wireless world

FEBRUARY 1978 40p

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This tuner must surely provide the best value for money available today. Combining the best of the modules shown below, it includes a full digital readout of frequency to a resolution of 0.1 MHz, so that exact station identification can be made. In addition, six pre-set stations may be selected by touch controls having internal solid state lamps, while manual tuning allows easy searching for distant stations under the guidance of the digital meter.

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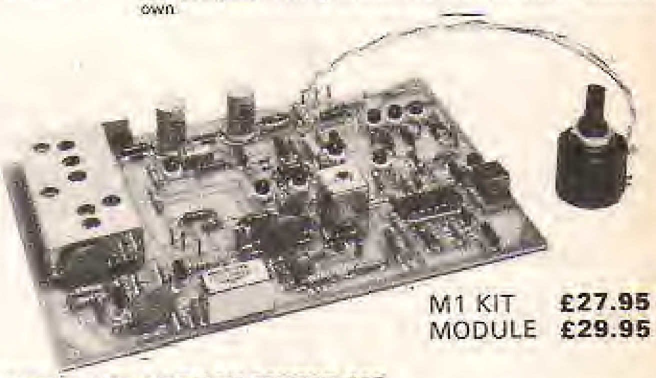

M1 KIT £27.95
MODULE £29.95

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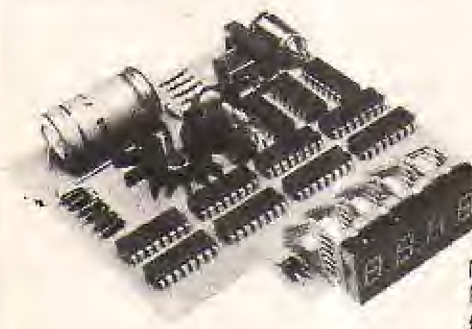

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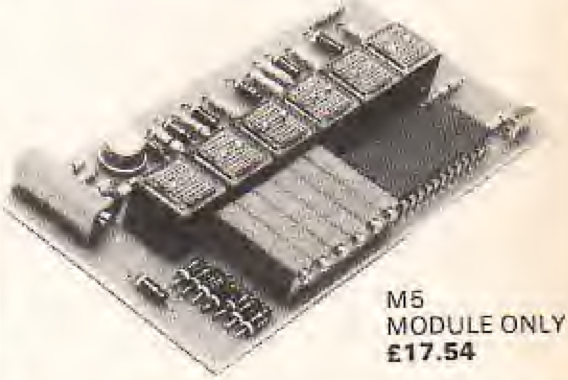

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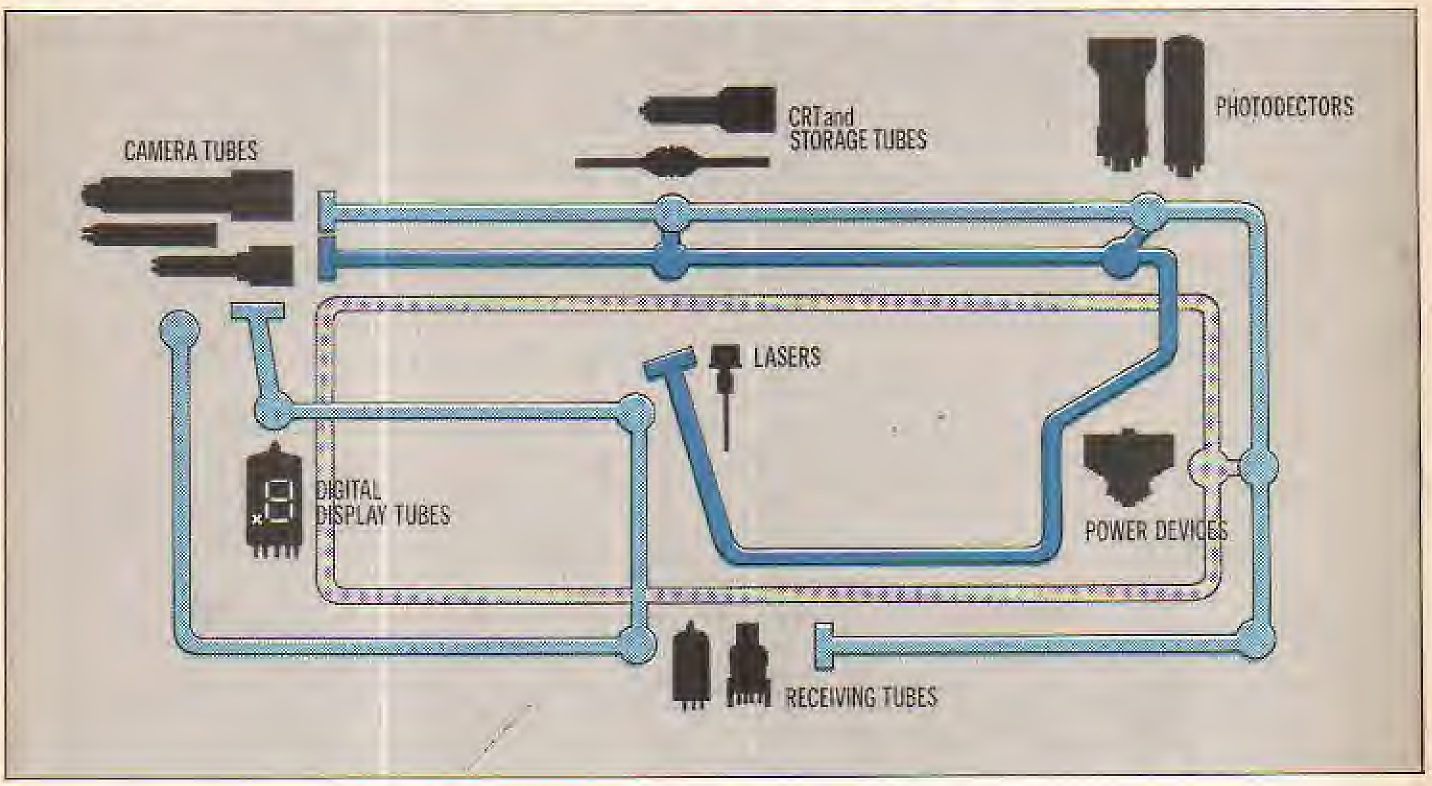
The Industrial Tube Guide



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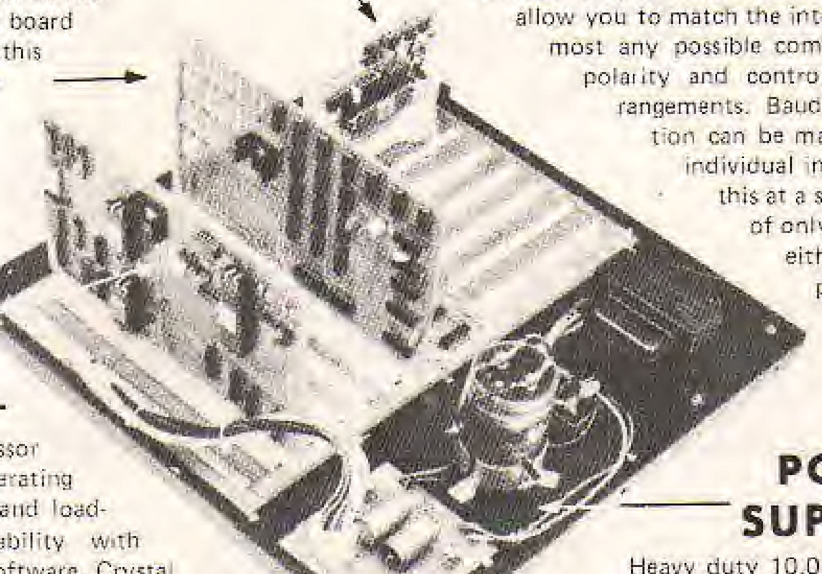

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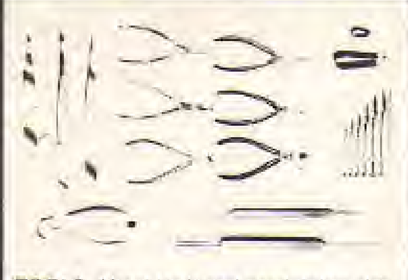

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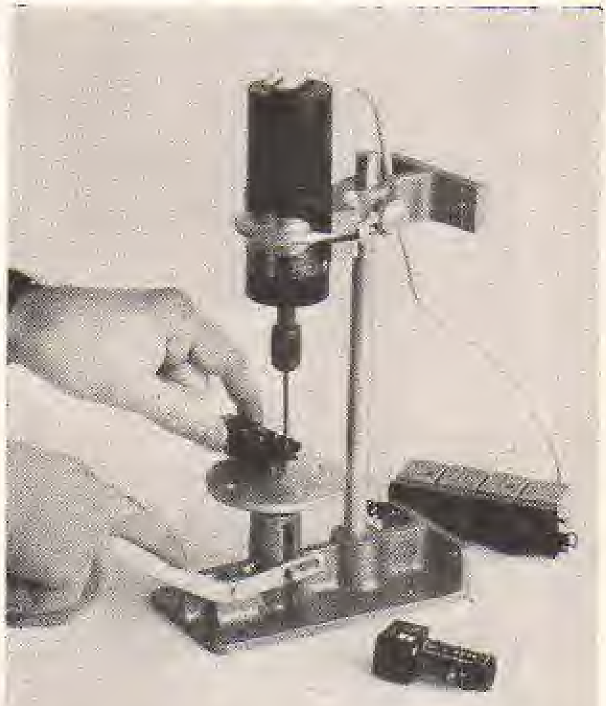

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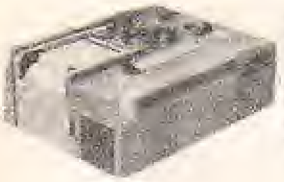

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Five-pen recorders: 50mm

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Chart drive: 200-250V 50Hz
Recording: Syphon pen directly attached to moving coil frames. Curvilinear co-ordinates.
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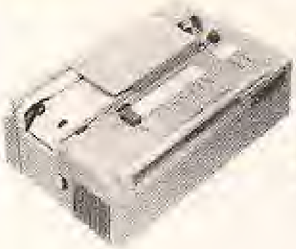

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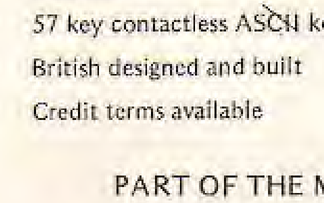

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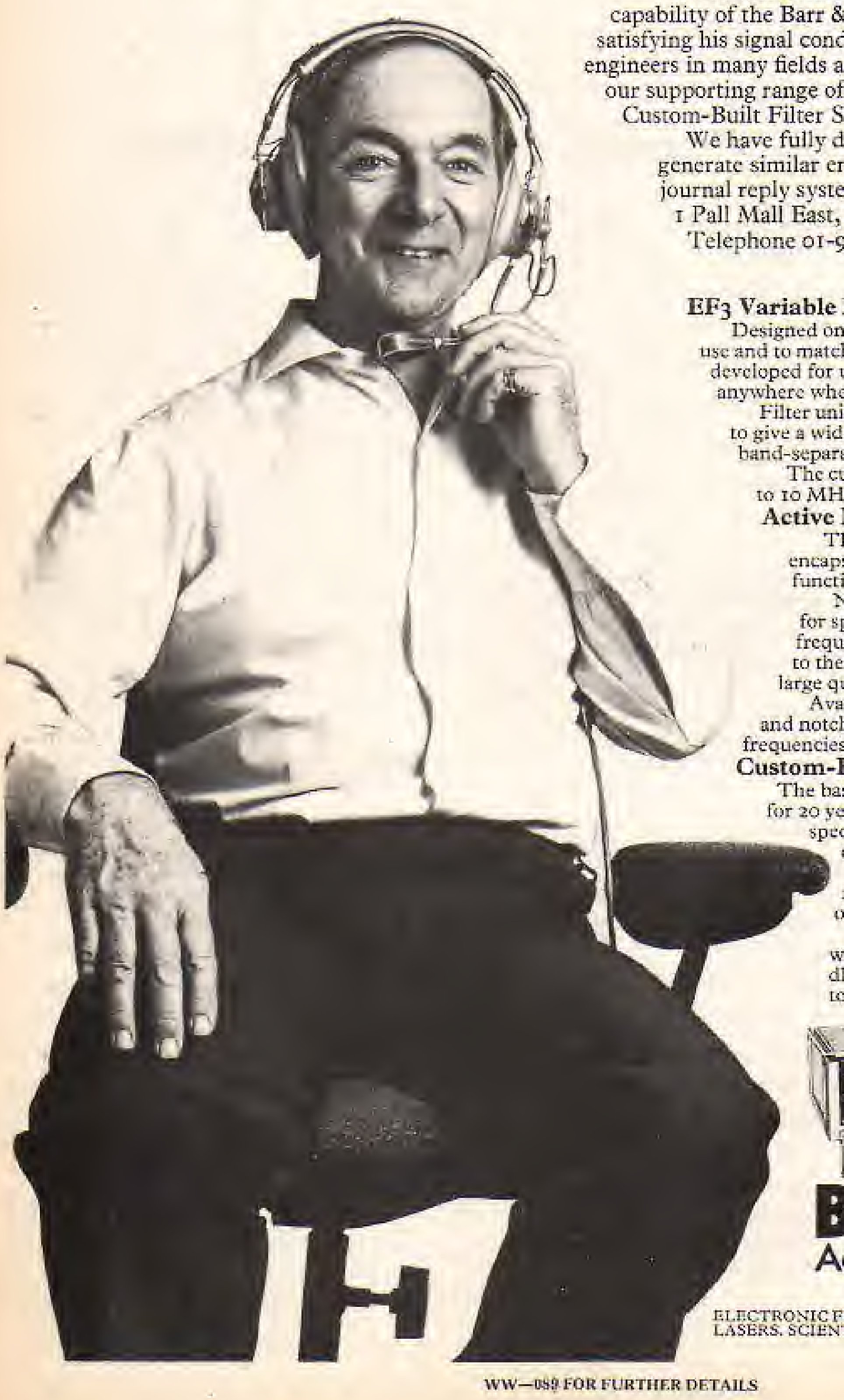
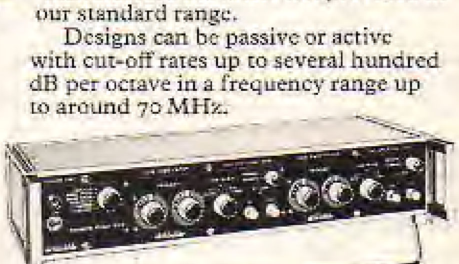




wireless world

Viewdata needs encouragement

DURING THE coming months Viewdata, the Post Office's experimental information system, will be undergoing market trials, and by this time next year we may be getting some idea of the extent and nature of the demand for such a service. One thing is certain. There's no use in waiting hopefully for as yet unknown applications to reveal themselves magically like buds responding to the sun. Viewdata is a new type of service and it has got to be sold. From an engineering and economic point of view it is obviously a good system, giving greater utilisation of the existing public telephone network by means of established television and computer technology, but this alone will not impress the man who has to pay the bill. It will be a great pity if Viewdata does not attract sufficient demand to make it a commercial success. If the Post Office is left in sole charge of it there is a strong chance it will not.

This is not to criticize the able Post Office executives who have the marketing job to do, but the nature of the organization itself. The Post Office is a public corporation that is also a monopoly. However great its capital resources, however competent its engineering and skilful its marketing, it will always lack one vital element — an awareness of the possibility of failure. By definition it cannot fail because, whatever it does, there is no other comparable organization against which to measure its performance (cf. the BBC before the arrival of independent broadcasting). In principle it is accountable to the public, but this only means explaining aloofly what profits or losses are made on the basis of charges it fixes for itself. In the event of losses the people concerned are unlikely to lose their jobs or reputations or suffer a reduction of income.

Last year the National Association of Radio Communication Services issued a manifesto declaring that the Post Office should not monopolise the very services that stimulate the use of the telecommunications network if these services can be provided as cheaply and as efficiently by private industry. It listed nine areas of activity and services including Viewdata, car radiotelephones, radio paging, facsimile and conference television, and claimed that private companies could have provided some of them far earlier than the Post Office has and at competitive prices. It also asserted that the monopoly "has been self defeating in that the Post Office has lost revenue from the lack of expansion of these services."

There is much good sense in these claims, even if some of the facts are in dispute, and NARCS's call for an Act of Parliament to remove the Post Office's monopoly powers deserves the support of everyone who wants to see our communication services developed fully and effectively. As for Viewdata in particular, there is no reason why such a service should not be run by competing private operators using the Post Office network and with nationally agreed technical standards but with their own data bases, computers, software and competing types of service. At such an early stage it is still not too late for the Government to allow at least an experiment with private operation, without necessarily affecting the Post Office's monopoly in any formal sense. If the experiment failed the losses would be borne by private investors, who are prepared for financial risks, and not by the taxpayer.

A basic radio telescope

Portable two aerial system for detecting the sun, milky way, and sources beyond the solar system.

by J. R. Smith

This radio telescope is a general purpose instrument that can be used for demonstration purposes, or adapted for specific observations as required. The units making up the receiver, excluding the pen recorder, can be carried in a briefcase and two aerials can be folded to pack on a car roofrack.

THE BASIC system operates as a phase-switched interferometer between 160 and 190 MHz where a clear space in the band can be found. It can also be used in the full power, Dicke, drift interferometer and beam switching systems which are described separately. Components preceding the i.f. amplifier can be replaced for operation on other frequencies as required. The instrument consists of several self-contained blocks which can be adapted for specific experiments. A single positive 12V supply is used to simplify portable operation, and a car battery will provide a stable supply voltage for two or three weeks. The total load current is about 55mA.

Both aerials were designed for 178MHz, although at present they are being used at 182MHz. In each aerial the reflector surfaces are of a cylindrical parabolic form consisting of parallel plastic-covered steel wires spaced at approximately 0.1 of a wavelength as shown in Fig. 1. Four flat panels of the reflector are placed to within 0.1λ of a parabola where $y = x^2/1.68$ m.

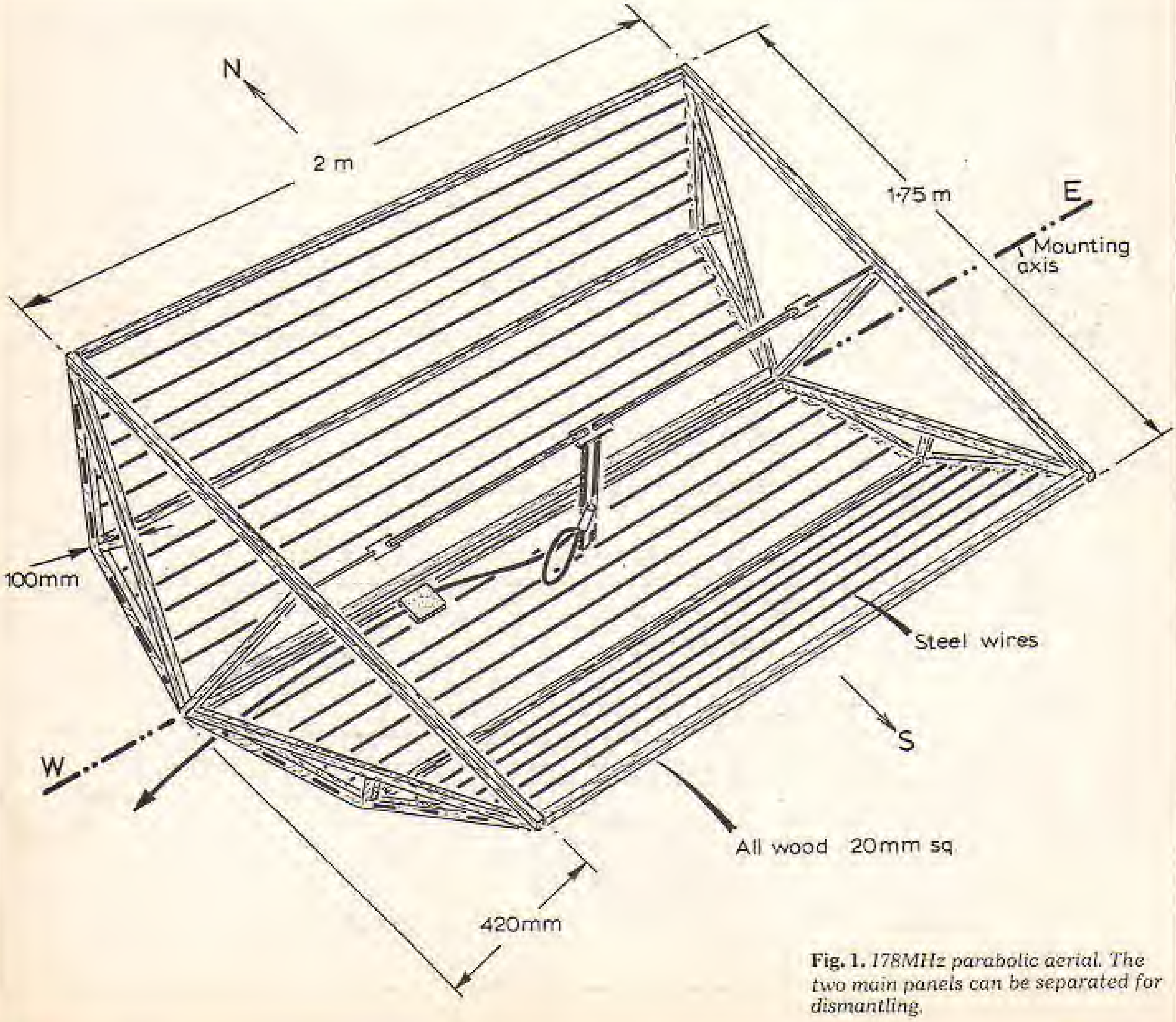


Fig. 1. *178MHz parabolic aerial. The two main panels can be separated for dismantling.*

R.f. switching is performed by series diodes as shown in Fig. 2. The coaxial plug arrangement permits the switch to be used as a selector between two signal inputs, or by the addition of a λ/2 length of coaxial cable, as a phase reversing switch. The two-pole, four-way switch permits phase reversal of the switching square wave, or locking of the diodes to assist in tuning and testing the complete system.

