dB) WW403 AHY10A/B. Data sheet for a germanium magnetic field sensitive diode for control applica-

BP300. Data and application information on a microelectronic two-pole active filter manufactured by TRW of America (f = 0.1 Hz to 2kHz; Q = 1 to 200, stability =  $\pm 0.005\%$ °C) ... WW406

MV/MX Series (TRW). Hybrid v.h.f. and u.h.f. power microcircuits with outputs from 0.75 to

Microsystems International Ltd, 1 Great Cumberland Place, London W1H 7AL, have produced a shortform catalogue which lists operational amplifiers, m.o.s. memories and zener diodes ......... WW408

GDS (Sales) Ltd, Michaelmas House, Salt Hill, Bath Rd, Slough, Bucks., have supplied us with data on two high-voltage avalanche rectifiers (S80HT1A and S100HT1A) manufactured by Westinghouse. (8 and 10kV at 1A at 25°C derating to 0.55A at 70°C, 50 to 400Hz, overload capability 

#### PASSIVE COMPONENTS

Home Radio (Components) Ltd, 240 London Rd, Mitcham, Surrey, CR4 3HD, have published a new edition of their catalogue (the seventh) which contains 311 pages and lists a wide range of components and equipment mainly intended for the home constructor ..... price 50p

We have received the following leaflets from GDS (Sales) Ltd, Michaelmas House, Salt Hill, Bath Rd, Slough, Bucks.:

Res	istors	 	 	 	 	WW413
	Resistor					
Keysw	ritch relays	 	 	 	 	WW412
	tone die-cas					
	n trimmers					

Pye TMC Ltd, Components Division, Roper Rd, Canterbury, Kent, have published a leaflet describing a range of illuminated push-button switches which 

Catalogue 102 from Cambion Electronic Products Ltd, Cambion Works, Castleton, Nr. Sheffield S30 2WR, lists solder terminals, r.f. chokes and 

Henry's Radio Ltd, Edgware Rd, London W.2, have published the tenth edition of their catalogue. It contains 352 pages and gives details of electronic components, communications equipment and devices for producing electronic music and lighting price 40p

New product bulletin 671DL/1U available from Special Products Distributors Ltd, 81 Piccadilly, London W1V 0HL, describes a range of magnetic 

Pye TMC Ltd, Capacitor Division, Oldmedow Rd, Hardwick Trading Estate, King's Lynn, Norfolk, have a leaflet available which describes extended foil 

An eight-page booklet gives the NATO stock numbers of oxide resistors to BS9111-N-002. Electrosil Ltd, Pallion, Sunderland, Co. Durham, 

The components stocked by Lugton & Co. Ltd, Radio House, 209-212 Tottenham Court Rd, London W1A 2BN, are listed in the short-form catalogue of the Industrial Division ...... WW420

The August/November catalogue of RS Components (formerly Radiospares), P.O. Box 427, 13-17 Epworth St, London EC2P 2HA, is avail-

Handles, locks, catches, hinges, feet, ventilation rings, lifting eyes, castors, clips and other parts for equipment cabinets are described in the 'Handles and Accessories' catalogue from Imhof-Bedco, Colne Way Trading Estate, By-Pass, Watford, Herts WD2 4NE ...... WW422

The Components Division of Ferranti Ltd, Dunsinane Ave, Dundee DD2 3PN, have supplied us with two

Radar systems components ...... WW423 Communications components .......... WW424

We have obtained a great deal of literature from FR Electronics, Wimborne, Dorset BH21 2BJ:

Reed switch catalogue (contains some useful Reed switch accessories (coils and magnets) ..... WW427 Logcell data sheets. Very small mercury wetted

relays available as basic switches or in monostable, latching, non-latching, i.c. compatible, coaxial, dual-in-line packaged and high-speed 'Pinlite' catalogue. Alphanumeric and other

Solid-state relays capable of handling up to 7A manufactured by Darpan Controls Ltd, Bridge Mills, Derby Rd, Long Eaton, Nottingham NG10 4QA, are the subject of a catalogue. They are 

Miniature incandescent lamps manufactured in Germany by Micro Gluhlampen Gesellschaft are described in a catalogue obtainable from H. F. Collison-Goodwell Ltd, Coleshill, Birmingham 

#### APPLICATION NOTES

Information sheet No. 209 from Integrated Photomatrix Ltd, The Grove Trading Estate, Dorchester, Dorset, describes how a dual-ramp digital panel voltmeter can be made using only four i.cs and a number of discrete components. Range and accuracy is 0 to 1.999V (positive or negative)  $\pm 0.1\% \pm 1$ digit. The range can of course be extended using 

A Multicore Solders leaflet (Bulletin P.C.1) which describes batch printed circuit soldering techniques is available from GDS (Sales) Ltd, Michaelmas House, Salt Hill, Bath Rd, Slough, Bucks. ..... WW435

A paper, 'The versatility of the h.r.c. fuse in protecting semiconductor equipments' by J. Feenan, may be obtained from English Electric Fusegear Ltd, East Lancashire Rd, Liverpool L10 5HB ... WW436

The National Research Development Council, Kingsgate House, 66-74 Victoria St, London S.W.1, have sent us details of some patent applications:

41470/68. Band-pass filter sets ........ WW437 51137/69. Low-noise tachometer generator 56771/70. Out-of-circuit d.c. ammeter ... WW439 52193/69. A novel cycloconverter ..... WW440

#### **EQUIPMENT**

We have received literature describing an audio equalizer which has a lift/cut control for each octave from 20 to 20,480Hz (10 in all) intended for matching audio systems to room conditions. Stereo versions are available. Soundcraftsmen, 1320 E. Wakeham Ave, Santa Ana, California 92705, U.S.A. ...... WW443

The Quickdraw Company Ltd, 10 Beechdale, Winchmore Hill, London N.21, have produced a new protractor head for technical drawing which is 

An American welder which electrically disassociates oxygen and hydrogen from distilled water and then uses these gases to produce a flame with a temperature of at least 3,316°C is described in a leaflet. The welder has to be connected to a mains power supply. The smallest model runs for twelve hours on 0.8 pints of water. Details from Special Product Distributors Ltd, 81 Piccadilly, London W1V 0HL ..... WW445

#### GENERAL INFORMATION

'Catalog No. C13.10:350. Time and frequency: A bibliography of NBS literature published July 1955— Dec. 1970' published by the American National Bureau of Standards may be obtained from: Super-intendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, U.S.A. price (inc. p & p) U.S. \$0.69

'About Patents' is a free booklet which describes the information retrieval services provided by the Patent Office. The Sales Branch, The Patent Office, Orpington, Kent BR5 3RD.

A 1971/72 prospectus may be obtained from The Registrar (Admissions), Cranfield Institute of Technology, Cranfield, Bedford.

The work of the National Economic Development Council (Neddy) and the 16 Economic Development Committees (Little Neddies) is described in a booklet 'What is Neddy?'. An associated catalogue 'Neddy in Print' gives a list of Neddy publications. Publications Dispatch, National Economic Development Office, Millbank Tower, Millbank, London SW1P 40X.

'Approach and landing at Heathrow—a layman's guide' has been published by BEA and International Aeradio Ltd. It is a folder containing charts and explanatory matter which describes airline landing procedures, 'stacking', radio beacons, 'talkdowns', taxi-ing and parking at Heathrow. It is available from V. Windett, International Aeradio Ltd, Hayes Rd, Southall, Middlesex .....price 60p

# Real and Imaginary

by "Vector"

## **Initial Suggestions**

Periodically (if you will forgive the pun) the newspaper world experiences a silly season when nothing much seems to be happening and editors have to scrape the bottom of the barrel. At such times photographs tend to become larger and what is left of the sheet is filled with banner headlines.

The problem is much more acute for the hapless contributor to an electronics journal, for he has to grapple with an industry which has a perpetual silly season. At this particular moment, for example, nothing much is happening except that the Almighty Dollar has flipped to sabotage our export market, the Japs are hypnotizing our home market into committing hari-kiri and our microcircuit industry has fallen flat on its expensively-lithographed epitaxial (as predicted on this page in March 1967, though it gives me no joy to say so). Not to mention the circumstance that the Labour Exchange now has a decided leer on its stucco'd countenance whenever we steal past it.

In short, in the immortal words of the poet who wrote 'over the wire the message came, he is not better, he is much the same", the electronics industry is ticking over pretty much as usual and company chairmen with ruin staring them in the face are staring back and buying yet another estate in the Bahamas. So, upon the well-known precedent of fiddling while Rome is burning I thought I might do worse than pass away the time by setting you a quiz on the same general lines as those by L. Ibbotson which used to appear in W.W. under the heading "Test Your Knowledge". So here, without further ado, it is:—

- (1) What is AVRO?
  - (a) A well-known multi-tester?
  - (b) A famous name in aviation?
  - (c) An estate agent's contraction for "average-sized-room"?
- (2) What is MELEX?
  - (a) A poultry food?
  - (b) A Chinaman telling us his name is Rex?
  - (c) A luncheon voucher for executives?
- (3) What is ILMAC?
  - (a) A Sassenach asking a Scotsman if he's under the weather?
  - (b) A waterproof coat for invalids?
  - (c) A brand of throat sweets?

- (4) What is/are SEMINEX?
  - (a) A new method of family planning?
  - (b) The Old Boys' Association of a school of theology?
  - (c) a breed of short-necked giraffes?
- (5) What is SICOB?
  - (a) A method of expressing the energy of a horse in S.I. units?
  - (b) A mentally deranged male swan?
  - (c) A computer language?
- (6) What is INTERNAVEX?
  - (a) An international trade union for belly dancers?
  - (b) The medical term for solar plexus?
  - (c) A NATO Navy Week?

If you haven't had much luck so far, perhaps you might care to try the following for size:—IMAS, IMEX, EMCON, EASCON, INTER/NEPCON—come on that lad at the back, put some effort into it! All right then, I'll hand it to you on a plate with WESCON and EUROCON. No, Einstein Minor, the last-mentioned is not an organization dedicated to conning Britain into the Common Market. Full marks to all the others for twigging that these are all exhibitions, congresses, conventions, seminars or symposia. Incidentally, I have yet to find out the actual difference between events bearing the latter four titles.

This is the in-cult of the acronym to which the trendy boys in the exhibitions world have latched on. Bourgeois reactionaries may complain that these titles are not only meaningless but in some cases downright misleading, and enquire bitterly whether an electronics engineer must not equip himself with a crystal ball to find out that MELEX is the Manchester Electronics Exhibition. Such carping critics may count themselves lucky that they live in a tolerant democracy and not in an area where Luddite opposition to progress is short-circuited to the saltmines.

Personally, my only complaint is that the notion is rather arriére-garde and dated, for acronyms have been with us for a long time now. Couldn't the organizers of exhibitions and conferences take a leaf out of the book of those other natural disasters, hurricanes, and use given names for their functions? It would somehow make the thing so much more personal if we could

go to an exhibition called Frieda or Janice or Laureen. Then if the organizers were fortunate enough to catch the ear of the Editor on one of his better days they might persuade him to publish a key in, say, the January issue or the Diary, so that even such an arrested mental development as mine could effect a translation.

But of course even this is not the real McCoy (whoever he was). It was our own Post Office which was courageous enough to provide us with a clear directive by ditching those emotive telephone exchange names (and what fantasies could be woven concerning the girl operators at Bluebell. Cherrywood or Virginia?). But where was I? Oh yes-when they discarded those exchanges and paid us the compliment of expecting us to memorize a gaggle of tendigit numbers. That was sheer good thinking on the part of some anonymous soul at the Ministry of Incomprehensibility and it behoves us one and all to benefit by example.

So, why not go the whole hog and sling out all these out-moded acronyms in favour of transistor-type codification? At the same time the electronics manufacturers should be urged to discard their trade names in favour of allocated serial numbers. Just think of the time saving effected by mentioning to a colleague that you were off to visit 123SE2095 instead of having to say 'I'm going to take a butcher's at the Semiconductor and Allied Technologies Seminar and Exhibition'. That's what I'd call Progress with a capital 'P'.

Even this need be only a halfway house toward the ultimate goal of scrapping the decimal system in favour of binary and digitizing not only exhibitions but everything else-railway stations, airports, striptease shows, Labour Exchanges—the lot. With all these in binary code stupendous new electronics markets would be opened up for portable back-pack computers for the general public who cannot be relied upon to recall, off-hand, that 1011101011 is Euston station. On a larger canvas the approach would give useful employment for all those highly expensive computers which the larger business houses have been conned into buying and which now serve no more useful function than providing rest homes for aged and infirm spiders.





# High fidelity Monolithic Integrated Circuit Amplifier

Two years ago Sinclair Radionics announced the World's first monolithic integrated circuit Hi-Fi amplifier, the IC.10. Now we are delighted to be able to introduce its successor, the Super IC.12. This 22 transistor unit has all the virtues of the original IC.10 plus the following advantages:

- 1. Higher power.
- 2. Fewer external components.
- 3. Lower quiescent consumption.
- 4. Compatible with Project 60 modules
- 5. Specially designed built-in heat nink. No other heat sink needed.
- Full output into 3, 4, 5 or 8 onms.
- 7. Works on any voltage from 6 to 28 volts
- NEW 22 transistor circuit.

available to all Sinclair customers.

without adjustment. SINCLAIR GENERAL GUARANTEE

Sinclain General. GUARANTEE
Should you not be completely satisfield with your purchase when you receive it from us, return the goods without delay and your money will be refunded in full, including cost of return postage, at once and without question. Full service facilities are available to all Singleir outstands.

Output power 6 watts RMS continuous (12 watts peak).

Frequency Response 5 Hz to 100KHz  $\pm$ 

Total Harmonic Distortion Less than 1%. (Typical 0.1%) at all output powers and all frequencies in the audio band.

Load Impedance 3 to 15 ohms.

Power Gain 90dB (1,000,000,000 times) after feedback.

Supply Voltage 6 to 28 volts (Sinclair PZ-5 or PZ-6 power supplies ideal).

Size 22 x 45 x 28 mm including pins and heat sink.

Input Impedance 250 Kohms nominal.

Quiescent current 8mA at 28 volts.

With the addition of only a very few external resistors and capacitors the Super IC.12 makes a complete high fidelity audio amplifier suitable for use with pick-up, F.M. tuner etc. Alternatively, for more elaborate systems, modules in the Project-60 range such as the Stereo 60 and A.F.U. may be added. The comprehensive manual supplied with each unit gives full circuit and wiring diagrams for a large number of applications in addition to high fidelity. These include car radios, oscillators etc. The very low quiescent consumption makes the Super IC.12 ideal for battery operation.



Price, inc. FREE printed circuit board for mounting.

Sinclair Radionics Ltd, London Rd, St. Ives Huntingdonshire PE17 4HJ Telephone St Ives (048 06) 4311

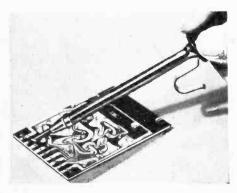


# Sinclair Project 60

## The World's leading range of high fidelity modules

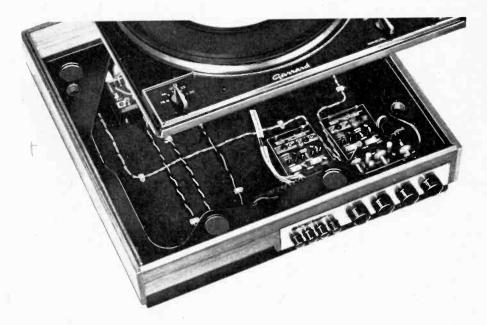






Sinclair Radionics Limited, London Road, St. Ives, Huntingdonshire PE17 4HJ. Tel: St. Ives (048 06) 4311





Project 60 offers more advantage to the constructor and user of high fidelity equipment than any other system in the world.

Performance characteristics are so good they hold their own with any other available system irrespective of price or size.

Project 60 modules are more versatile — using them you can have anything from a simple record player or car radio amplifier to a sophisticated and powerful stereo tuner-amplifier. Either power amplifier can be used in a wide variety of applications as well as high fidelity. The Stereo 60 pre-amplifier control unit may also be used with any other power amplifier system, as can the AFU filter unit. The stereo FM tuner operates on the unique phase lock loop principle to provide the best ever standards of sensitivity and audio quality. Project 60 modules are very easily connected together by following the 48 page manual supplied free with all Project 60 equipment. The modules are great space savers too and are sold individually boxed in distinctive white and black cartons. With all these wonderful advantages, there remains the most attractive of all — price. When you choose Project 60 you know you are going to get the best high fidelity in the world, yet thanks to Sinclair's vast manufacturing resources (the largest in Europe) prices are fantastically low and everything you buy is covered by the famous Sinclair guarantee of reliability and satisfaction.

System	The Units to use	together with	Cost of Units £4.48	
Simple battery record player	Z.30	Crystal P.U., 12V battery volume control		
Mains powered record player	Z.30, PZ.5	Crystal or ceramic P.U. volume control etc.	£9.45	
20 + 20 W. stereo amplifier for most needs	2 x Z.30s, Stereo 60, PZ.5	Crystal, ceramic or mag. P.U., F.M. Tuner, etc.	£23.90	
20 + 20 W. stereo amplifier with high performance spkrs.	2 x Z.30s, Stereo 60, PZ.6	High quality ceramic or magnetic P.U., F.M. Tuner, Tape Deck, etc.	£26.90	
40 + 40 W. R.M.S. de-luxe stereo amplifier	2 x Z.50s, Stereo 60 PZ.8, mains trsfrmr	As above	£34.88	
Indoor P.A. Z.50, PZ.8, ma transformer		Mic., guitar, speakers, etc., controls	£19.43	

## from a simple amplifier to a complete stereo tuner amplifier with Project 60 modules

#### Z.30 & Z.50 power amplifiers



The Z.30 and Z.50 are of advanced design using silicon epitaxial planar transistors to achieve unsurpassed standards of performance. Total harmonic distortion is an incredibly low 0.02% at full output and all lower outputs. Whether you use Z.30 or Z.50 amplifiers in your Project 60 system will depend on personal preference, but they are the same size and may be used with other units in the Project 60 range equally well.

#### SPECIFICATIONS (2.50 units are interchangeable with Z.30s in all applications)

Changeable With 2.50s in an applications).

Power Outputs

Z.30 15 watts R.M.S. into 8 ohms using 35 volts:

20 watts R.M.S. into 3 ohms using 30 volts.

Z.50 40 watts R.M.S. into 3 ohms using 40 volts:

30 watts R.M.S. into 8 ohms using 50 volts.

Frequency response: 30 to 300,000Hz±1dB. Distortion: 0.02% into 8 ohms.

Signal to noise ratio: better than 70dB unweighted. Input sensitivity: 250mV into 100 Kohms. For speakers from 3 to 15 ohms impedance.
Size: 14 x 80 x 57 mm.

Z.30

Built, tested and guaranteed with circuits and instructions manual. £4.48

Built, tested and guaranteed with circuits and instructions manual. £5.48

## Project 60 Stereo F.M. Tuner





First in the world to use the phase lock loop principle

The phase lock loop principle was used for receiving signals from space craft because of its vastly improved signal to noise ratio. Now, Sinclair have applied the principle to an F.M. tuner with fantastically good results. Other original features include varicap diode tuning, printed circuit coils, an I.C. in the specially designed stereo decoder and squelch circuit for silent tuning between stations. Good reception is possible in difficult areas, and often a few inches of wire are enough for an aerial. In terms of a high fidelity this tuner has a lower level of distortion than any other tuner we know. Stereo broadcasts are received automatically as the tuning control is rotated, a panel indicator lighting up as the stereo signal is tuned in. This tuner can also be used to advantage with any other high fidelity system.

SPECIFICATIONS—Number of transistors: 16 plus 20 in I.C. Tuning range: 87.5 to 108 MHz. Capture ratio: 1.5dB. Sensitivity:  $2\mu V$  for 30dB quieting:  $7\mu V$  for full limiting. Squelch level:  $20\mu V$ . A.F.C. range:  $\pm 200$  KHz. Signal to noise ratio: > 65dB. Audio frequency response: 10 Hz - 15 KHz ( $\pm 1\text{dB}$ ). Total harmonic distortion: 0.15% for 30% modulation. Stereo decoder operating level:  $2\mu V$ . Cross talk: 40dB. Output voltage:  $2 \times 150\text{mV}$  R.M.S. Operating voltage: 25-30 VDC. Indicators: Mains on; Stereo on; tuning. Size:  $93 \times 40 \times 207 \text{ mm}$ Size: 93 x 40 x 207 mm.

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## Stereo 60 Pre-amp/control unit



Designed for Project 60 range but suitable for use with any high quality power amplifier. Again silicon epitaxial planar transistors are used throughout, achieving a really high signal-to-noise ratio and excellent tracking between channels. Input selection is by means of push buttons and accurate equalisation is provided for all the usual inputs.

SPECIFICATIONS-Input sensitivities: Radio - up to 3mV. Mag. p.u. 3mV: correct to R.I.A.A curve ±1dB:20 to 25,000 Hz. Ceramic p.u.-up to 3mV: Aux-up to 3mV. Output: 250mV. Signal to noise ratio: better than 70dB. Channel matching: within 1dB. Tone controls: TREBLE + 15 to —15dB at 10 KHz: BASS + 15 to —15dB at 100Hz. Front panel: brushed aluminium with black knobs and controls. Size: 66 x 40 x 207mm.

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## Power Supply

Designed special for use with the Project 60 system of your choice. Use PZ.5 for normal Z.30 assemblies and PZ.6 where a stabilised supply is essential.

