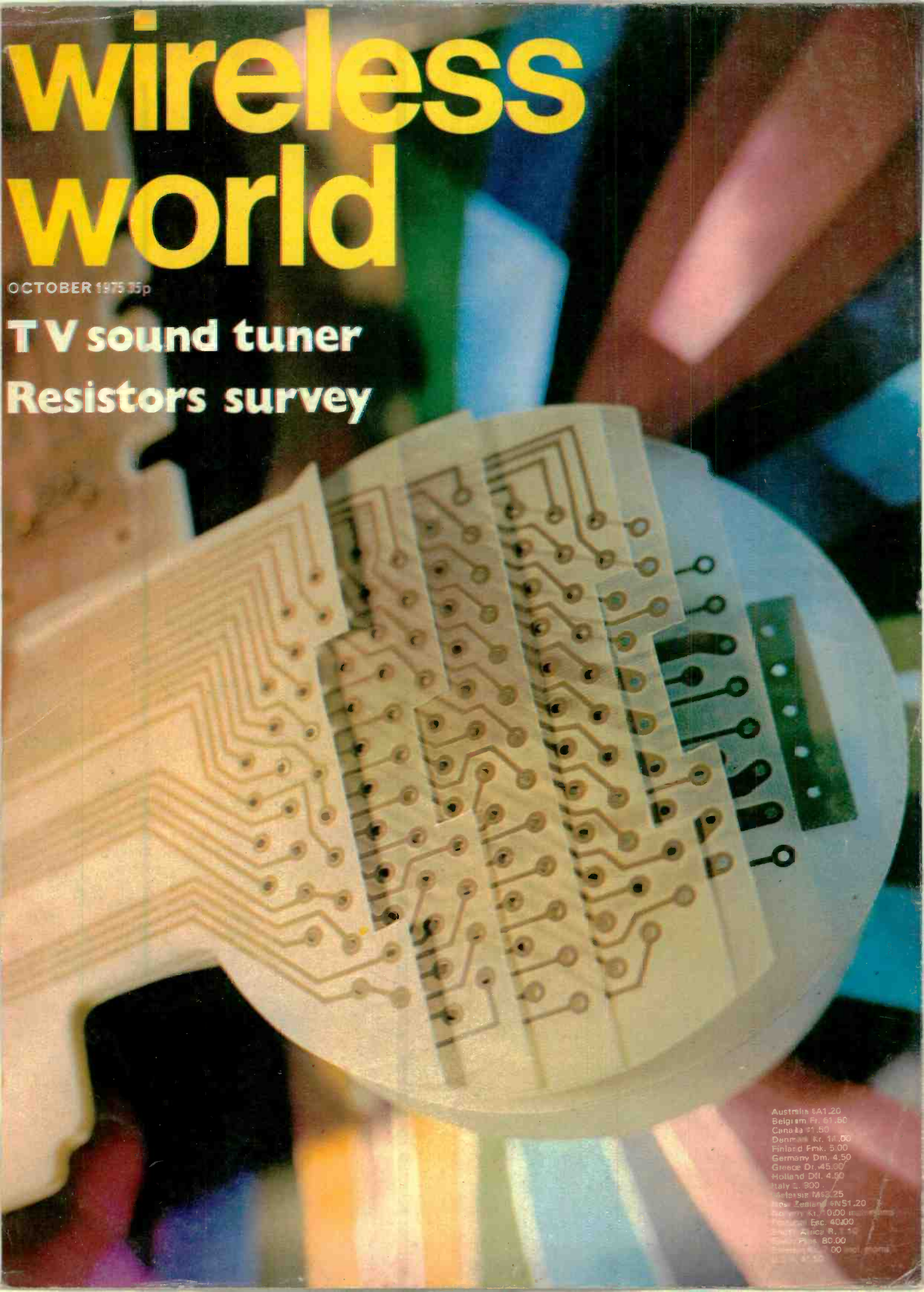
wireless world

OCTOBER 1975 35p

T V sound tuner
Resistors survey



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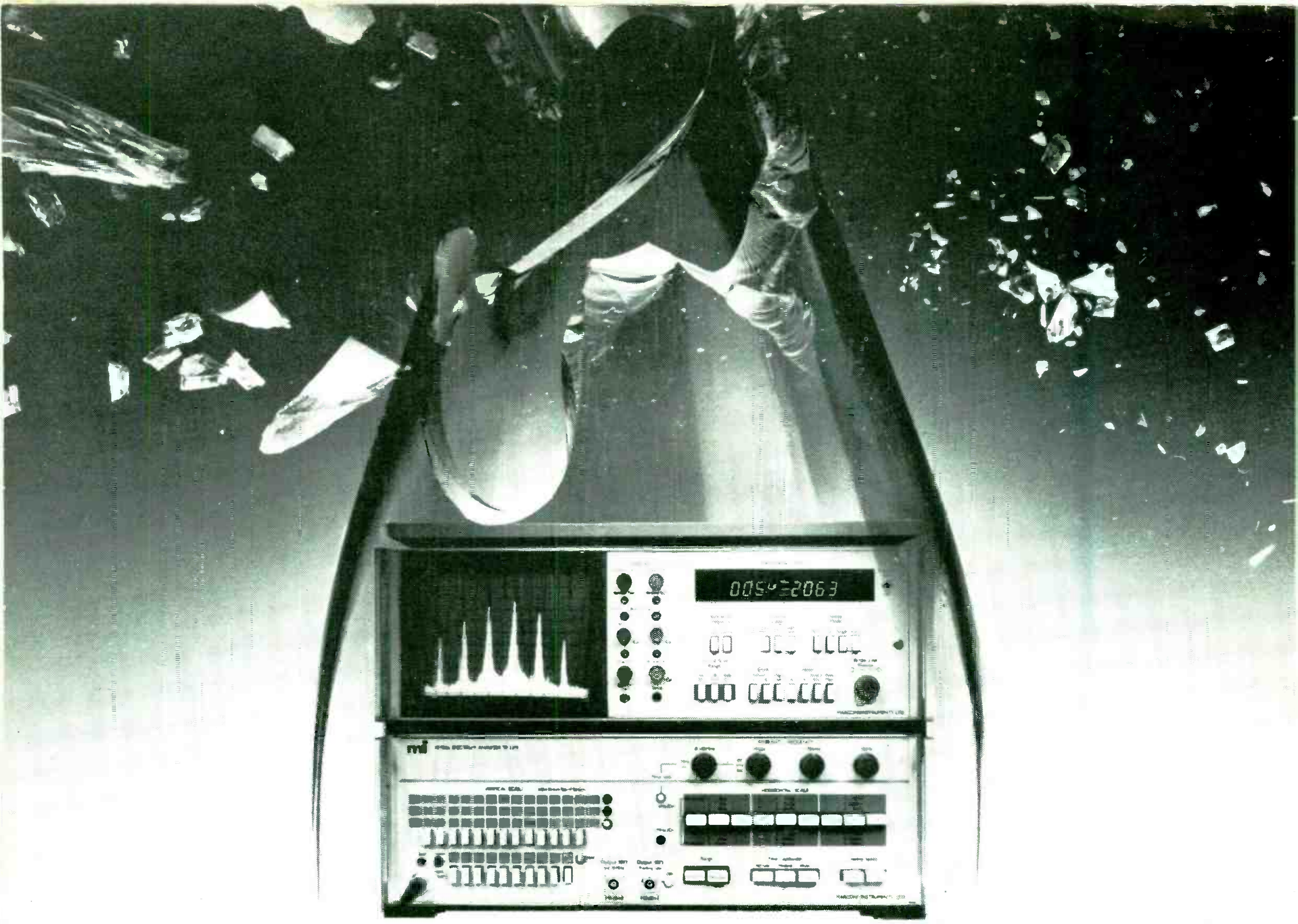
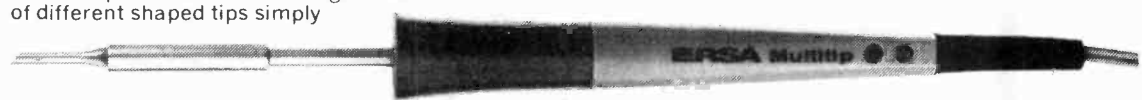
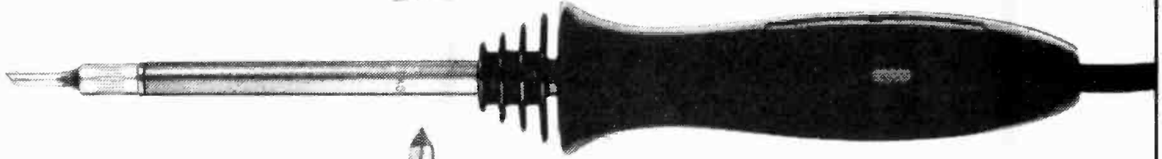
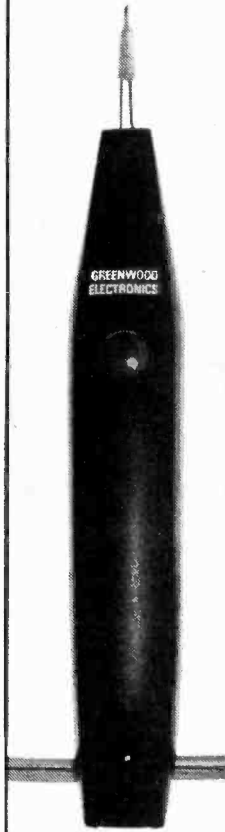


The Greenwood guide to professional soldering.

The Ersa Multitip. A top-quality iron that's ultra-light, offering reliability so necessary to achieve constant production flow. A range of different shaped tips simply push onto the stem of the iron. It has the unique advantage that you can change the element in seconds.

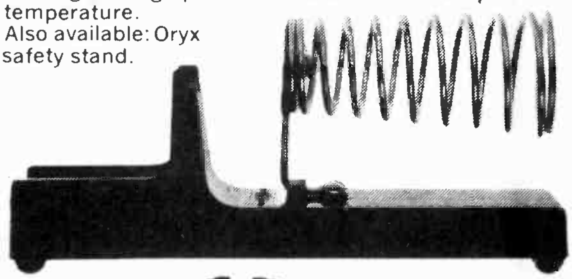


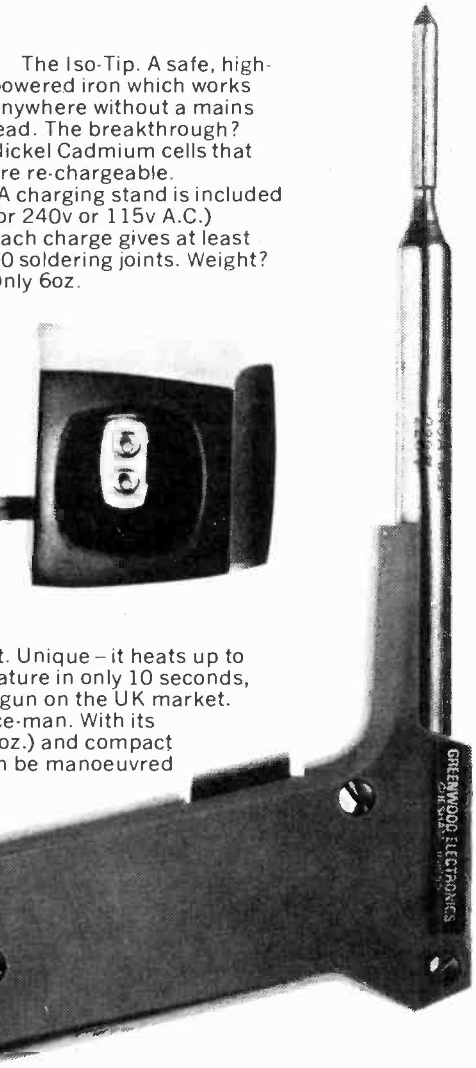




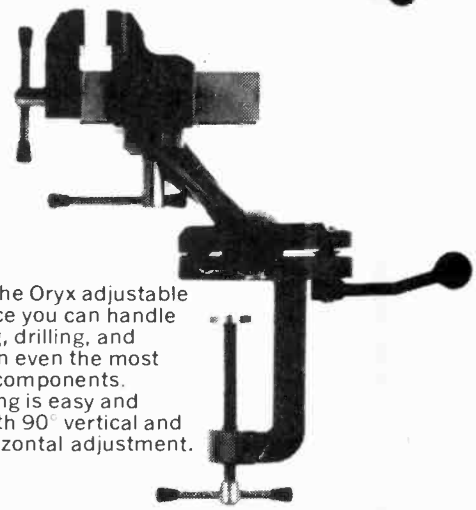
The Iso-Tip. A safe, high-powered iron which works anywhere without a mains lead. The breakthrough? Nickel Cadmium cells that are re-chargeable. (A charging stand is included for 240v or 115v A.C.) Each charge gives at least 60 soldering joints. Weight? Only 6oz.

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





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



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

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

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

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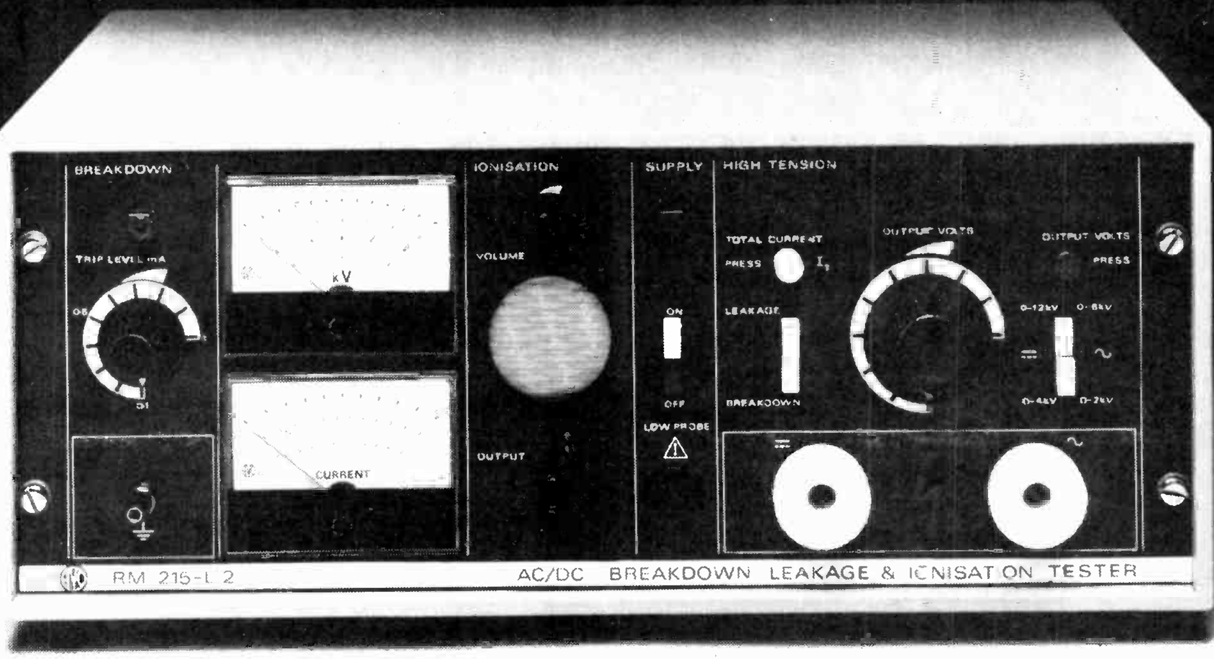

Ion out your quality control problems

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

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

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

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

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

APPLICATIONS

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

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

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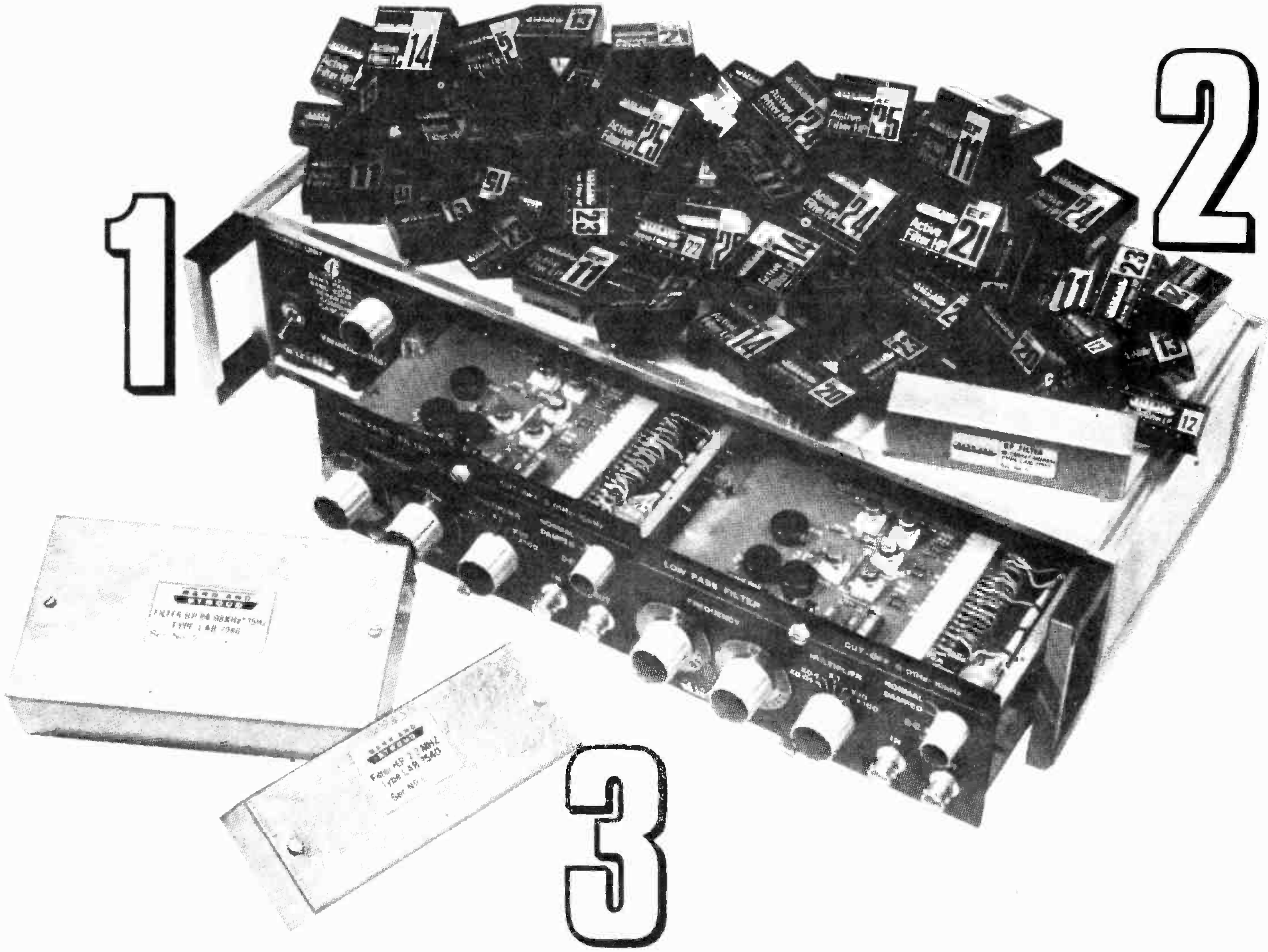
Thorn Measurement Control and Automation Division.

WW—064 FOR FURTHER DETAILS

BARR & STROUD ELECTRONIC FILTERS

The 3 aspects of our service



1. System EF3

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

2. Active Filter Modules

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

3. Custom Build Service

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

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Telephone: 01-930 1541 Telex: 261877

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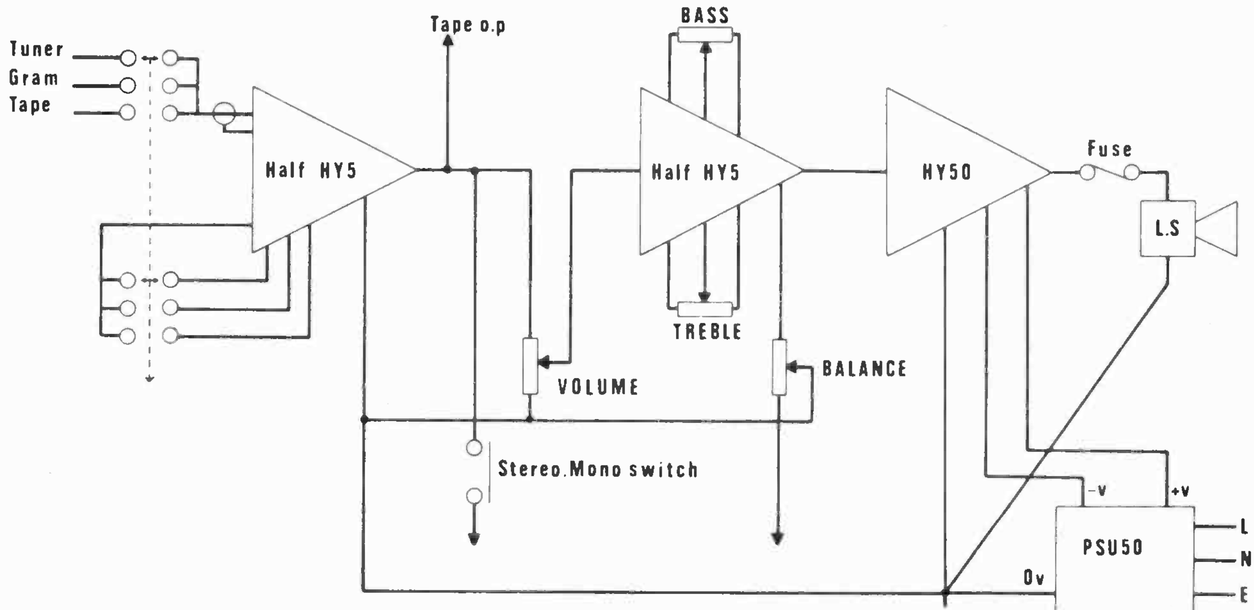
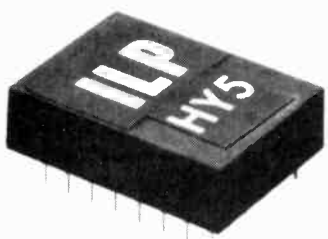
I.L.P. (Electronics) Ltd

SHEER SIMPLICITY!



Mono electrical circuit diagram with interconnections for stereo shown



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

TECHNICAL SPECIFICATION

Inputs

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

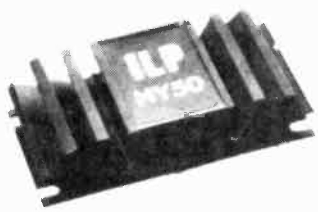
Outputs

Tape	100mV
Main output	Odb (0.775 volts RMS)

Active Tone Controls

Treble	±12db at 10kHz
Bass	±12db at 100Hz
Distortion	0.05% at 1kHz
Signal/Noise Ratio	68db
Overload Capability	40db on most sensitive input
Supply Voltage	±16–25 volts.

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

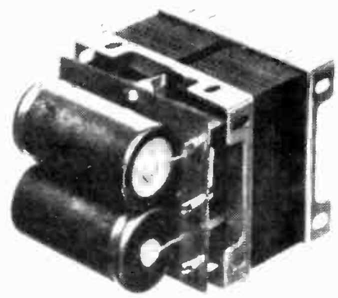


The HY50 is a complete solid state hybrid Hi-Fi amplifier incorporating its own high conductivity heatsink hermetically sealed in black epoxy resin. Only five connections are provided: Input, output, power lines and earth.

TECHNICAL SPECIFICATION

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

PRICE £6.20 + £1.55 V.A.T. P & P free



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

TECHNICAL SPECIFICATIONS

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

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WW—044 FOR FURTHER DETAILS

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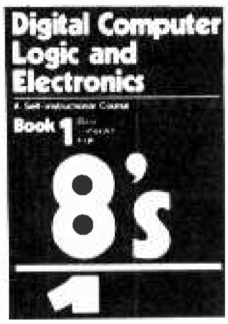

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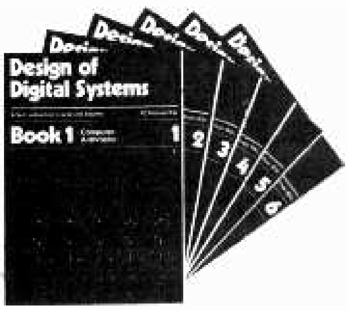

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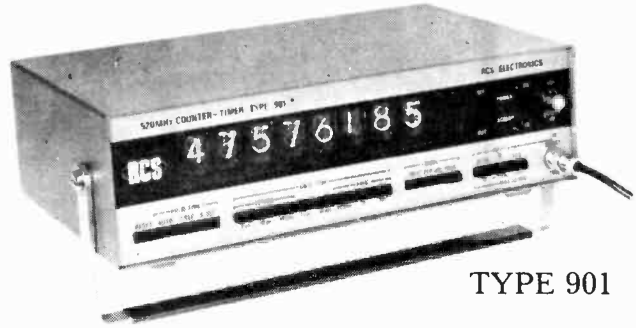

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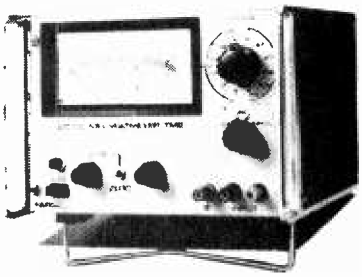
analogue instruments



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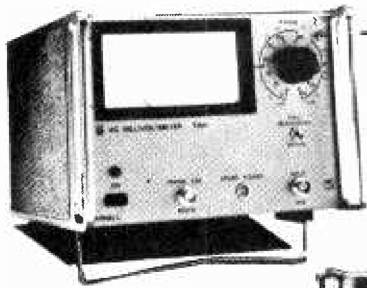

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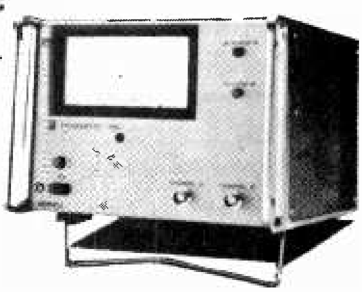

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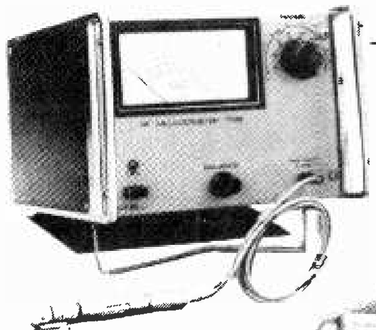

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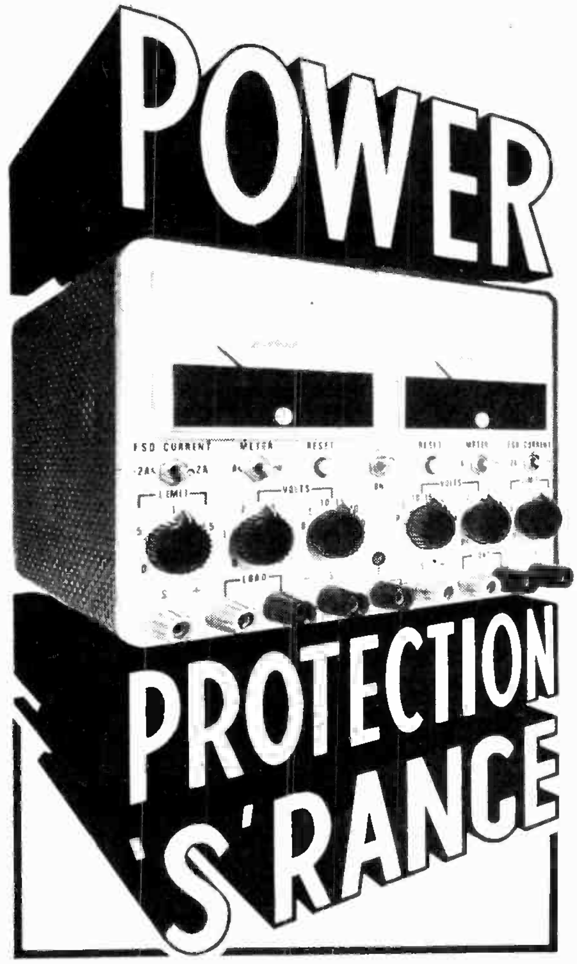

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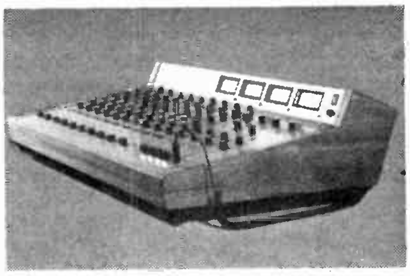

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Whiteley

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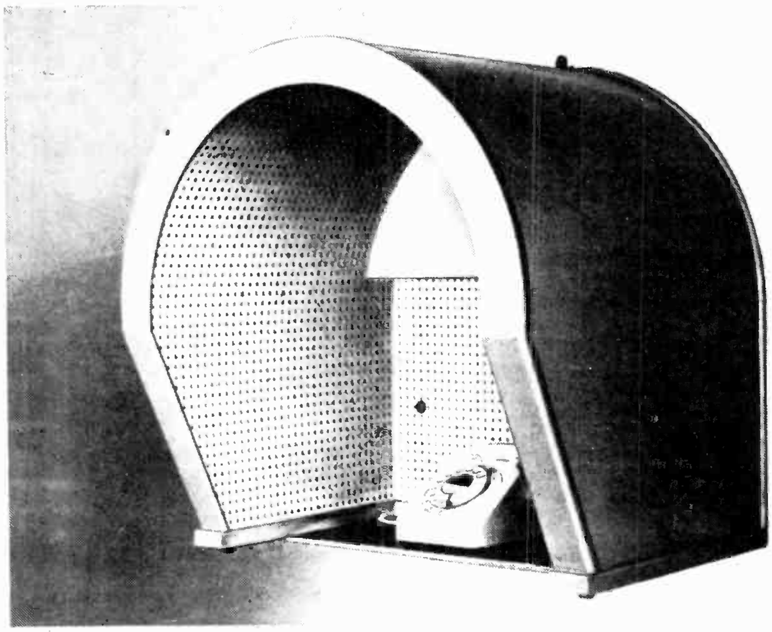

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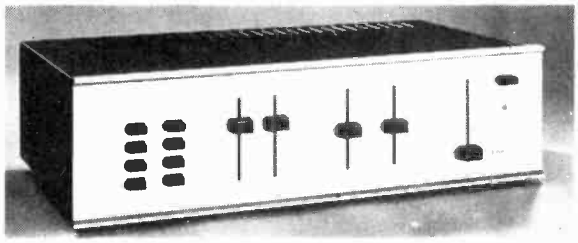

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Stereo Pre-amplifier Control Unit
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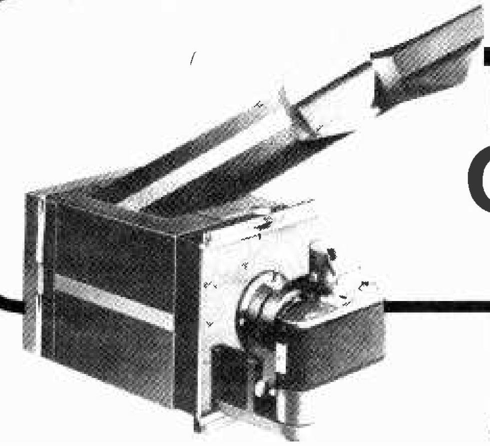

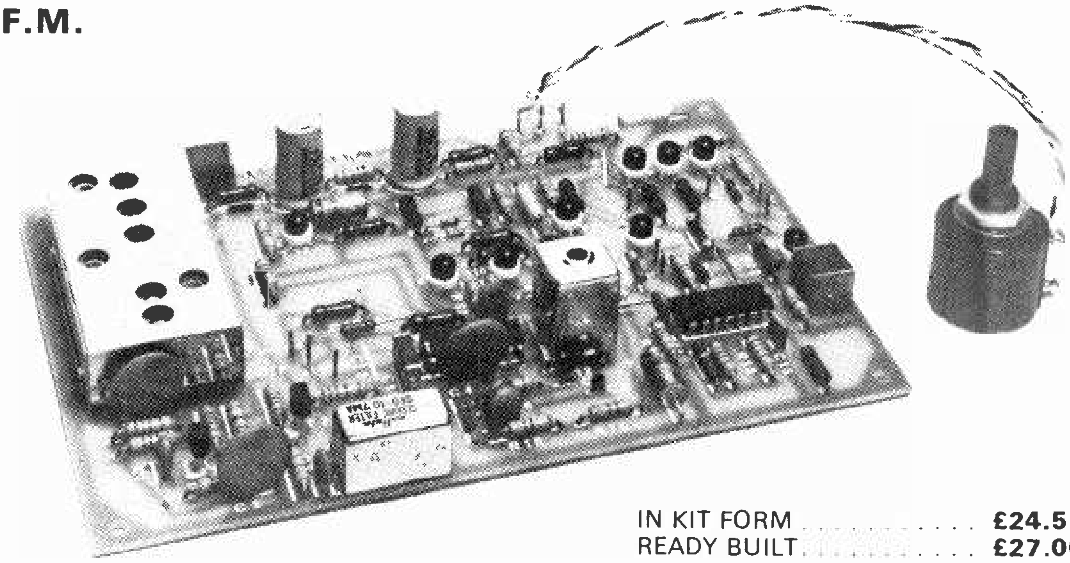

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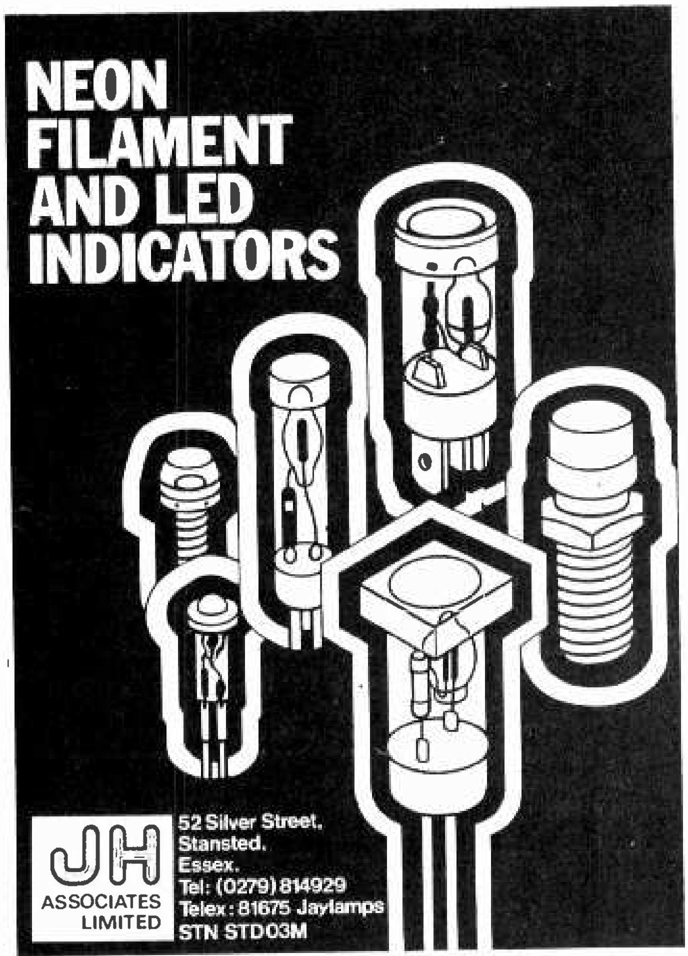

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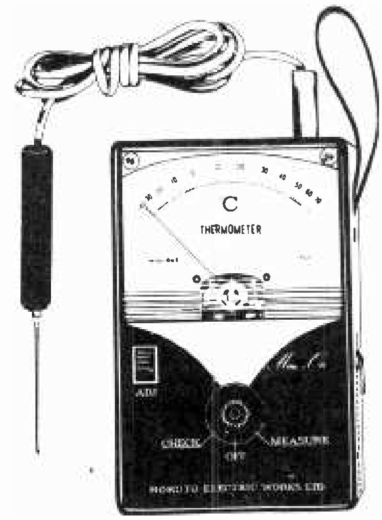

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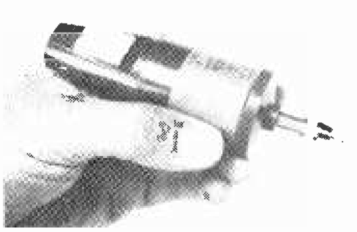

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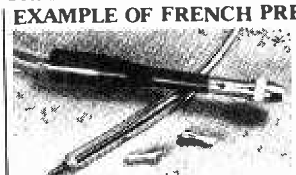

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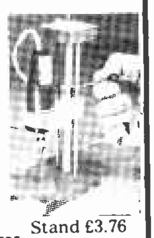

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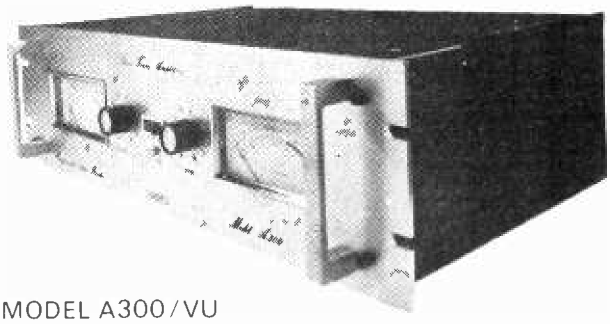

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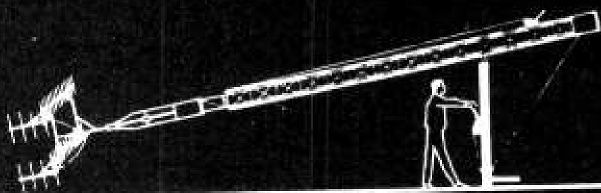

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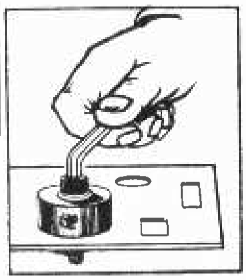

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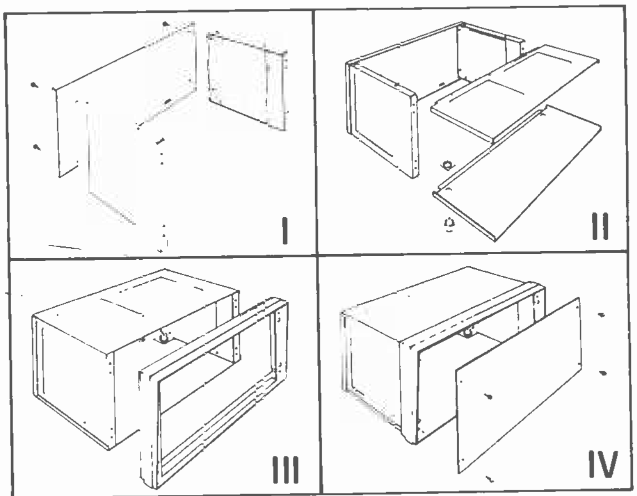

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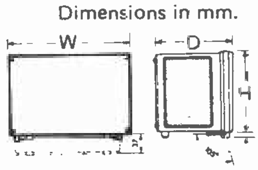

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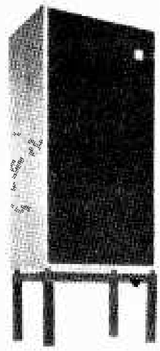

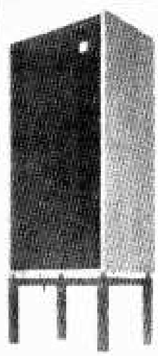

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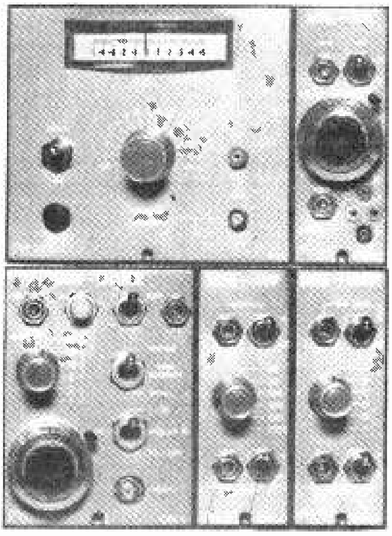

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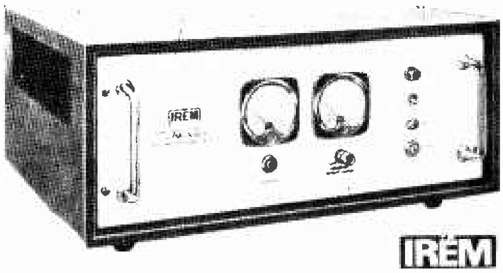

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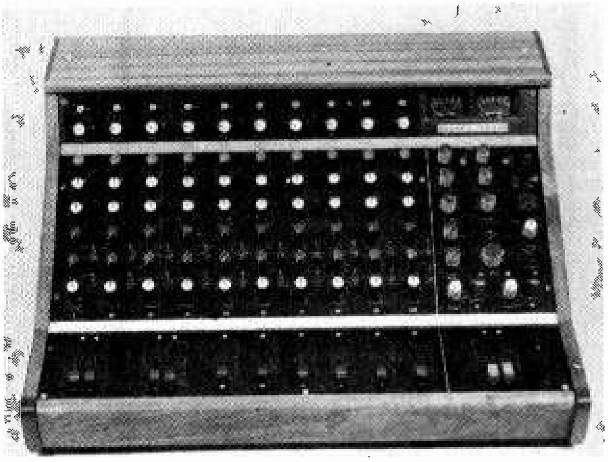

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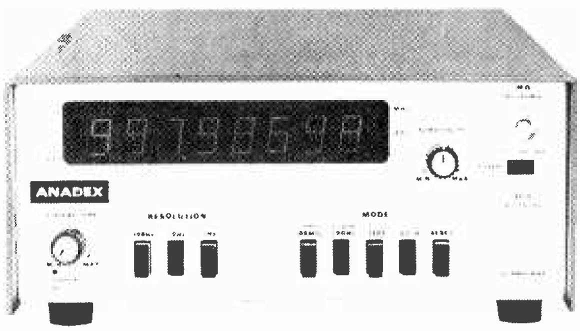

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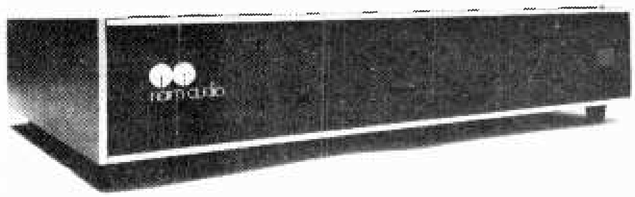

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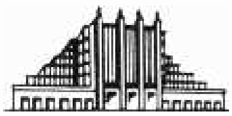

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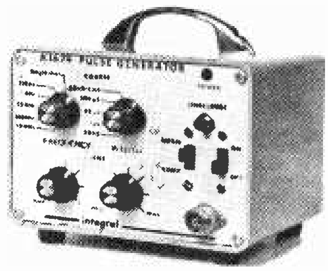

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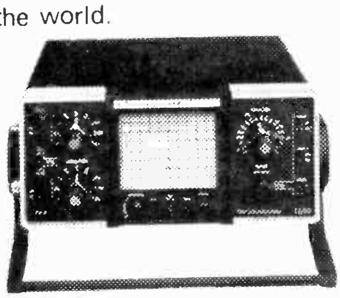

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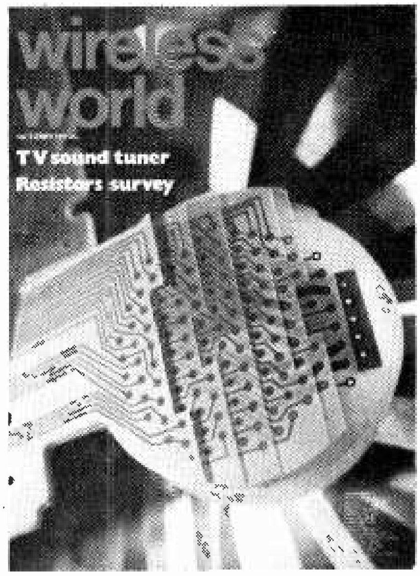

This month's front cover shows a multiple-layer printed circuit board made by BEPI (Electronics) Ltd. *(Photographer Paul Brierley)*

IN OUR NEXT ISSUE

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

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

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

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Deputy Editor:
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Broadcasting and communications

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

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

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

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

Television tuner design

Gives quality sound as well as vision signals

by D. C. Read, B.Sc.

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

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

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

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

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

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

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

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

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

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

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

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

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

varicap tuners do with high r.f. level. Details of this option will be given subsequently.
2. The output circuit of the u.h.f. module forms part of the first of two band-pass coupled circuits which together give a well-defined i.f. characteristic with a shape nearly that of the required ideal (see Figs. 6 and 8).
3. The i.f. gain is provided by a single a.g.c. amplifier which, together with the following grounded-base stage, operates in a cascode-type configuration. Because the controlled transistor works between low impedances (it is fed from an emitter-follower stage), it gives maximum gain and a large control range which can be covered with negligible adverse effect on the i.f. response shape.
4. The second of the two band-pass coupled circuits surrounds the combined own-sound trap and sound carrier take-off circuit. Because separation and rejection are obtained here by means of inductive coupling and cancellation, there is little unwanted in-band loss for either carrier.
5. The Motorola MC1330 is a synchronous demodulator giving a vision carrier rejection of at least 60dB and a conversion gain of about 35dB. Typical figures quoted give expected line linearity and differential gain of about 3%, and differential phase of 3° the performance realised here is of this order.
6. Instead of a 5.5MHz low-pass filter following the demodulator, two simple notch circuits – one each at the sound-carrier offset and twice colour-subcarrier frequencies – give sufficient protection against out-of-band interference. In practice, because of the high efficiency of the sound trap/take-off circuit mentioned in 4 above, the 6MHz trap has little work to do except during the temporarily disturbed conditions which can exist for short periods e.g. when first switching on the tuner. Additionally, the trap is included because its lower skirt completes the shaping of the video response, as will be illustrated later.
7. The correct trap-circuit termination is given by the following directly coupled amplifier which produces two outputs each of 4 volts pk-pk composite video. One of these feeds the a.g.c. circuit; the other is passed after impedance matching to a two-stage group-delay corrector and thence to the video output amplifier. Direct coupling is used from the MC1330 demodulator onwards so that true black-level registration can be achieved. For this reason, the directly-coupled stage mentioned above also provides a necessary d.c. shift so that signal blanking is at the required potential to suit following circuit conditions.
8. The tuner output circuit used will depend on the particular needs of a given installation. The complementary-pair amplifier shown in the full circuit diagram (see Fig. 2) provides one output at 75 ohms and one at higher impedance (about 270 ohms; this is specifically intended for a short link to the receiver decoder). If more than one 75-ohm output is required, larger transistors than those used in the suggested circuit will be necessary.