The aerial amplifiers in Fig. 3 are located as close to the aerials as possible to avoid degradation of the signal. A dual gate m.o.s.f.e.t. which is equivalent to a cascoded pair of transistors is used, and is resistant to cross modulation. Because these devices are susceptible to damage by voltage surges the input and output transformers are double wound and a zener diode is placed across the

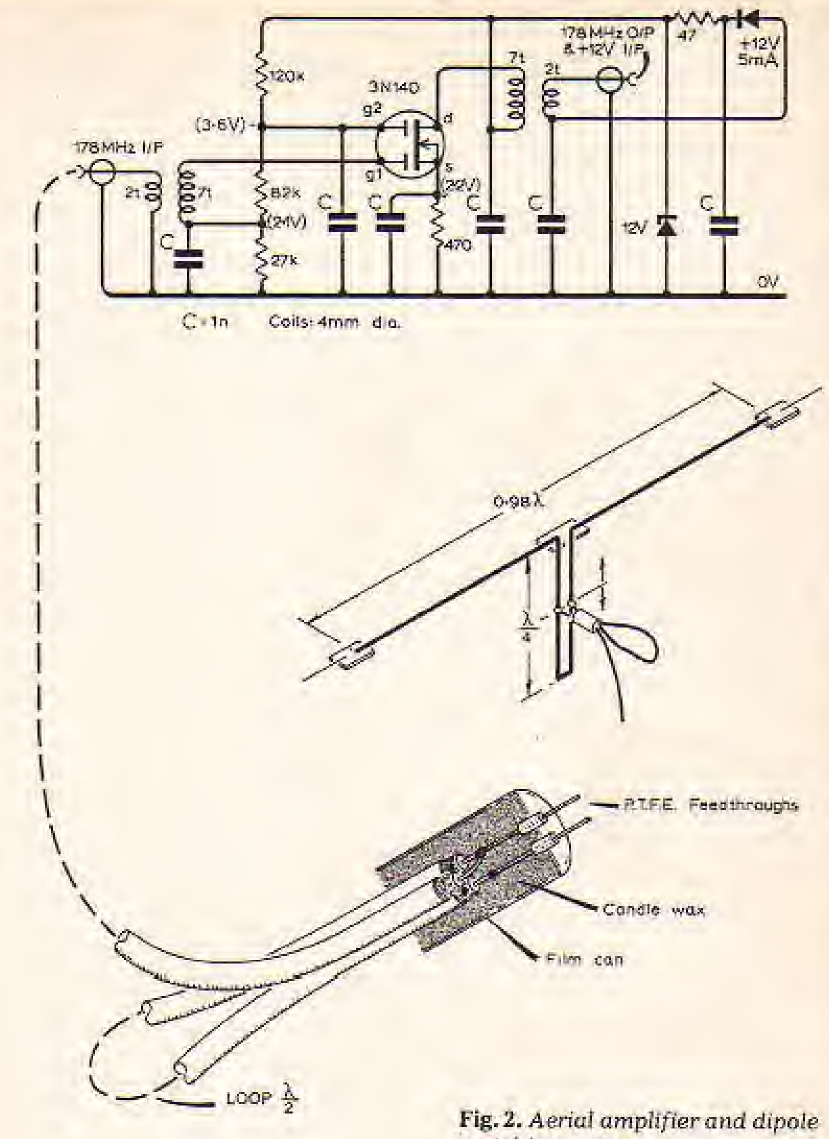


Fig. 2. *Aerial amplifier and dipole matching system.*

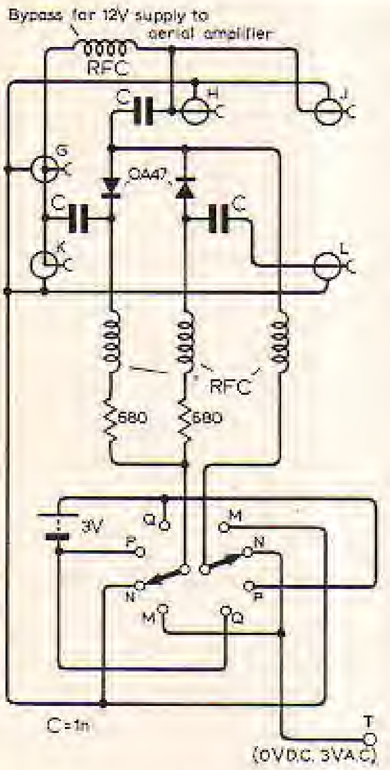
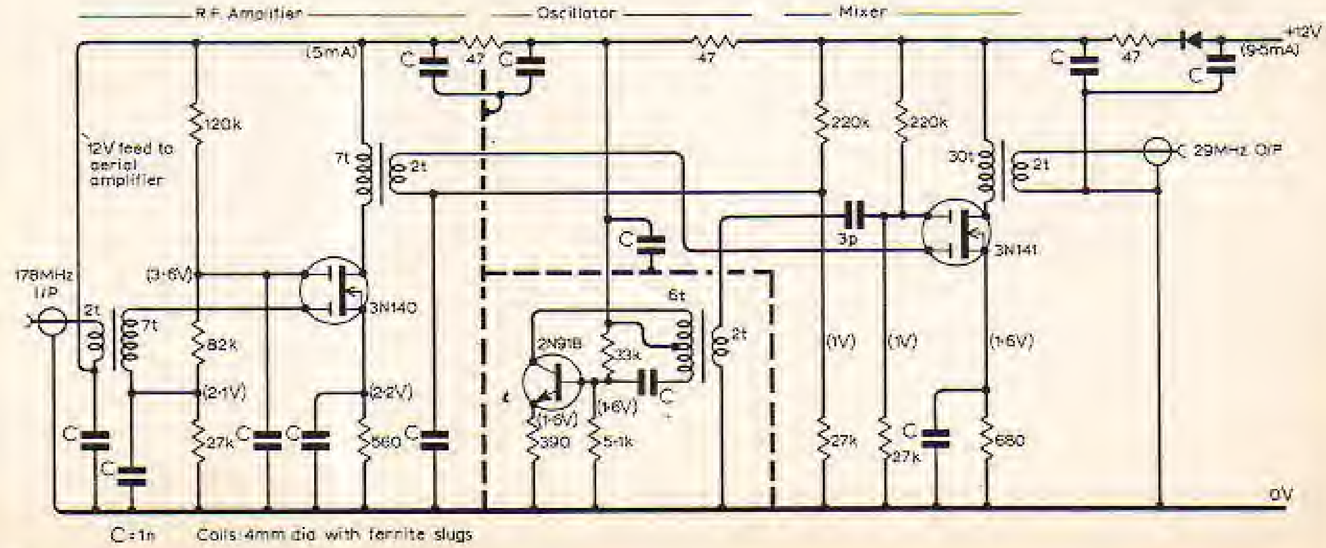


Fig. 3. *Aerial switch.*

Fig. 4. *R.f. amplifier, oscillator and mixer.*



supply. A series diode protects the f.e.t. from reverse voltages.

The r.f. section in Fig. 4 is similar to the aerial amplifiers. A separate oscillator is used in the frequency changer, and mixing is performed by a dual gate m.o.s.f.e.t. Although a radio telescope for general purposes should have the widest bandwidth possible, it is difficult to find a clear space in the band. For this reason a narrow band filter consisting of three well-isolated parallel LC tuned circuits is used as shown in Fig. 5. Coupling is by capacitors of about 0.2pF made from two short pieces of wire twisted together. A single transistor amplifier is included to partly compensate for the insertion loss. The bandwidth is about 0.5MHz and the net

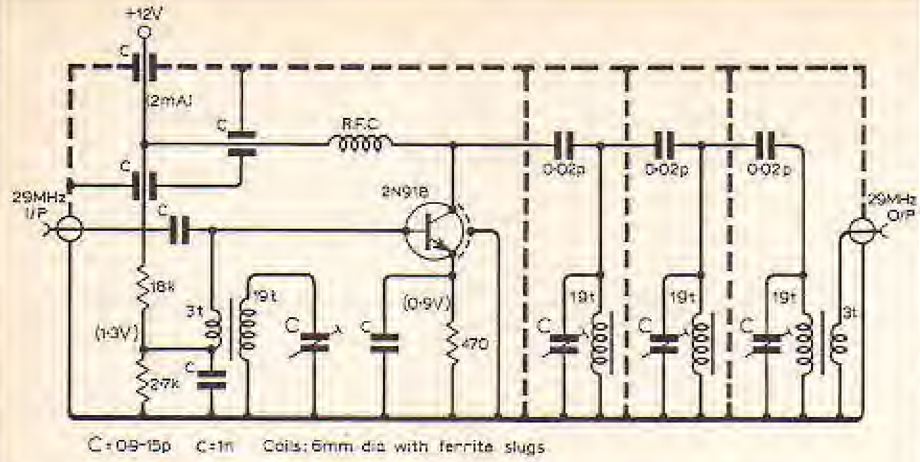


Fig. 5. *Narrow band i.f. filter.*

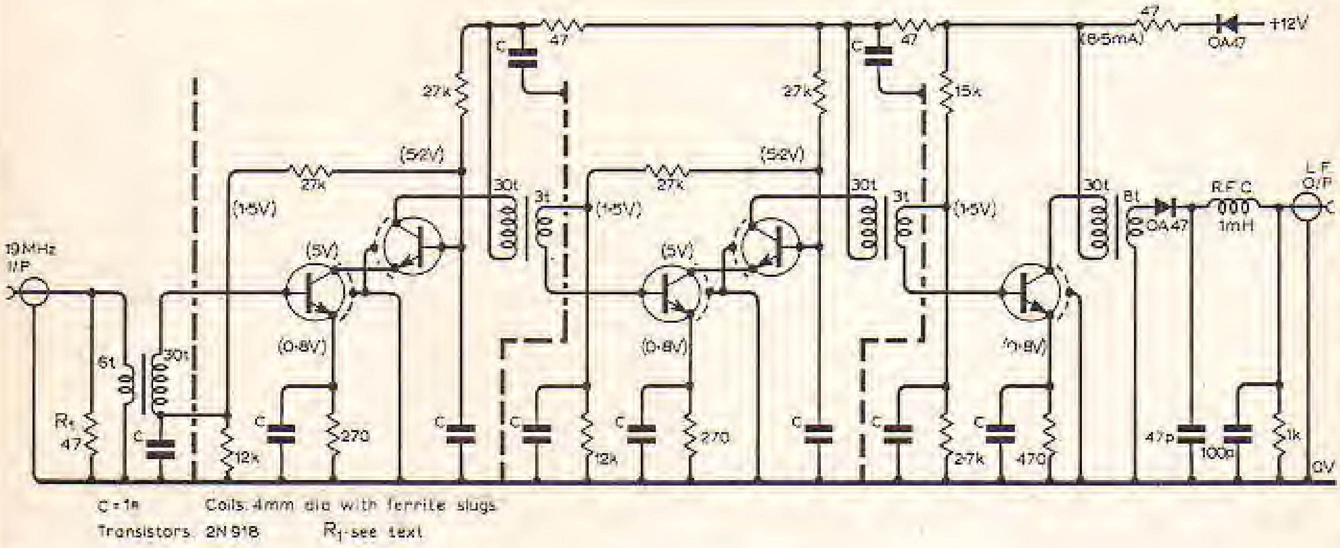


Fig. 6. *I.f. amplifier and detector.*

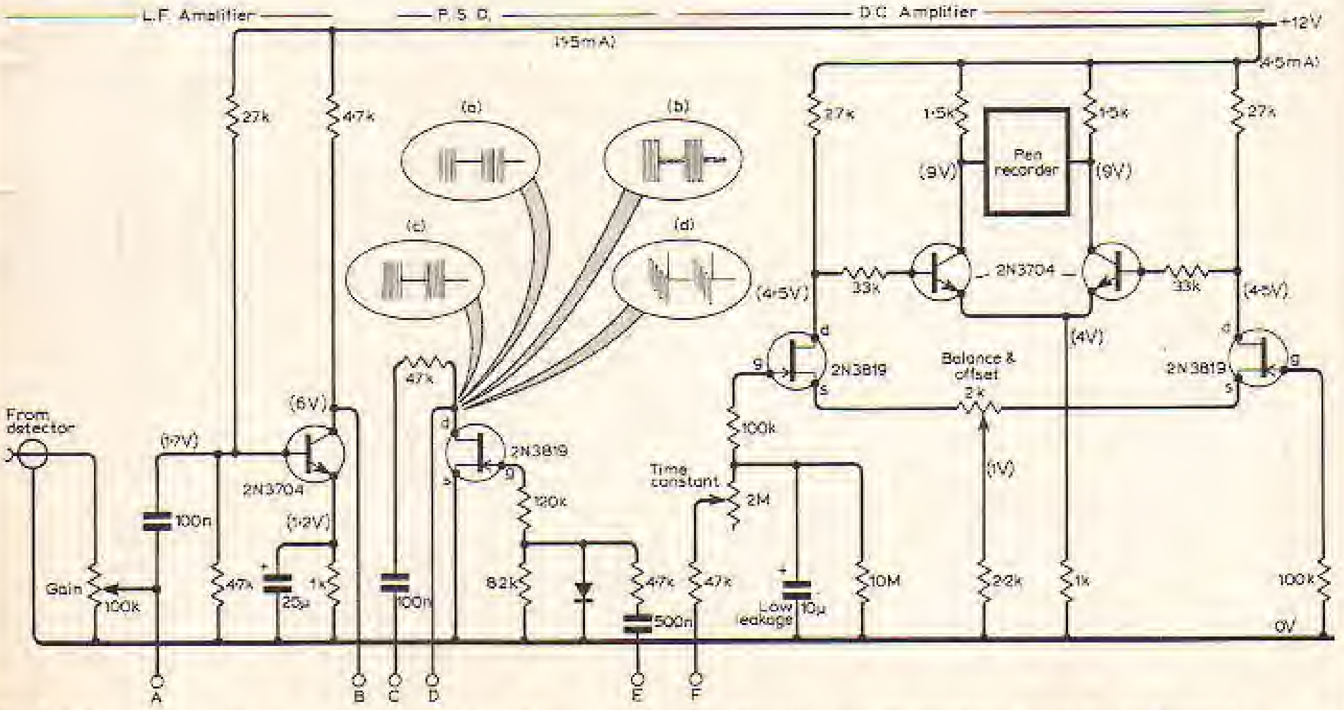


Fig. 7. *L.f. amplifier, phase sensitive detector, and d.c. amplifier. Oscilloscope waveforms from point D: (a) Normal signals at aerial switch unequal – d.c. output proportional to the difference. (b) Normal, both inputs equal – zero d.c. output. (c) Overload. (d) L.f. phase shift in the system, and spikes also leaking from the square wave generator.*

insertion loss is about 10dB. The i.f. amplifier and detector in Fig. 6 consists of two cascode pairs followed by a single transistor stage to give up to 2V from a 1000Ω output impedance. The original measured power gain was about 92dB, but this was reduced to 70dB by the inclusion of resistor R_1 across the input terminal, and some retuning to improve stability.

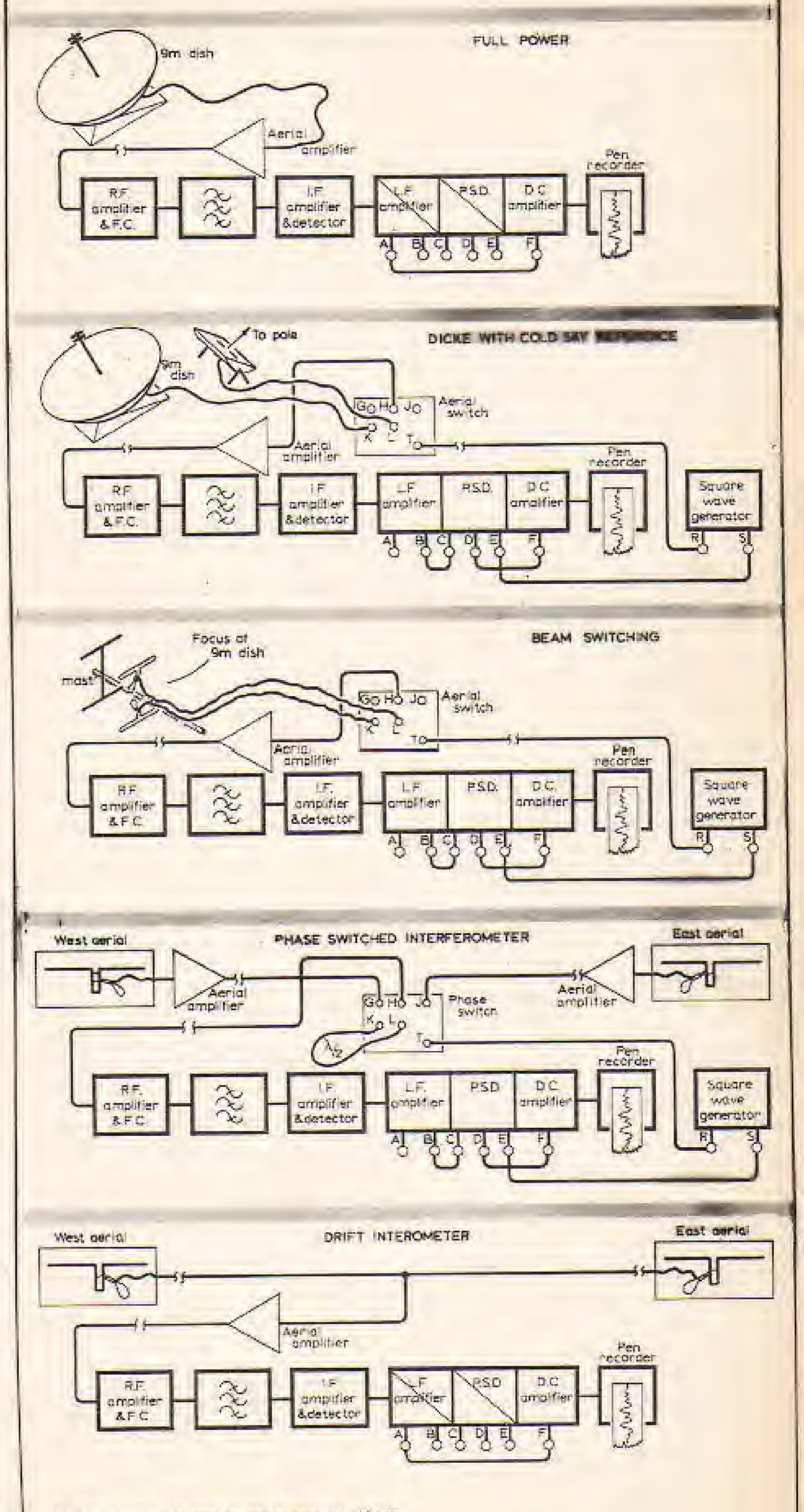
Construction

The aerial framework is constructed from 25 x 25mm timber, and the two main panels are joined by removeable wire pegs to permit easy dismantling. A full wave dipole is used as this conveniently fills the aperture. The dipole high impedence is transformed to a low impedance to match the balun by a short circuited λ/4 line. The position of the tap to the balun is found by trial and error. The dipole and λ/4 matching stub is made from one piece of 3.18mm diameter aluminium or copper wire and the insultors are cut from perspex sheet with holes at 25mm spacing. Brass connectors to the aluminium, and soldered connections to the balun are greased to prevent corrosion.

Each balun consists of a λ/2 section of 50Ω coaxial cable which gives a 4 to 1 impedance transformation as shown in Fig. 2. The coax and feed-through connections are housed in a 35mm film can which is subsequently filled with candle wax to form a hermetic seal. Similar baluns made eleven years ago and exposed to the weather are still working satisfactorily. The components are mounted on p.t.f.e. insulated studs or ceramic stand off tags attached to copper clad insulating board. The boards are bolted to the inside of diecast-box lids. All external connections pass through holes in the boards and lids. This method permits easier access for construction and maintenance. The transistors are located in holes which are drilled in the boards, and their screen leads are cut a short as possible and soldered to the copper cladding. All leads are kept as short as possible, particularly for the decoupling capacitors. Vertical screens cut from copper clad board are placed between stages, and where possible they are cut to bridge the transistors to provide electrostatic and electromagnetic isolation between the bases and collectors or gates and drains. The coils are wound on 4 or 6mm diameter formers with ferrite slugs. In the r.f. circuits the number of turns required is affected by the circuit layout and variations in the transistors.

As the detector output level is fairly high the l.f. amplifier in Fig. 7 is very simple. For some observations it can be omitted. In the phase sensitive detector of the same circuit the f.e.t. acts as a simple switch driven by the square wave generator.

To be concluded.



Techniques of radio astronomy that can be used with the telescope as shown above are summarized over the page.

Radio telescope systems

Most natural signals from space are in the form of white noise and are similar in character to the noise generated in a receiver. Factors affecting the overall sensitivity of a radio telescope are receiver system noise, gain fluctuations, aerial collecting area, aerial efficiency, aerial feeder loss, receiver bandwidth B, and receiver output time constant T. The minimum detectable signal at the receiver is roughly equivalent to the noise recorded on the pen recorder. The system noise fluctuations and hence the minimum detectable signal level can be reduced by using a wide bandwidth and a long time constant which produces an improvement proportional to $\sqrt{BT}$. Bandwidths greater than 1MHz and time constants greater than 10 seconds are desirable but unfortunately the bandwidth often has to be reduced to find part of the spectrum clear of man-made transmissions. This causes a loss of sensitivity. The output time constant needs to be between 0.1 and 2.5 seconds for recording rapid bursts from the sun, and from about ten seconds to several hours for galactic sources. This choice often depends upon the presence and type of interference.

The full power system consists of a single aerial connected directly to the receiver. The detector output is measured by a d.c. amplifier and a pen recorder. Often the d.c. component due to receiver noise is backed off by a stable bias supply. The full power system is very susceptible to receiver gain variations due to changes of temperature, supply voltage and component characteristics. These changes vary the output due to receiver noise and mask the output due to the signal. In the case of the Crab Nebula, the signal seen by the receiver is only $10^{-[illegible]}$ watts/Hz and will be lost in the smallest of receiver gain variations.

In the Dicke system the signal is continuously compared with the thermal noise produced by a high quality resistor that has been matched to the system input impedance. The receiver is switched alternately to the aerial and the resistor at about 500Hz and the detector output polarity is also switched synchronously so that over a complete cycle the system output is

$$\propto \frac{(s+n)-(r+n)}{2} \propto \frac{s-r}{2}$$

where s is the signal, r is the resistor noise and n is the receiver noise. Because s, r, and n are all randomly varying quantities, the output still needs to be averaged by the output time constant and wide bandwidth.

A disadvantage of the Dicke system is that the temperature of the reference resistor is different to the equivalent temperature of most celestial sources, and therefore these signals can differ considerably. Any variations of system gain will be modified by this difference and show up as drift on the pen recorder.

The cold sky reference is a simpler system where the resistor is replaced by an aerial pointing at a cold part of the sky which will have an equivalent temperature of a few degrees above absolute zero. If the aerial is pointing to the celestial pole, it will always see the same portion of the sky in spite of the Earth's rotation.

In the drift interferometer two aerials are set up on an East West base line facing a selected point in the sky on the meridian. The aerials are connected in parallel through two equal lengths of feeder and the rotation of the Earth scans the aerial beams across the sky at a fixed declination. When a radio source is on the meridian, the path lengths through each aerial to the receiver are equal and the signals collected by each aerial add together. The pen recorder responds to the sum of the signals plus the receiver noise. When the Earth has rotated so that the path length through the West aerial has shortened by a quarter of a wavelength, and increased through the East aerial by a quarter of a wavelength, the signals will be 180° out of phase and will therefore cancel. At this point the pen recorder trace will fall to the receiver noise level. After the path lengths have each changed by half a wavelength the signals are again in step and add together.

A sinusoidally varying multi-lobe or fringe pattern is recorded above the receiver noise bounded by an envelope corresponding to the overall beam-width of the two aerials.

One advantage of this system is that the signals from a celestial source can often be distinguished from unwanted signals.

In the phase switched interferometer the advantages of the Dicke, drift interferometer and cold sky reference systems can be combined. If the connections to one of the aerials of the drift interferometer system are reversed the fringe pattern is shifted sideways by half of a fringe width. A source located at a fringe maximum will then be located at a fringe minimum. Therefore, at any one moment the system is seeing the source, and in the next moment the cold sky alongside it. Reversal of the aerial polarity can be by two germanium diodes acting as r.f. switches to alternately insert or remove half a wavelength of the aerial feeder. Separation of the signal from the receiver noise is accomplished by feeding the receiver output to a synchronous detector as in the Dicke system.

When the source is on the meridian, the output is

$$\frac{(2s+n)-n}{2} \propto -s$$

where s is the signal due to one aerial and n is the receiver noise. When the source has moved by half a fringe, the output is

$$\frac{n-2s+n}{2} \propto -s$$

Unwanted signals reaching one aerial only or both aerials incoherently are treated as receiver noise unless there is gross overloading.

IN BRIEF

●SEMA, whose gas detection equipment we described in December (P.42), have moved to Unit 32, Dundonald Camp, Irvine, Ayrshire, KA11 5BJ. The telephone number is Irvine 311252.

●Millbank Electronics have been awarded an Export Year Award by the Federation of Sussex Industries for overseas sales of industrial sound equipment. The scheme was judged by the British Overseas Trade Board and the prize was presented by Sir Derek Ezra in November.

●A new 25,000 line local telephone exchange and expansion of existing exchanges by 42,000 lines are planned for Hong Kong. The largest exchange at Kwai Chung will be expanded form 54,000 to 69,000 lines. In the centre of Hong Kong 13 out of every 100 subscribers are on the phone at once in peak periods, each call lasting just over a minute. In Germany the figures are 7 and 2½ minutes. The work will be done by Siemens.

●The Spanish Goverment is to build 28 h.f. communications transmitters to US Defense Communications Agency standards. Twenty-three will be 10,000W and the rest 40,000W, all supplied by Communications Electronics of Dallas, Texas.

●Mr P. F. Fenton is to succeed Sir Edward Fennessy as managing director, Post Office Telecommunications. Sir Edward retired in July, since when the acting managing director has been Mr Kenneth Cadbury, who is to become deputy managing director.

●The German magazine *Funkschau* reports that Bogen, the makers of magnetic heads, are in financial difficulties. Wolfgang Bogen has left the company and a minority shareholder, Dr Helmut Becker, is now manager. The property of the company, as well as that of Bogen himself, has been taken over by the Berlin Senate.

●New TXE4 exchanges will be installed in Birmingham and Bristol early this year. The £35 million Bristol contract will increase the city centre exchange's capacity from 16,000 to 28,000 lines, and the £25 million for two exchanges in the Midland exchange building near Birmingham's New Street Station will begin by replacing 19,000 lines of Strowger equipment.

●Radio London have sent us a letter they have received from a South African listener requesting a QSL card. For about seven minutes at around 10pm on November 17 Mr V. Korinek received the allegedly local radio broadcast on 1,457 kHz.

A basic radio telescope — 2

Construction, performance and testing

by J. R. Smith

WHEN NO SIGNAL coherent with the square-wave generator is present the noise blocks are symmetrical about the zero line and the mean d.c. output is zero. If the signal and the square-wave are coherent the noise blocks are not symmetrical about the zero line and the d.c. output appears with a polarity dependent upon the phase of the noise blocks with respect the square wave. Integration of the output signal is carried out by a RC circuit. The time constant is adjusted by a variable 2MΩ resistor and the capacitor is selected for low leakage. The maximum time constant obtainable is 20 seconds. The d.c. amplifier consists of a bootstrapped pair of transistors with some carefully matched devices to provide an acceptable temperature stability. Field effect transistors are used for the input stage to provide a high input impedance which permits a long time constant. To obtain an equal mark-to-space ratio, an asymmetrical astable multivibrator is used to drive a divide-by-two monostable multivibrator, see Fig. 8. Buffer transistors provide low impedance outputs, and normal or inverted square-wave outputs at 1kHz are available as required. Early trials showed that these outputs require filtering to prevent radiation of r.f. fields. Values for r.f. chokes and capacitors are best found by trial and error, but excessive filtering degrades the shape of the square wave. The 12V power supply must be stable to within 5mV. As the total load current is about 55mA dry batteries can be used for short periods or a car battery for longer periods. With the last mentioned the voltage should be stable, after a charge, if it is partially discharged before use by about 5%.