PZ.5 30 volts unstabilised £4.98 PZ.635 volts stabilised £7.98 PZ.8 45 volts stabilised (less mains transformer) £7.98 PZ.8 mains transformer £5.98



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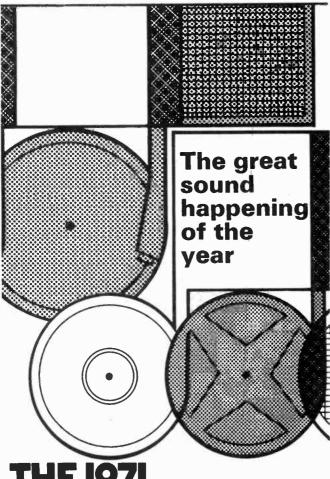
## A.F.U. High & Low Pass Filter Unit



For use between Stereo 60 unit and two Z.30s or Z.50s, and is easily mounted. It is unique in that the cut-off frequencies are continuously variable, and as attenuation in the rejected band is rapid (12dB/octave), there is less

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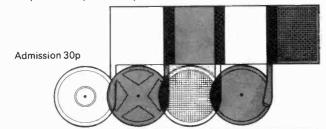
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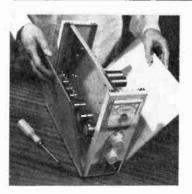
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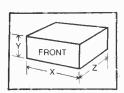


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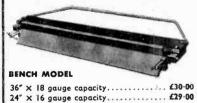
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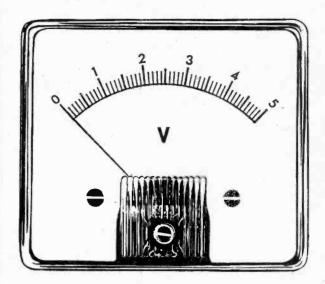
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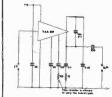
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٠	Type IN4001		47 b	 	 	P.I.V. 50	1-100 7p	100+ 6p	1000+
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page ea., £3:30 per doz. 1,250μF 25v. 1" dia. × 2", 50p ea., £4:50 per doz.

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DY86	0.30	EF40	0.50	PCF200	0.77
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DY802	0.48	EF80	0.25	PCF801	0.48
E88CC/01	1.80	EF83	0.55	PCF802 PCF805	0.72
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ECC83	0.30	EL86	0.40	PL83	0.42
ECC84	0.30	EL90	0.35		
ECC85	0.40	EL95	0.35	PL84	0.35
ECC86	0.50	EL500	0.85	PL500	0.73
ECC88	0.37	EM31	0.25	PL504	0.75
ECC189	0.52	EM80	0.40	PY 33	0.60
ECF80	0.35	EM84	0.35	PY80	0.35
ECF82	0.35	EM87	0.55	PY81	0.27
	0.75	EY51	0.40		0.27
ECF83		EY86	0.35	PY82	
ECF801	0.62	EY81	0.35	PY83	0.35
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ECH35	0.60	EZ41	0.42	PY800	0.52
ECH42	0.65	EZ80 EZ81	0.25	PY801	0.52
ECH81	0.28	GZ34	0.52	QQVO	-
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A5	0.20	OC29	0.62	IN21	0.17	2N5109	2.05	AF127	0.17	CR81/30	0.40
A10	0.25	OC35	0.50	1N21B	0.25	40362	0.62	AF139	0.30	CR81/35	0.43
A70	0.10	OC38	0.42	1N25	0.60	82303	0.50	AF178	0.48	CR81/40	0.48
A71	0.10	OC44	0.17	1N43	0.10	3F100	0.62	AF186	0.40	CR83/05	0.3
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A79		OC71	0.15	1N823A	1.30	3N139	1.75	ABY28	0.25	CR825/02	
(6D15)	0.10	OC72	0.25	IN 4785	0.50	3N140	0.97	A8Y67	0.48		0.7
A81	0.10	OC73	0.30	1ZMT5	0.35	3N154	0.95	BAW19	0.28	CR83/40	0.5
A91	0.07	OC75	0.25	1ZMT10	0.33	3N159	1.45	BC107	0.12	GET103	0.2
A200	0.07	OC76	0.25	1ZT5	0.67	6FR5	0.45	BC108	0.12	GET115	0.4
A202	0.10	OC81	0.25	1ZT10	0.63	12FR60	0.73	BC113	0.25	GET116	0.5
A210	0.25	OC81D	0.20			10D1	0.16	BC118	0.38	GEX66	1.0
A211	0.37	OC81DM	0.20	2G385	0.51	40954	1 37	BCY72	0.15	NKT222	0.2
DAZ200	0.55	OC82	0.25	2G403	0.51	40595	1.37	BF115	0.25	NKT304	0.5
AZ201	0.50	OC82DM	0.30	2N918	0.37	40636	1.45	BF173	0.30	@D918	0.2
AZ202	to	OC83	0.25	2N1304	0.25	40668	1.35	BFY51	0.20	8D928	0.3
AZ206	0.42	OC83B	0.15	2N1306	0.25	40669	1.45	BFY52	0.23	8 D938	0.3
AZ207	0-47	OC84	0.25	2N1307	0.25	AC126	0.25	B805	0.38	8D94	0.2
AZ208	to	OC122	0.50			AC127	0.25	BS	0.45	BD988	0.4
DAZ213	0-32	OC139	0.25	2N2147	0.75	AC128	0.25	B82	0.47	V405A	0.4
AZ223	to	OC140	0.37	2N2904A	0.32	AC176	0.25	BSY29	0.25		
AZ225	0.50	OC170	0.25	2N 3053	0.25	ACY17	0.30	BU100	1.80	ZENER	
OC16	0.50	OC171	0.30	2N3054	0.50	ACY28	0.17	BYZ13	0.25	DIODE	S
C22	0.50	OC172	0.37	2N3055	0.75	AD149	0.50	BYZ16	0.83		
C25	0.37	OC200	0.40			AD161	0.37			All prefe	erred
C26	0.25	OC201	0.60	2N3730	0.50	AO162	0.37	CRS1/10	0.25	volta	ge
C28	0.62	OC206	0.90	2N3731	2.75	AF118	0.62	CR81/20	0.38	1W	0.1
			-							iw	0.2
		YOTHE								1.5W	0.8
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0.17	30C17	0.80	6064	0.45
0.35	30C18	0.75	6065	0.65
0.27	30 <b>F</b> 5	0.84	6080	1.37
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0.32	30FL12 30FL13	0.92	8020 9001	2·25 0·20
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0.32	30L17	0.80	9004	0.15
0.45	30P12	0.80	9006	0.15
0.85	30P19	0.80		
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0.40 6BR7

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6F33 6H6M 6J4WA 6J5 6J5GT 6J6 6J7G

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1.50

0.20 0.75

0.56

0.32

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BP 00 = 7400	Quad. 2-input NAND Gate	15p	14p	12:
$BP \ 01 = 7401$	Quad. 2-input Pos. NAND Gate (with open collector output)	15.	14p	12:
BP 02 = 7402	open collector output)	15p 15p	14p	12:
BP 03 = 7403	Quad. 2-input Pos. NAND Gates (with		140	1~.
	open collector output)	15p 15p	14p	121
BP 04 = 7404		15p	14p	10.
BP 05 = 7405	Hex Inverter (with open-collector output) Triple 3-input Pos. NAND Gates Dual 4-input Schmitt Tripger	15p	14p	121
BP 10 = 7410	Triple 3-input Pos. NAND Gates	15p	14p	121
BP 13 = 7413	Dual 4 input Box NAND Coton	29p	26p	241
BP 30 = 7420	Dual 4-input Behmitt Trigger Dual 4-input Pos. NAND Gates 8-input Pos. NAND Gates Dual 4-input Pos. NAND Buffers BCD to declinal nixie driver	15p	14p 14p	12p 12p
BP 40 = 7440	Dual 4-input Pos. NAND Buffers	15p 15p	14p	12
BP 41 = 7441	BCD to declinal nixie driver	67p	64p	587
BP 42 = 7442	BCD to decimal decoder (4-10 lines, 1 of			
	10) ,,	67p	64p	58p
$BP \ 46 = 7446$	BCD-to-Seven-Segment Decoder Driver	£2.00	£1.75	£1.50
BP 47 = 7447	BCD-7-Seg. Decoder/Drivers (15-V out-	0 M-	0.4-	
DD 10 - 7110	puts) BCD-to-Seven-Segment decoder Driver.	97p	94p	88p
BP 50 = 7450	Expandable dual 2 Input AND-OR-	97p	A4Th	
DI 50 - 1450	INVERT	15p	14p	12r
BP 51 = 7451	Dual 2-Wide 2-Input NAND-OR-	100	7.47	120
	INVERT Gates	15p	14p	12p
BP 53 = 7453	Quad 2 Input Expandable NAND-OR- INVERT			
	INVERT	15p	14p	12p
BP 54 = 7454	4-Wide 2-Input NAND-OR-INVERT			
DD 00 5400	4-Wide 2-Input NAND-OR-INVERT Gates Dual 4-Input Expander Single-Phase J-K Flip-Flop Master-Slave J-K Flip-Flop Dual Master-Slave J-K Flip-Flop Dual D Type Flip-Flop Quad Latch Dual J-K with Pre-Set & Clear Gated Full Adders 16-Bit Read-Wright Memory 2-Bit Binary Full Adders Quad Vall Adders Quad 2-Input Excl. Nor Gates BCD Decader Counter 8-Bit Shirt Registers Divide-by-Twelve Counters 4-Bit Binary Counternt Register 4-Bit Up-Down Shirt Register 5-Bit Parallel in Parallel out Shirt-Register 8-Bit Bistable Latches Single J-K Flip-Flop equiv. 9000 Series Single J-K Flip-Flop Edet Shirt-Register Latches Master-Slave Flip-Flops Dual Data Lock-out Flip-Flop Hex Set-Reset Latches Hex Set-Reset Latches 24 pin Monostable Multivibrators BCD-to-Decimal Decoder/Driver BCD-to-Decimal Decoder/Driver BCD-to-Decimal Decoder/Driver BCD-to-Decimal Decoder/Driver BCD-to-Decimal Decoder/Driver	15p	14p	12p 12p 24p
BU 70 = 7470	Pingle Phase L.K. Flip Flor	15P	14p	120
BP 79 = 7470	Master-Slave J.K Flin-Flon	299	26p 26p	241 241
BP 73 = 7472	Dual Master Slave J. K Flin-Flor	375	35p	32p
BP 74 = 7474	Dual D Type Flip-Flop	37n	35p	32p
BP $75 = 7475$	Quad Latch	47p	35p 45p	42p
BP 76 = 7476	Dual J-K with Pre-Set & Clear	43p	40p	38p
BP 80 = 7480	Gated Full Adders	87p	64p	58p
BP 81 = 7481	16-Bit Read-Wright Memory	97p	94p	881
BP 82 = 7482	2-Bit Binary Full Adders	97p	94p	881
BP 83 = 7483	Quad Full Adder	£1.10	£1.05	951
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BP 93 = 7493	4-Bit Binary Counters	67p	64p	580
BP 94 = 7494	Dual Entry 4 Bit Shift Register	77p	74p	681
BP 95 = 7495	4 Bit Up-Down Shift Register	77p	74p	68p
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BP121 = 74121	Monostable Multivibrators	67p	64p	£1·10 58p
BP141 = 74141	BCD-to-Decimal Decoder/Driver	67p	64p	58p
BP145 = 74145	BCD-to-Decimal Decoder/Driver. O/C	£1 50	£1.40	£1:30 £1:60
BP150 = 74150	16-Bit Data Selectors (with strobe) 16-Bit Data Selectors (with strobe) 10ual 4-Line-to-1-Line Data 4 to 16 Line Decoder 10ual 2 to 4 Line Decoder 10ual 2 to 4 Line Decoder 20ual 2 to 4 Line Decoder 2	£1.80	£1.70	#I.60
BP153 = 74151	Duel 4-Line-to-L-Line Data	\$1.00	950	90p
BP154 = 74154	4 to 16 Line Decoder	£1.80	£1.70 £1.70 £1.30	95p
BP155 = 74155	Dual 2 to 4 Line Decoder	£1.40	£1 30	£1.60 £1.20 £1.20
BP156 = 74156	Dual 2 to 4 Line Decoder O/C	£1 40	£1.30	£1.20
BP160 = 74160	Sync. Decade Counter	£1 80	£1.70	£1 60
BP161 = 74161	Sync. 4-Bit Binary Counter	£1 80	£1.70 £1.70 £1.70	£1.60
BP190 = 74190	Sync. Up-Down BCD Counter	£3.50	£3.25	£3.00
BP191 = 74191	Sync. Binary Up-Down Counter (single			
DD100 #	clock line)  8 Sync. Up-Down Decade Counter  8 Sync. Binary Up-Down Counter (tow	£3 50 £2 10	£3 50	£3.50
BP102 = 74192	Sync. Up-Down Decade Counter	£2·10	£1 95	£1.75
DL193 = 14193	clock lines)	29.10	£1.95	21.75
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BP197 = 74197	clock lines) Pre-setable 50 MHZ Decade Counter Pre-setable 50MHZ Binary Counter 8-Bit Parallel L-R Shift Register	£1.80	£1 70	£1 60
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	PAK No.		PAK No.		PAK No.	
,,,,	$UIC00 = 12 \times 2$	7400N 50p	$UIC42 = 5 \times$	7450N 50	0p  UIC80 = 5	× 7480N 50p
	$UIC01 = 12 \times 3$	7401N 50p	$UIC50 = 12 \times$	7450N 50	Op UIC82 = $5$	× 7482N 50p
	$UIC02 = 12 \times 3$	7402N 50p	$UIC51 = 12 \times$	7451N 50		× 7483N 50p
	$UIC03 = 12 \times 3$	7403N 50p	$UIC60 = 12 \times$	7460N 50	0p UIC86 = 5	× 7486N 50p
	$UIC04 = 12 \times 2$	7404N 50p	$U1C70 = 8 \times$	7470N 50	$0p \ \ UIC90 = 5$	× 7490N 50p
	$UIC05 = 12 \times 7$	7495N 50p	UIC72 = 8 ×	7472N 50	Op UIC92 = 5	× 7492N 50p
	$UIC10 = 12 \times 7$	7410N 50p	$UIC73 = 8 \times$	7473N 50	Op UIC93 = 5	× 7493N 50p
	$UIC20 = 12 \times 3$	7420N 50p	$UIC74 = 8 \times$	7474N 50	Op UIC94 = $5$	× 7494N 50p
	$U1C40 = 12 \times 3$	7440N 50p	$UIC75 = 8 \times$	7475N 50	Op UIC95 = 5	× 7495 N 50p
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	- 1 - 757 111				
Туре				Price	
No.	Function		1-24	25-99	100 up
BP930	Expandable dual 4-input NAND	414	12p	11p	100
BP932	Expandable dual 4-input NAND buffer		13p	120	īli
BP933	Dual 4-input expander		13p	120	ĨĨ
BP935	Expandable Hex Inverter		13p	120	ĨĨp
BP936	Hex Inverter		13p	120	110
BP944	Dual 4-input NAND expandable buffer wi	ithout			~~.
	pull-up	4.0	13p	120	11p
BP945	Master-slave JK or RS		25p	24p	22
BP946	Quad, 2-input NAND		12p	11p	100
BP948	Master-slave JK or RS	4.0	25p	24p	22p
BP951	Monostable		65p	6Cp	55p
BP962	Triple 3-input NAND		12p	11p	100
BP9093	Dual Master-slave JK with separate clock		40p	38p	351
BP9094	Dual Master-slave JK with separate clock		40p	38p	35p
BP9097	Dual Master-slave JK with Common Clock	ς	40p	38p	35p
BP9099	Dual Master-slave JK Common Clock	4.4	40p	38p	35
Devices	may be mixed to qualify for quantity p	price. La	rger qua		
	application, (DTL 930 Seri				

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Pack	Qty.	per Description P	rice
No.		k Dedeset to DVD	
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Q 3	4	OC 77 type trans.	50p 50p
Q 4	6	OC 77 type trans Matched trans. OC44/45/81/81I	50p
Q 5	4	OC 75 transistors OC 72 transistors	50p
Q 6	4	OC 72 transistors	
Q 7	4	AC 128 trans. P.N.P. high gain	50p
0 9	7	OC 81 type trans	50p 50p
Q10	7	OC 71 type trans	50p
Qιί	2	AC 128 trans. P.N.P. high gain AC 126 trans. P.N.P. OC 81 type trans. OC 71 type trans. AC 127/128 Comp. pairs PNP/ NPN	50p
Q12	3	AF 116 type trans. AF 117 type trans. OC 171 H.F. type trans. 2N2926 Sil. Epoxy trans.	50p
Q13	3	AF 117 type trans	50p
Q14 Q15	3 5	OC 171 H.F. type trans.	50p
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Q17	3	NPN 1 8T141 & 2 8T140	50p
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Q19	3	Madt's 2 MAT 101 & 1 MAT 121	
Q20	4	OC 44 Germ, trans. A.F.	50p
Q21	3	OC 44 Germ. trans. A.F. AC 127 NPN Germ. trans	50p
Q22	20	NKT trans. A.F. R.F. coded	50p
Q23	10	OA202 Sil. diodes sub-min	50p
Q24	8	OA 81 diodes IN914 Sil, diodes 75PIV 75mA	50p
Q25 Q26	8	OA95 Germ. diodes sub-min.	50p
Q27	2	IN69 10A 600PIV Sil. Rects. 18425R	50p
Q28	/ 2	Sil. power rects RVZ 13	50p 50p
Q29	4	Sil. trans. 2 × 2N696, 1 × 2N697, I × 2N698	50p
Q30	7	Sil. switch trans, 2N706 NPN	50p
Q31	6	Sil. switch trans, 2N706 NPN Sil. switch trans, 2N708 NPN	50p
Q32	3	PNP 8il. trans. 2 × 2N1131, 1 × 2N1132	50p
Q33	3	8il. NPN trans. 2N1711	50p
Q34	7	Sil. NPN trans. 2N2369, 500MHZ	50p
<b>Q</b> 35	3	Sil. NPP TO-5 2 × 2N2904 & 1 × 2N295	50p
Q36	7	2N3646 TO-18 plastic 300MHZ NPN	50p
Q37	3	2N3053 NPN Sil. trans	50p
Q38	7	PNP trans. 4 × 2N3703. 3 ×	50p
Q39	7	2N3702 NPN trans. 4 × 2N3704, 3 ×	50p
Q40	7	2N3705 NPN amp, 4 × 2N3707, 3 ×	50p
		2N3708	50p
Q41 Q42	3 6	Plastic NPN TO-18 2N3904	50p
Q43	7	NPN trans. 2N5172 BC 107 NPN trans	50p
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Q45	3	BC 113 NPN TO 18 tmns	50р 50р
Q46	3	BC 113 NPN TO-18 trans BC 115 NPN TO-5 trans	50p
Q47	6	NPN high gain 3 × BC167, 3 × BC168	50p
Q48	4	BCY70 PNP trans. TO-18	50p
Q49	4	NPN trans. 2 × BFY51, 2 × BFY52	50p
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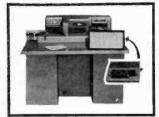
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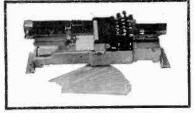
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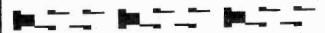
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50-0-50μΑ 100μΑ	£3·10 £3·10	1
100-0-100μA	£3·10	٤
200μA	£2.871 £2.75	1
500-0-500μA	£2.60	ŧ
1mA 1.0-1mA	£2.60 £2.60	
5mA	£2.60	1

	22.60
	22.60
	22.60
500mA £	2.60
1 amp 1	22-60
5 amp 1	2 60
15 amp \$	2.60
	2.60
	2.60
50V. D.C 4	2.60
	2 60
	22.60
	22.60
	2.60
8 Meter lmA	2.87
	E3-60
	2.60
	£2 60
	£2.60
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	2.60
30 amp. A.C. *	CE 00

Туре	MR.52P.	lin. square fronts	
50μΑ	£3·10	10V. D.C	£2.00
50-0-50µA	£2.60	20V. D.C	£2.00
100μΑ	£2.60	50V. D.C	£2.00
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10mA	£2.00	VU Meter	£3·10
50mA	£2.00	l amp. A.C.*	£2.00
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5 amp	£2.00	1 30 amp. A.C.	22'00
Type M	R.65P. 31	in. × 31 in. front	
50μA 50-0-50μΔ 100μA 100-0-100μA 200μA 5000-500μA 1mA 5mA 10mA 50mA 10mA 50mA 1 amp 5 amp 10 amp	£3:371 £2:75 £2:75 £2:60 £2:60 £2:371 £2:10 £2:10 £2:10 £2:10 £2:10 £2:10 £2:10 £2:10 £2:10 £2:10	10V. D.C. 20V. D.C. 50V. D.C. 180V. D.C. 100V. D.C. 15V. A.C. 50V. A.C. 150V. A.C. 500V. A.C. 8 Meter 1mA VU Meter 100mA A.C. 200mA A.C. 200mA A.C.	£2·10 £2·10 £2·10 £2·10 £2·10 £2·10 £2·10 £2·10 £2·10 £2·10 £2·37‡ £3·37‡ £2·10 £2·10 £2·10 £2·10 £2·10 £2·10
15 amp	£2:10 £2:10 £2:10 £2:37‡ £2:10	1 amp. A.C.* 5 amp. A.C.* 10 amp. A.C.* 20 amp. A.C.* 30 amp. A.C.*	£2:10 £2:10 £2:10 £2:10 £2:10

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5μA )μA )-0-50μA )00μA )00-100μA )0μA )0μA )0-1mA )mA )0mA )0mA	£3·50 £2·37} £2·25 £2·25 £2·25 £2·25 £2·25 £1·75 £1·75 £1·75 £1·75	30V. A.C 50V. A.C 50V. A.C 50V. A.C 500MA A.C 500mA A.C 5 amp. A.C 10 amp. A.C 20 amp. A.C 50 amp. A.C VU Meter .	£1.75