Sound circuit

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

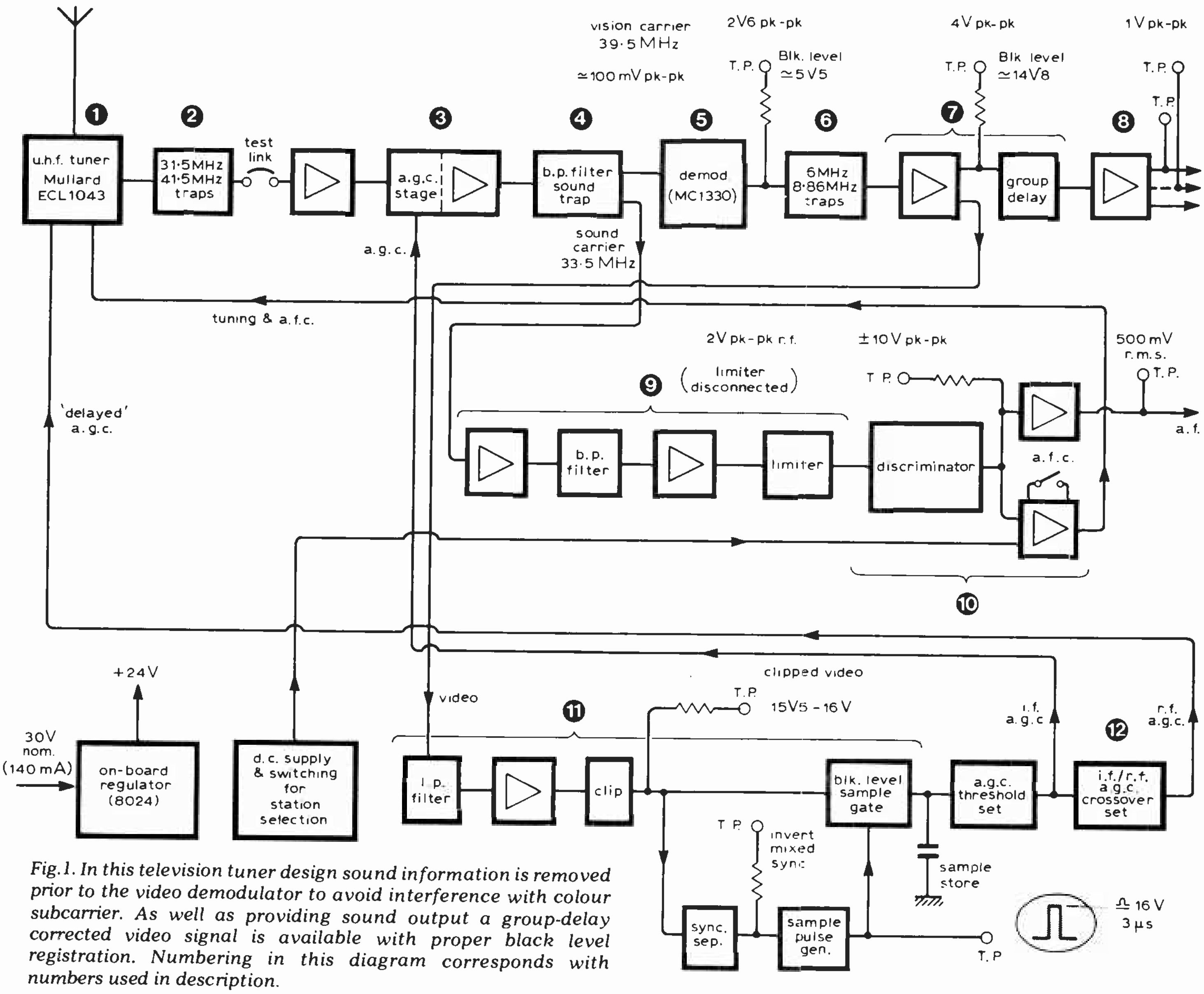
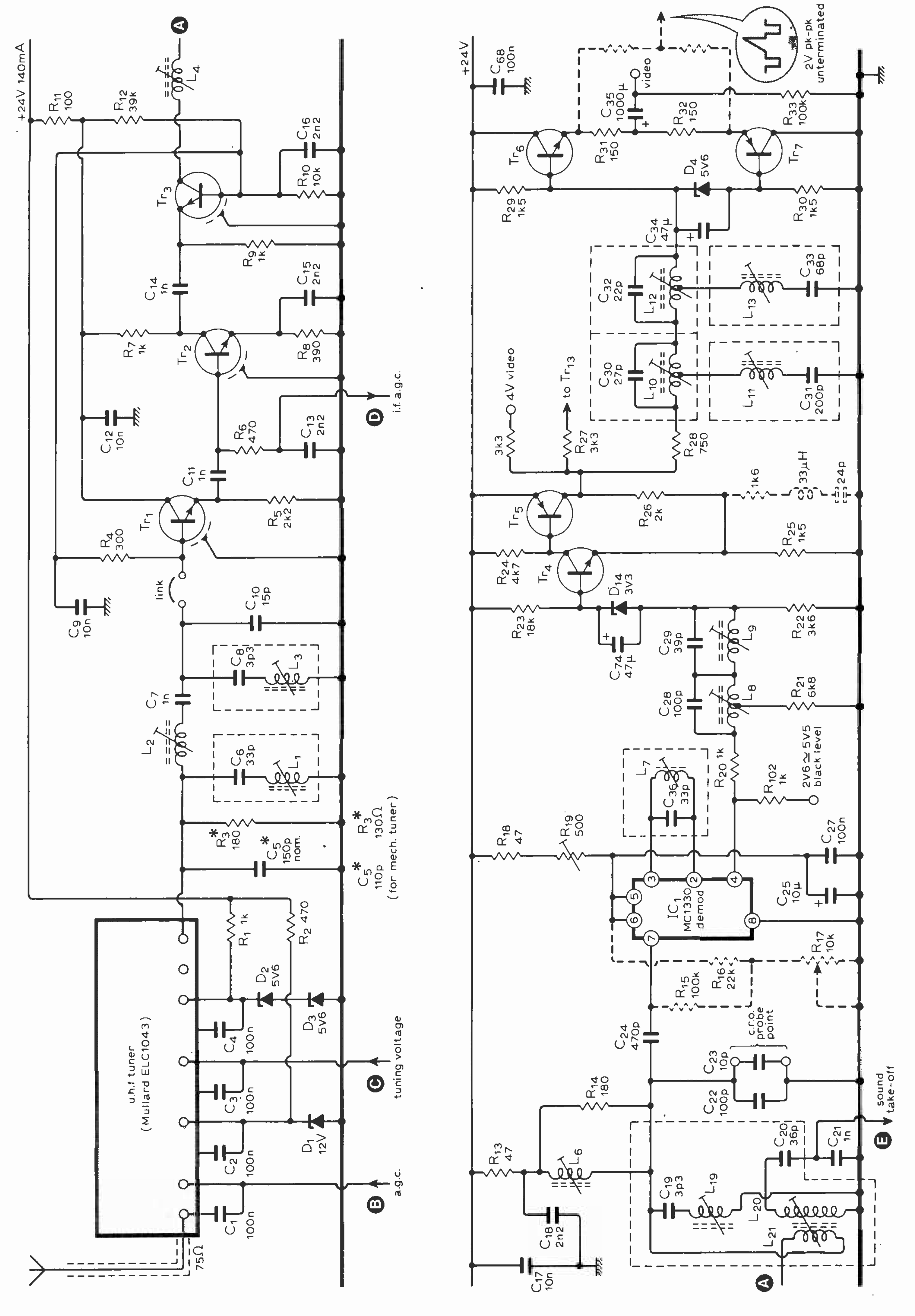


Fig. 1. In this television tuner design sound information is removed prior to the video demodulator to avoid interference with colour subcarrier. As well as providing sound output a group-delay corrected video signal is available with proper black level registration. Numbering in this diagram corresponds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


+24V 140mA
R11 100
R12 39k
L4
A
C16 2n2
R10 10k
Tr3
R9 1k
C14 1n
C15 2n2
R7 1k
Tr2
R8 390
C12 10n
R6 470
C13 2n2
D
i.f. a.g.c.
C11 1n
Tr1
R5 2k2
R4 300
link
C9 10n
C10 15p
C8 3p3
L3
C7 1n
L2
C6 33p
L1
R3* 180
C5* 150p nom.
R3* 130Ω
C5* 110p
(for mech. tuner)
u.h.f tuner
(Mullard ELC1043)
R1 1k
R2 470
D2 5V6
D3 5V6
C4 100n
C3 100n
C
tuning voltage
C2 100n
D1 12V
B
a.g.c.
C1 100n
75Ω
+24V
C68 100n
2V pk-pk unterminated
video
C35 1000μ
R32 150
R33 100k
Tr6
R31 150
Tr7
D4 5V6
R29 1k5
R30 1k5
C34 47μ
C32 22p
L12
C33 68p
L13
4V video
to Tr13
C30 27p
L10
L11
C31 200p
3k3
R27 3k3
R28 750
1k6
33μH
24p
Tr5
R26 2k
R25 1k5
R24 4k7
Tr4
D14 3V3
R23 18k
C74 47μ
C29 39p
L9
R22 3k6
C28 100p
L8
R21 6k8
L7
C36 33p
R20 1k
R102 1k
2V6 ≃ 5V5 black level
R18 47
R19 500
C27 100n
IC1 MC1330 demod
C25 10μ
R17 10k
R15 100k
R16 22k
C24 470p
C23 10p
c.r.o. probe point
C22 100p
R14 180
sound take-off
E
C20 36p
C21 1n
R13 47
L6
C19 3p3
L19
L20
C18 2n2
L21
C17 10n
A

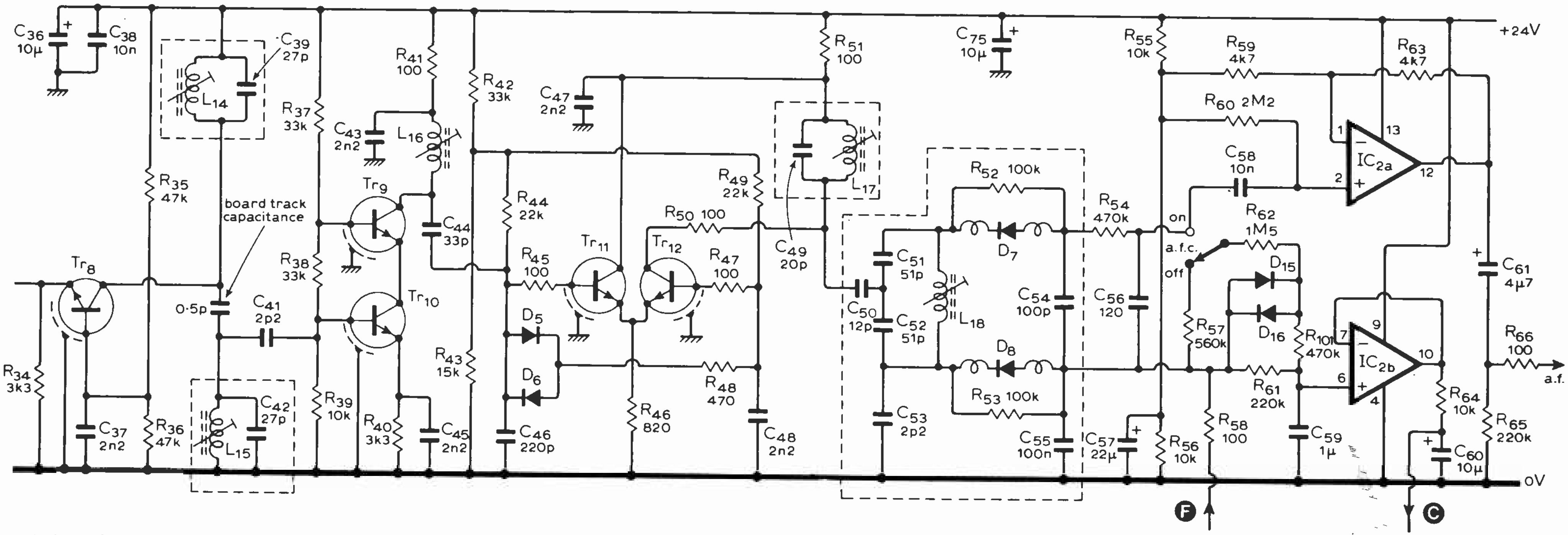
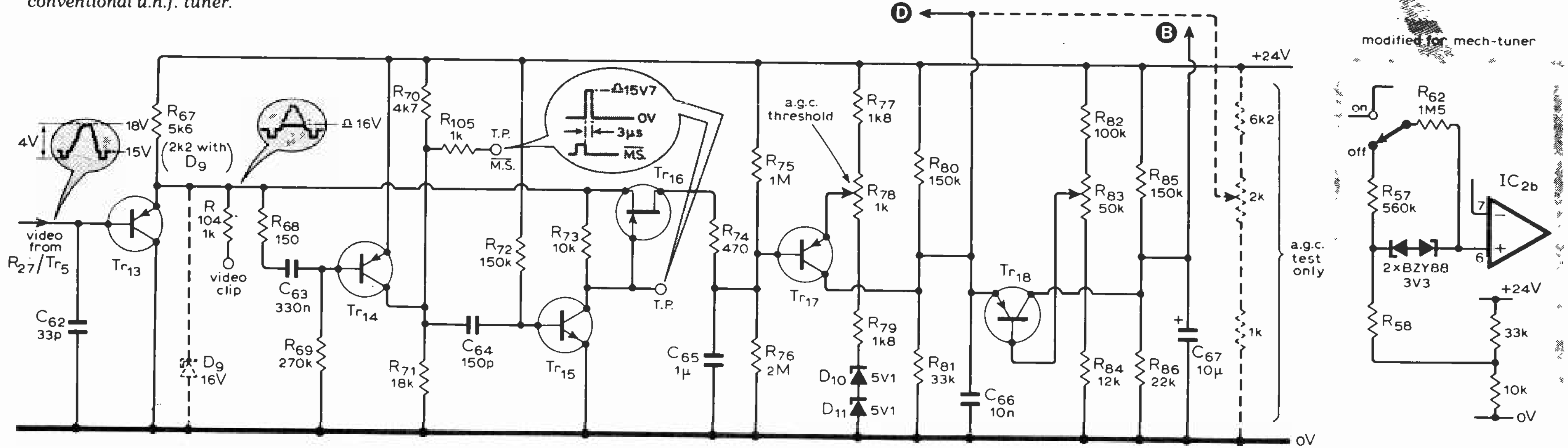
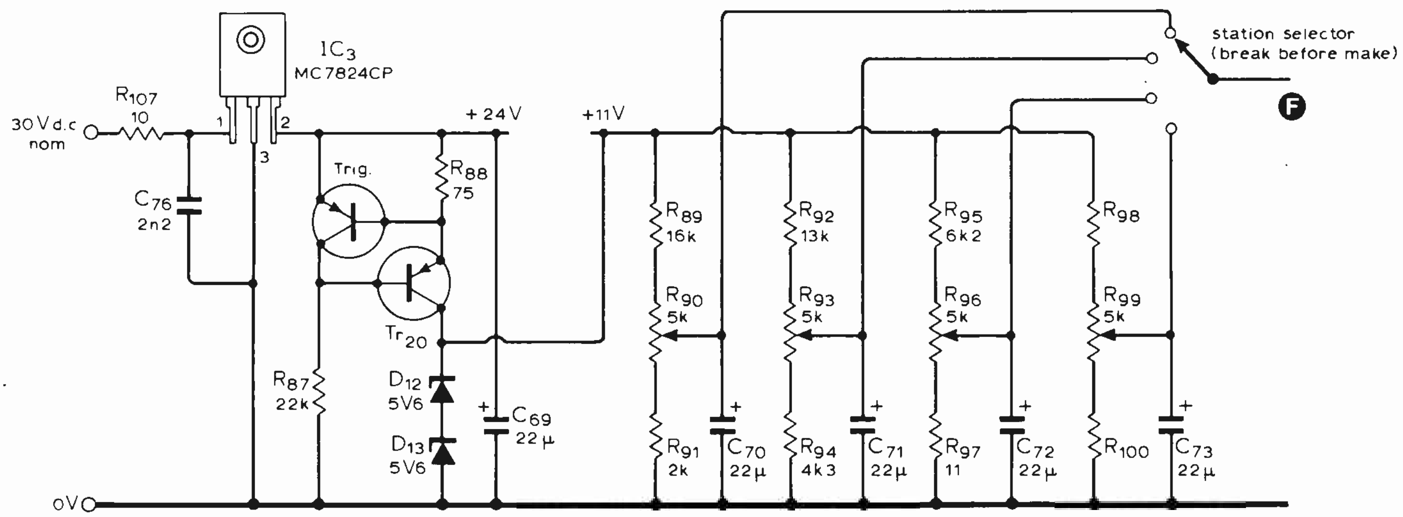


Fig.2. Coil winding details and p.c. board diagram for this circuit will be given in a subsequent article together with performance details and a modification for a conventional u.h.f. tuner.





Power supply arrangement for circuit of Fig.2 using varicap u.h.f. front end. Transistors Tr_{19} and Tr_{20} are BCY70 or 2N3906.

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

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

A.G.C. circuit

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

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

Circuit description

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

Aerial input to video output

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

The module i.f. output circuit is combined with C_5 and L_2 to form a 'bottom-C' coupled pair of tuned circuits giving part of the i.f. pass-band shaping; a small amount of in-band slope correction is carried out by C_7. Fig. 2 also shows a pair of conventional adjacent-channel traps at this point.

Emitter follower Tr_1 provides a low-impedance source of i.f. signal to the a.g.c. stage Tr_2 which feeds into the low-impedance offered by grounded-base amplifier Tr_3. The circuit arrangement is the outcome of a considerable amount of experiment to overcome the problem of obtaining adequate i.f. gain and control range without the attendant change in pass-band response. Because of the wide difference in input loading given by transistors working variously between maximum and minimum gain, it has usually been necessary to swamp the changing impedance of an a.g.c. stage by means of surrounding fixed low impedances. But although this arrangement represents a fairly effective cure, it necessarily causes loss of overall i.f. gain and of control range (for maximally-flat signals).

In the circuit used here, Tr_1 provides a source of constant signal voltage, Tr_3 is a 'virtual-earth' amplifier, so that Tr_2 and Tr_3 together effectively act as a cascode pair. Thus a higher maximum gain can be obtained from the combination and, as there is minimal signal voltage swing at the collector of Tr_2, the effect of Miller feedback on this stage is removed. The output impedence of Tr_3 is then matched by the following band-pass circuit to give an overall maximum gain of 38dB and an optimum signal of 30 to 35mV r.m.s. at the MC1330 demodulator input. Similar results can be obtained from a dual-gate f.e.t. (e.g. the RCA 40673), but these components are fragile, and the more robust circuit used here was chosen in preference.

The form of the network which completes the i.f. band shaping is that of a 'bottom-L' coupled pair; in Fig. 2, L_4 with self and stray capacitance added to the output capacitance of Tr_3 represents the 'input' tuned circuit, and L_8 is the coupling component. There are no components representing the 'output' tuned circuit; this is because they were deliberately computed to zero and do not have practical existence.

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

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

Semiconductor devices

BF173	Tr_1, Tr_3, Tr_{8-12}
BF167	Tr_2
2N3904	Tr_4, Tr_6, Tr_{15}
2N3906	Tr_5, Tr_7, Tr_{13}, Tr_{14}, Tr_{17}, Tr_{18}, Tr_{19}, Tr_{20}
2N3819	Tr_{16}
IC_1	MC1330
IC_2	SN72747
regulator	MC7824
AAZ13	D_5, D_6
1N916	D_7, D_8, D_{15}, D_{16}

Zener diodes — see Fig.2 for voltages

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

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

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

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

(To be continued)

Books Received

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

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

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

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

Guglielmo Marconi 1874-1937 by Keith Geddes is a Science Museum booklet describing the life and times of the Italian pioneer. His early experiments with "Hertzian waves," which led to the first wire-less telegraphy system, are described as well as the formation of the Marconi Company and the influence of the war years. The book concludes with an account of Marconi's last years in which he joined the Italian Fascist party, re-married and finally on 20th June 1937 died after several heart attacks. The booklet is well illustrated with photographs and is priced at 60p. Pp. 40. Her Majesty's Stationery Office, Atlantic House, Holborn Viaduct, London EC1P 1BN.

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

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

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

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

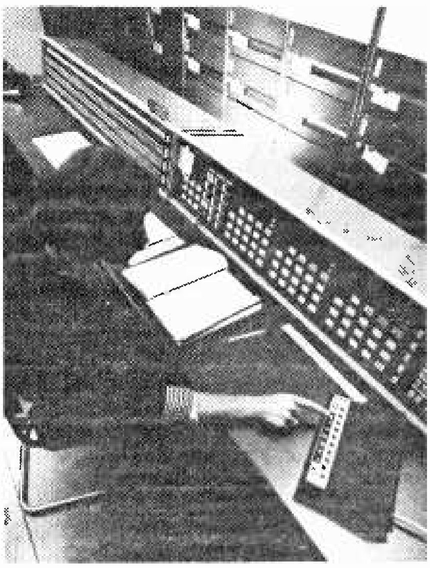
Towers' International Transistor Selector by T. D. Towers gives tabular information on ratings, characteristics, package and lead identification, application, manufacturers, and equivalents of over 10,000 transistors. The transistors are a selection of current or popular obsolete types from the UK, USA,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

News of the Month

A telegram a second

Savings of over £1½M a year are expected by the Post Office from a new £4½M centre now open in London which automatically routes telegrams into and out of the United Kingdom. The largest telegram system of its kind in the world, the new London transmission centre handles a telegram each second of the working day. It directly links 13 international telegraph area offices in the UK, six in London and the others in Belfast, Birmingham, Bradford, Bristol, Glasgow, Liverpool and Manchester, with 67 countries using 77 different international routes. Telegrams may be sent through the centre anywhere in the world, either direct or by way of a distant terminal. As an example of how the centre operates, outgoing telegrams for delivery abroad are received at the 13 telegraph area offices in Britain from customers, mostly by telex or telephone, but also by hand or from the sender's local post office. Operators at the area offices forward them by teleprinter to the telegram retransmission centre. Here, a computer automatically checks that each telegram is in the correct internationally agreed format, works out the route it has to take to its destination (its memory holds 10,000 overseas destination towns for this purpose), extracts accounting and billing information, adds the destination indicator and then directs the telegram to the outgoing circuit for the destination office, all in under a minute.

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



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

Integrated circuit in stitches

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

Breakthrough in quartz oscillators

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

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

Satellite interference suppressed

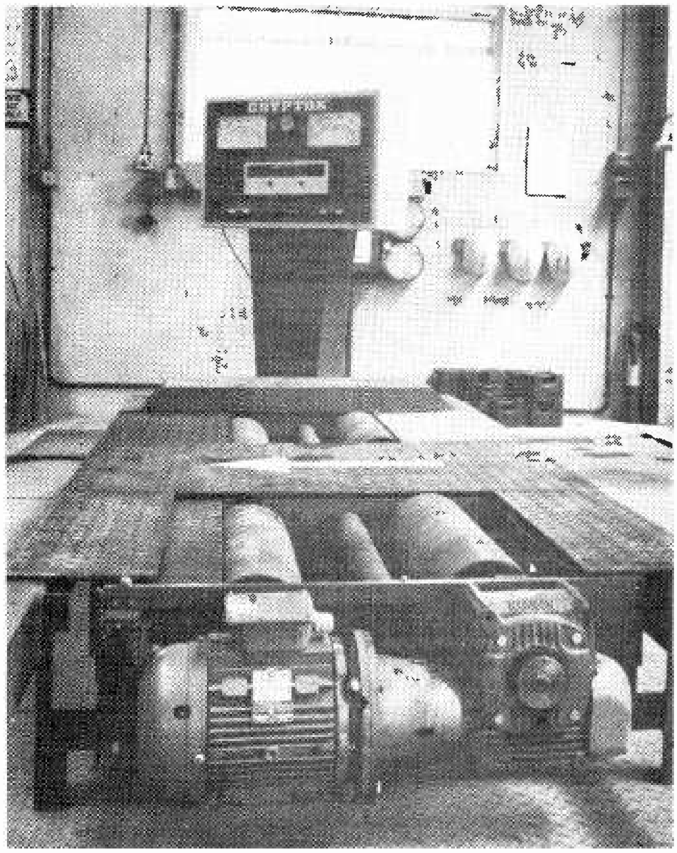
A new system for the suppression of unwanted signals which can interfere with transmission from communication satellites has been installed at the Satellite Earth Terminal Station, Goonhilly Downs, Cornwall. This station forms part of the INTELSAT satellite communications network which links virtually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

Under a preliminary study contract, Plessey proposed that the Post Office should consider use of a cancellation technique which had been used experimentally. This receives a significant level of the interfering signal only. By feeding a controlled amount of the signal from the auxiliary aerial into the main aerial receiver, the interference can be cancelled. This proposal was acceptable to the Post Office and Plessey believe that this is the first time that such a system has been applied to civil radio communications and foresees considerable potential for its further application in all fields of communication where interference is a growing problem.

Standstill brake tester

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

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



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

Perth to Adelaide by microwave

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

In this 60-hop system the low power-consumption of the 2GHz semiconductor equipment is particularly important since in many places there is no mains power supply and diesel fuel has to be transported up to distances of 650km. Power consuming air-conditioners have been eliminated at unattended repeater stations where the equipment is installed in a convection-cooled shelter which keeps the inside temperature within acceptable limits in spite of large diurnal variations outside of up to 22°C.

Colour TV deliveries down

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

Briefly

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

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

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

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

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

Progress in multiphonic organs

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

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

Many constructors of electronic organs make the mistake of thinking that if the output from a waveform generator is taken to the correct filter the desired tone will result. This is far from the truth. For example, some generators produce a square waveform and some a sawtooth. A square waveform contains only odd harmonics. The open diapason sound requires a predominance of even harmonics. No filter will produce missing harmonics. For a second example, a sawtooth contains both odd and even harmonics. For the closed diapason sound and for the clarinet sound a predominance of odd harmonics is required. A filter which severely attenuates the 2nd, 4th, 6th etc. harmonics will also attenuate the 3rd, 5th, 7th etc. harmonics. The open diapason sound cannot be produced from a square wave nor the closed diapason sound from a sawtooth. As well as the correct filter the correct input waveform is required.

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

In addition to different waveforms being provided, signals of different pitches for the same note are required to give the sound the "fullness" associated with organs. The most important additional pitch is one octave above the note being played. The second most important additional pitch is one octave below the note being played, particularly at the lower end of the keyboard. A separate complete switching system is usually provided for each pitch.[1]

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

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

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

Components list

Resistors — R

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

Capacitors — C

1 right hand side 100n, left hand side 400n — polystyrene or polycarbonate matched sets

2	70p		
3	220p		
4	220p		
5	1.5μ		
6	1.5μ	16	2.2n
7	1.5μ	17	100n
8	18n	18	2.2n
9	100n	19	2.2n
10	100n	20	330p
11	100n	21	2.2n
12	47n	22	2.2n
13	220n	23	18n
14	18n	24	220p
15	100n	25	18n

Integrated circuit

IC_1 op-amp 741

Variable resistors — RV

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

Transistors — Tr

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

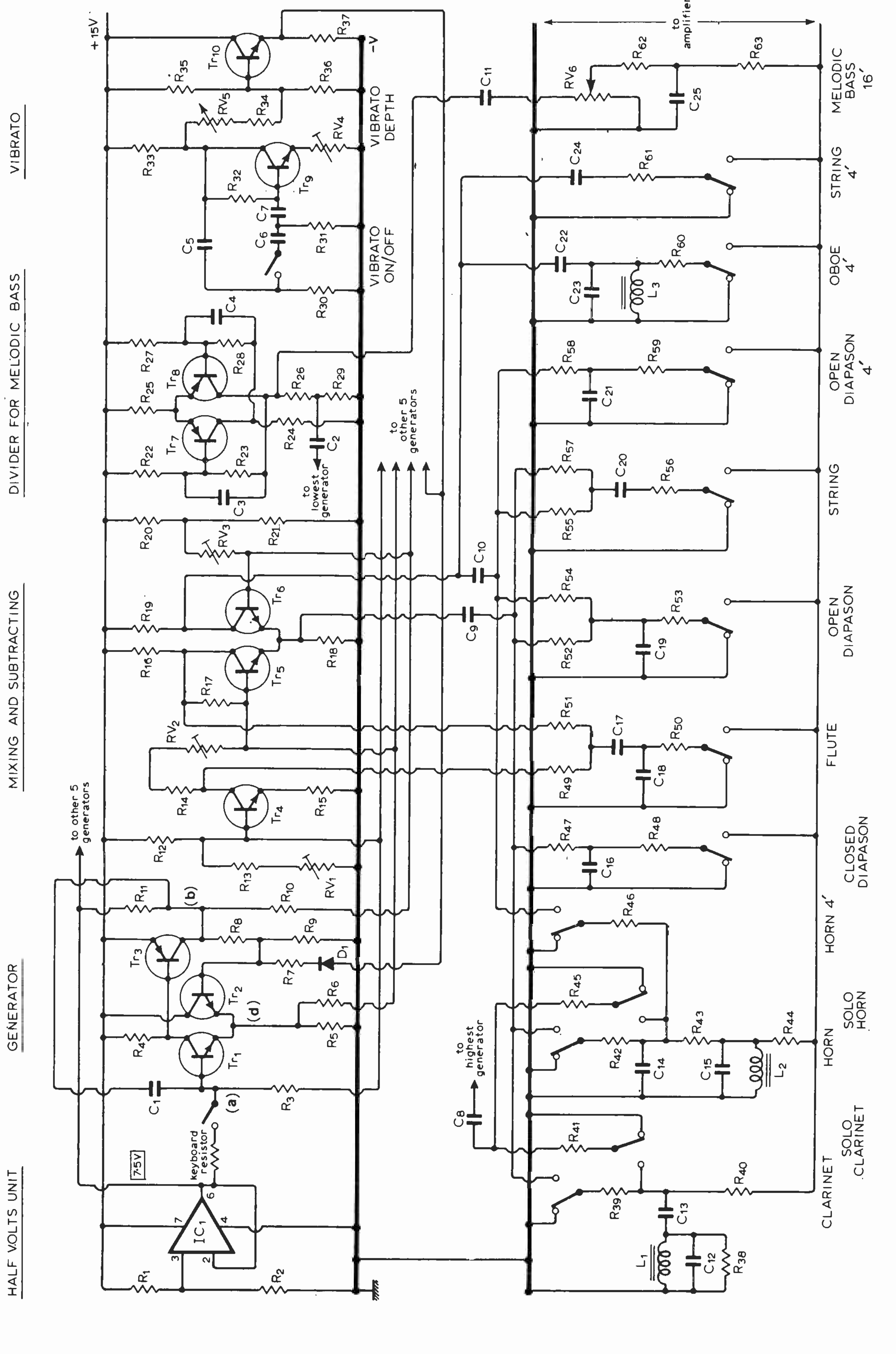
Inductors — L

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

Preset resistors — RV

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

All components are available from J. H. Asbery, 87 Oakington Manor Drive, Wembley, Middx. Where component types are not specified, *viz.* all capacitors except C_1 and resistors R_{19}, R_{22} upwards, any type may be used.


HALF VOLTS UNIT
GENERATOR
MIXING AND SUBTRACTING
DIVIDER FOR MELODIC BASS
VIBRATO
+15V
−V
7·5V
keyboard resistor
to other 5 generators
to lowest generator
to highest generator
to amplifier
VIBRATO DEPTH
VIBRATO ON/OFF
MELODIC BASS 16'
STRING 4'
OBOE 4'
OPEN DIAPASON 4'
STRING
OPEN DIAPASON
FLUTE
CLOSED DIAPASON
HORN 4'
SOLO HORN
HORN
SOLO CLARINET
CLARINET

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

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

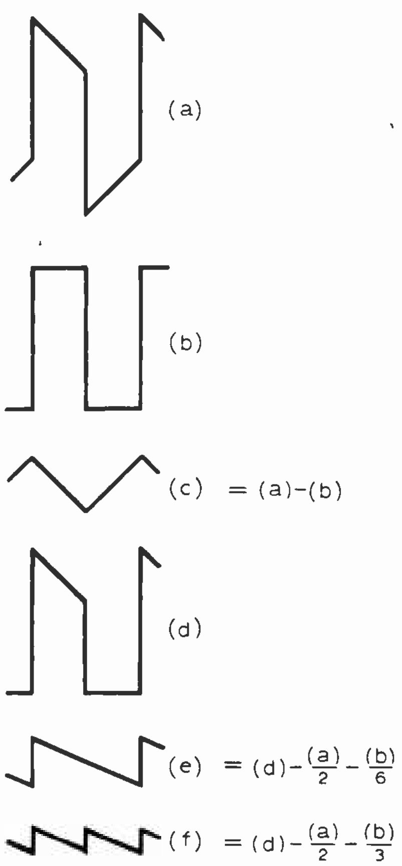


Fig. 2. Principle of combining different waveforms from the generator: (a) waveform on C_1; (b) waveform on R_{11}; (d) waveform on R_5. Triangle waveform (c) results from subtracting (b) from (a), while the sawtooth waveforms (e) and (f) result from the manipulations shown.

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

Pedal board and solo manual simulators. A further advantage of the multiphonic organ compared with a polyphonic organ is that the lowest note played in the left hand side of the keyboard always comes from the same generator regardless of what the note is. To give extra body to the sound a conventional divider, $Tr_{7\ \&\ 8}$, can be connected to the "lowest note generator" to give pedal-board simulation. The pitch of this note will be one octave lower. Stops controlling this are conventionally labelled 16ft.

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

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

References

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

Books Received

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

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

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

Sixty Years Ago

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

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

Facsimile scanner

Minimal-cost design for weather-satellite pictures

by J. M. Osborne

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

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

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

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

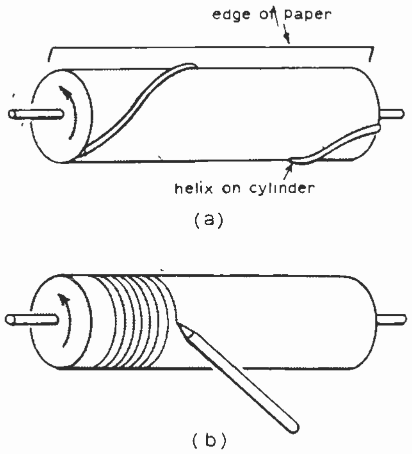


Fig. 1. An outline of the two mechanical scanning systems in use for facsimile recorders.

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

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

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

It was this fact which made the windscreen wiper product possible.

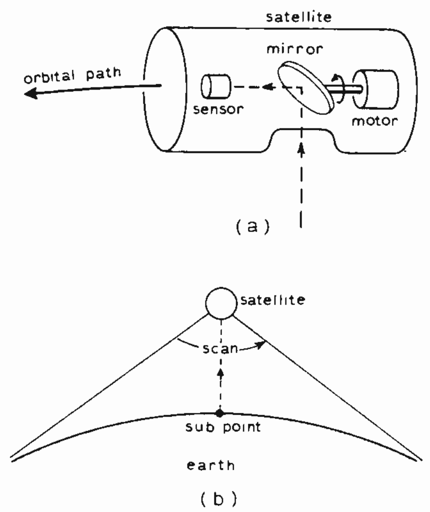


Fig.3. (a) shows diagrammatically the satellite's rotating scanning mirror; (b) shows the useful scanning angle swept by the mirror in the plane at right angles to the path of the satellite.

What follows shows that this concept is workable. Much can still be done to improve and extend this: some such suggestions will be mentioned later. While an extended period of operation should produce more interesting pictures, my object in presenting these preliminary results is twofold. Firstly, "projects" are never complete and are seldom suitable for direct copying. Secondly, the evidence supports an important general point about school projects. Except for those with considerable workshop facilities and advanced mechanical engineering facilities, imaginative and creative project work is most practicable in electronics, leaving mechanical work to the adaptation of existing machines and materials. A mechanical approach to the problem might well have started with adapting synchronous motors to drive home-made mechanisms. This would have entailed far more time-consuming mechanical development, with, in my estimation, less chance of success. In this case, the "mechanics" are provided by a junk windscreen wiper assembly, "free for the taking" from a motor scrap yard, and standard "Handy Angle" components.

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

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

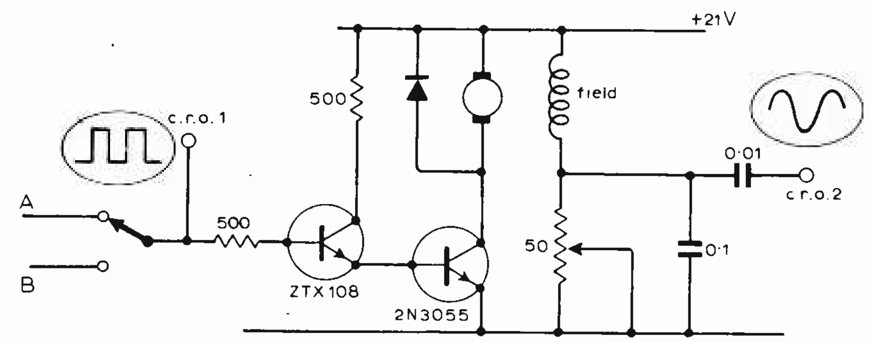
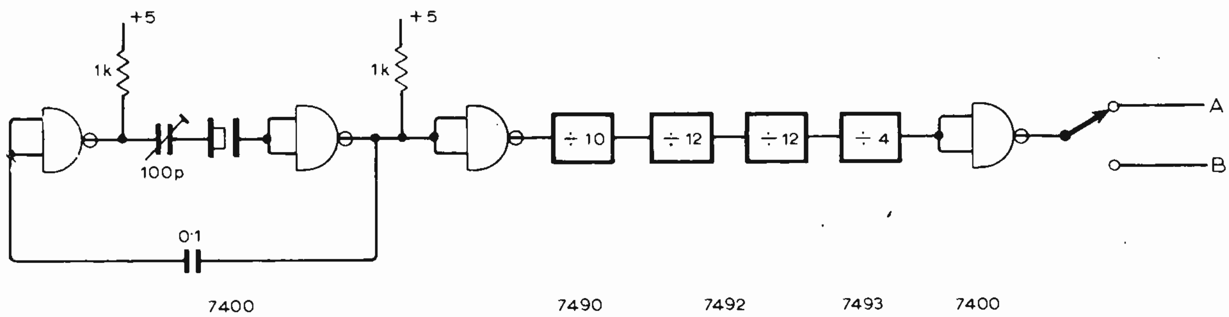


Fig.5. The quartz crystal oscillator and divider circuits to produce the required a.f. of 364.05Hz for synchronising the windscreen wiper motor.



A better idea developed when it was realised that in a commutator motor, the armature ripple superimposed on the direct current contained precise information, in the "ripple frequency", of armature and hence, sweep speed. This frequency is best observed across a speed control resistor in the field circuit. The armature a.c. ripple component is superimposed on the d.c. field current by transformer coupling between field and armature within the motor. While considering ideas of phase-lock loops, servo controls and the like, a simple experiment was first tried. A small-amplitude sinusoidal a.c. from a signal generator was fed in series with the armature d.c. supply. A weak tendency to "lock on" was observed when the ripple and generator frequency were sufficiently close. To exploit this phenomenon, a square wave drive was contrived (see Fig.4) to give the armature about twice the current for half the time. The armature torque remains about the same as for 12Vd.c. but the drive frequency takes significant control of the motor speed. Lock is held over substantial changes in field current. This may be observed by comparing the traces on a double beam 'scope from points CRO_1 and CRO_2 in Fig.4. The explanation of the phenomenon seems to lie in the armature segments acting like the teeth of a synchronous clock motor.

The next requirement was the precise frequency source to lock on to 48 r.p.m. By counting the commutator segments and gear ratios, the frequency was calculated on a pocket calculator to be 364.0519 Hz. (Not the most convenient figure, but hardly the fault of Lucas Ltd!) From a selection of quartz crystals and, again, with the aid of a pocket calculator[4], the circuit of Fig.5 was arrived at. The crystal was marked 2096 kHz (1944). This vintage being demountable, it proved possible to grind it with fine carborundum and turps on plate glass to near 2097 kHz. The frequency was checked every 5 or 10 minutes during grinding by using the circuit of Fig.6[5]. After 30 minutes of grinding, the correct output count could be bracketed by adjusting the series trimmer. The l.f. source of Fig.5 is cheaper, simpler to construct, more versatile and more reliable than its predecessor, the electrically maintained turning fork. Using this source to drive the circuit of Fig.4, no problem was encountered in getting the synchronous 48 r.p.m. sweep, although the field current has to be adjusted to get the approximate speed before lock is obtained. As the motor warms up during the first five or ten minutes of running, further adjustment of field current is required to maintain lock. The scribing of picture information on to the paper depends on the choice of the sensitive paper. The paper used was surface conducting, Type SC41 (8½ in) supplied by Electrosensitive Coatings Ltd.[2] Three metal roller-skate wheels, loaded by gravity, make surface contact, as in Fig.7. The pen stylus is a "V" obtained by cutting in half a normal stationery staple. This is fixed by clipping into a small bulldog clip (see Fig.8), mounted on, but insulated from, the wiper arm. No wiper arm spring is used as the weight of the arm gives adequate stylus pressure. A current, up to 15 mA, is supplied to the pen from a 120 V neon-stabilized supply with a 2.2kΩ limiter. The current is controlled by a transistor between the rollers and ground. The transistor[6] has a high collector/emitter rating of 250V.

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

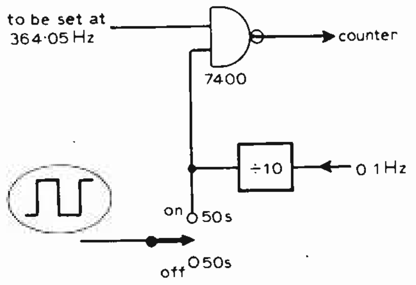


Fig.6. The circuit used for testing the precise frequency from the circuit of Fig.4. The 0.1Hz is derived from the Droitwich 200kHz transmission by the apparatus previously described[5]. The divide-by-two part of the SN7490 must follow the divide by five to give the accurately measured 50-second control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

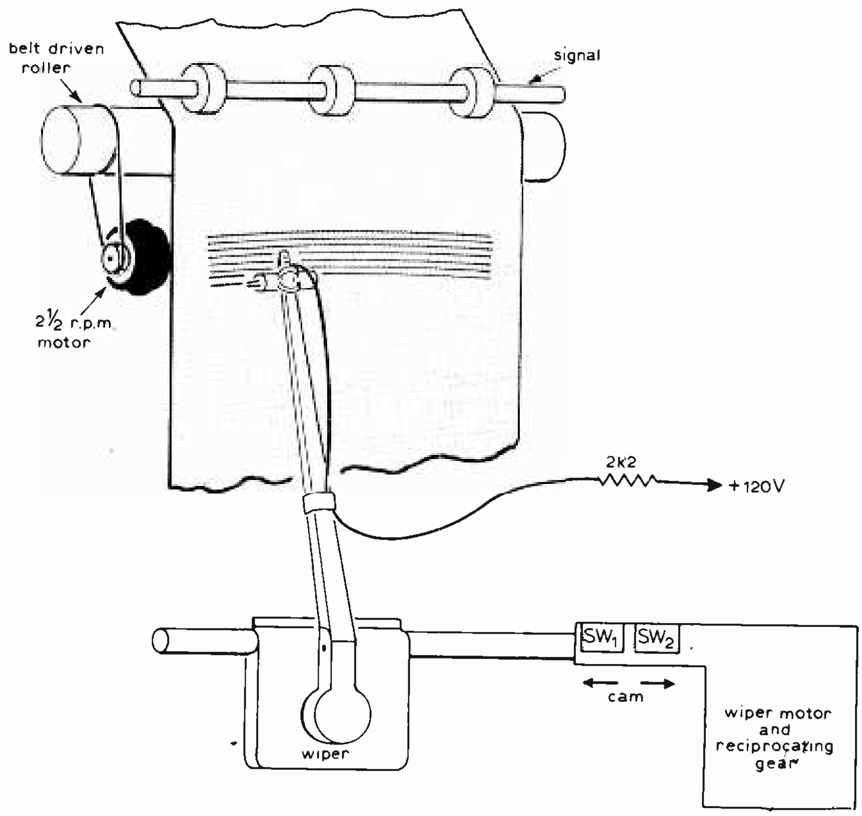


Fig.7. The diagram shows the mechanical layout of the apparatus. A general view of the apparatus is shown in the photograph.

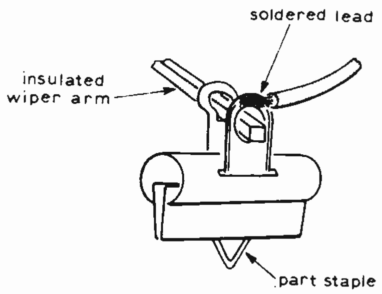


Fig.8. The detail shows how the stylus is mounted on the wiper arm.

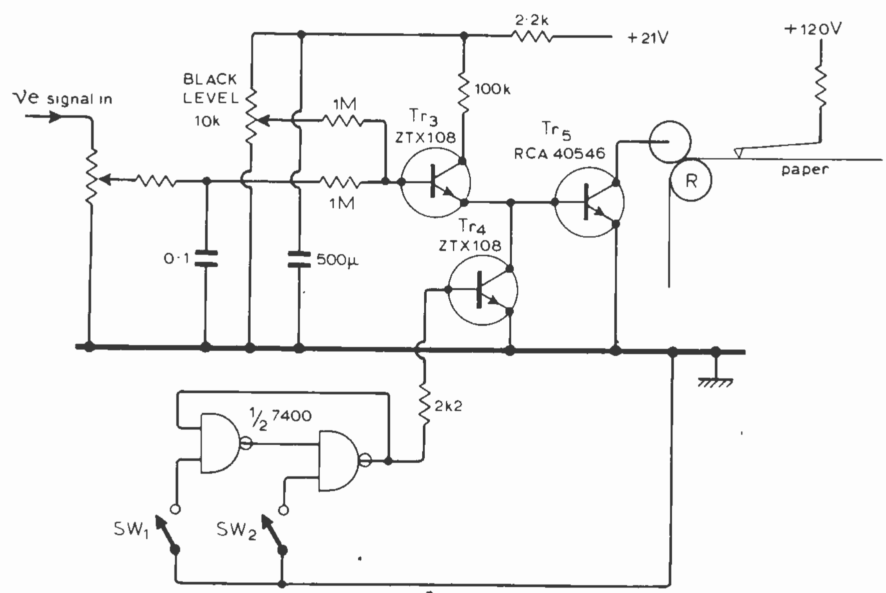


Fig.9. The circuit used to mark the sensitised paper with the signal from the satellite. SW_1 and SW_2 are microswitches operated by the "self parking" cam on the windscreen wiper motor assembly. They operate the 7400 latch circuit to blank the sweep in one direction while allowing the signal through in the other direction.

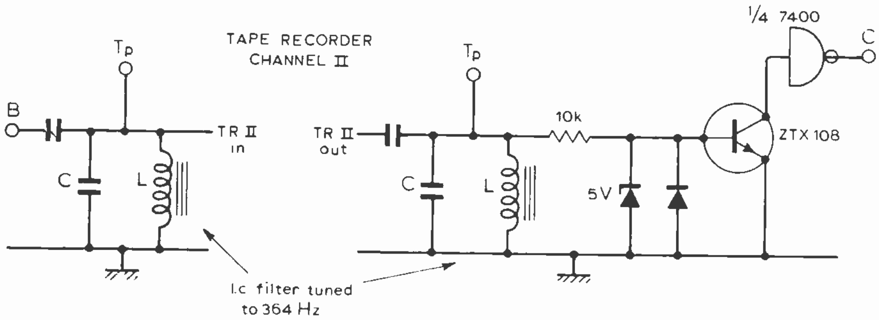
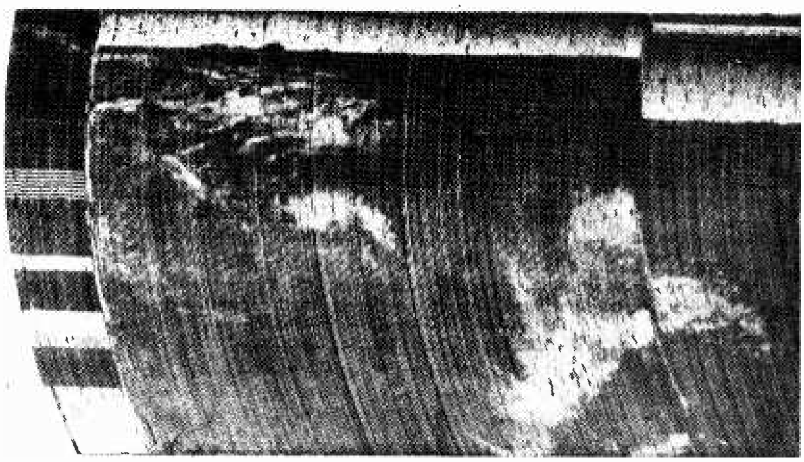


Fig.10. To interface the square wave pulses used for synchronising with the second channel on the tape recorder an LC circuit turned to 364Hz is used. On record it filters the high harmonics, giving an approximate sine wave input to the recorder. On play-back the filter cleans up the signal before it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

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



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

Blanking is achieved by grounding the base of Tr_5 through Tr_4, which is switched by two gates of an SN7400 connected as a latch. Micro-switches are mounted on the wiper motor casing so that each is momentarily closed at the end of the travel of the cam mechanism. This cam mechanism already exists for providing the wiper self-parking facility. The switches cause latch up for one half of the sweep and so blank off the signal, but latch down and let the picture signal through for the return sweep. It should be mentioned that to avoid erratic scanning due to mechanical backlash, a long weak spring applies a permanent mechanical bias in one direction to the wiper arm. This spring stretches across the width of the baseboard just below the wiper arm to which it is attached by a string over a pulley fixed to the wiper motor casing.