The values of most of the components are not critical although high stability resistors are used in potential divider circuits and the d.c. amplifier. Radio frequency chokes are made by winding between twenty and thirty turns of enamelled wire on polythene tubing of 5mm in diameter. The i.f. chokes consist of twenty to thirty turns

Measured performance of various stages

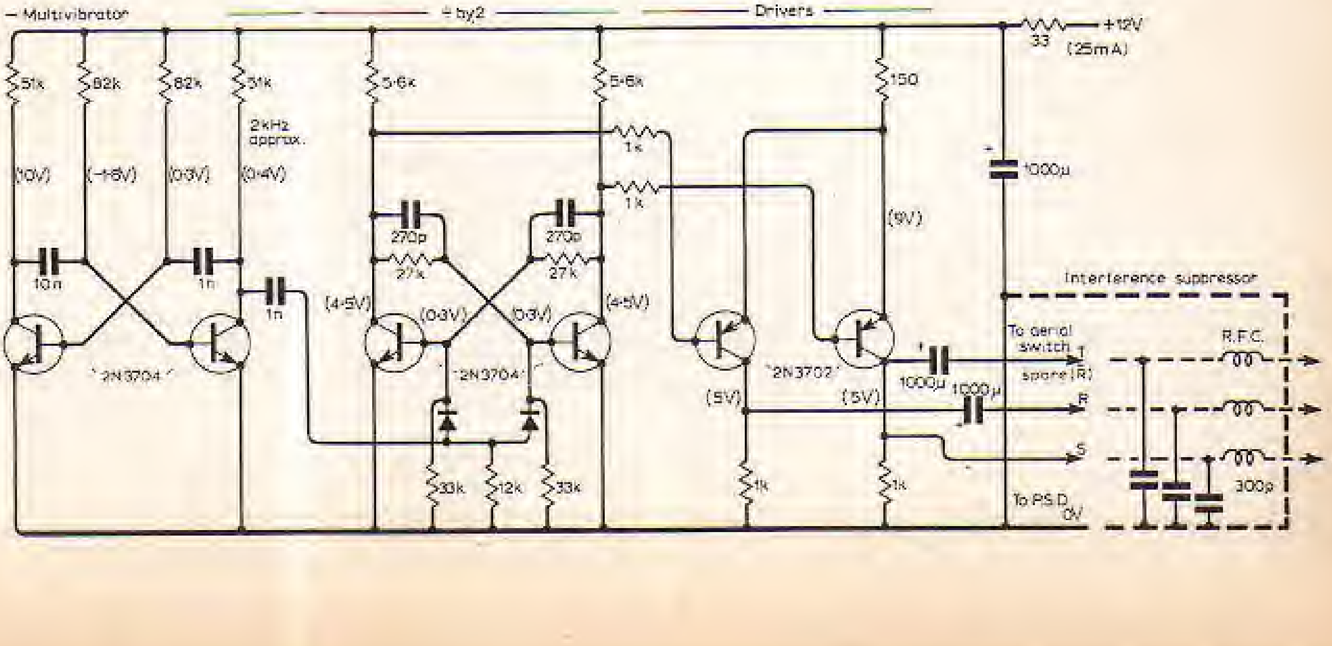
Stage	V_d when I is 0	I_a to double V_d	Noise factor	Noise figure	$\frac{I_a}{V_i}$	$\frac{dI_a}{dV_d}$	Stage gain	
	V	mA	No	dB	mA/V	mA per V	Absolute	dB
Aerial amplifier and coax	0.37	4.7	5.7	6.7*	0.8/0.1	8	16.2	12*
Frequency changer	0.15	14	15	11.5	13/0.1	130	11.3	10.5
Filter	0.12	–	–	–	38/0.03	1270	1/28	−14.5
I.f. amplifier	0.12	5	6	7.7	4.5/0.1	45	1.05×10[illegible]	70.2

* A 3N140 f.e.t. should achieve a noise figure of 4dB. Some improvement in gain should also be possible.

V_d is the detector voltage. Output power is assumed to be proportional to V_d because a square law detector is used.

I_a is the diode anode current. The diode resistor is 50Ω and the voltage gain of the d.c. amplifier is 18.5 (absolute).

Fig 8. *Square-wave generator*



wound and glued onto OBA ferrite slugs. A 1mA recorder that can be centred or end-of-scale zeroed is used with a chart speed of one inch per hour for most observations.

Noise diode

A valuable piece of test equipment is the valve noise diode, Fig. 9, which produces signals of a similar character and strength to a celestial radio source. The diode is modulated by supplying 240V a.c. to the anode while the detector output is fed to the Y plates of an oscilloscope. The X plates are fed from 240V a.c. through a phase adjuster. With the diode connected to the input of the correctly tuned aerial amplifier or i.f. amplifier a display similar to that shown in Fig. 9 is obtained. The left side of the trace corresponds to the receiver noise, and the right side to the receiver and diode noise. The system is adjusted to produce the largest difference between the two. The noise diode can also be connected to a dipole aerial which in turn can be placed near an aerial which requires adjustment for best performance. In this case, a pair of headphones is connected to the detector. The modulated noise can then be heard and adjustments made to produce the loudest buzz.

Because the noise diode operates at a high voltage, all exposed metal, including the dipole, must be correctly earthed. As the centre point of the folded dipole is at an r.f. voltage node, this point can be bonded to the earthed box without affecting the r.f. performance. All mains earthing leads must be made as secure as possible, and a one amp fuse should be placed in the mains line lead. Similar precautions are necessary for the transistor equipment when running from a mains operated power supply. Fig. 10 shows some typical results. The voltages given in the circuit diagrams were measured with a meter having a 100kΩ resistance. The i.f. amplifier gain was determined from the noise diode output corrected for the difference of the i.f. 4MHz bandwidth and the 0.5MHz filter bandwidth, divided into the change of the detector output power. □

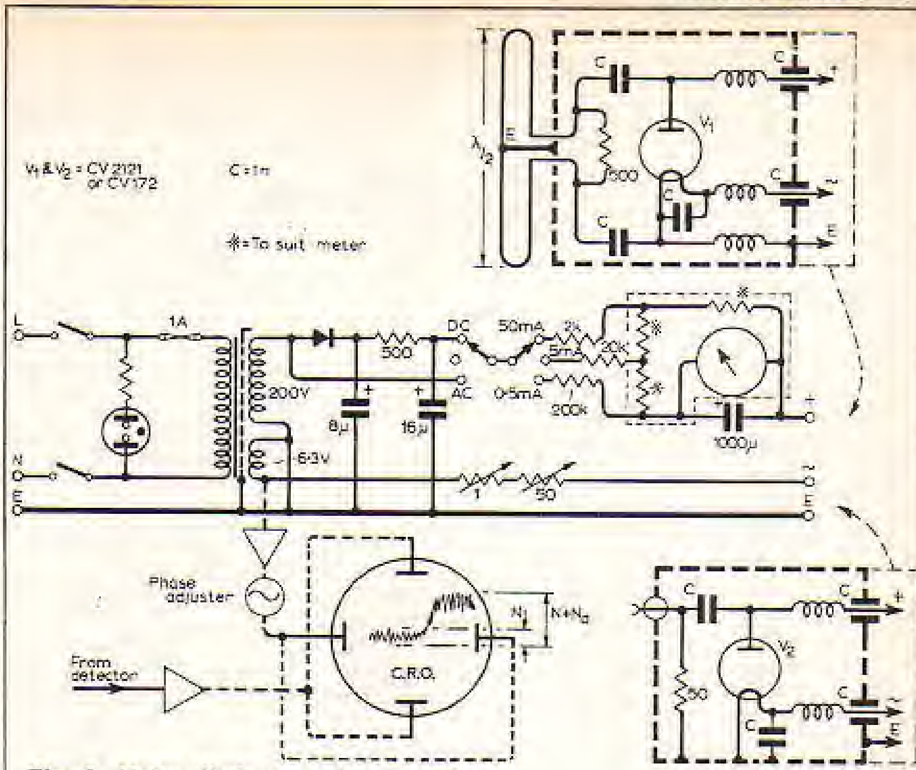
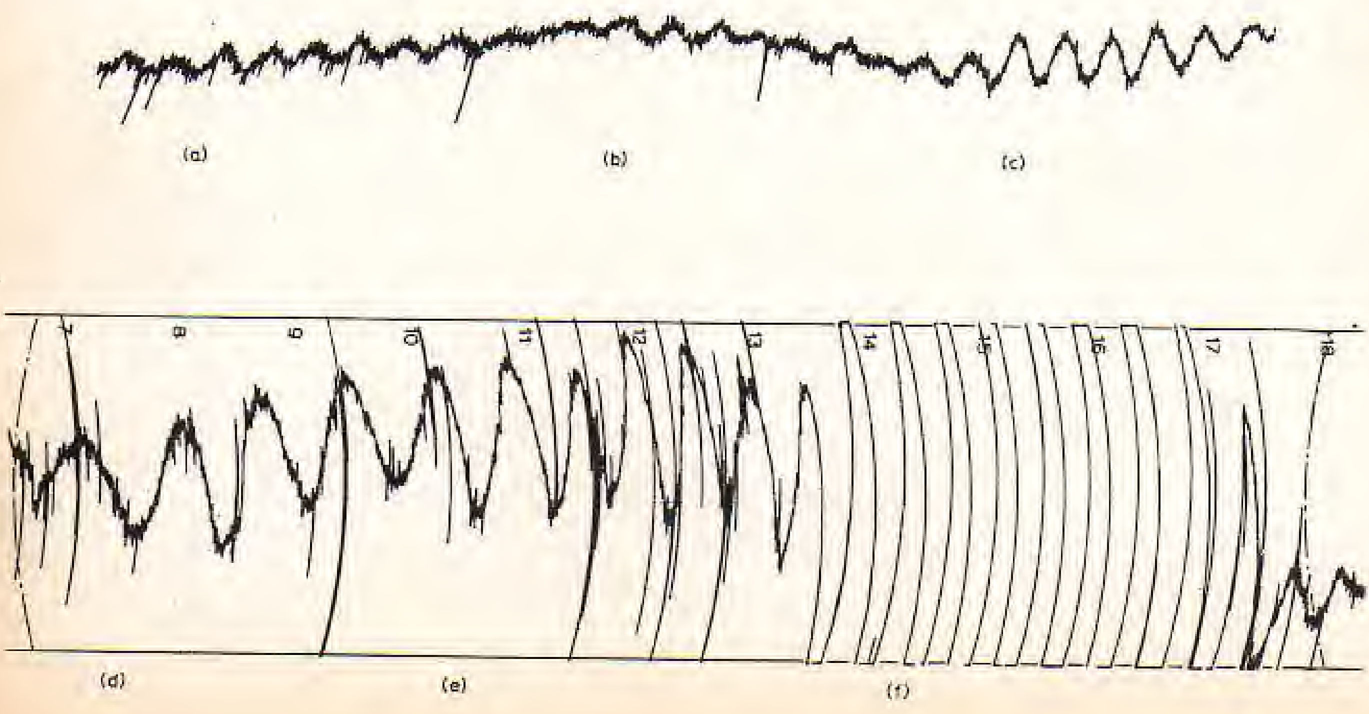


Fig. 9. *Noise diode test circuit and typical oscilloscope display of a.c. modulated noise.*

Fig. 10. *Pen recordings from the telescope used in the phase switched interferometer mode. Portion (a) shows Virgo A, galaxy M87. (b) Hercules A, a galaxy 1500 million light years distant. (c) Taurus A, Crab Nebula. (d) Cassiopeia A, a super nova reminent. (e) Cygnus A, a galaxy 600 million light years distant. (f) active sun.*



NEWS OF THE MONTH

EEA conditions for CB

The Electronic Engineering Association's working party on citizens' band, set up a year ago, recommends that the service should operate in a frequency band "between 60MHz and 500 MHz". The system should avoid "the worst aspects of the 27MHz systems now operating in the US and some 15 other countries," should provide work here, and should provide an outlet in overseas markets, especially Europe.

The working party's view that the service should be priced so as to be attractive to a large number of people — it recommends a unit price of no greater than £150 and a licence fee of £5 to £10 — indicates that the EEA is now in favour of the introduction of some form of c.b. They estimate that between two and ten million domestic and small business users would welcome a c.b. service in the UK.

The report also recommends that equipment should be approved to an agreed Home Office standard, and that all units should have a "unique and continuously transmitted identity", which should be stamped on the licence form supplied with the unit. This echoes a view of the Citizens' Band Association.

Hand-held transmitters should not exceed a power of 100mW e.r.p. and vehicle and fixed units should not exceed 1W e.r.p. in any direction. Distances should not exceed 8km, normally 2 to 3km.

There should be 40 channels with a maximum of 12.5kHz. Spurious emissions should be no more than 200 nW, depending on the band chosen. "It may be prudent that the service be opened with approximately ten channels in the middle of this block with the remainder held in reserve." Aerials should be no higher than 10m above the ground.

Users should not regard the service as reliable for emergency, security or business use, and action should be taken "to obtain European (EEC) agreement to a future c.b. service which would eventually replace the existing service".

The EEA working party will continue to examine developments in attitudes to c.b. The report had to obtain approval from the EEA mobile radio committee before it could be disseminated.

The Home Office told us they had no comment to make other than that they had already made clear their position about the shortage of frequencies and the dangers of interference to existing users. □

Hitachi update

Hitachi's announcement of their intention to withdraw an application to build a tv factory in the North-East came after our last issue went to press (January, p.34). The government has not been pleased by the result of the lobbying by the set makers, though it is difficult to believe that they were not relieved to have the decision taken off their hands.

In a radio interview the minister responsible, Mr Alan Williams, said it was his impression that Jack Akerman and Sir Richard Cave, the chiefs of Mullard and Thorn, were first of all asking for guarantees from Hitachi if the factory were built. "Having got the guarantees they then said, 'Well we don't care what guarantees you have because we don't believe them anyway'."

John Hobbs of the North-East Development Council described it as "A campaign of figures which have been wrong, of racial arguments. . . . It has been a disgraceful episode for the country as a whole." His reference to racial arguments concerned a remarkable lapse from *World in Action*'s usually-high standards in which a film clip showed a ferocious sword-wielding Samurai.

The *Financial Times* devoted considerable space to the decision on December 8. A leading article said the decision had made the government the laughing stock of the international business community. "It is an ironic commentary on the so-called industrial strategy that a decisive role in persuading the government to give in to the protectionist pressure has apparently been played by two of the sector working parties. It is well known that the main role of these bodies is to serve as lobbying instruments for the industry concerned, but up to now they have not been noted for getting things done. The National Economic Development Office, which often finds difficulty in explaining the work of the sector working parties, can now point to a concrete achievement; they have protected a domestic industry from a new source of competition and dealt a damaging blow to the government's stated policy of encouraging inward investment."

Elsewhere the paper points out that the government's embarrassment is due to their having promised Hitachi a year ago that permission to come to Britain would be granted under certain conditions. The embarrassment is compounded by the fact that one of the main planks in the opposition case was that Hitachi could not be trusted.

It may be, however, that Hitachi can turn the present hangover from the protectionist binge to their own advantage. It is too early to consider their decision final.

● US restrictions on tv imports from Japan have caused Hitachi to form a joint tv company with General Electric. The new company, to be called General Television of America Inc, will have headquarters in Portsmouth, Virginia, provided government approval is obtained. □

CEI counter-attack

Last year was a tough one for the Council of Engineering Institutions. There were times, just before the Finniston committee was announced, when it seemed the CEI didn't have anyone to speak up for it. But it begins to look as though the CEI is taking account of the criticism, even if only to ensure its own survival. Commons science and technology committee chairman Arthur Palmer has been a persistent critic of the council yet, referring to the CEI's offer to hold regional conferences as we reported last month, he told us he thought it was "extraordinary" how completely the CEI had turned over a new leaf.

In mid-October there was a declaration on trade union recognition the vehemence of which would normally be considered astonishing from what the civil service calls a quasi-autonomous, non-governmental organisation, or quango.

The CEI's view is that professional engineers should join an appropriate trade union in their own interests. When, therefore, W. H. Allen of Bradford refused to grant recognition to the United Kingdom Association of Professional Engineers, and ACAS, despite a 79% vote in favour of trade union membership by those at Allens, failed to recommend such union recognition, the CEI, issued a statement condemning ACAS. "The conclusion reached . . . is totally opposed to the overwhelming weight of evidence submitted by the negotiating parties," said the CEI. The decision "makes a mockery of the democratic process and poses a serious threat to the interests not only of professional engineers but all those to whom freedom of personal choice remains important." Strong stuff. Now the CEI have published a 20 page booklet summarising all the industrial relations legislation of the past few years and its effects on the engineer's working life. It costs 50p.

On top of all this comes the latest survey of professional engineers, the CEI's sixth since 1966. It shows that an engineer's income has fallen even further behind that of his colleagues since the last survey in 1975. According to the CEI, this is attributable to incomes policy and inflation. The median income of an engineer, adjusted to allow for the increasing cost of living, actually fell for the first time since the surveys began, from £2,315 to £2,180. Taking the year 1965/6 as 100, the engineer is now getting 112, compared with 119 last year, and the real average earnings index of all industries is 131 compared with 135. The chairman of the committee which produced the survey, Mr Brian Hildrew, described the figures as "rather alarming."

The report shows that Engineers in the East Midlands earn less than anywhere else, and that the lowest pay is earned by those working for firms of consultants. If you live in the Irish Republic, however, you're probably well-off, especially if you're a self-employed man; the self-employed, contrary to their own propaganda, earn a median income of £8,000, their nearest rivals being university teachers at £6,650. If you take into account that consultants are mostly self-employed, the picture is of a group who earn more but are prepared to pay less than anyone else.

Another feature to emerge from the survey is that there has been a steady decline in the number of engineers who work in commercial or industrial companies (44% compared with 46% in 1975) and a corresponding increase in the number of engineers who work in the public sector (42% and 39.5%). This may be because salaries are better for the engineer in the public sector, especially if he belongs to a trade union.

This may account for an increase in trade union membership from 41 to 44% in the last year. □

BS9000, the hidden face of protectionism

If a recent symposium at British Standards Institution headquarters is anything to go by, users of electronics components are firmly in favour of the universal adoption of BS9000. Questions centred on problems of implementation rather than doubt about the scheme itself. Over 1,100 approvals have now been granted for various components.

In the past component makers had to contend with a number of similar but distinct standards according to whom they were supplying. These have included CV and DEF military standards, and Post Office, CEGB, BS and commercial specifications.

Now, a supplier who has won BS9000 approval for his products can guarantee, if the scheme works properly, that his components can meet consistently any standard he agrees with his customer and this saves the customer the trouble of having to check the components at goods in. It also means he can use any BS9000 supplier he likes, and it may also result in more uniform finished products.

Nevertheless, acceptance of the scheme has been slow. The component manufacturers were in favour but the users, fearing that it would not be flexible enough to meet their particular requirements, dragged their feet. The Post Office seemed particularly slow to come into the fold.

When BS9000 surfaced ten years ago it met almost universal indifference. In the first five years the number of approvals applied for and granted was only 270, roughly a quarter of the present total. A year ago the figure was 651, so that nearly half the approvals have been granted in the last year.

There have been various explanations for the sudden rush or enthusiasm. The BSI attribute it to the wider range of components which can now gain approval and the wider publicity the BS9000 has received of late. But two other reasons, one national, the other international, lurk behind the snowballing growth of the scheme.

In the first place there is no doubt that the Ministry of Defence has been putting pressure on component makers to come into the system. This may be because, as the defence purse strings are pulled tighter, the MOD wants to shed itself of costly peripheral activities like component approval, though the MOD's Electrical Quality Assurance Directorate (EQD) is supervising all the approvals on behalf of the BSI.

BSI officials admit that suspicion of the scheme so far has been based on the (unjustified) notion of a plot between MOD and the component makers to force users to accept only military spec components.

But the international implications are what make BS9000 so attractive, and go a long way to explaining why most of the enthusiasm for the system has come from the component makers.

BS9000 is but the first stage towards the international standardisation of components. A standard will first be drawn up for Western Europe under the auspices of the CECC, the Electronic Component Committee of the European Electrical Standards Committee. Based upon experience in Western Europe the world regulating body, the International Electrotechnical Commission (IEC) will draw up a standard which will make components made according to it saleable anywhere in the world. In theory it is this that the BS9000 advocates are working towards.

But the real game was given away several times at the BSI symposium. It looks very much as though BS9000 will be the basis of the CECC standard – in many cases the corresponding CECC and BS9000 documents are the same but for the name – and hence of the IEC standard.

This is more than a matter of national prestige, they think. In their minds it means that British companies who have already been conforming to BS9000 standards will have an advantage when the other countries, especially America and Japan, are still catching up on the necessary procedures.

Thus the talk was not so much of how quickly the world standard could be adopted as of how far behind those dreadful foreigners were. The official reason given for excluding Hong Kong from the scheme, for example, was that the distance involved would make the crown colony difficult to administer within the scheme. Behind that, however, might lie concern about the level of electronic imports from the Far East.

In truth the foreigners no longer seem behind at all. Two years ago a Japanese team visited this country to find out all about BS9000. A system based on BS9000 is now operating in Japan. In January last year legislation was introduced into the American Congress to overcome the legal difficulties, caused by the anti-trust laws, of American manufacturers banding together to bring about component standardisation.

Anyone imagining, therefore, that BS9000 is going to give the British components industry any kind of advantage in world markets is deluding himself. □

Gatwick to manage without ground radar

It may be another five years before Gatwick airport is equipped with ground radar, according to a House of Lords answer in mid-December. The installation, to cost about £1½ million at current prices, is awaiting the building of an elevated control room in the terminal area.

The answer came in response to a question from Conservative Peer Lord Braye, who suggested that there might be a serious accident at Gatwick before the equipment goes in which could be avoided if the authorities acted sooner. The Lord in Waiting, Lord Oram, replied that "Expenditure on ground radar could only be justified where traffic levels and the complexities of the taxiway system are such that real dividends would accrue in terms of safety and expedition."

● Lord Braye's question may have been prompted by the Tenerife disaster in March, the worst in aviation history, when 577 people were killed as two jets collided on the ground. Ground radar could have helped to avoid the disaster.

Heathrow is the only British airport, and one of the few in the world, which has radar-monitored movements of aircraft on the ground, though until recently the equipment, Decca's airfield surface movement indicator (ASMI) was better suited to use at night. One reason for its installation is the large number of passengers the airport handles; at 24 million a year this makes it the busiest airport in the world. Gatwick handles a mere 6.4 million a year.

In addition, the ground movement control cabin where the equipment would go, now in Gatwick's 'old office block', is to move to a new position above a block on which work began in December. Since, however, the old and new buildings are at right angles, part of the apron will be hidden. The finishing date for this new block is 1979, according to a Gatwick spokesman, but Lord Oram gave the likely finishing date as 1981 to 1982. At that time another building, called the North Pier development, is planned for completion as part of a £100 million improvement plan, so it could even be that any ground radar installation may be put there.

Airfield surface movement indicator (ASMI) screen at Heathrow airport. See 'Gatwick to manage without ground radar.'

A spokesman for the Civil Aviation Authority, which is responsible for safety at Britain's airports, told *Wireless World*: "If we find it is going to be of value there then we will do something about it, but so far it hasn't been proved."

A Gatwick spokesman said that, while it would be foolish to say there was no chance of an accident happening in the next five years which ground radar might have avoided, "we would like to think that we're better off than Tenerife." A larger worry at the moment was the movement of passengers through the building work.

But it seems likely that a case will eventually be made for Gatwick's having the equipment. The airport is now taking an even greater share of Heathrow traffic. It will take ten million passengers in 1980 and 16 million five years later, most of the increase attributable to the use of larger aircraft. □

Investment plans look to Viewdata/teletext

Mullard has spent £3.5 million in the last two years on the l.s.i. plant at Southampton and a further £4.5 million is planned for the next two or three years. At a recent press conference the director of Mullard's industrial division, Bill Everden, said that at present the consumer i.c. market was around £12 million, but that by 1982 the figure would exceed £30 million, of which Mullard expect to take a healthy £18 million.

One of Mullard's main products is a remote controlled teletext/Viewdata package which is currently being prepared for market trials. This system comprises a set of four, recently-announced l.s.i chips for teletext, a video processor i.c., data acquisition and control i.c, digital timing chain i.c, and a character generator i.c. These devices are used together with seven 1k rams, two synchronous counters, and an adder. Mullard expect to have complete teletext units in production at Southampton later this year.

The Viewdata section at present consists of two modules. A line coupling unit (l.c.u.) which enables a standard telephone line to be connected via a jack socket, and provides all of the necessary interface for the microprocessor-based Viewdata acquisition/control section which itself acts as an interface between the l.c.u. and the teletext decoder. The v.a.c. module receives information from the Viewdata computer and feeds it to the teletext display circuit. Also, it transmits requests for new information from the remote control to the computer. The automatic user-identifier and password generator is included and uses a p.r.o.m. for the number storage.

The Viewdata modules can be added to the teletext system without any modification. Although the modules at present use standard components supplied on two printed-wiring boards measuring about 165 x 305 mm and 150 x 230 mm, Mullard say that l.s.i. chips for Viewdata should be available in 1979.

The cordless remote control end of the package is based on the SAA5000 and SAA5010 i.cs which have recently been available to the Industry. These devices have been designed to operate with a colour television receiver and teletext decoded, while a Viewdata mode of operation allows the control of an additional viewdata-terminal.

Mullard are also working on video games again based on the 2650 microprocessor together with the 2636 programmable video interface. Their system uses the object oriented approach where r.a.m.s contain the object description specified by the microprocessor. Each r.a.m. has its own co-ordinate register with which the position of the object is controlled. During a game the 2650 transfers each object pattern into a r.a.m. and sends out the appropriate location codes to the corresponding co-ordinate registers. This system, say Mullard, simplifies the software requirement as compared with the alternative r.a.m. mapping system. The hardware for the video games will be the cartridge format which enables the system to be easily expanded.