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2N2369 17p 2N2369A 17p	2N4287 17p 2N4288 15p	AF127 16p AF139 28p	BF185 20p BF194 17p	MJE521 87p MPF102 42p	OC204 40p OC205 75p	60				
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2N2905A 30p 2N2906 20p	2N5176 45p	ASY54 25p ASY67 45p	BFW91 20p BFX12 22p	NKT212 30p NKT213 30p	TIS43 40p TIS44 12p	40				
2N2906A 25p 2N2907 23p	2N5245 45p 2N5246 42p	ASY86 32p ASZ21 37p	BFX13 22p BFX29 25p	NKT214 22p NKT215 22p	TIS45 12p TIS46 12p	40				
2N2923 15p 2N2924 15p	2N5249 67p 2N5265 £3.25	AUY10 £1.50 BC107 10p	BFX30 25p BFX37 30p	NKT216 37p	TIS47 12p					
2N2925 15p 2N2926G 12p	2N5305 37p	BC108 10p BC109 10p	BFX 44 37p BFX 68 67p	NKT217 40p NKT219 30p	TIS48 12p TIS49 12p					
2N2926O 12p 2N2926Y 12p	2N5307 37p 2N5308 37p	BC113 15p BC114 15p	BFX84 25p BFX85 32p	NKT223 27p NKT224 22p	TIS50 17p TIS51 12p	10				
2N3011 24p 2N3014 25p	2N5310 42p	BC115 15p BC116 15p	BFX86 25p BFX87 25p	NKT225 22p NKT229 30p	TIS52 12p	20				
2N3053 20p 2N3054 49p	2N5354 27p 2N5355 27p	BC116A 30p BC118 15p	BFX88 20p BFX89 62p	NKT237 35p	XB112 12p	86				
2N3055 72p 2N3133 25p	2N5356 32p 2N5365 47p	BC119 35p BC121 20p	BFX93A 70p BFY11 42p	NKT238 25p NKT240 27p	XC141 35p ZTX107 14p	10				
2N3134 30p 2N3135 25p	2N5367 57p	BC122 20p BC125 15p	BFY18 25p BFY19 25p	NKT241 27p NKT242 20p	ZTX108 11p ZTX109 17p	-				
2N3136 25p 2N3390 25p	2N5457 34p 2N5458 35p	BC126 25p BC134 15p	BFY21 42p BFY24 45p BFY29 40p	N KT243 62p	ZTX300 11p	11				
2N3391 20p 2N3391A 30p	2N5459 48p 28102 25p	BC135 15p BC136 15p	BFY30 40p	NKT244 17p NKT245 20p	ZTX301 17p ZTX302 18p	11				
2N3392 17p 2N3393 15p	28103 25p 28104 25p	BC137 15p BC138 37p	BFY41 50p BFY43 62p BFY50 22p	NKT261 20p NKT262 30p	ZTX303 18p ZTX304 25p	A				
2N3394 15p 2N3402 22p	28301 47p 28302 47p	BC140 35p BC141 35p BC147 15p	BFY51 20p BFY52 22p	NKT264 20p NKT271 20p	ZTX500 16p	A A A				
2N3403 22p 2N3404 32p 2N3405 45p	28304 72p	BC147 15p BC148 11p BC149 15p	BFY53 17p BFY56A 57p	NKT272 20p	ZTX501 16p ZTX502 20p	B				
2N3414 22p	28502 35p	BC152 17p	BFY76 42p BFY77 57p	NKT274 20p NKT275 20p	ZTX503 17p ZTX504 40p	B				
2N3415 22p 2N3416 27p 2N3417 37p	28503 27p 3N83 40p 2N129 70p	BC153 35p BC154 35p BC157 15p	BFY90 65p	NKT278 25p	ZTX531 28p	B				
2N3417 37p 2N3439 £1.30 2N3440 97p	3N128 70p 3N140 77p	BC157 15p BC158 15p BC159 15p		TRIAGO		B				
2N3440 97p 2N3564 17p 2N3565 15p	3N141 72p 3N142 55p 3N143 67p	BC169 15p BC160 35p BC167 15p	8C 35A 100PIV	TRIACS 3A 90p 8C 45A	100PIV 10A £1.25	B				
2N3566 22p 2N3568 25p	3N152 87p	BC168B 14p BC168C 15p	8C 35B 200PIV 8C 35D 400PIV	3A 95p SC 45B 3A £1.00 SC 45D	200PIV 10A £1.35 400PIV 10A £1.50 100PIV 15A £1.65	-				
2N3569 25p 2N3570 £1.25	40050 55p 40250 50p	BC169B 14p BC169C 15n	8C 40A 100PIV 8C 40B 200PIV	6A £1 20 SC 50B	200PIV 15A \$1.75	P				
2N3572 97p 2N3605 27p	40251 32p	BC170 12p BC171 15p	8C 40D 400PIV	6A £1.25 SC 50D ST2 DIACS 16p	400PIV 15A £2.00	1 4				
21110 2119						5.				

TRIACS								
3C 35A 100PIV 3A 90p 3C 35B 200PIV 3A 95p 3C 35D 400PIV 3A £1.00 3C 40A 100PIV 6A £1.00 3C 40B 200PIV 6A £1.20 3C 40D 400PIV 6A £1.25	8C 45A 100PIV 10A £1·25 8C 45B 200PIV 10A £1·35 8C 45D 400PIV 10A £1·50 8C 50A 100PIV 15A £1·65 8C 50B 200PIV 15A £1·75 8C 50J 400PIV 15A £2·75							
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BRID	GE RECTI	FIERS	6 6
PLASTIC 600 PIV 1A 50 PIV 2A 100 PIV 2A 200 PIV 2A 400 PIV 2A 50 PIV 4A 100 PIV 4A	50p 200 55p 400 60p 50 80p 200 60p 400 70p	ULATED PIV 4A 75p PIV 4A 80p PIV 6A 62p PIV 6A 75p PIV 6A 85p PIV 6A 21·10	6 6 6 6 6 6 1
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4001 50PIV 4002 100PIV 4003 200PIV 4004 400PIV 4005 600PIV 4006 800PIV 4007 1000PIV 50+ les	IN Series 1 1 amp 8p 9p 10p 10p 12p 15p 20p	PL Series CL Series  1 · 5 amp	1 1 1 1 1 1 1 1 1 2 2
SILIC	ON RECT	IFIERS TING	2 2 2 2
100PIV 200PIV 400PIV 600PIV 800PIV 1000PIV	6A 10A 	17.5A 35A 50p £1.22 55p £1.42 62p £1.77 72p £2.12 87p £2.47 *1.05 £2.77	2 2 2
DIODE 1N34A 10p	DAIR! 15	CTIFIERS p GJ7M 37p	2
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AZ13	10p	BY100	15p	OA47	7p
AZ15	12p	BY103	22p	OA70	7p
AZ17	12p	BY122	37p	OA73	10p
3A100	15p	BY124	15p	OA79	9p
3A102	22p	BY126	15p	OA81	7p
3A110	32p	BY127	17p	OA85	7p
SAI11	27p	BY164	57p	OA90	7p
3A112	70p	BY210	35p	OA91	7p
3A115	7p	BYZ11	32p	OA95	7p
3A141	32p	BYZ12	30p	OA200	7p
3A142	32p	BYZ13	25p	OA202	10p
3A144	12p	BYZ16	40p	OA210	17p
3A145	20p	FST3/4	22p		
		THYRI	STOR	s	
IV	50	100	200	300	400
	25p	27p	37p	40p	47 p
	-	47p	55p	57p	77p
A	_	55p	65p	_	75p
A		55p	65p		97p
F	REDP			SINK	
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W 2"		22p	4W 4		37p
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OA2 OB2	38p	25 <b>Z</b> 4	30n	EL95	35p
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6AK6 6AL5	30p 57p 20p	50C5 80	40p 50p	PC97 PC900 PCC84	481
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6AU6 6AV6 6BA6	30p	AZ31 CY31	50n	PCF80 PCF82	30r 34p 50r
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6BH6 6BJ6	45p 45p	DAF96 DF91	42p 25p	PCF800 PCF801	801
6BQ7A 6BR7	40p	DF96	42n	PCF802 PCF805	501 501 751
6BR8	85p 65p	DK91 DK92	35p 50p	PCFS06	751 701
6BW6 6BW7	85p 70p	DK96 DL92	42p 35p	PCF808 PCL82	70 r 75 r 85 r
6BZ6	35p	DL94	45p	PCL83	
6C4 6CD6 6CL6	33p \$1.15	DL96 DM70 DY86	42p 32p	PCL84 PCL85	45 p 40 p
6CL6 6CQ4	50p 63p	DY86 DY87	33p 35p	PCL86	45; 70; 55;
6CQ4 6F1 6F6G	63p 62p 30p	E88CC E180F	65p 95p	PFL200 PL36 PL81	551 501
6F13 6F14	38n	EABC80	25n	PL82 PL83	45 r 45 r
6F15	65p 65p	EAF42 EB91	35p 20p	PLRA	45 r 40 r
6F18 6F23	45p 80p	FRC41	55p 30p	PL500	40; 75; 80;
6H6	20p	EBC81 EBF80	40p	PY32 PY33 PY80 PY81	551
6J4 6J5	50p 20p	EBF83 EBF89	40p 32p	PY 33 PY 80	551 631 351 301 301 381 401
6J5GT 6J6	30n	EBL21 EC86	60p 60p	PY81 PY82 PY83	30g 30g
6J7 6K8G	20p 45p 35p	EC88 ECC40	60p 60p	PY83	381
6L6GT	45p	ECC84 ECC85	30p	PY88 PY800 PY801	501
6LD20 6Q7 6SA7	40p 40p	ECC88	60p 40p	U25	501 751 751 321 331
68A7 68G7	40p 35p	ECF80 ECF82	35p 35p	U26 U50	75g 32g
68LT7	40p 35p	ECF86 ECH21 ECH35	65p 57p	U52 U191	33 <sub>1</sub> 75 <sub>1</sub>
68K7 68L7	35p	ECH35	60p	11281	401 401
68N7 68Q7	35p 40p	ECH42 ECH81 ECH83	70p 30p	U282 U301	401 401
6V6G	60p 25p	ECH83 ECL80	40p 40p	111801	#1.00
6V6G 6V6GT 6X4 6X5G 6X5GT	32p 30p	ECL80 ECL82 ECL83	35 p 65 p	UABC80 UAF42 UBC41	55
6X5G	30p 27p	ECL86 EF37A EF39	40p	UBC81 UBF80	55) 50) 40) 40) 35) 49)
	50p	EF3/A EF39	60p 40p	UBF89	40) 35)
10F1 10P13 10P14	90p 55p	EF40 EF41	50p 65p	UCC84 UCC85	491
10P14	£1.10	EF42 EF80	70p 25p	I IIICESO	401 551
12AT6 12AT7 12AU7	30p 30p	EF85	35p	UCH21 UCH42 UCH81	60 <sub>1</sub>
12AU7 12AX7	30p 30p	EF86 EF89 EF91	30p 28p	UCH81 UCL82	351 351
12AX7 12AV6 12BA6	30p 33p 35p	EF91 EF92	33p 40p	UCL82 UCL83 UF41	601 601
12BE6 12BH7	35p	EF183 EF184	30p	UF80	351
19AQ5	40p 35p	EH90	35p 40p	UF85	401
20D1 20F2	45p 75p	EL34 EL33	50p £1.25	UF89 UL41	35) 65)
20L1 20P1		EL41	55p 58p	UL84	301
20P3	50p 60p	EL42 EL81	55p	UY41 UY85	45 <sub>1</sub>
20P4 20P5	£1.10 £1.20	EL84 EL85	25p 43p	VR105/3	30 38
25L6	45p	EL91 i 12p in £	32p	VR150/S	30 35
		NER D	IODI		
400 M 3 3 3 3 3	W	1.5 watt	/olt	10 wa 3-9-100	tt Volt
3-3-33 15p ea	ich I	20n each		25p ea	
	25 + le	88 15%;	100+1	ess 20%	

A	dd 12p in s	for postag	e
7	ENER	DIODES	
400 MW	1.5 wat		10 watt
3 3-33 Volt	2.4-100		3-9-100 Volt
15p each 25 +	20p eac less 15%;	h     100 + less	25p each 20%
2N 3055	75p	AF239	37p
25 ±	62p	25+	32p
100+	50p	100+	28p
		500+	25p
		1000 +	20p
BC113	15p	BC148	11p
25 ÷	13p	25 +	9p
100 ÷	12p	100+	8p
500 +	10p	500+	7p
1000+	8p	1000+	6р
BYZ13	25p	BC168C	15p
25 +	20p	25+	12p
100+	17p	100+	10p
500 +	15p	500+	8p
1000+	13p	1000+	6p
BC107/8/9	10p	BC169C	15p
$25 \pm$	9p	25 +	121
100+	8p	100+	101
500 +	7p	500+	81
1000+	вр	1000+	61
OC71	12p	AD161/2	
25 +	10p	25+	301
100+	9p	100+	251
500+	8p	500 +	221
1000+	7p	1000+	201
OC72	12p	BF194	171
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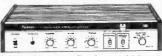


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CA3001	2.69 2.40	CA3050 1.84 1.6		1·46 4·37	SN7405 0.48	0.45	8N74111	1.57 1.45	FJH141 0.871	243 1.50
CA3002	1.80 1.60	CA3051 1:34 1:2		2.27	SN7427 0-48	0.45	SN74118	1.30 1.25	FJH161 0.871	263 0.771
CA3004	1.80 1.60	CA3052 1 65 1 4		1.07	8N7428 0-80	0.75	SN74119	1.92 1.80	FJH171 0.91	293 0.97
CA3005	1.17 1.05	CA3053 0-46 0-4		1.07	9N7430 0.23	0.21	8N74121	0.50 0.47	FJH221 0-874	300 1.75
CA3006	2.80 2.50	CA3054 1 09 0 9		1.00	8N7432 0.48	0.45	8N74122	1.44 1.35		310 1.25
CA3007	2.63 2.34	CA3055 2·40 2·1	3 CA3076 1-30	1.16	8N7433 0-80 8N7437 0-64	0.75	8N74123 8N74145	2·85 2·70 1·80 1·75	FJ.J101 1-371	320 0.721
CA3008 CA3008A	1.80 1.60 2.96 2.64	1			8N7438 0-64	0.60	8N74150	3.52 3.40	FJJ121 1.871	350 1.75 435 1.474
CA3010	1.37 1.23	MOTOROLA			8N7440 0-23	0.21	8N74151	1.40 1.35	FJJ141 3-121	521 1.324
CA3010A	2.53 2.25		ast range of Motorola I.C	.8. at	8N7441AN 0-87	0.83	8N74153	1.40 1.35	FJJ191 1.87}	522 3.60
CA3011	0.74 0.65	industrial distributor pr			8N7442 0.85	0.81	8N74154	2.20 2.10	FJJ251 3-121	530 4·95
CA3012	0.89 0.79	£	# PLESSEY		8N7443 2-86	2.70	8N74155	1.68 1.60	FJY101 0.80	570 1.97 L
CA3013	1.05 0.94	MC717 0.66 MC		£	8N7444 2-86 8N7445 2-50	2·70 2·40	SN74156	1.68 1.60 1.92 1.82		811 4.45
CA3014	1.24 1.10		1463 6-52 1466 4-44 SL403D	2.13	8N7446 1.00	0.95	BN 74157 BN 74160	1.80 1.75	MULLARD DTL #	TAB101 0-971 TAD100 1-971
CA3015 CA3015A	2·09 1·86 3·40 3·03		1469 2.97 SL610C		8N7447 1.00	0.95	SN74161	2.60 2.55		TAD100 1-974 TAD110 1-974
CA3016	2.46 2.19		1590 0.00	1.70	8N7448 1-00	0.95	BN74162	4.26 4.10	FCH101 0-87	TABILO 1979
CA3016A	3.73 3.33	MC790 1.29 MC	1533 6-60 SLOTIC	1.70	8N7449 1-00	0.95	BN74163	4.26 4.10	FCH121 1.05	OWNER A V
CA3018	0.84 0.75		1545 4.53 SL612C	1.70	8N7450 0-20	0.18	BN74164	2.20 2.10	FCH161 1.05	GENERAL ELECTRIC £
CA3018A	1.10 0.99		1550 0.59 8L620C	2.60	8N7451 0-20	0.18	8N74165	2.25 2.15	FCH201 1-324	PA222 2-60
CA3019	0.84 0.75		1670 9.19 SL621C	2.60	8N7453 0-20 8N7454 0-20	0·18 0·18	8N74166 SN74167	4·45 4·20 6·40 6·10	FCH231 1.50	PA230 1.40
CA3020 CA3020A	1.26 1.13 1.60 1.43		3060 2.76 BL630C	1.63	8N7460 0-20	0.18	8N74170	4.38 4.18	FCJ101 1.62}	PA234 0.92
CA3020A	1.56 1.39		C4000 1.05 8L640C	3.10	8N7470 0-40	0.38	8N74174	2.40 2.30	FCJ111 1:55	PA237 2-10
CA3022	1.30 1.16	MC1302 2.70 MF	C4010 1.00 8L641C	3.10	8N7472 0-32	0.30	SN74175	1.68 1.60		PA239 2·10
CA3023	1.26 1.13		C6000 0.68 CT TOLG	1.30	8N7473 0-43	0.41	SN74176	2.64 2.55	FCJ201 1.80	PA246 1.60
CA3026	1.00 0.90				8N7474 0-43 8N7475 0-45	0.41	8N74177	2.64 2.55	FCJ211 2.75	PA264 1.90 PA265 2.00
CA3028A	0.74 0.65		a Sheets 0 · 12   SL702C	1.30	8N7475 0-45 8N7476 0-45	0·44 0·44	8N74180 8N74181	2·13 2·05 9·33 9·00	FCK101 4·371	PA424 2.05
CA3028B CA3029	1·05 0·94 0·87 0·77		5-11 1-5 £ £	6-11	8N7480 0.70	0.65	BN74182	2.03 1.95	FCY101 1 05	PA436 1.90
CA3029A	1.65 1.47		# 0-37 L923 0-40		8N7481 1.40	1.38	SN74184	4-80 4-60		PA494 2.05
CA3030	1.37 1.23		1-37	0 31	SN7482 0.87	0.82	SN74185	4-80 4-60	sgs	Data & Application
CA3030A	2.53 2.25		-11 1-5	6-11	8N7483 0.87	0.82	8N74190	1.80 1.70	TAA661B 1.92	Sheets 5p per type.
CA3033	2.53 2.25		£	£	8N7484 2.00	1.85	8N74191	1.80 1.70	TAA621 2-15	
CA3033A	4.26 3.80		2.70 UA701C TO5 0.70		SN7485 3-62 SN7486 0-33	3·40 0·30	SN74192 SN74193	1.75 1.65 1.75 1.65	4 watt amp.	monwyn a
CA3035	1.23 1.10		0.75 UA716 TO5 1.87 1.30 UA723C TO5 1.62		8N7490 0.87	0.84	8N74194	2.67 2.55	TAA700A 3-75	TOSHIBA &
CA3036 CA3037	0.73 0.65 1.65 1.47		1.30 UA723C TO5 1.62 1.17 UA730C TO5 1.60		8N7491AN 1-21	1.10	8N74195	2.25 2.10		TH9013P 4.57 20 watt amp.
CA3037A	2.53 2.25		0-55 UA741C TO5 0-87		8N7492 0.87	0.84	8N74196	2.64 2.55		TH9014P 1.50
CA3038	2.53 2.25		1-52 UA741C DIL 0-87		8N7493 0.87	0.84	8N74198	5.95 5.65	TAA611C 2.03	Pre-amp
CA3038A	3.40 3.03		0.70 LM741CN DIL 0.75		8N7494 0-87	0.84	SN74199	5.95 5.65	TBA651 1.69	Data sheets 0.121
CA3039	0.84 0.75		17 SN72709DN 1.25		8N7495 0-87 8N7496 0-87	0·84 0·84	9300 9310	2·10 1·95 See SN74160		
CA3040 CA3041	2·40 2·14 1·09 0·97	TTL LOGICS £ £		25-99	8N7497 6-40	6.00	9311	2.80 2.60	BRIDGE RI	
CA3041	1.09 0.97	SN7400 0.20 0.1		0.18	8N74100 1-65	1.53	9316	Sec SN74161	CIR-KIT AMP. PI 1/16" £0.15 1 60	
CA3043	1.37 1.23	8N7401 0.20 0.1		0.18	SN74104 1-52	1.40	T15701	Sec SN74160	1/16 20·15 1 1·5 10	
CA3044	1.20 1.07	8N7402 0.20 0.1	8 8N7410 0.20	0.18	BN74105 1.52	1.40	9601	See SN74122	P.C. 2 10	
CA3045	1.23 1.09	8N7403 0-20 0-1		0.21	8 Pin TO-5 I.C. He				BOARD 4 10	0 0.70 (approx.
CA3046	0.69 0.60	8N7404 0-20 0-1		0.46	10 Pin TO-5 I.C. H				For PA246 4 20	
CA3047 CA3047A	1·37 1·23 2·53 2·25	8N7405 0.20 0.11 8N7406 0.80 0.7		0-38 0-78	12 Pin TO-5 I.C. E				I.C. circuit 6 5	
CA3047A	2.04 1.81	8N7407 0-20 0-1		0.78	14 Pin Dual-in-Lin 16 Pin Dual-in-Lin				as in Data 6 20 Sheet, £0.65 6 40	
				- , -	, to I'm Dust-III-III	C 1.O. 1101	4019 40.50		Silect. 20 00   0 40	0 1101