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

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

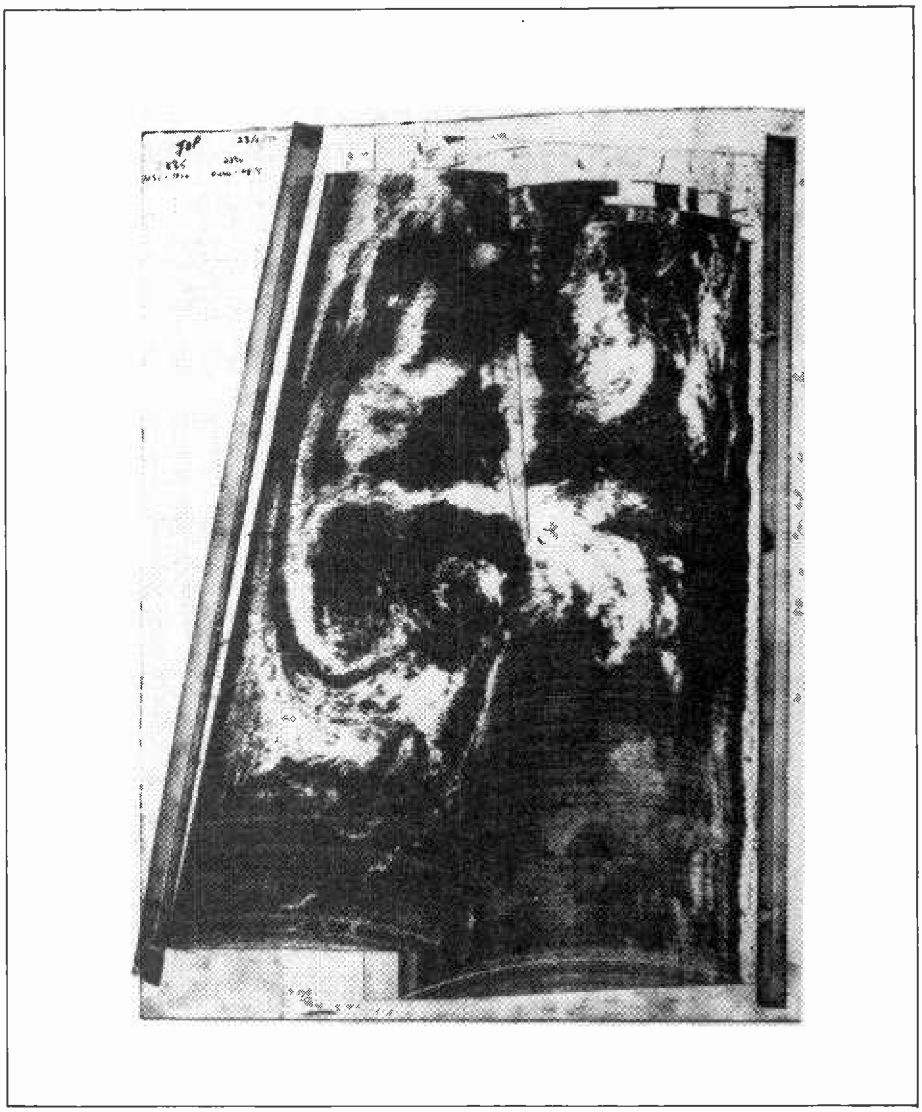
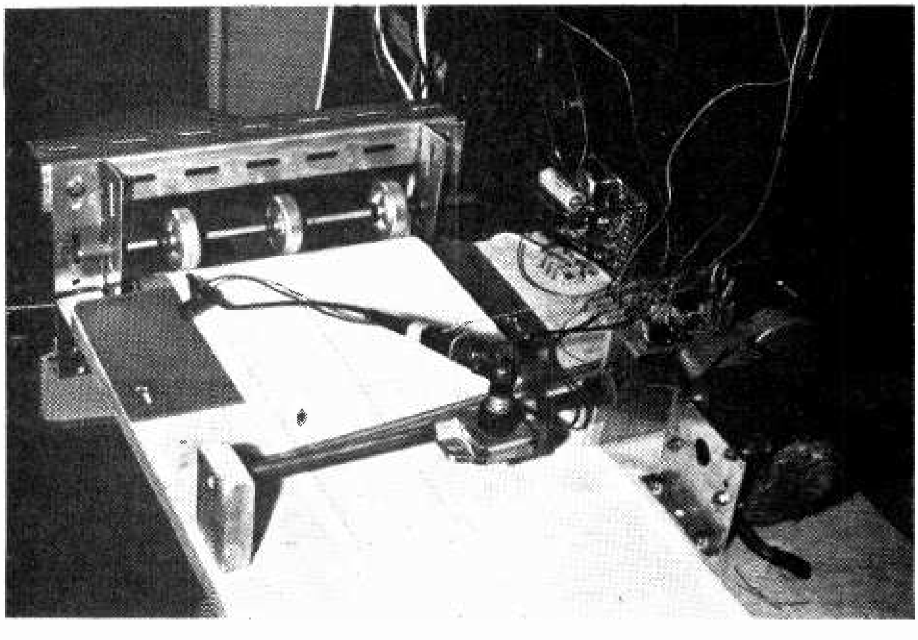


Fig.12. Pictures taken by the apparatus of two successive orbits of NOAA3. The overlap of cloud formation in the two pictures is not difficult to see.

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



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

The paper drive is obtained by turning the Handy Angle roller (R in Fig.9) by a belt drive from a 2½ r.p.m. synchronous motor (50p on the surplus market). The smallest available pulley was fitted to the motor spindle to drive the rubber belt (supplied as spares for a tape recorder). The resulting paper speed is about 50% too fast. The correct paper speed (to give an undistorted aspect ratio in the central region of the picture) can be calculated for a given pen speed taken at centre of the sweep. Firstly, we know the speed, say in km/s at which the satellite mirror scans the subpoint (see Fig.3(b)). At 48 r.p.m. and 1470 km high this is 7400 km/s. Next, we know the satellite subpoint speed – 5.8 km/s – from its period (115 minutes) and the circumference of the earth. This ratio, 1300, gives pen writing speed to paper speed. The pen writing speed can be deduced from the system geometry or more easily by feeding a known audio frequency signal to the pen and measuring the average dot spacing.

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

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

References.

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

Meetings

LONDON

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

BATH

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

BELFAST

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

BLANDFORD

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

BOLTON

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

BRIGHTON

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

BRISTOL

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

CAMBRIDGE

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

CARDIFF

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

CHATHAM

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

CHELMSFORD

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

COLCHESTER

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

COVENTRY

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

EVESHAM

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

FARNBOROUGH, Hants

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

HATFIELD

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

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

HULL

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

LEEDS

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

LEICESTER

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

LINCOLN

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

LIVERPOOL

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

LOUGHBOROUGH

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

NEWCASTLE-UPON-TYNE

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

PORTSMOUTH

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

PRESTON

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

READING

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

REDHILL

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

SOUTHAMPTON

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

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

SWANSEA

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

SWINDON

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

TEDDINGTON

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

WEYMOUTH

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

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

Digital wristwatch

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

Letters to the Editor

PERIL OF PUBLISHING

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

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

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

WIDE-BAND LOCAL NETWORKS

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

The first question is not primarily a matter of engineering but it may greatly affect the design of the system. One may hope, against all the odds, perhaps, that the aim will be to make the access to cable as free as it is to the printing press, so that anyone wishing to communicate with the public, who has the means to pay the distributor, is free to do so and free to set what price he likes on his publication. Some will offer it free because of the advertising it contains, some on a regular subscription basis; but others, and no doubt the great majority, on the logical and obvious basis of a separate price for each item like most ordinary economic transactions. This would be entirely in conformity with the principles enunciated by the Labour Party in "The People and the Media", thus:

> "Seek, wherever possible, to move away from concentration of power over printing and broadcasting outlets and to decentralise responsibility and diversify outlets.
>
> Make possible the widest practicable access to the media by community groups and by individuals.
>
> Improve the opportunity to publish and broadcast a diversity of views so as to eliminate any risk that the system might lead to government or commercial censorship."

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

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

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

There is plenty in the Post Office evidence to Annan to support this contention. For example, it says "the means of taking responsible judgement on returns on investment are not yet to hand". It has the commercial success[1] of the 1966 experiment by Pay-TV Limited in this country and the evident success and rapid growth of pay television in the USA to go on. What more does it want? Since the Post Office Act of 1969 it has had all the powers it needs to distribute sound and vision programmes of every conceivable kind on a pay television or any other basis; but it has done nothing, nothing at all except to install a few highly conventional communal aerial systems under contract to new town authorities.

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

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

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

Ralph Gabriel
Rediffusion Ltd
London, SW1

References

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

INSULATION TESTERS

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

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

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

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

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

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

LOW-COST PRACTICE ELECTRONIC ORGAN

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

K. J. Young.
Derby.

CONTROLLING STAGE LIGHTING

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

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

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

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

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

without an irritating and, to the audience, distracting rush of light?
4. Withstand hot-patching — that is the addition of an extra load to a partially loaded dimmer?
5. Genuinely not interfere with radio reception and audio equipment in the area?
6. Fade without an undue buzzing sound from the chokes?

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

Paul M. Hodgson
London, SW19

ELECTRONIC COMPONENT RETAILERS

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

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

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

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

ACTIVE NOTCH FILTERS

In the article "Active notch filters" in the July issue, the author states that "No passive *RC* notch network, however complex, is capable of achieving Q_0 higher than 0.9." This is presumably based on Ramachandran's theoretical limit[1] of $\frac{1}{2}\sqrt{e}=0.8243$, derived for a restricted form of response. However, the author has overlooked a subsequent contribution[2] which relaxes the conditions on the zero of the transfer function, thereby allowing transmission gains and enabling the maximum selectivity of an unbalanced *RC* network to reach a value of $\frac{1}{2}e=1.359$. Of course, this is still a low selectivity and extravagant in numbers of components; even a *Q* of 0.8875 requires as many as 31 passive components of large spread.

It is more practicable to resort to distributed *RC* null structures which, when exponentially tapered, can achieve gain slope and classical selectivities of 0.6585 and 0.860 respectively using only two integrated components[3]. Higher Qs are possible by resorting to other inhomogeneities and configurations.

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

P. Bowron
University of Bradford
Yorkshire

References

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

ELECTRODYNAMICALLY INDUCED E.M.F.

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

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

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

C. S. Evans
University of Reading

TRANSMISSION LINE IMPEDANCE

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

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

MUSIC WITHOUT MOVEMENT?

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

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

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

John C. Sager
Ipswich
Suffolk

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

Mr Young replies:

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

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

I also assumed mono. Would twice as many digits be needed for stereo? I think not. So, at 10 samples per data point, this gives $20\times10^3\times10\times3600=$ 720 megabits.

Since 1 megabit per cm² is now a commercial viability, this means 720cm² for a "feasible" (*sic*) one hour playback. Curiously, this is almost the same as one side of an l.p. record.

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

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

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

DIGITAL FREQUENCY SYNTHESIS

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

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

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

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

dB TO RATIO ON A CALCULATOR

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

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

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

If $a=e$ and $b=10$, then

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

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

To convert decibels back to a voltage ratio:

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

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

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

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

PEAK READING LEVEL METER

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

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

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

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

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

John Dawson and Chris Evans
Amplification & Recording
Cambridge

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

RADIO WAVES

What makes them go

by "Cathode Ray"

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

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

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

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

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

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

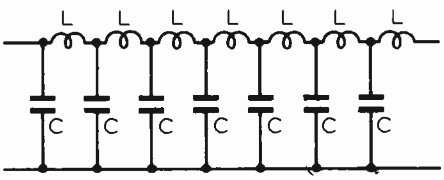


Fig.1 An ideal transmission line can be considered as a circuit in which the distributed capacitance and inductance are represented as a very large number of very small capacitors and inductors.

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

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

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

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

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

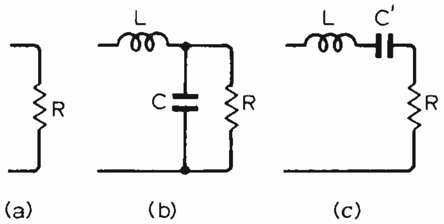


Fig.2 By selecting a suitable value of load resistance R, a pair of the small units of L and C in Fig.1 connected to it (b) can be made of no effect, because the series equivalent of C (C' at (c)) cancels out L. This process can be repeated until any length of line terminated by R is found to be equivalent,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

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

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

So to make a line or cable ideal for

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

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

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

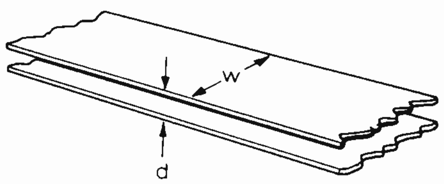


Fig. 3 A simple, if unusual, form of transmission line is a pair of parallel metal strips.

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

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

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

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

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

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

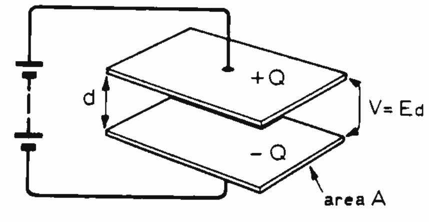


Fig.4 A short length of the Fig.3 type of line can be treated as a capacitor.

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

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

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

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

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

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

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

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

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

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

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

We can make a sort of coil of Fig. 3 if we short-circuit a length W at both ends and circulate a current I around this "coil". The flux passes through the "core" of this coil and doubles back to complete a loop around the current, as indicated in Fig. 5 by only two dotted lines, which represent the continuous flux filling the whole core. Its conventional direction, for a clockwise current, is inwards as shown (corkscrew rule). The flux density, denoted by B, is equal to Φ divided by the cross-sectional area A of the "window" inside the coil:

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

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

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

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

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

So, substituting for Φ and I in (8) we get

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

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

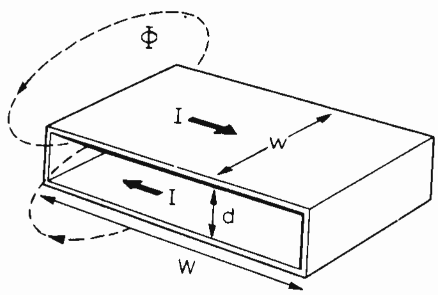


Fig.5 By adding short-circuiting pieces at the ends, the bit of line in Fig.4 can be made into an elementary coil.

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

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

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

Now at last we can combine (7) and

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

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

The values of μ and ϵ for air are almost the same as for a vacuum, μ_0 and ϵ_0, which are $4\pi \times 10^{-7}$ and 8.854×10^{-12} respectively. So $\sqrt{(\mu/\epsilon)} = 377$. For example, if the width of the strips in Fig. 3 was 10 times their separation, R_0 for this line would be 37.7Ω approximately (owing to edge and end effects it would be rather less).

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

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

What speed?

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

$$Q=CV=\frac{\epsilon wV}{d}$$

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

$$I=Qv=\frac{\epsilon wVv}{d}$$

therefore $$v=\frac{Id}{\epsilon wV}=\frac{d}{\epsilon wR_0}$$

and substituting from (14)

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

In space, where ϵ and μ are ϵ_0 and μ_0, this works out at nearly 3×10^8 metres per second, which is the speed of light, usually denoted by **c**. Together with much other convincing evidence, this discovery led to the conclusion that light is electromagnetic, differing from radio waves only in its much higher frequency.

In air, ϵ and μ are very slightly greater than ϵ_0 and μ_0, so the wave speed is very slightly (negligibly for most purposes) lower. But practical lines have to rely on solid insulating spacers with values of ϵ several times greater than ϵ_0, so the wave speed therein may be much less than **c**, and the wavelength along the line, at a given frequency, much less than in air.

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

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

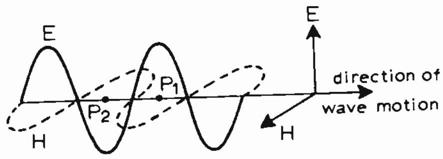


Fig.6 Plane, linearly-polarized electromagnetic waves consist of an electric field pattern, shown here in the vertical plane, accompanied by a similar magnetic field at right angles to it and to the direction in which the whole pattern is moving.

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

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

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

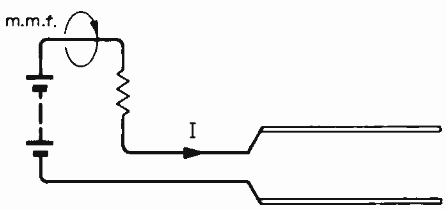


Fig.7 Although the space between capacitor plates carries no current in the ordinary sense, there is a "displacement current" which produces the same magnetomotive force around it as every other part of the circuit.

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

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

wider apart than usual in order to make this easier.

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

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

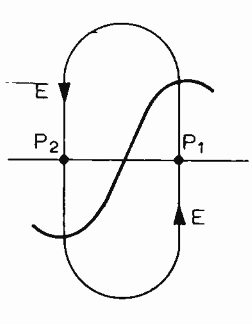


Fig.8 Although Fig.6 was based on the existence of electric charges moving along conductors (Fig.3), waves continue when the conductors are removed, because the fields join up to replace them, as far example this electric line of force at the P_1-P_2 section in Fig.6.

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

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

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

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

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

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

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

It is not essential to have two conductors for this guiding action; in certain circumstances an empty tube will do, called a waveguide. But that is too long a story to start on now. If anyone asks me kindly I might tell it some other time. But I do just have room to fulfil my promise about the impedance of space. We found that a transmission line or cable that is loss-free and infinitely long has an input resistance that is

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

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

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

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

which is analogous to

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

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

Circuit Ideas

Constant amplitude sawtooth generator

This sawtooth generator is designed to give a constant-amplitude output over a range of frequencies when driven by an external periodic waveform. The amplitude of the output is sensed and a corrective voltage is applied to the base of a transistor used as a constant-current source. The exponential current-voltage relationship of such a source renders it particularly useful for this purpose.

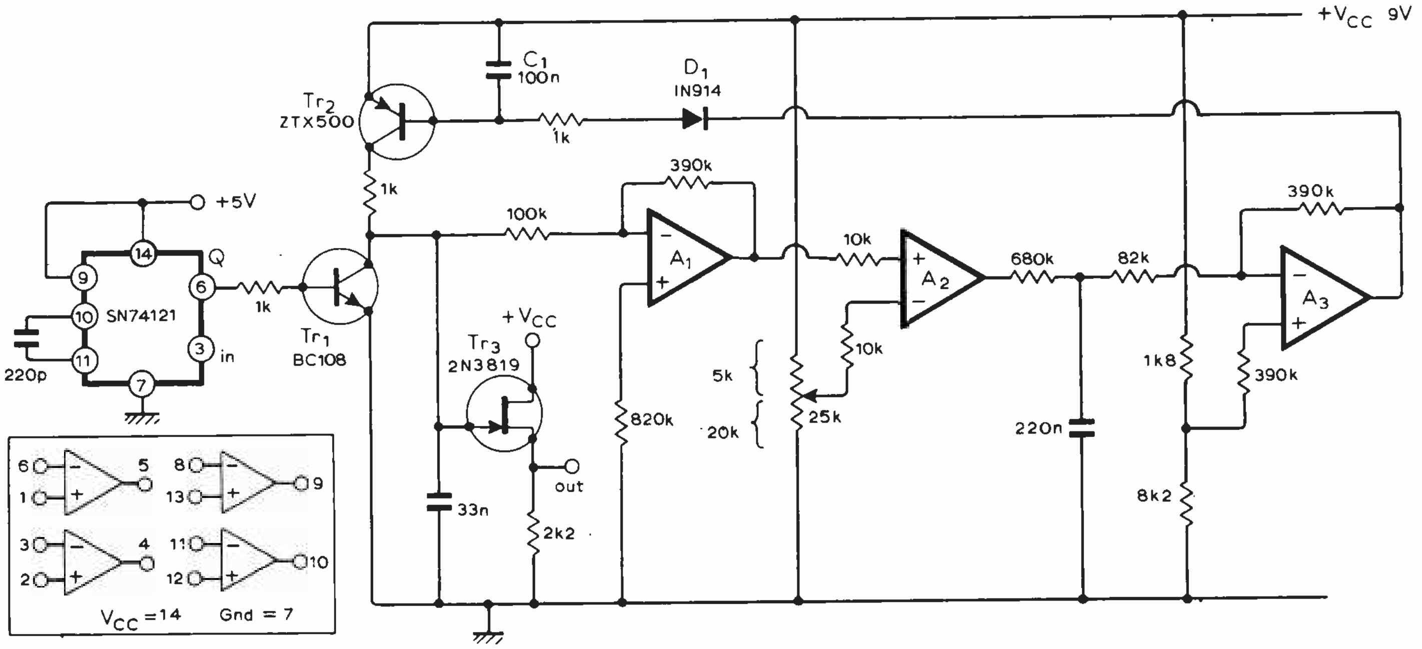
An MC3401P is the op-amp package used. This contains four single-supply internally-compensated amplifiers sharing common biasing circuitry, and operating over +5 to +18V. Each amplifier has a common-emitter type inverting input, and a current-mirror non-inverting input, often used to set quiescent output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

Transistors Tr_1 and Tr_2 form the basic sawtooth generator, Tr_1 being driven on at the input frequency by a 300ns pulse. The resulting waveform is amplified by IC_1 and fed to IC_2 which acts as a comparator — the amplitude sensing element. The threshold is set by the 25kΩ potentiometer which should be adjusted for maximum output-amplitude versus frequency linearity. Rectangular waves at IC_2 output are filtered to give a control voltage; this is shifted in level by IC_3 and D_1 to meet the input voltage requirements of Tr_2. Capacitor C_1 acts as a reservoir to smooth out any voltage fluctuations at Tr_2 base during each cycle.

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

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

J. N. Paine,
Oxford.

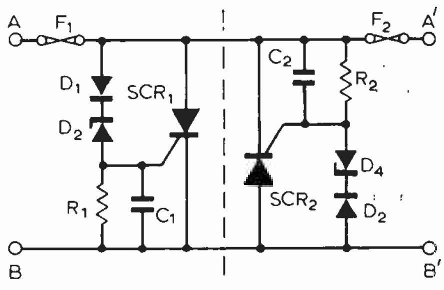


Thyristor protection circuit

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

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

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



prevent forward voltage drops across D_3 and D_4.

With the following values:

Z_1, Z_2 CV7144 10V zener
D_1, D_2 CV9637 small-signal silicon diode
R_1, R_2 10kΩ
C_1, C_2 0.047μF
Tr_1, Tr_2 2N4147

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

Higher powered thyristors may be used where necessary with consequent slowing down of edges. Typical component cost is £1.10 for values as shown.

S. G. Pinto,
A. P. Bell,
Ipswich.

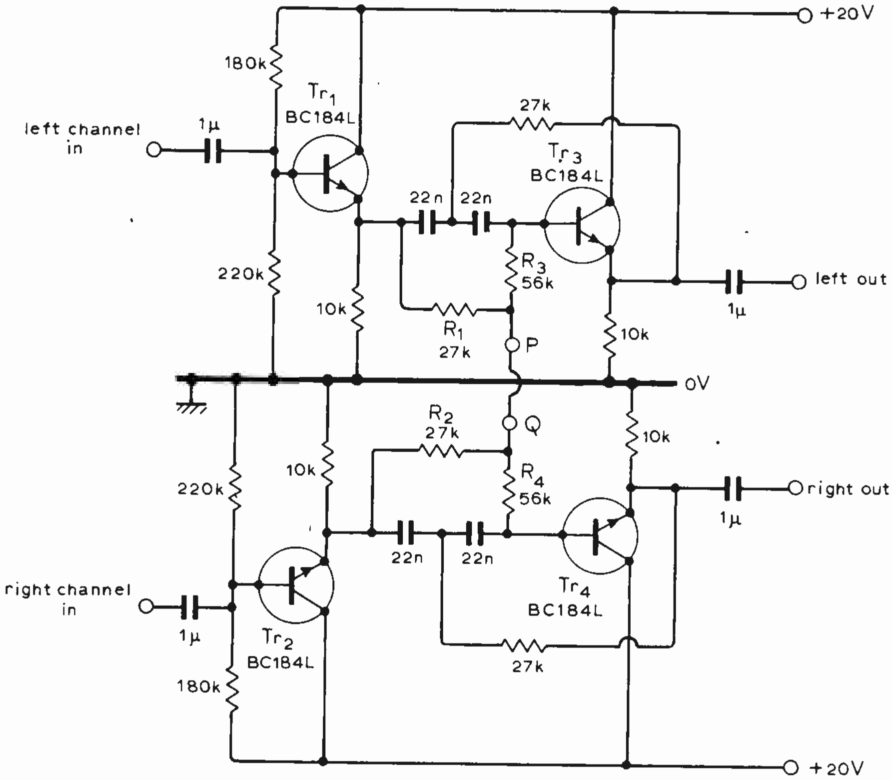
Stereo rumble filter

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

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

If identical signals are applied to the inputs (a mono signal), no current flows through P (P—Q acts as an open circuit), no filtering takes place, and the signals are unchanged. Resistors R_1 and R_2 provide low frequency paths around the capacitors and biasing to Tr_3 and Tr_4. However, if signals of equal amplitude but opposite phase (a stereo signal) are applied to the inputs, then, by symmetry, the voltage at P does not vary, and P becomes a signal earth. The filters then attenuate the difference signal below 200Hz. The filter chosen gives 12dB attenuation at 100Hz, with channel crosstalk of —11dB at 500Hz rising to —31dB at 5kHz.

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



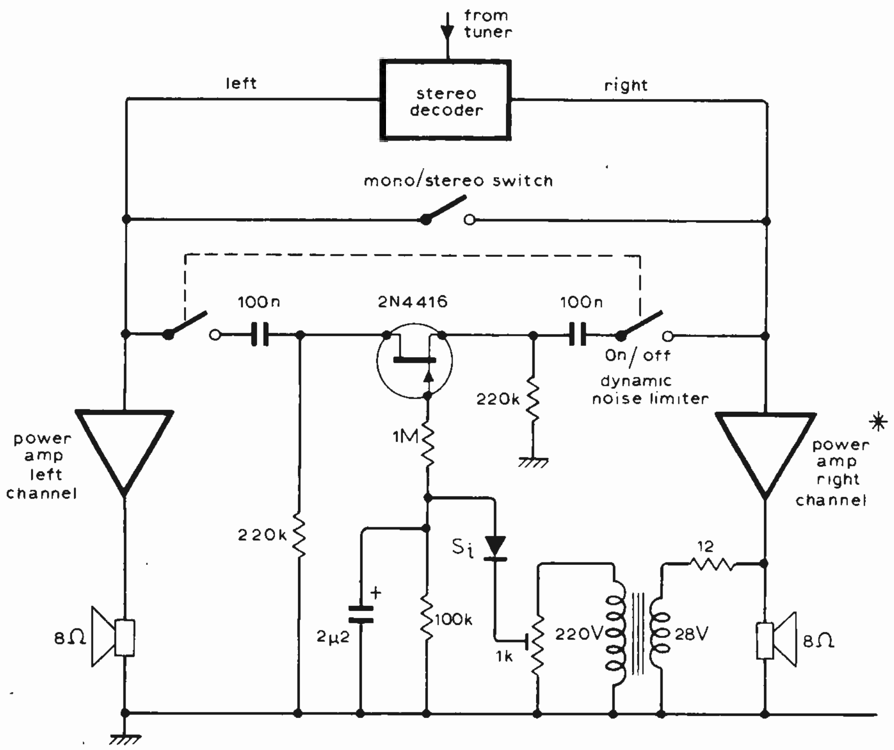
M. L. G. Oldfield,
Dept of Engineering Science,
Oxford University.

Stereo dynamic noise limiter

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

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

J. W. Richter,
Eindhoven.



(✱ includes; volume, balance and tone controls)

Electronic circuit calculations simplified

5 — RC combinations in a.c. circuits

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

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

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

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

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

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

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

These loss figures are plotted against frequency in Fig. 2 which shows that the frequency response becomes at each end a straight line, a horizontal straight line at high frequencies and a straight line with a slope of 6dB per octave at low frequencies. These two lines, if extended to the centre of the diagram, meet at the 3dB loss frequency, i.e. the frequency for which the reactance of C equals R. Thus if the 3dB loss frequency is known, it is possible to indicate it on graph paper and then to put in the straight line for zero loss and that for the 6dB-per-octave loss. With these as guides the response curve can now be drawn easily and rapidly yet with accuracy. Because of the low-frequency loss introduced by the circuit of Fig. 1, this is usually known as a bass-cut circuit.

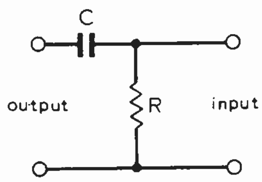


Fig. 1. Combination of series C and shunt R commonly encountered in electronic circuits.

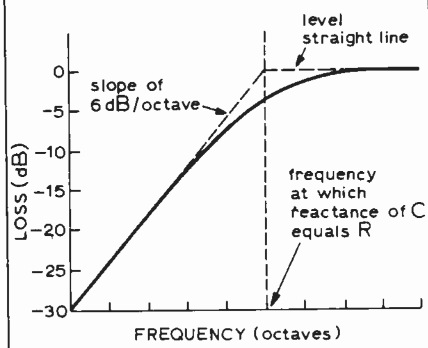


Fig. 2. Universal frequency response curve for all RC combinations.

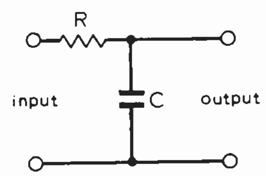


Fig. 3. Combination of series R and shunt C also commonly used in electronic circuits.

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

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

Frequency response of RC circuit

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

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

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

$$\frac{1}{2\pi fC_g}=R_g$$

from which

$$C_g=\frac{1}{2\pi fR_g}$$

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

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

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

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

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

The circuit of Fig. 4 can also be used at radio frequencies, e.g. for coupling a tuned circuit to a valve or f.e.t., and a repeat of the above calculation for a frequency of say 1MHz shows that C_g should be less than 1pF!. If however such a small value is used the coupling circuit would give a considerable loss because C_g forms with the input capacitance of the valve or transistor a capacitive potential divider (see Part 3). The input capacitance is likely to be many times 1pF and thus the potential divider gives a substantial loss. To minimise this effect C_g should be large compared with likely values of input capacitance: 100pF is a commonly-used value. Thus the type of calculation given above is confined to low frequencies at which the effects of input capacitance can be neglected.

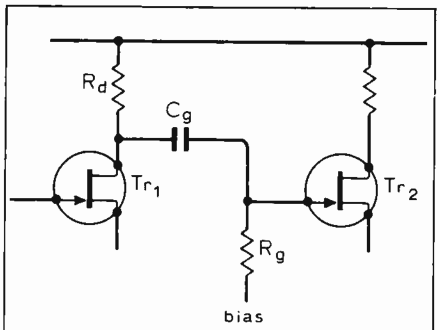


Fig. 4. The circuit of Fig. 1 used to couple two f.e.ts.

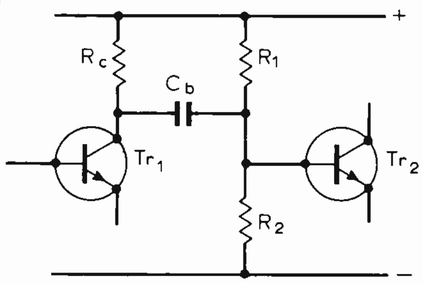


Fig. 5. The circuit of Fig. 1 used to couple two bi-polar transistors.

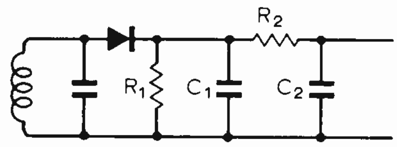


Fig. 6. The circuit of Fig. 3 used as an r.f. filter following a diode detector.

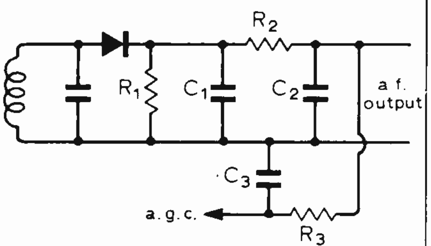


Fig. 7. The circuit of Fig 3 used as an a.g.c. filter following a diode detector.

Suppose now that Tr_1 and Tr_2 are bipolar transistors as shown in Fig. 5. The value of C_b required for an a.f. amplifier is quite different from those just calculated. The input resistance of a bipolar transistor is low (2 kilohms is typical for a collector current of 1mA) and the coupling circuit must be designed to ensure that as much of the output current of Tr_1 as possible enters the base of Tr_2. The current leaving Tr_1 collector splits at the junction of R_c and C_b and that which flows through C_b can be assumed to enter Tr_2 base. (R_1 and R_2 are usually large compared with Tr_2 input resistance and so absorb very little of the signal current.) The current division at R_cC_b junction is analogous to the potential division in R_gC_g in Fig. 4. Thus R_c and C_b determine the frequency response of the coupling circuit in Fig. 5 and, as an approximation, we can say that the loss is 3dB at the frequency for which the reactance of C_b equals R_c, losses at other frequencies being, of course, as indicated in Fig. 2 or the table.

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

$$C_b=\frac{1}{2\pi fR_c}$$

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

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

R.F. filter circuit. One application of the circuit of Fig. 3 is as a filter to attenuate r.f. signals in the output of an a.m. detector. A typical circuit is given in Fig. 6 in which R_1C_1 are the diode load components (see Part 4) and R_2C_2 form the r.f. filter. R_2C_2 should attenuate r.f. signals as much as possible but should not, of course, attenuate the upper audio frequencies significantly. In a medium- and long-wave receiver it would be satisfactory to make the attenuation 3dB at 5kHz: at this frequency therefore the reactance of C_2 should equal R_2.

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

$$C_2=\frac{1}{2\pi fR_2}$$

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

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

A.f. filter circuit. Diode detectors are generally used as a source of a.g.c. voltage and this voltage should be free of r.f. and a.f. signals. The circuit of Fig. 3 is therefore used to attenuate these unwanted signals: a typical circuit is shown in Fig. 7 in which R_3C_3 are the a.g.c. filter components. A loss of at least 12.5dB is required at the low-frequency limit, say 50Hz. Thus, from Fig. 2 or the table, the 3dB loss frequency is 12.5Hz. R_3 should be large enough not to shunt the detector components seriously but low enough to provide effective base bias for the controlled transistors. A typical value for R_3 is 15 kilohms and the reactance of C_3 must equal this value at 12.5Hz. The value of C_3 is thus given by

$$C_3=\frac{1}{2\pi fR_3}$$

$$=\frac{1}{6.284\times12.5\times15\times10^3}\ \text{F}$$

$= 1\mu$F approximately

Top cut circuit. A shunt capacitor such as C in Fig. 8 is often used to give top cut. Suppose, as a numerical example, a cut of 12.5dB is required at 10kHz. If Tr_2 has a high input resistance (e.g. is an f.e.t. or an emitter follower) then the current leaving Tr_1 collector effectively splits between R_c and C. R_1 and R_2 are normally large compared with R_c. Thus R_c and C determine the frequency response and Fig. 2 or the table can be used to determine the value of C in the usual way. The 3dB loss frequency is 2.5kHz and if R_c is 10 kilohms we have

$$C=\frac{1}{2\pi fR_c}$$

$$=\frac{1}{6.284\times2.5\times10^3\times10\times10^3}\ \text{F}$$

$=0.007\mu$F

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

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

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

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

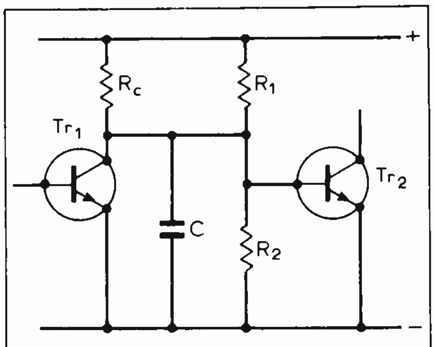


Fig. 8. Shunt capacitor C gives top cut.

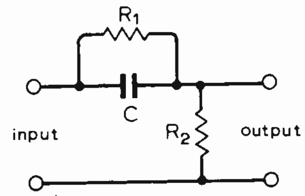


Fig. 9. Modification of the circuit of Fig. 1 to give top lift.

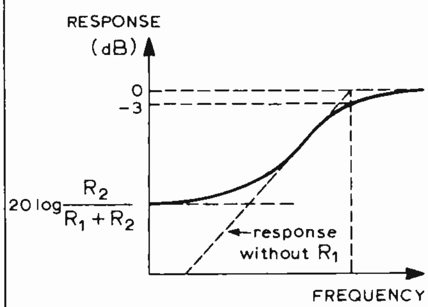


Fig. 10. Frequency response for Fig. 9.

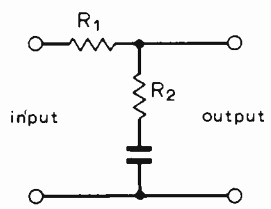


Fig. 11. Modification of the circuit of Fig. 3 to give bass lift.

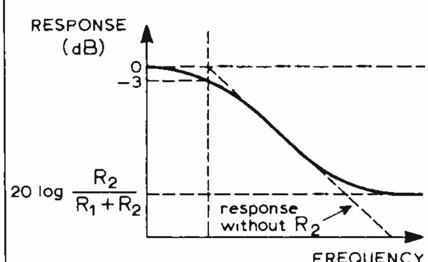


Fig. 12. Frequency response for Fig. 11.

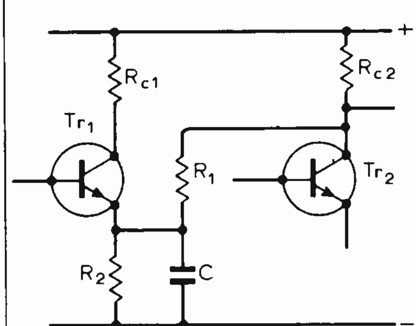


Fig. 13. RC circuit in feedback path of a voltage amplifier gives top lift.

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

C is thus given by

$$C=\frac{1}{2\pi fR_2}$$

$$=\frac{1}{6.284\times2.5\times10^3\times10\times10^3}\text{F}$$

$=0.0064\mu$F

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

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

$$C=\frac{1}{2\pi fR_1}$$

$$=\frac{1}{6.284\times200\times75\times10^3}\text{F}$$

$=0.011\mu$F

Negative feedback circuits. The RC circuits of Figs. 1 and 3 give bass cut and top cut when used in the main path of an amplifier: when used in the feedback path they give bass lift and top lift. A typical example of an RC circuit in a feedback path is given in Fig. 13. Tr_1 and Tr_2 are cascaded common-emitter amplifying stages but, for simplicity, the coupling components are omitted. As shown in Part 1 the potential divider R_1R_2 determines the voltage gain of the amplifier which is given approximately by R_1/R_2 provided R_1 is large compared with R_2. C shunts R_2, reducing feedback at high frequencies and so giving a top lift characteristic. The frequency-response-determining components are thus R_2 and C and their relative values can be calculated as shown earlier in this section. For example to obtain a lift of, say, 12.5dB at 15kHz the lift must be 3dB at 4kHz and at this frequency the reactance of C must be equal to R_2. A likely value for R_2 is 500 ohms and thus C is given by

$$C=\frac{1}{2\pi fR_2}$$

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

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

Another example of an RC circuit in a feedback path is given in Fig. 14. This is based on the circuit of Fig. 17 in Part 2. At low frequencies where the reactance of C is large, the feedback circuit consists effectively of the current divider R_1R_2 and the current gain of the amplifier is given approximately by R_1/R_2 provided R_1 is large compared with R_2. At high frequencies where the reactance of C is negligibly small R_1 and R_3 are effectively in parallel and their net resistance (call it R_1') is less than R_1. The current gain at these frequencies is R_1'/R_2 which is less than R_1/R_2. Thus the low- frequency gain is greater than the high-frequency gain and the circuit can be used to give a bass-lift characteristic. For example suppose a lift of 12dB is required at 50Hz. For 12dB difference in gain R_1 must be four times R_1' and this requires R_1 to be three times R_3. So if R_1 is 15 kilohms, R_3 must be 5 kilohms. The frequency-response-determining components are R_3 and C, and to give a lift of 12dB at 50Hz the lift must be 3dB at 200Hz and at this frequency the reactance of C must equal R_3. Thus the value of C is given by

$$C=\frac{1}{2\pi fR_3}$$

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

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

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

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

$$C=\frac{1}{2\pi fR}$$

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

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

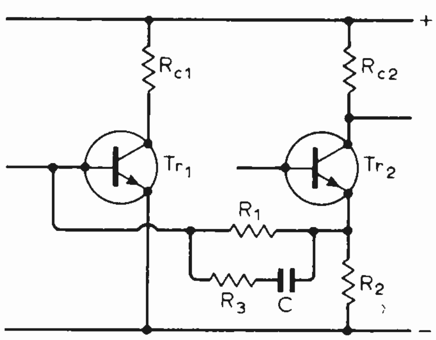


Fig. 14. An RC circuit in the feedback path of a current amplifier giving bass lift.

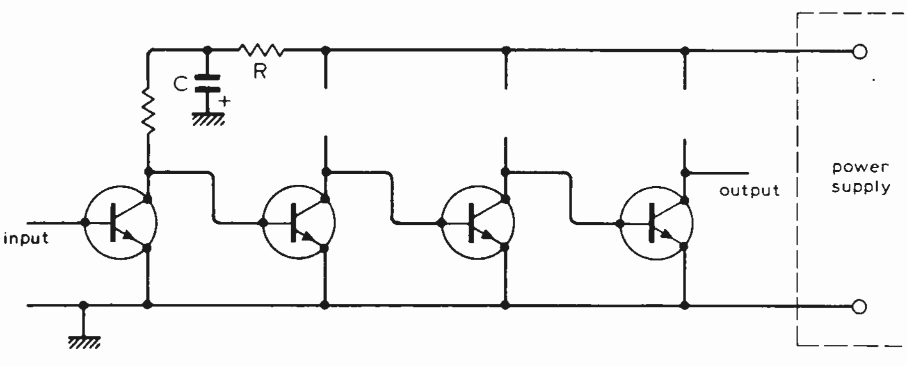


Fig. 15. Use of a decoupling network in a multi-stage amplifier.

HF predictions

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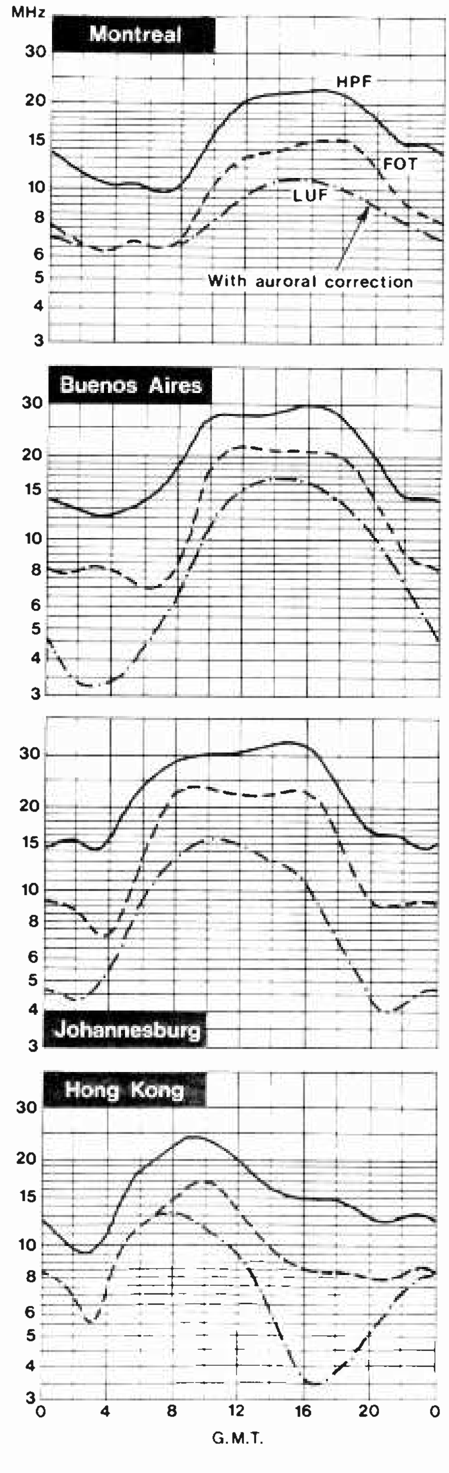

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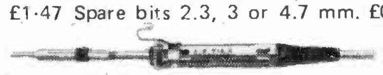

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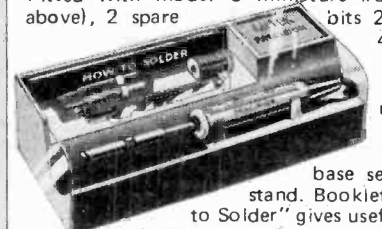

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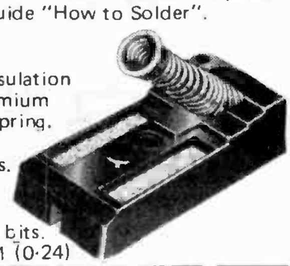

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Questions to ask before buying a video monitor

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

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

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

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

What about mounting? I need the utmost flexibility.

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

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

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

What facilities do Electrohome's small screen monitors offer?

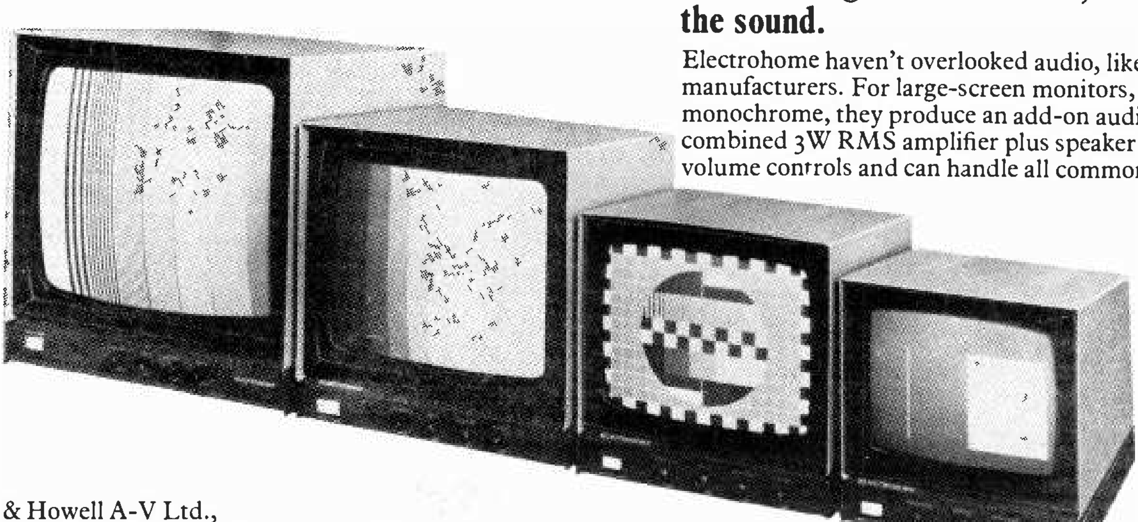
To complement this outstanding specification we have not forgotten the importance of switchable A-B inputs, switchable underscan, DC restoration and good geometry. Also the wide input sensitivity range and the input ground (which can be 'floated') will look after less favourable operating conditions.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

When should I use a colour monitor?

We'll ask a question which will help you decide. Everything you show on TV will be shown with a purpose. Will colour help to achieve that purpose? If so, use colour – and choose an Electrohome colour monitor because, simply, you cannot make a better choice. (This is only part of the answer to a complex question which we would enjoy discussing with you in proper depth.)

What about audio? You have convinced me that the video signal is first-class, but I need to hear the sound.

Electrohome haven't overlooked audio, like some manufacturers. For large-screen monitors, both colour and monochrome, they produce an add-on audio pod with a combined 3W RMS amplifier plus speaker unit. It has tone and volume controls and can handle all common audio inputs.



Bell & Howell A-V Ltd.,
Freepost, Wembley, Middlesex HA0 1BR
(no stamp required).

BELL & HOWELL

More questions? Write to us for the address of your nearest Bell & Howell Video Centre. You'll get the answers in the most convincing way possible – by seeing and hearing how Electrohome's monitors perform.

Specifications: the Electrohome monitor range from Bell & Howell

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

Accessories	
ECM-2	Ceiling mount
EWM-1	Wall mount
EVSA-2	Speaker/amplifier pod. 3W RMS amplifier available for large monochrome and colour monitors.
EPC-1	Pulse-Cross kit. Allows VTR users to optimise tracking and tape tension (EVM-23 only).

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WW—075 FOR FURTHER DETAILS

Transmitter power amplifier design — 2

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

by W. P. O'Reilly, M.Sc., M.I.E.E.
The Plessey Company Ltd

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

Power amplifiers for f.m.

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

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

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

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

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

Power amplifiers for a.m.

These transmitters may be classified as either high level or low level modulation systems. In the former the audio frequency modulation is impressed upon the supply voltage to the output and driver stages of the power amplifier. The output stage is driven to voltage saturation so that the power output is determined by the instantaneous value of the supply voltage. In some amplifiers the supply voltage to earlier stages is modulated in the upwards direction only in order to provide a greater increase in drive on peaks of modulation and compensate for the reduced gain of the output device as it nears current saturation. To achieve a depth of modulation approaching 100% the collector supply voltage must swing between zero and twice the average (or "carrier") voltage. Devices used for high level a.m. thus require a V_{CEO} in excess of twice the maximum "carrier" voltage. Devices having $V_{CEO} \geqslant 35$ volts are generally selected for 12 volts nominal "carrier" supply.

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

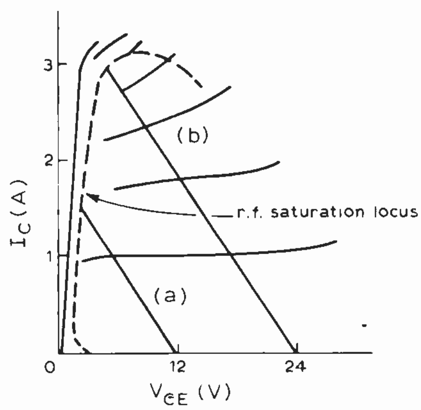


Fig. 1. Typical load line under carrier and peak modulation conditions for an eight-watt carrier power design (a) carrier conditions (b) peak modulation.

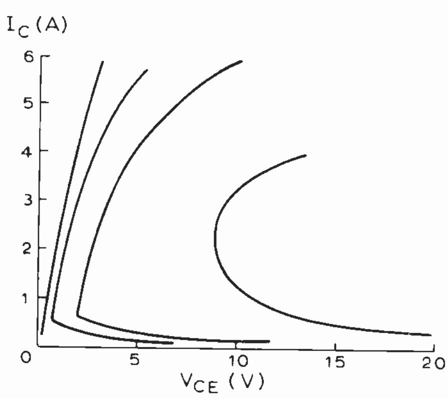


Fig. 2. Loci of constant f_T for a 100W power transistor.