Digital tuning is another area where Mullard have recently produced i.c.s. Called digital channel selection, this system operates by storing the frequency of each t.v. channel in a r.o.m. The t.v. receiver is tuned to the selected frequency by comparing the tuned frequency with an internal quartz-controlled oscillator. With this system, presetting can be carried out without any channels on the air. Because each channel number is stored in a r.o.m. the number can be displayed to identify a station. □

In the background Mullard's microprocessor-based Viewdata acquisition/control unit. Bottom left shows their teletext module based on four L.s.i. chips, and bottom right shows an infra-red remote control transmitter and receiver.

Meteosat: no hitches, almost

The first white light and infra-red pictures of the earth's surface and cloud cover have come back from Meteosat, Europe's first weather satellite. To NASA's immense relief the Thor Delta 2914 rocket took off at 1.45 GMT on November 23, and went into geostationary orbit over the equator at 0° longitude at quarter past six the following evening. There had been three postponements, one from November 15 to 17, another to November 21, and then to the 23rd.

Meteosat is one of five equally-spaced weather satellites which will be taking part in a world wide programme. There will also be two American, one Japanese and one Russian craft. Additional information will be gained from platforms, buoys, balloons and other sources. Together they will provide a continuously-changing picture of the world's weather, offering advance warning of typhoons, hurricanes and torrential rain. World Weather Watch involves 145 countries apart from those sending up satellites and the first collective observation period is due to start no later than December 1978.

Meteosat revolves 100 times a minute, building up its pictures by tilting its telescope. One line by line scan picture is taken every 30 minutes, the visible image being of 5,000 lines and the infra-red 2,500 lines. Resolution is 2.5km in daylight on the visible picture and 5km on the infra-red. The picture includes Europe, Africa, and parts of the Middle East and South America.

Another part of the payload transmits data and relays meteorological information to ten ground stations operated by those taking part in the programme. It collects and retransmits information from the remote weather stations and from other satellites.

Users can receive the Meteosat pictures direct or, via Meteosat, from Darmstadt in West Germany, where the pictures are improved by computer processing. □

"Instrument makers prospering"

Britain's makers of electronic instruments have held on to their share of the export market despite recent rises in the value of sterling, according to the managing director of Jordan Dataquest financial analysts. Mr Roger Coghill, speaking on publication of Jordan's survey of the instruments and communications industry, said that although the sterling rise had eroded British competitiveness slightly this had not been reflected in the volume of exports, and had resulted in increased profits for those in the industry. He pointed out, however, that this had not been reflected in wages and salaries. Even American subsidiaries, who paid higher wages than British companies, still paid less than could be obtained in other industries.

The instrument companies could expect even better profits this year as the recent dramatic improvement in the sterling rate worked its way through. "This is likely to be a boom year." Last year's survey had shown 19% of companies were loss-making, but this year the figure had dropped by 6%.

In the first half of the 1970s, says Coghill, the companies went all out for exports, largely because of depressed home demand. This led them to set up dealer networks in a great many foreign countries but the cost of this combined with changing trade conditions meant that at one point about three years ago Jordan were able to demonstrate that there was an inverse relationship between profits and the amount of production exported.

Now the picture has changed to such an extent that not only are British companies making "acceptable profits", but they are buying into companies in the US in quite a large way. Jordan attribute this to low US company profits, high UK company liquidity as a result of earlier write-offs, and a reluctance to invest in new plant and machinery because of the low volume, specialised nature of the product.

The survey covers 376 companies and costs £38. In the last couple of months Jordan have also published surveys on computers and data processing, electronic component distributors, and component manufacturers. The ten largest private component manufacturers are making profits or around 3.6%, while the largest public companies, at nearly 11%, "remain one of the most profitable and growing sectors of British industry." In component distribution the number of loss-making companies has gone up from 10.3% to 16.1%, and there are only a few which have shown exceptional growth. These three reports cost £32 each. □

British hi-fi scene drama

A curiously bitter storm has been raging in the hi-fi teacup. Some audio manufacturers feel so strongly about equipment reviews now appearing in the hi-fi magazines that they have grouped together to agree not to submit equipment for review. So far the group includes KEF, Quad, Armstrong and B & W.

There appear to be two reasons for their strong feelings. One, they say, is that the writers are not truly independent and may, as consultants, be working for a company whose equipment is being reviewed or, worse, for one of its competitors. A more widely-held source of friction, however, is that they believe the tests and measurements aren't being properly conducted.

Although there have been rumblings of this kind for some time the row first emerged over the compilation of the second *Hi Fi Choice* on loudspeakers, due to be published this spring. There had been a violent reaction to the first, written in 1976 by Angus McKenzie. One remark about an American speaker had attracted threats of legal action. This time *Hi Fi Choice* hoped to review 60 loudspeakers, written by Martin Colloms.

Curiously, in view of their action in refusing to submit equipment for review, the manufacturers appear to have a high opinion of Martin Colloms, and mean to imply no criticism of his abilities. What they object to is that on the one hand he did a considerable amount of work for speaker makers Monitor Audio and, on the other, that the equipment he has at his disposal does not meet the standards of the equipment they have in their expensively-equipped laboratories. They do not agree with the methods of measurement, and say that in any case you cannot carry out a serious comparative study of as many as 60 speakers, especially if you have to work to a deadline.

Martin Colloms told us that as he had done a number of these large reviews he had come to realise what the pitfalls were and how to avoid them. He was not using entirely his own resources but had been given or was paying for whatever was necessary to do the job properly, including some equipment or facilities loaned by other manufacturers, or at independent laboratories and he had hired the largest anechoic chamber in Europe at Watford. The panel would consist of members of his regular team as well as others who would be paid for their time. The source material would be of studio standard, and the results would be based on measurements as good as anything the manufacturers could obtain, with the possible exception of those makers who had their own computers. This would not affect the value of the results. He said that most projects had to be done to a timetable in any activity, and you merely planned accordingly.

What really irks the manufacturers, however, is that the younger reviewers cannot be relied upon to see things the manufacturers' way. Before hi-fi became a huge industry the relationship between manufacturers and the writers for such magazines as there were was so close as to be almost cosy.

Now all that has changed. The audio consumer boom attracted new manufacturers and more magazines. More to the point, the confused buyer of equipment often has no patience with long rambling pieces of text sprayed with distortion figures and dBs, especially when they come to no conclusion for fear of giving offence.

With the arrival of the consumer movement it was inevitable that someone would apply similar ideas to the audio industry, and that journals would appear which attempted to speak the consumer's language, even if they sometimes used it to say the wrong thing, and often scaled new heights of inarticulacy with each issue. The audio punter cannot understand why it is necessary to hear speakers in dimensionless rooms when his front room isn't like that, and he doesn't see why a group of people who take an interest in sound quality shouldn't listen to a lot of different speakers and publish what they think.

It was equally inevitable that manufacturers used to having magazines run for their benefit should look round for a scapegoat when the cold wind of competition blew in from the East.

The manufacturers now feel beleaguered. They resent the pressure exerted on them to co-operate with what they regard as a parasitic reviewing industry that has grown on the back of their own enterprise. They also feel that if a reviewer makes totally unjustified criticisms of their products a legal remedy is ineffective because the damage to their business has already been done, and they, unlike the reviewers, have employees to consider.

Hi Fi Choice reacted to the initial threat by inviting speaker makers to a lunch at a London restaurant, at which an agreed method of testing the speakers could be hammered out. The magazine said that KEF and the other three manufacturers did not take the opportunity to come. Raymond Cooke of KEF told us that he had not been invited, but that, having been to such occasions before, it would have been a waste of his time.

Hi Fi Choice aren't too worried. They're going to go out and buy the missing speakers anyway.

Peter Walker, of Acoustical Manufacturing, who make Quad equipment, and Chris Rogers, one of the newer school of audio reviewers are to take part in a debate on "Musicality, fact or fiction?" at the IEE. The date? St Valentine's Day. □

Post Office replies to Carter

The Post Office disagrees with the Carter committee's recommendation that there should be a Telecommunications Advisory Council. "Improvements will not be obtained by having layer upon layer of advice and monitoring for the new boards. In fact performance could be adversely affected if top management had to spend time servicing an additional body."

The Post Office welcomed the recommendation to split the Post Office into two corporations, one each for posts and telecommunications, but said it thought the Carter committee's assessment of the progress of System X (*WW* September 1977, p.51) under-estimated the extent of the preparatory work which had already been completed and the scale of the Post Office commitment. Contracts worth £30 million had already been placed. □

Tough next stage for optical fibre

If the optical fibre market reaches even a fifth of the £500 million a year predicted for it in 1985 then it will be well worth going into, according to Mr Ralph Baskett, head of STC's optical communications unit at Harlow. STC would hope to get a one-third market share.

In the year during which the unit has been operating it has made sales of £1½ million, say STC. They refused to discuss individual contracts or orders, but say that telecommunications, military and industrial customers have bought optical fibre, fibre made up into cable, and optical systems such as terminal equipment, repeaters and multiplex equipment. Some customers are beginning to order optical equipment to solve problems, though most has been bought for evaluation.

Eighteen months ago the unit was a one man operation — Baskett himself — who was deputed to investigate optical fibre as a potential threat to STC's well-established coaxial cable business. By Christmas 1976 the number of people involved had reached ten, and now stands at 25. In a year, he estimates, it will be around 40, though recruiting the right people to manage the transition from a research to a supervisory and production operation will be hard.

Telecommunications will form 20% of the market in 1980, and lot of interest will centre on it because it is a familiar market. STC expect that telecommunications will take a bigger share of sales as time goes on, but not until well into the 1980s. Home sales will be depressed by the existing investment in copper conductors and only new links or "troublesome areas" will attract the use of optical fibre technology.

A strong point in optical's favour, however, is that it is, for the moment, virtually eavesdrop-proof, and our authorities are becoming ever more obsessed with security.

Similar considerations make the military market an accessible one, especially when added to optical's much smaller size for the same carrying capacity, lighter weight and rapidly improving ruggedness. But the military market is subject to political pressures.

A large home market may develop, however, among public utilities, such as the CEGB — who could use optical fibre communications without difficulty in the most electrically-noisy conditions that exist — and the Post Office, who have to connect to those electrically-nasty CEGB installations.

Optical fibres also make it possible to see directly into hazardous environments, such as those in ovens, areas of toxic or flammable gases or at nuclear plants, without the intervention of a camera. It would also be surprising if STC did not press the knowledge they have gained in submarine repeaters into service to advocate the use of fibre-optics under water. Baskett expects sales to reach £1 million in 1978. "The hard work will come next year. That first £1 million will show whether there's any market there or not."

● The BBC has sent colour tv pictures over 12 miles of optical cable and five repeaters spaced every two miles. The experiments began in November. The pictures were sent from Hitchin to Stevenage over the optical fibre link opened in June last year and then, via a loop at the Stevenage exchange, back to Hitchin. Some minor changes to the BBC's equipment were necessary to change its bit rate from 120Mbit/s to the optical link's 140Mbit/s. □

Low-noise cassette deck — postscript

Further details of circuit design and methods of obtaining an even better s:n ratio

by J. L. Linsley Hood

Nearly two years has elapsed since the publication* of this design, and while the basic circuit design still appears, in retrospect, to have been satisfactory, without many unforeseen snags, there are one or two areas where some improvements can be made, and where some additional information can, usefully, be given. Also, because of the enormous amount of development activity in tape recording, particularly in respect of cassette tape coatings, it seems useful to take a fresh look at the potential of this medium.

REDUCTIONS in the background noise level in both recording and replay processes are possible, giving a worthwhile improvement in signal-to-noise ratio.

Replay noise level

In the basic design of the replay amplifier an attempt was made to design a circuit in which the inherent noise level was as low as currently available devices would permit and, while in general this aim was achieved, the integrated-circuit amplifier in the output stage was overlooked as a new source of noise. This is because the relatively limited slew-rate of the 741 leads to intermodulation-type effects when it is fed with signals which are outside its effective linear pass-band. Since the input amplifying stage has a bandwidth in the MHz region, as designed, and the impedance (and hence circuit noise) of the replay coil increases with frequency, the input of the 741 is presented, quite unnecessarily, with a substantial amount of noise energy well above the required audio passband, and some of this is heterodyned down into the audible region.

Fortunately, the solution to this problem is a simple one — to ensure that the input circuit impedance does not increase too greatly with increasing frequency, which can be done by putting a small capacitor, in the range 680-820 pF, across the input to the replay amplifier, and to limit the bandwidth of the input stages of the replay amplifier to a value which does not greatly exceed the required pass-band. This can be done by putting a small capacitor (150-220pF) in parallel with the 47kΩ feedback resistor (R). An amended circuit diagram, Fig.1, for the replay amplifier is given, showing these changes. The total improvement in CCIR weighted noise level of the replay amplifier, due to these changes, is about 2dB, and on the prototype and two other units so modified, one of which was made from a commercial kit, the replay amplifier noise level was 8-10dB better than that of the tape background — an adequate safety margin. This performance, however, also depends on the head type, and this is discussed later.

*Wireless World, May, June and August, 1976. High Fidelity Designs, 2nd edition.

Zero-recorded-level noise background

In view of the good signal-to-noise ratios which had been achieved with the modified replay amplifiers, the major residual source of background noise on the final recording, ignoring that associated with the incoming signal, was that apparently impressed on the tape during the recording process. Since some of the recent tape types have an impressively low inherent tape noise level (the Pyral Maxima is particularly noteworthy in this respect) an investigation was made to identify the separate contributions to this.

Since the tape, as received, is bulk erased, while that following recording has passed the cassette recorder erase head, it seemed possible that this re-

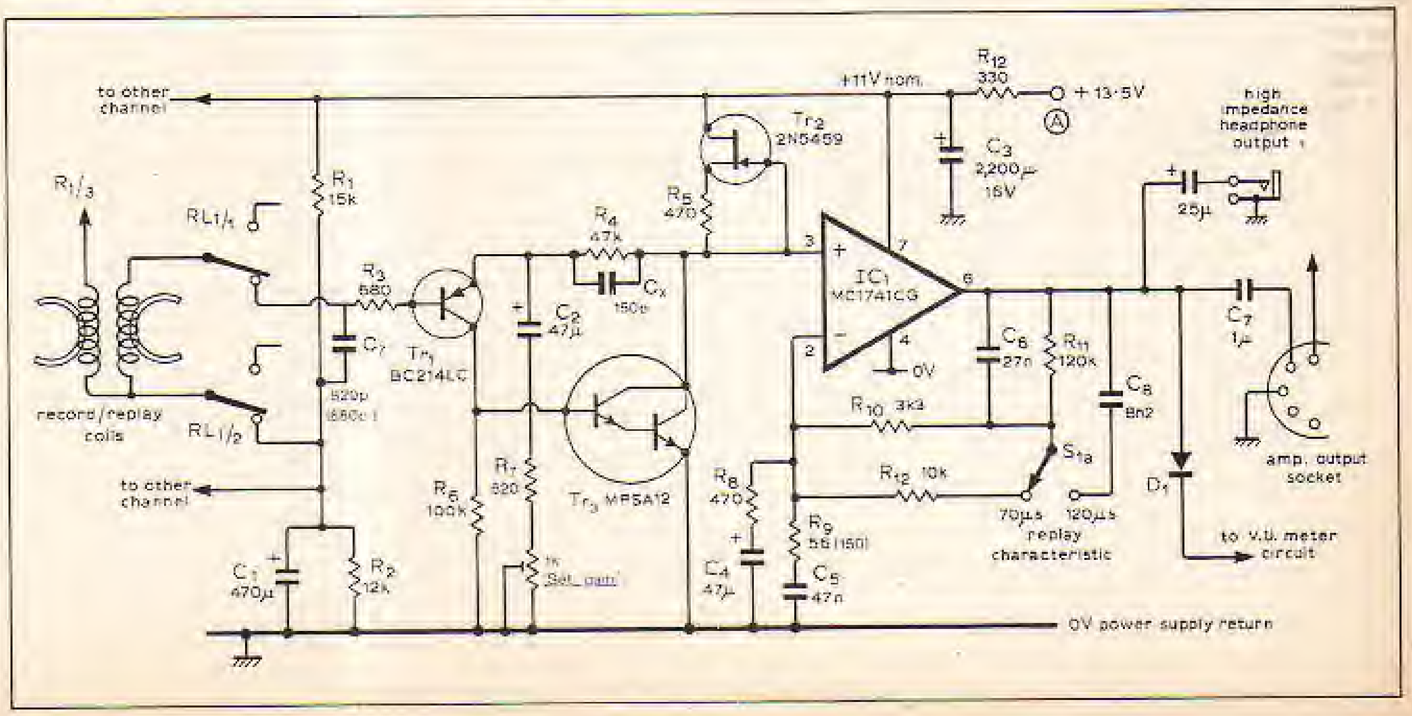


Fig. 1. *Suggested amendments to replay amplifier. Altered component values for 1.5 micron head-gap shown in brackets.*

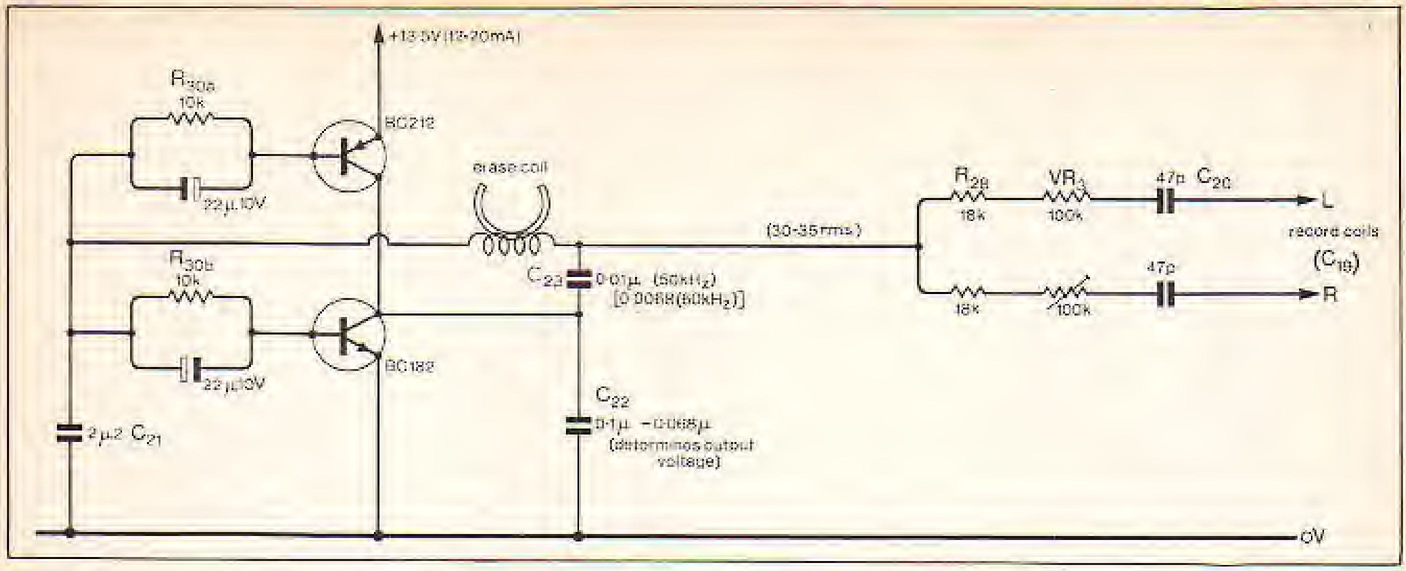


Fig. 2. *Alternative higher efficiency bias/erase oscillator. (Note: Output voltage can be increased, to 80V r.m.s., by increasing C_{22} and reducing R_{30a}, R_{30b} if needed for future tape types).*

erasure was 'wiping it dirty'. However, using a separate, though identical, bias oscillator, so that the on-cassette erase head could be disconnected, made no improvement in this respect. Indeed, the off-line oscillator was somewhat worse than the on-line one. Disconnecting the record amplifier also made no measurable improvement, while leaving the erase head in use but disconnecting the bias circuit from the record head left a tape noise level which was closely similar to that of the tape as received.

It was at this stage that the reason finally became clear. Typically, during recording, the magnitude of the h.f. bias waveform applied to the recording head in parallel with the signal is some 40-50dB greater than that of the signal. If the signal-to-noise ratio of the incoming signal is not to be impaired in the recording process, since the head is not able to discern the source of the signals which it receives, the s/n ratio of the bias waveform must be at least 60dB better than that of the record amplifier and signal source. It is probably this fact which has given rise to the widespread belief that good bias waveform purity is essential to low recorded noise level. Experimentally, it seems perfectly feasible to record with triangular and square-wave bias voltages (of the possible options a square-wave bias seems to have many advantages), non-sinusoidality seeming to be important only when this leads to bias waveform asymmetry and consequent even-harmonic distortion of the recorded signal. This arises because the recorded signal amplitude – in either direction – is bias voltage dependent.

Two steps can be taken to improve the oscillator signal-to-noise ratio: to improve its efficiency in terms of output-voltage swing for a given input power, and to reduce the proportion of wide-band noise generated by the oscillator which is transmitted to the record head along with the bias waveform. Improvement in the efficiency of the erase oscillator is effective in improving its s/n ratio because the transistor collector current is the major source of wide-band noise, assuming that the losses in the LC network containing the erase coil are small. An alternative oscillator circuit giving about 35V r.m.s. for about 12-15mA h.t. supply is shown in Fig. 2. The original circuit requires some 100-120mA for 30V r.m.s. Although the waveform purity of the two oscillator circuits is very similar, there is a small s/n improvement in the use of the later one.

The second possibility, that of reducing the component of oscillator noise within the audio pass-band which is fed to the record coil along with the 50kHz bias waveform, can be accomplished very simply by reducing the value of the coupling capacitor in the bias circuit (C_{20}) to the smallest value which will give adequate bias voltage; 33-47pF is suitable. This change is more effective in reducing zero-recorded-level noise than the improvement to the oscillator, and for those who have already built this cassette recorder, this is the only recommended change. Together, these modifications lead to about 1.5-2dB improvement in tape background noise level.

Although each of the changes suggested above will, in normal circumstances, lead only to a small, and perhaps imperceptible improvement in overall s/n ratio, taken together the improvement can be 2-3dB, which is worthwhile.

Factors affecting signal-to-noise ratio

In the earlier article, attention was drawn to the need to avoid excessive caution in the recording process, in that the overall quality of a recording in which the recording-level meter needles were occasionally driven 'into the red' would be likely to be much better than one in which, in the interests of low recorded distortion levels, the overload zone was always given a wide berth, and this point is worth restating.

However, it was expected, at the time of the earlier article, and this has been borne out by later experience, that the performance of the record/replay heads themselves would have a dominant effect upon the performance of the recorder. It seems, alas, to be a general rule that if a circuit design or process is evolved around some readily-available piece of commercial equipment or material, the publication of an article describing this will coincide with the discontinuation of the item upon which it was based.

Fortunately, in the case of the cassette deck, the Lenco cassette mechanism is identical mechanically, and at least as well made, as the Garrard unit upon which the prototype was based. However, the Garrard deck used the National Panasonic (Matsushita) record-replay head, type WY 435Z, which has a higher output and better h.f. response, and also a lower motor-noise pick-up, than some of the alternative types fitted in the Lenco unit. Luckily, it is a relatively simple matter to replace head units and to check the azimuth setting. Both the original head type and a superior unit of the same make are easily available so, in this particular instance, it is still practicable to copy the characteristics of the prototype if this is wished.

In view of the confusion which still seems to surround the design of cassette recording heads, and the relative merits of the materials used, it seems worthwhile to consider how these things will affect performance, and the basic characteristics of three different type record/replay heads are shown in Fig. 3. It can be seen from this that the use of a smaller head gap leads to a reduction in output at lower frequencies, but allows the increase in output with frequency to continue to a higher turn-over frequency. The use of 'hot-pressed' (polycrystalline) ferrite, which has lower eddy-current losses, gives an even better h.f. response for the same gap width than laminated Permalloy, but the lower magnetic permeability of the ferrite material leads to a further lowering of output at lower frequencies. Materials such as Super Permalloy and Sendust offer, respectively, improvements in wear resistance for the same permeability, and improvements in permeability for the same low level of eddy-current loss, with respect to ferrite. However, with available materials, there is a general trend towards lower output and less good s/n ratio as the h.f. performance of the heads is improved.

An additional factor, in the head design, which affects the output from the head is the extent of the magnetic shunt provided by the proximity of the internal pole faces within the head. As can be seen from the schematic representation in Fig. 4, the narrower this internal face is the better will be the head output — and also the more quickly the wear on the head face, due to tape abrasion, will impair the gap integrity. Happily, developments in tape coating technology (reductions in ferric particle size and improvements in particle size uniformity) have markedly reduced the abrasiveness of the tapes marketed during the last few years. Measurements made on the prototype unit over the last two and a half years and 1000-1200 hours of use, have shown little significant change in performance after the initial, fairly rapid, improvement in output — presumably due to an improvement in tape to head contact as the head is lapped in.

The two remaining important factors affecting s/n ratio are bias level and head magnetism. Taking the last point first, it cannot be stressed too strongly that inadvertent magnetism of the record/replay head — which can occur for a variety of reasons, and will most certainly arise if it is handled or remounted — will lead to a most substantial degradation of performance, both in respect of sensitivity and in respect of h.f. response, so that common prudence suggests periodic head demagnetisation, just to be on the safe side.

So far as the effect of bias is concerned, this was dealt with in the original article (Part 2) and the effects of changing bias voltage levels were shown graphically in the original Fig. 9. It can be seen from this that the use of too high a value of h.f. bias has a bad effect on the h.f. recording levels, due probably to partial re-erasure. While many of the modern tape types, such as ferro-chrome and cobalt-doped materials, benefit from somewhat higher levels (typically 7V r.m.s., measured across the record coil with a low capacitance h.f. probe), the several cases which I have encountered in which the record/replay performance was much below par were due either to undemagnetised heads or to excessive bias levels (in the 10-15V range!).