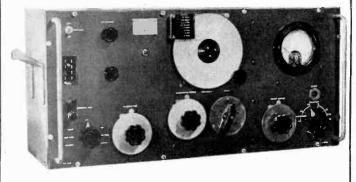
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The content of the		T SELECTION		S AND RETURN OF POST SERVICE
100-0-100	Gallot 0.20   2N3393   0.15   3N128   0.70   2012   2N3393   0.15   3N1404   0.771   2N3605   0.15   3N1404   0.771   2N3606   0.20   2N3404   0.321   3N143   0.671   2N3606   0.20   2N3405   0.32   3N1404   0.321   3N143   0.671   2N3605   0.32   2N3405   0.32   3N1404   0.321   3N143   0.671   2N3605   0.32   2N3405   0.32   2N3406   0.32   2N340	BG(122 0.20 BFY25 0.25 BC(125 0.20 BFY26 0.20 BC(140 0.37  BFY26 0.20 BC(140 0.37  BFY26 0.50 BC(140 0.37  BFY26 0.50 BC(140 0.37  BFY36 0.50 BC(140 0.10 BFY36 0.62 BC(140 0.10 BFY36 0.62 BC(157 0.12 BFY36 0.17 BC(158 0.11 BFY36 0.17 BC(158 0.11 BFY36 0.17 BC(158 0.11 BFY36 0.17 BC(160 0.62) BFY36 0.17 BC(160 0.62) BFY36 0.17 BC(160 0.62) BFY36 0.17 BC(160 0.11 BFY36 0.17 BC(160 0.17 BFY36 0.17 BC(160 0.	NKT215	No.   100   200   400   600   800   1000   1200   1400     A
2-2µF 135p  PRESETS Carbon Miniature and Sub miniature. Vertical and Horizontal. 0·1 watt, 0·2 watt, all at 0·06 each. 0·3 watt 0·075.  Antex 15W. Soldering Iron . 1-70 D.G. 30 W. Soldering Iron . 1	100-0-100	ZENER DIODES 400 mW (from 3-3v to 33v)	0 15 0 37 1	16 450 0 16 250 25 0 14 5000 25 0 57 25 10 0 06 250 50 0 19 5000 50 0 97 25 25 0 06 320 10 0 06 5000 85 1-75
0-12+ VAIU3/ U-12+	PRESETS Carbon Miniature and Sub miniature. Vertical and Horizontal. 0·1 watt, 0·2 watt, all at 0·06 each. 0·3 watt 0·075.  CARBON POTENTIOMETERS	POSTAGE AND PACKING CH	ARGES 0·12} 0·25 (minimum)	R53 (STC)

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# FIG. 1.0 48 N338 0.44 | FX4 1.16 | U05 0.40 | N11934.53 | AP139 0.65 | F8Y41A 23 | GC22 0.38 | CC2 ACOUSTIC DRPORATION 38 CHALCOT ROAD, CHALK FARM, LONDON, N.W.1 THE VALVE SPECIALISTS Telephone 01-722-9090 GLOUCESTER ROAD, LITTLEHAMPTON, SUSSEX. Littlehampton 6743 Please forward all mail orders to Littlehampton OZ4 0.23 1A3 0.23 1A7GT 0.33 1B3GT 0.37 1D5 0.38 1D6 0.48 1FD1 0.33 1FD9 0.20 1G6 0.30 1H5GT 0.33 28 0 32 0 50 0 50 0 50 0 50 0 60 8469 0 35 5 64 5 523 0 45 5 524 6 6 9 6 7 8 9 6 8 9 8 9 6 8 9 6 8 9 6 8 9 6 8 9 6 8 9 6 8 9 6 8 9 6 8 9 6 8 9 6 8 9 8 6AN8



MARCONI SIGNAL GENERATOR TYPE TF-144G: Freq. 85 Kc/s-25Mc/s in 8 ranges, Incremental: ± 1% at 1Mc/s. Output: continuously variable 1 microvolt to 1 volt. Output Impedance: 1 microvolt to 100 millivolts, 10 ohms 100mV - 1 volt - 52.5 ohms. Internal Modulation: 400c/s sinewave 75% depth. External Modulation: Direct or via internal amplifier. A.C. mains 200/250V, 40.100c/s. Consumption approve 40 worth Measurement 200, 40-100c/s. Consumption approx. 40 watts. Measurements 29  $\times$   $12\frac{1}{4} \times 10$  in. New condition. £45 each, Second hand condition £27.50 each, Carr. £1.50.

MARCONI SIGNAL GENERATOR TYPE TF-144H/S: Frequency Range 10Kc/s-72Mc/s. RF Output  $2\mu V$ -2V at  $50\Omega$ . Int. Mod. 400 and 1000c/s. Excellent condition with Manuals. £200.00 each. Carr. £2.

MARCONI UNIVERSAL BRIDGE TF-866A and TF-868: £75.00 each, Carr. £2.

MARCONI DEVIATION TEST SET TF-934: 2.5-100Mc/s (can be extended up to 500Mc/s on Harmonics). Dev. Range 0-75Kc/s inmodulation range 50c/s-15Kc/s. 100/250Va.c. £45each, £1·50 carr. TELEPRINTER CREED TYPE 7B: "as new" condition, original packing case, £25·00 each. Second-hand condition (excellent order), no parts broken, £15·00 each. Carriage both types £2.

#### FOR EXPORT ONLY BRITISH & AMERICAN

## COMMUNICATION EQUIPMENT

VRC.19X Trans-ceiver, 150-170Mc/s, 2 Channel, 20 Watts, Output 12/24V d.c. operation. General Electric Transmitter, 410-419Mc/s, thin line tropo scatter system, with antennae. W.S. Type 88, Crystal controlled, 40-48 Mc/s. W.S. Type HF-156, Mk. II, Crystal controlled, 2.5-7.5 Mc/s. W.S. Type 62, tunable, 1.5-11 Mc/s. C.44, Mk. II, Radio Telephone, Single Channel, 70-85 Mc/s, 50 watts, output, 230V. a.c. input. G.E.C. Progress Line Tx Type DO36, 144-174 Mc/s, 50 watt, narrow band width. A.C. input 115V. BC-640 Tx, 100-156 Mc/s, 50 watt output, 110V or 230V input. STC Tx/Rx Type 9X, TR1985; RT1986; TR1987 and TR1998, 100-156 Mc/s. TRC-1 Tx/Rx, Types T.14 and R.19, FM 60-90 Mc/s. With associated equipment available. Redion GR410 Tx/Rx, SSB, 1.5-20 Mc/s. Sun-Air Tx/Rx Type T-10-R. Collins Tx/Rx/Type 1854A. Collins Tx/Rx Type ARC-27, 200-400 Mc/s, 28V d.c. With associated equipment available. ARC-5; ARC-3; and ARC-2 Tx/Rx. BC-375; 433G; 348; 718; 458; 455 Tx/Rx. Directional Finding Equipment CRD.6 and FRD.2 complete Sets available and spares. Complete system with full set of Manuals.

FREQUENCY METER BC-221: 125-20,000 Kc/s, complete with original calibration charts. Checked out, working order £18.50 + £1 carr.; OR BC-221 (as received from Ministry), good condition, less charts, £8.50 + £1 Carr.

**RACK CABINETS:** (totally enclosed) for Std. 19 in. Panels. Size 6 ft. high  $\times$  21 in. wide  $\times$  16 in. deep, with rear door. £12 each, £2.50 Carr. OR 4 ft. high  $\times$  23 in. wide  $\times$  19 in. deep, with rear door. £8.50 each, £2 Carr.

RECEIVER BC-348: Operates from 24V d.c. Freq. Range 200-500 Kc/s, 1·5-18Mc/s. Secondhand £20 each, £1 Carr.

APR-9 SEARCH RECEIVER: Complete with two Tuning Units TN128, 1000-2600Mc/s, and TN129 2300-4450Mc/s. £250·00 each.

TELEPRINTER CREED TYPE 7B: "as new" condition, in original packing case, \$25.00 each. Second-hand condition (excel-

If wishing to call at Stores, please telephone for appointment.

MILLS 3-B TRULOCK ROAD, LONDON, N17 OPG

Phone: 01-808-9213



USM-24C OSCILLOSCOPE: 3 in. oscilloscope with 2c/s to 10Mc/s vertical response, and 8c/s to 800Kc/s horizontal response. Sensitivity 50 mv. rms/inch. Triggered sweep, built-in trigger pulses and markers. Mains input 15V, 50c/s. Complete with all leads, probes and circuit diagram. £42-50 each, carr. £2.

each, carr. £2.

SIGNAL GENERATOR TS-403B/U (or URM-61A): (Hewlett Packard). A portable, self-contained, general-purpose test equipment designed for use with radio and radar receivers and for other applications requiring small amounts of RF power such as measuring standing-wave ratios, antenna and transmission line characteristics, conversion gain, etc. Both the output freq. and power are indicated on direct-reading dials. 115V, AC, 50 c/s. Freq.—1800-4000 Mc/s. CW, FM, Modulated Pulse—40-4000 pulses per sec. Pulse Width—0.5-10 microsecs. Timing—Undelayed or delayed from 3-300 microsecs from external or internal pulse. O/put—1 milliwatt max., 0 to —127 db variable. O/put Impedance—50 Ω. Price: £120 each + £2 carr.

variable. O/put Impedance—90 11. Frice: £120 each + £2 carr.

SIGNAL GENERATOR TYPE 902: (P.R.D.). A portable, general-purpose, broadband, microwave signal generator designed for testing and maintenance of aircsaft radio and radar receivers in the SHF band. The RF output level is regulated by a variable attenuator calibrated in dbm. The frequency dial is calibrated in Mc/s. Provision is made for external modulation. Power Supply—115V, ±10% A.C., 50 c/s. Freq.—3650-7300 Mc/s. Internal Transmission—CW, Pulse, FM. External Transmission—Square Wave, Pulse. Power O/put—0.2 milliwatts. O/put Attenuator: —7 to —127 dbm. Load—50 Ω. Price: £135 each + £2 carr.

E135 each + £2 carr.

TEST SET TS-147C: Combined signal generator, frequency meter and power meter for 8500-9600 Mc/s. CW or FM signals of known freq. and power or measurement of same. Signal Generator: O/put —7 to —85 dbm. Transmission—FM, PM, CW. Sweep Rate—0-6 Mc/s per microsec. Deviation—0-40 Mc/s per sec. Phase Range—3-50 microsec. Pulse Repetition Rate—to 4000 pulses per sec. RF Trigger for Sawtooth Sweep—5-500 watts peak. 0.2-6 microsec. duration, 0.5 microsec pulse rise time. Video Trigger for Sawtooth Sweep—Positive polarity, 10-50V peak. 0.5-20 microsec duration at 10 % max. amplitude, less than 0.5 microsec rise time between 90 % and 10 % max. amplitude points. Frequency Meter: Freq. 8470-9360 Mc/s. Accuracy—+2.5 Mc/s per sec. absolute, + 1.0 Mc/s per sec. for freq. increments of less than 60 Mc/s relative, ±1.0 Mc/s per sec. at 9310 Mc/s per sec. calbration point. Accuracy measured at 25° C and 60 humidity. Power Meter: Input: +7 to +30 dbm. Output — 7 to —85 dbm. Price: £75 each + £1 cart.

SIGNAL GENERATOR TS-497B/URR: (Boonton). Freq. 2-400 Mc/s in 6 bands. Internal Mod. 400 or 1000 c/s per sec. External Mod. 50 to 10,000 c/s per sec. External PM. Percent Mod. 0-30 for sine wave. Am or Pulse Carrier. O/put Voltage 0.1-100,000 microvolts cont. variable. Impedance 50 Ω. Price: £85 each + £1.50 carr.

FREQUENCY METER TS-74 (same TS-174): Heterodyne crystal controlled, Freq. 20-280 Mc/s. Accuracy .05%. Sensitivity 20 mV. Internal Mod. at 1000 c/s. Power Supply—batteries 6V and 135V. Complete with calibration book. (Manufactured for M.O. D. by Telemax. "As new" in cartons.) £75 each. Fully stabilised Power Supply available at extra cost £7.50 each. Carr £1.50.

CT.54 VALVE VOLTMETER: Portable battery operated. In strong metal case with full operating instructions. 2.4V-480V. A.C. or D.C. in 6 Ranges,  $1\Omega$  to  $10 \text{Meg}\Omega$  in 5 Ranges. Indicated on 4in. scale meter. Complete with probe, excellent condition. £12-50, carr. 75p.

CT.381 FREQUENCY SWEEP SIGNAL GENERATOR: 85Kc/s-30Mc/s and response curve indicator with 6in. CRT tube and separate power supply. Fully stabilised. Price and further details on request.

AVO WIDE RANGE SIGNAL GENERATOR: Freq. 50Kc/s-80Mc/s in 6 bands. Mains input 100-130V; 200-260V, 50-60c/s. Second-hand, excellent cond. £14 each, or: New cond. complete with all leads and transit case £20 each. Carriage £1.

DESK TYPE TELEPHONES: Black, without dial, new cond. £2 each, 50p post. USA Type 500 series, with dial, black, new £4 each, 50p post. USA Type, with dial, second-hand cond. £1 25 each, 50p post.

CANADIAN HEADSET ASSEMBLY: Moving coil headphones 100Ω with chamois leather earmuffs. Small hand microphone complete with switch and moving coil insert. New Condition. £1.75 each, post 25p.

HEADSET ASSEMBLY TYPE No. 10: Moving coil headphones and microphone. (Similar to above) new cond. £1.75, post 25p; or second-hand cond. £1.25, post 25p.

HEADSET ASSEMBLY: with lightweight boom microphone. Good second-hand condition. £2:50, post 75p.

DLR HEADPHONES: 2  $\times$  balanced armature earpieces. Low resistance. £1.25 a pair, 25p post.

MOVING COIL INSERT: Ideal for small speakers or microphones. Box of 3 £1, post 23p.

HAND MICROPHONE: (recent design) with protective rubber mouthpiece. £2, post 23p.

MICROLINE IMPEDANCE METER MODEL 201: 5300-8100Mc/s. £75 each, £1 carr.

MICROLINE DIRECTIONAL COUPLER MODEL 209: 5260-8100Mc/s. 24DB. £12-50 each, post 35p.

POWER UNITS AVAILABLE FOR FOLLOWING SETS: 52 set—mains input, 1500 @ 60mA and 12V @ 3 amps, new cond. £3.50. Receiver type 82 (1475)—mains input, 250V @ 80mA and 6.3V @ 4 amps, new cond. £3.50. No. 19 set £2.50. C12 set £4.00. 88 set £2.50. Carriage all types £1 extra.

STABILISED BENCH POWER SUPPLY: fully smooth, dual output, positive or negative, 2-6V; 6-9V; 9-12V and 12-16V all at 2 amps d.c. from mains input. £25 + £2 carr.

DIGITAL VOLTMETER & RATIOMETER Model BIE. 2116, £65, carr. £2. DIGITAL VOLTMETER Model BIE. 2114, £55, carr. £2. (Mnftrs. Blackburn Instruments).

MARKA SWEEP GENERATOR MODEL VIDEO (Kay Electric, USA) £65, carr. £2.

ROTARY CONVERTERS: Type 8a, 24 v D.C., 115 v A.C. @ 1.8 amps, 400 c/s 3 phase, £6.50 each, post 50p. 24 v D.C. input, 175 v D.C. @ 40mA. output, £1.25 each, post 20p.

CONDENSERS: 40 mfd, 440 v A.C. wkg. £5 each, 50p post. 30 mfd 600 v wkg. d.c., £3.50 each, post 50p. 15 mfd 330 v a.c., wkg., 75p each, post 25p. 10 mfd 1000 v. 63p each, post 13p. 10 mfd 600 v. 43p each, 25p post. 8 mfd 2500 v. £5 each, carr. 63p. 8 mfd 600 v. 43p each, post 15p, 8 mfd. 1% 300 v. D.C. £1.25, post 25p, 4 mfd. 3000 v. wkg. £3 each, post 37p. 4 mfd 2000 v. £2 each, post 25p 4 mfd 600 v., 2 for £1. 0.25 mfd, 2Kv, 20p each, post 10p. 0.01 mfd MICA 2-5Kv. £1 for 5, post 10p. Capacitor 0.125 mfd, 27,000 v. wkg. £3.75 each, 50p post.

TCS MODULATION TRANSFORMERS, 20 watts, pr. 6,000 C.T., sec. 6,000 chms. Price £1.25, post 25p.

SOLENOID UNIT: 230 v. A.C. input, 2 pole, 15 amp contacts, £2.50 each. post 30p.

CONTROL PANEL: 230 v. A.C., 24 v. D.C. @ 2 amps, £2·50 each, carr. 75p. OHMITE VARIABLE RESISTOR: 5 ohms, 5½ amps; or 40 ohms at 2·6 amps. Price (either type) £2 each, 25p post each.

TX DRIVER UNIT: Freq. 100-156 Mc/s. Valves 3 × 3C24's; complete with filament transformer 230 v. A.C. Mounted in 19in. panel, £4.50 each, carr. 75p.

POWER SUPPLY UNIT PN-12A: 230V a.c. input 50-60 c/s. 513V and 1025V @ 420 mA output. With 2 smoothing chokes 9H, 2 Capacitors, 10Mfd 1500V and 10Mfd 600V. Filament Transformer 230V a.c. input. 4 Rectifying Valves type 523. 2 × 5V windings @ 3 Amps each, and 5V @ 6 Amp and 4V @ 0.25 Amp. Mounted on steel base 19°Wx11°Hx14°D. (All connections at the rear.) Excellent condition £6:50 each, carr. £1.

AUTO TRANSFORMER: 230-115V, 50-60c/s, 1000 watts. mounted in a strong steel case  $5'' \times 6\frac{1}{2}'' \times 7''$ . Bitumen impregnated. £6 each, Carr. 63p. 230-115V, 50-60c/s, 500 watts.  $7'' \times 5'' \times 5''$ . Mounted in steel ventilated case. £3-50 each, Carr. 50p.

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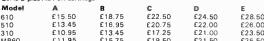
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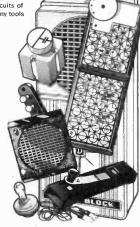
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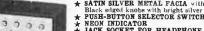
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Garrard 5200 Changer with low mass pick-up arm and Stereo Cartridge. Controls: TREBLE, BASS, VOLUME, STEREO, BALANCE.

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18" speaker

# COMPONENTS

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+ 10	Donner	4310	Resistive .	80.00
+ 10	J. A. Thompson	LAZ Mod 3C	Resistive .	25.00
	J. A. Thompson			
	. S.E.L			
			3B	
+ 12.5	Graseby			
	Graseby			
	Graseby			
+ 32	. Graseby	GW6 Mk 6	441-03-14-111-	18.50
± 64	Graseby	GW6 Mk 8		18.50
± 0 · · ·	. Lan-Elec	ITI-99F-31		15.00
	GEC			
	SIC de Far			
	. Penny & Giles			
5 1 9	Turner	TT 1 (IF	Industive	19.00
- 0 + o			Inductive .	
	Glennite			· · · TO:00

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ELLIOTT	Type	3B6297			 	 	 	 £10	.00
ELLIOTT	Type	3C635 .			 	 		 £10	.00
ELLIOTT	Type	3C2758	A.Z		 	 	 	 £10	·öö
ELLIOTT	Type	3C5019			 	 	 	 £10	·ÕĈ
ELLIOTT	Type	3C5161			 	 	 	 £10	٠ŎĊ
ELLIOTT									
PULLIN KEARFOTT	Type	R601-1.	A-B	٠.	 	 		 £6	.50
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R. B. Pullin									

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#### STANDARD CELLS

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MUIRHEAD Type D-845-A Reference Cell. As D-845-D above but mounting suitable for direct replacement in American instruments. £5:00
MUIRHEAD Type D550A Miniature Standard Cell Mounted in plastics case. £5.00
<b>SANGAMO WESTON</b> Type 8-134-1-20
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Type 5312A Standard Cell Battery 1-01827V to 7-12789V @ 20°C £45-00

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K.G.M.