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

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

Pulse operated power amplifiers

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

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

Linear v.h.f. power amplifiers

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

- The maximum linear output in Class AB is usually about 20% to 35% of the Class C rating of the transistor.
- Transistors having high gain at the required operating frequency generally provide best performance in linear amplifiers but are less tolerant of load mismatch.
- If possible use the transistor at a slightly reduced supply voltage for improved ruggedness. 24- or 26-volts supply is ideal for 28-volt c.w. devices.
- Select transistor types showing least variation of f_T over the required operating loadline. Fig 2 shows contours of constant f_T for a v.h.f. power transistor rated at 100W c.w. in Class C. This device is ideal for linear operation and can supply up to 30W p.e.p. in the two-metre band with two-tone intermodulation products better than −30dB.
- A low impedance, temperature compensated bias network must be used. (The subject of biasing Class AB amplifiers was discussed in part 1 of this series where some suggestions for suitable circuitry were made.)
- Provide an adequate heat sink. The gain obtained by Class AB operation at reduced output power is typically 4 to 6dB above the gain obtained in Class C at full rated output. The efficiency usually achieved, however, is much lower (typically 45 to 55%) and due allowance must be made in calculating the thermal performance of the heat sink. The linear power output falls with increased temperature and the reliability is greatly reduced.
- Note that transistors having the same type number from different manufacturers often have quite different performance in linear circuits even though they may be similar in Class C performance.

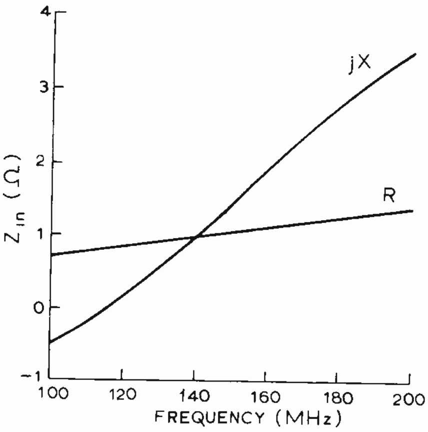


Fig. 3. Variation of input impedance with frequency for a typical 25W v.h.f. transistor.

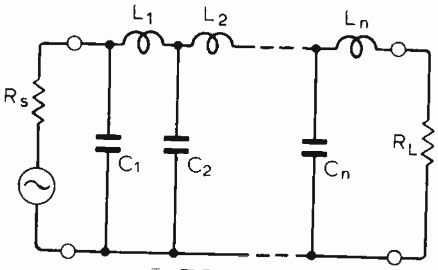
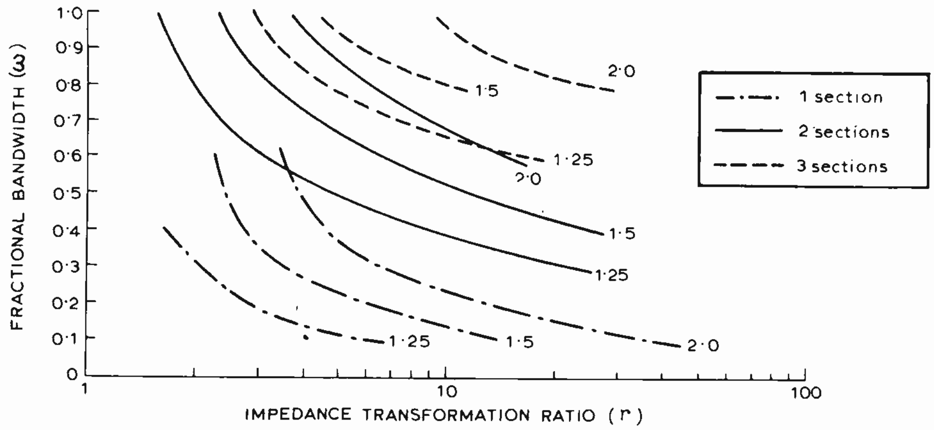


Fig. 4. Lumped element low-pass ladder matching network.

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



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

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

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

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

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

Power transistor impedances

One of the most critical factors in v.h.f. power amplifier design is the matching of the input and output impedances of the r.f. transistor to the source and load between which it must operate. The input impedance is generally low and complex while the required load is determined by the operating supply voltage and output power, not by the output impedance of the transistor itself. Radio frequency power transistors are far from unilateral, the input and output impedances being functions of the load and source impedances respectively. For this reason it is advisable to measure the input impedance under actual operating conditions if the transistor is to be used at a power much below its rating or with a different class of bias, since the input impedance may then be quite different from the value quoted by the manufacturer.

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

Matching networks

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

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

A very popular type of matching network using lumped elements – i.e. discrete capacitors and inductors – is the low-pass ladder of Fig. 4. The number of sections necessary to achieve the required impedance ratio and bandwidth may be determined from Fig. 5, in which curves for three values of voltage standing wave ratio have been prepared based on the work of Matthaei[3]. In practice due to component tolerances and especially the variation of input impedance between one sample and another of the same transistor type an input v.s.w.r. of less than 1.25 can rarely be achieved without individual adjustment of the matching components. The low-pass nature of these networks is useful in providing a degree of harmonic rejection. Lumped element networks can also be realised in high-pass or bandpass form if desired, and Motorola[4] have published tables of element values for various circuit configurations. For very wide band amplifiers the natural gain roll-off of the transistor may be compensated by using networks having a matching accuracy which improves progressively through the frequency band. Tables of element values for 4, 5 and 6dB per octave slopes have been computed[5]. The slope is obtained by controlled reflective mismatch and as a result stages using such networks are best driven through unilateral coupling networks such as circulators or 3dB couplers.

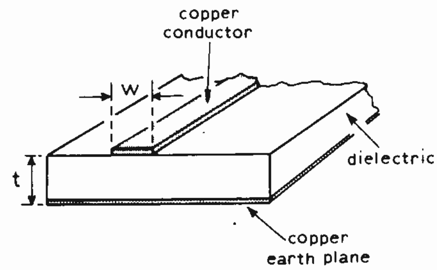


Fig. 6. Typical microstrip transmission line.

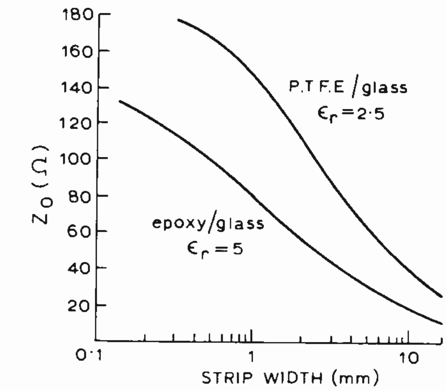


Fig. 7. Characteristic impedance of micro-strip on 1.6mm (1/16 in) 1oz copper clad p.c.b.

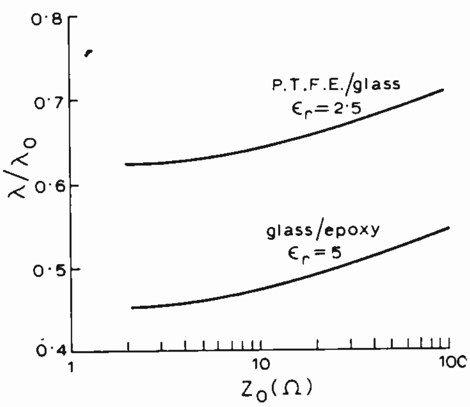


Fig. 8. Ratio λ/λ_o versus characteristic impedance for microstrip lines on 1.6mm substrate.

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

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

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

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

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

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

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

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

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

Designing in microstrip

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

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

(To be continued)

Acknowledgement correction

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

Phase shift in loudspeakers

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

Papers were read, exploring various points of view, and some of these will appear as articles in *Wireless World*. In the discussion which ensued some new and interesting ideas were expressed, and a selection of these will appear in the letters columns in subsequent issues of the journal.

Announcements

A conference on "Electronic Systems — Pilot 'A' Level" is to be held at The City University, St John Street, London EC1V 4PB on October 10th from 2.00 to 5.30 p.m. The aims are to describe the nature and content of the AEB "A" level syllabus in Electronic Systems and to make widely available the experiences of those schools teaching the course. Further information can be obtained from The Secretary, National Electronics Council, Abell House, John Islip Street, London SW1P 4LN.

"Electronic Calculators" and **"Integrated Circuits"** are two new short courses to be held at South London College commencing on Oct. 7 and Oct. 9 respectively. Applications should be made to the Senior Administrative Officer, South London College, Knight's Hill, London SE27 0TX.

The **RAE classes** which have previously been offered by Slough College of Technology will be taken over by the new Langley College of Further Education from September. The courses will continue to use accommodation at Slough College during the Autumn term. Full details of the courses can be obtained from E. C. Palmer, G3FVC, Langley College of Further Education, c/o Education Offices, 48 High Street, Slough, Berks SL1 1EN.

The Polytechnic of North London, Department of Electronic and Communications Engineering, Holloway, London N7 8DB is offering a range of **courses on audio engineering and acoustics** in 1975/76. For full-time students a new B.Sc degree in Electronics and Communications Engineering with audio engineering as a specialization starts this year. Part-time students can attend for one year on a course of Sound Studios and Recording. Fee for this course is £15 and it begins on October 28. Full details can be obtained from the Head of Department.

Communication and its consequences is an external studies course of nine lectures that has been organized at the University of Kent, Caterbury. The first talk will be at 7.00 p.m. on Oct. 16. The fundamentals of modern electronic communication systems and techniques will be discussed and demonstrated during the course. For further information contact Dr A. T. Barbrook, External Studies Office, Rutherford College, University of Kent.

Bedford Audio Club, 8 Emerton Way, Wooton, Beds, hold monthly meetings and are arranging a Winter programme and demonstrations. The club would be pleased to hear from enthusiasts in the area who wish to join or attend meetings.

The first class for the City & Guilds **Radio Examination Course** (No 765) to be held at the North and West Farnborough Further Education Centre, St Johns Road, Cove, Farnborough will be on Oct. 2nd, beginning at 7.30 p.m. There will also be a Morse Proficiency course beginning on September 29th at 7.30 p.m. at Oak Farm School, Farnborough, Hants.

Bury and Rossendale Radio Society will be holding RAE classes during 1975/76. The classes will be held at the Society HQ and full details of enrolment fees etc, can be obtained from Mr J. Marrow, 12 Halcombe Road, Tollington, Nr Bury, Lancashire.

A **Radio Amateur Examination** course will be held on Thursday evenings from 7.30 to 9.30 at the Technical College Annexe, Tamworth Road, Croydon, Surrey commencing on Oct. 2nd. Enrolment will be at the College Annexe on September 20th (10 a.m.-3 p.m.) or on the first evening. Further details may be obtained from P. L. A. Burton, Tel. 01-669 6700 (day) or Downland 51413 (evenings).

Two new companies have been set up to market **Redac software** and services in the German Federal Republic and the U.S.A. They are CADE, Laichingen, Nr Stuttgart and Redac Interactive Graphics Inc, Littletown, Mass., USA. Redac Software Ltd is the computer aided design division of the Racal Electronics Group.

On July 18, the share capital of **Jaybeam Ltd**, Moulton Park Industrial Estate, Northampton NN3 1QQ was transferred to Jones Stroud Ltd of Nottingham and consequently the Group of Campanies is now a subsidiary of Jones Stroud (Holdings) Ltd.

A weekly bulletin which lists all **published UK patents** relating to electronics and associated technologies is available from PATINEL, 13 North Avenue, Gosforth, Newcastle upon Tyne NE3 4DT. The bulletin is despatched within one week of the original publication of the patents by the Patent Office.

Integrated Circuit Design Workshop is a weekly afternoon laboratory design course of 12 weeks duration beginning on November 12, 1975 at the North East London Polytechnic, Department of Electrical Engineering, Barking Precinct, Longbridge Road, Dagenham, Essex RM8 2AS, tel: 01-599 5141.

As from September 1st, D.D. Electronics, 42 Bishopsfield, Harlow, Essex becomes **Rock Electronics** operating from the same premises.

The Autumn lecture meeting of the **Society of Cable Television Engineers** will be held on Oct. 14 at 2.15 p.m. in the Faraday Room at the IEE, Savoy Place, London WC2, when EMI Sound & Vision Equipment Ltd present a paper on "Hybrid v.h.f. to u.h.f. Cable Television Systems".

The Library and Information Services, IEE, Savoy Place, London WC2R 0BL are offering a **literature search service** covering the fields of electrical and electronic engineering, computers, control engineering and physics. Costs to users vary according to search method and/or length of search. Short manual searches are free of charge and all manual searches are subject to a discount for Institution members. For more information contact Hugh Wilman, Head of Library and Information Services, tel: 01-240 1871.

RC oscillators

Tested circuits for a wide variety of oscillators are given in sets 25 & 26 of Circards. This article summarizes the various kinds

J. Carruthers, J. H. Evans, J. Kinsler and P. Williams

Paisley College of Technology

Amplifiers oscillate; oscillators may not. These guiding principles have been developed and confirmed over many years of patient experimenting, not least during the preparation of Circards. Early versions of operational amplifiers were particularly critical of the source/load/supply impedances and were prone to oscillate at high frequencies unless carefully used. Early transistors had low values of current gain and cut-off frequencies making it difficult to produce controlled oscillations.

These properties point to a dividing line between oscillators and amplifiers with feedback viz that they are of the same kind, differing only in the quantity and nature of the feedback. The point can be illustrated by Fig. 1 in which an amplifier of gain A has a portion of its output volage β subtracted from the signal at the input. The gain of the amplifier with feedback can be greater or less than A, and the output will in general differ in phase. For well-controlled characteristics, the phase-frequency response has to be such that the feedback does not become regenerative until the magnitude of the βA term is below unity.

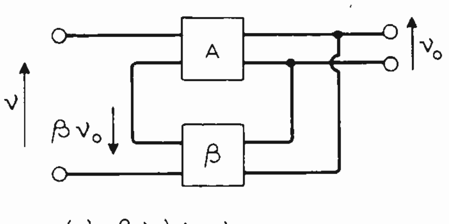
Feedback theory is formally expressed in many different ways, but one graphical approach that is helpful is to consider the root locus (Fig. 2). The graph plots the locus of the system transfer function as the frequency varies. Points on the horizontal axis correspond to phase shifts of zero (to the right of the origin) and 180° (to the left). Points on the vertical axis represent phase shifts of +90° and −90°. The distance of a point from the origin represents the magnitude of the transfer function. Thus in many amplifiers the region of the locus near the horizontal axis would represent a very wide range of frequencies since the gain remains constant and the phase-shift is zero or 180° over this range.

An important point on this graph is the point $1\angle 0°$. A general criterion, due to Barkhausen, suggests that if the locus of the system response does not enclose this point then the loop may be safely closed and the feedback will not cause the amplifier to become unstable. An exceptional state of conditional stability can result where the amplifier/feedback network has multiple reactive elements producing a complex locus which would enclose the point in the event of a fall in the magnitude of the gain.

When the locus passes through the point we have $\beta A = 1\angle 0°$ commonly called positive feedback and this constitutes an oscillator of constant but undefined amplitude, i.e. the signal feedback is just sufficient to sustain the output unchanged and without the need for an input signal. Alternatively we may view it as an amplifier of infinite gain, the denominator of the expression, $1-\beta A$, having gone to zero.

The inevitable small variations in β and A caused by temperature, supply or load conditions as well as by long term drift in component values, cause the amplitude either to decay away ($\beta A > 1$) or to increase ($\beta A < 1$). The limit is set by non-linearities in the system either inherent to the amplifier or deliberately added externally in the feedback network(s). These reduce βA and the oscillations settle down to a stable situation in which the mean value of βA over the cycle is unity.

For good frequency stability a number of precautions have to be observed (1) the amplifier should have negligible or very closely controlled phase-shift at the frequency of oscillation. (2) Amplitude of oscillation should be controlled to minimize distortion, since harmonics are fed back to the



$$(v+\beta v_o)A = v_o$$
$$v_o(1-\beta A) = Av$$
$$T_v = \frac{v_o}{v} = \frac{A}{1-\beta A}$$

Fig. 1. A fraction of the output is added to the source at the input in deriving a standard form of the basic feedback equation. Positive feedback occurs when βA is positive.

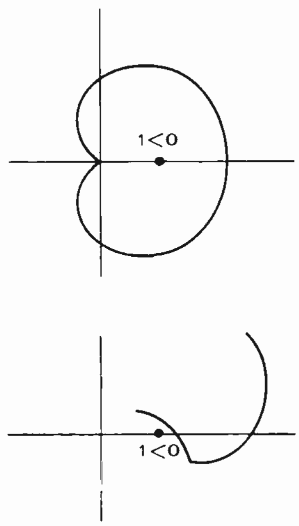
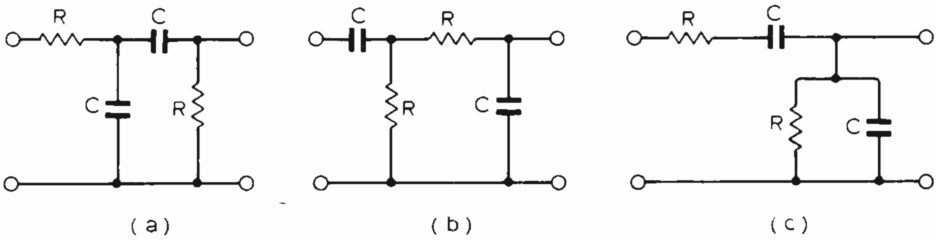


Fig. 2. If the in-phase and quadrature components of the overall loop gain are used as axes, the locus as the frequency is varied indicates the stability of the system.

Fig 3. These three networks have an identical transfer function and can be used interchangeably in oscillators.



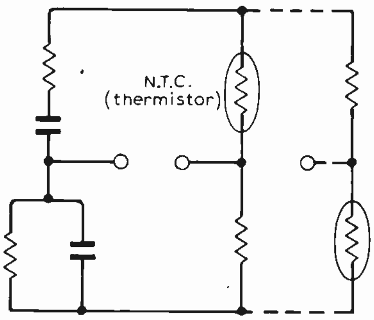


Fig. 4. Some oscillators use temperature-dependent resistors heated by the amplitude of the oscillation.

input and the resulting intermodulation reduces the frequency of oscillation below that predicted from the simple theory. (3) Input and output impedances of the amplifier must not load the RC networks significantly.

A major class of oscillators which includes the Wien bridge circuits, uses networks as in Fig. 3. Using equal values of R, C throughout, the transfer function of each of these circuits is the same, with the output reaching a maximum of one third of the input when the phase shift is zero. Frequency is $1/2\pi RC$. Each can be used with an amplifier of gain +3 to produce sustained oscillation. Many other combinations of these networks and amplifiers can be devised, by using current, transconductance and transresistance amplifiers.

Amplitude control may be via a gain-controlled amplifier whose gain is reduced as the output exceeds a given value, usually via a peak- or mean-rectifier and f.e.t. or similar controlled resistor. The classical solution is to use the RC network as part of a bridge configuration with a high-gain amplifier monitoring the bridge unbalance. One of the bridge resistors is made amplitude sensitive, e.g. a filament lamp or thermistor arranged so that increasing amplitude of oscillation increases the amount of negative feedback thus stabilizing the oscillation amplitude Fig. 4.

These oscillators are controlled in frequency over a very wide range commonly by switching in pairs of capacitors as the coarse control or range-setting, with ganged resistors for fine control. The reverse is possible with high input-impedance amplifiers where high resistances allow the use of ganged tuning capacitors. Single-element control has obvious advantages of simplicity and economy, as well as the possibility of remote control via light dependent resistors and the like. Most solutions to this problem require a larger number of amplifiers to provide separate feedback paths by splitting the passive network in some way, and in addition there is an effective loss in Q of the system that results in increased distortion. One example out of many that have been designed is shown in Fig. 6. Frequency ranges of up to three decades have been reported, while the amplitude control mechanisms are similar to those above.

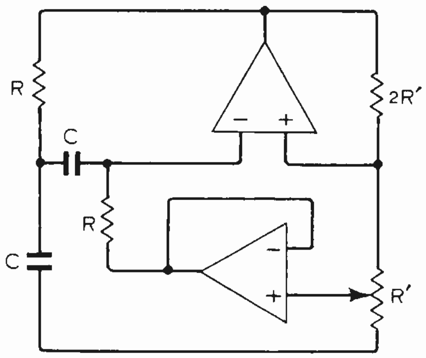
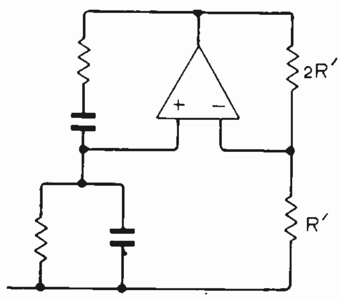


Fig. 6. Adding another amplifier at appropriate points in various oscillators allows a single control to change the frequency without varying loop gain.



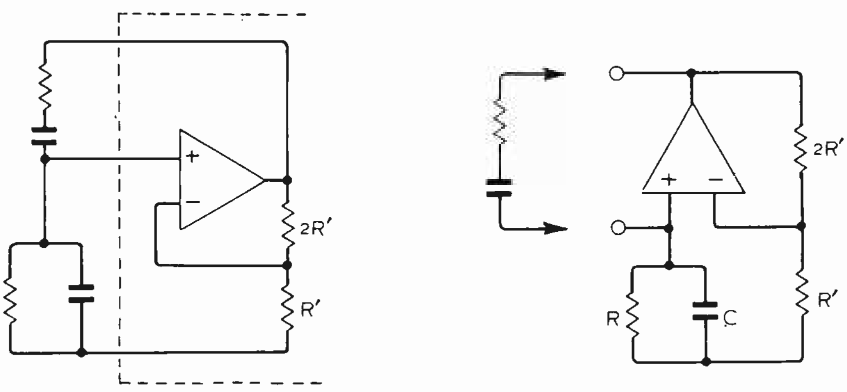


Fig 5 (a). A standard configuration uses an operational amplifier to activate the bridge. (b) Circuit partitioned to show an amplifier of gain +3 with the frequency-dependent network providing positive feedback. (c) Removing one section of the network, the impedance across the port is found to be negative, leading to Negative Impedance Converter interpretations.

T, phase-shift, and two integrators

Since both inverting and non-inverting amplifiers are obtainable, circuits can be designed in which the phase-shifts in the external networks are 180° and zero (or 360°) respectively. An example of the former is the classical three section phase-shift circuit shown in Fig. 7. Using equal values of resistors and capacitors the network attenuation is rather large, the output being 1/29th of the input at the frequency where the overall phase-shift is 180°. It is usually preferred to the alternative form using interchanged Rs and Cs, because the increased attenuation at high frequencies reduces the harmonic distortion and with it the corresponding shift in frequency.

If the RC values are scaled, then with n large each section can be analysed separately since the loading effects of the following section can be ignored. The phase shift of each section is then close to 60° at the critical frequency with a halving of the signal level. The amplifier then needs a voltage gain of −8 but the demands on input and output impedances are more severe (the current that can be drawn from the network without loading it becomes very small while the current needed to supply it increases). Alternative methods are to separate the phase-shift networks, using one amplifier of gain −2 between each section. Fig. 8 shows a related circuit that combines the gain and phase-shifting sections. Variants such as this are convenient for three-phase oscillators particularly as gain required from each stage is minimal.

A separate class of oscillators is based on null/notch/band-stop RC networks in which the signal transfer function tends to zero or a low value at a particular frequency (Fig. 9). These can give improved sharpness of tuning with lowered distortion, but interaction between the impedances can make them less tolerant of component drift. More important is the difficulty of tuning such circuits since several components need to be changed simultaneously. Separating the paths through these networks and driving them with individual amplifiers can allow control of the frequency without change in the amplitude condition.

There is a very close relationship between active filters and oscillators. They share common passive networks and in many cases one can be converted simply into the other by adjusting the damping factor (sharpness of tuning). A very important configuration which has wide application in both fields is the two-integrator loop (Fig. 10). Well-known in analogue computing, it and its near relatives appear under a number of names including 'bi-quad,' 'triple,' 'state-space,' 'gyrator' etc. For ideal amplifiers the circuit Q is infinite without the need for positive feedback and it is particularly suited to the design of high-Q active filters by the addition of a small amount of negative feedback. In practice the net feedback will depend on internal phase-shifts as well as finite-amplifier gains, and both positive and negative feedback may be used to produce controlled oscillations.

If a single resistor or capacitor is varied then with ideal amplifiers, the circuit is still on the edge of oscillation, but the frequency at which oscillation can be sustained is varied. Single-element control of frequency is of considerable advantage in simplifying the construction of oscillators, since dual-gang controls are difficult to keep in a well-matched condition over a wide range. The feedback needed remains small under these conditions, being sufficient only to overcome amplifier imperfections and the finite Q of the capacitors.

Because the amount of feedback required is small it can be introduced via a clipping network that comes into action sharply at a particular amplitude without bringing in significant distortion. This gives instantaneous control of amplitude without the time delay due to heating effects with thermal control. In addition there are three separate outputs with 90° phase differences and the addition of another inverting amplifier gives the fourth phase if required. Again there are a number of combinations of amplifiers and network which share these desirable properties as in Fig. 11. In all of them there is a tendency to instability at high frequencies where the slew-rate limiting of the amplifiers produces a jump phenomenon that locks the oscillator into an output oscillation of higher frequency and uncontrolled amplitude.

Some of these networks are more usually interpreted as forms of impedance inverters/converters, in particular the gyrator, *viz*, a circuit that with a capacitor across one port synthesizes a purely inductive reactance across a second port. If that port has a second capacitor placed across it, a resonant circuit is established which sustains oscillation if a small amount of positive feedback is introduced. It is instructive to draw out the passive networks in such circuits since this clarifies the interrelationships between the various forms of oscillator and filter (Fig. 12).

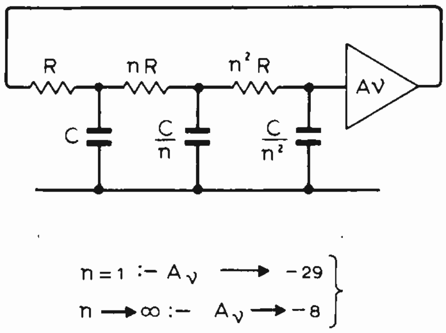


Fig. 7. If the impedances are graded to minimize loading of each section on the preceding one, each contributes 60° to the overall phase-shift at the frequency of oscillation.

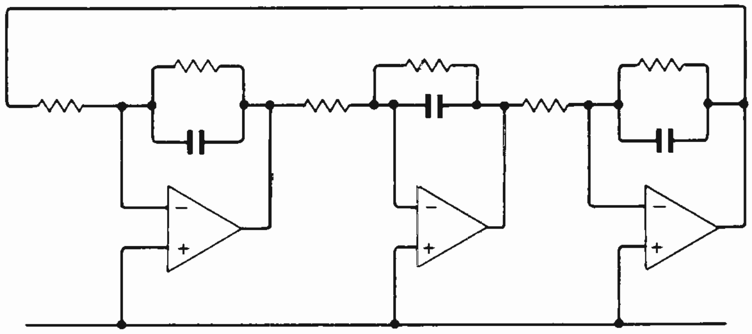


Fig. 8. Three amplifier stages with defined gain/phase characteristics comprise a three-phase oscillator.

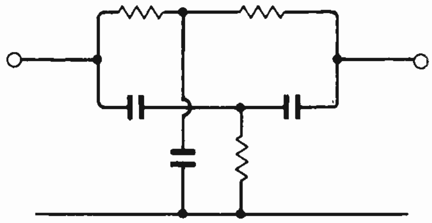


Fig. 9. T-networks can have zero-transmission at a particular frequency. Oscillators utilize positive feedback with the T-network in a negative feedback path.

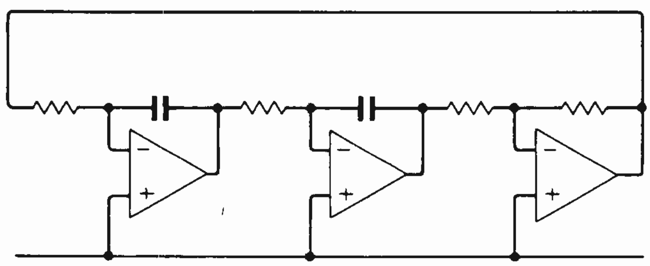


Fig. 10. Two integrators plus an inverter form the nucleus of a number of oscillators and filters.

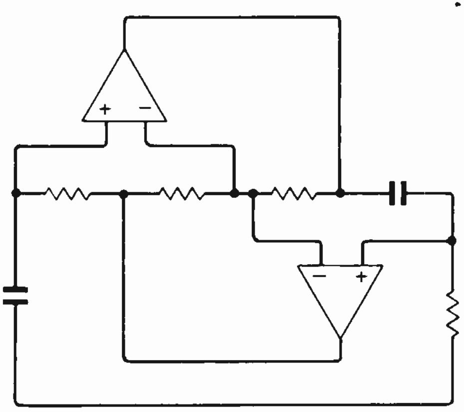
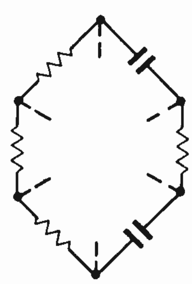


Fig. 11. Gyrators are a class of circuits that synthesize an inductive reactance from a capacitor. An oscillator results from resonating the reactance with a second capacitor.

Fig. 12. The previous two oscillators share a common passive network and can be shown to be functionally identical.



World of Amateur Radio

Typewriters rampant

Recently, on 3.5 MHz, I was in touch with Ian Trusson, G3RVM, near Swindon. A few minutes later, switching to 7 MHz, the next contact was with DL2QB in Cologne. Nothing very unusual about that — except for an interesting coincidence. Both of these c.w. stations, it transpired, were not using any of the usual froms of Morse key. Instead the operators were typing their messages on a typewriter keyboard — and electronics was doing the work of converting the letters into perfect international Morse. While still unusual enough to make two successive contacts surprising, this approach is clearly gaining ground. Although the keyboard encoders used by these stations were apparently home constructed, such equipments are now marketed. For example the DKB-2010 dual mode keyboard provides an output encoded either as r.t.t.y. (radio teleprinter) or c.w. and is claimed by Hal Communications Corporation as "one of the most sophisticated products ever offered to radio amateurs". It permits r.t.t.y. at the various standard rates up to 100 words per minute (or optionally 132 w.p.m.) or c.w. between 8 and 60 w.p.m. Normally it is used with a 3-character memory, but 64-character memories are available.

Another use of electronic keyboards is reported by Richard Thurlow, G3WW. For several months he has been using one for slow-scan television (s.s.t.v.). His unit, the first in Europe, was constructed by Howard Watson, G3GGJ to a design by WoLMD, first demonstrated in the United States in 1973. Two Swiss amateurs and several others outside the USA are now using a commercial version of this design, made by Sumner Electronics.

Slow-scan continues to attract growing interest and a special s.s.t.v. convention is being organised by the British Amateur Television Club at Aston University, Birmingham on Saturday, October 11 (1000 to 1800 hours), open to all interested in the subject. One possible demonstration will be of a Robot slow-to-fast and fast-to-slow storage tube converter capable of giving a "frozen" s.s.t.v. picture on a normal domestic TV set. Details and tickets (50p) from Mike Crampion, G8DLX, 16 Percival Road, Rugby CV22 5JS.

A transatlantic link severed

With the death of 82-year-old Fred Schnell, W4CF (formerly W1MO etc) all three participants (Delroy, Schnell and Reinartz) on the first amateur two-way contact across the Atlantic in November 1923 are now with us only in memory. The significance of that historic contact was not just that it happened — but that it happened on about 100 metres, rather than the 200 metres on which all earlier amateur transatlantic tests had concentrated. It was this contact, more than any other single event, that started the rush to shorter wavelengths and so heralded the opening of the short waves.

Schnell was the original "traffic manager" of ARRL and a little later vividly demonstrated to the American navy the effectiveness of compact short-wave radio equipment during a famous voyage of the battleship *U.S.S. Seattle*. The British pioneer, Gerry Marcuse, G2NM, used to tell the story of how, during the time when he maintained regular contact with the Seattle in the Pacific, an American reporter woke him early one morning by throwing stones at his window. He had come to Caterham because of widespread disbelief in America that such communication was really possible and insisted on Marcuse obtaining from Schnell the answers to five questions. Marcuse successfully obtained these and the American returned to London to report to the United States that these incredible contacts were really happening!

American opinions

The American Radio Relay League received no less than 56,000 replies to a detailed questionnaire seeking members' opinions on the FCC "re-structuring" Docket 20282. These replies provide perhaps the most detailed "snapshot" of opinions, activities and interests of amateur opinion ever compiled.

Almost half of the 56,000 were aged 50 years or over; only 11% less than 25; only 5% under 20. Half had taken out licences between 1950 and 1970; 18% before 1939; 19% since 1970. Almost half held the two most difficult-to-obtain licences; extra class (12%), advanced (36%). There was very strong support for the American system of "incentive" licensing which encourages amateurs to qualify for more difficult licences by offering extra privileges (81% either strongly agree or agree with this approach; only 10% oppose).

At present *all* classes of American licence impose a Morse code requirement (Technician and Novice classes at 5 w.p.m.) and the analysis shows that generally American amateurs oppose the institution of a new "Communicator" class of licence for v.h.f.-only without a code requirement (51% disagree, 39% agree this would be a good way to bring in more amateurs).

And while most of those replying agree that there is a need to change the existing structure to encourage growth there is strong dislike of the idea of code-less licences with Novice-level technical requirement: 60% believing this would "bring in more undesirable than worthwhile new amateurs" compared with 26% who favour the idea. Almost exactly half disagree or strongly disagree with the suggestion that knowledge of Morse is not as important as it once was, compared with 43% who believe this to be true. But it is clear from the replies that American amateurs are not particularly knowledgeable about what happens in other countries: 64% replying "don't know" to the question whether other countries have issued no-code licences.

Some 39% of the 56,000 are active on h.f. only; 13% on v.h.f. only; 36% on both h.f. and v.h.f., giving a breakdown of 75% h.f. compared with 49% v.h.f.

One has the impression looking at the detailed analysis that amateur radio in the United States is an ageing hobby, still based primarily on h.f. and that the participants are aware of this and anxious to encourage growth among youngsters, but not at the risk of making fundamental changes to the hobby that has retained their interest over many years.

Moonbounce

Moonbounce (EME) communication between G3LQR and ZE5JJ, Rhodesia was achieved first during pre-arranged tests this Spring. During EME tests arranged by the Stanford Research Institute using a 150ft dish aerial some 55 contacts were made on 144MHz and 11 on 432MHz. An s.s.b. moonbounce contact has been made between VK5MC and W8PKY on 144MHz, the Australian station using rhombic aerials. The French amateur F9FT has made moonbounce contacts with stations in Europe and North America on 432MHz.

In brief

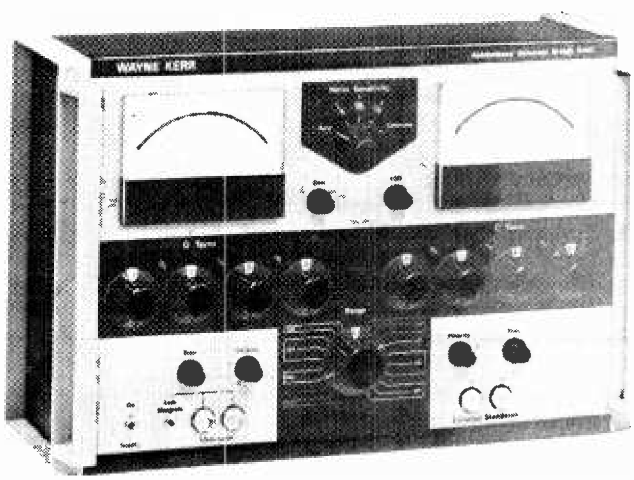
The annual Amateur Radio Retailers Association's "Fourth Midlands National Amateur Radio Exhibition" is at the Granby Halls, Leicester on October 30, 31 and November 1 . . . Overall winner of the 1975 National Field Day was the Channel Contest Group and the leading single-station entry was once again the East Barnet Amateur Radio Contest Club with the Racal group as second in this section. Band leaders were: 1.8MHz Mansfield; 3.5MHz Reigate; 7MHz Ariel; 14MHz Channel; 21MHz Glenrothes; and 28MHz Channel.

PAT HAWKER, G3VA

Each of these bridges has ten decade ranges and can be used to measure any type of component or complex impedance. Transformer ratio-arms are used to cover a very wide range of measurement using a minimum number of standards which are set digitally. The three terminal facility provided by this type of bridge enables small values of capacitance or high values of resistance to be measured at the end of long lengths of cable. Components can also be effectively isolated electrically from a complex network allowing individual measurements to be made without disconnection from the circuit being necessary.

The world's most universal audio bridges

Wayne Kerr's B224 and B642



The B224 is a manually operated bridge, the resistive and reactive terms being independently set to a null indicated on the meter. A rechargeable battery is fitted in order to make the instrument portable.

The B642 balances itself automatically. The meters read real and quadrature terms and highly stable analogue outputs are provided which are directly proportional to capacitance and conductance above 10Ω impedance and also to inductance and resistance below 10Ω. One or two decades can be set to provide the first significant figures of the measurement, thereby increasing the meter sensitivity by 10 or 100 times. If a chart recorder is connected to the output of either term, drifts in component values to at least four significant figures can be observed.

SPECIFICATION

	B224 (Manual balance)		B642 (Autobalance)	
Frequency	1592Hz (internal) 200Hz – 50kHz (external)		1592Hz (internal) 200Hz – 20kHz* (external)	
Ranges for specified accuracy				
	0.1%	0.3%	0.1%	0.3%
C	100fF – 10μF	10μF – 10mF	1pF – 10μF	10μF – 10mF
G	1n℧ – 100m℧	100m℧ – 1k	10n℧ – 100m℧	100m℧ – 100 [illegible]
L	1mH – 10kH	100nH – 1mH	1mH – 10kH	1μH – 1mH
R	10Ω – 1GΩ	1mΩ – 10Ω	10Ω – 100MΩ	10mΩ – 10Ω

NOTE: 0.1% accuracy relates to parallel component measurements above 10Ω impedance. 0.3% accuracy relates to series component measurements below 10Ω impedance

Manual operation only

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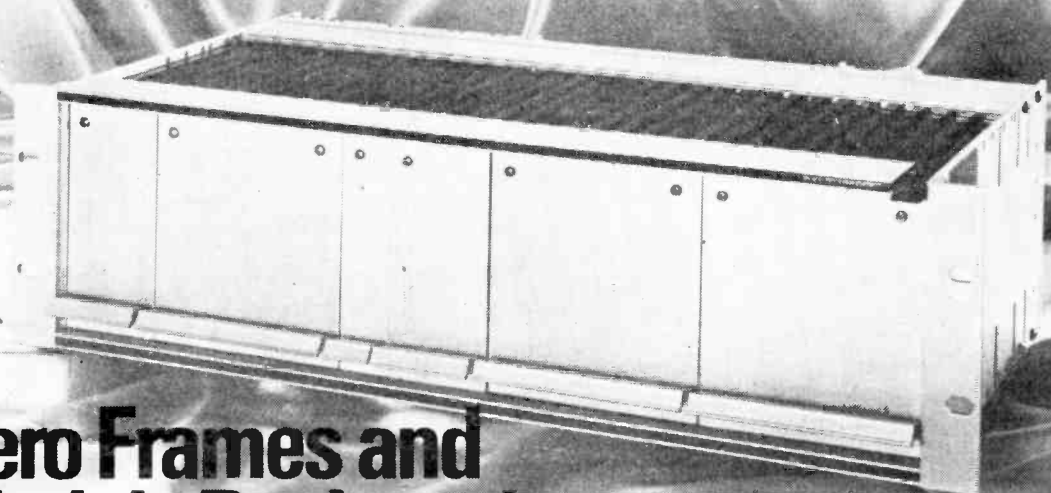


Resistors

A survey of current resistor technology and applications

by R. A. Fairs, B.Sc.
Rank Radio International

This survey, a sequel to "Capacitors" by the same author published in *Wireless World*, December 1974, describes the circuit analysis of simple equivalent circuits, the physics and significance of noise in resistors, the construction and properties of different resistor types and gives notes on their application. An applications chart relates the different properties and parameters.

Resistors are the most commonly used components in electrical networks. Their presence in circuits is often taken for granted — a demand for a 470-ohm half-watt resistor is met by going to the appropriate box, selecting the component, placing it in circuit and usually forgetting about it.

Perhaps the first curious fact that would manifest itself to a newcomer to electronics would be the "odd" values that resistors take, for instance 4.7 and 680 ohms. These values are in answer to a problem. One requires to fill a certain band, say one to ten ohms with resistors manufactured to a particular tolerance in the most practical way. A good method is to use a logarithmic sequence (eqn. 1) which generates the *E* series of preferred values when *Rn* is rounded to two significant figures.

$$\sqrt[\epsilon]{10^n} = Rn \qquad (1)$$

$$\epsilon = \frac{100}{t}(1+0.2)(0.8)^m \qquad (2)$$

Where $\epsilon = E$ number, n = integer $\geqslant 0$ and in (2), t = tolerance of resistors in per-cent, $m=0$ for $5 \leqslant t \leqslant 20$ $=1$ for $0.5 \leqslant t \leqslant 2$.
For 10% tolerance resistors equations (1) and (2) give the *E*.12 series of preferred values. For 5% tolerance resistors the *E*.24 series result. The two series are shown schematically below where (3) is the *E*.12 series and (3) + (3a) is the *E*.24 series.

1.0 1.2 1.5 1.8 2.2 2.7 3.3 3.9 4.7 5.6 6.8 8.2 (3)

1.1 1.3 1.6 2.0 2.4 3.0 3.6 4.3 5.1 6.2 7.5 9.1 (3a)

Equivalent circuit

By virtue of its construction, a practical resistor will include phenomena different from pure resistance. Fig. 1 shows an equivalent circuit for a resistor. If we take C_p as proportional to the magnitude of the resistor and constant along its body (to a first approximation) then we have an impedance, *Z*, described by eqn. (4), and having the form of Fig. 2 when plotted against frequency, *f*, (on log-log graph paper).

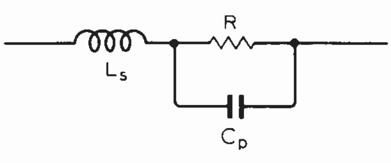


Fig. 1. Equivalent circuit for a resistor where L_s is the equivalent series inductance due to leads and construction, R is the apparent d.c. resistance and C_p is the parallel capacitance.

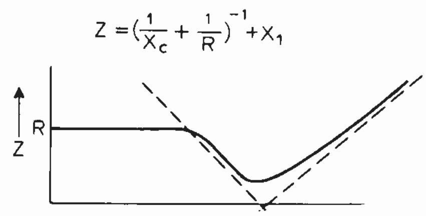


Fig. 2. Impedance of the equivalent circuit shown in Fig. 1.

$$Z = \left(\frac{1}{X_c} + \frac{1}{R}\right)^{-1} + X_l \qquad (4)$$

From this we can make the following observations: for large R (>500 ohms) $X_l \ll X_c$, $Z \simeq X_c$. For small R (<100) ohms) $X_l \gg X_c$, $Z \simeq R + X_l$.

Some cancellation of X_l and X_c will occur if:

$$\frac{1}{X_c} \approx X_l, \quad X_l \gg \frac{1}{R}$$

For practical resistors (carbon composition type) variations of resistance with frequency are shown in Fig. 3.

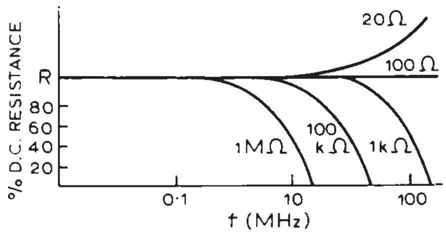


Fig. 3. Frequency characteristics for carbon composition types of resistor.

The curves shown are not entirely explained by eqn. (4). One may regard C_p as varying along the body of the resistor and not just as the simple sum of distributed capacitances. A more accurate interpretation of C_p is obtained by considering the body of the resistor as a distributed transmission line with capacitive and resistive elements*. From this theory one may show that for each value of $2\pi f$ there is a parallel combination of resistance R_{rf}, and capacitance, C_{rf} which is an equivalent circuit for the resistor at a given frequency, *f*, provided the effects of inductance are negligible. In this case C_{rf} may change in sign as indicated in Fig. 4(a). The variation of R_{rf}/R is shown in Fig. 5.

Frequency effects are most pronounced in carbon composition and wire-wound resistors. In the latter type the variation of C_{rf} is extremely complex due to inductance effects which occur in the windings, however special winding techniques have been devised to improve the high frequency performance. Carbon film resistors have good stability at frequencies of 500MHz and over but in this instance mounting and connection become of importance.

* Due to Howe 1933 (this theory also holds to some extent for film type resistors).

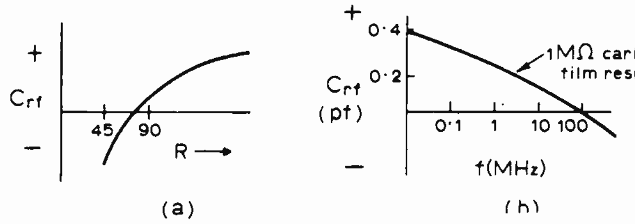
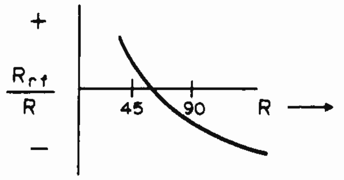


Fig. 4. Variation of C_{rf} with resistance at a fixed frequency.

Fig. 5. Variation of the ratio R_{rf}/R with resistance.



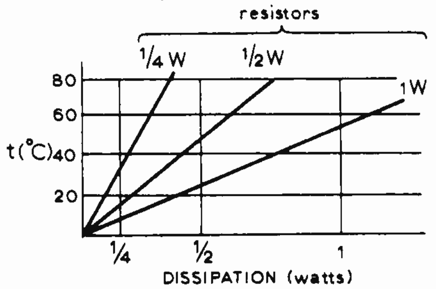


Fig. 6. Wattage curves for typical carbon film resistors.

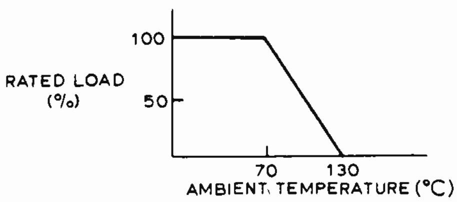


Fig. 7. Typical derating curve for a carbon film resistor.

The temperature at which a resistor is operated affects its stability (the ability of the resistor to keep to a particular resistance), and to a lesser degree its impedance characteristics. For resistance value a temperature coefficient (t.c.) is defined by:

$$\text{t.c.} = \frac{r \times 10^6}{R.t}$$

$$= \frac{\text{change in resistance} \times 10^6}{\text{orig. resistance} \times \text{change in temp.}}$$

$= a$ ppm/°C where ppm = parts per million

By defining the temperature coefficient in this manner it is independent of the units of resistance, and thus comparisons between resistors of differing magnitude may be made, as the change of resistance with temperature is rarely linear.

The wattage rating of a resistor is uniquely determined by the amount of power dissipated within it that creates a given long term stability of resistance value. The practical method of determining the wattage rating is to limit the body temperature to a certain quantity (see Fig. 6), but it is of importance that this will also depend on the ambient temperature of the surroundings, since this will affect the amount of heat transfer. For operation of resistors in high ambient temperatures a derating curve must apply; this curve is of the form shown in Fig. 7.

An excessive amount of power dissipated within a resistor causes violent changes in resistance and ultimately thermal limitation occurs when the resistor breaks down.

For carbon film resistors definite observable changes manifest themselves during this type of overload. Firstly the resistor begins to emit a steady stream of smoke with a characteristic odour, it then glows cherry red and finally breaks down with three possible results: the resistor becomes open circuit, the resistor becomes short circuit or the resistor splutters hot carbon particles and eventually flames.

In practice the fact that the second case occurs means that detrimental effects could happen to other components (especially semi-conductors) in the circuit not necessarily responsible for the stress condition imposed on the resistor. Similarly, because of case three, components adjacent to the resistor may be permanently damaged by fire, and the risk of fire in the circuit as a whole is not to be dismissed lightly, particularly in consumer electronics.

For convenience it is desirable to select, where possible, a resistor which under extreme overload becomes open circuit and non-flammable.

In high resistance values there is a maximum permissable voltage which, rather than the maximum wattage, limits the use of a resistor. This is due to the dielectric of the resistor breaking down under the extreme electric fields created by the applied voltage. Local voids occur within the material and observable sparking becomes apparent in most cases.

Pulse ratings

The response of resistors to transient effects is also of importance in circuit design. The same basic limitations of steady state conditions still apply here although the considerations are somewhat different.

In the transient case we have the form of Ohm's Law given by eqn. (5).

$$V^2 = W_p R \qquad (5)$$

where: V = pulse voltage, W_p = peak wattage and R = resistance. The peak wattage is related to the maximum continuous wattage, W, by: $W_p = W/ft$ (6)

where: f = frequency of the pulse and t = duration of pulse. Combining (5) and (6) we get

$$V^2 = \frac{WR}{ft} \qquad (7)$$

From thermal considerations eqn. (7) suggests that there is no limitation on the pulse voltage, provided it is applied for a sufficiently short time. However, the reaction of the resistor to voltage stresses is almost instantaneous and there is a distinct stress region below which the resistor will not fail. Thus there is no gain achieved by pulsing the voltage.

Catastrophic failure by the spreading of voids in the material will increase with the frequency of the pulse since neutralization of the external field by space or surface charges cannot always take place (due to this being a time dependent process). Experience with the Corona effects in carbon film resistors limits the safe pulse voltage to twice the normal rated d.c. voltage.