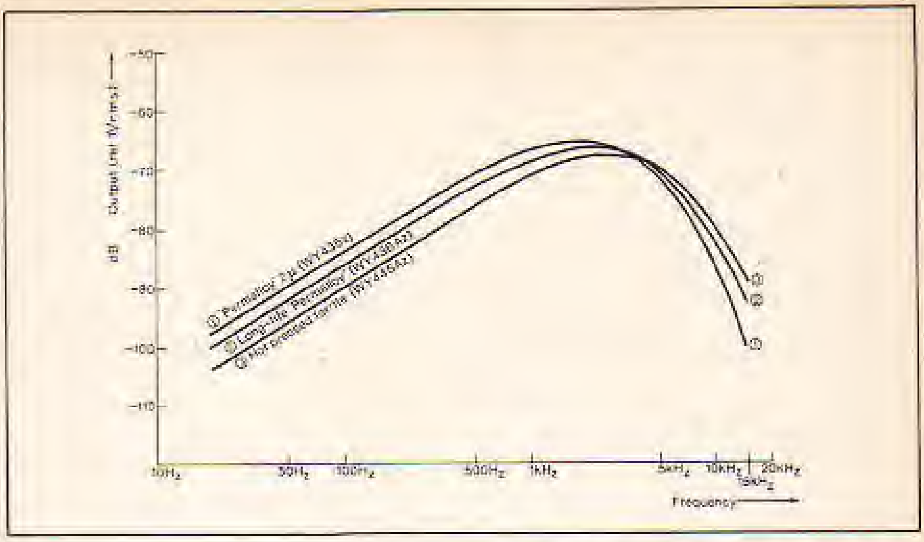
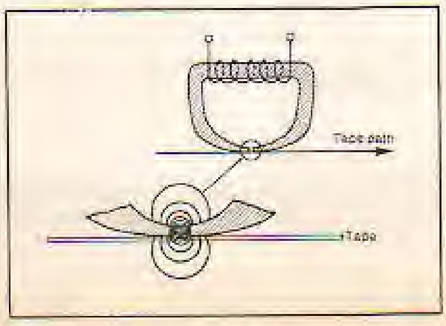


Fig. 3. *Record/replay head characteristics.*

Since the actual output from the oscillator depends on the Q of the erase coil oscillatory circuit, there can be variations from manufacturer to manufacturer, and the coils fitted to the Lenco mechanisms tend to give a higher bias and erase voltage than that of the Garrard unit used in the prototype. This all to the good, but it is recommended that the bias adjustment pots (VR_3) be increased to 100kΩ from 47kΩ to give a wider adjustment range. It is appreciated that many constructors may not have access to suitable h.f. voltmeters for on-coil voltage measurements, but some simple practical experiments in recording a steady tone, using a prearranged programme of bias potentiometer adjustments, and choosing the setting which gives the highest output on the replay recording level meters — for a tone in the 300-1kHz range — will take one close to the optimum level, and such a test will compensate for variations in the bias requirements of differing types of record heads.

Head replacement procedure. Many horrifying tales of gross head wear, due to the use of cheap tapes, chromium dioxide formulations, Permalloy heads, or excessive use of the recorder, have gained currency during the growth of popularity of the cassette medium, and many users must entertain some apprehensions about the inevitability of head wear incapacitating or impairing their machines, with the consequent need for specialist skills in head replacement. While the availability of a calibration tape, and a double-beam oscilloscope, makes this task a bit easier, simple alternatives will suffice.

Fig. 4. *Schematic drawing of tape record/replay head, showing flux linkage in head and tape.*



Since many users will have built up their own library of tapes, recorded on their own instruments it will be more important when the time for head replacement approaches, that a replacement head should be in the same position as its predecessor, with respect to the tape, than that it should be in accurate 'azimuth' (gap verticality) and height conformity to the notional standard. A standard cassette recorded on their own machines will meet their needs. It is suggested that a range of frequencies from 300Hz to 10kHz should be recorded, with both channel inputs in parallel, at '0 VU'. (300, 1k, 3k, 6k and 10kHz for two minutes each will be adequate.) If the replacement head is in the same position as the head with which the test cassette has been recorded, the output of this tape will be of identical magnitude in each channel and the outputs will be in phase. Output magnitude can be checked from the recording level meters, and phase equality can be checked by a headphone or a.c. voltmeter across the two 'live' outputs of the recorder or subsequent amplifier. When the two signals are in phase, the voltage difference between the 'R' and 'L' channels will be at its least.

This test becomes more critical as the recorded frequency is increased, and as the higher frequencies are approached errors in azimuth also become apparent. If the gap between the replay head polepieces is not truly perpendicular to the direction of motion of the tape, the h.f. output will be diminished. If the condition of phase coherence between the two channels does not correspond to the maximum h.f. output, the original record head azimuth setting was probably in error. If phase coherence between channels does not correspond to amplitude equality between them, the replacement head centre height is incorrect, which can be remedied by the addition or removal of washers from the non-adjustable end of the head mounting. For the record, a relative positional (angular) error of less than 0.05° can be seen by phase coherence checks at 10kHz, which is well within the azimuth accuracy requirements for optimum h.f. output.

The dimensions and agreed heights for the EIAJ (Japanese) 'Y' type, and Lenco/Garrard, 'Z' type, heads are shown in Fig. 5, together with the mounting system employed on the Staar type mechanisms. National Panasonic (Matsushita Co., Ltd.) offer two heads, WY 435 Z (2 micron gap Permalloy) and WY 436 AZ (1.5 micron gap, long-life Permalloy) which are of a suitable type for the Garrard and Lenco mechanisms. The latter head is of a superior construction, having a somewhat higher specific output, which compensates in part for the loss in sensitivity due to the narrower head gap, and allows the record/replay frequency response to be extended to at least 15kHz with suitable tape types. If the changes noted above are carried out, the approximately 2dB loss in output due to the use of the narrower head gap can be accepted with a final s/n ratio no worse than that of the original specification and the advantage of a better overall frequency response. It may well be that there are other head units, either now or in the future, which will be superior in performance to the National Panasonic units referred to above, since this, like that of tape composition improvements, is a field in which intensive development work will certainly continue.

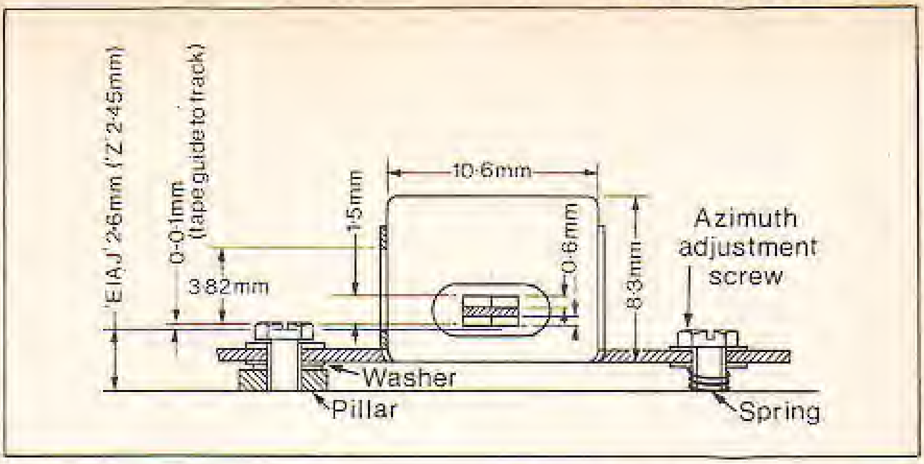


Fig. 5. *Specified dimensions for cassette record/replay heads and method of mounting used on Staar mechanisms.*

Some adjustments to circuit component values are desirable if the 2 micron gap record/replay head is replaced with a unit having a 1.5 micron gap width, and these suggested changes are indicated by the values shown in brackets in Fig. 1 and 6. In the prototype, with square-wave response adjusted to give minimal overshoot, the h.f. response with the 1.5 micron WY 436 AZ head is −5dB at 15kHz, ref. 300Hz, using Fuji FX tape. There is little doubt that the system could be made to yield a more uniform h.f. response than this, if required, by accepting a less well damped response to a square-wave signals, but earlier experiments indicate that the subjective response of the system is not improved by the attempt to obtain optimal flatness of steady state frequency response by sacrificing accuracy of transient waveform reproduction.

It seems probable that this is because the tape recording mechanism is truly a 'slew-rate-limited' one, in that there is a minimum and readily calculable time which is required for a point on the tape, travelling at 4.75cm/s (1⅞in/s) to pass the 1.5 or 2 micron (0.000059 or 0.000078in) head gap. This implies that, for an ideally perfect tape impressed with a recorded square-wave, the output from the system cannot 'slew' at a greater rate than the replay head

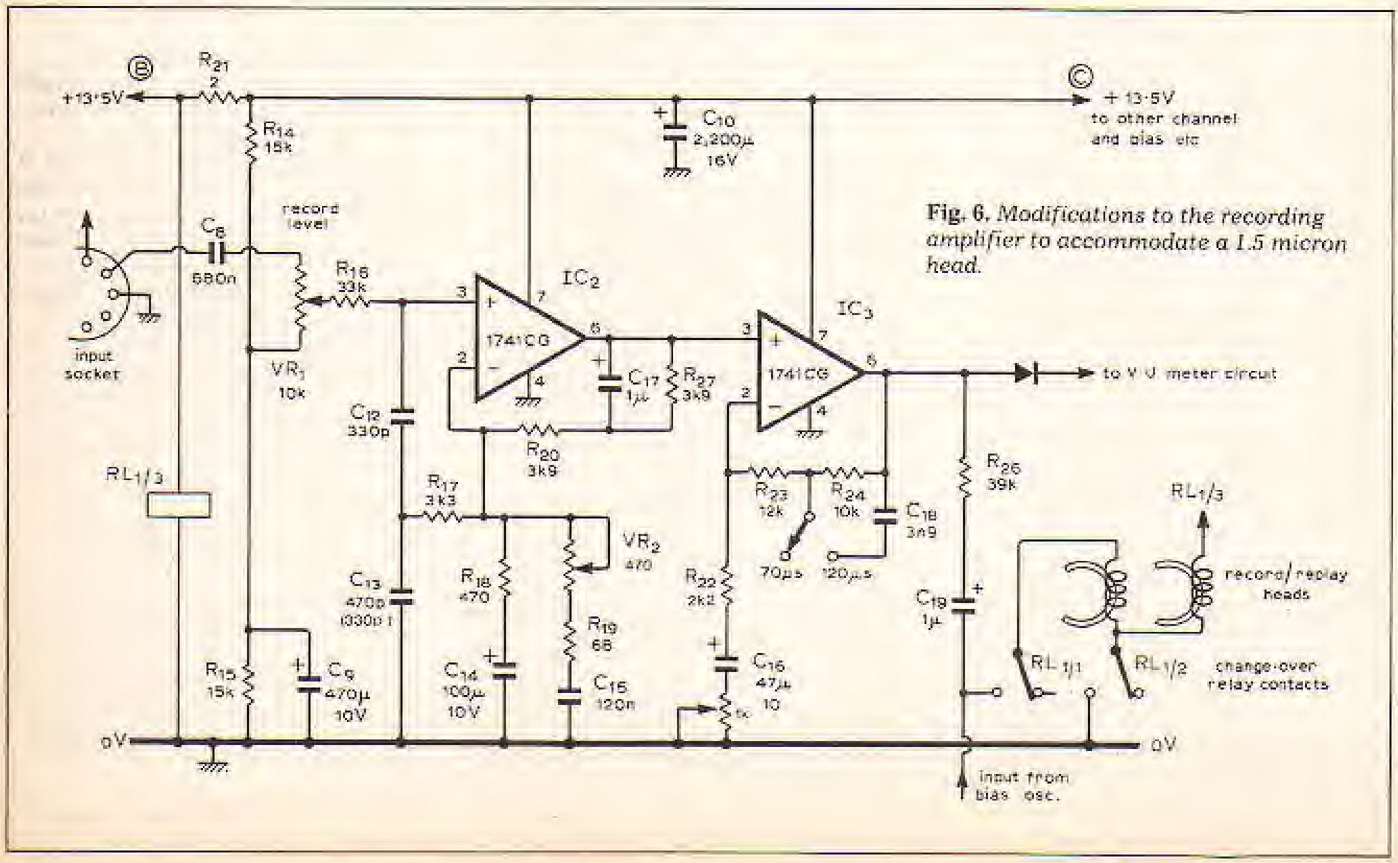


Fig. 6. *Modifications to the recording amplifier to accommodate a 1.5 micron head.*

geometry will allow, so that, if a greater input signal is impressed on the system, in the attempt to achieve improved h.f. response, the only likely effect will be to convert waveforms into a triangular shape, with a consequent increase in h.f. intermodulation distortion.

Hart Electronics of Oswestry have agreed to stock equivalent units to the Matsushita WY 436 AZ 1.5 micron head for those constructors interested in making the substitution.

Choice of h.f. bias frequency

The original choice of bias frequency (50kHz) was simply that of the recommendations of Garrard Ltd, the manufacturers of the original cassette mechanism. There is a considerable tradition in the high-quality tape recorder field that the bias frequency should be at least five times greater than the highest intended recording frequency. This arises because the action of the bias waveform is effectively to sample the signal waveform at the bias frequency, and it is plausible that the desired waveform cannot be reconstructed accurately unless there is an adequate number of samples within one cycle of the highest required frequency.

However, experimental results obtained with differing bias frequencies — obtained by using differing values of C_{23} — show that on the tapes used the remanent recorded flux and hence the s/n ratio for a given recording level, decreases significantly as the bias frequency is increased to 60 or 75kHz, so that even though a wider bandwidth can be obtained with alternative head units a change in bias oscillator values is not recommended. Some support for retaining the original 50kHz bias frequency is given by the observation that some very high quality audio systems are based on sampling rates which are lower than this. For example, the current BBC f.m. stereo radio transmissions have an L-R sampling frequency of 38kHz; the digital encoding process, by which the p.c.m. signal is transmitted over cross-country land-lines, uses a 32kHz sample rate; and the very highly regarded Denon p.c.m. encoded gramophone recordings employ a sample rate of 47.25kHz. I accept the qualification that square-wave sampling and sine-wave biassing may not be equivalent and since a square bias waveform (in effect, a triangular current waveform) appears to work quite well I intend also to explore this approach.

Dubbing

If it is desired to 'over-dub' an existing recording, without erasing the existing material, this can be done by the use of a coil other than the existing erase head in the bias oscillator circuit, so that the erase head can be switched out of circuit. Although, in principle, any coil of suitable Q and an inductance of 1mH could be used for this purpose, the simplest approach is to use another, similar, erase head, mounted in a convenient position remote from the deck and connected to a change-over switch.

Miscellaneous design oversights

It is, I suppose, inevitable, following the contemplation of a design for a couple of years, even without the benefit of criticism in print, that the designer will feel that there are certain aspects which could have been done better.

Gain adjustments. Apart from the changes in bias oscillator, feed capacitor and adjustment potentiometer value noted above, and the modifications to the replay circuit noise bandwidth limiting components, I feel I should have provided some means for adjustment of the relative channel sensitivities in the record and replay amplifiers, in order that the effects of component value errors could be removed. This can be done by making the lower feedback resistor, R_7, in the replay amplifier variable over the range 820-1k8 ohms, in either one or both channels, which can be done conveniently by altering the value of R_7 to 820 ohms, and putting a 1kΩ preset pot. in series with this. A good quality unit such as a cermet type, should be used for this duty to avoid worsening the input noise level.

A similar relative gain adjustment can be made in the record amplifier if the value of R_{22} is reduced to 2k2, and a 1kΩ pot. is placed in series with it at the earthy end. This can then be used to set the relative record levels to equality at the l.f. (say 300Hz) end of the spectrum, as indicated on the meters — assuming that these have already been correctly calibrated — while the h.f. pre-emphasis trimmer pot., VR_2, can be used to achieve record level balance between channels at the h.f. end (say 10kHz). These suggested changes are shown in Fig. 1 and Fig. 6.

Bias oscillator. In the bias oscillator circuit (the original Fig. 7) the lower potential divider capacitor in the Clapp oscillator (C_{21}) was shown as 2.2μF. With some erase heads, this did not give enough circuit gain to ensure that the oscillator would always operate. A 1μF capacitor in this position gives a greater tolerance of erase coil characteristics variations. This change was shown in the reprint* and is recommended for adoption in future units employing the original oscillator circuit design.

Meters. Some justified criticism has been received concerning the tendency of the recorded level meter needles to hit their limit stops on switch-on. This type of behaviour is difficult to avoid entirely, but it can be minimised, if necessary, by reducing the slightly over-generous value of the rectifier circuit series capacitor (C_{26}) from 10μF to 2μ2F.

Headphone amplifier. I also regret that the input p-n-p transistor in the Class A headphone amplifier was incorrectly labelled BC182L instead of BC212L. Any small-signal p-n-p device will serve, since its application is a very uncritical one.

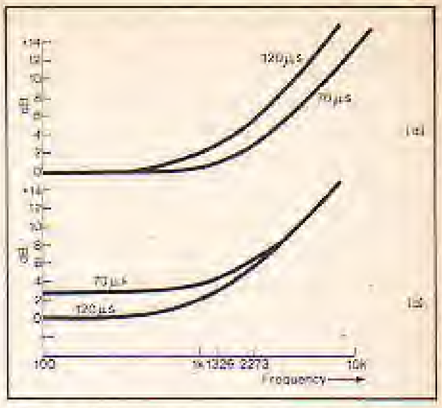


Fig. 7. *Effect of recording pre-emphasis 'time-constants'.*

Replay equalisation

Not entirely unexpectedly, I have come in for a certain amount of 'stick', both in correspondence and in the Letters columns, for my advocacy of the 70μs record/replay characteristic for general use. I note, however (with a certain amount of inward satisfaction, since it is nice occasionally to be right) that much of this has stemmed from a failure to understand just what the record/replay equalisation compensations are introduced for, or how they are derived. To shed a certain amount of extra light on what is obviously a somewhat shadowy area, I have appended a simplified analysis of the situation below, which can be omitted by those familiar with the subject.

In an ideal world of perfect magnetic tapes, and replay heads with complete external flux linkage and infinitesimally small pole-piece gaps, a tape could be recorded at all desired frequencies at a constant magnetic flux level, at some convenient value a little below the tape, or head, saturation level, and this would be found, on replay, to have generated an electrical output which increased linearly with increasing frequency, in such a manner that a doubling of frequency would cause a doubling of output, as defined by the classical laws of electromagnetic induction. A replay output which was constant, independent of frequency, could be obtained by a simple replay equalisation circuit which gave an output, starting at some conveniently low frequency, which decreased at a rate of −6dB/octave.

However, because of shortcomings in the tape and head characteristics, at the h.f. end of the recorded spectrum, it is customary to incorporate a degree of recording h.f. pre-emphasis, starting, in the case of the Phillips cassette system,

* High Fidelity Designs — a book of reprinted *Wireless World* articles on audio equipment construction.

at 1-2kHz. The actual pre-emphasis characteristics are defined by a specified time-constant, having the agreed values of 70 and 120μs. This can be converted into a known ±3dB point by the relationship $f=1/2\pi CR=1/2\pi\times$time const. which gives +3dB values for the 70 and 120μs characteristics of 2273 and 1326Hz respectively, leading to the type of recording pre-emphasis characteristics shown in Fig. 7(a). If it is assumed that during recording the recorded signal levels are adjusted so that the recording level meters achieve the same recorded levels on peaks, and if it is assumed that this is mainly influenced by the greater signal level of the pre-emphasised region, the effective recorded level will, in reality, be that of Fig. 7(b). In the case of the 70μs characteristic, this assumes that the h.f. losses will be less, requiring less correction, and permits the recording of all frequencies below the 2.2kHz turnover point at about 3dB higher level than is the case for the 120μs characteristic.

If a similar characteristic were to be adopted on replay, the effect would be to arrest the downward slope of the replay characteristic at a turn-over point of 2273 or 1326Hz, beyond which the response would be level. In practice, however, the equalisation adopted is the recording one, and the replay characteristics are then corrected in the light of the experimentally derived replay-head/tape characteristics, so that the final record-replay frequency response is acceptably level. This usually involves some additional replay treble lift, to compensate for the finite replay-head gap width. The overall residual advantage is, therefore, due to the greater signal level in the mid-range frequency band, on the 70μs equalisation, due to the decision to adopt a lesser degree of h.f. boost, which gives about a 3dB benefit in terms of signal to noise ratio. Since tapes, and heads, are no less able to accept a given magnetic flux density at 300Hz than at 10kHz (in fact rather the converse), the imputation of a less satisfactory recorded distortion level due to this technique appears ill-conceived.

Technical inaccuracies

It is a matter of genuine concern in the preparation and publication of technical articles that inaccuracies of fact or terminology should be avoided. With the best will in the world, however, inadvertent errors do creep in, and, in the case of the original articles, there are three corrections I would like to make concerning the 'VU' nomenclature.

'VU' levels. If one constructs a piece of equipment which has signal level indicating instruments, which have calibrations ranging from −20 to +3, and which their manufacturers have labelled 'VU', then, so far as the signal levels indicated by these instruments are concerned, one is rather in the position of Humpty Dumpty — "... 'when I use a word,' Humpty Dumpty said in a rather scornful tone, 'it means just what I choose it to mean, neither more nor less' ..." — so that although '0 VU' has a precise and specific meaning in the recording studio and sound engineering field (that of a signal level equivalent to 1 milliwatt in a 600 ohm load, or 0.775 volts r.m.s.) the '0' level on one's own instruments may, for practical reasons, be quite different from this.

Since I intended to redefine this level, for the purposes of this design, as being a level of 2.25 volts r.m.s., at 600Hz, as measured at the output of IC_3 in the record amplifier, it had been my intention, in the original article, to refer to VU levels, in this context, only within inverted commas, in order to indicate my temporary misuse of the definition. However, this I found, in print, that I had failed to do, and for this I apologise.*

Mr. Warren, writing from Australia,[1] did indeed reproach both *Wireless World* and me, respectively, for permitting and committing the solecism of referring to the recording level instruments as VU meters at all, in that this term should only be applied to instruments having certain, internationally agreed, standards of impedance, sensitivity and ballistic response, which the simple instruments I had described did not, and were not intended to, meet. I accept this rebuke, and am happy to substitute the somewhat more lengthy term 'recording level meter' for these display instruments. However, these strictures could be more widely spread, in that there are a large number of commercially available instruments which have signal level meters referred to as VU meters, which also fall a long way short of the international standards. While it is obviously desirable to prevent the corruption of specific descriptions by their careless use, I suspect that this particular case is going to prove a difficult battle to win.

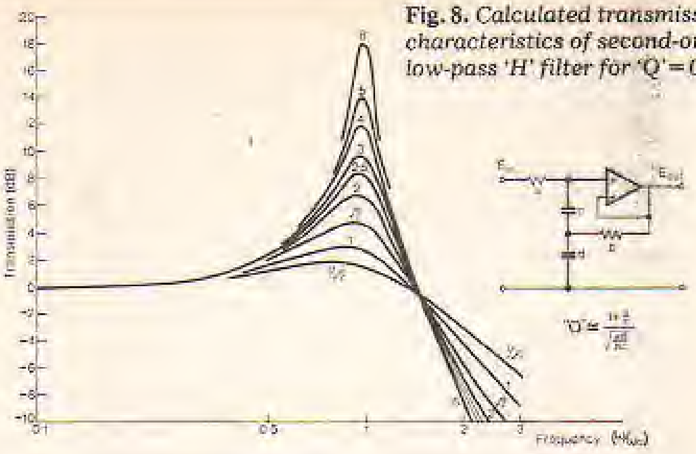


Fig. 8. *Calculated transmission characteristics of second-order low-pass 'H' filter for 'Q' = 0.707–8.*

Finally, in describing the technique which I had adopted to generate the desired recording pre-emphasis characteristic, I showed a family of curves in my Fig. 15, as being typical of the type of response which would be generated by the use of an under-damped second-order low-pass filter, for various values of 'Q'. Although the mathematical derivation of the transmission characteristics of such filters is relatively straightforward, and in the case of the circuit which I used, is shown elsewhere,[2] the plotting of the frequency response, for various values of Q and frequency, is a laborious task in the absence of a suitable computer programme, so, since an illustration was required, I used that of the active lead+lag system, for which I had previously determined the frequency response characteristics, and which are similar to those of the system I had actually used, though not identical. It had been my intention, in the text, to make clear the fact that the curves were typical rather than actual. Mr Good[3] has drawn my attention to my error in this, so, by way of penance, I have calculated the actual performance characteristics, and show these in Fig. 8. For convenience in calculation I define Q and $1/\alpha$ in these graphs.

Because of the influence of the lag network, (VR_2, R_{12} and C_{15}), on the operation of the circuit, the actual resonant frequency of the circuit is lower than the value calculated from R_{16}, R_{17}, C_{12} and C_{13}, and decreases in frequency as well as increasing in magnitude, as the value of VR_2+R_{12} is reduced. This is a convenient characteristic from the point of view of suiting the h.f. equalisation peak response frequency to the characteristics of the heads in use, and is an additional reason for choosing this type of circuit in preference to the more conventional inductor based systems.

* Examination of the original shows that Mr Linsley Hood did use quotes. In an excess of editorial zeal they were deleted — we are sorry for this. — P.R.D.

References

1. Warren, E. G., *Wireless World*, "Letters", p.46, Jan. 1977.
2. Linsley Hood, J. L., *Electronic Engineering*, July 1976, pp.55-58.
3. Good, E. F., Private communication.