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COLVERN

**K.G.M.** Type M4 Digital Displays. As M3 above except digit size  $1^* \dots \pounds 3.50$ 

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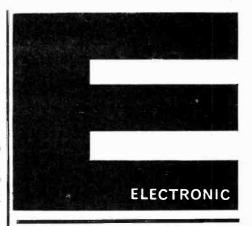
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GRIOM (Amber filter)	4- 10	£1.35	20p
	11~ 25	£1.30	Each
	26-100	£1.20	
Side Reading (14 m/m Fig.	Ht.) 0-9 disp	lay	
		-	Less Bases
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V N 11/F 38 m/m lend	(Pad )	96 100	60.05

| SPECIAL | DISPLAYS | XN9 | 38 m/m leads (Clear filter) | 6 m/m leads (Clear filter) | 38 m/m leads (Clear filter) | 38 m/m leads (Clear filter) | 6 m/m leads (Clear filter) | Displays Fig. "‡"
Displays "+, — and"
Displays "Vx, A, Ω Vmv"
Displays "+, — and"

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tivity 41 \mu A/L	ELECTRONICS voltage 1130V 0.003 μA for 10 A/I	. Sensi-
		£8.50
E.M.I. Type 6097A		£8.50

## **POTENTIOMETERS**

EN	TUR	3600	ROTATION		
	į	Linearit-	Manufacturers Beckman Beckman Beckman Beckman Beckman Colvern Colvern Relcon Relcon Beckman Reliance General Controls	Model	Price
es. Ol	ms I	er cent	Manujacturers Beckman	A	£8·0
UNI POLITOR	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	.5	Beckman	A.S	£3.0
00	0	5	Beckman	A	£3.0
90	0	1	Beckman	8	£3.5
00			Colvern	2501	£2.2
00			Foxes	PX4	£2 (
00			Colvern	96/1000/11	£2.0
00,			Colvern	HEL107.10	£0.0
30			Relcon	HEL0710	£2.5
K		1.5	Beckman		£3.0
K	4	1.25	Beckman	7216	£3.0
K			Reliance	GPM15	£2.
K			General Controls	3.GPA15/4	£2.0
κ			Relcon	07-10	£2:
K			Colvern	CLR2503	£3.0
0K		0.5	Beckman	A	2.31
0K		0.1	Beckman A	CI R26/1001	20.0
UK		0.1	Colvern	CL R2402	£3.0
OK			Relcon Colvern Beckman Beckman X Colvern Colvern Beckman	. A	£3
OTZ		0.05	Reckman	SA1244	. +4
0K			Corvern	2402	. 2014
0K			Beckman	BA95C	£3.
0K		0.1	Beckman	A.88	23
0K		0.5	Beckman	SA1679	£3.
0K		1.0	Colvern	2402/1	£1
OK .			Beckman Beckman Beckman Beckman Colvern Reliance	07 · 10	£2.
0K			Colvern Foxes Beckman Beckman	07 · 5	£2.
0Κ			Colvern	2503	£2 £2
0K		X	Foxes	PX4	22
0K	!	0.5	Beckman	A	£3.
ONLO	001/	0.1	Ford	. A	£5.
00K	LUUR	0.1	Beckman	. A	£3.
00K		0.5	Beckman	A	£3.
00K .			Colvern	2501	£2.
00K.			Colvern		£2.
98K .		0-1	Beckman		2.0
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HR	EF IL	י אאר	Paskman	· · ·	69.
00/10	0	0.9	Beckman.	Type C	£3 £2 £2 £2
00/10	0		Beckman	9303	£2.
К			Fox	PX2/H3	£2
0K		0.5	Fox Beckman Beckman Beckman Beckman	C.88	£2:
0K/20	K	0.1	Beckman	c.s	£3.
0K/10	)K	0.1	Beckman		£3
υK	EENL 3	0.0	FADO POTAT	ION	. T.I.
11 T	ECN I	UKN	Beckman B	10 watta	. £6∙
OK/2	) K		Beckman B	10 watts	£6
UN/41	NTY	TURN	7200° ROTAT	ION	
Men			General Control	s . PX M130	£4.
0K			Reliance		£2
56	TURN	56/60°	ROTATION		
60		, - +	Kelvin Hughes	KTP0701	£9.
IVE	TUR	N 180	0° ROTATION		
00			Relcon	HEL07-05	
		h.		F/11	£2:
00		******	Colvern	CLR2505	£2.
11.5K			Colvern Colvern LF TURN Colvern	CLR2609	£2.
	-AND	-А-НА	LF TUKN		
. 1 4 E			Calman	0.405	. £2·

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TAIL	INICE LEGICOT OF MENT ONLY STORE STO	

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heat	diodec	For building	computer	OF	storing	informa	tion i	n bina

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5 pole 5 way £1.30
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DIFFERENTIAL PRESSURE	
H/Duty rotary solenoid only	£O
1 pole 4 way	řΙ
4 pole 11 way	ĒΪ
12 pole 11 way H/Duty reversible	ŧΰ
1 pole 1 way H/Duty	ĔΪ
6 pole 11 way	ĔΪ
5 pole 5 way	ΕŢ
Rotary Solenoid Switches	

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0-2000 JLT 548 Resistive 25 .00 12V 2K
0-2000 KDGTD-216 Resistive 25:00
0-2500 JLT
0-3000 SEL SE165 Inductive 25.00 C/W Mod
0-4000 SEL Inductive 25.00 C/W Mod
0-4000 .JLT
<ul> <li>JLT = J. Langham Thompson.</li> </ul>

## S E LABS OSCILLATOR/AMPLIFIER DEMODULATOR

DEF	8E62/12 complete with 0-4000 p.s.i. transducer £65.00	,
	LABS TRANSDUCER MODULATOR	
Type	8E441/2 O/P 5V into 50k£25.00	į

## DISPLACEMENT

Type 1T 2-31-3	35 BONDED	RESISTANCE	DISPLACEMENT
TRANSDUCER.	Range ± incl	1	£15·00

## STRAIN GAUGES

<b>PHILLIPS</b>	STRAIN	GAUGE	
Type PR 9816			£15.00

## **TRANSFORMERS**

	and the second s
	TYPE 40788
	PRI 0-200-220-240V. SEC 20-0-20V, 45-0-45V, 0-12V £1.50
	75 WATT AUTOTRANSFORMER
	Tapped 0-110-200-220-240V 50Hz£1.95
ı	100 WATT AUTOTRANSFORMER
	Tapped 0-110-200-230-240V 50Hz£2 15

## UNISELECTORS

MINIATURE TYPES
<b>A.E.1.</b> 3 bank 12 way1400 ohm
<b>A.E.1.</b> 3 bank 12 way15 ohm 12V plug in
<b>A.E.1.</b> 3 bank 12 way35 ohm 12V plug in
<b>A.E.I.</b> 3 bank 12 way50 ohm 12V plug in
<b>A.E.1.</b> 3 bank 12 way

## VALVES

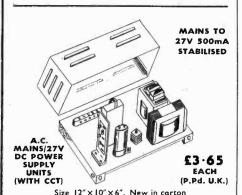
PRESSURE	CONTROLS	LTD.—SOLENOID
VALVES Working Pressure DC	600 p.s.i. max. Ope	erating Voltage 24/28V 0.9A£10.00
DOWTY MO	OG SERVO V	

## **VIBRATORS**

District Control	
Type V5123	12 volts £1.25
PLESSEY Type 12148D	12 volts£1.25
PLESSEY Type 614	6 volts£1.25
PLESSEY Type 61HD4	6 volts H/Duty£1.50
PLESSEY Type 68R6	6 volts£1.25
WEARITE Type QXA6 Type QXA24 Type QD24	6'volts split reed synchronous. £2:50 24 volts split reed synchronous. £2:50 24 volts split reed synchronous. £2:50 25:50

## **AVOMETERS!**

MOD. 7 SPECIAL OFFER £13.75 IN HIDE CASE (Postage Paid U.K.)



POWER SUPPLY UNITS

ADVANCE. DC22 (later version of DC6). 19" rack meeting. Mains to 24V 5A D.C. Ripple 1% total output. Stabilisation & to full load. 4-6R. £17:50 New, boxed with handbook. (P. pd., U.K.)

FARNELL. SSB 0/25V 2A. 25/30V IA. Free standing. Ripple 500µV P/P. Stabilisation 0 to full load. < 5mV. £25.50 New, boxed with handbook. (P. pd. U.K.)

#### NEUTRON COUNTING ASSEMBLY

Manufactured by Bendix-Ericsson (U.K.) Ltd., comprising: Lead Castle, Head Amplifier, 2 Neutron Counting Units, I Calibrator Jig. (Weight approximately 5 cwt.) New. Unused. £320.00 (C. pd. U.K.)

#### REDIFON FSK UNITS

1·7-9MHz in 2 ranges, 19" rack meeting. AP 104590 £22-50 (C. pd. U.K.)

#### RATE GYROS

Several types in stock. Send for details.

#### SOLARTRON OSCILLOSCOPES

CD.711S2. As received from H.M. Government. Excellent condition but offered as seen at £45 each. Buyers

Fully reconditioned and calibrated £90.00 (C. pd. U.K.)

## HOLLOW CATHODE DISCHARGE LAMPS

Require open circuit striking. Voltage of 750V D.C. and 500V at 100mA to run. For Si, Cu, Ni, Ti .. £5.00 each 

or any 15 for £75 the set. (All C. pd. U.K.)

Mg, Pb/Cd, Ca/Mg £7:00 each

#### GARDNER 240V 75W Auto, 350-0-350V 70mA, 700V 10mA (3kV working), 3-15-0-3-15V 3-5A £3-00 GARDNER 250-0-250V 15mA, 0-400-600V 105mA, 6-3V 2A, 0-6-3V IA .. €2.75 GARDNER 0-20-30V 250mA (twice) GARDNER 0-12V IA (twice) .. £1-85 £1.60 GARDNER 0-1200V 20mA, 6-3V IA (twice) £3-65 GARDNER 200-0-200V 25mA, 0-6-3V 0-6A (twice) £1-75 GARDNER 3-15-2-0-2-3-15V 2A (twice) ... WARDRAY 0-6-3V 2-5A, 0-6-3V 1-5A, 0-220V 20mA, 0-375V 100mA, 0-375V 75mA .. £2·60 WARDRAY 0-400V 20mA ... All above 230V tapped Primaries 50/60 Hx except Wardray 240V 50Hx GARDNER 0-1H 2-5A PARMEKO 0-2H 3A (0-8H No D.C.) GARDNER 10H 250mA £1.75 .. £3·50 .. £2·50 .. £1.00 Gardner 180H 24mA .. £2-35 (All C. pd. U.K. METERS

TRANSFORMERS AND CHOKES

TURNER Model 702 20-0-20V Rect. .. £2-50 TURNER Model 703 0-34mA Rect. CAL. 10-0-10, 20-0-20, 50-0-50, 50-0-50µA F.S.D. 63.25 (All C. pd. U.K.)

## SPECIALIST STOCKISTS OF SERVOMOTORS, SYNCHROS, MAGSLIPS AND PLUGS AND SOCKETS

# ervo and Electronic Sales .

Electrical and Servo Control Engineers - Electrical Suppliers - Engineering Stockists - Aeronautical Suppliers Post orders to 43 HIGH STREET, ORPINGTON, KENT. Phone: Orpington 31066/33976/33221 19 MILL ROAD ,LYDD, KENT (Works). Phone: Lydd 252 67 LONDON ROAD, CROYDON, SURREY (Retail Branch and Instrument Repairs).

Phone: 01-688-1512 (Croydon)

## DRY REED INSERTS

Overall length 1.85" (Body length 1.1") Diameter 0.14" to switch up to 500 mA at up to 250v D.C. Gold clad contacts. 621p per doz. £3.75 per 100; £27.50 per 1,000; £250 per 10,000. All carriage paid.

# Kinsons



Contacts up to 8 changeover

- \* QUICK DELIVERY
- \* KEEN PRICES
- DUST COVERS—QUOTA-

P.O. TYPE UNISELECTORS FROM STOCK, 50V. II LEVEL, I BRIDGING, 10 NON-BRIDGING, 3, 4 AND 5 LEVEL ALSO AVAILABLE.

MERCURY WETTED CONTACT RELAY Elliott type HG2M 145 ohms. 2 normally-open 2 normally-closed contacts £3 ea. GEARED MOTORS. 1 r.p.m. or 3 r.p.m. 4 watts very powerful, reversible 24v A.C. £1.75, post 20p, can be operated from A.C. mains with our £1 Transformer. Post 30p, IMHOF BLOWER UNITS in a standard 19 in. rack mounting assembly with Glass Fibre Air Filter and directional Duct. Capacitor Fan Motor 1/50th H.P. 200/250 Volts or 100/125 Volts 2,800 R.P.M. £12, carriage £1.50.

VACUUM PUMP Plessey Type B.3.X Mk. 2, Pat. No. CV, 5072 rotary vane type 6 in. HG inlet depression at 2000 r.p.m. and 7.5 c.f.m., with 20, in. Hg. delivery pressure. 5 in. Hg inlet depression at 1200 r.p.m. and 3.5 c.f.m., with 20 in. Hg. delivery pressure. Limited stocks availiable, send for details.

BRIDGE MEGGERS, SERIES 1, 1000 v., range 0/100M Ohms-Infinity, complete with Resistance Box 0/9999 Ohms. Brand New in sealed case. The Maker's price for this instrument is £189-50. Our Price £65.00.

MINIATURE BUZZERS, 12 volts, with tone adjuster 40p each as illustrated. LEDEX ROTARY SOLENOIDS AND CIRCUIT SELECTORS, size 5S. 4 pole II way and off £5-50, 24 pole II way and off £10-50, 54 pole On/Off £7-50. CHILTON BLUE LINE HEAVY DUTY SWITCHES made by Kraus & Naimer Code No. AALI31 type E size C25 & C200 with Black Handle, also quantity of other 8LUE LINE SWITCHES under usual price reasonable offer considered.

INDUSTRIAL FANS 16 in. blades 230/240 Volt A.C. motor 1,400 R.P.M. in housing with adjustable louvres & fold-up filter, £25

## HIGH SPEED COUNTERS

3½ in. x 1 in. 10 counts per second, with 4 figures. The following D.C. voltages are available, 6 v., 12 v., 24 v., 50 v., or 100 v. auxiliary contacts. normally open 40p extra.



WILKINSON (CROYDON) LTD. LONGLEY HOUSE LONGLEY RD. CROYDON SURREY

EX COMPUTER PRINTED CIRCUIT PANELS 2" x 4" packed with semi-conductors and top quality resistors, capacitors, diodes, etc. Our price, 10 boards, 50p. P. & P. 7p. With a guaranteed minimum of 35 transistors. Transistor Data included.

SPECIAL BARGAIN PACK. 25 boards for £1, P, & P, 18p, With a guaranteed minimum of 85 transistors. Transistor Data included,

Data Included.

PANELS with 2 power transistors sim. to OC28 on each board plus components. 2 boards (4 x OC28) 50p. P. & P. Sp.

9 OA5, 3 OA10, 3 Pot Cores, 26 Resistors, 14 Capacitors, 3 GET872, 3 GET872B, 1 GET875. All long leaded on panels 13" x 4". 4 for £1. P. & P. 25p.

## 12V 4A POWER SUPPLY

Extremely well made by FRAKO GmbH in W. Germany, with constant voltage mains transformer, tapped input from 115V to 240V. Full wave rectification and capacitor smoothing. Size 9" x6" x5", weight 11 lb. These units are brand new, unused and fully guaranteed. Maker's price believed to be around £80. Our Price £9-50. Carr. 50p

250 MIXED RESISTORS fand 1/2 Watt 62p

#### DIODES EX EQPT. SILICON

I Amp I,000 PIV

20 Amp 150 PIV

4 for 50p 4 for £1.00

P. & P. 5p

QUARTZ HALOGEN BULBS with long leads 12V 55W for car spotlights and projectors etc. 50p

## RELAY OFFER

Single Pole Changeover Silver Contacts 2" x 6" x 7", 2.5 KΩ Coil operates on 25 to 50V, 8 for 50p, P, & P, 8p,

## BUMPER BARGAIN PARCEL

BUMPER BARGAIN PARCEL
We guarantee that this parcel contains at least 1,750 components. Short-leaded on panels, including a minimum of 350 transistors (mainly NPN and PNP germanium, audio and switching types—data supplied). The rest of the parcel is made up with: Resistors 5% or better (including some 1%) mainly metal oxide, carbon film, and composition types. Mainly and ½ watt... diodes, miniature silicon types OA90, OA91, OA95, IS130, etc... capacitors including tantalum, electrolytics, ceramics and polyesters... inductors, a selection of values... also the odd transformer, trimpot, etc., etc.... These are all miniature, up to date, professional, top quality components. Don't miss this, one of our best offersy etf. Price 43.25. P. & P. 9.33p—U.K. New Zealand £l P. & P. Limited stocks only.

## EX-COMPUTER POWER SUPPLIES

POWER SUPPLIES

Reconditioned, fully tested and guaranteed.
These very compact units are fully smoothed with a ripple better than 10mv, and regulation better than 10m. Over voltage protection on all except 24v, units. 120v,-130v, a.c. 50c/s input, Mains transformer to suit £1 extra if required.

We offer the following types:
6v. 8a. £10 20v, 15a. £15
6v. 15a. £14 30v, 7a. £12
12v. 20a. £16 24v. 4a, £14

Carriage 75p per unit.

150 High Stabs 2, 1 and 1 Watt, 5% and Better 62p

## LARGE CAPACITY ELECTROLYTICS

41" x 2" dia. 10,000 mfd 30V 5,000 mfd 55V 16,000 mfd 12V 40p each ×3" dia. 8,000 mfd 55V

P. & P. 6p each

50p each P. & P. 12p each

## **EXTENSION TELEPHONES**

99p ea. P. & P. £1.75 for 2 P. & P



These phones are extensions and do not contain bells,

KEYTRONICS MAILING ADDRESS 44 EARLS COURT ROAD, LONDON W.8 WAREHOUSE AND DISPATCH 01-478 8499



## DRILL CONTROLLER

New 1kW model.

Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by finger-tip control. Ktt includes all parts, case, everything and full instructions 21.50, plus 13p post and insurance. Made up model also available £2.25 plus 13p p. & p.



#### MAINS MOTOR

Precision made—as used in record decks and tape recorders—ideal also for extractor fans, blower, heater, etc. New and perfect. Snip at 50p. Postage 20p for first one then 5p for each one ordered.

#### MAINS TRANSISTOR POWER PACK

MAINS I RANSISIOR POWER PACK. Designed to operate transistor sets and amplifiers. Adjustable output 6v., 9v., 12 volts for up to 500mA (class B working). Takes the place of any of the following batteries: PPI, PPS, PP4, PP6, PP7, PP9, and others. Kit comprises: mains transformer rectifier, smoothing and load realstor, condensers and instructions. Real sulp at only 83p, plus 18n postage. plus 18p postage.

#### DOUBLE LEAF CONTACT



Very slight pressure closes both contacts. 6p each. 60p doz.

Plastic push-rod sultable for operating. 5p each, 45p doz.

## MAINS OPERATED CONTACTOR

220/240. 50 cycle solenoid with laminated core so very silent in operation. Closes 4 circuits each rated at 10 amps. Extremely well made by a German Electrical Company. Overall size 2½ × 2 × 2 in. £1 each.



((0)

AUTO-ELECTRIC CAR AERIAL

with dashboard control switch—fully extendable to 40in, or fully retractable. Suitable for 12v positive or negative earth. Supplied complete with fitting instructions and ready wired dashboard switch. £5.75 plus 25p post and ins.



TOGGLE SWITCH 3 amp 250v. with fixing ring. 7½p each 75p doz.





MINATURE WAFER S. WITCHES

2 pole, 2 way—4 pole, 2 way—2 pole, 3 way—4 pole, 4 way—3 pole, 4 way—2 pole, 6 way 1 pole, 12 way. All at 18p each, £1 80 dozen, your assortment.

## WATERPROOF HEATING

26 yards length 70W. Self-regulating temperature control. 50p post free.

## PAPST MOTORS

Est. 1/20th h.p. Made for 110-120 volt working, but two of these work ideally together off our standard 240 volt mains. A really beautiful motor,



## EXTRACTOR FAN

Cleans the air at the rate of 10,000 clubic ft. per hour. At the pull of a cord it extracts grease, grime and cooking smells before they dirty decorations. Buitable for kitchens, bathrooms, factories, changing rooms, etc., it's so quiet it can hardly be heard. Compact, 5½ casing with 5½ fan blades. Buttable wherever it is necessary to move air fast. Kit comprises motor, fan blades, sheet steel casing, pull switch, mains connector, and fixing brackets. £2 plus 36p post and ins.





## SOLENOIDS

Model 772—small but powerful 1" pull—approx. slze 1; × 1; × 1; pull—approx. 8126 1, 60p. Model 400/1 [" pull. 812e 2 2 × 2 × 1 2"

75p.

Model TT10 1‡ pull. Size 3 × 2½ × 2½ 21 80 plus 20p post and ins.

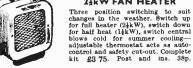
## MAINS RELAY BARGAIN



Special this month are some single, double and treble pole changeover relays. Contacts rated at 15 amps. Operating coll wound for 240V. A.C. Good British Make. Unused. Size approx. 1½×1 ins. Open construction. Single pole 25p each 10 for £2:25 Treble pole 35p each 10 for £3:15

CAR ELECTRIC PLUG
Fits in place of cigarette lighter. Useful
method for making a quick connection into
the car electrical system. 38p each or
10 for £3:42.







#### HORSTMANN "TIME & SET" SWITCH

(A 30 Amp Switch.) Just the thing if you want to come home to a warm house without it costing you a fortune. You can delay the switch on time of your electric fires, etc., up to 14 hours from setting time or you can use the switch to give a boost on period of up to 3 hours. Equally suitable to control processing. Regular price probably around 25. Special snip price 21:50 Post and ins. 23p.

ERGOTROL UNITS
These units made by the Mullard Group are for operating and controlling d.c. Motors and equipment from A.C. mains.

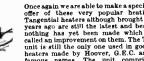
operating and controlling d.c. Motors and equip-ment from A.C. mains.
Thyristors are used and these supply a variable d.c. resulting in motor speed control and operating efficiency far superior to most other methods.
The units are contained in wall mounting cabinets with front control panel on which are fuses—push buttons for on/off and the variable thyristor fring control.
4 models are available—all are brand new in makers cases:

Model 2410 for up to 5 amps 217.50
Model 2411 for up to 10 amps Model 2415 for up to 80 amps 297.50
Note: 2415 is a floor mounting 3 phase u



## OUT OF SEASON BARGAIN

TANGENTIAL HEATERS



TANGENTIAL HEATERS

Once again we are able to make a special bargain ofter of these very popular heating units. Tangential heaters although brought out a tew years ago are still the latest and best type as nothing has yet been made which could be called an improvement on them. The Tangential unit is still the only one used in good quality heaters made by Hoover, G.E.C. and all the famous names. The unit comprises quiet wand one-third-two-thirds and full heat in the case of the 2kw and one-third-two-thirds and full heat in the case of the 2kw. These heaters are also fitted with a safety cut-out to cut the heaters should the impelier stop or the air flow be impeded. They are free standing and need only the simplest of cases, even a wooden cabinet. Is out of customers missed our special aummer offer of these beaters last year so order early. 200/240 2kw model £2:50. Control switch heaters only £5p or two-heat, cold-blow and off 35p. Postage and insurance 33p on heaters.



#### AMPLIFIER MAINS TRANSFORMER

50V l $\frac{1}{4}$  amp. Upright mounting with fixing brackets and metal shrouds to contain magnetic field, 50 c/s primary, tapped 110V, 117V, 210V, 230V and 250V. 2 secondaries, one 50V l $\frac{1}{4}$  amp, other 6V l amp for pilot light, etc. £1 95, postage 30p.