Noise considerations

Noise in an electrical circuit is an unwanted parameter. Being by far the most worrisome factor, resistors must be selected to give the lowest possible noise for a given application. Metal oxide resistors can be used at the input of audio amplifiers to promote low noise performance, if cost is not a prime consideration.

An intrinsic property common to all types of resistor is the generation of noise due to thermal agitation (Johnson Noise, J). In any resistor we have three types of transport phenomena, viz: (a) random motion of free electrons, (b) thermal motion of molecules and (c) electron drift current due to the p.d. across the resistor. In order that the laws of physics be satisfied, equilibrium between (a) and (b) must exist. This causes a noise voltage, e, whose magnitude is (intuitively) dependent on temperature and the magnitude of the resistance to be superimposed on (c).

An exact expression for Johnson Noise has been given by Nyquist, i.e.,

$$\bar{e}^2 = 4KRT.\delta f \qquad (8)$$

where: K = Boltzmann's constant

$= 1.38 \times 10^{-23} WK^{-1}$. T = temperature in degrees kelvin (K), R = resistance in ohms, δf = bandwidth of measuring equipment (Hz), $\bar{e}$ = mean noise voltage (volts).

Carbon composition resistors also exhibit noise due to the current flowing through the resistor. In this instance the noise is generated by random changes in the constituent material caused by the current flow. This noise (see appendix), termed current noise, E, is different in character from Johnson Noise, J, in the following ways: $E^2 \alpha \log(f_2/f_1)$ where $f_2 - f_1 = \delta f$ (for δf = const $E \alpha 1/f$); $E^2 \alpha V$ where V = direct voltage across resistor; and $E \gg J$ (see Fig. 8).

It should also be mentioned that low noise in resistors can be obtained by operating the component well below its rated wattage (see Fig. 9). The noise figures for resistors are quoted in μV/V or in dB referred to a fixed figure (usually 1μV/V); a comparison between types is given in the Applications Chart.

Solderability

Solderability can, by virtue of overheating, cause a change in resistance. In miniature resistors the change can be excessive if the soldering time is not limited. Soldering time can be shortened by the cleaning of soldering surfaces (particularly important for resistors that have been in stock). The tinning of leads will also reduce the soldering time, and the latter can often be seen to have been done by the manufacturer if the leads have a bright, clean appearance. A soldering time of two seconds at a temperature of 240°C is a maximum for flow soldering. For hand soldering, fifteen seconds at the same temperature is a safe maximum for the component.

The most important considerations in choosing a resistor for particular applications are: rated wattage, working voltage and resistance value; frequency characteristics and noise; environmental conditions (temperature and humidity considerations) and stability; physical size and cost.

It should be noted that a manufacturer cannot achieve a specific life or failure rate, but is able by quality of materials to ensure that the resistor is not subject to any known wear-out mechanism. Information such as resistance drift with respect to applied load, ambiant temperature and time will be important in circuit application and thus individual manufacturers' data must be consulted.

A survey of the various types of fixed resistors now follows.

Carbon composition resistors

Carbon composition resistors were used extensively in the radio and television industries for power ratings of up to two watts during the valve era, and to some extent in the early days of transistors. Commercially the resistors were cheap and hence the detrimental effects of poor stability, large temperature coefficient, and high noise levels were to some degree offset.

The construction of carbon composition resistors falls into two basic types. In the first (uninsulated) the resistive element consists of finely ground carbon particles dispersed by a refractory filling, and bonded together with a synthetic resin binder. The resultant black powder (whose proportion of constituents determines the value of the resistance) is then compressed into shape and solidified in a kiln. The end connections are made by either forcing a metal end cap onto the carbon rod (Fig. 10) or by spraying the ends with metal and the leads soldered (Fig. 11). Alternatively the enlarged ends of the connecting leads may be moulded directly into the carbon rod.

The second type of resistor (insula-

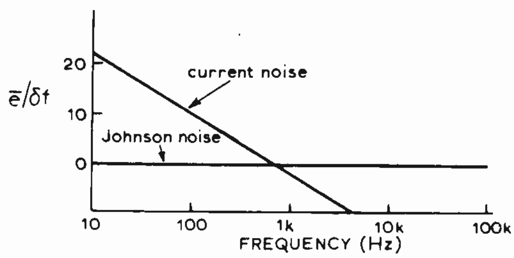


Fig. 8. Comparison of Johnson and current noise for carbon composition resistors.

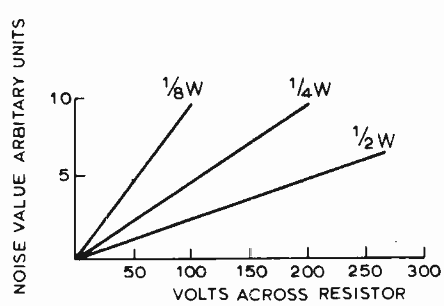


Fig. 9. Noise figures for carbon film resistors of differing wattage.

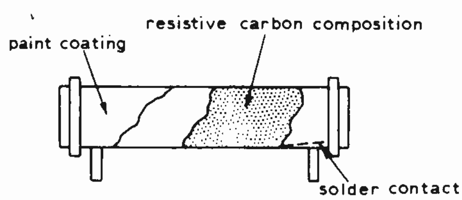


Fig. 10. Carbon composition resistor with the end connections made by forcing a metal end-cap onto the carbon rod.

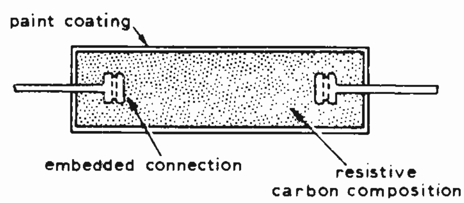


Fig. 11. Carbon composition resistor with the end connections made by spraying the ends with metal and the leads soldered.

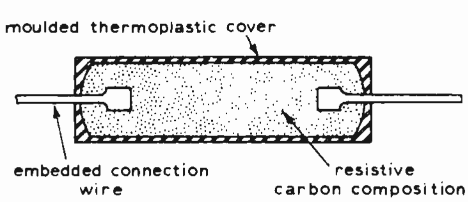


Fig. 12. Insulated carbon composition resistor construction.

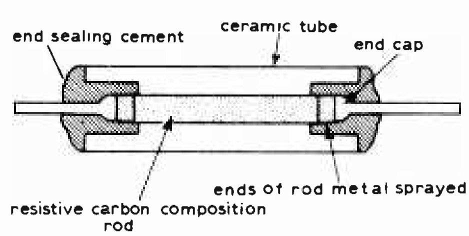


Fig. 13. Assembly of a ceramic tube type insulated carbon composition resistance.

ted) is constructed by encapsulating the carbon rod in either a thermoplastic insulation (Fig. 12), a moisture resistant silicone lacquer, or a ceramic tube. With the latter, construction is by placing the rods in ceramic tubes and fitting brass caps over the copper sprayed ends, which are then cemented with a moisture resistant cement. A typical assembly is shown in Fig. 13. Another method of constructing an insulated composition resistor is by dispersing the carbon granules and filler in a varnish which is applied to a glass tube. Leads are then projected into the tube and the whole assembly encapsulated by a moulded case.

The uninsulated form of carbon composition resistors are smaller than the insulated type for a given wattage. This is due to their open construction permitting good heat dissipation. However due to the necessity of preventing short circuits to adjacent components the insulated type of composition resistor is more widely used.

Carbon composition resistors have a large voltage coefficient which means that there is a change in resistance due to the applied voltage. This coefficient is insignificant in film types. Failure in composition resistors is rarely catastrophic, but on account of a large negative temperature coefficient the hotspot of the resistor is at the centre and will exhibit failure if overloaded by way of a reduction in resistance value in the first instance.

Abnormally high noise is generally due to poor terminations on the end cap which causes poor contact with the resistive element. Microphony may also be caused by the modulation of the noise voltage on the signal passing through the resistor.

The demand of transistor circuits caused high stability resistors to become dominant in electronics. On account of the initial investment of continental designers in their use of carbon film resistors during the post war boom in consumer electronics, manufacturing techniques caused the price gap between carbon composition and film to narrow and it is chiefly this reason that has caused carbon film resistors to be widely used in many branches of electronics.

Carbon film resistors

In a cracked or pyrolytic film resistor a hydrocarbon vapour at a temperature of about 1000°C is decomposed onto a ceramic rod to produce a thin carbon film. The thickness of the film is a compromise between good electrical properties and detrimental temperature effects as indicated by Fig. 14.

The inherent value of the resistor is increased by spiralling the film to form a long continuous path thus yielding a typical gain in resistance value of 10-10000. The final resistor is thus compact in size and values of up to 10^8ohms can be obtained.

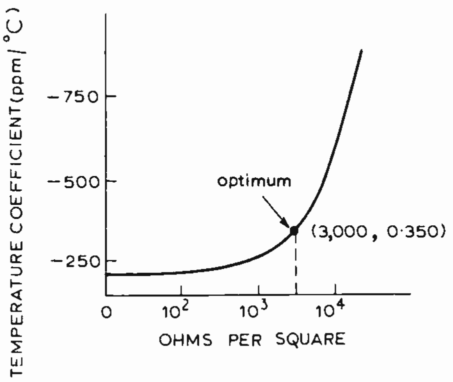


Fig. 14. Variation of the temperature coefficient with resistivity (thickness of carbon film).

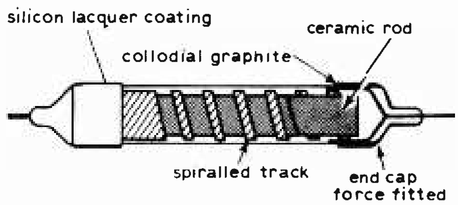


Fig. 15. Construction of a carbon film resistor.

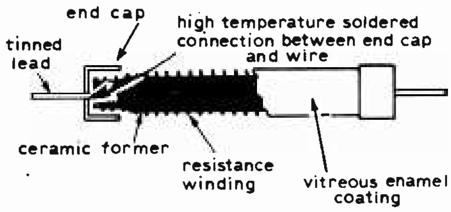


Fig. 16. One construction example of wirewound resistor.

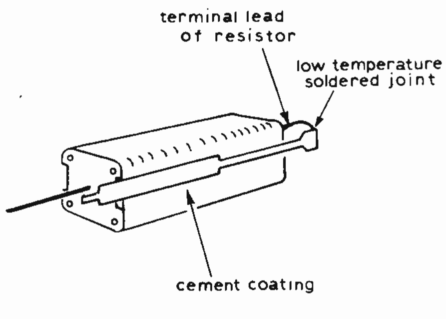


Fig. 17. Fusible type wire wound resistor.

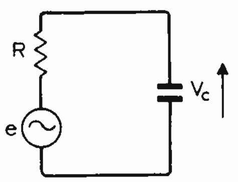


Fig. 18. Equivalent noise circuit where e is the noise voltage generator, R is a noiseless resistor and C is the parallel capacitance.

Terminations may be metal end caps pressed over the carbon film, or alternatively the ends of the ceramic rod may be metallized and the leads soldered to them. Owing to the delicate nature of the carbon film, protection against moisture and handling is necessary, hence apart from enclosing the resistive element in a ceramic or glass tube numerous varnishes are applied.

Construction of a carbon film resistor is shown in Fig. 15, and it is noted that this figure is representative of all types of film resistors as are the noise and failure considerations that follow.

The noise, n, in carbon film resistors is much less than in their composition counterparts. Its general properties are summarised by eqn. 9.

$$\text{(i)}\ n = f(v, 1/t) \qquad \text{(ii)}\ n \propto 1/l^2 \qquad (9)$$

where v = voltage stress, t = thickness of film and l = length of film.

Typical noise figures are given in the application chart. Carbon film resistors are available in ratings of up to two watts, and in the latter case may be flameproofed for safety.

Failure is more common in the higher value resistors and is often caused by irregularities in the spiralled track and film. In the former a shallow groove causes an intermittant bridge between tracks whilst a deep groove will produce isolated sections of film along its edge resulting in instability and noise.

Of particular interest in carbon film resistors is the dependence of the temperature coefficient of resistance (t.c.r.) on the resistance value and rated wattage of the resistor due to the amount of effective carbon film involved in constructing the resistor. This is another instance where manufacturer's data is to be consulted.

Metal oxide film resistors

The resistive film for these resistors is formed by the chemical reaction of acqueous stannic chloride on a glass or ceramic rod at red heat. A resulting hard glass-like oxide varying in thickness between 10^{-9} and 10^{-7} metres is produced. This oxide film is electrically conducting and inert to common chemicals. Its resistivity (typically 10^3ohm/sq.) and temperature coefficient of resistance (usually ±250ppm/° C) may be modified by the addition of small amounts of antimony or boron added to the original chloride solution.

The final resistance value of the film is adjusted by cutting a helix along the ceramic rod. Terminations are similar to those of carbon film resistors but with more attention paid to detail to improve noise and reliability considerations. Encapsulation of the resistive element is usually by means of a suitable epoxy.

The noise and t.c.r. vary little with the value of the resistor and are a good deal lower than in carbon film types. The t.c.r. may be either positive or negative

Application chart

	carbon comp.	carbon film	metal oxide	metal glaze service	metal glaze commercial	metal film	wirewound commercial	wirewound precision
Resistance range (Ω)	10-22M	1-10M	10-150k	10-150k	10-150k	100-1M	100-1M	10-500k
Selection tolerance (%)	5-20	5	1-5	0.5	1	0.2-1	5-10	<0.5-0.1
Max d.c. voltage (V)	500	500	500	350	350	350	dependent on type	350
Insulation resistance (Ω)	10^4	10^7	10^8	10^9	10^9	10^9	10^7	10^9
Voltage coefficient (ppm/V)	3000	100	negligible	negligible	negligible	negligible	negligible	negligible
Average size (length × diam) (mm)	15×6	10×3	7×2.5	7×2.5	7×2.5	7×2.5	dependent on type	
Cost	low	low	fair	fair	fair	fair	fair	high
Noise (μV/V)	3	0.15	0.03	0.4	1.0	0.015	negligible	negligible
Average frequency range (MHz)	~10	~50	~50	~50	~50	~50		
Stability after 1000 hours (%)	<20	<1	<0.5	<0.5	<1.0	<0.2	<2	<0.05
Max operating temp (ambient + load)	110	150	150	95	120	150	350	150
Temperature coefficient* of resistance (ppm/°C)	<1200	250-1200	50-250	100	100	15-100	<200	<5
Max wattage (W) at surface temp of 70° C	2	2	10	1	5	1**	50	1**

* Absolute value.

** High power types also available.

due to the semi-conducting nature of the oxide film. Most resistive films used in the construction of resistors are semi-conductive; the limit of precision in the composition of the film results in the t.c.r. being a positive or negative quantity for a given value and type of resistor.

Metal oxide resistors are used in circuit applications where stability and low noise are of importance. There is an increasing tendency to use metal film types.

Another application of metal oxide film is in power resistor developments. In this instance tolerance is typically 5% and the resistors are coated with a non-inflammable silicon cement and exhibit fusing characteristics. The considerations of cost and stability render this component competitive. High power types (up to 5000W) are also produced.

Metal film resistors

The film used in these resistors is achieved by the vacuum evaporation of nickel chromium alloys (surface resistivity 10^3ohm/sq.) or by the chemical deposition of nickel alloys (surface resistivity 10^5ohm/sq.) onto a cylindrical ceramic substrate. The metal film is eroded rapidly in humid conditions with a light d.c. load, and for this reason the resistive element is protected by encapsulation in one of the three following ways: lacquering and encapsulation in a moulded plastic case, sealing in a resin filled tube and lacquering and hermetic sealing in a ceramic tube with soldered ends.

The general construction of metal film resistors is similar to the types of film resistor already discussed, the difference being that the terminations may be made via forced metal caps which are in good contact with the resistive element by vacuum deposited terminating bands. Current noise level of metal film resistors is determined only by the cut of the helical groove (c.f. appendix). The t.c.r. may be as low as ±20ppm/°C. The stability of metal film is good; results in laboratory test conditions have given failure rates of 0.0012% for 1000 hours of life test.

From these considerations metal film resistors are becoming widespread in military and scientific applications where reliability and close tolerance are of importance. Power types are also available.

Metal glaze resistors (cermet)

In these resistors an organic suspension of metal and glass particles is applied to a ceramic rod and fired. As a result a thick resistive film remains on the rod. The firing process causes the ceramic to fuse with the thick film, thus the type of ceramic used influences the physical properties of the resistive element. Unsuitable thermal characteristics of the ceramic rod will cause an expansion effect with the film, as in a bimetallic strip of two dissimilar metals.

The construction of metal glaze resistors is similar to film resistors and shown in Fig. 15. The resistive film can be varied from 10ohm/sq. to 10^6ohm/sq. depending on the glaze used. An excess of glass in the suspension causes the metal particles to be disjointed, and hence produces a high but uncontrollable resistance.

Due to the high initial firing temperature, metal glaze resistors may be run at high temperatures and loads, in this instance conduction of heat away from the resistive element is via the terminations and the ceramic rod.

The noise level of metal glaze resistors is intermediate between film resistors and carbon composition. The t.c.r. is low (±100ppm/° C) and stability is excellent on account of the body temperature of the resistor being low for the amount of power dissipated.

Wirewound resistors

In resistors of this type a length of resistance wire is wound on a bobbin (usually ceramic) and its ends anchored to terminal leads. A coating or case protects the wire from damage or corrosion. A suitable wire for general purpose wire wound resistors is nickel chromium since it has good stability, a low t.c.r., and a high operating temperature. Encapsulation of the wirewound resistive element may be by cement, lacquer or vitreous enamel. Open wound resistors may be used in high power applications.

General purpose wirewound resistors are supplied to tolerances of 5% and 10% with wattage ratings of up to 50 watts. In the latter case a cement coating is used for the lower wattage types (up to 20 watts) which is not impervious to moisture but has the advantage of cheapness.

Vitreous enamelled types are usually of 5% tolerance but a 0.1% tolerance may be selected. Excellent protection against moisture is afforded by the vitreous enamel, and one general example of construction is shown in Fig. 16. In precision resistors the resistance wire is Eureka, which has a low t.c.r., but a relatively low operating temperature. In this case certain variations exist, viz: hermetic sealing in an oil filled tube, sealing in a ceramic tube, moulded plastic casing, and various kinds of lacquer. In the latter, protection against moisture is satisfactory but the working temperature is limited to around 170° C.

In the use of wirewound resistors particular care must be taken concerning the high ambient temperature from affecting surrounding components. Power resistors of tubular construction convect heat through the hole. The operating temperature of the resistor may be used to effect a fusible resistor an example of which is shown in Fig. 17.

Frequency characteristics of wirewound resistors may be improved by special winding techniques, such as winding in anti-phase. Exact analysis of the effects encountered is impossible due to the number of variables, e.g., physical size, wire size differences, spacing etc. At around 2.5MHz low value resistors become capacitive so non-inductive windings are not of value.

Failure in wirewound resistors may be due to the following: (1) in high value resistors the wire may be blemished, (2) in vitreous enamel types expansion differences between the ceramic substrate and the enamel coating may cause cracking and penetrating of moisture, (3) corrosion of the wire due to d.c. load conditions can induce an excess of alkali in the enamel.

In order to eliminate (2) in their precision wirewound resistors, one manufacturer uses the same material for encapsulation as for the bobbin.

Special types

High value resistors are composed of a carbon composition film resistive element in an evacuated glass envelope, the assembly strongly resembling a glass thermistor. Values of resistance up to 10^{13}ohm may be obtained.

Ceramic carbon resistors are able to withstand high voltages (typically 25kV) and are used as current limiting resistors in voltage multiplier circuits in television sets. Standard resistors are constructed as precision wirewound types, the wire used being manganin. A small adjusting resistor in parallel with the main resistive element gives trimming of the exact value. The range of ohmic value is between 10^{-4} and 10^5ohm.

Precision power resistors (0.5%) may be constructed by mounting a suitable wirewound resistor or power metal film resistor in an extruded aluminium casing. With additional heat sinking this type of encapsulation is capable of dissipating 200 watts.

Recent developments in resistors include the encapsulation of an array of high stability resistive elements (15% to 2% tolerance) in a dual-in-line package similar to the micro-circuits already available. One immediate advantage here is that in low power applications repetitive resistors such as in current limiting for l.e.d. displays, assembly and overall cost are reduced.

Two types of resistive ink are used in the manufacture of resistor arrays giving rise to the terms plane film (sometimes referred to as thin film) and thick film.

In plane film types two inks are principally used, nickel/chromium (t.c.r. 30ppm/° C) and tantalum/aluminium (t.c.r. 150ppm/° C). The substrate is alkali free glass and the method of manufacture is by vacuum deposition. The geometry of resistors is achieved by selective etching which may be laser trimmed. Evaporated gold film is used for the patterns of the conductors, external connection being by soldering or thermocompression. Encapsulation may be d.i.l. or in an inert gas filled metal can.

Thick film types are constructed in a similar manner to plain film. The ink used is the same as for metal glaze resistors and this consists of an organic suspension of metal or metal oxide with fine glass powder. The ink is screen printed onto the ceramic substrate, dried and then fired, insulating pastes are applied next and are in turn dried. Three or four printings may be required to build up the resistive network and the complete assembly (including terminal leads) is then passed through a furnace under a controlled process as some reaction with the ink may occur. In thick film circuits encapsulation is in d.i.l. form. Whole circuits including small capacitors may be designed into the package and most manufacturers offer a design service. The tolerance of the resistors produced may be as low as 2%.

Further reading and acknowledgement

Many manufacturers provide excellent information on fixed resistors, among those of particular interest are technical literature by Mullard, Electrosil, VTM, Allan Bradley, Utronix, Dale, Welwyn, and ITT.

A short list of further reading and references includes:

1. Dummer, Fixed Resistors, Pitman, 1956.
2. Dove, K. L. Metal Glaze Resistors, *Wireless World*, June 1970.
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4. Boswell, D. & Russel, R. F. Thick and thin film resistors: performance and reliability comparison. *Microelectronics*, Vol. 1, No 1.
5. Browning, J. Film Resistors, *Electronic Components*, Vol. 16, No. 2.
6. B.S.9000 for methods of test and interpretation of information and results.

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Appendix

Noise in resistors

The noise voltages that appear across the terminals of any resistor are attributed to the random motion of free electrons in the material of the resistance. Electrons in a conductor are free to move by virtue of their thermal energy, and at a given instance more electrons may be directed toward one terminal of the resistor than the other. The result is a small p.d. across the resistor, and this p.d. will fluctuate as the electrons move.

Since the noise voltage across the resistor fluctuates randomly, it has Fourier components covering a wide range of frequencies. It is thus convenient to specify the noise voltage in terms of bandwidth as given by eqn. (8), viz:

$$\bar{e}^2 = 4KRT\delta f \qquad (A1)$$

Eqn. (A1) may be derived as follows: consider the equivalent circuit shown in Fig. 18. We have:

$$V^2_c = \frac{e^2}{1+(\omega RC)^2} \qquad (A2)$$

The condition of Fig. 16 is completely determined by V_c. In thermodynamic terms the circuit is a system with one degree of freedom. According to the equipartition theorem in themodynamics the total energy of the capacitor must be equal $1/2KT$, thus:

$$1/2KT = 1/2CV^2_c = \int_0^\infty \frac{e^2 df}{1+(\omega RC)^2} \qquad (A3)$$

The integration extends over all frequencies f due to the random nature of the noise. Assuming that the noise voltage is independent of frequency, we have:

$$KT = Ce^2 \int_0^\infty \frac{df}{1+(\omega RC)^2} = e^2/4R$$

i.e. $e^2 = 4RKT$ (A4)

Eqn. (A4) shows that the noise voltage of resistances is independent of frequency, and accordingly, is termed "white" noise in analogy with the uniform spectral distribution of white light energy. This noise in resistors is also called Johnson or Nyquist noise after its discoverers. For a given bandwidth, δf, eqn. (A4) assumes the form of eqn. (A2).

Noise voltages in excess of Johnson noise are observed experimentally in certain resistances when a direct current is present. Although the physical origins of this additional noise are uncertain, an empirical expression for the effect is given by (c.f. eqn. (8)):

$$\bar{e}^2 = \alpha \frac{I^2}{f} \delta f \qquad (A5)$$

where α = constant (dependent principally on the geometry and material of the resistor), I = d.c. current and f = frequency.

The magnitude of the noise shown by eqn. (A5) (termed current noise, E) varies markedly with the material of the conductor and its physical form. It is entirely absent in metals and hence is not observed in wirewound resistors. Composition resistors generate a large current noise due the intergranular contacts in such resistors as shown by Fig. 8 in the main article.

Peak-reading level indicator

The following notes are related to "Peak-reading audio level indicator," August issue. The value of R_{11} quoted in the components list applies to R_{11} connected to Tr_3 gate and R_{16} in Fig. 3. The second resistor marked R_{11} connected to Tr_3 source and C_8 should be 47kΩ. The latter R_{11} is that mentioned on p.357, column 3. Left-hand side of the logic equation (p.359, column 3) should be Y_r not X_r. On page 360, VR_2 should be R_{13}. Under the heading of "Construction" the second sentence should begin "Three *types* of board were used" not "Three boards were used." Finally, in Fig. 10 a diode 0A202 should be included connected from the inverting input of the second op. amp. to the base of the 2N2905 transistor.

New Products

Low profile i.c. socket

Known as the Ultra Low Profile Socket, this i.c. socket is available in 6, 8, 14, 16, 18 and 22 pin, 0.3in pitch versions. When fully inserted, the i.c. is 0.16in from the p.c.b. Contacts first grip the flat of the i.c. pin and also make contact with the wider surface area at the top, reducing contact resistance to typically 6mΩ.

The socket confirms to the vibration requirements of BS2011 and DEF5011, and beneath the socket are four 0.02in high feet acting as a moisture barrier, thus conforming to the BS9500 specification for i.c. sockets. Jermyn Manufacturing, Sevenoaks, Kent.

WW 301 for further details

Cooling fans

Designed for forced cooling applications where space is at an absolute premium, the Rotron Piccolo fans are 80mm square by 38mm deep. From 9 to 13 litres per second of air flow are provided by the fans which are double insulated and protected.

Versions are available with either sleeve bearings for use up to 55°C, or ball bearings for use up to 75°C. Both versions can be supplied with either 115V or 240V motors. G.D.S. Sales Ltd, Michaelmas House, Salt Hill, Bath Road, Slough, Bucks.

WW 302 for further details

Vibration analyzer

A Mark 2 version of the VM3C portable vibration analyzer is being offered by Vibro-Meter Ltd. Designed for use, even in hazardous environments, with signal supplied from both piezo-electric and magnetic transducers, the read-out may be made in one of three modes. These are velocity, displacement or acceleration, shown as a deflection on a built-in meter.

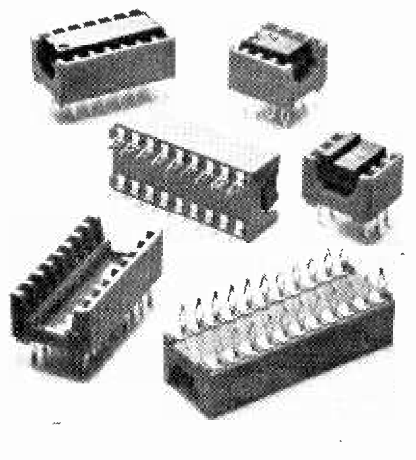
Narrow band analysis is possible using the variable filter which ranges from 10Hz to 10kHz. Powered from mains or internal, re-chargeable Ni-Cd batteries the unit is 300mm × 130mm × 310mm. Vibro-Meter Ltd, Newby Road, Hazel Grove, Stockport, Cheshire.

WW 303 for further details

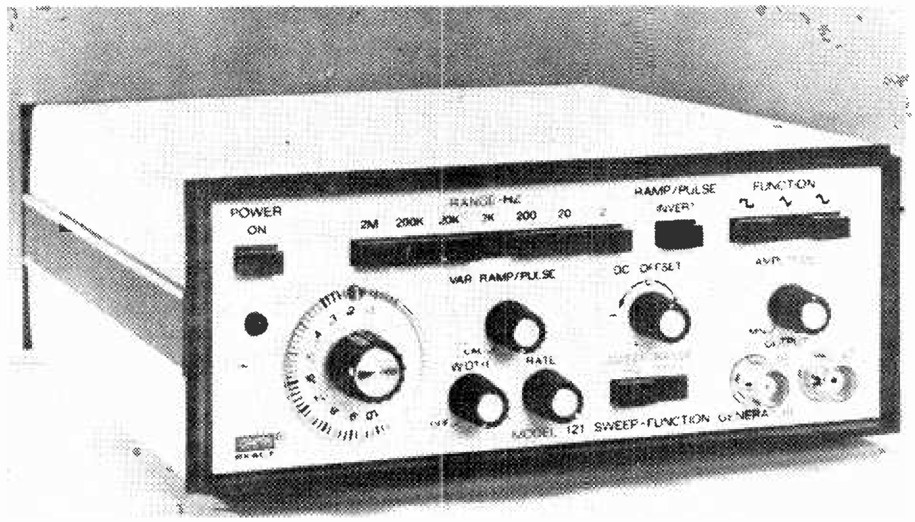
Sweep/function generator

The model 121 Exact is a portable swept function generator with a frequency range from 0.002Hz to 2MHz and a range of waveforms with variable time symmetry. Outputs may be sine, square or triangle and have a swept range from zero to 1000:1 with a sweep rate continuously adjustable from 1ms to 10s.

Two output levels are available, 20V pk-pk open circuit, dropping to 10V pk-pk into 50Ω, and 632mV pk-pk open circuit, dropping to 316mV pk-pk into



WW 301 for further details



WW 304 for further details

WW 303 for further details

WW 302 for further details

50Ω. An invert switch is provided to reverse the polarity of the pulse and ramp outputs, a ±10V of d.c. offset and an external frequency control socket. The sweep waveform is available from a rear mounted socket. Price is £155, or the model 121A, with a 20dB step attenuator, is available at £195. Dana Electronics Ltd, Collingdon Street, Luton, Beds.
WW 304 for further details

Static meter

With static becoming a serious problem in industry and the medical world, the model 703 non-contact static meter from 3M Nuclear Products can be useful to examine suspect surfaces.

It can be set to read at distances of 2, 6 or 12 inches and will detect potentials from 50V to 2000kV. The meter is battery operated from two 9V dry batteries, giving up to 100 hours continuous service.

The instrument operates on the principle of the discharge of a metal sensor plate in the muzzle, using a weak beta ray source. The small current thus generated is measured by means of an amplifier connected to the meter. The value and polarity of the charge is indicated.

A free "static analysis service" is also offered on industrial premises. Product Public Relations, 3M United Kingdom Ltd, 380 Harrow Road, London W9 2HU.
WW 305 for further details

Test set

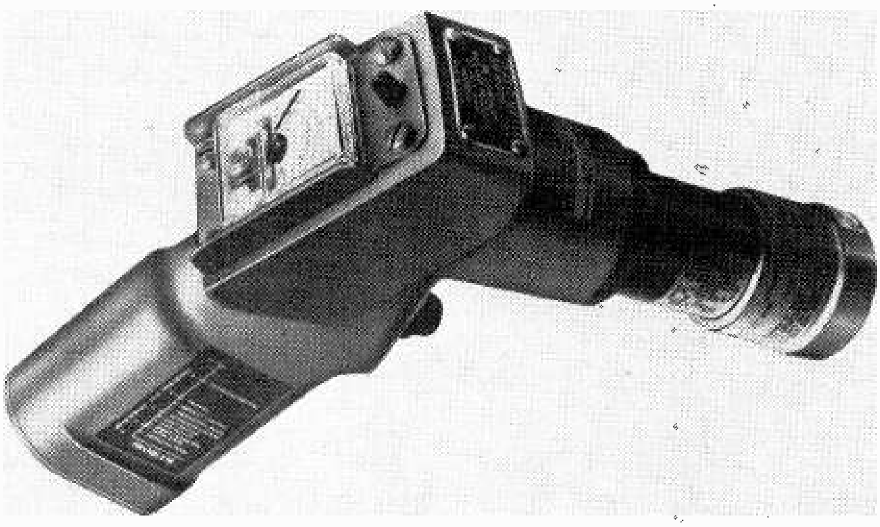
A hand-held test set designed for fault-finding in data transmission systems, has been announced by IAL Data Communications. The Data Monitor Set PDMS 9801 shows, on a "go–no go" basis, the signal states on the ten most frequently used data and control circuits of a CCITT V24 interface. It is Post Office approved for connexion to their modems and other approved modems in series with the modem-to-computer interchange cable.

The test set imposes negligible loading on the system being tested and is powered by readily available dry cells. International Aeradio Ltd, Aeradio House, Hayes Road, Southall, Middx.
WW 306 for further details

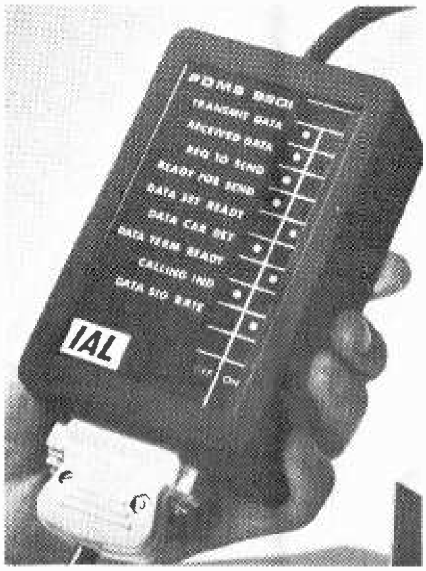
Multipurpose instrument

Digical is a precision voltage and current generator, v.o.m. and constant voltage or current power supply. Designed to provide a calibration source for d.c. instrumentation or other equipment, it offers five functions and 25 ranges.

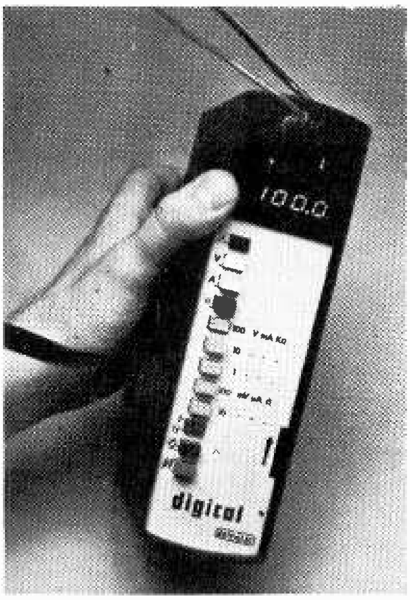
An 8mm, 3½-digit l.e.d. display indicates the instrument's output which can be from 10μV to 100V at up to 100mA or 10nA to 100mA at up to 100V.



WW 305 for further details



WW 306 for further details



WW 307 for further details

WW 308 for further details

It will also measure external voltages or currents of a similar range and additionally measure resistance from 10mΩ to 100kΩ. Delresistor Ltd, 21 Windsor Street, Uxbridge, Middx.
WW 307 for further details

Standard frequency receiver

One of a range of frequency standards manufactured by R.C.S., the type 103 receiver operates from the Droitwich signal and provides two outputs at 3V pk-pk square wave into 300Ω, of 10MHz and 1MHz.

The short-term stability is 1 part in 10^8 and the long term stability, that of Droitwich itself. Manual controls are eliminated by the use of an automatic lock taking up to 20s from switch-on to operate.

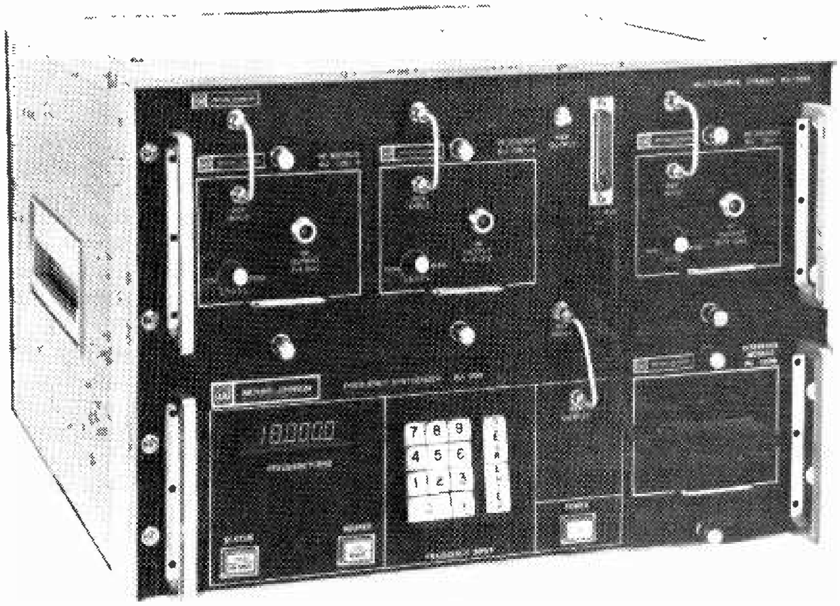
A remote ferrite rod assembly is supplied for use as an aerial and the power requirements for the receiver are 220/250V, a.c. 50-60Hz. R.C.S. Electronics, National Works, Bath Road, Hounslow, Middx.
WW 308 for further details

Portable tachometer

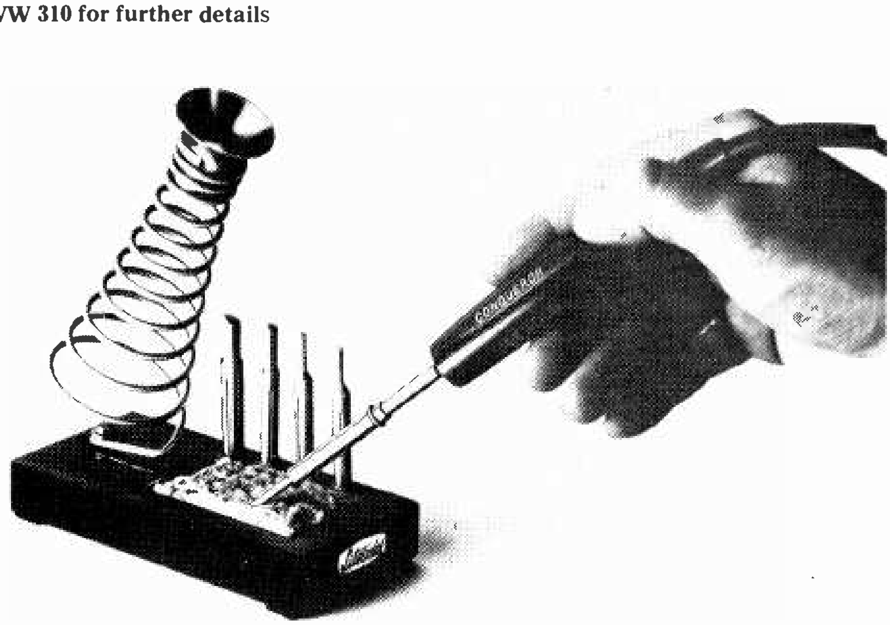
The Philips PR 9131 is a portable tacho-meter for direct measurements between 1 and 9999 r.p.m. An extension of the range above this is obtained by contactless measurement, from 100 to 999,900 r.p.m.

Accuracy is claimed to be ±0.2% (±1 digit) of the true speed, the display being a 4 digit l.e.d. indicator. Power is provided from either mains or battery, the latter giving 180 minutes continuous use. Recharging takes approximately 10 hrs.

Price with case and accessories, but without batteries is £295. Pye Unicam Ltd, York Street, Cambridge.
WW 309 for further details



WW 310 for further details



WW 311 for further details

Frequency synthesizer

Additional components are being offered to extend the range of the basic WJ—1250 modular synthesizer by Watkins-Johnson. These consist of a chassis (WJ—1253A) which can house up to three WJ—1251 r.f. sources, with automatic interfacing with the WJ—1250 microwave synthesizer main frame.

Two double-band r.f. sources using fundamental y.i.g.-tuned oscillators, one of which (WJ—1251—7) provides from 8 to 18GHz at 5mW (min), the other supplying 20mW (min) from 1 to 4GHz.

Various options and auxiliary modules are also available. Watkins-Johnson International, Shirley Avenue, Windsor, Berks.
WW 310 for further details

Soldering iron

A 24V soldering iron suitable for continuous production usage has been introduced by Light Soldering Developments. Called the Conqueror, it weighs 35g and is supplied with a range of five bits from 1.6mm to 6.3mm and a spiral spring holder mounted on a Bakelite base. The base is fitted with a wiping sponge and can be fitted directly onto many existing 24V power units. Light Soldering Developments Ltd, 97-99 Gloucester Road, Croydon, Surrey
WW 311 for further details

Injection moulded capacitors

High humidity protection is claimed for the 8017 series of capacitors from Advance Filmcap. The process eliminates voids occurring in normal resin encapsulation and ensures the accurate central location of the axial leads.

The range of values available matches the existing Filmcap polycarbonate and polyester ranges and has received British Post Office approval. Advance Components Ltd, Rhosymedre, Wrexham, Denbighshire.
WW 312 for further details

Etch and wash unit

This is a heated p.c.b. processing tank with a spray wash bath, designed as a bench top unit 16 × 22 × 20ins. Heating and agitation is by a patented integral wall heater with air agitation. The wash tank contains two spray bars.

All controls, thermostat and air pump are part of the units which only require connection to the 240V mains supply, mains water and drainage.

Other units with develop, etch, tin or strip tanks each combined with a wash tank are available. Circuitape Ltd, 33 New Street, Aylesbury, Bucks.
WW 313 for further details

Real and Imaginary

by "Vector"

ON COMMITTEES

There's this friend of mine, see, who's the proud father of a seven-year-old son. One day, junior returns from school bursting with exictement and announces that his class is working on a new project, to wit, the manufacture of a papier-maché cow. You know – wire netting framework and that kind of lark. Pa, suitably impressed, asks questions, and in particular what son's contribution is going to be.

"Well, actually," says junior, voice trembling with pride, "teacher's appointed me chairperson of the crumpled horn committee!"

In these troubled times it's reassuring to know that our educational system is solidly behind us, nurturing our tender plants so that in the fullness of time the young idea will emerge completely meeting-orientated and ready to pull their full weight in British Industry.

I feel sorry for our forebears. I just don't know how they managed to cope in the B.C. (Before Committee) era. For, incredible as it may seem, Graham Bell, Edison, Marconi *et al.* seemed to have functioned on a bull-at-a-gate, suck-it-and-see basis and entirely without benefit of committees. That they got anywhere at all can only be attributed to beginner's luck. Fluking their way through, you might call it.

Yes, it's a great pity that the old-timers hadn't latched on to the committee approach, which, as all thinking men agree, was the greatest single invention since the wheel and girls. For, properly employed in industry, it confers two major boons; it's an almost foolproof safeguard against getting the sack and it creates an intense eager-beaver atmosphere without actually getting anything done.

Consider the instance of Bludswet and Teeres Ltd, electronic equipment manufacturers in a smallish way of business. In days of yore if one of their engineers had an idea (and they sometimes did) he'd wheel it along to the Chief Engineer. If the Chief liked it, he'd say go ahead and if it subsequently proved to be a success – well, Chief Engineers were paid to spot winners. If it didn't, another C.E. was appointed sharpish. Each position of high responsibility carried a built-in chopper; that was what it was all about.

How primitive! Thank goodness we have none of that barbarism nowadays! In the interim period Bludswet and Teeres have prospered and now constitute a democracy by committee. Their Research Dept. dream up an idea and, after lots of meetings, pass it to Development who hold a lot more and tag every electron involved so that they'd know it again if they met it in the street. The prototype is then processed through various channels and is eventually offered to the Commercial Manager; by this time it's not nearly such an original idea as it once was because a lot of water has gone under the bridge and those fiendish Japanese are believed to have got something similar up their kimonos.

In short, the new equipment is a dodgy potato and the Commercial Manager has been too long in the business to stick his neck out. So he sets up a committee of senior executives to brood over the project and eventually to advise him on a straightforward digital yes-no basis.

Naturally, they do nothing of the sort. They have serious responsibilities like week-end cottages, cabin cruisers and Mercedes cars to think about and they know just as much about hedging bets as the Commercial Manager. So they promptly appoint another set of committees at the next level below them. Thus, if we start off with a top-brass committee of ten (a reasonable figure) and each of these appoints a coven of similar size to advise him on his own peculiar interests in the equipment, we already have 110 good men and true involved in committee work.

But that's only the start. The lower (but still quite senior) stratum have no intention of facing a firing squad either, so they in turn delegate subordinates to . . . but I needn't go on because you know the picture anyway. And naturally, everybody on a committee has to hold a prior meeting with a few immediate colleagues in order to establish what he's got to say at *the* meeting. So, in no time at all, half the personnel at Bludswet and Teeres are involved in reporting to somebody or other. There are steering committees, whose members are specially selected for their complete lack of a sense of direction, and there are also things called working parties. Nobody has yet discovered what a working party is supposed to do. Nevertheless, momentous issues are being solved all the time. Somewhere in the morass a sub-committee has been haggling for months as to whether the chassis should be stoved in baby blue or a crackle finish.

The immediate consequence of decision-by-committee is that a mass of paper ascends to high heaven and flutters down to the IN-trays beneath. These memoranda require the utmost care and deliberation in their composition; they must be verbose enough to impress the committee conveners but at the same time they mustn't actually say anything; particularly anything that could be construed as a recommendation one way or another. This continuous interdepartmental to-and-froing of memos has been unkindly described as a closed oscillatory circuit using paperwork coupling.

But at long last the moment of truth can no longer be delayed and, from the information dredged up, the Commercial Manager reluctantly decides that the new equipment shall go into production. The lengthy business of tooling up, buying in components and producing working drawings begins, and, of course, this necessitates a whole lot of new committees. Then, just after the point of no return, those perfidious Japs, who have no sense of the correct procedures, bring out something better on immediate delivery. But do heads roll at Bludswet and Teeres? They do not. The buck is passed down and down and you can't sack a committee complex consisting of half the factory, with at least three trade unions behind them.

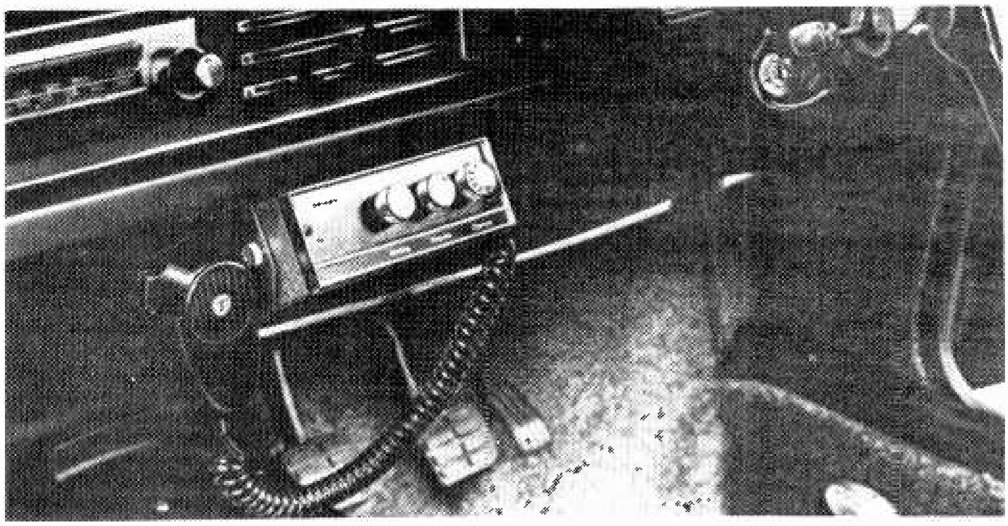
There are, broadly speaking, two distinct categories of meeting-attenders. There are the dedicated committee-men and those who have been co-opted protestingly from their lawful occasions to pronounce judgement on a technical issue. The latter are the sacrificial lambs who can (and assuredly will) be put on the altar should appeasement be demanded from on high.

Professional committee men come in various types. There is the Chairman, born with an agenda in his hand, who has an inexhaustible fund of Rabelaisian anecdotes with which to jolly the meeting along but who is known to have the ear of Sir upstairs, so watch it. Then there are at least two members of any given meeting who like to hear the sound of their own voices and are adepts at saying nothing at interminable length. There is Terribly Ernest, a junior executive from Trends and Tendencies Department; it is his first meeting and he's anxious to make a good impression upon his seniors.

Another well-known frequenter is Humpty Dumpty, so adept at sitting on the fence. There's the Doodler who spends the meeting sketching positions from the Kama Sutra on his pad. And then there's the Ancient, in his prime when the new-fangled triode was ousting the crystal detector; nobody is at all sure who he represents. He just sits in dour silence until the meeting's over and then totters off to a blue movie. And then there's — but you know them, anyway.

Meanwhile, back on the Works Floor the machines are on short time and the pound's taken yet another turn for the worse. H'm; it looks as though we'd better convene another meeting.

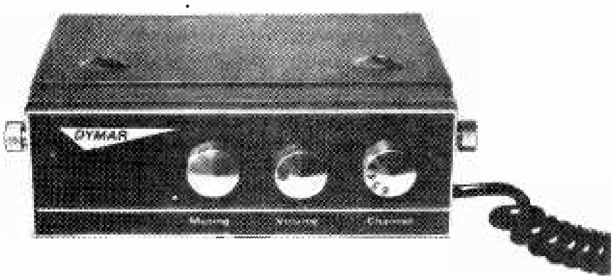
The Dymar 971 radiotelephone.



So many savings, you'd think your accountant had designed it.