Reliability

Principles of reliability prediction and factors affecting the life of components

by H. R. Henly M.I.E.R.E.

Reliability is the responsibility of the engineer concerned with the design of a system or a sub-system, yet it seems to be one of the least understood concepts which he has to use. Engineers in general seem to prefer not to get involved in any calculations of the reliability of the equipment which they are designing. The reasons for this are probably a lack of understanding of the techniques involved — considered to be bordering on the "Black Arts" by some, and is probably largely due to the fact that the data used in reliability prediction has been derived statistically — and prediction infers crystal balls. But those who shudder at the thought of anything statistical should be reminded that even the value of a resistor is really a statistical statement and not an exact value.

MANY DESIGNERS will say "I don't need to do all those calculations. I design reliable equipment by using the best components". On the face of it this argument is quite sound, but it can only be at all valid in a situation where cost is of no consequence. Cost and reliability are closely related, and cost can be of equal, if not greater importance. There is also another aspect to be considered. The user of an equipment also has to maintain it. Nothing, however reliable, will work for ever and a prediction of failure rate is a useful indication of future maintenance effort required and likely store's holdings (today's components will not be available for ever, particularly in the rapidly developing world of electronics). These considerations may be of no importance where Grandma's portable telly is concerned, but it is a different story where a data-processing installation or a telephone exchange is concerned.

Certain aspects of reliability calculations can be a little involved. The object of this article is to present some of the fundamental ideas. Excellent works are available on the subject, of which references 1 and 2 are considered by the author to be the best.

What is reliability?

Every component, whether electronic, electro-mechanical or purely mechanical, has a finite life. After a certain period of operation there will be signs of deterioration in its performance until a point is reached where it no longer performs satisfactorily. We then say that it has reached the end of its life. These last two sentences should pose some questions in the reader's mind. Such a definition is rather loose. Unless the device ceases to function completely, that which means failure for one application may not be so for another. Again, in a test situation where a device's parameters are being measured, the end-point of its life may be different to an application where negative feedback might mask the fall-off in performance to give an extended life. We can escape this quandary by recognising that the test situation has the advantage that it yields the more pessimistic estimate of device life and furthermore, that it is application-independent.

Reliability information comes from two main sources; the component manufacturer and the user. Firstly from the component manufacturer, and this applies mainly to active electronic components, e.g., semi-conductors. Batches of components are taken from the output of the production line according to a pre-determined sampling scheme. These components are placed on life-test during which they are exposed to various types and levels of stress, according to the specification of the device, and key parameters are monitored. When any of these parameters fall outside prescribed limits the component is deemed to have failed. The cause of failure is determined in order that the mechanism of failure can be better understood. In most cases this simple picture of life testing would be impracticable due to the length of life of most electronic components; reliability data would not be available in time for it to be of any use to the designer. For this reason, accelerated life testing is used. Considerable knowledge of the relationship between the life of a component and the temperature of operation, particularly in the case of semi-conductor components, has been accumulated. Thus by testing components at a suitably elevated temperature the life can be reduced to a lower, measurable value, and the component's life at other lower temperatures may be computed.

As stated above, the type of life testing conducted by component manufacturers is application-independent. Furthermore, the test environment is closely controlled and the results which have been obtained over many thousands of device hours, enable the designer to predict the behaviour of his system even under different environmental and operational conditions. One possible draw-back with the reliability data produced by component manufacturers is that for economic reasons the number of devices of any one type that can be tested at a time is limited. Thus, it still requires a considerable length of time for the number of device-hours of testing for any particular component to reach the level required for the data to be statistically 'reliable'.

The second main source of reliability information comes from component users. In general most large organisations in the electronic and electro-mechanical sphere keep some record of the reliability of the components which they use. Some of the information may have been accumulated over many device-years and is therefore 'reliable'. These data are, however, extremely application-dependent and in the general case the published information drawn from these sources does not give details of environment, levels of stress, etc, under which the device concerned was operated. Indeed, the published information may in fact be the grand average of many different applications, etc.

This information is, in fact, very valuable. Because it is drawn from a very wide range of applications and operating conditions, it tends to present an average value and because in most cases the environment is not defined, the net result is very much more pessimistic than the data obtained from the manufacturer. Furthermore, because of the very much greater number of device-years encompassed in this type of information one may have more (statistical) confidence in it. Although the method of derivation of this information is the very antithesis of the scientific approach adopted by the manufacturer's quality control organization, i.e., it does not set out to separate and control or limit the many factors which affect reliability, this is, of course, far more typical of many industrial applications where little control can be exercised over, for example, environment. In many cases, particularly with electro-mechanical components, this may be the only source of information.

Before pursuing the subject of component life data further and its application to the prediction of equipment life we should now look more closely at some of the terms used and how they are related. We have spoken, thus far rather loosely, of reliability, when most published data tends to be in terms of 'failure rate' and 'mean time between failures' (m.t.b.f.).

Since the behaviour of most physical systems follows some sort of exponential law it will come as no surprise to the reader that the probability of a failure occurring is also an exponential function of time. Reliability is the probability that a component will perform its function correctly for a given period of time under the specified operating conditions. The term probability is used here in its mathematical sense, where complete certainty that an event will occur is given the probability value 1 and complete certainty that the event will *not* occur is given the value zero. The probability of an event occurring must therefore always be between 0 and 1[3].

We cannot simply consider the failure of a single component, since this is a single event in time; instead, we must consider what happens in the general case where a number of a given type of component operates in an equipment. If we plot the number of failures against time we get a curve similar to that of Fig 1 – often referred to as the 'bath-tub' curve. This curve has three distinct areas, the first being known as the burn-in period. During this time the number of failures is high and these are due to infant mortalities caused by component weaknesses, for example fragile leads, leakages in case seals, high leakage currents, etc. For electronic equipment this period is typically of the order of 200-300 hours and is not amenable to mathematical prediction.

At the end of the burn-in period the number of failures will have fallen to a low level and the failure rate – the number of failures per unit time – then remains sensibly constant for a very much longer period of time until the components near the end of their life, the third area where the failure rate rises due to 'wear-out' failures.

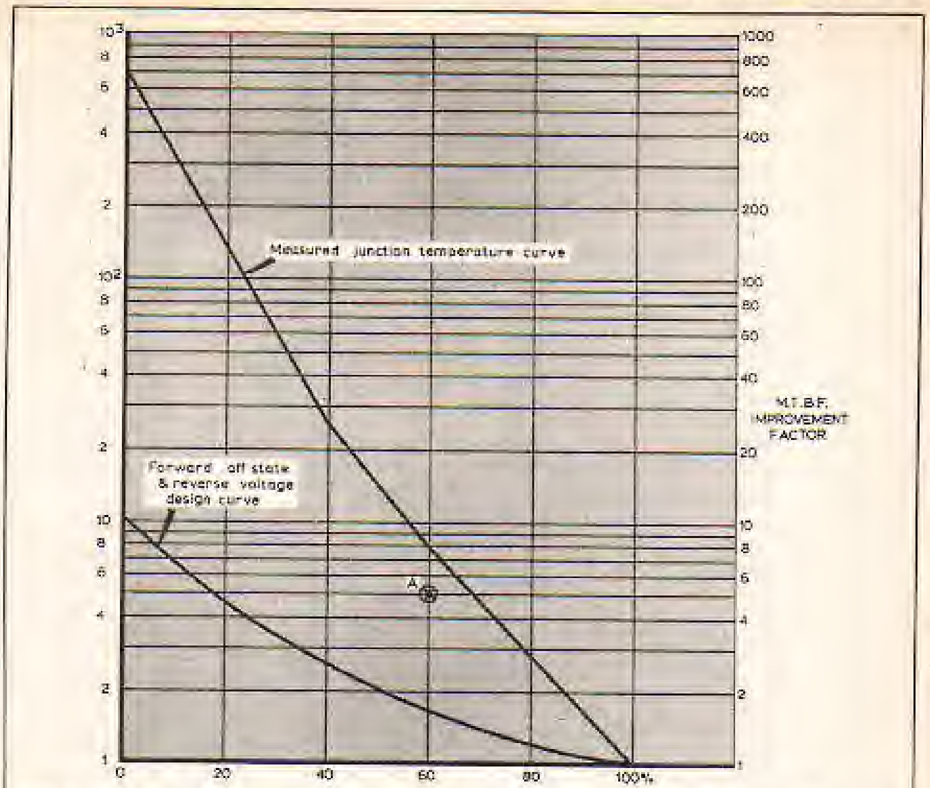


Fig. 2. *Effect of junction temperature and voltage on m.t.b.f. for silicon thyristors.*

In this article we are concerned primarily with electrical applications and of the above period that represents the useful life period. Failure studies have shown that in this period components tend to fail randomly with time and that the number of failures after a given operating time is exponentially related to time and the number of components in service. Thus:

$N_f = N_T e^{-t/m}$ .... (1)

where N_f = number of failures after time t

N_T = total number of the component in service and e = 2.71828, the base of Naperian logarithms.

The constant m was found to be the arithmetic average of the time to failure for the component concerned or m.t.b.f. Equation (1) can be rewritten in the more useful form:

$R(t) = N/N_T = e^{-t/m}$ where $R(t)$ is the probability that the component will not fail within time t, (the probability of survival). In this form $R(t)$ ranges in value from 0 (zero probability of survival) for $t = \infty$ to 1 (complete certainty of survival) for $t = 0$. From the above equation, it will be seen that, in a similar fashion to the charge/discharge curve for a capacitor resistor circuit the controlling parameter is the 'time-constant' m. For example, for $t = m$, $R(t) = 0.37$. That is, the probability of survival for a time equal to the m.t.b.f. m is 0.37 (or 37%). The probability of survival for a time of $t = 0.2m$ is $R(t) = e^{-0.2m/m} = e^{-0.2} = 0.82$ or 82%. Conversely, we can find the value of t for which the probability of survival is, say, 98%. By taking logarithms we can rearrange the equation to give:

$t = m\log_e(1/R) = m\log_e(1/0.98) = 0.02m$

That is to say we can be 98% certain that the component or equipment will operate without failure for $0.02m$ hours. Alternatively one can use the last form of the equation in a similar way to find what the equipment m.t.b.f. must be to achieve a given survival time with the required level of confidence.

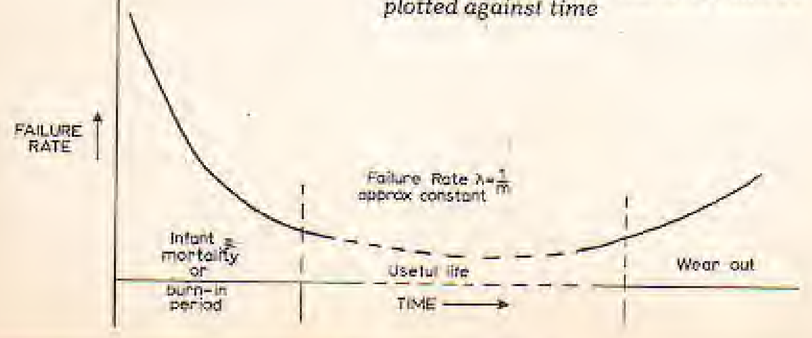


Fig. 1. *The "bath-tub" curve of failures plotted against time*

It is seen from the above that the probability of survival, that is, of operation without failure is determined by the parameter m, the m.t.b.f. It must be remembered that m.t.b.f. is, as the term implies, an average value – which in turn implies that there will be components whose time to failure will be less than m and also those whose time to failure will be greater than m. It is a common misconception that the m.t.b.f. m, when quoted for an equipment, is the life which one can expect before a failure occurs. As one can see from the survival equation, one can only be 37% certain that such a life will be achieved.

Failure rate, which we have already mentioned, is related to m.t.b.f. The average failure rate of a component is $\lambda = 1/\text{m.t.b.f.}$ or $1/m$ per unit time. If m is in hours then λ is failure rate/hour. Failure rate is usually expressed as the percentage component failures per 1000 hours. For example, in a data-processing installation, 500 integrated circuits of a particular type were in service for five years. In this time only two failures were recorded. The percentage failure was, therefore, $(2/500) \times 100 = 0.4\%$. The total number of operating hours was 43680 (5 yrs). Thus, failure rate $= (0.4/43680) \times 1000 = 0.0092\%/1000$ hours. This form is useful when comparing the performance of components, but must be converted to failures per unit time when performing failures rate calculations.

Equipment reliability

So far we have only considered what happens in the life of a single component or equipment. In practice we are concerned more with the reliability of equipment which contains numbers of different components and systems which comprise more than one equipment. These two cases are in many respects the same and what follows can be applied to both. However, the reliability of a system can be complicated by the presence of duplicate elements (redundancy) such that the failure of a single one of these elements will not result in failure of the equipment.

Since an equipment will contain numbers of components of varying types and individual reliabilities we would expect the overall reliability to be lower than that of the worst (least reliable) component. The relationship above gives the probability of a component's life extending to time t. If we have two components with individual probabilities of survival of $R_1(t)$ and $R_2(t)$ respectively, their joint probability of survival to time t will be $R_E(t) = R_1(t) \times R_2(t)$. If we substitute in this expression the exponential relationship for R(t) we get:

$R_E(t) = \exp(-\lambda_1 t) \times \exp(-\lambda_2 t)$ where λ_1 and λ_2 are the failure rates of the two components.

Then $R_E(t) = \exp -(\lambda_1 + \lambda_2)t = \exp(-\lambda_E t)$. Clearly $E = \lambda_1 + \lambda_2$, and the m.t.b.f. of the combination is $1/\lambda E = 1/(\lambda_1 + \lambda_2)$. This leads to a very simple rule; to find the failure rate of an equipment in which failure of the equipment results from the failure of any one of the constituent components we simply add together the individual failure rates of all the components. For example, let us consider the case of a simple photo-electric system in which a beam of modulated infra-red radiation is generated by a gallium arsenide diode and is detected by a silicon diode. A typical system with a self-contained mains power supply might contain the components shown in Table 1.

Table 1. Component list of typical photo-electric system discussed as an example.

Component list for Photo-electric Beam Control Unit

Section	Component	Quantity	Unit Failure Rate %/1000 hours	Joint Failure Rate %/1000 hours
1. **Amplifier**	Resistors ¼w composition	20	0.021	0.0042
	Capacitors: polystyrene	9	0.0008	0.0001
	electrolytic	5	3.33	0.1665
	Transistors low power 150mW	6	0.017	0.001
	Diodes signal GaAs	1	0.008	0.00008
	light source	2	0.02	0.0004
	Soldered joints	120	0.18	0.216
	Printed circuit board	1	0.01	0.0001
	Output transformer	1	0.1	0.001
2. **Relay Driver**	Resistors composition ¼w	6	0.021	0.0013
	Capacitors polystyrene	3	0.0008	0.00002
	Transistors medium power	1	0.6	0.016
	Diodes Zener	2	0.7	0.034
	Soldered Joints	30	0.18	0.054
	Printed circuit board	1	0.01	0.0001
	Relay (2 c/o contacts)	1	1.57	0.0157
3. **Power Supply**	Power Transformer 100 VA	1	0.2	0.002
	Diodes power	4	0.7	0.028
	Capacitors electrolytic	2	3.333	0.066
	Power connector	1	0.005	0.00005
	Soldered Joints	30	0.18	0.054

Summing the joint failure rates in the right-hand column of Table 1 yields the overall failure rates of 0.6605/1000 hours. The m.t.b.f. will therefore be $1000/0.6605 = 1514$ hours. Using the survival equation we see that we could only expect around 160 hours (with 90% confidence) of fault-free operation and this ignores, for example, failures due to the build-up of dust on the optical system. If this equipment were in use in a process-control installation with, say, nine other identical equipments and a failure of any one equipment would mean failure of the installation, then the overall failure rate would be ten times greater. The m.t.b.f. is therefore reduced to 151.4 hours. We could expect, with 90% confidence, a period of fault-free operation of only 16 hours.

Suppose that it is essential that the installation shall operate with 90% certainty for a minimum period of 22 hours without a failure. We can use the survival equation to find what overall m.t.b.f. is required; in this example we get $\text{m.t.b.f.} = 22/\log_e(1/0.9) = 208.83$, say 209 hours. This requires that the m.t.b.f. of the individual equipments must be at least ten times this value — 2090 hours.

At this stage we might reasonably question the design of this unit and consider what improvements, if any, we can make to its reliability. The first step is to examine Table 1 to see how the failure rates are distributed over the different parts of the equipment. There are three distinct parts to this equipment; the photo-cell, light source and amplifier, the relay driver and the power supply. The joint failure rates and m.t.b.fs for each are shown in Table 2.

TABLE 2
Approximate Distribution of Failure Rates

Item	Failure rate	mtbf hours
photo-cell light source and amplifier	0.3894	2568
relay driver	0.1211	8258
power supply	0.1501	6662

In this case the photo-cell, light source and amplifier contributes most to the unreliability of the system. One now has to decide whether any worthwhile improvements can be made.

The m.t.b.f. of the relay driver and power supply together is 3687 hours and this represents the highest m.t.b.f. which can be achieved — by reducing the failure rate of the amplifier to zero. Although this is not possible, this calculation does enable one to answer the question 'is any improvement likely to be significant?'. In this case, if the amplifier failure rate were zero the m.t.b.f. of the system would be increased by a factor of 2.5. In practice, of course, we cannot expect to achieve such a vast improvement, but at least the scope is there. Had the ratio been much smaller, it is doubtful whether any practical improvement could be made which would be significant when compared with the rest of the system.

The two components with the highest failure rates are the electrolytic capacitors and the soldered joints. Provided the required values are not high the electrolytics can be replaced by Mylar film types with a unit failure of 0.0008%/1000 hours. This results in an overall m.t.b.f. for the amplifier of 4485. The overall m.t.b.f. for the equipment becomes 2023 hours; an improvement of 34%. The likely cost of this modification would be small, so a worthwhile improvement would be obtained.

As far as the other high failure rate component is concerned — the soldered joints — a significant reduction could only be achieved by a pro-rata reduction in the number of components. For example, if the amplifier could be replaced by two operational amplifiers in dual-in-line integrated packages, then the number of soldered joints would be reduced to about 60, but there would be a considerable reduction in the other components also. An estimate of the resulting failure rate (assuming the integrated circuits to each have failure rates of 0.0005%/1000 hours) is 0.1097/1000 hours. The resulting m.t.b.f. of the amplifier is therefore 9115 hours, and the overall m.t.b.f. of the equipment becomes 2625 hours, making the overall improvement due to both modifications about 1.7:1. This second modification is quite drastic however and would only be considered at the design stage of the equipment.

The time for which we could expect fault-free operation of ten units (with 90% confidence) is now increased to 27.7 hours. Clearly this is a considerable improvement but it is still hardly a satisfactory situation. In the original example we quote the case of ten such units, the failure of any one unit causing system failure. In such a situation we would be justified in looking for further improvements, but some of these may affect the design of the rest of the installation and would require careful consideration. Redesigning the relay driver to eliminate the relay, for example; although it would increase its intrinsic reliability, it would mean a drastic change in the interface with the rest of the system. Undoubtedly the power supply is another high failure rate area with its electrolytic capacitors and high power level devices. If the overall system design would permit, since 10 such photo-electric units are used, the use of a common power supply would make a significant change to the overall reliability. The joint m.t.b.f. for 10 units would become (assuming the improvements to the amplifier discussed above) 422 hours, nearly a 3:1 improvement over the original situation.

The above example serves to bring out one or two important points. The overall failure rate of an equipment will be greater, sometimes very much greater than that of any of the components used. Whether or not this overall failure rate is acceptable depends upon the system in which it is being used. Failure implies maintenance and calculation of the expected annual maintenance cost is often the best criterion for determining whether the expected failure rate is acceptable or not. It may seem a defeatist attitude to even consider that a failure rate could be acceptable but we must not lose sight of another factor — that the capital cost and the failure rates of components are closely related. For example, in the case of t.t.l. integrated circuits, when the costs and reliabilities of different packages are compared it is seen that by using Class A devices the cost is increased by a factor of 3:1 over that of industrial devices, whilst the m.t.b.f. is increased by a factor of 5.

Unfortunately there is no easy solution to this problem. A process of trial and error must invariably be used, employing a table similar to that of Table 1, but with an additional column giving the cost of each type of component, so that each component change will enable not only the effect upon reliability but also upon cost to be calculated. This table is inspected to identify those components which significantly affect the overall failure rate and alternative components and/or circuit redesign considered to improve the reliability bearing in mind the effect this might have on the overall capital cost. It may well pay to trade-off increased capital cost against reduced maintenance costs since the former is a 'once only' cost whereas the latter is a continuing cost.

It has already been remarked that failure rate of an equipment is not always due to complete failure of a component but instead is due to parameters varying with age and falling outside acceptable limits. It follows therefore that a positive contribution to reliability can be made by proper attention to equipment design. Electronic circuits should be designed to be as tolerant of component parameter variation as possible. Computer programmes are available which enable circuits to be simulated and the effect of component parameter variations to be accurately determined as well as power dissipations and stress levels. As well as making for a more reliable equipment these design techniques can lead to cheaper designs using wider tolerance components. The design of circuits which are tolerant of component parameter degradation is also very dependent upon the equipment performance specification. Performance specifications should not be unnecessarily tight since this is immediately reflected in component tolerances.

Choice of components

The reliability of a component is determined by various factors and the degree to which these factors are operative in a given equipment must be decided by the equipment designer before an accurate assessment of reliability can be made. Some of the factors which affect the reliability of a component are:

— component quality and type of construction
— temperature
— vibration
— humidity
— electrical stress level.

Component manufacturers aim their products at various application fields and often have separate product lines for each – military and aero-space, industrial, domestic consumer, etc. Particularly in the semi-conductor industry the specifications for each of these fields are well defined. For example, in the case of t.t.l. integrated circuits the military product line differs from the industrial version in packaging as well as the performance testing to which the finished product is exposed (on a batch-sampling basis). There are significant differences in the reliability obtained but there are also equally significant differences in cost.

Capacitors are another example of a component field in which there are many types of construction. Here the constraints on the designer are not only cost and reliability but also physical size, maybe weight, and electrical performance. One may for example be faced with the quandary of requiring a silver-mica construction from stability considerations, a polystyrene in order to meet space requirements, etc.

The effect of temperature upon the life of a component may be judged in a qualitative fashion by remembering that the rate at which a chemical reaction takes place doubles for every 10°C rise in temperature. In general, electrical components show an increase in their useful life as their operating temperature is reduced. Fig. 2 shows the relationship between junction temperature and m.t.b.f. for silicon transistors.

At high temperatures other effects come into play which affect the mechanical structure of the device in addition to affecting its electrical operation; for example, thermo-plastics soften and distort at temperatures around 95°C, metal-glass seals rupture due to differential expansion and dielectrics change their characteristics. Under these conditions it is difficult also to maintain stable temperature levels and thermal run-away often occurs. For these reasons electronic equipment should be designed so that it operates well within the temperature ratings of its components with adequate ventilation to remove excess heat. In calculating the expected operating temperature of an equipment the effect of external sources of energy such as solar radiation should also be considered in addition to the expected range of ambient temperatures.

At the other extreme, operation of equipments at low temperatures can also adversely affect the life expectancy. For example, differential contraction of materials in seals, hardening of oils and grease in bearings. Complete failure of electrolytic capacitors, primary and secondary cells (except the Nickel-Cadmium type) in which the electrolyte has a very much lower freezing point than the lead-acid type.

Associated with the effects of operating temperature is the electrical stress level at which a component is operated. In the case of semiconductors, reduction of the applied bias and operating current and voltage levels results in a significant increase in useful life. Tungsten filament lamps which typically have useful lives of some 2,000 hours at full rating, show an increase of up to five times this value for a derating of only 10%.

Closely associated with temperature is humidity. The absolute humidity is determined primarily by the air temperature and is highest at high temperatures and generally decreases with the temperature. Of all the various environmental factors humidity has probably the greatest effect upon component life, and performance. Absorption of moisture by a material used as a dielectric or just as an insulant causes an increase in loss angle with consequent local generation of heat and reduction in performance. Absorption also leads to dimensional changes, lowering of flexural strength and, over a period of time, corrosion of metallic parts, which is exacerbated by galvanic action where the contact of dissimilar metals is involved.

Any equipment which moves or in which there are moving parts will suffer vibration. The design of mechanical structures to minimise the effects of induced vibration upon the components is a complex exercise. To be carried out effectively the precise nature of the induced vibration in individual components must be known. In certain cases the effects of vibration may be alleviated by the use of anti-vibration mounts. Joints of all kinds and connectors are particularly vulnerable, as also are potentiometers, variable capacitors, switches, lamps and lamp-holders.

In this context particularly one must also consider the effects of maintenance work. This is one of many aspects of reliability where there is intersection with the subject of maintainability. In this particular case any component which may be moved in the course of testing may be subjected to damage.

For example, it is often necessary to remove printed circuit boards in order to mount them on extender boards or to effect a repair. Apart from affecting the electrical contact between the mating contacts of the edge connector due to disturbance of dirt and oxidation layers — which should be cleared anyway before re-insertion — physical damage may also occur during the removal/replacement process. Careful selection of board connectors and design of their mounting plays an important part here. Similar problems arise where it is necessary to replace components. The quality of soldered joints must be controlled and the damaging effects to printed-circuit tracks and the board minimised.

It is, of course, an intractable problem as far as reliability is concerned to include the above and similar effects in any reliability equations at the design stage, unless one has available historical records for similar equipment operated and maintained under similar conditions. However, one is able at the design stage to design with the maintainability of the equipment in mind. The process whereby a faulty component is located should be made as direct as possible thus minimising the amount of speculative board removal and replacement for testing which otherwise occurs in practice.