#### -LIGHT DIMMER -



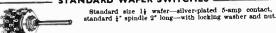
For any lamp up to 200 watt. Mounted on switch plate to fit in place of standard switch. Virtually no radio interference. Price £1.99 plus 20p post and ins.

## CAPACITOR DISCHARGE CAR IGNITION



This system which has proved to be amazingly efficient and reliable was first described in the Wireless World about a year ago. We can supply kit of parts for an improved and even more frient version (Practical Wireless, June). Price 24-95 plus 30p post. When ordering pleases state whether for positive or negative systems. Also available, ready made ignition systems for 6V, vehicles. 25-25 plus 20p.

## STANDARD WAFER SWITCHES -



No.of Pole		3 way	4 wav	5 way	6 way	8 way	9 way	10 way	12 way
1 pole	40p	40p	40p	40p	40p	40p	40p	40p	40p
2 poles	40p	40p	40p	40p	40p	40p	40p	70p	70v
3 poles	40p	40p	40p	40p	70p	70p	70p	95p	95p
4 poles	40p	40p	40p	70p	70p	70v	70p	£1.20	£1 20
5 poles	40p	40p	70p	70p	95p	95p	95p	£1.45	£1 45
6 poles	40p	70p	70p	70p	95₽	95p	95p	£1.70	£1 70
7 poles	70p	70p	70p	95p	£1 20	£1.20	£1 20	21 95	£1.95
8 poles	70p	70p	70p	95p	£1 20	£1 ·20	£1 20	£2 20	£2·20
9 poles	70p	70p	95p	95p	£1 45	£1.45	£1.45	22.45	£2·45
10 poles	70p	70p	95p	£1 20	£1 45	£1 45	£1.45	£2.70	£2.70
11 poles	70p	95p	95p	£1 20	£1.70	£1 70	£1.70	£2·95	£2.95
12 poles	70p	95p	95p	£1 20	£1.70	£1.70	£1·70	£3 20	£3·20

## MINIATURE INSTRUMENT SWITCHES

Precision made with diseast indexing mechanism and 1' moulded waters. Full length \( \frac{1}{2} \) in, spindle, 5 amp and silver-plated contacts.

Range except for 9-way is as standard water switches. Prices obviously higher. For 40p, read 60p; for 70p, read 21; for 95p, read 21-40; for £1-20, read 21: 80; for £1-3f read 22: 20. Note also 2-way types available up to 36 poles; 3-way, 30 poles; 4-way, 24 poles; 5-way, 19 poles; but 10- and 12-way only available up to 6 poles.

## 3 STAGE PERMEABILITY TUNER



3 STAGE PERMEABILITY TUNER

This Tuner is a precision instrument made for the famous Radiomobile Car Radio. It is a medium wave tuner (but set of long wave coils available as an extra if required) with a frequency coverage 1620 Kc/s-525 Kc/s and intended to operate with an i.F. value of 470 Kc/s. Extremely compact (size only 24 × 2× ½ in. thick) with reduction gear for fine tuning. 65p, with circuit of front end suitable for car radio o r as a general purpose tuner for use with Amplifier.

## ELECTRIC CLOCK WITH 20 AMP. SWITCH

Made by Smith's these units are as fitted to many top quality cookers to control the oven. The clock is mains driven and frequency controlled so it is extremely accurate. The two small dials enable switch on and off times to be accurately set—also on the left is another time or alarm—this may be set in minutes up to 1 hour. At the end of the period a bell will sound. Offered at only a fraction of the regular price—22.50, less than the value of the clock alone—post



## DISTRIBUTION PANELS

Just what you need for work bench or lab. 4 × 13 amp sockets in metal box to take standard 13 amp fused plugs and on/off switch with neon warning light. Supplied complete with 7 feet of heavy cable. Wired up ready to work, £2:55 less plug; £2:50 with fitted 13 amp plug; £2:65 with fitted 15 amp plug, plus 23p P. & P.



#### MULTI-SPEED MOTOR

-



MULTI-SPEED MOTOR

Replacement in many well-known food mixers. 8ix speeds are available 500, 850 and 1,100 r.p.m. from either or both of the nylon sockets (where the beaters of the food mixers normally go) and 8,000, 12,000 & 15,500 r.p.m. (ideal pollshing speeds) from the main drive shaft. This drive shaft is \(\frac{1}{2}\) in diameter and approximately \(\frac{1}{2}\) in long. A further point about this motor is that being 230/240v. AC-DC series wound its speed may be further controlled with the use of our Thyrister controller. This is a very powerful and useful motor size approx. 2 in. dis. x \(\frac{5}{2}\) in. long, mains 230/240v. Price 88p plus 23p postage and insurance. 12 or more post free. more post free.

#### **REED SWITCHES**

REED SWITCHES
Glass encased, switches operated by external magnet—gold
welded contacts. We can now offer 3 types:
Miniature. 1' long x approximately i' diameter. Will make
and break up to iA up to 300V. Price 139 each, £1.20 dozen.
Standard. 2' long x 1/h\* diameter. This will break currents
of up to 1A, voltage up to 250V. Price 10p each, 90p per
dozen.

dozen.

Stat. Flat type, 2' long, just over 'f' 'thick, flattened out, so that it can be fitted into a smaller space or a larger quantity may be packed into a square solenoid. Rating LA 200V. Price 30p each, 23 per dozen.

Small ceramic magnets to operate these reed switches 9p each, 90p dozen.

## BALANCED ARMATURE UNITS

These Capsules are 1' in diameter and 1' thick. They will operate as a microphone or loud speaker so can be used in intercom and similar circuits. 33p. Ten for £3. Ten to:



12 VOLT 1‡ AMP
POWER PACK
This comprises double-wound 230°
230V mains transformer with full
wave rectifier and 2000 m/t/d/
smoothing. Price £1 50.

#### MAINS CONNECTOR

A quick way to connect equipment to the mains safely and firmly—disconnection by plugs prevents accidental switching on; has sockets which allow insertion of meter without disconnection; cable inlets firmly hold one hair wire on up to four 7,029 cables. 85p each.



#### QUICK CUPPA

Mini Immersion Heater. 350W. 200/240V. Bolls full cup in about two minutes. Use any socket or lamp holder. Have at bedside for tea, baby's food, etc. £1.25, post and insurance 14p. 12V car model also available. Same price. Jug model also available £1.50 plus P. & P. 14p.



TELESCOPIC

for portable, car radio or transmitter. Chrome plated— slx sections, extends from 7; to 47'. Hole in bottom for 6BA screw. 38p KNUCKLED MODEL FOR F.M. 50p.

## AC FAN

Small but very powerful mains motor with 5 in. blades. Ideal for cooling equipment or as extractor. Silent but very efficient. 90p, post 23p. Mounts from back or front with 4BA



## TREASURE TRACER

Complete Lit (except wooden battens) to make the metal detector as described editorially in Practical Wireless, August issue. 22.50 plus 20p post and insurance.



## LIGHT CELL

Aimost zero resistant in sunlight increases to 10 K. Ohms in dark or dull

ight, epoxy resin scaled. Size approx. lin. dia. by lin. thick. Rated at 500 MW, wire ended, 43p. Sult most circuits.

TRANSDUCER
Made by Acos, reference No. 1.D.1001. For
measuring vibration, etc., to be used in
conjunction with "G" Meter. Regular
price 25. Our price 24. Brand new
and unused. Acos "G" meters available
£12 or with auto cut-out £18.



## HIGH ACCURACY THERMOSTAT

Uses differential comparator 1.C. with thermister as probe. Designer claims tem-perature control to within 1/7th of a degree. Complete kit with power pack 25.50.





A New Service to Readers. A bulletin bringing news of new lines, special snips and "too few to advertise" lines will be posted to subscribers during first week of each month. The bulletin will be called "Advance Advert News" and the Subscription is 60p per year. Subscribers will also receive our completed 1971 catalogue when this is published.

## J. BULL (ELECTRICAL) LTD.

Dept. W.W.7, Park Street, Croydon, CRO 1YD

HEAVY DUTY LT TRANSFORMERS by famous maker. Fully Tropicalised. Pri tapped 100, 110, 120, 200, 220, 240v. E.S. Three Separate Secondories 27v. 9a., 9v. 9a., 3v. 9a. Plus 17-0-17v. 0-25a and 17v. 0-25a. Table Top Connections. &4-00. Carr. Sop.

PARMEKO "C" CORE TRANSFORMERS
Pri. tapped | 10-200-240v. Sec. | 250v. | 197 m/a. Sec. 2 | 161v. | 10 m/a. Sec. 3 | 152v. 76 m/a. Sec. 4 | 124v. 25 m/a. Sec. 5 26v. 0-4a. Sec. 6 6 4v. 6 2a. 6 3v. 3 -32 a. 6 -3 v. 1-4a. Table top connections. Size 5 x 4 x 4 ins. Brand new boxed, £ 1 75. P. & P. 45p.

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176 m/a. 75p. P. & P. 20p. 22v., 0.9a and 21v., 60 m/a.
75p. P. & P. 25p. 370-390-410v., 6 m/a. 50p. P. & P. 200.
28-8-0-28-8v., 150 m/a. 90p. P. & P. 25p. 128-0-128v., 20 m/a.
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Twice. £1-50. P. & P. 30p. 90-0-90v., 100 m/a. 75p. P. & P. 20p.

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Pri Tapped 10. 0, 200. 220, 240v. sec. Tapped 110-112-5115v. Conservatively rated at 9 amps. Tropicalised open frame type. Terminal Board connections. Size 9 x 9 x 7 ins. Weight 60 lbs. £15-00. Carr. 90p.

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10H 300m/a DC. Conservatively rated. DC Res 50 \( \Omega\). Size

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FORM BLOC No.	ERS.		CTIO	NS.	DED (	NEW excepted PRIMAI	RIES 2	RANS- IINAL 20/240v Corr.
IA.	25_22	-40-50			15		0.50	65p
İB		-40-50		v .	iŏ		75	50p
ic		-40-50			6		75	50p
iŏ	25-22	-40-50			3		.00	40p
2A	4-16-		41.74		12		25	45p
2B	4-16-				8		-50	45p
2C	4-16-				4		75	40p
2Ď	4-16-			2.0	2		-50	30p
3A .	25-30				40	€16		75p
3B.	25-30			* *	20	Žio		65p
3C	25-30				10		25	60p
3Ď	25-30				5		25	45p
3E	25-30				2		25	45p
4A •	12-20		• •		30	cii		75p
4B	12-20		2.5	* *	20		25	50p
4C	12-20				10		-50	50p
4D	12-20				5		75	45p
5A	3-12-				30		75	45p
5B	3-12-				20		25	50p
5C	3-12-				10		-50	45p
5D	3-12-		• •		5		-00	
6A	48-56				2		·75	40p
6B	48-56				1		·75	40p
7A •	6-12	-60				610		35p
7B	6-12				50			55p
7C	6-12				20	46		45p
7D		9.41	9.94		10	63		35p
	6-12		* *		5	Ω		35p
8A 9A	12-24		* *.		1	41		3 <b>5</b> p
					8	16		35p
IOA*	9-15		1.7	15. *		41		35p
LIA					15	42		35p
12A	30-25	-0-25	SU.,		2	43		35p
13A	36				45	£16		75p
Note:					rediat	e taps	many	other
voltag						7-25-33-	40 EO.	
-	xample					/-25-33- 0-24-32\		
		No. 2					<b>/</b> .	
		No.	5	3-0-9-	-12-15	-16V.		

	A	JTO TRAI	SFORMERS	
240v11	0v. or 10	by. Compl	etely Shroude	ed fitted with
				blocks. Please
	hich type			
Type			ight Price	Carr.
1	80	24 lb.		30p
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3	300	6+ lb.		35p
3 4 5 6 7•	500	8 i lb.	£5-25	45p
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8 *	2250	30 lb.	£17·85	75p
• Comp	letely enclo	sed in beaut	ifully finished r	netal case fitted
with two	2-pin Ame	rican socker	s, neon indicate	r, on/off switch,
	ving bandl			

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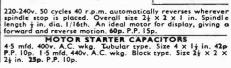
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#### SPECIFICATION R100/101

14 watts per channel into 3 to 4 ohms. Total distortion 14 watts per channel into 3 to 4 ohms. I otal distortion @ 10W @ 1kHz 0.1%. P.U.1 (for ceramic cartridges) 150mV into 3 Meg. P.U.2 (for magnetic cartridges) 4mV @ 1kHz into 47K. equalised within  $\pm 1 dB$  R.I.A.A. Radio 150mV into 220K. (Sensitivities given at full power). Tape out facilities; headphone socket, power out 250mW per channel. Tone controls and filter characteristics. Bass: +12dB to -17dB @ 60HZ. Bass filter: 6dB per octave cut. Treble control: treble +12dB to -12dB @ 15kHz. Treble filter: 12dB per octave. Signal to noise ratio: (all controls at max) RT101 – P.U.1. & radio – 65dB. P.U.2. – 58dB. **R100** same as RT101 but P.U.2. (for crystal cartridge) 450mV into 3 Meg. Cross talk better than – 35dB on all inputs. Overload characteristics 26dB on all inputs. Size  $1\frac{3}{4}$  x 9 x  $3\frac{3}{4}$ 

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The R.C.74 comes with an attractive moulded deck cover, which has positions for tone and volume controls. The unit is built into a rigid die-east frame, and overall size of the whole units 12½ x 11½ x 6 inches. Every single deck fully tested before dispatch. Spools not supplied.



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		AU1	TO SERIES (NOT	ISOLATED)		
Ref.	VA	Weight	Size cm,	Auto Taps	P	& P
No.	(Watts)	lb oz			€.	Np
113	20	1.1	7·3× 4·3× 4·4	0-115-210-240	0.74	20
64	75	1 14	7.0 x 6.4 x 6.0	0-115-210-240	1:44	30
4	150	3 0	8.9 x 6.4 x 7.6	0-115-200-220-240	1.74	36
66	300	6 0	10.2 x 10.2 x 9.5	" "	3.38	52
67	500	12 8	14.0 × 10.2 × 11.4	n n	5.03	67
84	1000	16 0	11-4 × 14-0 × 14-0		9-12	82
93	1500	28 9	13.5 × 14.9 × 16.5		13-22	
95	2000	40 0	17 8 × 16 · 5 × 21 · 6		17-26	
73	3000	45 8	17.4 C I R. I C 21.3		23.47	

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Ref.	Amps		Weight	Size cm.	Secondary Windings		P & P
No.	12V	24V	lb oz			£	NP
111	0.5	0.25	12	7.6 x 5.7 x 4.4	0-12V at 0-25A x 2	0.74	22
213	1.0	0.5	1 0	8-3 x 5-1 x 5-1	0-12V at 0.5A x 2	0.88	22
71	ž	Ĭ	1 0	7.0 x 6.4 x 5.7	0-12V at 1A x 2	1.16	22
18	4	2	2 4	8.3 x 7.0 x 7.0	0-12V at 2A x 2	1 62	36
70	6	3	3 12	10.2 x 7.6 x 8.6	0-12V at 3A x 2	1.95	42
72	10	5	6 3	7.9 × 10.8 × 10.2	0-12V at 5A x 2	2.56	52
17	16	8	7 8	12·1 x 9·5 x 10:2	0-12V at 8A ×2	3.95	52
115	20	10	11 13	12-1 × 11-4 × 10-2	0-12V at 10A x 2	5.03	67
187	30	15	16 12	13:3 × 12:1 × 12:1	0~12V at 15A × 2	9.28	82
226	60	30	34 0	17·0 × 14·5 × 12·5	0-12V at 30A x2	17:05	

Ref.	Amps.	W	eight	Size cm.	Secondary Taps	P	& P
No.		1b	oz.			£	NÞ
112	0.5	- 1	4	8.3 x 3.7 x 4.9	0-12-15-20-24-30V	0.88	22
79	1.0	2	0	7.0 x 6.4 x 6.0	17 11	1.18	36
3	2.0	3	2	8.9 x 7.0 x 7.6		1.75	36
20	3.0	- 4	6	10.2 x 8.9 x 8.6	ii ii	2-16	42
21	4.0	6	ō	10.2 × 10.0 × 8.6	D 10	2.56	52
51	5.0	6	Ř	12·1 × 10·0 × 8·6		3-18	52
117	6.0	7	8	12·1 × 10·0 × 10·2		3.79	52
89	10.0	12	ž	14.0 × 10.2 × 11.4		6.21	67

ı	0,	100		14001020114	** **		••
	Ref.	Amps.	Weight Ib oz	Size cm.	50 VOLT RANGE Secondary Taps	₽& € N	
ı	102	0.5	111	7·0 × 7·0 × 5·7	0-19-25-33-40-50V		0
ı	103	ĭ٠ō		8.3 x 7.3 x 7.0			16
ı	104	2.0	2 10 5 0 6 0 9 4	10.2 x 8.9 x 8.6	** **	2.34	12
ı			3 0		ps 11	2 12	14
ı	105	3.0	6 0	10.2 × 10.2 × 8.3	12 17	3-18	52
ı	106	4.0		12·1×11·4×10·2	22 25	4-20 5	2
ı	107	6.0	12 4	12·1 × 11·1 × 13·3			57
ı	118	8-0	18 9	13-3 x 13-3 x 12-1	0 0	8-10 9	7
l	119	10.0	19 12	16.5 x 11.4 x 15.9	17 11	10-15 9	7
ŀ	Ref.	Amps,	Weight	Size cm.	60 VOLT RANGE	P &	
ı	No.		lb oz			€ N	
	124	0.5	2 4	8.3 × 9.5 × 6.7	0-24-30-40-48-60V		16
ľ	126	1.0	3 0	8.9 x 7.6 x 7.6		1.64 3	16
	127	2.0	5 6	10.2 x 8.9 x 8.6		2.56 4	12

127	2.0	5 6	10.2 x 8.9 x 8.6			2.56	42
125	3.0	8 8	11.9 x 9.5 x 10·0		T,	3.90	52
123	4.0	10 6	11-4× 9-5×11-4	"	.,	5.03	67
120	6.0	16 12	13·3 × 12·1 × 12·1	9.2	111	7.28	82
122	10.0	23 2	16·5×12·7×16·5	11		12.05	
					•Ca	rriage via B	.R.S.
PRIN	1ARY 20	LEAD A 0-250 VOL	CID BATTERY CHA				RIES
Ref	Amos.	Weight	Size cm.			1	8 P

Ref.	Ambs.	Weight	Size cm.		P & P
No.		lb oz	70 (4 (4	4	Np
45	1·5 4·0	3 11	7.0 x 6.0 x 6.0 10.2 x 7.0 x 8.3 Please note, these	1.17	30 42
86	6.0	5 12	10.2 x 8.9 x 8.3 > units do not in-	2.67	52
146	8.0	6 4	8-9 x 10-2 x 10-2 clude rectifiers	3.04	52
50	12.5	11.14	13·3 × 10·8 × 12·1 /	4-52	67

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A range of audio Pre-amplifier Modules is now available enabling the construction of custom-built audio mixers for studio, P.A. and discotheque installations alterasonable cost and with many facilities usually available only on expensive systems. The Modules, constructed on glass fibre printed-circuit boards, are complete with anodised aluminium black facia plates and four control knobs identified: L.F., H.F., Echo Send and P.F.L. The modules are designed for use with external faders or volume controls and fulfill most requirements in the audio field. Un to the input modules may be mixed into requirements in the audio field. Up to ten input modules may be mixed into the combined Mixer/Line Amplifier Type MX/LNTA which is available on a matching facia plate with V.U. meter. The line amp will deliver +20dBM. All mixing may be effected with 10k log faders.

The modules are fixed with four screws and dimensions are  $7\frac{1}{2}$ in x  $2\frac{3}{4}$ in.

Input modules available:

UM1 200-600 ohm MIC UM2 50k ohm MIC UM3 Mag P/U 1.5mV R.I.A.A. UM4 Mag P/U 5mV R.I.A.A.

UM5 Crystal P/U 500mV UM6 High Level Tape/Tuner 500mV

Mixer/Line amp MX/LNTA: 10 inputs plus expander input; 600 ohm line out with preset for V.U. adjustment.

Power Unit for above Modules: Type PU11/30, 30V, 500mA. 100W slave amplifier—100W into 4 ohm load.  $13\frac{3}{4}$ in x  $10\frac{1}{2}$ in x  $7\frac{1}{2}$ in.