Dymar's 971 mobile radiotelephone offers fleet operators a whole series of super-saving features –

● ***Plug-in transceiver units.*** With the 971 the vehicle mounting cradle carries all power and aerial services. The transceiver simply plugs in, and can be switched from vehicle to vehicle without disconnection or reconnection of wires or cables.



● ***Rugged construction.*** The 971 is built to take the knocks, and has proved it over hundreds of thousands of miles of overseas operation. Should something go wrong, instant testing is also a simple plug-in operation. You save, again, on equipment down-time.

● ***Base and transportable versatility.*** That's right, more plug-in economies. The 971 simply slots into a mains power supply speaker unit for base station use, or into a portable shoulder pack (with rechargeable batteries) if the need arises to use it away from the vehicle.

● ***Top efficiency VHF-AM communication.*** Improved contact with vehicles saves in all direction . . . on fuel . . . on driver time . . . and in gained business opportunities.

● ***Economy pricing.*** 971 prices come as a pleasant surprise in these days of rising costs – the final argument to convince your accountant, or bank manager.

Designed by experts to provide the answer to just some of the problems facing fleet operators in the mid-Seventies, the 971 is the newest product from Dymar, producers of the world-famous Lynx range of AM and FM VHF mobile radiotelephones.

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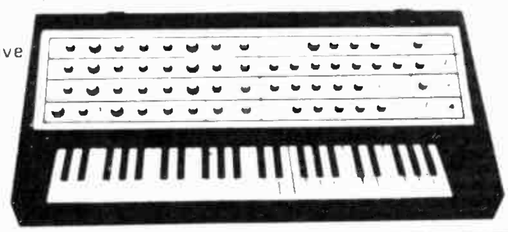
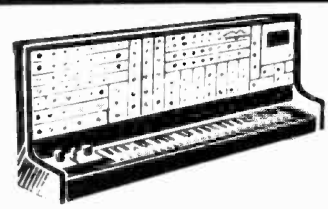
The 3600 SYNTHESISER

The 3600 synthesiser includes the most popular features of the 4600 model, but is simpler. Faster to operate, it has a switch patching system rather than the matrix patchboard of the larger unit and is particularly suitable for live performance and portable use.



S.A.E. please for price list

The 4600 SYNTHESISER



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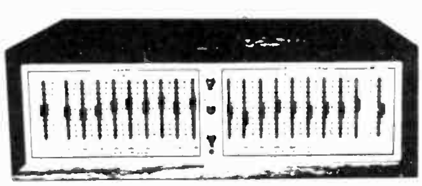

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Build yourself an exciting Electronic Organ. Our leaflet MES51, price 15p, deals with the basic theory of electronic organs and describes the construction of a simple 49-note instrument with a single keyboard and a limited number of stops. Leaflet MES52, price 15p, describes the extension of the organ to two keyboards each with five voices and the extension by an octave of the organ's range. Solid-state switching and new footages along with a pedal board and a further extension of the organ's range are shown in leaflet MES53, price 35p.

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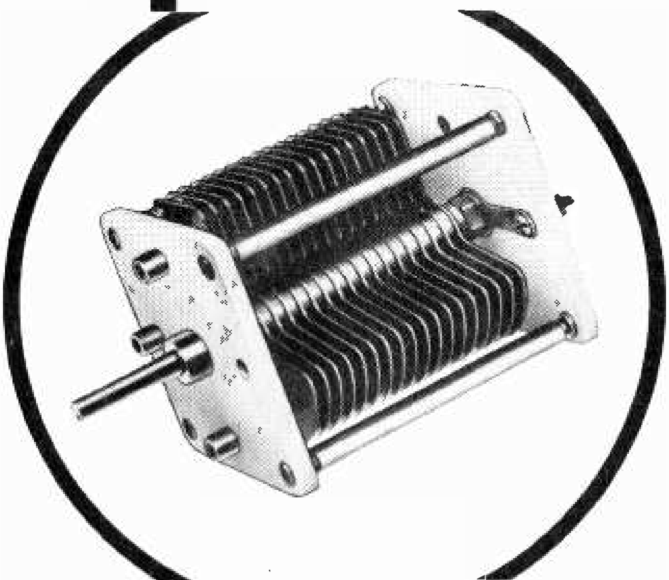

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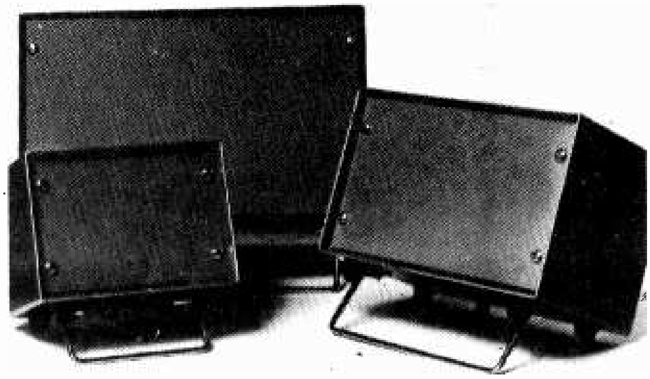
WW—017 FOR FURTHER DETAILS

OLSON

MINICASES



Standard minicases are made from 20g. mild steel sheets zinc-coated and finished in silver grey hammertone stove enamel. Front panels made from 18g. steel, finished in light grey high gloss enamel.

Type	Overall Dimension Width	Height	Depth	Case no vents	Case with vents	Chrome leg
21	6½″	4½″	4½″	—	3.92	0.90
22	8½″	5½″	5½″	—	4.40	0.90
23	10½″	6½″	6½″	—	5.25	0.95
24	12½″	7½″	7½″	—	5.74	0.95
25A	6½″	4½″	4½″	3.80	4.28	0.90
25B	6½″	4½″	6¼″	4.00	4.48	0.90
26A	8¾″	5¾″	6¼″	5.37	5.85	0.95
26B	8¾″	5¾″	8¼″	5.62	6.10	0.95
27A	12¼″	7½″	5½″	5.75	6.35	0.95
27B	12¼″	7½″	8″	6.35	6.95	0.95
28A	14″	10½″	6½″	6.95	7.55	—
28B	14″	10½″	8½″	7.55	8.15	—
29A	10″	4″	6″	4.85	5.33	0.95
29B	10″	4″	8″	5.15	5.63	0.95
30A	12″	5″	6″	5.25	5.85	0.95
30B	12″	5″	8″	5.56	6.16	0.95
31A	14″	6″	6″	5.75	6.35	0.95
31B	14″	6″	8″	6.05	6.65	0.95
61	15½″	7½″	9½″	—	8.75	—
62	17½″	8½″	9½″	—	10.15	—
63	16½″	9½″	9½″	—	10.15	—
64	15½″	7½″	12½″	—	10.15	—
65	17½″	8½″	12½″	—	11.60	—
66	16½″	9½″	12½″	—	11.60	—

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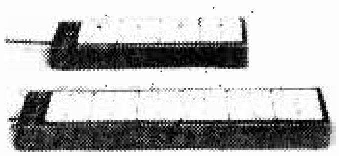

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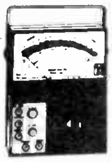

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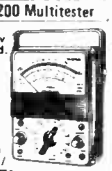

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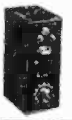

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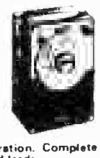

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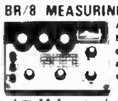

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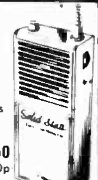

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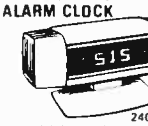

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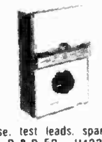

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1.5μF 63V	7p	100μF 10V	7p
2.2μF 63V	7p	100μF 25V	7p
3.3μF 63V	7p	100μF 63V	17p
4.0μF 40V	7p	150μF 16V	7p
4.7μF 63V	7p	150μF 63V	17p
6.8μF 63V	7p	220μF 6.4V	7p
10μF 16V	7p	220μF 10V	7p
10μF 25V	7p	220μF 16V	8p
10μF 63V	7p	220μF 63V	25p
15μF 16V	7p	330μF 16V	14p
15μF 63V	7p	330μF 63V	28p
16μF 40V	7p	470μF 6.4V	8p
22μF 25V	7p	470μF 40V	25p
22μF 63V	7p	680μF 16V	17p
32μF 10V	7p	680μF 40V	28p
33μF 16V	7p	1000μF 16V	25p
33μF 40V	7p	1000μF 25V	28p
47μF 10V	7p	1500μF 6.4V	17p
47μF 25V	7p	1500μF 16V	28p
47μF 63V	8p	2200μF 10V	28p
68μF 16V	7p	3300μF 64V	26p

VEROBOARD

	0.1	0.15
2½×5"	45p	45p
2½×3¾"	41p	30p
3¾×5"	51p	53p
3¾×3¾"	45p	45p
2½×1"	11p	10p
2½+5" (Plain)		22p
2½×3¾" (Plain)		20p
5×3¾" (Plain)		37p
Insertion tool	87p	87p
Track cutter	68p	68p
Pins, Pkt 25	25p	25p

TRANSISTORS

AC127	13p	BC212L	21p
AC128	13p	BC213L	22p
BC107	18p	BC214L	12p
BC108	12p	OC44	12p
BC109	13p	OC71	13p
BC148	17p	OC81	13p
BC149	29p	OC170	13p
BC182L	34p	TIS43	45p
BC183L	13p	2N2926	13p
BC184L	14p	2N3702	14p

POTENTIOMETERS

Carbon Track 5K Ω to 2M Ω log or lin (and 1K lin). Single, **17½p.** Dual Gang **48p.** Log single with switch **28p.** Slider pots, 60mm, 5K to 500K log or lin, **45p.** Dual **55p.** Knob **10p.**

DIODES

IN4001	6½p
IN4002	7½p
IN4003	9p
IN4004	9p
IN4005	12p
IN4006	14p
IN914	7p
IN916	7p
BA100	10p
0A5	42p
0A47	9p
0A81	11p
0A200	8p

PLUGS

Din 2 Pin	12p
3 Pin	13p
5Pin 180°	16p
Std. Jack	20p
2.5mm jack	13p
Phono	7p

SOCKETS

Din 2 Pin	10p
3 Pin	10p
5 Pin 180°	12p
Std. Jack	18p
2.5mm Jack	13p
Phono	7p

ELECTROLYTIC CAPICITORS. Tubular and Large Cans

(μF/V) 1/25, 2/25, 4/25, 4.7/10, 5/25, 8/25, 10/10, 10/50, 16/25, 22/63, 25/25, 25/50, 32/25, 50/25, 100/10, 100/25, 7p. 50/50, 8p. 100/50, 200/25, 10p. 250/50, 18p. 500/10, 10p. 500/25, 17p. 500/50, 25p. 1000/10, 17p. 1000/25, 25p. 1000/50, 40p. 2000/10, 20p. 1000/100, £1.10. 2000/25, 35p. 2000/100, £1.20. 2500/25, 38p. 2500/50, 68p. 5000/25, 69p. 5000/50, £1.20.

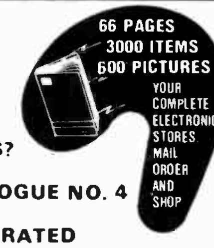
HI-VOLT: 4/350, 20p. 8/350, 23p. 100/100, 20p. 16/350, 35p. 16/450, 38p. 32/350, 38p. 50/250, 27p. 100/250, 40p.

METALLISED PAPER CAPACITORS

250V: 0.05μF, 0.1μF, 6p. 0.25, 6p. 0.5μF, 7½p. 1μF, 9p. 500V 0.025, 0.05, 6p. 0.1, 6p. 0.25, 7½p. 0.5, 9p. 1000V: 0.01, 12p. 0.022, 13p. 0.047, 0.1, 19p. 0.22, 28p. 0.47, 36p.

LEIGHTON ELECTRONICS CENTRE

New Electronics Centre is now open in Leighton Buzzard and all callers are welcome. As well as our normal stock of over 2,000 products, we have a large range of surplus bargains and calculators, etc. Open six days, 9-12.30, 1.30-5 p.m.



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COMPLETE WITH DISCOUNT VOUCHERS WORTH 20p **20p**

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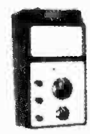
★ **DEPENDABLE SERVICE**

MULTIMETER U4323

22 Ranges plus AF/IF Oscillator
20,000Ω/Volt
Vdc—0.5—1000V in 7 ranges
Vac—2.5—1000V in 6 ranges
Idc—0.05—500mA in 5 ranges
Resistance—5Ω—1M Ω in 4 ranges
Accuracy—5% of F.S.D.
OSCILLATOR—1KHz and 465KHz (A. M.) at approx. 1 Volt.
Size—160×97×40mm.
Supplied complete with carrying case, test leads and battery PRICE £8.64 net + P & P 50p U4323

MULTIMETER U4341

27 Ranges plus Transistor Tester.
16,700Ω/Volt. Overload protected.
Vdc—0.3—900V in 8 ranges.
Vac—1.5—750V in 6 ranges.
Idc—0.06—600mA in 5 ranges.
Iac—0.3—300mA in 4 ranges.
Resistance—2KΩ—2MΩ in 4 ranges. Accuracy—dc—2½% ac—4% of F.S.D.
hfe—10—350 in 2 ranges.
Size—115×215×90mm
Complete with steel carrying case, test leads, and battery. PRICE £11.88 net + P & P 50p. U4341



NEW CAPACITOR KITS

C280 Kit—PC Mounting polyester 250V 5 of each value: 0.01, 0.022, 0.047, 0.1, 0.22μF 2 of 0.47, 1μF **£1.40** net.
C296 Kit—Tubular polyester. 400V 5 of each value. 0.01, 0.022, 0.047, 0.1, 0.22μF, 2 of 0.47μF **£1.40** net.
Ceramic Kit—square plaquette 50V 5 of each value. 22, 33, 47, 100, 220, 330, 470, 1000pF, 2200, 4700pF, 0.1μF, **£1.40** net.
250V Paper Kit—Tubular metal case 3 of each value 0.05, 0.1, 0.25, 0.5, 1μF, **£1.00** net.
500V Paper Kit—Tubular metal case. 3 of each value. 0.025, 0.05, 0.1, 0.25, 0.5μF **£1.00** net.
1000V Paper Kit—Tubular metal case. 3 of each value: 0.01, 0.025, 0.05, 0.1μF, **£1.20** net.

TRANSISTORS

Type	Price (£)
AC107	0.35
AC117	0.24
AC126	0.25
AC127	0.25
AC128	0.25
AC141	0.26
AC141K	0.27
AC142K	0.19
AC153K	0.28
AC154	0.20
AC176	0.25
AC178	0.27
AC179	0.27
AC187	0.25
AC187K	0.26
AC188	0.25
AC188K	0.26
AC193K	0.30
AC194K	0.32
ACY28	0.25
ACY39	0.68
AD140	0.50
AD142	0.52
AD143	0.51
AD149	0.48
AD161	0.48
AD162	0.48
AF114	0.25
AF115	0.25
AF116	0.25
AF117	0.20
AF118	0.50
AF121	0.32
AF124	0.29
AF125	0.25
AF126	0.25
AF127	0.25
AF139	0.35
AF147	0.35
AF149	0.45
AF178	0.55
AF179	0.60
AF180	0.55
AF181	0.50
AF186	0.40
AF239	0.40
AF279	0.84
AL100	1.10
AL102	1.10
AL103	1.10
AL113	0.95
AU103	2.10
AU110	1.90
AU113	2.40
BC107	0.12
BC107B	0.14
BC108	0.12
BC108A	0.12
BC108B	0.13
BC108C	0.14
BC109	0.13
BC109C	0.14
BC113	0.13
BC114	0.20
BC115	0.20
BC116	0.20
BC117	0.20

Type	Price (£)
BC119	0.29
BC125	0.20
BC126	0.20
BC132	0.15
BC134	0.20
BC135	0.19
BC136	0.20
BC137	0.20
BC138	0.20
BC142	0.30
BC143	0.35
BC147B	0.13
BC148	0.12
BC149	0.14
BC149B	0.15
BC152	0.25
BC153	0.20
BC154	0.20
BC157	0.15
BC158	0.13
BC159	0.15
BC161	0.48
BC167B	0.15
BC168B	0.13
BC169C	0.13
BC170	0.15
BC171A	0.15
BC172	0.14
BC173	0.20
BC176	0.22
BC177	0.20
BC178	0.22
BC178B	0.22
BC179	0.20
BC179B	0.21
BC182L	0.11
BC183	0.11
BC183K	0.12
BC183L	0.11
BC184L	0.13
BC186	0.25
BC187	0.27
BC208	0.12
BC212L	0.12
BC213L	0.12
BC214L	0.15
BC238	0.12
BC261A	0.28
BC262A	0.18
BC263B	0.25
BC267	0.16
BC268C	0.14
BC294	0.37
BC300	0.60
BC301	0.35
BC303	0.60
BC307B	0.12
BC308A	0.10
BC309	0.15
BC323	0.68
BC377	0.22
BC441	1.10
BC461	1.58
BCY42	0.16
BCY71	0.22
BCY87	4.65
BCY88	2.42

Type	Price (£)
BD115	0.65
BD123	0.98
BD124	0.80
BD130Y	1.42
BD131	0.45
BD132	0.50
BD135	0.40
BD136	0.46
BD137	0.48
BD138	0.50
BD139	0.55
BD140	0.62
BD144	2.19
BD145	0.75
BD163	0.67
BD183	0.56
BD234	0.75
BD519	0.76
BD520	0.76
BOX18	1.45
BOX32	2.55
BDY16A	0.38
BDY18	1.78
BDY20	0.99
BF115	0.20
BF117	0.45
BF120	0.55
BF121	0.25
BF123	0.28
BF125	0.25
BF127	0.30
BF158	0.25
BF159	0.27
BF160	0.22
BF161	0.45
BF162	0.45
BF163	0.45
BF167	0.25
BF173	0.25
BF177	0.30
BF178	0.33
BF179	0.33
BF180	0.35
BF181	0.33
BF182	0.44
BF183	0.44
BF184	0.26
BF185	0.26
BF194	0.15
BF195	0.15
BF196	0.15
BF197	0.17
BF198	0.20
BF199	0.25
BF200	0.35
BF218	0.35
BF222	1.08
BF224J	0.15
BF240	0.20
BF241	0.22
BF244	0.18
BF254	0.45
BF255	0.45
BF256	0.45
BF257	0.49
BF258	0.66
BF259	0.93
BF262	0.70
BF263	0.70

Type	Price (£)
BF273	0.16
BF336	0.35
BF337	0.35
BF458	0.60
BF459	0.63
BF596	0.70
BF597	0.15
BFR39	0.24
BFR41	0.30
BFR61	0.30
BFR79	0.24
BFT43	0.55
BFW10	0.55
BFW11	0.55
BFW16A	1.70
BFW30	1.38
BFW59	0.19
BFW60	0.20
BFW90	0.28
BFX16	2.55
BFX29	0.30
BFX30	0.35
BFX84	0.25
BFX85	0.26
BFX86	0.26
BFX87	0.28
BFX88	0.24
BFY18	0.53
BFY40	0.40
BFY41	0.43
BFY50	0.25
BFY51	0.23
BFY52	0.23
BFY57	0.32
BFY64	0.42
BFY72	0.31
BFY90	0.70
BLY15A	0.79
BPX25	1.90
BPX29	1.70
BPX52	1.90
BRC4443	0.68
BRY39	0.47
BRY56	0.40
BR101	0.47
BSW64	0.38
BSX19	0.13
BSX20	0.19
BSX76	0.15
BSX82	0.52
BSY19	0.52
BSY41	0.22
BSY52	0.45
BSY54	0.50
BSY56	0.80
BSY65	0.15
BSY78	0.40
BSY91	0.28
BT106	1.24
BT116	1.20
BU105/02	1.95
BU108	3.25
BU126	2.99
BU204	1.98
BU205	1.98
BU207	3.00
BU208	3.15
BU209	2.55
BUY77	2.50

Type	Price (£)
C106F	0.43
C111E	0.56
CRS1/40	0.75
CRS3/40	0.95
D40N1	0.45
E1222	0.55
E5024	0.20
ME6001	0.16
ME6002	0.17
ME8001	0.18
MJE340	0.68
MJE341	0.72
MJE370	0.65
MJE520	0.85
MJE521	0.95
MJE2955	1.20
MJE3000	1.85
MJE3055	0.74
MM721	0.70
MPF102	0.40
MPSA05	0.47
MPSA55	0.50
MPS6566	0.21
MPSU05	0.66
MPSU06	0.76
MPSU55	1.26
MPSU56	1.26
OC26	0.38
OC28	0.65
OC35	0.59
OC36	0.64
OC42	0.45
OC44	0.32
OC45	0.32
OC70	0.32
OC71	0.32
OC72	0.32
OC73	0.51
OC75	0.25
OC81	0.53
OC81D	0.57
OC139	0.76
OC140	0.80
OC170	0.25
OC171	0.30
OC200	0.92
OCP71	0.43
ON188	2.19
ON236A	0.65
ORP12	0.55
R2008B	2.05
R2010B	2.95
TAG3/400	1.54
TIC44	0.29
TIC46	0.44
TIC47	0.44
TIC29A	0.49
TIP30A	0.58
TIP31A	0.65
TIP32A	0.73
TIP33A	0.99
TIP34A	1.73
TIP41A	0.80
TIP42A	0.91
TIS43	0.30
TIS73	1.36
ZTX109	0.12
ZTX300	0.12
ZTX304	0.22

Type	Price (£)
ZTX310	0.10
ZXT313	0.12
ZTX500	0.17
ZTX502	0.17
ZTX504	0.42
ZTX602	0.24
2N525	0.88
2N696	0.23
2N697	0.15
2N706	0.12
2N706A	0.15
2N708	0.35
2N744	0.30
2N914	0.19
2N916	0.20
2N918	0.42
2N930	0.35
2N1304	0.21
2N1305	0.21
2N1306	0.31
2N1307	0.22
2N1308	0.26
2N1309	0.36
2N1613	0.34
2N1711	0.45
2N1890	0.45
2N1893	0.48
2N2102	0.51
2N2217	0.36
2N2218	0.60
2N2219	0.50
2N2221A	0.41
2N2222A	0.50
2N2369A	0.42
2N2401	0.60
2N2484	0.41
2N2570	0.18
2N2646	0.53
2N2712	0.12
2N2904	0.22
2N2904A	0.26
2N2905	0.28
2N2905A	0.28
2N2926G	0.13
2N2926Y	0.12
2N2926O	0.12
2N3019	0.75
2N3053	0.21
2N3054	0.55
2N3055	0.50
2N3133	0.54
2N3134	0.60
2N3232	1.32
2N3235	1.10
2N3254	0.28
2N3323	0.48
2N3391A	0.23
2N3702	0.13
2N3703	0.15
2N3704	0.15
2N3705	0.11
2N3706	0.10
2N3707	0.13
2N3715	2.30
2N3724	0.72
2N3739	1.18
2N3771	1.70
2N3772	1.90
2N3773	2.90

Type	Price (£)
2N3790	4.15
2N3794	0.20
2N3819	0.35
2N3820	0.49
2N3823	1.45
2N3866	1.70
2N3877	0.25
2N3904	0.16
2N3905	0.18
2N3906	0.15
2N4032	0.43
2N4036	0.52
2N4046	0.35
2N4058	0.17
2N4123	0.13
2N4124	0.15
2N4126	0.20
2N4236	1.90
2N4248	0.12
2N4284	0.19
2N4286	0.19
2N4288	0.13
2N4289	0.20
2N4290	0.14
2N4291	0.18
2N4292	0.20
2N4871	0.24
2N4902	1.30
2N5042	1.05
2N5060	0.32
2N5061	0.35
2N5064	0.45
2N5087	0.42
2N5294	0.35
2N5296	0.57
2N5298	0.58
2N5322	0.85
2N5449	1.90
2N5457	0.30
2N5458	0.35
2N5494	0.85
2N5496	1.05
2N6027	0.65
2N6178	0.71
2N6180	0.92
2SC643A	1.36
2SC1172Y	2.80
3N140	1.2
40250	0.60
40327	0.67
40361	0.48
40362	0.50
40429	0.80
40439	2.67
AC128/AC176	0.52
AC141K/AC142K	0.56
AC187/AC188	0.60
AC188K/AC187K	0.61
AC193K/AC194K	0.71
AD161/AD162	0.95
BC142/BC143	0.70

DIODES

Type	Price (£)
AA113	0.15
AA119	0.09
AA129	0.20
AA143	0.10
AAZ13	0.30
AAZ17	0.12
BA100	0.15
BA102	0.25
BA110U	0.30
BA115	0.12
BA141	0.17
BA145	0.17
BA148	0.17
BA154	0.13
BA155	0.16
BA156	0.15
BA157	0.25
BAX13	0.06
BAX16	0.07
BAY72	0.11
BB105B	0.52
BB110B	0.45
BR100	0.50
BY100	0.15
BY103	0.22
BY126	0.16
BY127	0.17
BY133	0.23
BY140	1.40
BY164	0.55
BY176	1.68
BY179	0.70
BY206	0.31
BYX10	0.15
OA47	0.07
OA81	0.12
OA90	0.08
OA91	0.07
OA95	0.07
OA200	0.10
OA202	0.10
OA210	0.29
IN914	0.07
IN916	0.10
IN4001	0.05
IN4002	0.06
IN4003	0.07
IN4004	0.08
IN4005	0.09
IN4006	0.11
IN4007	0.14
IN4148	0.05
IN4448	0.10
IN5400	0.15
IN5401	0.17
IN5402	0.20
IN5403	0.22
IN5404	0.25
IN5405	0.27
IN5406	0.30
IN5407	0.34

ZENERS

400mW 3.3V	0.12
1W 3.3-100V	0.18

THYRISTORS, TRIACS AND TRIACS WITH TRIGGER

IF VRM	50V	100V	200V	400V	600V
3A	—/—/—	—/28/30	—/34/36	—/50/52	—/66/70
4A	26/—/—	30/—/—	38/—/—	60/—/—	75/—/—
6A	29/—/—	33/44/46	42/56/58	68/80/84	80/100/105
8A	32/—/—	38/50/52	47/64/61	75/92/97	90/114/120
10A	36/—/—	42/60/63	51/74/78	84/104/109	100/128/13
16A	—/—/—	—/82/90	—/88/95	—/132/140	

Notes: All prices are in pence per unit. First price in each group is thyristor, second is triac, third is triac with trigger. Encapsulation depends on current rating and device type. Connection data supplied with each device. Quantity enquiries welcomed.

INTEGRATED CIRCUITS

Type	Price (£)
CA3045	1.40
CA3046	0.70
CA3065	1.90
MC1307P	1.19
MC1310P	2.94
MC1327PQ	1.01
MC1330P	0.76
MC1351P	0.75
MC1352P	0.82
MC1358PQ	1.85
MC1496L	0.87
MC3051P	0.58
MFC4000B	0.43
MFC4060A	0.70
MFC6040	0.91
NE555	0.72
NE556	1.34
SL414A	1.91
SL901B	3.84
SL917B	5.12
SN76003N	2.92
SN76013N	1.95
SN76013ND	1.72
SN76023ND	1.72
SN76023N	1.95
SN76033N	2.92
SN76530P	1.05
SN76533	1.20
TAA300	1.76
TAA320	0.94
TAA350A	2.02
TAA435	0.85
TAA450	2.70
TAA550	0.55
TAA570	2.02
TAA611B	1.85

Type	Price (£)
TAA630Q	4.18
TAA630S	4.18
TAA700	4.18
TAA840	2.02
TAA861A	0.49
TAD100	2.66
TBA120S	0.99
TBA240A	2.97
TBA480Q	1.90
TBA500	1.99
TBA550Q	2.00
TBA510	1.99
TBA520Q	3.34
TBA530	2.71
TBA530Q	2.71
TBA54D	3.21
TBA540Q	3.21
TBA550Q	4.10
TBA560C	4.09
TBA560CQ	4.10
TBA570	1.17
TBA641	0.76
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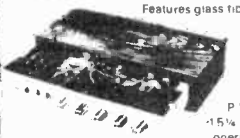

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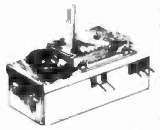

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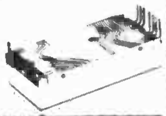

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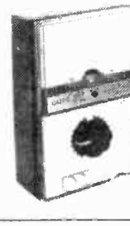

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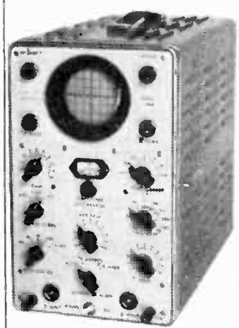

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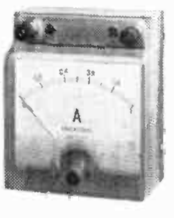

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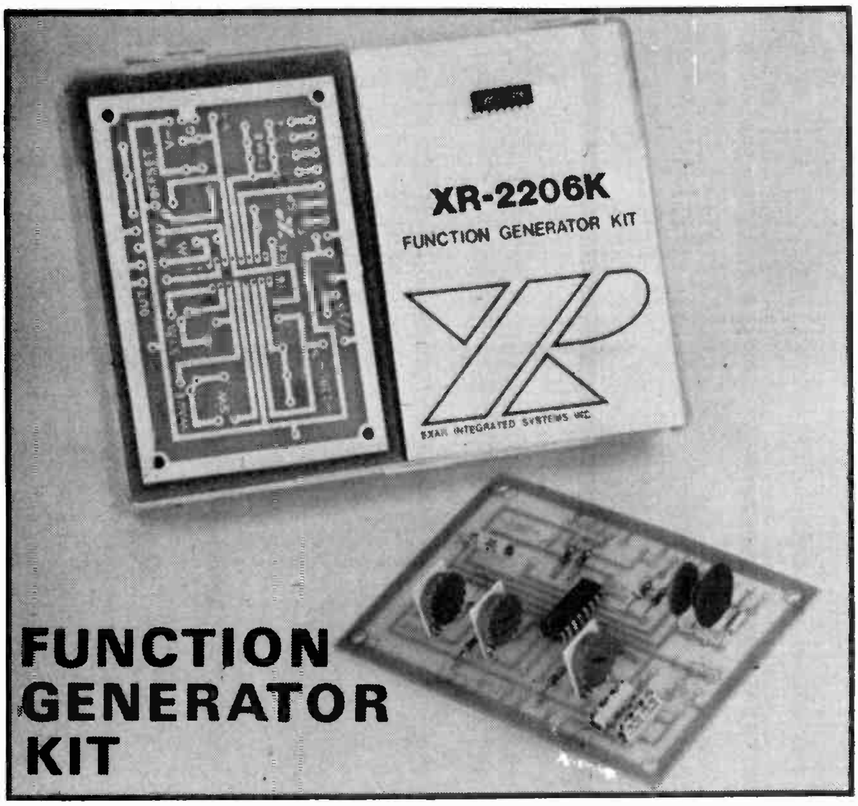

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SN7404	0.15	0.14	0.13
SN7405	0.15	0.14	0.13
SN7406	0.30	0.29	0.28
SN7407	0.30	0.29	0.28
SN7408	0.15	0.13	0.12
SN7409	0.15	0.13	0.12
SN7410	0.14	0.13	0.12
SN7411	0.23	0.22	0.21
SN7412	0.19	0.18	0.17
SN7413	0.30	0.29	0.28
SN7414	0.71	0.70	0.69
SN7415	0.30	0.29	0.27
SN7416	0.28	0.27	0.26
SN7417	0.28	0.27	0.26
SN7420	0.14	0.13	0.12
SN7421	0.95	0.94	0.93
SN7422	0.25	0.24	0.23
SN7423	0.28	0.25	0.22
SN7425	0.28	0.25	0.22
SN7426	0.28	0.25	0.22
SN7427	0.26	0.25	0.22
SN7428	0.39	0.38	0.37
SN7430	0.14	0.13	0.12
SN7432	0.25	0.24	0.22
SN7433	0.36	0.35	0.34
SN7437	0.27	0.26	0.22
SN7438	0.27	0.26	0.22
SN7439	1.10	1.08	1.06
SN7440	0.14	0.13	0.12
SN7441	0.70	0.69	0.66
SN7442	0.63	0.60	0.53
SN7443	1.00	0.99	0.90
SN7444	1.08	1.07	1.05
SN7445	0.85	0.83	0.70
SN7446	1.03	1.00	0.85
SN7447	1.03	1.00	0.85
SN7448	0.85	0.83	0.70
SN7450	0.14	0.13	0.12
SN7451	0.14	0.13	0.12
SN7453	0.14	0.13	0.12
SN7454	0.14	0.13	0.12
SN7455	0.40	0.39	0.38
SN7460	0.14	0.13	0.12
SN7462	0.45	0.44	0.42
SN7464	0.45	0.44	0.42
SN7465	0.45	0.44	0.42
SN7470	0.30	0.27	0.25
SN7471	0.60	0.59	0.58
SN7472	0.25	0.24	0.21
SN7473	0.30	0.27	0.26
SN7474	0.31	0.29	0.26
SN7475	0.40	0.39	0.38
SN7476	0.31	0.29	0.26
SN7478	0.65	0.63	0.61
SN7480	0.43	0.41	0.36
SN7481	1.00	0.95	0.90
SN7482	0.75	0.70	0.62
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SN7492	0.45	0.42	0.35
SN7493	0.45	0.42	0.35
SN7494	0.48	0.45	0.40
SN7495	0.60	0.56	0.50
SN7496	0.70	0.67	0.60
SN7497	0.70	0.69	0.68
SN74100	1.35	1.30	1.25
SN74104	0.31	0.29	0.26
SN74105	0.31	0.29	0.26
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SN74152	1.55	1.50	1.45
SN74153	0.68	0.62	0.55
SN74154	1.55	1.50	1.45
SN74155	0.68	0.62	0.55
SN74156	0.68	0.62	0.55
SN74157	0.90	0.85	0.80
SN74158	1.50	1.45	1.40
SN74160	0.95	0.90	0.80
SN74161	0.95	0.90	0.80
SN74162	0.95	0.90	0.80
SN74163	0.95	0.90	0.80
SN74164	1.60	1.55	1.50
SN74165	1.60	1.55	1.50
SN74166	1.40	1.30	1.15
SN74170	2.40	2.30	2.20
SN74173	1.65	1.60	1.55
SN74174	1.15	1.10	1.00
SN74175	0.97	0.90	0.80
SN74176	1.10	1.05	1.00
SN74177	1.10	1.05	1.00
SN74180	1.10	1.05	1.00
SN74181	3.50	3.45	3.35
SN74182	1.10	1.05	1.00
SN74184	1.60	1.55	1.50
SN74185	2.30	2.25	2.20
SN74188	4.90	4.85	4.80
SN74190	1.75	1.70	1.65
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4013AE	0.59	0.47	0.39
4014AE	1.65	1.33	1.10
4015AE	1.65	1.33	1.10
4016AE	0.62	0.50	0.41
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4018AE	2.45	2.40	2.30
4019AE	0.62	0.50	0.41
4020AE	1.82	1.46	1.21
4021AE	1.65	1.33	1.10
4022AE	1.65	1.33	1.10
4023AE	0.24	0.19	0.16
4024AE	1.13	0.91	0.75
4025AE	0.24	0.19	0.16
4026AE	6.50	6.40	6.30
4027AE	0.42	0.41	0.40
4028AE	1.41	1.14	0.94
4029AE	1.95	1.57	1.30
4030AE	0.62	0.50	0.41
4033AE	2.80	2.70	2.60
4035AE	1.71	1.38	1.14
4040AE	1.82	1.46	1.21
4041AE	0.90	0.85	0.80
4042AE	1.00	0.90	0.80
4043AE	1.00	0.90	0.80
4044AE	1.00	0.90	0.80
4047AE	1.50	1.45	1.40
4048AE	1.30	1.25	1.20
4049AE	0.54	0.44	0.36
4050AE	0.54	0.44	0.36
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4066AE	0.95	0.90	0.85
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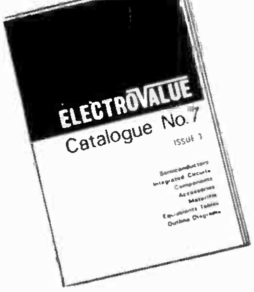

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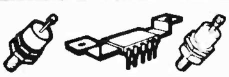

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NAS0161 W	100v	.2?
NAS0161X	100V	.26
NAS0162W	200V	.30
NAS0162X	200V	.28
NAS0164W	400V	.40
NAS0164X	400V	.38
NAS0166W	600V	.55
NAS0166X	600V	.57

6AMP ISOLATED TAB

NAS0651W	100V	.46
NAS0651X	100V	.44
NAS0652W	200V	.58
NAS0652X	200V	.56
NAS0654W	400V	.84
NAS0654X	400V	.80
NAS0656W	600V	1.05
NAS0656X	600V	1.00

10AMP ISOLATED TAB

NAS1001W	100V	.63
NAS1001X	100V	.60
NAS1002W	200V	.78
NAS1002X	200V	.74
NAS1004W	400V	1.09
NAS 1004X	400V	1.04
NAS1006W	600V	1.34
NAS1006X	600V	1.28

3AMP "CLIPPED TAB"

NAS0301W	100V	.30
NAS0301X	100V	.28
NAS0302W	200V	.36
NAS0302X	200V	.34
NAS0304W	400V	.52
NAS0304X	400V	.50
NAS0306W	600V	.70
NAS0306X	600V	.66

8.5AMP ISOLATED TAB

NAS0851W	100V	.52
NAS0851X	100V	.50
NAS0852W	200V	.67
NAS0852X	200V	.64
NAS0854W	400V	.97
NAS0854X	400V	.92
NAS0856W	600V	1.20
NAS0856X	600V	1.14

16AMP ISOLATED METAL

NAS1601W	100V	.90
NAS1601X	100V	.82
NAS1602W	200V	.95
NAS1602X	200V	.88
NAS1604W	400V	1.40
NAS1604X	400V	1.32
NAS1606W	600V	1.85
NAS1606X	600V	1.75

Devices with Internal Trigger have "W" suffix. "X" denotes Standard Triac.

THYRISTORS

1.6AMP MIN. TO5 ●

NAS006P	50PIV	.25
NAS006Q	100PIV	.28
NAS006R	200PIV	.31
NAS006S	400PIV	.40
NAS006T	600PIV	.52

4AMP ISOLATED TAB

NAS106P	50PIV	.26
NAS106Q	100PIV	.30
NAS106PR	200PIV	.36
NAS106S	400PIV	.56

6AMP ISOLATED TAB

NAS206P	50PIV	.37
NAS206Q	100PIV	.42
NAS206R	200PIV	.50
NAS206S	400PIV	.77

8AMP ISOLATED TAB

NAS306P	50PIV	.41
NAS306Q	100PIV	.47
NAS306R	200PIV	.59
NAS306S	400PIV	.85

16AMP ISOLATED TAB

NAS806P	50PIV	.50
NAS806Q	100PIV	.58
NAS806R	200PIV	.73
NAS806S	400PIV	1.15

Quantity Prices on application. S.A.E.

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Ref. No.	VA (Watts)	£	P&P p
07*	20	2.80	38
149	60	4.37	45
150	100	4.89	45
151	200	8.13	53
152	250	9.83	73
153	350	11.88	73
154	500	13.65	91
155	750	20.51	BRS
156	1000	29.15	BRS
157	1500	33.23	BRS
158	2000	37.07	BRS

*115 or 240 sec only

12 and/or 24-VOLT

PRIMARY 220-240 VOLTS

Ref. No.	AMPS 12v	AMPS 24v	£	P&P p
11	0.5	0.25	1.35	23
213	1.0	0.5	1.74	30
7	2	1	2.29	38
18	4	2	2.86	38
70	6	3	4.12	45
108	8	4	4.56	45
72	10	5	5.14	53
116	12	6	5.52	53
17	16	8	7.28	60
115	20	10	10.39	73
187	30	15	13.59	83
226	60	30	16.83	BRS

30 VOLT RANGE

SECONDARY TAPS
0-12-15-20-25-30

Ref. No.	Amps	£	P&P p
112	0.5	1.81	30
79	1.0	2.40	38
3	2.0	3.49	38
20	3.0	4.53	45
21	4.0	5.13	53
51	5.0	6.41	53
117	6.0	7.16	60
88	8.0	9.87	67
89	10.0	9.90	73

50 VOLT RANGE

SECONDARY TAPS
0-19-25-33-40-50

Ref. No.	Amps.	£	P&P p
102	0.5	2.58	30
103	1.0	3.38	38
104	2.0	4.68	45
105	3.0	5.81	53
106	4.0	7.60	67
107	6.0	12.10	67
118	8.0	12.98	85
119	10.0	16.99	BRS

60 VOLT RANGE

SECONDARY TAPS
0-24-30-40-48-60

Ref. No.	Amps	£	P&P p
124	0.5	2.33	38
126	1.0	3.41	38
127	2.0	5.08	45
125	3.0	7.52	60
123	4.0	8.75	67
40	5.0	9.75	73
120	6.0	11.30	85
131	8.0	15.00	BRS
122	10.0	17.52	BRS
189	12.0	19.98	BRS

AUTO TRANSFORMERS

Ref. No.	VA (Watts)	AUTO TAPS	£	P&P p
113	20	0-115-210-240	1.67	30
64	75	0-115-210-240	2.90	38
4	150	0-115-210-220-240	4.12	45
66	300	"	5.82	53
67	500	"	8.82	67
84	1000	"	13.68	91
93	1500	"	18.11	BRS
95	2000	"	24.20	BRS
73	3000	"	35.09	BRS

SCREENED MINIATURES

Ref.	mA	Volts	£	P&P p
238	200	3-0-3	1.54	10
212	1A1A	0-6, 0-6	1.84	30
13	100	9-0-9	1.41	13
235	330.330	0-9, 0-9	1.56	19
207	500.500	0-8-9, 0-8-9	1.92	30
208	1A 1A	0-8-9, 0-8-9	3.30	38
236	200, 200	0-15, 0-15	1.43	19
214	300, 300	0.20, 0.20,	1.93	30
221	700 (DC)	20-12-0-12-20	2.17	38
206	1A 1A	0-15-20, 0-15-20	3.46	38
203	500, 500	0-15-27, 0-15-27	3.00	38
204	1A 1A	0-15-27, 0-15-27	3.85	38
S112	500	12, 15, 20, 24, 30	1.88	37

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Power Supplies for 25w	£3.00
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Transformer for 5-10w	£2.13
Transformer for 25w	£2.60
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2	Set of metal oxide resistors, thermistor, capacitors, cermet preset for mounting on pack 1	£4.80
3	Set of transistors, diodes, LED, integrated circuits for mounting on pack 1	£6.25
4	Pre-aligned front end module, coil assembly, three-section ceramic filter	£8.80
5	Fibreglass printed circuit board for stereo decoder	£1.10
6	Set of metal oxide resistors, capacitors, cermet preset for decoder	£2.60
7	Set of transistors LED, integrated circuit for decoder	£3.45
8	Set of components for channel selector switch module including fibreglass printed circuit board, push-button switches, knobs, LEDs preset adjusters, etc.	£8.30
9	Function switch, 10 turn tuning potentiometer, knobs	£5.30
10	Frequency meter, meter drive components, fibreglass printed circuit board	£8.60
11	Toroidal transformer with electrostatic screen. Primary: 0–117V–234V	£4.45
12	Set of capacitors, rectifiers, voltage regulator for power supply	£2.95
13	Set of miscellaneous parts, including sockets, fuse holder, fuses, inter-connecting wire, etc.	£1.50
14	Set of metal work parts including silk screen printed facia panel, acrylic silk screen printed tuning indicator panel insert, internal screen, fixing parts, etc.	£6.50
15	Construction notes (free with complete kit)	£0.25
16	Teak cabinet	£9.85
	One each of packs 1–16 inclusive are required for complete stereo FM tuner.	
	Total cost of individually purchased packs	£76 85

NOVEL STEREO FM TUNER

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

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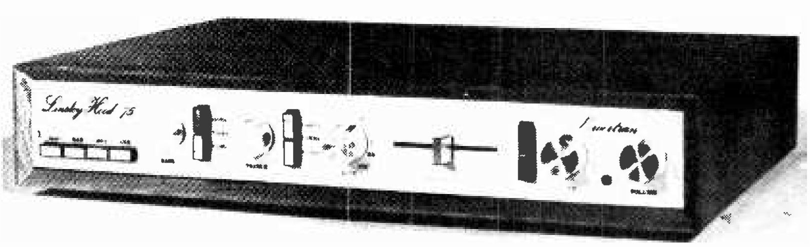
MORE ON NEXT PAGE!

****

DESIGNER APPROVED KIT

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

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



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

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KIT PRICE only **£62.40** carriage free (U.K.)

Pack		Price
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3	Set of semiconductors for power amp. (now using BDY56, BD529, BD530)	£6.50
4	Pair of 2 drilled, finned heat sinks	£0.80
5	Fibreglass printed-circuit board for pre-amp.	£1.30
6	Set of low noise resistors, capacitors, pre-sets for pre-amp.	£2.70
7	Set of low noise, high gain semiconductors for pre-amp.	£2.40
8	Set of potentiometers (including mains switch)	£2 05
9	Set of 4 push-button switches, rotary mode switch	£3.70
10	Toroidal transformer complete with magnetic screen/housing primary: 0-117-234 V, secondaries: 33-0-33 V, 25-0-25 V.	£9.15
11	Fibreglass printed-circuit board for power supply	£0.65
12	Set of resistors, capacitors, secondary fuses, semiconductors for power supply	£3.50
13	Set of miscellaneous parts including DIN skts, mains input skt, fuse holder, interconnecting cable, control knobs	£4.25
14	Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£6.30
15	Handbook	£0.30
16	Teak cabinet	£9 85
	2 each of packs 1–7 inclusive are required for complete stereo system	
	Total cost of individually purchased packs	£72.25

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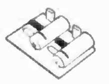

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Compact I.C. amp. 3 watts R.M.S. Single channel (mono). On P.C.B. size 3½"x2". Needs 10-20V supply. **£1.75**

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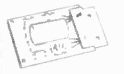
Stereo version of above. (Two I.Cs.) **£3.25**



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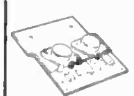

SS140*
Beautifully designed. Will give up to 40w R.M.S. into 4Ω. Excellent S.N.R. and transient response. Fine for P.A., disco use, etc. Operates from 45V DC. Two in bridge formation will give 80w R.M.S. into 8Ω. **£3.75**

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Active tone control to provide Bass and Treble (stereo). With full instructions. **£1.60**

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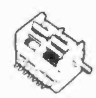
Pre-amp for stereo ceramic cartridges, radio and tape. **£1.60**

SS102
Pre-amp for low-output stereo magnetic cartridges, radio and tape. **£2.25**

BUILD A STEREO F.M. TUNER WITH THESE MODULES



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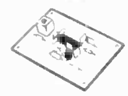
Front End assembly. Ganged tuning with well engineered slow-motion geared drive in robust housing. A.F.C. facility. Requires 7-10V. Excellent sensitivity. 88-108mHz. **£6.25**



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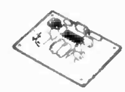

SS203
Stereo Decoder. Designed essentially for use with SS201 and SS202, this excellent decoder can also make a stereo tuner of almost any single channel FM tuner. Supplied ready aligned. A.L.E.D. can easily be fitted. 9-16V. **£5.62**

SAVE £5 ON THE S/S TUNER
By buying Units SS.201, SS.202 and SS.203 together, the price is £12.12 — a genuine saving of £5 on this very efficient tuner. **£12.12**

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- **TP23** Twenty NPN Silicon uncoded T05. Similar to BFY50/2, 2N696, 2N1613, etc. Complementary to TP24.
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40P1	PNP	15	15	20p
40P2	PNP	40	40	30p

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Type	Polarity	Gain	VCE	Price
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90N2	NPN	40	40	35p
90P1	PNP	15	15	25p
90P2	PNP	40	40	35p

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FOUNDED IN 1959

RECORD PLAYBACK TAPE HEADS

Individual prices of these are:
2 track record playback heads **75p** each
4 track record playback heads **£1.10** each
Erase heads are also available separately —
2 track **50p** — 4 track **85p.**
MV metal mounting shields **60p** each
2 track heads already fixed on heavy mounting plate with shield **£1.85.**
ALL PLUS 25% VAT.

DRILL CONTROLLER

NEW 1KW MODEL

Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by finger-tip control. Kit includes all parts, case, everything and full instructions. **£2.50** plus 45p post & VAT. Made up model also available. **£3.50** plus 55p post & VAT.

NEED A SPECIAL SWITCH

Double Leaf Contact. Very slight pressure closes both contacts. **12p** each. Plastic pushrod suitable for operating, **10p** each, 10 for **68p.**

1 R.P.M. MOTOR + GEAR BOX

Made by the famous Chamberlain & Hookham Ltd. These could be made to drive clock or similar. Really robust, reliable unit. Price **£1.50** + 30p post & VAT.

MULTI-SPEED MOTOR

Six speeds are available 500, 850 and 1,100 r.p.m. and 8,000, 12,000 and 15,500 r.p.m. Shaft is ¼ in. diameter and approximately 1 in. long 230/240v. Its speed may be further controlled with the use of our Thyristor controller. Very powerful and useful motor, size approx. 2 in. dia. x 5 in. long. Price **£1.40** + 45p post & VAT.