It is not possible to consider these and other topics which affect reliability in greater detail within the scope of this paper. The subject is very adequately and explicitly dealt with in reference 2, which also goes a long way towards formulating the whole process of reliability calculations.

System reliability

Much of the foregoing discussion on equipment reliability applies also to system reliability. The system designer will be concerned with integrating a number of equipments into a complete system. When he has some control over the design of the individual equipments also, he will have the necessary data from which to assess the overall system reliability. A difficulty arises, however, with proprietary equipment, for example, a digital processor, where the system designer must rely to a large extent upon the information provided by the equipment supplier, weighted by any previous experience.

The system designer's work does not start when all the separate equipments comprising the system have been designed, it must start, before any detailed design can begin, with the complete specification of the system for which he must state the required minimum overall system performance objectives. These objectives must include minimum reliability and maximum cost boundaries. It would be super-idealistic to suggest that such boundaries can be fixed absolutely at this early point in the design but an initial feasibility study would indicate where they should be.

The overall design of a system from a reliability point of view requires more than the simple integration of a number of component equipments and the calculation of the overall reliabilities. In the earlier example of a photo-electric system the reliability which was calculated referred only, in this case, to its electrical performance. In practice the system designer must consider the overall operation of the system. In this example, experience shows that in most industrial applications of photo-electric systems an important contributory factor to the un-reliability of the system, is the accumulation of dust on to the exposed optical surfaces. Prior knowledge of this factor could be taken into account in the design of the optical system and any recorded data relating to failure due to this cause used when calculating the expected m.t.b.f.

Furthermore, the remarks made above regarding the effects of maintenance work on the reliability of an equipment apply equally to a complete system. It is, therefore, equally imperative that the quality control of maintenance work should be at least, as vigorous as that employed at the manufacturing stage. This consideration together with the rising cost of maintenance for complex electronic systems has made the employment of centralised repair depots economically viable. First-line servicing is thus reduced to the task of identifying and replacing a faulty module.

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Microwave hybrid integrated circuit technology

A review of microwave circuitry and systems progress

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This article describes some of the processes and devices used in microwave hybrid integrated circuit (m.i.c.) technology and considers example m.i.c. subassemblies which are currently in use. Since m.i.c. technology has influenced only the lower portion of the microwave section of the electromagnetic frequency spectrum, which extends from 1 to 300GHz (30cm to 1mm wavelength), the following text is concerned only with circuits for frequencies between 1 and 40GHz.

WHILE INITIALLY almost dedicated to a radar role, microwaves now find applications in communications, scientific, industrial and even consumer activities. The attractions of microwaves are many and include broad bandwidth potential, spectrum availability, simple aerials with high gain and directivity and the existence of low sky noise at these frequencies. However, they were initially excluded from most applications as a result of the cost and complexity of the basic components. With the advent of solid state devices, capable of generation and amplification at microwave frequencies, the potential was very much increased. The devices were accompanied by basic technical advantages as well as the well known advantages of improved cost, size, weight and lifetime. For example, the complex global satellite communication systems now in existence depend for their viability on solid state, low-noise amplifiers.

Solid state microwave devices thus enabled microwaves to find new applications. The potential of microwave techniques was further enhanced when these solid state devices were combined with microwave components in hybrid m.i.c. subassemblies. These subassemblies are now making an impact at the production stage and we are finding that microwave techniques are becoming increasingly competitive in certain new fields. Traffic control, for example, is already an established area for microwave devices and systems, as illustrated by the traffic-light radar unit in Fig. 1. In the communications field, new subassemblies include those used in the experimental television receiver systems which have been employed in Canada recently to receive 12GHz satellite transmissions. Another example m.i.c. assembly is the 12GHz-to-400MHz frequency converter shown in Fig. 2.

It is the object of this article to review the current status of subassemblies such as these in the light of device and circuit progress.

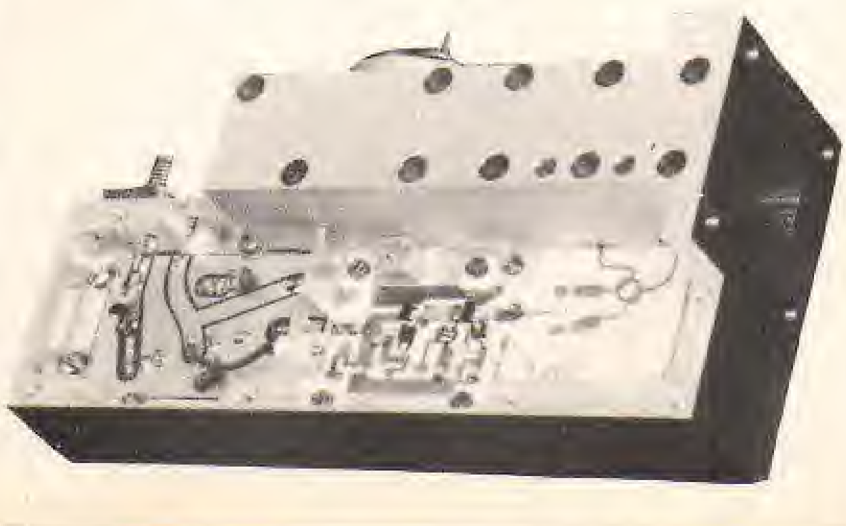
Developments and trends in microwave electronics

Microwave technology developed around vacuum tube devices such as triodes, klystrons, magnetrons and travelling wave tubes. Waveguide and coaxial techniques were fully compatible with these devices but resulted in large and expensive systems. The advent of microwave solid state devices offered the possibility of reliable, cheap and small components for the generation, amplification and detection of microwave energy. However, solid state devices were incompatible with waveguide components and consequently their potential was reduced. The Gunn diode, for example, has dimensions of the order of microns, but until fairly recently it was packaged and mounted in a 3cm waveguide. Furthermore, waveguides have proved an unsatisfactory basis for miniaturisation.

The alternative, the coaxial transmission line, has an impedance level more compatible with that of semiconductor devices, but unfortunately it is not suitable for integration with semiconductor devices. A planar structure is desirable for this purpose. By distorting the coaxial line or the open transmission line, as indicated in Fig. 3, a range of miniaturised, open systems has evolved.

Fig. 1. *Traffic-light radar unit which uses microwave frequencies.*

Fig. 2. *12GHz-to-400MHz converter for satellite television.*



Examples are triplate, coplanar waveguide and microslot, suspended microstrip and trapped inverted microstrip (t.i.m.). Lumped elements have also found applications in the microwave frequency range[1,2]. Although microstrip is often encountered, in combination with one of the other techniques, in subassemblies, we will concentrate on the microstrip technique since it is playing the major role at this time.

The microstrip structure supports a hybrid mode but it is permissible, at low microwave frequencies, to approximate its field configuration to that of a transverse electromagnetic (t.e.m.) mode. At these frequencies the transmission line properties can be derived by calculating the effective capacitance and inductance per unit length of the line by conformal mapping of the strip geometry[3]. Recently, microstrip structures have been constructed at frequencies beyond 12GHz where dispersion effects are significant[4] and the t.e.m. representation is inadequate. Here the situation is far more complex and the hybrid structure must be solved. This problem has been the subject of substantial research effort and as a consequence it is now possible to design a complete range of passive circuit elements including impedance transformers, cavities, filters and directional couplers.

The microstrip configuration is suitable for accommodating semiconductor device chips either directly or on the supporting ground plane immediately adjacent to the substrate. Thus we have the possibility of hybrid, microwave integrated-circuit subassemblies. The realisation and performance of these components will be discussed in the remainder of this article.

Table. Electrical properties of commonly used substrates

Material	Dielectric constant	Loss tangent
alumina	9.6	1.0×10^{-3}
fused quartz	3.78	1.2×10^{-4}
sapphire	9.3*	0.3×10^{-4}
	11.5**	0.9×10^{-4}
	*parallel to A axis **parallel to C axis	
ferrite (e.g. Trans. Tech. G1021)	14.8	2.0×10^{-4}

Technology

As indicated in the introduction, a hybrid microwave integrated circuit consists of a number of semiconductor devices mounted either directly on or adjacent to a planar circuit. The planar circuit, commonly microstrip, consists of a metallic pattern, which defines the passive circuit elements on one surface of a dielectric substrate, the other side being completely covered by a metallic sheet.

Microstrip circuit patterns are commonly defined on 0.020in or 0.025in thick dielectric substrates. At frequencies in excess of 12GHz thinner substrates are sometimes used to suppress "surface wave" modes and over-moding effects. However, careful circuit design can prevent the excitation of such modes on 0.025in alumina, even at 30 GHz[5].

The basic process for manufacturing m.i.c.s consists of the following steps:

(a) substrate selection and processing
(b) complete metallisation of the substrate surfaces
(c) defining the circuit pattern
(d) a plating process to produce conductors of the correct thickness
(e) etching to remove the metallisation from the appropriate areas of the substrate
(f) mounting the semiconductor chips
(g) bonding and etching chips
(h) trimming the circuit components as required
(i) packaging
(j) passivation

It should be noted that processes (b), (c), (d) and (e) depend upon whether a thick or thin film metallisation is used. This will be discussed more fully later in the article.

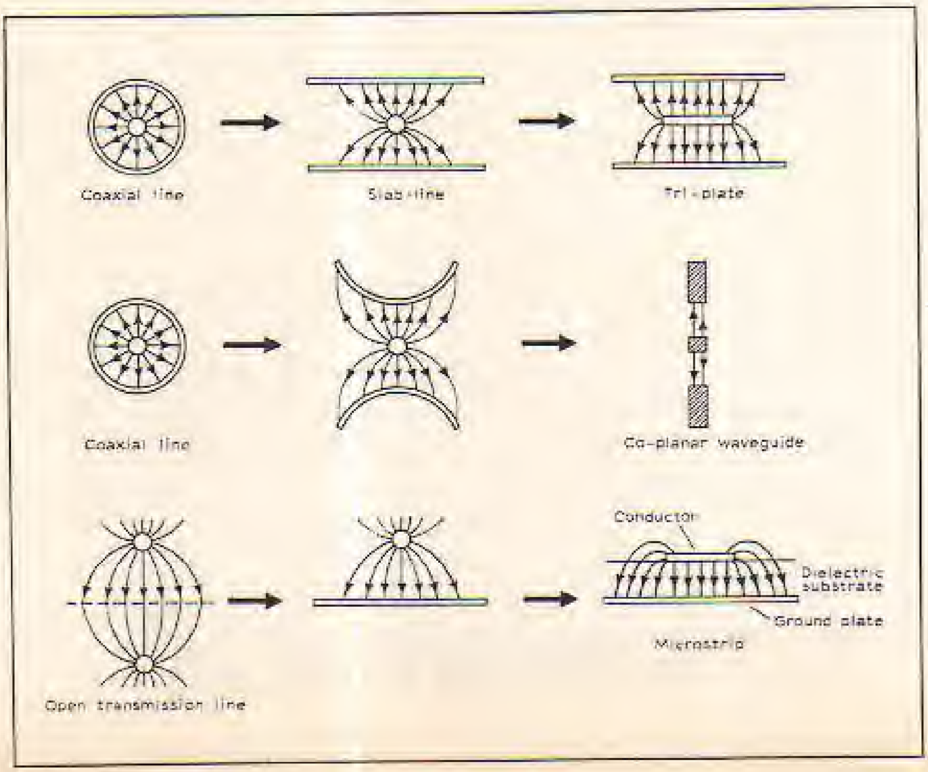


Fig. 3. *Miniaturised microwave systems have evolved, as the drawings show, from coaxial or open transmission lines which have been distorted.*

The substrate

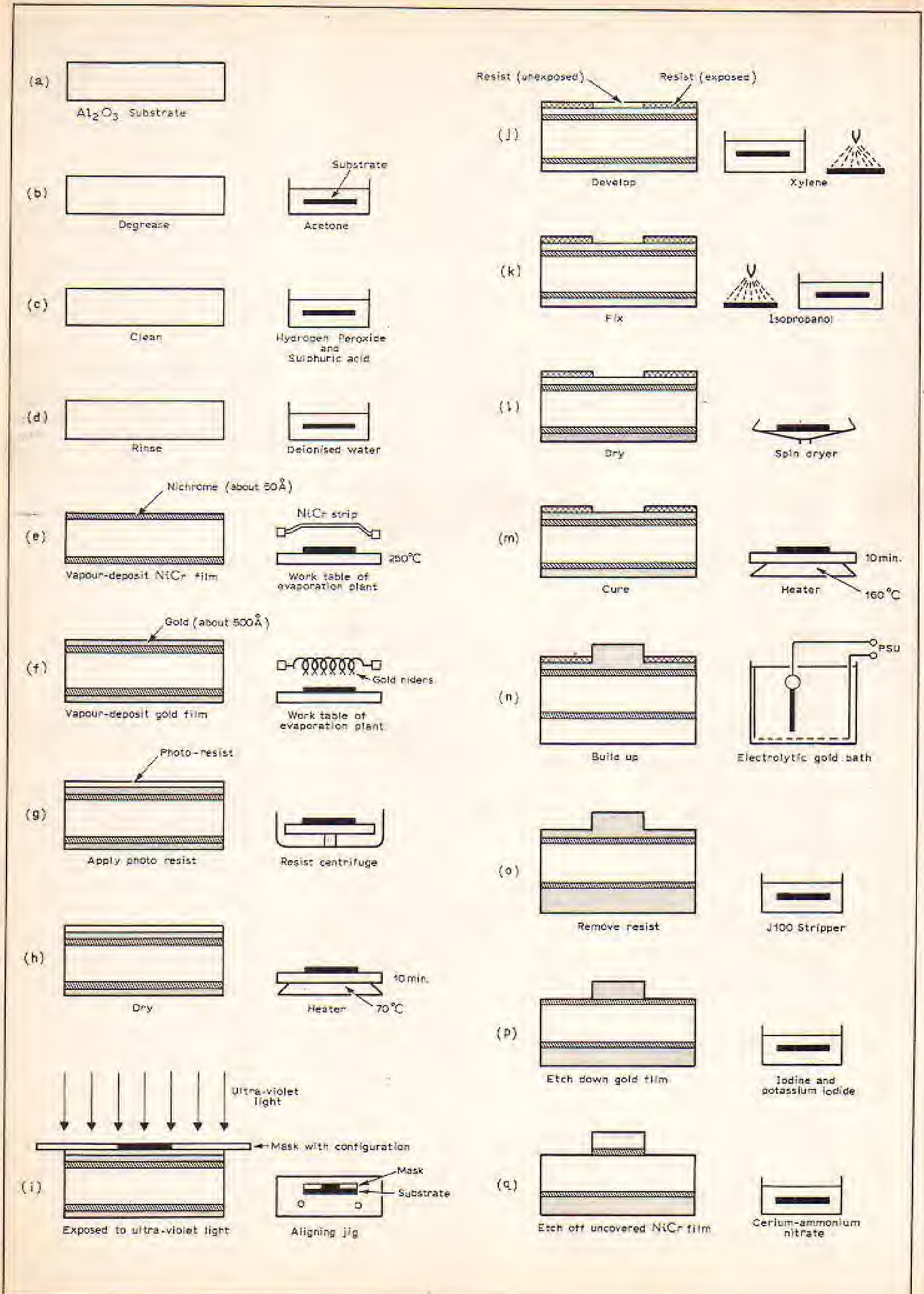
The substrate is selected on the basis of its low loss and high dielectric constant. A fine surface finish is also required to provide close circuit tolerances. A further significant parameter is the temperature dependence of the dielectric constant. The parameters of the basic substrate materials are summarised in the table shown.

Alumina is the most widely used substrate material. However, fused quartz is encountered where either fine definition or high frequency operation is required. Sapphire is sometimes employed, because of its high dielectric constant, to minimise the surface area. Ferrite substrates are used when non-reciprocal elements such as isolators and circulators are required, though the ferrite is often used in the form of a puck inserted in a dielectric substrate. Teflon and beryllia are also suitable for low loss substrates, and the latter is sometimes used to provide a high thermal conductivity (2.5W/cm°C). The use of beryllia, however, is very much restricted by its toxicity.

Alumina can be used in the "as fired" state and can be cut into appropriate sizes using a diamond saw or laser. Ultrasonic drilling can be used to drill holes in the substrate, and substrates can be thinned by a grinding process using diamond pastes.

Before metallisation, quartz and ferrite have to be polished using methods similar to those used for thinning alumina. Ferrite, however, requires some care, because intergranular holes may be formed

Fig. 4. *This display of drawings shows the sequence of operations for forming a microwave circuit on a substrate.* ▶


(a)
Al_2O_3 Substrate
(b)
Substrate
Degrease
Acetone
(c)
Clean
Hydrogen Peroxide and Sulphuric acid
(d)
Rinse
Deionised water
(e)
Nichrome (about 50Å)
NiCr strip
250°C
Vapour-deposit NiCr film
Work table of evaporation plant
(f)
Gold (about 500Å)
Gold riders
Vapour-deposit gold film
Work table of evaporation plant
(g)
Photo-resist
Apply photo resist
Resist centrifuge
(h)
10 min.
Dry
Heater
70°C
(i)
Ultra-violet light
Mask with configuration
Mask
Substrate
Exposed to ultra-violet light
Aligning jig
(j)
Resist (unexposed)
Resist (exposed)
Develop
Xylene
(k)
Fix
Isopropanol
(l)
Dry
Spin dryer
(m)
10 min.
Cure
Heater
160°C
(n)
PSU
Build up
Electrolytic gold bath
(o)
Remove resist
J100 Stripper
(p)
Etch down gold film
Iodine and potassium iodide
(q)
Etch off uncovered NiCr film
Cerium-ammonium nitrate

during this process. Holes in the substrate of the order of 1μm to 2μm diameter would preclude circuits requiring fine geometry[6].

Metallisation

The metallisation should provide low loss conductors which are firmly attached to the substrate. The conductors should resist corrosion and should be capable of receiving a bond wire attachment from semiconductor devices.

Two basic processes, thick-film and thin-film, are employed for metallising the substrate and producing the required conductor pattern. The thick film technique is simpler and potentially cheaper and consists essentially of a printing process. The conductors, in the form of ceramic inks, are extruded onto the ceramic substrate through fine silk or metal screens on which the required pattern is defined. The pattern is subsequently sintered at a high temperature (800°C). Circuits processed in this manner, however, lack definition and often have a loss which is too high for many applications[7,8].

The thin film process is most commonly encountered today because of the precision and low loss it offers.

Gold is generally used as the conducting metal because of its low electrical resistivity (2.3μΩ–cm), high resistance to corrosion and compatibility with thermo-compression bonding. However, gold makes a weak bond to the substrate and a thin seed layer (about 200A) of chromium, nichrome, titanium or tantalum is used to improve the adhesion. When resistive elements are required the nichrome-gold system is very attractive since resistors can be produced by exposing the nichrome seed layer.

Alternative conductor systems involving copper and aluminium have the advantage that they do not require a seed layer. Both metals, however, corrode rapidly to produce a mainly oxide layer which has to be removed before semiconductors can be attached. The metal layers are deposited, either by a vacuum evaporation or sputtering process, to a thickness of about 2000A.

Resistive elements which are based on the nichrome-gold system and made by the evaporation technique, have improved stability due to the oxidation of the nichrome. This oxidation inhibits the diffusion of nichrome into the gold layer.

In dual metallisation systems the seed layer can diffuse into the gold layer, especially at elevated temperatures, and a barrier layer is often included. Platinum is most commonly used for this purpose but molybdenum and palladium are also employed.

Circuit definition

The required circuit is magnified twenty times and defined on a "cut and strip" film. The film consists of two layers of material, one optically transparent, the other opaque. A positive (or negative) of the pattern can be prepared by removing the appropriate section of the opaque layer. A mask is then prepared by photographic reduction. Computer aided design (c.a.d.) techniques are commonly applied to this part of the process. A computer, fed with the basic component specification, generates a punched tape representing the circuit configuration. This tape is used to drive an automatic cutting machine to produce the desired pattern on the film material. The circuit pattern is transferred to the metallised substrate by the photolithographic process summarised in Fig. 4.

Devices

Currently, most semiconductor devices used in m.i.c. subassemblies are based on either silicon or gallium arsenide material. These devices are available for power generation and low noise amplification. As an example, state-of-the-art performance curves are given in Fig. 5.

Varactors, limiters, switching diodes, impatt and trapatt diodes and bipolar transistors are commonly constructed using silicon technology. Chips of these devices are mounted on the circuit and wire bonds are made to the various contacts. The chip is often mounted on the circuit by heating under ultrasonic abrasion. For this purpose it is not

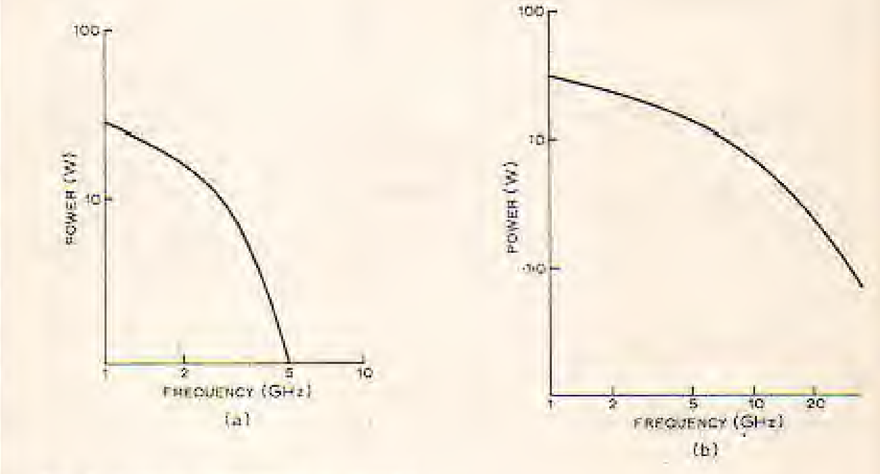
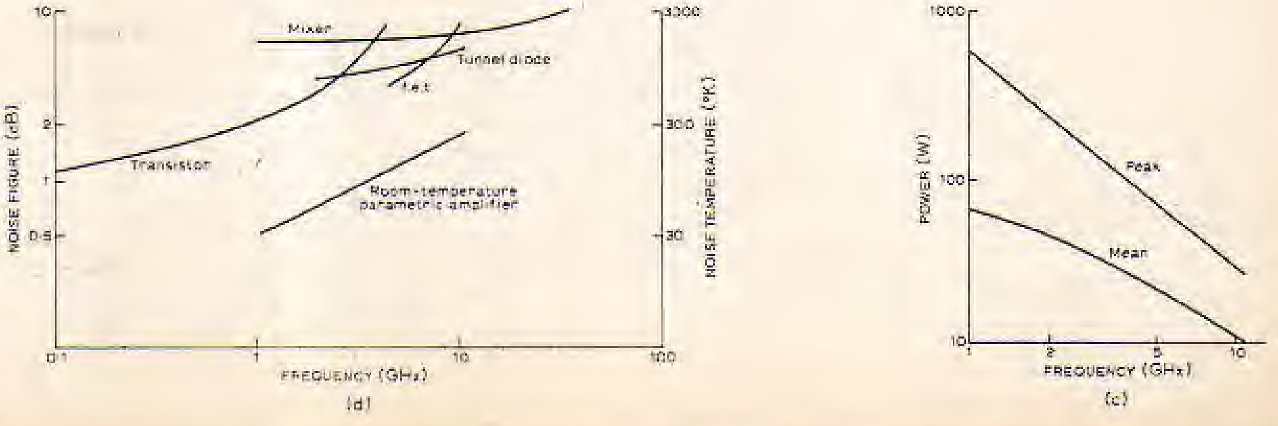


Fig. 5. *Typical performance graphs for semiconductor devices now used in m.i.c. technology; (a) microwave power transistor, (b) impatt oscillator, (c) trapatt oscillator, (d) low noise amplifiers.*



necessary to metallise the silicon if the surface of the mount is gold. A low resistance silicon-gold eutectic alloy is formed. The contacts on the other surface of the chip are suitable for thermocompression wire bonds.

Gunn and impatt diodes, f.e.ts and high quality varactors are all based on gallium arsenide technology. Chips are usually mounted using a preformed gold-germanium alloy, and for this purpose the chip is metallised with gold. The upper contact is again compatible with thermocompression bonding and it is often gold metallised at the end of the process.

The process of alloying the semiconductor devices into microstrip circuits is very important. Poor alloying or contacting appears as a loss resistance in series with the device. Since the resistance of microwave devices is often very low, even a small loss can result in a considerably degraded performance. For example, an additional contact resistance of only 0.5Ω can double the noise temperature in a parametric amplifier application and reduce the efficiency from 40% to about 25% for an S-band trapatt oscillator.

The upper limit on the chip temperature is commonly taken to be 200°C. Chips for oscillators and amplifiers should therefore be connected to the heat reservoir via a low resistance path. Since the substrate is usually a poor thermal conductor, device chips are mounted directly on a gold-plated copper stud. Typical values of thermal resistance are in the range 10 to 100°C/W.

Packaging and protection

Semiconductor devices were initially mounted in sealed packages which were designed to minimise parasitic reactances and thermal resistances. They were small and expensive. Now unencapsulated semiconductor devices are, where possible, mounted directly in the circuit. Careful attention to the contact design and the use of silicon rubber compounds for passivation can result in simple, reliable subassemblies which can survive the environments applicable to the consumer market. For applications involving a wide temperature range the complete circuit is sealed. This involves the use of sealed r.f. connectors.