Prices: UM1-6, £9 each. MX/LNTA, £12. PU11/30, £8.100W Slave Amp £60. Manual showing mixing arrangements, connection data, etc., 25p. S.A.E. all inquiries. Trade inquiries welcome

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AD149 50p B8X21 20p TTP31A 60p 2N2221A AD149 50p B8X21 20p TTP31A 60p 2N2222A AD161 35p B8Y27 15p TTP32A 70p 2N2222 20 AD162 35p B8Y95A 12p TTP33A 2N2222A AP114 25p B8Y95 12p 41-90	gates	BY 27 Mullard   15p 25 + 12p 100 + 10p 500 + 9p 1000 + 8p	OA202 10p 25 + 8p 100 + 7p 500 + 6p 1000 + 5p
AFI16 25p BY100 15p 41:50 2N2369A AFI17 25p BY126 12p T1729B 55p 51761 AFI18 60p BY127 15p T1729B 60p 2N2646 4 AFI24 25p BY127 35p T1730C 70p 2N2904A AFI25 20p BY271 30p T1731B 65p AFI27 20p BY271 30p T1731B 65p AFI27 20p BY271 30p T1731C 70p 2N2905 25	7420 Dual 4-input NAND gates 20p 18p 15p 13p 10p 7430 Single 8-input NAND gates 20p 18p 15p 13p 10p 17440 Dual 4-input NAND sates 20p 18p 15p 13p 10p 17440 BCD-Decimal decoder/Nixie driver 75p 70p 60p 55p 50p 17421 BCD-Decimal decoder (4-line to 10-line) TTL outputs 75p 70p 60p 55p 50p 7441 BCD-Decimal decoder TTL outputs 15p 70p 60p 55p 50p 7441 BCD-Decimal decoder 64p 7441 BCD-Decimal decoder 64p 7441 BCD-Decimal decoder 74p 7441 BCD-Decimal 94p 74p 7441 BCD-Decimal 94p 74p 74p 74p 74p 74p 74p 74p 74p 74p 7	OC35 Mullard 50p 25 + 45p 100 + 40p 500 + 35p 1000 + 30p	OC28 Mullard 60p 25 + \$5p 100 + \$0p 500 + 45p 1000 + 40p
AP180 50p BZ Y78\$1-00 TTP38C 8Cp AP181 45p GET102 35p TTP33B 71P33B AP186 50p GET103 25p AF186 40p GET111 45p TTP33C 3Cp AP39 40p GET113 25p AF193 40p GET113 25p AF193 40p GET115 50p AP186 40p GET115 50p AP186 40p GET116 50p GET116 50p AP186 40p GET16 50p GET16 50p AP186 40p AP186 40p GET16 50p AP186 40p	7447 BCD-Decimal seven segment decoder/ indicator driver	TIP29A Texas 50p 25 + 45p 100 + 40p 500 + 35p 1000 + 30p	SC45D Triac £1·25 25 + £1·10 100 + £1·00 500 + 95p 1000 + 90p
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EC92	324p 474p	EL85	421p	N78	£1.05	PY33	62 tp	UCL82	51p	6AM3	25p	6DQ6B	60p	682	40p	12BA6	321p	30P18	35p	7199	75p
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ECC82/		EL90	32 p	PC86/8	51p	PY81	41p							68A7	37 p	12BE6	32 p	30 PL1	77 p	7586	£1.25
ECC82/3		EL91	25p	PC95	36p	PY800	41p	UF41/2	55p	6AQ5	32 <b></b> ₽	6EA8	55p	68G7	321p	12BH7	32 p	30PL13	90p	9002	32 p
ECC84/5		EL95	35p	PC97	41p	P,Y801	41p	UF80/5	371p	6AQ6	50p	6EH7	32 ½ p	68J7	374p	12BY7	50p	30PL14	85 p		50p
ECC88	55p	EL360	£1-15	PCC84	46p	PY82	35p	UF89	41p	6AR5	32½p	6EJ7	35p	68K7	32 ł p	12K5	50p	35 A3	50p	9003	SUP

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Туре		New	Budget £	Туре	New £	Budget £
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MW36-21			£4.50	AW53-80	28.93	£6.25
	an arias		14.00	AW53-88 CME2	101 #8-93	£6.25
MW43-69Z	CRM171			AW59-90 AW59-91 CMES	303 £9·584	£7.20
	CRM172	£6.60	£4-621	A59—15W CMES		2, 20
MW43-80Z	CRM173	£6.60	£4.62}	CMES		
AW43-80Z	CME1702	£6-60	£4-621	CME		£7.20
	CME1703	£6-60	£4-621	A59-11W CME2		
	CME1706	26-60	£4-62}	A59—13W CME2		£10.97
				A59—16W CME2		£10.971
	C17AA	26-60	£4 62 ½	A59—23W CME2		£10.50
	C17AF	£6.60	24 62 1	A59—23W/R A61—120W/R CMES	£12-60 £13-50	£10.50 £11.50
AW43-88	CME1705	£6.60	£4·62}	A61—120W/R CMES A65—11W CMES		£14·50
AW47-90				COLOUR TUBE		411 00
AW47-91	A47 14W	£5-95	£4·87	A49—191X 19 inc		
A47 14W	CME1901	£5-95	24-87	A56—120X 22 inc		
241 2411	CME1902	£5.95	£4·87	A63—11 X 25 inc		
				PORTABLE SET		
	CME1903	£5·95	£4·87	TSD217	£11.50	
	C19AH	£5·95	£4.87	TSD282	£11.50	
A47-11W	CM E1905	£8-86‡	£7.00	A28—14W	£9·161	
A47-13W	CME1906	£10 274	£8·50	1100		Not
A47-26W	CME1905	£8-861	£7·75	1		supplied
		_	E1.13	CME1601		27.75
A47-26W/R	CME1913R	£9-33}		CM E1602		£8·00

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G.E.C. G.E.C. G.E.C. G.E.C. G.E.C. G.E.C.	2043			£4.75 £4.75 £4.75 £4.75 £4.75	Philips Pye Pye	2000 Serie 19TG Mod. 36 Mod. 40	28	. 24-75
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Single Tip "S" Single Tip "D"	4.5		13p 37p	Double Tip "D"	47
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2N697	20p	40398	P.A.	AF115	30p	BC147	17+p	BF257	47 tp
2N698	25p	40458	P.A.	AF116	25p	BC148	15p	BFX84	30p
2N706	12 è p	2N4061	224p	AFI17	25p	BC149	17±p	BFY19	33p
2N706A	124p	2N 4062	22 p	AF118	60p	BC152	17 p	BFY50	224p
2N930	27 lp	2N4286	17 to	AF119	20p	BC157	20p	BFY51	22 ł p
2N1132	32 tp	2N4291	17 p	AF124	221p	BC158	17 p	BFY52	22 p
2N1303	17 tp	AC107	30p	AF125	20p	BC169B	140	B8X21	37 tp
2N1305	22 p	AC117	60p	AF126	20p	BC169C	15p	OC25	50p
2N1306	25p	AC126	20p	AF127	174p	BC171	1740	OC26	324p
2N1307	25p	AC127	25p	AF139	374p	BC175	27 p	OC28	62 p
2N1711	25p	AC128	20p	AF178	45p	BC183	22 tp	OC29	75p
2N2147	72 p	AC154	22 t p	AF179	45p	BC184	22 p	OC35	40p
2N2160	57 p	AC176	25p	AF180	52 p	BC187	28 p	OC36	62 ł p
2N2614	30p	AC187	62 p	AF181	42 p	BC213L	261p	OC42	25p
2N2646	57 p	AC188	37 p	AF186	66 p	BCY32	37 p	OC44	20p
2N2905	40p	ACY17	27 tp	AF239	42 tp	BCY58	22 p	OC45	124p
2N2926		ACY18	25p	A8 Y 28	28p	BCY70	20p	OC46	15p
Green	14p	ACY19	25p	BC107	15p	BD115	78p	OC70	15p
Yellow	12 p	ACY20	25p	BC108	15p	BD121	65p	OC71	12 p
Orange	12 p	ACY21	25p	BC109	15p	BD123	82 ł p	OC72	12 p
2N3053	27 p	ACY22	20p	BC113	27 p	BD124	62 p	OC74	321p
2N3055	75p	ACY28	20p	BC114	37 èp	BD131	97 ∳ p	OC75	22 p
2N3391	20p	ACY 40	20p	BC115	32 p	BD132	971p	OC76	22 p
2N3392 2N3702	20p	ACY41 ACY44	25p	BC116	621p	BF115	25p	OC77 OC78	27 p 25 p
2N3704	17 p 22 p	AD140	40p	BC116A	37 p	BF117	47 p	OC81	20p
2N3704 2N3705	20p	AD142	40p 58p	BC117 BC118	39p	BF160 BF162	P.A. P.A.	OCSID	20p
2N3711	20p	AD149		BC134	321p	BF163	35p	OC83	25p
2N3819	35p	AD150	571p 621p	BC135	57 p P.A.	BF167	25p	OC84	25p
2N3826	30p	AD161	37 p	BC136	P.A.	BF173	321p	OC139	32 ł p
2N3905	37p	AD162	371p	BC137	P.A.	BF178	35p	OC140	32 tp
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Value μF Description 0·001 30V. 10% Suflex H5	Cost each	6K3 5	ISKRA UPM		Value Ohms Tol ± % Supplier and Ref. 150 5 MULLARD B803104NB	ost/100
0.001 30V. 10% Suflex H5 0.005 250V. Paper Hunts W95-BD14 or	]	8K2 5	ISKRA UPM		150 5 MULLARD B803104NB 220 5 MULLARD B803104NB	
0.005 250V. Paper Hunts W95-BD14 or 310 SLM 51	1	22K 5	ISKRA UPM		220 5 MULLARD B803104NB 330 5 MULLARD B803104NB	
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0.1 160V. 10% Polyester Film		1M2 5	ISKRA UPM	> 35p	820 5 MULLARD B803104NB	
0.1 250V. 10% Polyester Film		l iM5 5	ISKRA UPM		IK 5 MULLARD B803104NB	
0:022 250V. Paper Hunts W95-BD14 or	> 3p	2M7 5	ISKRA ŪPM		1K2 5 MULLARD B803104NB	
310 SIM SI	i i	3M3 5	ISKRA UPM	1	1K5 5 MULLARD B803104NB	
0-047 20/25V. Ceramic 2-5 16V. Electrolytic		3M9 5	ISKRA UPM ISKRA UPM		1K8 5 MULLARD B803104NB	
2.5 I6V. Electrolytic		4M7 5	ISKRA UPM	Į	2K2 5 MULLARD B803104NB	
25 25V. Electrolytic Hunts AW 1515 A0	0	68 2	ELECTROSIL TR5	]	2K7 5 MULLARD B803104NB	
or MEW 29T		82 2	ELECTROSIL TR5		3K3 5 MULLARD B803104NB	
100 I5V. Electrolytic	J	91 2	ELECTROSIL TRS		3K9 5 MULLARD B803104NB	
0.47 160V. Foil Waycom Tropyfol M		100 <u>2</u> 150 <u>2</u>	ELECTROSIL TR5 ELECTROSIL TR5		4K7 5 MULLARD 8803104NB 5K6 5 MULLARD 8803104NB 6K2 5 MULLARD 8803104NB	
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5 25V. Electrolytic Waycom Printilyt	> 5p	220 2	ELECTROSIL TRS		6K2 5 MULLARD B803104NB 6K8 5 MULLARD B803104NB	
10 25V. Electrolytic Waycom Printilyt	36	270 2	ELECTROSIL TRS	1	6KB 5 MULLARD B803104NB 8K2 5 MULLARD B803104NB	
250 25V. Electrolytic Hunts MEF 35BT		330 2	FLECTROSIL TRS	1 1	IOK 5 MULLARD B803104NB	
		360 2	ELECTROSIL TRS		IIK 5 MULLARD B803104NB	
I 160V. Foil Waycom Tropyfol M	``	390 2	ELECTROSIL TR5		12K 5 MULLARD B803104NB	
l 250V, Polyester	> 10p	470 2	EFECTIVOSIF TV3		15K 5 MULLARD B803104NB	
1.5 20V. Tantalum	, 10p	560 2	ELECTROSIL TR5	1	18K 5 MULLARD B803104NB	
12-5 25V. Electrolytic	,	680 2	ELECTROSIL TR5		22K 5 MULLARD B803104NB	35p
1.E. 35V T		820 2	ELECTROSIL TRS		27K 5 MULLARD B803104NB 33K 5 MULLARD B803104NB	3.3B
1·5 35V. Tantalum 2·2 35V. Tantalum 2·7 35V. Tantalum	) .	910 2	ELECTROSIL TRS		33K 5 MULLARD 8803104NB	
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3-3 100V. Polycarbonate S.T.C. PMA		K5 2	ELECTROSIL TRS	100p	56K 5 MULLARD B803104NB	
3-3 100V. Polycarbonate S.T.C. PMA 3-3K 100		Ka 2	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS	ТООР	56K 5 MULLARD B803104NB 68K 5 MULLARD B803104NB	
3·3 35V. Tantalum	20p	28 2	ELECTROSIL TRS	1	82K 5 MULLARD B803104NB	
3.9 35V. Tantalum		2K2 2	ELECTROSIL TRS	1 1	100K 5 MULLARD B803104NB	
4·7 35V. Tantalum		2K4 2	ELECTROSIL TRS	1 1	120K 5 MULLARD B803104NB	
4.7 63V. Polycarbonate Waycom MK5		2K7 2	ELECTROSIL TR5	1	150K 5 MULLARD B803104NB	
5.6 35V. Tantalum		3K3 2	ELECTROSIL TR5	1	180K 5 MULLARD B803104NB	
8·2 20V. Tantalum		3K9 2	ELECTROSIL TR5		220K 5 MULLARD BROSLOANB	
Price each in quantities 1-100		4K5 2	ELECTROSIL TR5		270K 5 MULLARD B803104NB 390K 5 MULLARD B803104NB	
SEMI-CONDUCTORS		4K/ 2	ELECTROSIL TRS	l 1	390K 5 MULLARD B803104NB	
Description	Cost each	5K6 2	ELECTROSIL TRS		390K 5 MULLARD B803104NB 470K 5 MULLARD B803104NB 560K 5 MULLARD B803104NB 820K 5 MULLARD B803104NB	
Diode   S92  Tayas	2.5p	6K2 2	ELECTROSIL TRS		820K 5 MULLARD B803104NB	
Zener Diode C7V5 Mullard BZY88	1	6K8 2	ELECTROSIL TRS			
Zener Diode Cov2 Muliara BZ 188		8K2 2	ELECTROSIL TRS		IM 10 MULLARD B803104NB IM2 10 MULLARD B803104NB	
		9K i 2	ELECTROSIL TRE		IM5 10 MULLARD B803104NB	
Zener Diode C9VI Mullard BZY88						
Zener Diode C6V8 Mullard BZY88		13K 2	ELECTROSIL TRS ELECTROSIL TRS		3M3 IO MULLARD B803104NB	
Zener Diode C6V8 Mullard BZY88 Zener Diode C5V6 Mullard BZY88		13K 2 15K 2	ELECTROSIL TRS ELECTROSIL TRS		3M3	
Zener Diode C6V8 Mullard BZY88 Zener Diode C5V6 Mullard BZY88 Zener Diode C8V2 Mullard BZY88	> 7·5p	13K 2 15K 2 33K 2	ELECTROSIL TR5 ELECTROSIL TR5 ELECTROSIL TR5		3M3	
Zener Diode C6V8 Mullard BZY88 Zener Diode C5V6 Mullard BZY88 Zener Diode C8V2 Mullard BZY88 Transistor 2N3704/K Texas Silec	7·5p	13K 2 15K 2	ELECTROSIL TR5 ELECTROSIL TR5 ELECTROSIL TR5		3M3 10 MULLARD B803104NB 6M8 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TR5	
Zener Diode C6V8 Mullard BZY88 Zener Diode C5V6 Mullard BZY88 Zener Diode C8V2 Mullard BZY88 Transistor 2N3704/K Texas Silec Transistor 2N4062/K Texas Silec	7 ·5p	13K 2 15K 2 33K 2 Prices per 100 in quant	ELECTROSIL TR5 ELECTROSIL TR5 ELECTROSIL TR5		3M3	
Zener Diode	7·5p	13K 2 15K 2 33K 2 Prices per 100 in quant	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000	5	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000	
Zener Diode C6V8 Mullard BZY8B Zener Diode C8V6 Mullard BZY8B Zener Diode C8V2 Mullard BZY8B Transistor 2N3704/K Transistor 2N3704/K Transistor 2N3711/K Transistor 2N3710/K Transistor 2N3710/K Transistor 2N3710/K Transistor 2N3710/K Transistor 2N3710/K Transistor 2N3710/K Texas Silec	7·5p	13K 2 15K 2 33K 2 Prices per 100 in quant	ELECTROSIL TR5 ELECTROSIL TR5 ELECTROSIL TR5 ities 100-10,000  Supplier and Ref.	Cost/100	3M3 10 MULLARD B803104NB 6M8 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TR5 Prices per 100 in quantities 100-10,000	
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Zener Diode	20р	13K 2 15K 2 33K 2 Prices per 100 in quant  **WATT RESISTORS Value Ohms Tol ± % 33 47 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD MULLARD	Cost/100	3M3 10 MULLARD B803104NB 6M8 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TR5 Prices per 100 in quantities 100-10,000	ost/100 750 <b>p</b>
Zener Diode C6V8 Mullard BZY88 Zener Diode C8V2 Mullard BZY88 Transistor 2N3704/K Texas Silec Transistor 2N3701/K Texas Silec Transistor 2N3701/K Texas Silec Transistor 2N3702/K Texas Silec Transistor 10C 28 Transistor 1	20р	13K 2 1 5K 2 33K 2 2 33K 2 2 2 33K 2 2 2 33K 2 2 2 3 3 5 2 3 3 5 5 6 8 5 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD MULLARD MULLARD MULLARD MURLARD MURLA	Cost/100	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. 22 10 WELWYN W22  Prices per 100 in quantities 100-10,000	ost/100 750p
Zener Diode C6V8 Mullard BZY8B Zener Diode C8V2 Mullard BZY8B Transistor 2N3704/K Transistor 2N4062/K Transistor 2N3708/K Transistor 2N3708/K Transistor 2N3708/K Transistor 2N3708/K Transistor 2N3708/K Transistor 2N3702/K Transistor CC28 Mullard BZY8B Mu	20p 45p	13K   2   15K   2   2   33K   2   2   33K   2   2   2   2   2   2   2   2   2	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD MULLARD MULLARD MULLARD MURLARD MURLA	Cost/100	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20hms Tol ± % Supplier and Ref. 20 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS	750p
Zener Diode C6V8 Mullard BZY88 Zener Diode C8V2 Mullard BZY88 Zener Diode C8V2 Mullard BZY88 Transistor 2N3704/K Texas Silec Transistor 2N3701/K Texas Silec Transistor 2N3708/K Texas Silec Transistor 2N3702/K Texas Silec Transistor OC 28 Mullard Price each in quantities I-100 POTENTIOMETERS Value Description	20р	13K 2 15K 2 33K 2 33K 2 Prices per 100 in quant  \$\frac{1}{2}\text{WATT RESISTORS}\$ Value Ohms \text{Tolder} \frac{1}{2}\text{%} 33  47 68 100 5 150 5 220 \$\frac{5}{2}\text{Colored} \frac{5}{5}\text{Colored} \$\frac{5}{2}\text{Colored} \frac{5}{2}\text{Colored} \$\frac{5}{2}\text{Colored} \frac{5}{	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD MULLARD MULLARD MULLARD MURLARD MURLA	Cost/100	3M3 10 MULLARD B803104NB 6M8 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms 701 ± % Supplier and Ref. 22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref.	750p
Zener Diode C6V8 Mullard BZY8B Zener Diode C8V2 Mullard BZY8B Zener Diode C8V2 Transistor 2N3704/K Transistor 2N4062/K Transistor 2N3711/K Transistor 2N3701/K Transistor 2N3701/K Transistor 2N3702/K Transis	20p 45p	13K   2   15K   2   2   33K   2   2   2   2   2   2   2   2   2	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD MULLARD MULLARD MULLARD MURLARD MURLA	Cost/100	3M3 10 MULLARD B803104NB 6M8 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms 701 ± % Supplier and Ref. 22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006	750p ost/100 20p
Zener Diode C6V8 Mullard BZY8B Zener Diode C8V2 Mullard BZY8B Zener Diode C8V2 Mullard BZY8B Transistor 2N3704/K Texas Silec Transistor 2N3701/K Texas Silec Transistor 2N3701/K Texas Silec Transistor 2N3702/K Texas Silec Transistor 2N3702/K Texas Silec Transistor 2N3702/K Texas Silec Transistor 2N3702/K Texas Silec Transistor 2S 302 Transistor OC 2B Mullard Price each in quantities I-100 POTENTIOMETERS Value Description IK Pre-set ISKRA PNIIB ZK Pre-set ISKRA PNIIB	20p 45p	13K 2 15K 2 33K 2 Prices per 100 in quant  **WATT RESISTORS** Value Ohms Tol ± % 33 47 68 100 5 150 5 220 5 270 5 330 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM	Cost/100	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Gounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Millard 56201 Parts A and B	750p
Zener Diode Zener	20p 45p	13K 2 15K 2 33K 2 Prices per 100 in quant  1 WATT RESISTORS Value Ohms 70 ± % 33  47 5 100 5 150 5 220 5 270 5 330 5 390 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM	Cost/I00	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Gounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Millard 56201 Parts A and B	750p ost/100 20p 25p
Zener Diode Zener	20p 45p	13K 2 15K 2 33K 2 Prices per 100 in quant  **WATT RESISTORS*  Value Chms Tol ± % 33  47  68 100 5 150 5 220 5 270 5 330 5 390 5 470 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM	Cost/100	3M3 10 MULLARD B803104NB 6M8 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. 22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006	750p ost/100 20p 25p
Zener Diode	20p 45p Cost each	13K 2 15K 2 33K 2 Prices per 100 in quant  1 WATT RESISTORS Value Ohms 70 ± % 33  47 5 100 5 150 5 220 5 270 5 330 5 390 5 470 5 680 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD ISKRA UPM	Cost/100	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Gounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Millard 56201 Parts A and B	750p ost/100 20p 25p
Zener Diode	20p 45p	13K 2 15K 2 33K 2 Prices per 100 in quant  **WATT RESISTORS*  Value Chms Tol ± % 33  47  68 100 5 150 5 220 5 270 5 330 5 390 5 470 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM	Cost/100	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  2u 0 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Company Com	750p ost/100 20p 25p
Zener Diode	20p 45p Cost each	13K 2 15K 2 33K 2 Prices per 100 in quant  1 WATT RESISTORS Value Ohms 70 ± % 33  47 5 100 5 150 5 220 5 270 5 330 5 390 5 470 5 680 5	ELECTROSIL TRS ELECTROSIC TRS ELECTR	Cost/100	3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  2u 0 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Company 100 Company	750p ost/100 20p 25p 100p
Zener Diode	20p 45p Cost each	13K 2 15K 2 33K 2 Prices per 100 in quant  1 WATT RESISTORS Value Ohms 70 ± % 33  47 5 100 5 100 5 120 5 220 5 270 5 330 5 390 5 470 5 680 5 820 5 1K 5	ELECTROSIL TRS ELECTROSIC TRS ELECTR		3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  2u 0 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Company 100 Company	750p ost/100 20p 25p 100p
Zener Diode Zener	20p 45p Cost each	13K 2 15K 2 33K 2 Pices per 100 in quant  **WATT RESISTORS*  Value Chms Tol ± % 33  47  68 100 100 150 220 270 330 390 470 680 5 120 5 11K 5 11K 5 11K 5 11K 5 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM	Cost/100	3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Yalue Ohms Tol ± % Supplier and Ref. Carlot of the Company o	750p ost/100 20p 25p 100p
Zener Diode	20p 45p Cost each 3p	13K 2 15K 2 33K 2 2 Prices per 100 in quant  1 WATT RESISTORS Value Ohms 7 5 68 5 100 5 120 5 220 5 220 5 230 5 330 5 390 5 470 5 680 5 820 5 1K2 5 1K2 5 3K3	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co MOUNTING Pad Jermyn EPX002 Mounting Pad	750p ost/100 20p 25p 100p
Zener Diode Zener	20p 45p Cost each	13K 2 15K 2 33K 2 2 Prices per 100 in quant   # WATT RESISTORS  Value Chms Tol ± % 33  47  68 100 150 150 5 220 5 270 330 5 390 5 470 680 5 18 820 1 K 1 K 2 3 K3 5 8K2 1 OK 1 BK	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Company Comp	750p ost/100 20p 25p 100p
Zener Diode Zener	20p 45p Cost each 3p 5p	13K 2 15K 2 33K 2 2 Prices per 100 in quant  1 WATT RESISTORS  Value Ohms 7 5 68 5 100 5 120 5 120 5 220 5 220 5 180 5 820 5 1K2 5 1K2 5 3K3 8 8K2 5 10K 5 18K 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 6MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Company Comp	750p ost/100 20p 25p 100p
Zener Diode Zener	20p 45p Cost each	13K 2 15K 2 233K 2 2 Prices per 100 in quant   # WATT RESISTORS  Value Chms Tol ± % 33  47  68 100 100 5 150 220 270 330 390 470 680 5 18K 5 10K 5 3K3 5 8K2 10K 5 18K 5 22K 5 220K	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 16MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 182 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 2 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T050006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T050006 MOUNTING MOUNTING MOUNTING MODELS CAR	750p ost/100 20p 25p 100p
Zener Diode Zener	20p 45p Cost each 3p 5p	13K 2 15K 2 33K 2 Prices per 100 in quant  1 WATT RESISTORS  Value Ohms 7 5 68 5 100 5 120 5 220	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS IELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TAS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS Value Ohms Tol ± % Supplier and Ref. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Community Pad Jermyn EPX002 Community Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mou	750p ost/100 20p 25p 100p
Zener Diode Zener	20p 45p Cost each 3p 5p	13K 2 15K 2 23K 2 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \times \text{MATT RESISTORS} \text{Value Ohms} \text{70} \frac{1}{5} \text{8}  150 5 150 5 120 5 120 5 120 5 120 5 140 5 330 5 390 5 1470 5 680 5 820 5 1K 5 820 5 1K 5 1K2 5 3K3 5 8K2 1 10K 5 18K 5 18K 5 18K 5 18K 5 22K 5 820K 5 820K 5 820K 5 820K 5 820K 5	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 16MB 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 182 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS 20 10 WELWYN W22 2 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T050006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T050006 MOUNTING MOUNTING MOUNTING MODELS CAR	750p 0st/100 20p 25p 100p
Zener Diode	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 Prices per 100 in quant  **WATT RESISTORS Value Ohms Tol ± % 33  47 68 100 5 150 5 220 5 270 5 330 5 390 5 470 680 5 680 5 680 5 820 5 1K 2	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ILECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co Mounting Pad Jermyn EPX002 Mounting Pa	750p  0st/100 20p 25p 100p  ORS
Zener Diode	20p 45p Cost each 3p 5p	13K 2 15K 2 33K 2 33K 2 Prices per 100 in quant  \$\frac{1}{2} \text{ WATT RESISTORS} \text{ Value Ohms}  Tollow S S S S S S S S S S S S S S S S S S S	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ILECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode Zener	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 Prices per 100 in quant  **WATT RESISTORS  Value Ohms	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TAS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS Value Ohms Tol ± % Supplier and Ref. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Community Pad Jermyn T05006 Mounting Pad Jermyn T05000 Parts A and B Prices per 100 in quantities 100-10,000	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode Zener	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 33K 2 Prices per 100 in quant  ** WATT RESISTORS  Value Chms 70 ± % 33 5 68 5 100 5 150 5 220 5 270 5 330 5 390 5 470 6 820 5 1K 5 820 5 1K 5 1K2 5 3K3 5 8K2 5 10K 5 18K 5 22K 5 22	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS  Supplier and Ref. Co. Mounting Pad Jermyn EPX002  Mounting Pad Jermyn EPX00	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \times \text{MATT RESISTORS} \text{Value Ohms} \text{70} \frac{5}{5} \text{68} \text{100} \text{50}	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS  Supplier and Ref. Co. Mounting Pad Jermyn EPX002  Mounting Pad Jermyn EPX00	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \text{ WATT RESISTORS} \text{ Value Ohms}  Total Strong	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS  Supplier and Ref. Co. Mounting Pad Jermyn EPX002  Mounting Pad Jermyn EPX00	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \times \text{ MATT RESISTORS} \text{ Value Ohms} \text{ Tol. } \frac{1}{2} \times \text{ MATT RESISTORS} \text{ Value Ohms} \text{ Tol. } \frac{1}{2} \times \text{ MATT RESISTORS} \text{ Value Ohms} \text{ 5} \text{ 68} \text{ 100} \text{ 5} \text{ 150} \text{ 5} \text{ 220} \text{ 270} \text{ 5} \text{ 380} \text{ 390} \text{ 5} \text{ 5} \text{ 18K} \text{ 5} \text{ 18K} \text{ 5} \text{ 10K} \text{ 5} \text{ 18K} \text{ 5} \text{ 22NK} \text{ 5} \text{ 18K} \text{ 5} \text{ 22NK} \text{ 5} \text{ 22NK} \text{ 5} \text{ 22NK} \text{ 5} \text{ 5} \text{ 18K} \text{ 22NK} \text{ 5} \text{ 18K} \text{ 5} \text{ 22NK} \text{ 5} \text{ 18K} \text{ 22NK} \text{ 5} \text{ 18K} \text{ 5} \text{ 18K} \text{ 22NK} \text{ 5} \text{ 18K} \text{ 18M} \text{ 5} \text{ 18K} \text{ 18M} \text{ 5} \text{ 18M} \text{ 18M} \text{ 2} \text{ 18M} \text{ 18M} \text{ 2} \text{ 20M} \text{ 5} \text{ 18M} \text{ 20M} \text{ 5} \text{ 18M} \text{ 20M} \text{ 5} \text{ 18M} \text{ 20M} \text{ 20M} \text{ 20M} \text{ 30M} \text{ 20M} \text{ 20M} \text{ 30M} \text{ 20M} \text{ 20M} \text{ 30M} \text{ 20M} \text{ 30M} \text{ 20M} \text{ 30M} \t	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  22 10 WELWYN W22  Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS  Supplier and Ref. Co. Mounting Pad Jermyn EPX002  Mounting Pad Jermyn EPX00	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 23K 2 2 Prices per 100 in quant  \$\frac{1}{2} \text{WATT RESISTORS}\$ Value Ohms	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM I		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS.  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. Co. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Kit Mullard 56201 Parts A and B Prices per 100 in quantities 100-10,000  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in: SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc.  NEW and UNUSED 150p e SHOP SOILED and EX-DEMONSTRATION 75p e Terms: Cash with order. Post and Package—e 24p extra on orders less than L5.  Quantity discount: 10% orders over £250 20% orders over £50 20% orders over £50 20% orders over £50 negotiable orders over £500 negotiable orders over £250	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p Cost each 3p 5p Cost each 5p	13K 2 15K 2 33K 2 2 33K 2 2 Prices per 100 in quant   **WATT RESISTORS  *Value Ohms	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  SUPPLIED TO THE SOURCE SOURCE  SUPPLIED TO THE SOURCE  SUPPLIED TO TH		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS.  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. Co. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Kit Mullard 56201 Parts A and B Prices per 100 in quantities 100-10,000  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in: SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc.  NEW and UNUSED 150p e SHOP SOILED and EX-DEMONSTRATION 75p e Terms: Cash with order. Post and Package—e 24p extra on orders less than L5.  Quantity discount: 10% orders over £250 20% orders over £50 20% orders over £50 20% orders over £50 negotiable orders over £500 negotiable orders over £250	750p  0st/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 23K 2 2 Prices per 100 in quant   # WATT RESISTORS  Value Ohms Tol ± % 33 5 68 100 5 150 5 220 270 5 330 5 390 5 470 5 680 5 18K 5 31K 7 3	ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ities 100-10,000  Supplier and Ref. MULLARD B803104 NB ISKRA UPM		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Ref. Co. Mounting Pad Jermyn T05006  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in: SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc. NEW and UNUSED 150p e SHOP SOILED and EX-DEMONSTRATION 75 pe Terms: Cash with order. Post and Package—e 24p extra on orders less than £5. Quantity discount: 10% orders over £55 20% orders over £50 negotiable orders over £25 Enquiries to: Mr. S. H. Hardwick	750p  ost/100  20p 25p 100p  ORS  s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 33K 2 33K 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \text{WATT RESISTORS}\$  Value Ohms	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM ISKRA	≥ 35p	3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TAS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS Value Ohms Tol ± % Supplier and Ref. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. 4 Comment of the Welwyn W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. 4 Jermyn T0006 Mounting Pad Jermyn EPX002 Comment of the Welwyn W22 Prices per 100 in quantities 100-10,000  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc. NEW and UNUSED 150pe 150pe 150pe 24p extra on orders less than £5. Quantity discount: 10% orders over £25 24p extra on orders less than £5. Quantity discount: 10% orders over £25 Enquiries to: Mr. S. H. Hardwick BRICO ENGINEERING LIMITE	750p  ost/100  20p 25p 100p  ORS  s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 2 33K 2 2 Prices per 100 in quant   # WATT RESISTORS  Value Ohms Tol ± % 33 5 68 100 5 150 5 220 270 5 330 5 390 5 470 680 5 820 5 1K 5 3K3 5 8K2 5 10K 5 3K3 5 8K2 1 10K 5 220K 5 18K 2 220K 5 18K 2 220K 5 18K 2 220K 6 220K 6 220K 6 220K 6 230K 6 240K 6 250K 6 250	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM ISKRA		3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS.  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. Co. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. MOUNTING Pad Jermyn TO5006 MOUNTING Pad Jermyn TO5006 MOUNTING Pad Jermyn EPX002 MOUNTING Pad Jermyn TO5006 MOUNTING PAD Jermyn TO5006 MOUNTING PAD JERMYN TO5006 FOR SUPPLIED PATE A AND BPRICES PART OF TOTAL PROPERTY OF TOTAL	750p  ost/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 33K 2 2 Prices per 100 in quant  **WATT RESISTORS  Value Ohms	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM ISKRA	≥ 35p	3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TAS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS Value Ohms Tol ± % Supplier and Ref. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. 4 Comment of the Welwyn W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. 4 Jermyn T0006 Mounting Pad Jermyn EPX002 Comment of the Welwyn W22 Prices per 100 in quantities 100-10,000  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc. NEW and UNUSED 150pe 150pe 150pe 24p extra on orders less than £5. Quantity discount: 10% orders over £25 24p extra on orders less than £5. Quantity discount: 10% orders over £25 Enquiries to: Mr. S. H. Hardwick BRICO ENGINEERING LIMITE	750p  ost/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \text{WATT RESISTORS}\$  Value Ohms	ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM ISKRA	≥ 35p	3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. Co 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Nat Mullard 55201 Parts A and B Prices per 100 in quantities 100-10,000  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in: SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc.  NEW and UNUSED 150p e SHOP SOILED and EX-DEMONSTRATION 75p e Terms: Cash with order. Post and Package—24p extra on orders less than £5. Quantity discount: 10% orders over £250 20% orders over £50 20% orders over £50 15% orders over £50 150 per 60 per 100 negotiable orders over £250 Enquiries to: Mr. S. H. Hardwick BRICO ENGINEERING LIMITE HOLBROOKS COVENTRY CV6 4	750p  ost/100 20p 25p 100p  ORS s.
Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 2 33K 2 2 Prices per 100 in quant  \$\frac{1}{2} \text{WATT RESISTORS}\$  Value Ohms	ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ELECTROSIL TAS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM ISKRA	≥ 35p	3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS.  Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. Co. 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co. MOUNTING Pad Jermyn TO5006 MOUNTING Pad Jermyn TO5006 MOUNTING Pad Jermyn EPX002 MOUNTING Pad Jermyn TO5006 MOUNTING PAD Jermyn TO5006 MOUNTING PAD JERMYN TO5006 FOR SUPPLIED PATE A AND BPRICES PART OF TOTAL PROPERTY OF TOTAL	750p  ost/100 20p 25p 100p  ORS s.
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Zener Diode	20p 45p  Cost each 3p  5p  Cost each 5p 20p  Cost/100	13K 2 15K 2 23K 2 2 Prices per 100 in quant  # WATT RESISTORS  Value Ohms Tol ± % 33 47 68 100 5 150 5 220 5 330 5 330 5 330 5 3470 5 6820 5 1842 5 3843 5 3842 5 3	ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ELECTROSIL TRS ities 100-10,000  Supplier and Ref. MULLARD  B803104 NB ISKRA UPM ISKRA	≥ 35р	3M3 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 10M 10 MULLARD B803104NB 1K2 ELECTROSIL TRS Prices per 100 in quantities 100-10,000  6 WATT RESISTORS  Value Ohms Tol ± % Supplier and Ref. Co 22 10 WELWYN W22 Prices per 100 in quantities 100-10,000  TRANSISTOR MOUNTINGS Supplier and Ref. Co Mounting Pad Jermyn EPX002 Mounting Pad Jermyn T05006 Mounting Pad Jermyn T05006 Mounting Nat Mullard 55201 Parts A and B Prices per 100 in quantities 100-10,000  FOR SALE  12V. DC PERMANENT MAGNET ELECT. MOTO 2000-2300 r.p.m. at 12 volts—Current Consumption 5 amps (max.)—Torque 19 oz in: SHAFT ROTATION REVERSIBLE IDEAL FOR WORKING MODELS, CAR ACCESSORIES, etc.  NEW and UNUSED 150p e SHOP SOILED and EX-DEMONSTRATION 75p e Terms: Cash with order. Post and Package—24p extra on orders less than £5. Quantity discount: 10% orders over £250 20% orders over £50 20% orders over £50 15% orders over £50 150 per 60 per 100 negotiable orders over £250 Enquiries to: Mr. S. H. Hardwick BRICO ENGINEERING LIMITE HOLBROOKS COVENTRY CV6 4	750p  Dost/100  20p 25p 100p  DRS  DRS  ach each