SLIDE SWITCHES

Slide Switch. 2-pole changeover panel mounting by two 6B.A. screws. Size approx. 1in. x ¾in. rated 250V lamp. **15p** +7p post & VAT. **Sub Miniature Slide Switch.** DPDT 19mm (¾in. approx.) between fixing centres. **28p** each + 9p post & VAT or 10 for **£1.90.** SP Change over spring return 250v 1 amp. **25p** + 8p post & VAT.

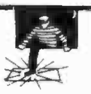
PRESSURE SWITCH

Containing a 15 amp change over switch operated by a diaphragm which in turn is operated by air pressure through a small metal tube. The operating pressure is adjustable but is set to operate in approx. 10 in. of water. These are quite low pressure devices and can in fact be operated simply by blowing into the inlet tube. Original use was for washing machines to turn off water when tub has reached correct level, but no doubt has many other applications. **£2.10** each + 25p post & VAT.

LIGHT DIMMER KIT

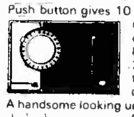
For dimming up to 250w without heat sink or 750w with heat sink. This comprises quadrac variable control potentiometer, condenser, resistors, tag strip for mounting and data. Price **£1.95** + 30p post & VAT.

SWITCH TRIGGER MATS



So thin is undetectable under carpet but will switch on with slight pressure. For burglar alarms, shop doors, etc.
24in. x 18in. **£1.90,** post & VAT 30p. 13in. x 10in. **£1.50,** post & VAT 25p.

SMITHS CENTRAL HEATING CONTROLLER

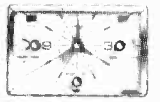


Push button gives 10 variations as follows: (1) continuous hot water and continuous central heating (2) continuous hot water but central heating off at night (3) continuous hot water but central heating on only for 2 periods during the day (4) hot water and central heating both on but day time only (5) hot water all day but central heating only for 2 periods during the day (6) hot water and central heating on for 2 periods during the day time only — then for summer time use with central heating off (7) hot water continuous (8) hot water day time only (9) hot water twice daily (10) everything off. A handsome looking unit with 24 hour movement and the switches and other parts necessary to select the desired programme of heating. Supplied complete with wiring diagram. Originally sold, we believe, at over **£15** — we offer these, while stocks last at **£6.95** each, VAT & Postage 85p each.

AUDIO AMPLIFIER

Part of the famous Rediffune background music system, secondhand, but believed in good order. However, no guarantee; we are selling for spares value only. These are 6 valve amplifiers, the output valves are 2 x EL 84 in push/pull, complete with mains transformer, rectifier and ample smoothing equipment. The mains transformer alone, today would cost at least £4. Size is 9½" x 5½" x 4½". Price only **£2.00** + postage & VAT £1.50.

15A ELECTRICAL PROGRAMMER

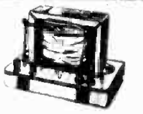


Learn in your sleep. Have radio playing and kettle boiling as you awake — switch on lights to ward off intruders — have a warm house to come home to. All these and many other things you can do if you invest in an electrical programmer. Clock by famous maker with 15 amp. on/off switch. Switch-on time can be set anywhere to stay on up to 6 hours. Independent 60 minute memory jogger. A beautiful unit. Price **£2.45.** VAT & Postage 60p. or with glass front, chrome bezel, **£1.50** extra.

THIS MONTHS'S SNIP

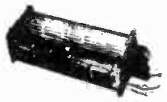
Smiths 24 hr. timer heart, really the "Autoset" without its plastic case. This is a 24 hr. twice on, twice off, clock switch which will repeat until re-programmed. Switches rated at 15 amps. Limited supplies — **£3.95** each + VAT & post 55p.

12 VOLT 1½ AMP POWER PACK



This comprises double-wound 230/240V mains transformer with full wave rectifier and 2000 mfd smoothing. Price **£3.75** plus VAT & post £1.
Heavy Duty Mains Power Pack. Output voltage adjustable from 15-40V in steps — maximum load 250W — that is from 6 amp at 40V to 15 amp at 15V. This really is a high power heavy duty unit with dozens of workshop uses. Output voltage is very quick — simply interchange push on leads. Silicon rectifiers and smoothing by 3,000mF. Price **£10.50** plus £1.25 VAT & post.

TANGENTIAL HEATER UNIT



This heater unit is most efficient and quiet running. Is as fitted in Hoover and blower heaters costing £15 and more. Comprises motor, impeller, 2kW element and 1kW element allowing switching 1, 2 and 3kW, and with thermal safety cut-out. Can be fitted into any metal line case or cabinet. Only needs control switch. **£5.82** plus post & VAT £1. 2kW Model as above except 2kW **£4.25** plus VAT & post 75p. Don't miss this. Control Switch **44p.** P. & P. 40p.

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Starterless control gear, complete with tube ends and tube clips for window lighting, signs, fascias, etc. 4ft. 40w **£1.90.** 5ft. 65w. **£2.00;** 5ft. 80w **£2.20;** 6ft. 80w. **£2.45.** and for pairs as follows: — twin 2ft. 20w. **£2.55;** twin 3ft. 30w. **£3.55;** twin 4ft. 40w. **£3.25;** twin 5ft. 65w. **£3.25;** twin 5ft. 80w. **£3.95;** twin 8ft. 125w. **£5.75.** These are about one half of maker's current prices and can't be repeated once stocks are cleared. Please add 30p per piece to cover postage or carriage and 8% VAT.

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6.3v	2 amp	**1.25**
6.3v	3 amp	**1.75**
9v	1 amp	**.95**
9v	3.5 amp	**2.50**
12v	1½ amp	**1.50**
12v	1 amp	**1.00**
6.5v-0.6 ov	1 amp	**1.50**
18v	1 amp	**1.50**
24v	2 amp	**2.25**
24v	3 amp	**3.50**
12.0-12v	50mA	**1.20**
6.0-6v	50mA	**1.20**
8.0-8v	½ amp	**1.50**
18.0-18v	2 amp	**3.50**
25v	1½ amp	**1.95**
50v 2 amp & 6.3v	1 amp	**4.50**
60v 5 amp & 5v	1 amp	**7.50**
27v	8 amp	**4.50**
30v	37 amp	**22.00**
80v tapped 75v & 70v	4 amp	**5.50**
230v-60mA & 6.3v	1.5 amp	**1.75**
275-0 275v at 90mA & 6.4v	3 amp	**2.25**
EHT Transformer 5000v 23mA	(intermittent)	**5.50**
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6v and 12v	2 amp	**1.50**
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RELAY BARGAIN

Type 600 relay. 2 changeover one open and one closed contact. Twin 500 ohm coils make this suitable for closing off DC 6v, DC 12v, DC 24v or AC mains using resistor and rectifier. **40p** each. Resistor and rectifier **20p** extra. Post and VAT 20p.

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As used in discotheques and for stage effects, etc. Virtually no white light appears until the rays impinge on luminous paint or white shirts, etc. We offer 9" 6w tubes complete with starter, choke, lamp-holders and starter-holder. Price **£2.75** + 30p post. Tubes only **£2.** Post & VAT 50p

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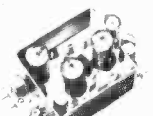
All in module form, each ready built complete with heat sinks and connection tags, data supplied.



Model 1153 500mW power output **£1.10** + 40p post & VAT.
Model 1172 1w power output. **£1.35** + 45p post VAT.
Model EP9000 4 watt power output, **£2.40** + 50p post & VAT.
EP 9001 twin channel or stereo pre-amp, **£2.50** + 50p post & VAT

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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, PP1, PP3, PP4, PP6, PP7, PP9 and others. Kit comprises: main transformer rectifier, smoothing and load resistor, condensers and instructions. Real snip at only **£1.50.** VAT & Postage 60p.

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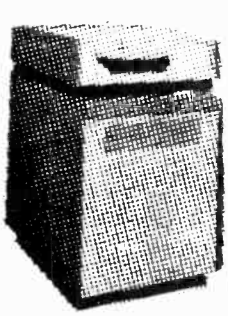
PAPER TAPE PUNCHES & READERS

TELETYPE BRPE 110 cps Synchronous Punch 5/7/8 channel. Self-contained, mains-operated unit consisting of punch unit, base, motor and tape supply spool. Price £145.00. Sound-reducing cabinet available at £25.00.

INVAC P135 solenoid-actuated punch, 35 cps. 5/6/7/8 channel. Compact unit 7½" × 6½" × 5". Power requirements: Tape transport solenoids 26V DC 2A. Punch solenoids 26V 4.5A. Punch return solenoids 26V 2A. Minimum pulse width 16 millisec. Price £69.50.

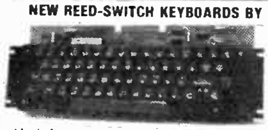
DATA DYNAMICS 1114 Rack-Mounted 110 cps Punch, as new. Mounted in sound-reducing rack cabinet and complete with control and interface electronics and power supply unit with short circuit and overload protection. Asynchronous operation up to 110 cps. Our special price **£550.**

JUST ARRIVED — SPECIAL PURCHASE OF DISK STORAGE DRIVES BY CDC WILL ACCEPT 6-SPEED DISK-PACKS AVAILABLE EITHER 2 OR 4 MEG CAPACITY NEVER OFFERED BEFORE. PRICES FROM £450.00.



Keyboards

NEW REED-SWITCH KEYBOARDS BY CLARE-PENDAR WITH

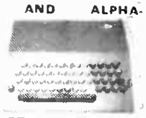


READ ONLY MEMORY ASCII-CODED OUTPUT

Ideal for communications equipment, VDUs, prototype designs, etc. 68-key positions plus 11 instruction keys. Positive logic. Input voltage −12V DC+5V

OUR INCREDIBLE PRICE £29.50 (DUE TO SPECIAL PURCHASE) + £1.00 P&P

ELECTRO-MECHANICAL NUMERIC AND ALPHA-NUMERIC KEYBOARDS originally designed for 80-column card punch and verifier machines. Numeric with 12 character keys and 8 instruction keys. Alpha-numeric with 47 character keys and 8 instruction keys. Price: Numeric **£4.50** + £1.00 P&P. Alpha-numeric **£15** + £3.00 P&P



4 BANK HONEYWELL ALPHANUMERIC KEYBOARD — BRAND NEW
Mounted on printed circuit board (non-coded). 53 character keys + 10 instruction keys and 2 space bars. Layout can be re-arranged as required. Ideal for prototypes and special applications. Hall-effect switches. Power requirement + 5V 420 mA. Price £20.00 (P&P £1).

REED-SWITCH 4-BANK ALPHA-NUMERIC KEYBOARD mounted on printed circuit board with ASCII coded output, 43 character keys + 2 shift keys and 12 instructional keys. Ideal for data displays, computer programming, etc. (a) Ex-equipment, housed in metal case: **£30.00** + £3.00 P&P. (b) Brand new, mounted on PC board only: **£30.00** + £1.00 P&P

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ASR35 Heavy-duty console-mounted version of ASR33. Designed for continuous running with minimum maintenance. **£950.00.**
KSR33 Input/Output Console (hard copy only) **£375.00.**
COSSOR DIDS SERIES 402.2 and 402.2A Visual Display Units. Provide high-speed visual access from computer or other information sources. Data transfer rate 120 cps. The model 402.2 displays 13 lines of 40 characters with a viewing surface of 8" x 4½", while the 402.2A displays 13 lines of 80 characters with a viewing surface of 8" x 6". 64 character alphanumeric keyboard. Prices from **£325.00.**
HAZELTINE 1000 Video Display Terminal. 64 character ASCII-coded alphanumeric keyboard. Display area 12 lines of 80 characters. Data transmission rate 110/300. Price **£475.00**
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Overall length 1.85in (Body length 1 1in), Diameter 0.14in to switch up to 500mA at up to 250vDC Gold clad contacts **74p** per doz **£4.15** per 100, **£29.95** per 1,000, **£272** per 10,000 All carriage paid U K
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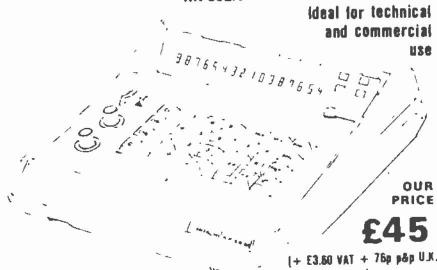

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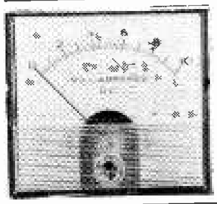
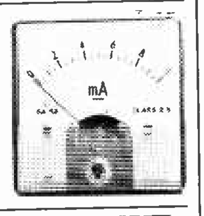


TYPE TAD

Dims in mm	48 x 42	66 x 50	85 x 70	118 x 106	150 x 110
50 µA	£3.63	£3.81	£4.00	£4.90	£5.46
500 µA	£3.34	£3.51	£3.72	£4.62	£5.32
1mA	£3.27	£3.44	£3.64	£4.53	£5.23
15vDC	£3.30	£3.49	£3.67	£4.57	£5.26
300vAC	£3.47	£3.66	£3.84	£4.73	£5.30

TYPE SA

Dims in mm	43 x 43	51 x 51	61 x 61	82 x 78
50 µA	£3.52	£3.59	£3.87	£4.12
500 µA	£3.21	£3.28	£3.53	£3.76
1mA	£3.11	£3.18	£3.43	£3.72
15vDC	£3.15	£3.22	£3.50	£3.76
300vAC	£3.39	£3.46	£3.67	£3.92



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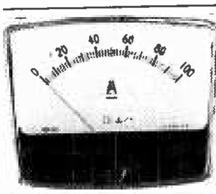

TYPE SR

Dims in mm	73 x 56	78 x 63	92 x 72
50 µA	£3.93	£4.18	£4.42
500 µA	£3.58	£3.83	£4.08
1mA	£3.48	£3.73	£3.98
15vDC	£3.60	£3.84	£4.09
300vAC	£3.73	£3.87	£4.22

LABORATORY TYPE SA65F

Metric size 82 x 78mm

50 µA	£6.51
500 µA	£6.26
1mA	£6.06
1A	£6.16
15vDC	£6.16
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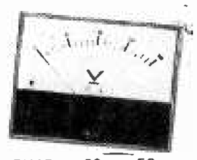
ALL ABOVE PRICES INCLUDE P. & P. and VAT

NEW ADDITIONS to our range of PANEL METERS available at present only in MANUFACTURING QUANTITIES

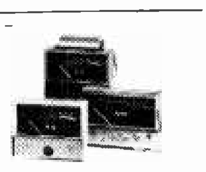
SE45	64	×	52 mm
SE52	80	×	60 mm
SE65	100	×	80 mm
SE85	120	×	100 mm



SU45	69	×	53 mm
SU55	87	×	63 mm
SU65	105	×	77 mm

Above meter forms are for moving coil movements only and may house S-meter and VU-meter instruments.

ALL VU METERS
SF100 72 × 68 mm
SF104 63 × 60 mm
SF106 63 × 60 mm



All meters can be supplied with special or personalised scales, internal illumination, coloured front lenses, mirror scales, special pointer forms, etc

Full details and prices on request

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A modern high grade low noise solid state amplifier to feed a potentiometer recorder 18 input ranges from 10^{-12} to 5 x 10^{-7} A with 5 outputs of 1mV to 100mV Linearity 0 1% f s Noise less than 0 5% f s at max sensitivity Back off facility Dimensions 28 x 10 x 43 cm deep With operating information **£28.50.** (C Pd U K)
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400HZ ROTARY CONVERTERS. Both DC & AC input available, e g 415v 50Hz 3ph to Cab 115v 400HZ 1 pr 50w at **£27.50.** Multiway cables in stock up to 50 way or up to 750 amp Also PTFE insulated types

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BC117	20p
BC118	15p
BC119	30p
BC143	25p
BC147	12p
BC148	12p
BC149	12p
BC149c	14p
BC157	14p
BC158	14p
BC159	15p
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BC213L	12p
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2N1303	30p
2N1304	30p
2N1305	30p
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2N3553	£1.40
2N3643	30p
2N3702	12p
2N3703	12p
2N3704	12p
2N3705	12p
2N3706	12p
2N3707	12p
3N3708	14p
2N3709	14p
3N3771	£1.50
2N3772	1.60
2N3792	£1.80
2N3794	30p
2N3819	35p
2N3820	55p
2N3823	70p
2N3866	85p
2N3904	22p
2N3905	25p
2N3906	25p
2N4014	80p
2N4036	62p
2N4037	14p

2N4058	14p
2N4059	14p
2N4060	12p
2N4061	12p
2N4062	12p
2N4126	18p
2N4286	25p
2N4287	25p
2N4288	27p
2N4289	30p
2N4290	25p
2N4291	32p
2N4302	45p
2N4444	£1.00
2N4871	35p
2N4903	£1.80
2N4919	90p
2N5063	£1.30
2N5191	96p
2N5192	£1.20
2N5194	£1.10
2N5195	£1.40
2N5245	46p
2N5296	55p
2N5298	50p
2N5457	35p
2N5458	35p
2N5459	40p
2N5485	55p
2N5490	55p
2N5555	65p
2N5777	40p
2N6027	45p
2N6028	45p

TO3 VOLTAGE REGULATORS
L005 5V 650mA
L036 12V 600mA
L037 15V 450mA £1.60 ea.

BRIDGE RECTIFIERS
W02 1A 200V 38p
BY164 1 4A 200V 57p
MOA952/2 6A 100V 80p

ZENER DIODES
BZY88 Series 400mW
3.3V-33V. 5% 11p
1.5W range 25p
10W range 45p

L.E.D.
TIL209 38p
HP5082 28p
MA2082R 20p

L.D.R.
ORP12 60p
NE555 Timer 80p

BNC PLUGS at **35p** each
UHF (N) PLUGS at **50p** each
UHF VSWR probes ex UHF transmitters **£5** each + 8% VAT
All the above are new in original packets.
Please add 8% VAT P&P 30p

POTENTIOMETERS
Linear or Log Rotary Pots
Rotary Switched
Single 17p 25p **Double** 45p —

LINEAR I.C.s
LM304 Neg Voltage Reg. £2.10
LM309K 5V. 1A. Voltage Reg. £2.10
LM723C 2.37V 150mA Voltage Reg. £1.05
MFC4000 250mW Audio 75p
TBA800 5Watt Audio 99p
709C Op Amp D.I.L./TO99 35p
741C Op Amp 8/14 D.I.L./TO99 35p
747C Dual Op Amp £1.20
748C Op Amp D.I.L. 75p
ZN414 Radio I.C. £1.25
TAD100 Radio I.C. inc. Filter £1.90
CA3014 £1.55
CA3018 £1.00
CA3028 £1.20
CA3036 £1.00
CA3046 95p
CA3048 £2.35
CA3075 £1.60
CA3089E £1.90
CA3090Q £4.85
MC1303L £2.20
MC1310P £2.80
SN76023N 5 wat Texas IC £1.60
SN76660 EQ TBA120 65p

25% VAT, QTY. DISCOUNTS: 12+10%; 25+ 15%; 100+ 20%

★★ SPECIAL OFFERS ★★

MULTICORE CABLE. 20 way 14/0076 + Screen at 70p per yard + postage by weight.
MULTICORE CABLE. 25-way, individually screened, 14/0076. **£1.00** per yard + VAT. Postage by weight.
3 CORE PVC INSULATED MAINS CABLE. GREY ML6650. 3x7/0.2mm Price 100m-**£4.50.** 1,000m-**£35.** 10,000m-**£330.**
METAL OXIDE RESISTORS TR4/5/6 in stock. All values. 1-off price **3p** each. Discount on quantity.
10 TURN TRIMPOTS by Bourns, Mec, Painton, etc. All values in stock. **50p** each. Discount on quantity.

KOKUSAI MECHANICAL FILTER. 455 Kc/S. 6 Kc/S overall. Ideal for A.M. **£5** each INC VAT. Postage 33p each.
TRANSFORMER 240V A.C. Primary 1185-0-1185V at 360Ma Secondary **£12** + 8% VAT + £1.50 postage.
OMRON OCTAL RELAY 240V A.C. 3P c/o **75p** each + 8% VAT.
SLEEVING 2000 pieces approx. size ¾" x 2mm. Price **£1** + 33p P&P + VAT 8%.
FREE basic short form list available. Sae

★★ SPECIAL OFFERS ★★

MINIATURE MAINS TRANSFORMER. PRI240V SEC. 12V. 100Ma Manuf.: Hinchley. Size 36 x 45 x 40mm. F.C. 53mm.
Price **1.65.** 100 **60p ea.** 1,000 **50p ea.** 10,000 **40p ea.** 8% VAT.
MINIATURE MAINS TRANSFORMER. Primary 115/240v Sec 18v/250 Ma at **80p ea. + VAT & postage 33p, 8% VAT.**
MULLARD POT CORE TYPE FX2241 at **60p ea. + 33p p.p. 8% VAT.**
24V D.C. SOLENOID by MAGNETIC DEVICES **60p** each 2½ long x ⅝ x ⅝in. + 8% VAT.
240VA.C. SOLENOID. Reversible operation: twin coil. Size approx. 2¾ x 1½ x 1¾in. **90p.**
30 unmarked OC71 transistors **£1.00**
25 Unmarked 250mW Zener diodes. 4.7V, 5.1V, 6.2V, 7.5V, 9.1V, 10V. Measured and tested **£1.00**
Please stage voltage required.
50 GE Diode OA47 equivalent **£1.00**
8µF 600V WKG **PAPER CAPACITORS,** ideal for Strobe Constructors **£1.50** each + 8% VAT + 33p post.
Many other values of **PAPER CAPACITORS** in stock. Phone for details.
JACKSON AIRSPACED CAPACITORS to suit ¼in. spindle:
100pF Two Gang at **55p** + 25%
500pF Two Gang at **75p** + 25%
MULLARD TUBULAR CEREAMIC UHF TRIMMERS (PROFESSIONAL)
Type 092 0.8-2.2p; 801 0.8-2.2p; 991 0.5-1.3p — Price 10p ea.

METAL BOXES 8% VAT

ALUMINIUM BOXES IDEAL FOR VEROBOARD WITH BASE & P.K. SCREWS

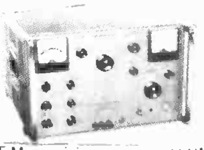
AB7	2¾" Long	5" Wide	1½" high	55p
AB8	4"	4"	1½"	55p
AB9	4"	2¾"	1½"	55p
AB10	4"	5¼"	1½"	55p
AB11	4"	2½"	2"	65p
AB12	3"	2"	1"	50p
AB13	6"	4"	2"	77p
AB14	7"	5"	2½"	90p
AB15	8"	6"	3"	£1.16
AB16	10"	7"	3"	£1.32
AB17	10"	4½"	3"	£1.10
AB18	12"	5"	3"	£1.32
AB19	12"	8"	3"	£1.80

ALUMINIUM BOXES WITH SLOPING TOP PANEL—IDEAL FOR PRE-AMPS, ETC., USING SLIDER CONTROLS
AB20 8" Long 9" Wide 3½" High at back 2" High at front 6" Slope to front With P.K. Screws £2.20
AB21 As above but 10" Long £2.20
AB22 As above but 12" Long £2.60

ELECTRONIC BROKERS

SIGNAL SOURCES

FM AM SIGNAL GENERATOR TYPE 202H



This superb generator in grade one condition. F.M., A.M., C.W. & pulse coverage 54 to 216MHz. Used to testing and calibration of F.M. receiving systems, V.H.F., T.V., Mobile and general Communications. Freq. range 54-216MHz ÷ 2 Bands. R.F. stability 0.01%. R.F. output 0.1 µV-0.2V. V.S.W.R. 1.2. Signal to noise ratio 50dB below 10KHz. Dimensions 16¾" x 10¼" x 18⅜".

PRICE NEW OVER £1,000!

OUR PRICE £495

ADVANCE

Audio Signal Generator HIB 15Hz-50 KHz, 200µV-20Vm± 2dB. Sine Wave & Square Wave **£65**

Audio Signal Generator JIB 15Hz-50KHz 0.2V-25V **£65**

VHF Square Wave Generator SG21 9KHz-100MHz. Max O/p 2V **£35**

Signal Generator D1 **£39**

A.F. Signal Generator J.2E 15Hz to 50KHz in 3 ranges Cal. Accuracy ±2%+1Hz. Output 250mV to 25V variable. Overall distortion at full Power output above 100Hz is <2% **£65**

A.F. Signal Generator J.2B **£45**

A.F. Signal Generator J.2 **£35**

AIRMEC

Signal Generator 702 30Hz-30KHz in 3 bands **£60**

Signal Generator 701 **£60**

H.F. Signal Generator 201 30KHz-30MHz in 7 Bands. Int.Xtal calibrator o/p level variable 1µV-1.1V 75 ohms impedance Int. Mod. at 1KHz. Ext. Mod 30Hz-10KHz **£75-£115**

GENERAL RADIO

Unit Oscillator 1218-A P.O.A.

Unit Oscillator. General Radio Type 1209C. Freq. 250-920 MHz. Accuracy 1% Drift 0.2%. Output into 50 ohms = 150 MW with PSU 1201 — CQ18 as illustrated **£215**

HEWLETT PACKARD

U.H.F. Signal Generator 614A 900-2100MHz 1% Accuracy. Output 0.1uV-0.2V into 50 ohms. Modulation: CWInt. or EXT. FM & Pulse

S.H.F. Signal Generator 618C 3.8-7.6GHz ± 1% 50 ohms **£550**

Signal Generator 608B 10-400MHz 0.1µV-0.8V **£195**

Signal Generator 608E **£625**

Signal Generator 612A 450MHz-1230MHz Internal & Ext. A.M. 50 ohms **£495**

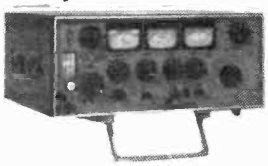
Audio Oscillator Type 201C 20 Hz-20 KHz 0-40 dB in 10 dB steps. Distortion less than 0.5%. Also 200 CD & 200B **£95**

Audio Generator 206A 20Hz-20KHz. Calibration accuracy ±2%. Distortion < 0.1% at frequencies above 50Hz and < 0.25% from 20Hz to 50Hz. O/P Attenuators 111 dB in 0.1 dB steps **£145**

Audio Oscillator 201C 20Hz-20KHz. Calibration Accuracy ±1%. Output (600 ohms) 3W Max. Distortion 0.5% **£95**

Audio Oscillator 202C 1Hz-100KHz Cal. Accuracy ±2%. Max. Distortion 0.5% (above 5Hz) O/P Impedance 600 ohms **£95**

MARCONI INTS.



Phase/AM Signal Generator TF 2003 0.4-12 MHz. Bargain price — super condition **£150**

FM/AM Signal Generators:

TF995A **£185**

TF995A/2 **£225**

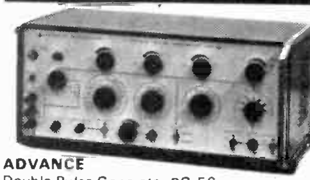
TF995A/2M **£385**

FM/AM Signal Generator TF 995A/3S. 1.5 MHz-220 MHz. 2µ V-200mV. Superb condition **£385**

U.H.F. Signal Generator TF 1060/2. 450-1200 MHz. 0.15µV-447mV. Sine and pulse mod. facilities **£420**

U.H.F. & S.H.F. Signal Generator TF 1058 1600-4000 MHz 0.1µV-445mV **£295**

PULSE GENERATORS



ADVANCE

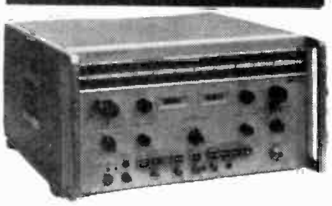
Double Pulse Generator PG.56

Pulse Amplitude 0.1V-10V. Sq. wave 0-10V. Rise Time 10nsec. (typically) **£87.50**

Pulse Generator PG.55 P.O.A.

Modular Pulse Generator Advance Type PG.52. System of 5 Signal generating & Processing units. Repetition freqs. up to 20MHz & Output pulses to 20V (50 ohms) Rise & Fall times 5nsec. Its versatility enables the production of complex pulse & ramp waveforms not obtainable from conventional pulse generators **£250**

SWEEP GENERATORS



HEWLETT PACKARD

Sweep Oscillator 692D 2-4GHz **£495**

Sweep Oscillator 693B 4-8GHz **£495**

VOLTMETERS

MARCONI INSTRUMENTS

TF 1041B V.T.V.M. AC, DC and Ohms **£65-£80**

Sensitive Valve Voltmeter TF 1100 **£85**

HEWLETT PACKARD

D.C. Vacuum Tube Voltmeter 412A 1mV-1000V 1% Accuracy. Can also be used as Ohmeter & Ammeter **£75**

VTVM. 400D 1mV to 300V FSD. 12 ranges 10Hz to 4MHz. 2% accuracy. Input Impedance 10Mohms **£85**

VTVM. 400L. Logarithmic version of 400D. Reads RMS value of sine wave. Log. voltage scale 0.3 to 1 & 0.8 to 3. Linear dB scale. Input Impedance 10Mohms **£90**

PHILIPS

L.F. Millivoltmeter GM 6012 **£65**

H.F. Millivoltmeter GM 6014 **£55**

D.C. Microvoltmeter GM 6020 **£60**

ADVANCE

Voltmeter VM 80 AC Volts 0-500. DC Volts 0-1500V. R 0-1000 Mohms **£45**

INSULATION TESTERS

EVERSHED & VIGNOLES

Circuit Tester Ohmeter 0-3 ohms 0-30 ohms **£18**

Circuit Tester Ohmeter 0-1000 ohms, 100-200 kohms **£18**

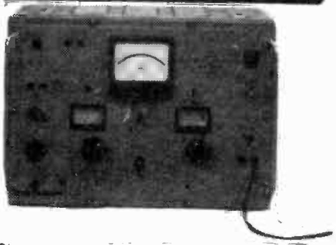
Megger Series +II 250V **£12**

Megger Series III Mk. 3 250V **£20**

Megger 250V **£20**

Battery Megger 500V **£37**

TELEPHONE TEST EQUIPMENT



Siemens Level Meter 3D 335 10KHz-17MHz. Complete system by Siemens Comprising 3W.518 Level Oscillator, 3D. 335 Level Meter, 3W.933 Sweep Attachment, 3D.346 Screen Level Tracing Receiver P.O.A.

Siemens Level Meter 3D 332 0.3-1200KHz, Level Oscillator 3W.29. 0.3-1200KHz P.O.A.

S.T.C.

Octave Filter 74143A 37.5-12,800Hz. For analysing noise and interference on comms. systems, particularly useful with 74142 psophometer P.O.A.

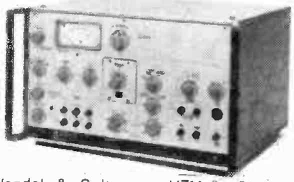
Selective level Measuring Set 74184B 60-1364KHz P.O.A.

Measuring Set 74831A P.O.A.

WANDEL & GOLTERMAN

Level Transmitter TFPS 42 10KHz-14MHz **£375**

Level Meter TFPM 43 10KHz-14MHz **£375**



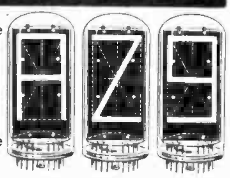
Wandel & Golterman VZM 2 Distortion measuring set for phase & amplitude mod. For multichannel FM Radio Systems up to 12MHz Base bands **£400**

MARCONI

Sine Squared Pulse & Bar Generator TF 2905/8 **£225**

COMPONENTS

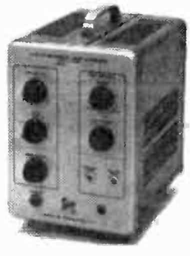
Numeric Tube B.5853 0-9 Digit 1.4" height Brand New **£1.00**



Also Alpha Numeric Nixie Tube

B 7971. Displays alphabet & 0-9 numerals **99p**

OSCILLOSCOPE TEST EQUIPMENT



TEKTRONIX

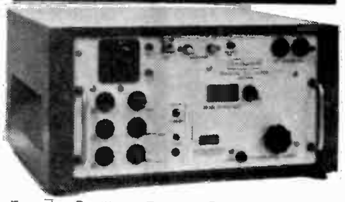
Pulse Generator Type 111. 0.5µsec risetime. Amplitude ± 5V. 30 to 250 nsec. difference between trigger and output pulses **£60**

Time Mark Generator 180A **£85**

Pulse Generator 109 0.25 nsec. Risetime 0-55V Calibrated variable amplitude. Impedance 50 ohms **£35**

Pre-trigger Pulse Generator 111 **£60**

MISCELLANEOUS



Transfer Oscillator Type 7580HBy Beckman. DC-15GHz with counter, 7.5MHz-15GHz without counter. Sensitivity 100mV (R.M.S.) **£350**

MARCONI

Distortion Factor Meter TF 142F Fundamental Freq. Range 100Hz-8KHz. Dist. measurement ranges 0-5% & 0-50% **£60**

Portable Receiver Tester TF 888/3. 70KHz-70MHz. Xtal check 500KHz & 5MHz. 1KHz A.F. Oscillator, A.F. Power 10mW, 100mW & 1W **£69**

Wave Analyser TF 455E **£95**

Noise Generator TF 1301. 200-1700 MHz **£60**

Amplitude Modulator TF 1102. Basic Carrier Frequency Range 100KHz-300Mhz/500MHz CW or FM output of any conventional signal generator can be amplitude modulated, including sine waves, square waves pulses, picture signals **£25**

SOLARTRON

Resolved Component Indicator VP 253.3 **P.O.A.**

Low Freq. Decade Oscillator OS 103.3 **P.O.A.**

EKCO INSTS

(Nucleonics)

Ratemeter N.600B **P.O.A.**

S.T.C.

Level Measuring Set 74307A **P.O.A.**

RADIOMETER

1MHz Capacitance Comparator Type CMB 11bS2 **P.O.A.**

BELL

Gaussmeter 120 **P.O.A.**

HEWLETT PACKARD

Microwave Link Analyser 3701/02/03 **£2000**

Distortion Analyser 380C **P.O.A.**

Ratio Meter 416B **P.O.A.**

Univerter 207H (for use with 202H and J Generators) **P.O.A.**

MUIRHEAD

Facsimile Transmitter Receiver Type 900. Easily convertible to receive weather pictures from satellite systems **£850**

SAVAGE

Amplifier Mark II Star Model 1KM2Z. 1 KW output. Freq. 50-10 KHz. Good condition **£1650**

WAYNE KERR

Video Noise Level Meter M 131 **£75**

B.P.L.

Component Comparator CZ457/5 **P.O.A.**

AIRMEC

Modulation Meter 210 **£75**

Modulation Meter 210A **£135**

HEWLETT PACKARD

Time Domain Reflectometer 140A + 1415A **£750**

Trolley for 175A scope **£50**

Digital Recorder 561B **£150**

MARCONI

Blank & Sync. Mixer TF 2908 **£95**

VHF/UHF Probe TM 9650 (New) **£30**

TEKTRONIX

Scope Camera C-13 **P.O.A.**

MUIRHEAD

Various Pametrada Analysers **P.O.A.**

SOLARTRON

Analogue Tutor TY 1351. Ask for details **P.O.A.**

AC/DC Converter LM 1219 **£200**

P.R.D.

Noise Generator 904A **P.O.A.**

TELEMAX-SOUTHERN

TD1 Freq. Meter/Generator. 10KHz-3000 MHz **P.O.A.**

POTENTIOMETERS

Manuf.	Type	Turns	Value	Price
Relcon	0705/1001/A	5	100 ohm	**£1.75**
Relcon	0705/05/F11	5	200 ohm	**£1.75**
Beckman	7246/5019	10	50 ohm	**£2.00**
Bourns	35005-2-500	10	50 ohm	**£1.95**
Bourns	35005	10	1K	**£2.00**
Beckman	A/S303	10	5K	**£1.00**
Beckman	72212/5	10	10K	**£2.00**
Relcon	0710-1-1-001A	10	10K	**£2.00**
Beckman	A	10	20K	**£3.00**
Borg	KS1302512	10	20K	**£2.00**
Beckman	7223	10	50K	**£3.50**

WW—099 FOR FURTHER DETAILS

BI-PAK SEMICONDUCTORS

TRANSISTORS

BRAND NEW, FULLY GUARANTEED

Type	Price	Type	Price	Type	Price	Type	Price
AC107	0.20	BC171	0.15	BFX88	0.22	2N718	0.25
AC113	0.19	BC172	0.15	BFY50	0.20	2N718A	0.51
AC115	0.20	BC173	0.15	BFY51	0.20	2N726	0.29
AC117K	0.30	BC174	0.15	BFY53	0.20	2N727	0.29
AC122	0.12	BC175	0.22	BFY53	0.18	2N743	0.20
AC125	0.18	BC177	0.19	BSX19	0.16	2N744	0.20
AC126	0.18	BC178	0.19	BSX20	0.16	2N914	0.15
AC127	0.19	BC179	0.19	BSY25	0.16	2N918	0.31
AC128	0.19	BC180	0.25	BSY26	0.16	2N929	0.21
AC132	0.15	BC181	0.25	BSY27	0.16	2N930	0.31
AC134	0.15	BC182	0.15	BSY28	0.16	2N1131	0.20
AC137	0.15	BC182L	0.15	BSY29	0.16	2N1132	0.22
AC141	0.19	BC183	0.15	BSY38	0.19	2N1302	0.15
AC141K	0.30	BC183L	0.15	BSY39	0.19	2N1303	0.15
AC142	0.19	BC184	0.20	BSY40	0.29	2N1304	0.18
AC142K	0.26	BC184L	0.20	BSY41	0.29	2N1305	0.18
AC151	0.16	BC186	0.29	BSY95	0.13	2N1306	0.21
AC154	0.20	BC187	0.29	BSY95A	0.13	2N1307	0.21
AC155	0.20	BC207	0.11	BU105	2.04	2N1308	0.24
AC156	0.20	BC208	0.11	C111E	0.51	2N1309	0.24
AC157	0.25	BC209	0.12	C400	0.31	2N1613	0.20
AC165	0.20	BC212L	0.13	C407	0.26	2N1711	0.20
AC166	0.20	BC213L	0.13	C424	0.26	2N1889	0.32
AC167	0.20	BC214L	0.17	C425	0.51	2N1890	0.46
AC168	0.25	BC225	0.26	C426	0.36	2N1893	0.38
AC169	0.15	BC226	0.36	C428	0.20	2N2147	0.73
AC176	0.20	BC301	0.28	C441	0.31	2N2148	0.58
AC177	0.25	BC302	0.25	C442	0.31	2N2160	0.61
AC178	0.29	BC303	0.31	C444	0.36	2N2192	0.36
AC179	0.29	BC304	0.37	C450	0.22	2N2193	0.36
AC180	0.20	BC440	0.31	MAT100	0.19	2N2194	0.36
AC180K	0.30	BC460	0.37	MAT101	0.20	2N2217	0.22
AC181	0.20	BCY30	0.25	MAT120	0.19	2N2218	0.20
AC181K	0.30	BCY31	0.27	MAT121	0.20	2N2219	0.20
AC187	0.22	BCY32	0.31	MJE521	0.56	2N2220	0.22
AC187K	0.23	BCY33	0.22	MJE2955	0.88	2N2221	0.20
AC188	0.22	BCY34	0.26	MJE3055	0.57	2N2222	0.20
AC188K	0.23	BCY70	0.15	MJE3440	0.51	2N2368	0.18
ACY17	0.20	BCY71	0.20	MPF102	0.43	2N2369	0.15
ACY18	0.20	BCY72	0.15	MPF104	0.38	2N2369A	0.15
ACY19	0.20	BCZ10	0.20	MPF105	0.38	2N2411	0.25
ACY20	0.20	BCZ11	0.26	OC19	0.36	2N2412	0.25
ACY21	0.20	BCZ12	0.26	OC20	0.65	2N2646	*0.48
ACY22	0.17	BD115	0.63	OC22	0.47	2N2711	0.21
ACY27	0.19	BD116	0.81	OC23	0.49	2N2712	0.21
ACY28	0.19	BD121	0.61	OC24	0.57	2N2714	0.21
ACY29	0.36	BD123	0.67	OC25	0.39	2N2904	0.18
ACY30	0.29	BD124	0.70	OC26	0.30	2N2904A	0.21
ACY31	0.29	BD131	0.51	OC28	0.51	2N2905	0.21
ACY34	0.21	BD132	0.61	OC29	0.51	2N2905A	0.21
ACY35	0.21	BD133	0.67	OC35	0.43	2N2906	0.16
ACY36	0.29	BD136	0.41	OC36	0.51	2N2906A	0.19
ACY40	0.18	BD137	0.46	OC41	0.20	2N2907	0.20
ACY41	0.19	BD138	0.51	OC42	0.25	2N2907A	0.22
ACY44	0.36	BD139	0.56	OC44	0.16	2N2923	0.15
AD130	0.39	BD140	0.61	OC45	0.13	2N2924	0.15
AD140	0.49	BD155	0.81	OC70	0.10	2N2925	0.15
AD142	0.49	BD175	0.61	OC71	0.10	2N2926G	0.13
AD143	0.39	BD176	0.61	OC72	0.15	2N2926Y	0.11
AD149	0.51	BD177	0.67	OC74	0.15	2N2926O	0.10
AD161	0.36	BD178	0.67	OC75	0.16	2N2926R	0.10
AD162	0.36	BD179	0.71	OC76	0.16	2N2926B	0.10
AD161 &		BD180	0.71	OC77	0.26	2N3091	0.71
AD162(MP)	0.69	BD185	0.67	OC81	0.16	2N3011	0.15
ADT140	0.51	BD186	0.67	OC81D	0.16	2N3053	0.18
AF114	0.25	BD187	0.71	OC82	0.16	2N3054	0.47
AF115	0.25	BD188	0.71	OC82D	0.16	2N3055	0.42
AF116	0.25	BD189	0.77	OC83	0.20	2N3319	0.15
AF117	0.25	BD190	0.77	OC139	0.20	2N3391A	0.17
AF118	0.36	BD195	0.87	OC140	0.20	2N3392	0.15
AF124	0.31	BD196	0.87	OC169	0.26	2N3393	0.15
AF125	0.31	BD197	0.92	OC170	0.26	2N3394	0.15
AF126	0.29	BD198	0.92	OC171	0.26	2N2295	0.18
AF127	0.29	BD199	0.98	OC200	0.26	2N3402	0.21
AF139	0.31	BD200	0.98	OC201	0.29	2N3403	0.21
AF178	0.51	BD205	0.81	OC202	0.29	2N3404	0.29
AF179	0.51	BD206	0.81	OC203	0.26	2N3405	0.34
AF180	0.51	BD207	0.98	OC204	0.26	2N3414	0.16
AF181	0.51	BD208	0.98	OC205	0.36	2N3415	0.16
AF186	0.51	BDY20	1.02	OC309	0.41	2N3416	0.29
AF239	0.38	BF115	0.25	OCP71	*0.44	2N3417	0.29
AL102	0.68	BF117	0.46	ORP12	*0.44	2N3525	*0.77
AL103	0.68	BF118	0.71	ORP60	*0.41	2N3614	0.69
ASY26	0.26	BF119	0.71	ORP61	*0.41	2N3615	0.76
ASY27	0.31	BF121	0.46	P20	*0.51	2N3616	0.76
ASY28	0.26	BF123	0.51	P346A	0.20	2N3646	0.09
ASY29	0.26	BF125	0.46	P397	0.43	2N3702	0.12
ASY50	0.26	BF127	0.51	ST140	0.13	2N3703	0.12
ASY51	0.26	BF152	0.56	ST141	0.18	2N3704	0.13
ASY52	0.26	BF153	0.46	TIP29	0.44	2N3705	0.12
ASY54	0.26	BF154	0.46	TIP30	0.52	2N3706	0.12
ASY55	0.26	BF155	0.71	TIP31A	0.56	2N3707	0.13
ASY56	0.26	BF156	0.49	TIP32A	0.68	2N3708	0.08
ASY57	0.26	BF157	0.56	TIP41A	0.68	2N3709	0.09
ASY58	0.26	BF158	0.56	TIP42A	0.81	2N3710	0.09
ASZ73	0.26	BF159	0.61	TIS43	*0.31	2N3711	0.09
ASZ21	0.41	BF160	0.41	UT46	*0.28	2N3819	0.29
BC107	0.08	BF162	0.41	ZN414	1.11	2N3820	0.51
BC108	0.08	BF163	0.41	2G301	0.19	2N3821	0.36
BC109	0.08	BF164	0.41	2G302	0.19	2N3823	0.29
BC113	0.10	BF165	0.41	2G303	0.19	2N3903	0.29
BC114	0.16	BF167	0.22	2G304	0.25	2N3904	0.31
BC115	0.16	BF173	0.22	2G306	0.41	2N3905	0.29
BC116	0.16	BF176	0.36	2G308	0.36	2N3906	0.28
BC117	0.19	BF177	0.36	2G309	0.37	2N4058	0.12
BC118	0.10	BF178	0.31	2G339	0.20	2N4059	0.10
BC119	0.31	BF179	0.31	2G339A	0.17	2N4060	0.12
BC120	0.81	BF180	0.31	2G344	0.19	2N4061	0.12
BC125	0.12	BF181	0.31	2G345	0.17	2N4062	0.12
BC126	0.19	BF182	0.41	2G371	0.17	2N4284	0.18
BC132	0.12	BF183	0.41	2G371B	0.12	2N4285	0.18
BC134	0.19	BF184	0.26	2G373	0.18	2N4268	0.18
BC135	0.12	BF185	0.31	2G374	0.18	2N4287	0.18
BC136	0.16	BF187	0.28	2G377	0.31	2N4288	0.18
BC137	0.16	BF188	0.41	2G378	0.17	2N4289	0.18
BC139	0.41	BF194	0.12	2G381	0.17	2N4290	0.18
BC140	0.31	BF195	0.12	2G382	0.17	2N4291	0.18
BC141	0.31	BF196	0.15	2G401	0.31	2N4292	0.18
BC143	0.31	BF197	0.15	2G414	0.31	2N4293	0.18
BC145	0.46	BF200	0.46	2G417	0.26	2N5172	0.12
BC147	0.10	BF222	0.98	2N388	0.36	2N5194	0.56
BC148	0.10	BF257	0.46	2N388A	0.56	2N5294	0.56
BC149	0.12	BF258	0.61	2N404	0.20	2N5296	0.56
BC150	0.19	BF259	0.87	2N404A	0.29	2N5457	0.32
BC151	0.20	BF262	0.56	2N524	0.43	2N5458	0.32
BC152	0.18	BF263	0.56	2N527	0.50	2N5459	0.41
BC153	0.29	BF270	0.36	2N598	0.43	2N6122	0.69
BC154	0.31	BF271	0.31	2N599	0.46	2S301	0.51
BC157	0.19	BF272	0.81	2N696	0.13	2S302A	0.43
BC158	0.12	BF273	0.36	2N697	0.14	2S302	0.43
BC159	0.12	BF274	0.36	2N698	0.25	2S303	0.56
BC160	0.46	BFW10	0.61	2N699	0.36	2S304	0.71
BC161	0.51	BFX29	0.28	2N706	0.08	2S305	0.80
BC167	0.12	BFX84	0.22	2N706A	0.09	2S306	0.80
BC168	0.12	BFX85	0.31	2N708	0.12	2S307	0.80
BC169	0.12	BFX86	0.22	2N711	0.31	2S321	0.75
BC170	0.12	BFX87	0.25	2N717	0.36	2S322	0.43

* 74 SERIES T.T.L. I.C.'s

BI-PAK STILL LOWEST IN PRICE. FULL SPECIFICATION GUARANTEED. ALL FAMOUS MANUFACTURERS

Type	Quantities 1	25	100+	Type	Quantities 1	25	100+
7400	0.14	0.13	0.12	7486	0.32	0.31	0.30
7401	0.14	0.13	0.12	7489	3.70	3.47	3.24
7402	0.14	0.13	0.12	7490	0.60	0.58	0.56
7403	0.14	0.13	0.12	7491	1.02	0.97	0.93
7404	0.14	0.13	0.12	7492	0.69	0.66	0.59
7405	0.14	0.13	0.12	7493	0.69	0.66	0.59
7406	0.36	0.31	0.29	7494	0.79	0.76	0.69
7407	0.36	0.31	0.29	7495	0.79	0.76	0.69
7408	0.23	0.22	0.21	7596	0.89	0.86	0.80
7409	0.23	0.22	0.21	74100	1.39	1.34	1.30
7410	0.14	0.13	0.12	74104	0.56	0.54	0.51
7411	0.23	0.22	0.21	74105	0.56	0.54	0.51
7412	0.28	0.25	0.24	74107	0.41	0.39	0.37
7413	0.30	0.29	0.28	74110	0.56	0.51	0.46
7416	0.28	0.27	0.26	74111	0.83	0.81	0.78
7417	0.28	0.27	0.26	74118	0.93	0.88	0.83
7420	0.14	0.13	0.12	74119	1.39	1.30	1.20
7422	0.28	0.27	0.26	74121	0.46	0.44	0.41
7423	0.37	0.36	0.35	74122	0.65	0.63	0.60
7425	0.37	0.36	0.35	74123	0.69	0.68	0.65
7426	0.37	0.35	0.33	74141	0.79	0.76	0.73
7427	0.37	0.35	0.33	74145	1.20	1.16	1.11
7428	0.42	0.39	0.37	74150	1.39	1.30	1.20
7430	0.14	0.13	0.12	74151	1.02	0.97	0.93
7432	0.37	0.35	0.33	74153	0.93	0.88	0.83
7433	0.39	0.37	0.35	74154	1.57	1.43	1.48
7437	0.32	0.30	0.28	74155	1.11	1.06	1.02
7438	0.32	0.30	0.28	74156	1.11	1.06	1.02
7440	0.14	0.13	0.12	74157	0.93	0.88	0.83
7441	0.69	0.66	0.59	74160	1.30	1.25	1.20
7442	0.69	0.66	0.59	74161	1.30	1.25	1.20
7443	1.11	1.06	1.02	74162	1.30	1.25	1.20
7444	1.11	1.06	1.02	74163	1.30	1.25	1.20
7445	1.48	1.44	1.39	74164	1.67	1.62	1.55
7446	1.11	1.06	1.02	74165	1.67	1.62	1.55
7447	1.02	0.99	0.97	74166	1.48	1.44	1.39
7448	1.02	0.99	0.97	74174	1.48	1.44	1.39
7450	0.14	0.13	0.12	74175	1.02	0.97	0.93
7451	0.14	0.13	0.12	74176	1.16	1.11	1.06
7453	0.14	0.13	0.12	74177	1.16	1.11	1.06
7454	0.14	0.13	0.12	74180	1.16	1.11	1.06
7460	0.14	0.13	0.12	74181	3.66	3.56	3.47
7470	0.30	0.27	0.25	74182	1.16	1.11	1.06
7472	0.30	0.27	0.25	74184	1.67	1.62	1.55
7473	0.38	0.36	0.32	74190	1.81	1.76	1.71
7474	0.38	0.36	0.32	74191	1.81	1.76	1.71
7475	0.56	0.54	0.52	74192	1.81	1.76	1.71
7476	0.41	0.40	0.39	74193	1.81	1.76	1.71
7480	0.56	0.54	0.51	74194	1.20	1.16	1.11
7481	1.02	0.97	0.93	74195	1.02	0.97	0.93
7482	0.83	0.79	0.74	74196	1.11	1.06	1.02
7483	1.11	1.06	0.97	74197	1.11	1.06	1.02
7484	0.93	0.90	0.88	74198	2.55	2.50	2.45
7485	1.48	1.44	1.39	74199	2.31	2.21	2.11

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

* D.T.L. 930 SERIES

Type	Quantities 1	25	100+	Type	Quantities 1	25	100+
BP930	0.14	0.13	0.12	BP948	0.28	0.26	0.23
BP932	0.15	0.14	0.13	BP951	0.65	0.60	0.56
BP933	0.15	0.14	0.13	BP962	0.14	0.13	0.12
BP935	0.15	0.14	0.13	BP9093	0.42	0.40	0.38
BP936	0.15	0.14	0.13	BP9094	0.42	0.40	0.38
BP944	0.15	0.14	0.13	BP9097	0.42	0.40	0.38
BP945	0.28	0.26	0.23	BP9099	0.42	0.40	0.38
BP946	0.14	0.13	0.12				

Devices may be mixed to qualify for quantity price. Larger quantity prices on application. (DTL 930 Series only).

* THYRISTORS

PIV	0.6A TO18	0.8A TO92	1A TO5	3A TO66	5A TO66	5A TO64	7A TO48	10A TO48	16A TO48	30A TO48
10	0.13	0.15	—	—	—	—	—	—	—	—
20	0.15	0.18	—	—	—	—	—	—	—	—
30	0.19	0.22	—	—	—	—	—	—	—	—
50	0.22	0.28	0.20	0.25	0.36	0.36	0.48	0.51	0.54	1.18
100	0.25	0.30	0.25	0.25	0.48	0.48	0.51	0.57	0.58	1.43
150	0.31	0.38	—	—	—	—	—	—	—	—
200	0.38	0.44	0.25	0.30	0.50	0.50	0.57	0.62	0.62	1.63
400	—	—	0.30	0.39	0.55	0.57	0.62	0.71	0.77	1.79
600	—	—	0.39	0.48	0.69	0.69	0.78	0.99	0.90	—
800	—	—	0.58	0.65	0.81	0.81	0.92	1.22	1.39	4.07

LINEAR I.C.'s

Type	Quantities 1	25	100+	Type	Quantities 1	25	100+
72702	0.46	0.44	0.42	TAA350A	1.71	1.67	1.57
72709	0.23	0.21	0.19	uA703C	0.26	0.24	0.22
72709P	0.19	0.18	0.17	uA709C	0.19	0.18	0.17
72710	0.32	0.31	0.28	uA711C	0.32	0.31	0.28
72741	0.28	0.27	0.26	uA712C	0.32	0.31	0.28
72741C	0.26	0.25	0.24	uA723C	0.45	0.43	0.40
72741P	0.28	0.27	0.26	76003	1.39	1.34	1.30
72747	0.79	0.74	0.61	76023	1.39	1.34	1.30
72748P	0.35	0.33	0.31	76660	0.88	0.86	0.83
SL201C	0.46	0.42	0.37	LM380	0.93	0.90	0.88
SL701C	0.46	0.42	0.37	NE555	0.45	0.43	0.40
SL702C	0.46	0.42	0.37	NE556	0.88	0.86	0.83
TAA263	0.74	0.65	0.56	TBA800	1.39	1.34	1.30
TAA293	0.93	0.88	0.83	ZN414	1.11	—	—

SILICON RECTIFIERS

PIV	300mA (DO7)	750mA (S016)	1A Plastic	1A (SO16)	1.5A (SO10)	3A (SO10)	10A	30A (TO48)
50	0.05	0.06	IN4001	0.05	0.07	0.14	*0.19	*0.56
100	0.05	0.07	IN4002	0.06	0.09	0.16	*0.21	*0.69
200	0.06	0.09	IN4003	0.07	0.12	0.20	*0.23	*0.93
400	0.07	0.14	IN4004	0.08	0.14	0.28	*0.35	*0.25
600	0.08	0.16	IN4005	0.09	0.16	0.33	*0.42	*1.76
800	0.11	0.18	IN4006	0.10	0.18	0.35	*0.51	*1.94
1000	0.13	0.28	IN4007	0.11	0.23	0.44	*0.60	*2.31
1200	—	0.32			0.28	0.54	*0.69	*2.88

* TRIACS

	Case	100V	200V	400V
2 Amp	TO5	0.31	0.51	0.71
6 Amp	TO66	0.51	0.61	0.77
10 Amp	TO48	0.77	0.92	1.12

SUPER UNTESTED PAKS

Pak No.	Description	Price
U 1	120 Glass Sumbmin. G.P. Germ. diodes	0.60
U 2	50 Mixed Germanium transistors AF/RF	0.60
U 3	75 Germ. gold bonded sub-min. like OA47	0.60
U 4	30 Germ. transistors like OC81, AC128	0.60
U5	60 200mA sub-min. silicon diodes	0.60
U 6	30 Sil. trans. NPN like BSY95A, 2N706	0.60
U 7	16 Sil. rect. 750mA up to 1000	0.60
U 8	50 Sil. diodes DO-7 250mA like OA200/202	0.60
U 9	20 Mixed voltages, 1 Watt Zener Diodes	0.60
U10	20 BAY50 charge storage diodes DO-7	0.60
U11	20 PNP Sil. trans. TO-5 like 2N1132, 2N2904	0.60
U13	30 PNP-NPN Sil. trans. OC200 & 2S104	0.60
U14	150 Mixed silicon and germ. diodes	0.60
U15	20 NPN Sil. trans. TO-5 like 2N696	0.60
U16	10 3Amp Sil. rect. stud up to 1000 PIV	0.60
U17	30 Germ. PNP AF trans TO-5 like ACY17-22	0.60
U18	8 6 Amp sil rect. BYZ13 tupe up to 600 PIV	0.60
U19	20 Silicon NPN trans. like BC108	0.60
U20	12 1.5 Amp sil. rect. top hat up to 1000 PIV	0.60
U21	30 AF. Germ. trans. 2G300 series & OC71	0.60
U23	25 MADT's like MHz series PNP series	0.60
U24	20 Germ. 1 Amp rect. GJM up to 300 PIV	0.60
U25	25 300MHZ NPN sil. trans. 2N708, BSY27	0.60
U26	30 Fast switching sil. diodes like IN914	0.60
U29	10 1 Amp SCR's TO-5 up to 600 PIV	*1.20
U32	25 Zener diodes 400mW DO-7 3-33 volts mixed	0.60
U33	15 Plastic 1Amp sil. rect. IN4000 series	0.60
U34	30 Sil. PNP trans. TO-5 BCY26 2S302/4	0.60
U35	25 Sil. trans. PNP TO-18 2N2906	0.60
U36	20 Sil NPN trans. TO-5 BFY50/51/52	0.60
U37	30 Sil. trans. SO-2 PNP OC200, wS322	0.60
U38	30 Fast switch sil. trans. NPN 400MHz	0.60
U39	30 RF Germ. PNP trans. 2N1301/5 TO-5	0.60
U40	10 Dual trans. 6 lead TO-5 2N2060	0.60
U43	25 Sil. trans. plastic TO-18 BC113/114	0.60
U44	20 Sil. trans. plastic TO-5 BC115	0.60
U45	7 3A SCR. TO66 up to 600 PIV	*1.20
U46	20 Unijunction trans. similar to TIS43	*0.60
U47	10 TO220AB plastic triacs 50V 6A	*1.20
U48	9 NPN sil. power trans. like 2N3055	1.20
U49	12 NPN sil. plastic power 60W like 2N5294	1.20

Code Nos. mentioned above are given as a guide to the type of device in the pak. The devices themselves are normally unmarked.

QUALITY TESTED PAKS

Pak No.		Price £ p
Q 1	20 Red spot transistors PNP	0.60
Q 2	16 White spot R.F. transostors PNP	0.60
Q 3	4 OC77 type transistors	0.60
Q 4	6 Matched transistors OC44/45/81/81D	0.60
Q 5	4 OC75 transistors	0.60
Q 6	5 OC72 transistors	0.60
Q 7	4 AC128 transistors PNP high gain	0.60
Q 8	4 AC126 transistors PNP	0.60
Q 9	7 OC81 type transistors	0.60
Q10	7 OC71 type transistors	0.60
Q11	2 AC127/128 Compmentary pairs PNP/NPN	0.60
Q12	3 AF116 type transistors	0.60
Q13	3 AF117 type transistors	0.60
Q14	3 OC171 H.F. type transistors	0.60
Q15	7 2N2926 Sil. Epoxy transistors mixed colours	0.60
Q17	5 NPN 2 x ST141 & 3 x ST140	0.60
Q18	4 MADT's 2 x MAT100 & 2 x MAT120	0.60
Q19	3 MAT's 2 x MAT101 & 1 x MAT121	0.60
Q20	4 OC44 Germanium transistors A.F.	0.60
Q21	4 AC127 NPN Germanium transistors	0.60
Q22	20 NKT transistors A.F. R.F. coded	0.60
Q23	10 OA202 Silicon diodes sub-min	0.60
Q24	8 OA81 diodes	0.60
Q25	15 IN914 Silicon diodes 75PIV 75mA	0.60
Q26	8 OA95 Germanium diodes sumb-min-IN59	0.60
Q27	2 10A 500 PIV Silicon rectifiers 1S425B	*0.60
Q28	2 Silicon power rectifiers BYZ13	*0.60
Q29	4 Sil transistors 2 x 2N696, 1 x 3N697, 1 x 2N698	0.60
Q30	7 Silicon switch transistors 2N706 NPN	0.60
Q31	6 Silicon switch transistors 2N708 NPN	0.60
Q32	3 PNP Sil. trans. 2 x 2N1131, 1 x 2N1132	0.60
Q33	3 Silicon NPN transistors 2N1711	0.60
Q34	7 Sil. NPN trans. 2N2369, 500MHz (Code P397)	0.60
Q35	3 Silicon PNP TO-5 2 x 2N2904 & 1 x 2N2905	0.60
Q36	7 2N3646 TO-18 plastic 300 MHz NPN	0.60
Q37	3 2N3053 NPN Silicon transistors	0.60
Q38	5 PNP transistors 3 x 2N3703, 2 x 2N3702	0.60
Q39	5 NPN transistors 3 x 2N3704, 2 x 2N3705	0.60
Q40	5 NPN transistors 3 x 2N3707, 2 x 2N3708	0.60
Q41	3 Plastic NPN TO18 2N3904	0.60
Q43	5 BC107 NPN transistors	0.60
Q44	5 NON transistors 3 x BC108, 2 x BC109	0.60
Q45	3 BC113 NPN TO-18 transistors	0.60
Q46	3 BC115 NPN TO-5 transistors	0.60
Q47	4 NPN high gain transistors 2 x BC167, 2 x BC168	0.60
Q48	3 BCY70 PNP transistors TO-18	0.60
Q49	3 NPN transistors 2 x BFY51, 1 x BFY52	0.60
Q50	7 BSY28 NPN switch transistors TO-18	0.60
Q51	7 BSY95A NPN transistors 300MHz	0.60
Q52	8 BY100 type silicon rectifiers	1.20
Q53	25 Sil. & Germ. trans., mixed all marked new	1.50
Q54	6 TIL209 Red LED	*1.20

UNTESTED TTL PAKS *

Pak no	Contents	Price
UIC00	= 12x7400	0.60
UIC01	= 12x7401	0.60
UIC02	= 12x7402	0.60
UIC03	= 12x7403	0.60
UIC04	= 12x7404	0.60
UIC05	= 12x7405	0.60
UIC06	= 8x7406	0.60
UIC07	= 8x7407	0.60
UIC10	= 12x7410	0.60
UIC13	= 8x7413	0.60
UIC20	= 12x7420	0.60
UIC30	= 12x7430	0.60
UIC40	= 12x7440	0.60
UIC41	= 5x7441	0.60
UIC42	= 5x7442	0.60
UIC43	= 5x7443	0.60
UIC44	= 5x7444	0.60
UIC45	= 5x7445	0.60
UIC46	= 5x7446	0.60
UIC47	= 5x7447	0.60
UIC48	= 5x7448	0.60
UIC50	= 12x7450	0.60
UIC51	= 12x7451	0.60
UIC53	= 12x7453	0.60
UIC54	= 12x7454	0.60
UIC60	= 12x7460	0.60
UIC70	= 8x7470	0.60
UIC72	= 8x7472	0.60
UIC73	= 8x7473	0.60
UIC74	= 8x7474	0.60
UIC75	= 8x7475	0.60
UIC76	= 8x7476	0.60
UIC80	= 5x7480	0.60
UIC81	= 5x7481	0.60
UIC82	= 5x7482	0.60
UIC83	= 5x7483	0.60
UIC86	= 5x7486	0.60
UIC90	= 5x7490	0.60
UIC91	= 5x7491	0.60
UIC92	= 5x7492	0.60
UIC93	= 5x7493	0.60
UIC94	= 5x7494	0.60
UIC95	= 5x7495	0.60
UIC96	= 5x7496	0.60
UIC100	= 5x74100	0.60
UIC121	= 5x74121	0.60
UIC141	= 5x74141	0.60
UIC151	= 5x74151	0.60
UIC154	= 5x74154	0.60
UIC193	= 5x74193	0.60
UIC199	= 5x74199	0.60
UIC X1	25 Assorted 74s	1.50

VOLTAGE REGULATORS

TO.3 Plastic Encapsulation

µA 7805/L129 5V (equiv. to MVR5V)	1.25
µA 7812/L130 12V (Equiv. to MVR12V)	1.25
uA 7815/L131 15V (Equiv. to MVR15V)	1.25
uA 7818 18V (Equiv. to MVR18V)	1.25

ALL PRICES EXCLUDE V.A.T.

Postage & packing add 20p overseas add extra for airmail.

Minimum order 75p

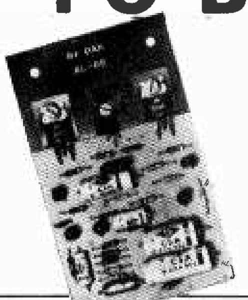
D.I.L. SOCKETS

	1	25	100+
TSO14 14 pin type	0.31	0.28	0.25
TSO16 16 pin type	0.35	0.32	0.30
TSO24 24 pin type	0.69	0.64	0.62
BPS8 8 pin type (low cost)	0.14	0.12	0.10
BPS14 14 pin type (low cost)	0.15	0.13	0.11
BPS16 16 pin type (low cost)	0.16	0.14	0.12

DIODES

Type	Price	Type	Price
AA119	0.08	BYZ16	0.41
AA120	0.08	BTZ17	0.36
AA129	0.08	BYZ18	0.36
AAY30	0.09	BYZ19	0.28
AAZ13	0.10	CG62	
BA100	0.10	(OA91Eq)	0.06
BA116	0.21	CG651	
BA126	0.22	(OA70-OA79)	
BA148	0.15		0.07
BA154	0.12	OA5 Short	
BA155	0.15	Leads	0.21
BA165	0.14	OA10	0.14
BA173	0.15	OA47	0.07
BB104	0.15	OA70	0.07
BY100	0.16	OA79	0.07
BY101	0.12	OA81	0.07
BY105	0.18	OA85	0.09
BY114	0.12	OA90	0.07
BY124	0.12	OA91	0.07
BY126	0.15	OA95	0.07
BY127	0.16	OA200	0.07
BY128	0.16	OA202	0.07
BY130	0.17	SD10	0.06
BY133	0.21	SD19	0.06
BY164	0.51	IN34	0.07
BYX38/30	0.43	IN34A	0.07
BYZ10	0.36	IN914	0.06
BYZ11	0.31	IN916	0.06
BYZ12	0.31	IN4148	0.06
BYZ13	0.26	IS021	0.10
		IS951	0.07

PO BOX 6 WARE HERTS



AL 60 ONLY £3.95

50w. PEAK (25w. R.M.S.)

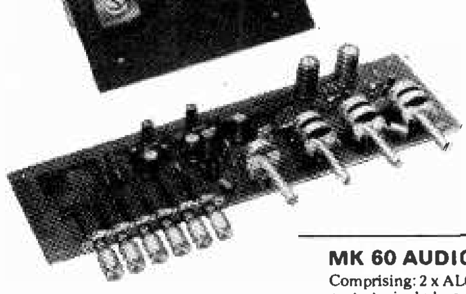
● Max Heat Sink temp 90°C ● Frequency Response 20Hz to 100K Hz ● Distortion better than 0.1 at 1KHz ● Supply voltage 15-50 volts ● Thermal Feedback ● Latest Design Improvements ● Load — 3, 4, 5 or 16 ohms ● Signal to noise ratio 80dH ● Overall size 63mm x 105mm x 13mm. Especially designed to a strict specification. Only the finest components have been used and the latest solid state circuitry incorporated in this powerful little amplifier which should satisfy the most critical A.F. enthusiast.

STABILISED POWER MODULE SPM80

SPM80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watt (r.m.s.) per channel simultaneously. This module embodies the latest components and circuit techniques incorporating complete short circuit protection. With the addition of the Mains Transformer BMT80, the unit will provide outputs of up to 1.5 amps at 35 volts. Size: 63mm x 105mm x 30mm.

These units enable you to build Audio Systems of the highest quality at a hitherto unobtainable price. Also ideal for many other applications including:—Disco Systems. Public Address Intercom Units, etc. Handbook available 10p.

TRANSFORMER BMT80 £2.60 **PRICE £3.00**



STEREO PRE-AMPLIFIER TYPE PA100

Built to a specification and NOT a price, and yet still the greatest value on the market, the PA100 stereo pre-amplifier has been conceived from the latest circuit techniques. Designed for use with the AL50 power amplifier system, this quality made unit incorporates no less than eight silicon planar transistors, two of these are specially selected low noise NPN devices for use in the input stages.

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

£13.20

MK 60 AUDIO KIT

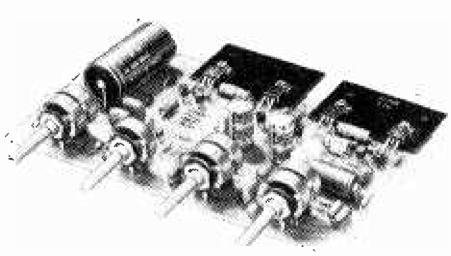
Comprising: 2 x AL60, 1 x SPM80, 1 x BTM80, 1 x PA100, 1 front panel, 1 kit of parts to include on-off switch, neon indicator, stereo headphone sockets plus instruction booklets.

COMPLETE PRICE: **£27.55** plus 45p postage.

TEAK 60 AUDIO KIT

Comprising: Teak veneered cabinet size 16¾" x 11½" x 3¾", other parts include aluminium chassis, heatsink and front panel bracket, plus back panel and appropriate sockets, etc.

KIT PRICE: **£9.20** plus 45p postage.



STEREO 30 COMPLETE AUDIO CHASSIS

7 + 7 WATTS R.M.S.

The Stereo 30 comprises a complete stereo pre-amplifier, power amplifiers and power supply. This with only the addition of a transformer or overwind, will produce a high quality audio unit suitable for use with a wide range of inputs, i.e. high quality ceramic pickup, stereo tuner, stereo tape deck, etc.

Simple to install, capable of producing really first-class results, this unit is supplied with full instructions, black front panel, knobs, mains switch, fuse & fuse holder and universal mounting bracket, enabling it to be installed in a record plinth, cabinets of your own construction or the cabinet available.

Ideal for the beginner or advanced constructor who requires Hi-Fi performance with a minimum of installation difficulty. Can be installed in 30 mins.

PRICE £15.75 Plus 45p postage & packing

TRANSFORMER £2.45 plus 45p postage & packing **TEAK CASE £3.65** plus 45p postage & packing

PLEASE ADD V.A.T. AT 25% TO ALL ITEMS EXCEPT
*** ADD 8%**
 # NO V.A.T.
GIRO NUMBER 388-7006

AL 10/AL 20/AL 30

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

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

AL10 £2.30, AL20 £2.65, AL30 £2.95

SPEAKERS

E.M.I. LEK 350 Loudspeakers Enclosure kit in teak veneer, including speakers. Rec. retail price £4.50 per pair.
OUR SPECIAL PRICE ONLY £27.75 per pair P&P £3
WHILE STOCKS LAST!

HEADPHONES

4-16 ohms impedance frequency response 20 to 20,000 Hz stereo/mono switch and Volume Control £4.55

FRONT PANEL

FOR PA100. Attractive matt silver. Finish with black trim and lettering. Adds that professional touch **£1.10 only.**

M.P.A.30

Enjoy the quality of a magnetic cartridge with your existing ceramic equipment using the new Bi-Pak M.P.A.30 which is a high quality pre-amplifier exist for the use of ceramic cartridges only.

Used in the construction are 4 low noise, high gain, silicon transistors and it is provided with a standard DIN input socket for ease of connection.

Supplied with full, easy to follow instructions.

PRICE £2.65

STORAGE-CARRY CASES

RECORD CASES
7 in E.P. 18 3/8th in. x 7 in x 8 in (50 records) *£2.48
12 in L.P. 13¾in x 7 3/8th in x 12¾ in (50 records) *£3.30

CASSETTE CASES
Holds 15. 10in x 3¾in x 5in. Lock and handle *£1.50

8-TRACK CARTRIDGE CASES
Holds 14. 13in x 5in x 6in. Lock and handle *£2.20
Holds 24. 13 3/8th in x 8 in x 5 3/8th in Lock and handle *£3.20

CARTRIDGES

ACOS	GP91-1SC	200mV at 1.2cms/sec	£1.11
	GP93-1	280mV at 1cm/sec	£1.43
	GP96-1	100mV at 1cm/sec	£2.31
TTC	J—2005	Crystal/Hi Output	£0.97
	J—2010C	Crystal/Hi Output	£1.11
		Compatible	£1.52
	J—2006S	Stereo/Hi Output	£1.81
	J—2105	Ceramic/Med Output	
	J—2203	Magnetic 5mV/5cm/sec	£4.78
		including stylus	£2.88
	J—22038	Replacement stylus for above	
	AT—55	Audio-technica magnetic cartridge 4mV/5cm/sec	£3.06

DYNAMIC MICROPHONE

TYPE B1223 200 ohms impedance. Complete with stand, on/off switch and 2.5mm and 3.5mm plugs. Suitable for cassette tape recorders.
PRICE £1.67

JUST OUT!

STEREO FM TUNER

WRITE *NOW* FOR FULL DETAILS

Appointments

Advertisements accepted up to 12 noon Tuesday, September 30th, for the November issue subject to space being available.

DISPLAYED APPOINTMENTS VACANT: £6.99 per single col. centimetre (min. 3cm).
LINE advertisements (run on): 99p per line (approx. 7 words), minimum three lines.
BOX NUMBERS: 40p extra. (Replies should be addressed to the Box numbers in the advertisement, c/o Wireless World, Dorset House, Stamford Street, London SE1 9LU).
PHONE: Allan Petters on 01-261 8508 or 01-261 8423.
Classified Advertisement Rates are currently zero rated for the purpose of V.A.T.

Quality Assurance & Test Engineers Product Support, Installation & Service Engineers

MEDICAL ELECTRONICS. RADAR. BROADCAST SYSTEMS.

At EMI Electronics Ltd., Hayes, we are in the forefront of electronics technology with a wide range of award winning projects. Increased demand for our products, particularly from overseas, means that we now need more engineers in the Quality Assurance and Test Departments of our major Divisions. The vacancies are:

Medical Systems

Junior and Senior positions ranging from trouble-shooting of logic circuitry, video displays, and electro-mechanical systems to design and development of advanced control circuitry. Also installation and service positions involving world-wide travel.

Radar and Equipment

Junior and Senior positions involving systems and unit test of advanced radar and automatic test equipment systems, fault diagnosis and building special to type test equipment. Product support positions involving design and development of conversions and modifications to radar and associated systems, defect investigation, and liaison with military users.

Sound and Vision Equipment

Functional testing of broadcast equipment including TV colour cameras, studio equipment, community TV amplifiers, and logic circuitry.

For this interesting and varied work we need engineers with qualifications from C & G to degree standard preferably with Test and Quality Assurance experience, but we would consider anyone with suitable qualifications and recent practical experience in similar areas.

We offer competitive salaries related to experience; a good Company Pension Scheme, 4 weeks holiday; a staff discount; subsidised lunches, but most of all, experience second to none in modern electronics systems with prospects of advancement either in Test/Quality Assurance or Development.

To apply contact J. Docherty, Personnel Department, EMI Limited, 135 Blyth Road, Hayes, Middlesex. Tel: 01-573 3888 Ext. 3016. (Or Record-a-Call any time on 01-573 5524).

EMI

The international music, electronics and leisure Group. 4916

CRANFIELD INSTITUTE OF TECHNOLOGY

has vacancies for a

TECHNICAL OFFICER and a TECHNICIAN

in the Environmental Sciences Research Unit to join a team concerned with all aspects of instrumentation and data recording in laboratory and site experiments. Current activities include measurement of engineering parameters: noise, vibration, turbulence, stress, temperature on industrial installations; and of meteorological variables: wind, humidity, radiation in field and laboratory environmental studies.

Salaries according to qualifications and experience within the University Technical Staffs salary grades, which are currently under review.

TECHNICAL OFFICER: Qualifications preferred H.N.C. or full C and G certificate in Electrical or Mechanical Engineering. Experience of strain gauge techniques would be an advantage. Salary grade 5 (£2439-£2895) p.a. or exceptionally, grade 6 (£2844-£3450) p.a.

TECHNICIAN: Appointment is initially limited to two years. Qualifications preferred O.N.C. or C and G technician certificate in electronic, electrical or mechanical engineering. Salary grade 4 (2247-£2628) p.a.

Application form from Staff Records Officer, Cranfield Institute of Technology, Cranfield, Bedford, MK43 0AL. For further information telephone or write to Guy West (Tel: Bedford 750111 ext. 570/1).

4956

Well-organised German enterprise working on the sector of loudspeaker chassis and accessories is looking for an

ACTIVE REPRESENTATIVE

with good contacts to manufacturers and relevant quarters of special commerce.

We supply loudspeaker chassis for all applications such as Hi-Fi, Ela, bass guitars, autocars, frequency converters; also fabrics for loud-speakers.

Please contact us quoting Box No. WW.

Opportunities in the

ELECTRONICS FIELD

Men with analogue or digital qualifications / experience seeking higher paid posts in: TEST - SERVICE - DESIGN - SALES.

Phone: Mike Gernat, Ref. W.W.

NEWMAN APPOINTMENTS
360 Oxford Street, W.1,
01-629 0501

(94)

Looking for a new job?

Perhaps we can help!

We have regular contact with hundreds of electronics and electrical companies needing qualified electronics engineers and technicians and TV service engineers.

We can, therefore, help you to find an interesting and well paid job. All you need to do is to return the coupon below or give us a ring. Our service is confidential and costs you nothing.

TJB Technical Services Bureau,
3A South Bar,
Banbury, Oxfordshire.
Banbury (0295) 53529

TJB

Technical Services Bureau is a division of Technical & Executive Personnel Ltd and is solely concerned with job placement in the Electronics and Electrical Industries

Please send me an "Application for Registration" form
NAME ....
ADDRESS ....
....
.... (4932)

AR
Acoustic Research
A TELEDYNE COMPANY

A SENIOR POSITION IN LOUDSPEAKER DESIGN

ACOUSTIC RESEARCH is an international manufacturer of high fidelity loudspeaker systems. The laboratories at the company's United Kingdom facility in Bedfordshire now undertake all the design work for AR's loudspeaker drive unit and loudspeaker system program of development.

The team at present undertaking this work requires the addition of a senior engineer with extensive experience in the above fields. The person we are looking for will be capable of carrying full responsibility for design projects from conception to a finalised product. He will be a person with an innovative approach for design work and with a keen interest in making significant improvements in sound reproduction in the home.

The laboratory at Houghton Regis is well equipped to aid him in this work with a large and unusually versatile anechoic chamber together with a newly completed large reverberation chamber.

The company operates a free life assurance plan and contributory pension scheme.

Please reply in writing giving brief details of career to date to:

AR
Acoustic Research
A TELEDYNE COMPANY

TIM HOLL
Director of Acoustics
Acoustic Research
International
High Street
Houghton Regis
Dunstable
Bedfordshire

4958

MILITARY MANPACK DESIGN ENGINEERS

for Spain

Engineers with good experience of fully synthesised transmitter-receivers for military applications in the MF band are required by NORTRON of Spain.

The posts are suitable for graduates with not less than 4 years of experience in this field, and command excellent salaries. Full relocation expenses will be met by the Company.

Please send comprehensive curriculum vitae to:

NORTRON, Fernando el Católico 63, Mádrid 15, Spain. Attention of the Engineering Manager, and state phone number and suitable hours to be contacted.

(4924

ELECTRONIC ENGINEERING STAFF

TWO ELECTRONIC ENGINEERS

are required by EMI Electronics, Electron Tube Division, Ruislip, Middx.

The first vacancy exists for an electronics engineer to assist the photomultiplier group. He will ensure that the production test gear performs satisfactorily and will also assist the photomultiplier development group to set up experiments and specialised equipment. He will be responsible for supervising a trainee. The post involves looking after advanced equipment including a minicomputer, with one of the major suppliers of electro-optical components in this country.

The second vacancy exists in the Equipment Section for an electronics engineer to undertake electronic equipment design and subsequent development through to small scale production. The equipment may incorporate photo-electric devices and it would be necessary for him to investigate some of the mechanical, thermal and optical aspects of the design.

The candidates should preferably have an Honours Degree but applicants with other qualifications and some experience would be considered.

Personal interviews arranged by telephone at a time to suit your convenience or call for immediate interview 9 a.m. - 11 a.m. or 2 p.m. - 4 p.m.

Telephone Mrs. E. A. Crossman, Personnel Department, EMI Electronics Ltd., Bury Street, Ruislip, Middx. Ruislip 30771.

4954

Technical Author

c. £3,600 London, SE1

A Technical Author is required to join a small team of authors in the Development Department of Cable and Wireless Limited (location: Southwark, between Waterloo and London Bridge). Current involvements include message switching systems (telegraph), telex, data communications and airport traffic control equipment.

The successful applicant would be responsible for compiling Customer handbooks and must therefore combine a good electronic engineering background with the ability to interpret circuit diagrams, and to transfer the information into a logical and readable form, in lucid English. A knowledge of logic and linear circuitry and previous experience of technical writing are essential.

Qualifications should be preferably HNC (Electronics) or City and Guilds Final Telecom. Technicians Certificate standard, but other applicants will be considered if their experience is suitable. Starting pay around £3650 per annum according to qualifications and experience, on career salary scale.

Please write or telephone for application form to:

CABLE & WIRELESS

Personnel Officer (Recruitment),
Cable and Wireless Limited,
Dept. A31/417,
Theobalds Road,
LONDON, W.C.1.
01-242 4433 Extn. 211

4948

SOUND SYSTEMS ENGINEER

for Spain

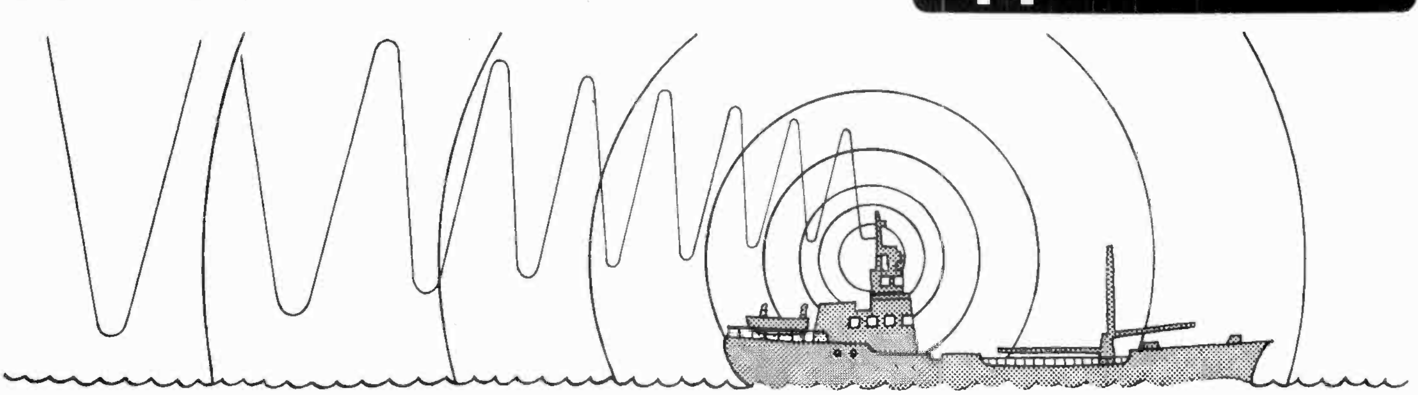
NORTRON, the leading Spanish designers and manufacturers of TV, FM and Sound Broadcasting equipment, require a SYSTEMS ENGINEER with not less than 4 years' experience in multichannel Mixer Desks and with good knowledge of the Broadcasting industry.

The post is based in Madrid, Spain, and attracts a substantial salary and full relocation expenses.

Please apply in writing sending comprehensive resume of career to:

NORTRON, Fernando el Católico 63, Madrid 15, Spain. Attention of the Engineering Manager, and state phone number and suitable times to be contacted.

(4925)



Radio Officers–now you can enjoy the comforts of home.

Working for the Post Office Maritime Services really makes sense. You still do the work that interests you, but with all the advantages of a shore-based job: more time to enjoy home life, job security and good money. To qualify, you need a United Kingdom Maritime Radiocommunication Operator's General Certificate or First Class Certificate of competence in Radiotelegraphy, or an equivalent certificate issued by a Commonwealth Administration or the Irish Republic.

Starting salaries, at 25 or over, are £2905 rising to £3704 after three years service. Between 19 and 24, the starting salary varies from £2234 to £2627 according to age. You'll also receive an allowance for shift duties which at the maximum of the scale averages £900 a year and there are opportunities to earn overtime. There's a good pension scheme, sick pay benefits and prospects of promotion to senior management.

Right now we have vacancies at some of our coastal radio stations, so if you're 19 or over, write to: ETE Maritime Radio Services Division (R/B/10), ET 17.1.1.2., Room 643, Union House, St. Martins-le-Grand, London EC1A 1AR.

Post Office Telecommunications

93

ELECTRONIC ENGINEERS

Applications are always invited from Engineers with a background of test and R and D. Bias to Avionics systems.

Technical Reserves
362 Euston Road
London, NW1
Tel: 388 1609

(4944)

MEDICAL ELECTRONICS

Technician/Academic (non-tutorial). Salary not less than £2,511 rising possibly to £6,050, plus London Weighting.

Applications invited from graduates preferably with industrial experience, to work in new Medical, School & Teaching Hospital as part of team evaluating drugs under laboratory and clinical conditions. Successful applicant to operate and maintain wide range of electronic monitoring equipment including colour TV. **Research interest in design fields encouraged.**

Apply: The Secretary, Dept. of Pharmacology, Charing Cross Hospital Medical School, Brandenburgh House, Fulham Palace Road, London, W6 9HH.

(4927)

Opportunities for
Electronics Engineers

To change to wider fields of electronics – join the EMI Service Team at Hayes.

Vacancies exist on repair and calibration of a wide range of electronic test gear including oscilloscopes, DVMs, pulse generators, power supplies etc.

Also

Servicing and commissioning closed circuit television equipment including cameras, VTRs, Monitors etc.

Applicants should have at least 5 years practical experience.

These positions offer varied and interesting work. Attractive starting salaries, subsidised lunches, 4 weeks holiday and excellent sick pay and pension schemes.

For further details telephone or write to:- M. Ford, 01-573 3888, Ext. 2167, EMI Service, 254 Blyth Road, Hayes, Middlesex.

EMI

The international music, electronics and leisure Group.

(4926

British Relay

Communication and Call Systems - Speech and Visual

We are acquiring an increasing volume of business in this field including many very long term contracts, and we are seeking to expand the range of our activities. Consequently, we have immediate requirements for engineers with good practical experience and ability in any of the following aspects of the work:—

System Design
Planning and Estimating
Project Control
Installation Supervision
Test and Commissioning

Duties are varied and interesting, with frequent opportunities for travel, and for acquiring experience in new fields. Enquiries and application for interviews will be treated in strict confidence, and should be sent to:—

BRITISH RELAY TV

The General Manager,
British Relay
(Electronics) Limited,
41 Streatham High Road,
London SW16 1EP
Tel. 01-677 9681.

(4937)

ELECTRONIC DEVELOPMENT ENGINEER

Do you have an H.N.C. Technician's qualification?
Have you obtained a five-year apprenticeship and mechanical experience?
Are you interested in joining a "high-powered" team?
If so, we have the job for you —

Our Research and Development staff need an engineer to assist in the design and development of high power electronic X-ray supplies (including the redesigning of conventional X-ray power supplies), test equipment and general laboratory duties.
The engineer must be able to work under minimum supervision and high voltage engineering and transformer design would be an advantage to applicants. This is a senior staff position and carries an appropriate salary level.

If you would like an interview, please contact:

The Personnel Officer
Pantak (EMI) Ltd.
Vale Road
Windsor
SL4 5JP
Telephone: Windsor 60306

4946

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

ELECTRONICS TECHNICIAN

Applications are invited for a post in the Department of Engineering Production. Duties include the setting up and maintenance of a range of instrumentation for experimental work in the Department's laboratories. The person appointed would be expected to give assistance to projects in the form of development and construction of electronic equipment and devices. There would be an opportunity to gain experience in the fields of control engineering, numerically controlled machine tools, and application of computers in Production Engineering.

Education to ONC/OND or City and Guilds Intermediate Certificate standard and experience, including apprenticeship, of at least ten years required.

Salary on Grade 5 scale: £2,439-£2,895 per annum.

Applications in writing or by telephone for application form to: **Administrative Officer, Department of Engineering Production, University of Technology, Ashby Road, Loughborough, Leics., LE11 3TU. Telephone Loughborough 63171, ext. 323.**

(4935)

DESIGNERS ABOUT TOWN

We have posts based in LONDON & H. COUNTIES at all levels from fresh Graduate to Section Leader with Clients expanding their Design Departments.

Expensive city? Look at the compensations: many salaries are over £5000 p.a. All posts offer stability + career prospects. Ring/write now. Ref. WW9.

NEWMAN APPOINTMENTS (TECHNICAL)
360 Oxford St., W.1
01-629 0501

4947

ROYAL HOLLOWAY COLLEGE
(University of London)
Egham Hill, Egham, Surrey

LANGUAGE LABORATORY TECHNICIAN

Experienced Language Laboratory Technician required. Salary on scale £2013-£2343 or £2247-£2628 plus £260 London Allowance, according to age and experience. Applications stating training and experience, together with the names and addresses of two referees should be sent to the Personnel Officer (WW) as soon as possible, from whom further details may be obtained.

(4920

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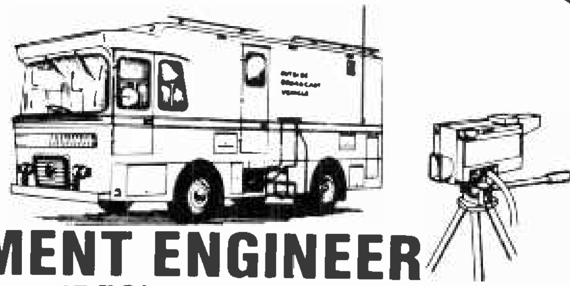

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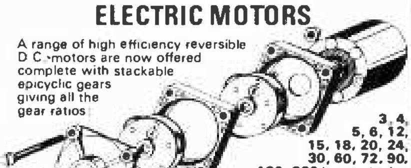

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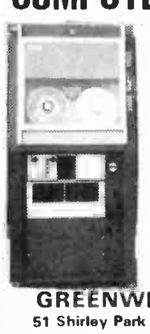

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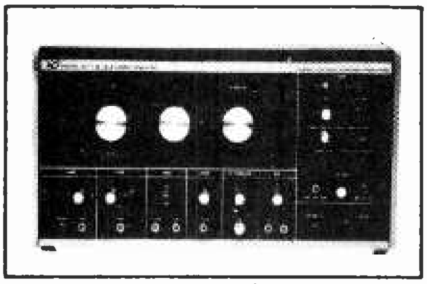

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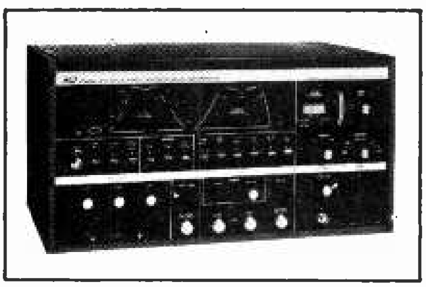

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2.0µF	50.8	25.4	£1.44	22µF	£4.28	£3.68	£3.06

TANTALUM BEAD CAPACITORS — Values available: 0.1, 0.22, 0.47, 1.0, 2.2, 4.8, 6.8µF at 15V/25V or 35V; 10µF at 16V/20V or 25V; 22.0µF at 6V or 16V; 33.0µF at 6V or 10V; 47.0µF at 3V or 6V; 100.0µF at 3V. ALL at 10p each, 10 for 95p, 50 for £4.

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AC128	14p	BC213/213L	11p	BF173	24p
BC107/8/9	9p	BC214/214L	11p	BF178	26p
BC114	12p	BC267	12p	BF184	22p
BC147/8/9	10p	BC268A/384	10p	BF194/BF195	12p
BC153/7/8	12p	BC547/558A	12p	BF196/BF197	13p
BC182/182L	11p	BCY72	12p	BF200	27p
BC183/183L	11p	BD131	39p	BF262/BF263	60p
BC184/184L	12p	BD132	39p	BFY50/51/52	20p
BC212/212L	14p	BF115/BF167	22p	BR101	41p
GET872	25p	2N2926Y	11p	TIP30A	52p
OC44/OC45	14p	2N3054	65p	TIP31A	55p
OC71	12p	2N3055	50p	TIP32A	64p
2N2926G	12p	2N3702/		TIP3055	55p
2N2926O	11p	2N3704	11p	MPU131	40p
TAA611B	£1.50	SN76013ND	£1.50	ZN414	£1.15

POPULAR DIODES—1N914 6p, 8 for 45p, 18 for 90p; 1N916 8p, 6 for 45p, 14 for 90p; 1S44 5p, 11 for 50p, 24 for £1.00; 1N4148 5p, 6 for 27p, 12 for 48p; 1N4001 5½p; 002 6p; 003 6½p; 004 7p; 006 8p; 007 8½p.

LOW PRICE ZENER DIODES—400MW. Tol. ±5% at 5mA. Values available: 3V, 3.3V, 3.6V, 4.7V, 5.1V, 5.6V, 6.2V, 6.8V, 7.5V, 8.2V, 9.1V, 10V, 11V, 12V, 13V, 13.5V, 15V, 16V, 18V, 20V, 22V, 24V, 27V, 30V. All at 7p each; 5 for 33p; 10 for 65p. SPECIAL OFFER: 100 Zeners for £6.00.

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FN	70	24	20	68	£17.00
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★ Racal S.S.B. Transmitter Receiver 3/12 m/cs 10w	P.U.R.
★ Racal 1KW S.S.B. Linear amplifiers 1.5/30 m/cs	P.U.R.
★ Advance H1 Signal Generators. 15/50Kcs	£18.00
★ Co-ax. Attenuators 2 to 50dB	£3.00
★ Varian VA175EA Backward Wave Oscillators	P.U.R.
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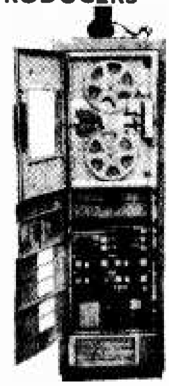

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Ersin Multicore– the international solder

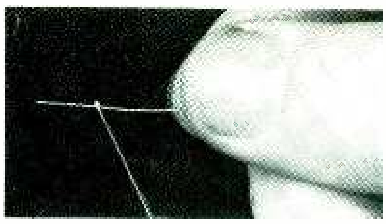
Ersin Multicore 5-Core Solder

The proved superiority of ERSIN Multicore Solder for over thirty years is due to many factors. We have specialised throughout this period in the manufacture of cored solders. Consequently our research and manufacturing staff have been able to devote all their energies to the development of Multicore Solders. All alloys are of highest purity, carefully formulated and checked.

Our unsurpassed ERSIN flux is rigorously tested before and after it is incorporated in the solder wire. Our five separate cores of flux ensure flux continuity, leave only an ultra-thin layer of solder separating flux from work for instant wetting and provide a more accurate ratio of flux to solder. It is therefore possible to use less solder and obtain greater reliability.

Our Quality Control at all stages of manufacture is guaranteed and recorded by the batch number on every reel.

Needle fine gauges



In addition to our standard range of wire diameters (10-22 swg: 3.2-0.7 mm) supplied on 2½ kg and ½ kg reels we also mass-produce needle-fine gauges (24-34 swg: 0.56-0.23 mm) on 250 g reels for microminiature soldering applications—still with 5 Cores of flux.

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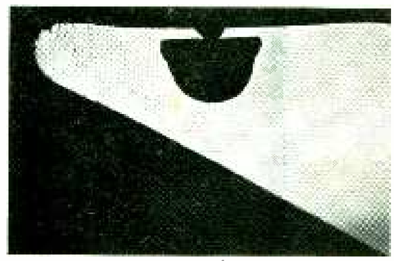
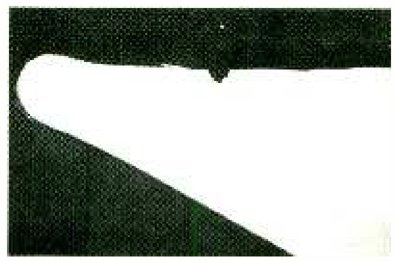
One of our most popular special ERSIN Multicore Solder alloys is SAVBIT alloy. Compared with ordinary tin/lead solders it dramatically reduces the erosion of soldering iron bits, copper wires and printed circuit conductors. It also saves costs and increases reliability. SAVBIT alloy containing 5-Cores ERSIN 362 flux has received special Ministry approval—under DTD. 900/4535 for Military applications.



Sectioned iron-plated bit, after 40,000 simulated operations using 60/40 Solder.



Sectioned iron-plated bit, after 40,000 simulated operations using SAVBIT Solder.

ALLOY

Composition (nominal major elements)	Grade	Melting Temperature Solidus °C	Melting Temperature Liquidus °C	Specification
50/33/17 Sn/Pb/Cd	TLC	145	145	DIN 1707
62/36/2 Sn/Pb/Ag	LMP	179	179	DIN 1707
62/35.7/2/0.3 Sn/Pb/Ag/Sb	Sn62	179	179	QQ-S-57 1E
63/36.7/0.3 Sn/Pb/Sb	Sn63	183	183	QQ-S-57 1E
60/40 Sn/Pb	K	183	188	B.S. 219
60/39.7/0.3 Sn/Pb/Sb	Sn60	183	188	QQ-S-57 1E
50/50 Sn/Pb	F	183	212	B.S.219
50/49.7/0.3 Sn/Pb/Sb	Sn50	183	212	QQ-S-57 1E
50/48.5/1.5 Sn/Pb/Cu	Savbit 1	183	215	DTD 900/4535 DIN 1707
45/55 Sn/Pb	R	183	224	B.S.219
40/60 Sn/Pb	G	183	234	B.S.219
40/59.7/0.3 Sn/Pb/Sb	Sn40	183	234	QQ-S-57 1E
30/70 Sn/Pb	J	183	255	B.S.219
20/80 Sn/Pb	V	183	275	B.S.219
15/85 Sn/Pb	—	225	290	—
Pure Tin	P.T.	232	232	B.S.3252
95/5 Sn/Sb	95A	236	243	B.S.219
5/93.5/1.5 Sn/Pb/Ag	H.M.P.	296	301	B.S.219

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