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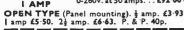
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		4 c/o			40-70		50p*
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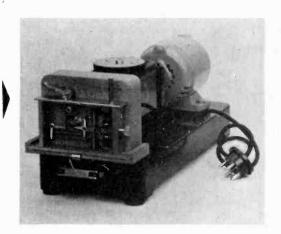


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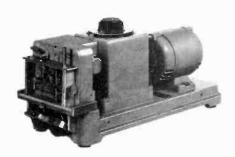
**MODEL 1532** 

Specially designed for training. Prints dots and dashes on tape with variable paper speed drive. Speed range 0-40 words per

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MODEL 115

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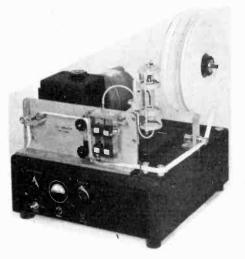
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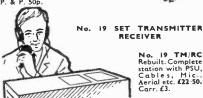
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2N 1303	19p	2N3704	I3p	ACY22	lép	BC169	Hp .		35p
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2N 1309	36p	2N3710	l3p	AFI14	24p	BCI84L	llp	NKT403	65p
2N1613	23p	2N 3711	I3p	AFI15	24p	BC212L	.lép	NKT405	79p
2N1711	26p	2N3819	23p	AFI 17	22p	3C213L	l ép	OC7I	38p
2N 1893	54p	2N3904	35p	AFI24	33p	BC214L	16p	OC81	25p
2N2147	95 <sub>R</sub>	2N 3906	35p	AFI27	22p	BCY70	19p	OC83	20p
2N2218	34p	2N 4058	l3p	AFI39	33p	BCY71	33p	ZTX300	14p
2N2218A	44p	2N4059	10p	AF239	36p	BCY72	15p	ZTX301	I6p
2N2219	38p	2N 4060	Пр	ASY26	27p	BF115	23p	ZTX302	22p
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2N 2270	62p	2N4062	120	BC107	I2p	3F173	19p	ZTX304	27p
2N2369A	190	. 2N4124	18p	BC108	Hp	3F194	I4p	ZTX500	18p
2N2483	35p	2N4126	27p	BC109	12p	BF195	15p	ZTX50I	2lp
2N2484	42p	2N4284	I5p	BCI25	15p	BFX29	3lp	ZTX502	25p
2N2646	47p	2N4286	15p	BCI26	22p	BFX84	25p	ZTX503	22p
2N2904A	42p	2N 4289	15p	BCI47	10p	BFX85	34p	ZTX504	52p

## RESISTORS—10%. 5%. 2%

			,,_,	7 — 1			
Code	Power	Tolerance	Range	Values available	to 9 (see no	10 to 99 ote below),	100
000	1/20W 1/8W 1/4W	5% 5%	82Ω-220ΚΩ 4·7Ω-470ΚΩ	E12 E24	9	8 0 8	7
000	1/200	10%	$4.7\Omega$ - $10M\Omega$ $4.7\Omega$ - $10M\Omega$ $4.7\Omega$ - $10M\Omega$	E12 E24 E12	1·2 2·5	0·8 1	0.
MO	1/2W 1W	10%±1/20Ω	$10\Omega - 1M\Omega$ $0.22\Omega - 3.9\Omega$	E24 E12	4 7	3·5 7	3
ww	3W 7W	5%	12Ω-10ΚΩ 12Ω-10ΚΩ	E12	7	7	6

Codes: C = carbon film, high stability, low noise.

MO = metal oxide, Electrosil TRS, ultra low noise.

WW= wire wound, Plessey.

Values: E12 denotes series: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and their decades. E24 denotes series: as E12 plus 11, 13, 16, 20, 24, 30, 36, 43, 51, 62, 75, 91 and their decades.

CARBON TRACK POTENTIOMETERS, long spindles. Double wiper ensures minimum noise level.

noise level.
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Values available	to 9 (see n	10 to 99 ote below),	100 up
E12	9	8	7
E24	1	0.8	0.7
EI2	l l	0.8	0.7
E24	1.2	1	0.9
EI2	2.5	2	1.8
E24	4	3.5	3
E12	7.	7	6
Eł2	7	7	6
E12	9	9	8

Prices are in pence each for quantities of the same ohmic value and power rating. NOT mixed values. (Ignore fractions on total value of resistor order.)

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Replies will be forwarded in strictest confidence to the PA consultant advising on these appointments. They should include comprehensive career and salary details, not refer to previous correspondence with PA, quote the reference on the envelope and be addressed to:



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#### UNIVERSITY OF SURREY

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

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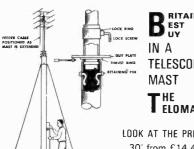
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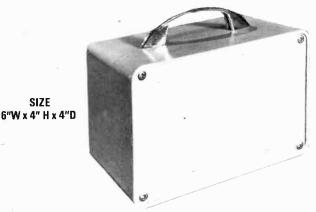
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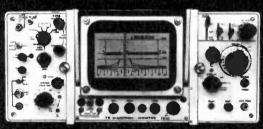
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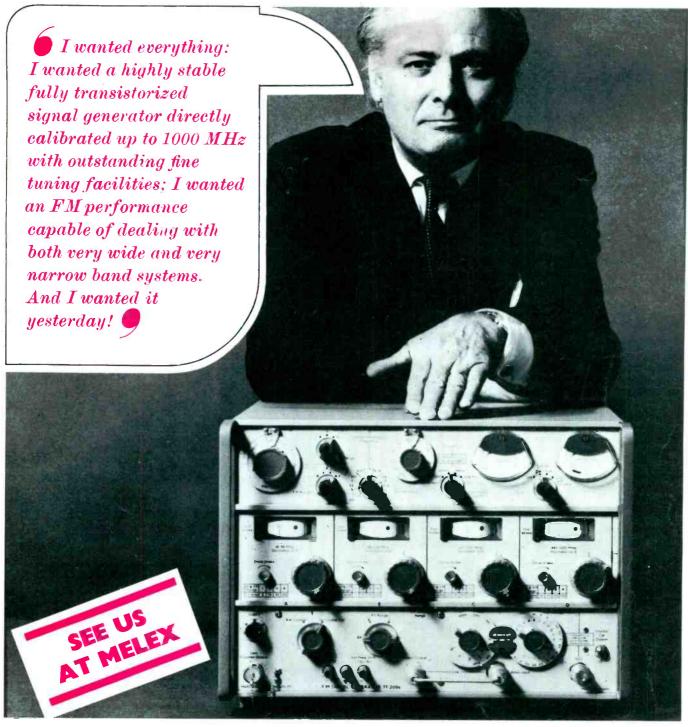
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