Examples of microwave integrated circuits

Five hybrid m.i.c. subassemblies, which employ the technology described above, are shown in Figs. 6 to 10. These examples are selected to demonstrate that simple circuits can perform adequately for systems applications. They extend from simple oscillators to fairly complex subassemblies.

Figure 6 shows an X-band varactor-tuned Gunn oscillator. The circuit is constructed on a ferrite substrate and includes a circulator to provide output isolation. The Gunn diode chip is mounted on a gold tab to minimise the thermal resistance. It is series resonated by the wire which connects between the chip contact and the circuit and a varactor diode chip. The necessary temperature stability is achieved by coupling the circuit to a microstrip resonator.

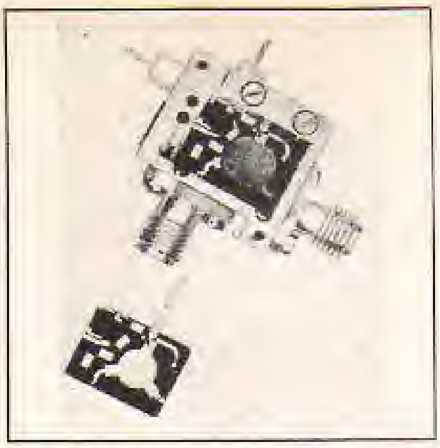


Fig. 6. *An X-band Gunn oscillator on a ferrite substrate.*

Fig. 7. *An X-band Doppler module on a ferrite substrate.*

The performance figures for the oscillator are as follows. The power, voltage and current ratings are 10mW, 8V and 100mA respectively. It has a centre frequency of 9.4GHz, an electronic tuning range (e.t.r.) of 100MHz and it requires a tuning voltage from 2 to 6V. Over the e.t.r. the temperature stability is 1MHz/°C.

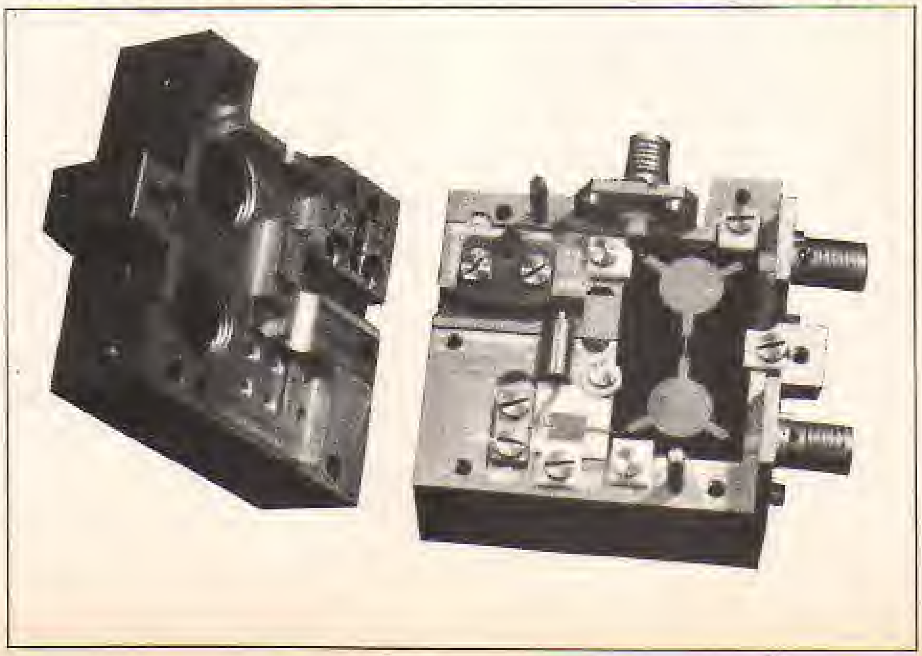
Figure 7 is a simple Doppler radar module which is essentially an extension of the varactor tuned oscillator. A detector diode is mounted on the third port of the circulator and the transmitted and received frequencies are permitted to mix within this device. The unit shown is in the final stages of development and indicates the practicality of the m.i.c. approach.

Figure 8 is a photograph of a parametric amplifier[9]. This unit indicates the problems of applying hybrid techniques to components which involve a wide frequency range. Under such conditions it is necessary to use multiple substrates, and these may still be combined with waveguide technology at frequencies around 40GHz.

Figure 9 illustrates a subassembly which combines the microwave circuit (consisting of a Gunn local-oscillator, similar to that in Fig. 6, and a double balanced mixer, on alumina) with two i.f. amplifiers. Chip capacitors and integrated resistors are used in this assembly. Figure 10, however, shows a 900MHz transistor amplifier in which all components are fully integrated on the

continued on page 67

Fig. 8. *An X-band parametric amplifier.*



LETTERS TO THE EDITOR

CITIZENS' BAND

IN response to correspondence on the subject of the allocation of a small part of the radio spectrum for citizen use I received a reply from the Radio Regulatory Department of the Home Office which stated that, "the Government has announced that the disadvantages outweigh the advantages and that it has no intention of introducing citizens' radio in the UK."

It would seem that the official attitude has now hardened and the Government and its advisers have been unimpressed by arguments based on possible uses in accidents and disasters and more impressed by reports of misuse in USA, problems of regulation, interference to other users and services and possible frustration of law enforcement efforts. The citizens' band lobby appears to have failed and supporters will now have to consider whether to accept the official line or to increase political pressure upon MPs.

W. G. C. Austin
Newcastle upon Tyne

Editor's note: At least the electronics industry has not given up hope. A working party of the Electronic Engineering Association (March 1976 issue, letters, p. 61) has recently made an interim report on the possible introduction of CB in the UK, and in this has considered the scope of the service, how it will be licensed, how the equipment will be approved for use, and the standards to which the equipment will be designed and manufactured. It seems the manufacturers are ready if and when the Government changes its mind.

AMATEURS' POWER LEVELS

I REALLY must take issue with the greatly over-estimated power levels quoted by your correspondent Pat Hawker in his December issue "World of Amateur Radio". I am at a loss to understand how he can possibly infer powers of 50-100kW e.r.p. as being typical of those used on 432MHz. Even if an amateur does manage to achieve 400W output at this frequency, which is doubtful, he will have to face at least 2dB, and probably more, loss in the coaxial cable feeding the antenna. This will bring his power at the antenna to around 200W. Many antennae have over-estimated gain figures and a fair estimate of the highest gain aerial being used regularly in the London area would have approximately 17dB gain. The e.r.p. would, thus, be about 10kW. To infer an output power of 100kW would suggest an installation having 27dB gain which, frankly, is preposterous at this frequency.

The limitation of British amateurs to an input of 150W d.c. power is highly misleading since, assuming a class C efficiency producing an output of 100W carrier, when fully modulated with a.m. the output, in fact, becomes 400W p.e.p., identical to the maximum equivalent peak envelope power allowed for s.s.b. In many countries there is far greater legislation against manufacturers forcing them to produce adequate filtering to stop domestic tv sets from picking up frequencies that they are not theoretically licensed to receive. I must insist that domestic tv and radio equipment must have the same components fitted as are supplied in sets produced for the German market, for example. Whilst I agree with a.m. and f.m. being limited in the way that it is already, I see no reason why the rating for c.w. should not be the same as for s.s.b.

I will admit that I have gone to extremes in my own v.h.f./u.h.f. installation and by using cable that is extremely expensive can produce an absolute maximum of around 12kW e.r.p. on 432MHz. While being a long way short of Pat Hawker's 100kW, this is adequate for my purposes but only just sufficient for specialised DX working, which is my primary interest.

As Public Relations Officer of the UK FM Group (London) I wish to state categorically that there has never been any decision by any committee member or by the committee in general even to consider closing down the London GB3LO 2m repeater. I must assume that Mr Hawker had foreknowledge of a forged letter sent to the RSGB and not to him. I must criticise his making use of information in a letter which was not authenticated. The November issue of the RSGB magazine *Radio Communication* deals with the matter at length, but please rest assured that the opinions of the UK FM Group (London) are most certainly to press for more repeaters on 2m in the London area, preferably a further three.

Finally, as far as aerial heights are concerned, many tests have been made at different power levels and heights and it is clear that for repeaters to have an adequate coverage when used by mobile stations, heights of 100-300ft above ground level are essential if transmissions are to be received adequately under all traffic and obstacle conditions. The present heights employed by repeaters are ideal for the purpose and in no way are they causing interference other than relaying that produced by unlicensed pirate operators whom the Post Office seem to be either unprepared or unable to locate and prosecute. Over 99% of regular users of repeaters behave as one would expect of them, and it is most undemocratic to think of closing down any forms of amateur radio transmissions because of the extremely small minority of vandal operators. Perhaps next, someone might suggest doing away with telephone boxes, in order to stop financial losses through their vandalisation.

Angus A. McKenzie G3OSS
Angus McKenzie Facilities Ltd
London, N3

Pat Hawker comments: To keep it short: I did not say a maximum of 50-100 kW e.r.p. was "typical" on u.h.f.; nor did I infer it was even feasible in the UK with legally-rated transmitters. I agree that only a few amateurs currently exceed about 10kW e.r.p. on 432MHz. But does Angus McKenzie deny that some amplifiers in current use are capable under two-tone or speech conditions of up to say 800W p.e.p. *(not average)* output? A transmission line loss of 1-2 dB may be difficult to achieve at u.h.f. but is feasible; similarly an aerial power gain of 20 or 21 dB. I make that a maximum of about 50 to 80kW (peak) e.r.p. So is "50-100 kW" greatly over-estimated?

I find it difficult to take seriously the suggestion that I had "foreknowledge" of, or used unethically, that forged letter. I, like others, was misled — but, then, only a few months before I had reported a statement by the chairman of the UK FM Group London that "some of the things I hear through GB3LO make me ashamed to be associated with it. There have been suggestions that GB3LO should be closed down completely, and more specifically that it should be closed in the evenings". That hardly squares with Angus McKenzie's categorical statement. Through no fault of the UK FM Group (or the RSGB) GB3LO has undoubtedly gravely damaged the reputation of amateur radio in this country. If it cannot be cleaned up, it will eventually be closed down, fairly or unfairly.

GEOMAGNETIC SENSE IN BIRDS

MR WHATWORTH'S proposal (December, 1977, letters) that wing movement may be a basis for geomagnetic sense in birds is most interesting. However, any general model of such a magnetic sense should consider two facts. First is the relatively large current flows produced in tissues by muscular activity and second is the remarkable behaviour of the Emperor Penguin.

Co-ordinated muscular activity may produce potential gradients on the skin of more than 100 microvolts per millimetre due to current flow from the active muscles into the tissues around them. Some mechanism would need to be postulated, therefore, capable of separating any signals produced by wing movement in a magnetic field from the potential difference produced by the muscles which move the wings. The currents associated with muscular contraction are several orders of magnitude larger than those generated in Mr Whatworth's model and both would be highly correlated with wing movement.

The Emperor Penguin breeds interalia in a rookery near Halley Bay in Antarctica. The position of the rookery appears to be constantly related to a major geomagnetic anomaly. The location is on the winter sea ice close to the cliffs of the Brunt ice shelf. The topography of the cliffs and their distance from the anomaly is variable from year to year as icebergs calve during the summer months. The birds have no constant visual reference for the annual relocation of the rookery.

When breeding, one of the pair travels from the rookery to the edge of the ice, about 100 miles away, to feed on fish. It then returns to the rookery to feed the chick on the products of the stored food. This remarkable journey is made by walking or sliding but never by flying. The penguins' fore limbs are highly adapted for swimming but are useless for flying.

If, as seems possible, the Emperor Penguin navigates to its rookery by a magnetic sense and the local peculiarities of the earth's magnetic field, then it must either have an extraordinary differential sensitivity to any e.m.f. produced by movement of its small flippers, or some different type of mechanism must be considered.

J. D. Dawson
British Medical Association
and
G. D. Dawson
University College, London

DISTORTION IN LOW-NOISE AMPLIFIERS

IN his otherwise informative article on distortion in transistor amplifiers (August 1977 issue), Mr Taylor is incorrect in stating that the equation

$$\exp\left|\frac{eV}{KT}\cos\omega t\right| = \alpha_0 + \alpha_1\cos\omega t + \alpha_2\cos 2\omega t + \ldots \quad (1)$$

cannot be solved analytically. The required mathematical identity is [1,2]

$$\exp(\lambda\cos\theta) = I_0(\lambda) + 2\sum_{n=1}^{\infty} I_n(\lambda)\cos(n\theta) \quad (2)$$

where the coefficients $I_n(\lambda)$ are n^{th} order, modified Bessel functions whose values may be found in standard tables [2,3]. Thus the amplitude of the n^{th} harmonic relative to the fundamental is given by

$$A_n/A_1 = I_n\left(\frac{eV}{KT}\right)/I_1\left(\frac{eV}{KT}\right) \simeq \frac{1}{n!}\left(\frac{eV}{2KT}\right)^{n-1} \quad (3)$$

where the last expression is an approximation, correct for small values of eV/KT. The exact value of t.h.d. may be easily calculated since successive coefficients are of rapidly decreasing value.

However, for approximate calculations neither tables nor computers are required. Equation (3) shows that the second harmonic distortion level in per-cent is roughly given by

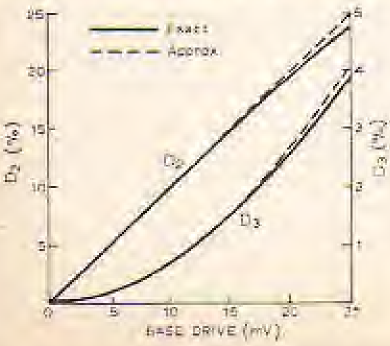
$$D_2 = \frac{100}{2}\left(\frac{eV}{2KT}\right) = 25\frac{eV}{KT} \quad (\%) \quad (4)$$

Further, since the t.h.d. is predominantly second harmonic, and since KT/e is 0.025 volts at room termperature, we find the remarkably simple numerical approximation.

$$D = V \quad (5)$$

where D is the t.h.d. in percent and V the base drive in millivolts. As Mr Taylor noticed from his numerical calculations, the distortion is 1% at 1mV drive and is 10% at 10mV!

To see the degree of approximation involved, the accompanying figure compares



the approximate and exact values of the second and third harmonic components D_2 and D_3 (note different scales) using equation (3). One can show numerically that the t.h.d. curve lies between the exact and approximate D_2 curves. Thus equation (5) is accurate to 1% up to 15mV base drive and is less than 3% high at 25mV.

P. D. Edgley
Department of Engineering Science
University of Oxford

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3. British Associates for the Advancement of Science, Bessel functions, Mathematical Tables Vol. VI (1950) and Vol. X (1952), Cambridge University Press.

Dr Taylor replies:
It is evident from Mr Edgley's letter that I should have been more cautious in my choice of words when I stated that the Fourier Series expansion for the exponential base-emitter characteristic of a transistor could not be solved analytically. Mr Edgley is quite correct in pointing out that a table of modified Bessel Functions allows an analytical solution. Unfortunately it is normally necessary to resort to recurrence relations to determine the higher order functions (see for example Mr Edgley's ref. 2) and again the solution becomes laborious. The repetitive nature of the calculations to determine t.h.d. as a function of input signal amplitude is ideally suited to a numerical computing technique which, with a minor programme modification, also allows the distortion performance of the long tailed pair input stage to be calculated.

I would now like to reply to the comments made by Mr Dytch and Mr Bishop in their letter in the November 1977 issue.

When the design of this pre-amplifier was initiated some time ago I consulted a well known cartridge manufacturer to determine whether the input bias current would damage the cartridge and was informed that it would not. It seems unlikely that 100nA of bias current will have any effect on the performance of a magnetic cartridge and recently Shure have been kind enough to conduct tests with their V15 Mk III cartridge and confirm that this in in fact so. If however the amplifier is adapted for use with a moving-coil cartridge it would perhaps be advisable to a.c. couple the input to prevent damage to the cartridge.

I have received some correspondence concerning the accuracy of the RIAA equalisation, typically −2.5 dB at 20Hz and +2.5dB at 20kHz with my original circuit. The discrepancy at low frequencies is primarily due to the 10μF capacitor and 1kΩ resistor in the input circuitry giving a low frequency roll off at 16Hz. Increasing the capacitor to 47μF brings the equalisation to within 1.0dB of the RIAA characteristic with the preferred values of components used in the equalisation network. Correct high frequency equalisation of a series feedback pre-amplifier presents certain problems because it is not possible to obtain a gain of less than unity. These problems become more severe as the sensitivity is reduced and therefore, for a particular amplifier design, the accuracy of equalisation is related to the overload capability. The high frequency equalisation of my original circuit can be improved, however, to within 1.0dB of the RIAA characteristic at 20kHz by shorting out R_4 and increasing C_4 to 75pF to maintain closed loop stability. As yet I have not made any measurements with this circuit modification but cannot see any reason why it should significantly effect the distortion performance of the amplifier.

Eric F. Taylor.

DIRECT SENSING OF RADIO WAVES?

MR DONALD WOOD, who writes in the December issue concerning the direct perception of electromagnetic waves, might be interested to learn of some experiments carried out by A. F. Collins in 1902. These were aimed at verifying "the casual observations long since made that approaching electrical storms manifested their presence in persons afflicted with certain forms of nervousness and other pathological conditions, though the storm influencing them might be many miles beyond, or even below, the horizon. To accomplish this task it was necessary, of course, to decide conclusively that electric waves exercised some behaviour or produced a change, molecular or otherwise, on the brain cells."

Collins' technique was to insert two electrodes into the brain to see if it would act as a "coherer" – i.e. to search for a decrease in resistance under the influence of electromagnetic radiation. He experimented initially with a dead mammalian brain obtained from a slaughter-house, and with the brain of a live cat which, in Collins' own words, "willingly lent itself to the subject for the investigations to be made on brain matter in the living state". Coherence was obtained, and also some twitching of the base of the brain was seen in response to the application of the electromagnetic stimulus.

Encouraged by these results, he repeated the experiments on a human brain from a recently deceased person, and found that the rust-red material in the cerebellum showed the greatest response. Finally, he carried out some measurements of resistance to determine the effect of 24 hours brain deterioration, but found that his instruments were behaving very erratically, the galvanometer needle jumping all over the scale. "This state continued for a few minutes, when a peal of thunder awaked me to the actual cause. A storm was approaching.... As the storm approached, the deflections grew more and more pronounced, the needle quivering at either end of the scale alternately as though endowed with life. The very phenomenon I sought to verify with a 2cm spark coil was here produced by the lightning itself.....In these tests I was favoured with circumstances which, with me, might never occur again, for the reason that a fresh human brain was necessary, and that an electrical storm should be in progress when all was in readiness was quite remarkable".

Some other relevant remarks were made by the editor of the journal *The Electrician* in 1913. He was commenting on the experiments performed by Prof. Lefeuvre of Rennes, and verified by H. R. B. Hickman. In these, the sciatic nerve of a frog's leg was connected to an aerial (via a rectifier) and to earth. The incoming c.w. telegraphy signals were then read from the Galvanic twitchings of the frog's leg. The editor wrote, "Perhaps those who write 'scientific' articles for our daily contemporaries will see in this an explanation of the twitchings which some folk feel at the approach of a thunderstorm. But it occurs to us that oscillatory current cannot in fact affect nerves and muscles, for it if could, then in spite of the 'skin effect' the neighbourhood of a large wireless telegraph station would be full of votaries of St Vitus during the despatch of a message."

V. J. Phillips
Sketty
Swansea

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6. *Electrician*, vol. 71, 1913, p. 81.

MOBILE RADIO SPECTRUM UTILISATION

YOUR article "Home Office sifts WARC Evidence" in the October 1977 issue highlights a number of interesting points. Prominent among them are the views of an American manufacturer in which (a) they see mobile radio development moving towards the use of digital techniques and (b) they consider any channel bandwidth of less than 25kHz as a backward step. One infers from the text that the two points are linked.

Undoubtedly trends in the evolution of mobile radio indicate that certain types of user, in particular those users requiring security and speed of communication on a large scale, will, during the next decade, move towards the use of new techniques in which digital methods will form a major role. Three points, however, emerge:

- Conventional speech methods will undoubtedly still remain the prime mode of communication for many years to come — in particular with the small user.
- The transmission by radio of high speed data, digital speech etc. is still in a relatively early stage of development.
- Indications are that the digital methods are currently wasteful in the use of frequency spectrum. Consequently doubt must be expressed as to the wisdom of allocating a common channel bandwidth standard, adequate to accommodate today's digital communication systems, but considerably in excess of that accepted as adequate for transmitting speech or slow speed data intelligence.

It seems likely that future developments of digital techniques will produce methods capable of operation in reduced bandwidths; it may however be wrong to base *all channel allocations* at this time on such a possibility. However, I believe that a more realistic approach would be to divide the available spectrum into channel units suitable for conventional speech communication — 12½kHz for example — and, where a need for a channel of wider bandwidth is justified, to combine the use of two or more adjacent channel units for the purpose. By this method, subsequent changes to spectrum planning, brought about by a reduction in bandwidth needs as development proceeds, could be implemented by merely adding other users in the vacated slots.

Certainly the use of digital techniques — high speed data, digital speech etc. — will grow, but it is anticipated that by the time more users, large or small, need to employ such techniques, the state of the art may well be sufficiently advanced as to require a totally different approach to spectrum planning.

W. M. Pannell
Stapleford
Cambridgeshire

Editor's note: Mr Pannell is the principal author of the "Pannell report" on private mobile radio issued by Pye Telecommunications last year (see February 1977 issue, p.31).

TUMOUR ERADICATION BY R.F.

THE paragraph in Pat Hawker's column in the November, 1977, issue reminded me of some experiments I conducted when working on the ionophone project at Plessey in the early 'fifties. As readers of *Wireless World* will remember ("Loudspeaker without diaphragm," January, 1952) the ionophone is a loudspeaker in which the conventional diaphragm is replaced by a column of ionised air located at the throat of an exponential horn. The excitation is provided by an amplitude modulated r.f. arc. The power for this was provided by two EL38s operating in class C at 20MHz, coupled to a self-resonant inductance. Power input was about 40 watts.

Having tried unsuccessfully to eliminate a large wart near my knuckle with silver nitrate, trichloracetic acid and finally a soldering iron, I conceived the notion of employing r.f. energy from the ionophone oscillator. About five seconds treatment with a stub tapping, a few turns up the self-resonant secondary, generated enough heat in the wart to kill it, and healing was complete in two weeks.

J. A. Carder
Wrecclesham
Surrey

Editor's note: Mr Carder's experience is interesting, but we would not like to encourage readers in self-treatment of this kind.

SYNTHESIZED F.M. TRANSCEIVER

IT was good to see an article aimed at the amateur fraternity but using current technology, viz. the c.m.o.s. variable divider chain in the synthesizer (November and December, 1977 issues). While not wishing to criticise in any way Mr Forrester's article, which obviously relates to a transceiver now giving him excellent service, I feel the following comments may be helpful to other potential constructors:

1. The 4059 divider, used here to 6.08MHz, is guaranteed by the manufacturer to operate to 3.0MHz (at 10V), 6MHz being only a typical figure. Since the 4059 costs about £6, selection of a suitable sample could be risky or expensive.

2. The set of 4059 plus 3-off 4560 c.m.o.s. i.cs forming the variable divider chain cost about £12. A v.h.f. prescaler is relatively inexpensive — the Plessey SP8655 is guaranteed to 200MHz (÷ 32), interfaces directly with t.t.l. or c.m.o.s., draws 50mW (typical) and costs about £8. By using such a device the v.c.o. could be operated at final frequency, avoiding spurious signals from the usual multiplication process, thus saving two multipliers in the transmitter chain, two multipliers in the receiver chain, and the existing ÷4 prescaler. Moreover, the reference frequency would be 25/32kHz and the maximum input to the 4059 reduced to 4.56MHz (still outside the guaranteed figure, but more acceptable than 6.08MHz).

3. When changing frequency in a synthesizer there is always a period prior to locking when the v.c.o. is sweeping towards the new frequency. Although this may exist only for about 100ms in a system such as this with a reference frequency around 1kHz, it will occur every time the transmitter is energised. The transmitter would be capable of delivering full power while its output is swept from receiver l.o. frequency to transmitter frequency, i.e. over 10.7MHz. The block diagram given does not indicate the presence of a suitable "inhibit until locked" circuit for the transmitter, and so operation could certainly cause interference to other users, apart from the operator unwittingly contravening the terms of the amateur licence.

4. It is essential to provide an adjustment for pulling the reference crystal to precisely the correct frequency, since the typical manufacturing tolerance of ±0.005% on crystal frequency represents ±7.25kHz at 145 MHz.

J. A. Short
Farnborough
Hants

EXPERIMENTS ON PHASE AUDIBILITY

SEVERAL readers have asked for further clarification of two points in my article on phase audibility (October 1977 issue, pp. 79-81). I would therefore like to add a few comments to the record, as follows.

Question: Were the Bose 901 loudspeaker tests done "up close", and were they "blind"?

Answer: The single Bose speaker, and also the crossed-over pair of Bose speakers, were compared with the live performance "up close", that is, at a distance of ten feet from the listening jury. The tests were run blind, through a lit-up gauze curtain. Listeners could not be fooled at this distance, but a rank ordering of quality (best, equal, worst) was attempted. The essentially phase-coherent playback was not any more like the live performance than was the phase-distorted playback.

When the tests were run indoors, in a typical household environment, the Bose speakers were able to fool listeners at a distance of 35 feet (through a large, open doorway), but not any closer. The Magnepan speakers fooled the listeners at 25 feet indoors and 15 feet outdoors, but not at ten feet.

Daniel Shanefield
Princeton, N.J.
USA

Editor's note: The following corrections should be made to Dr Shanefield's article. On page 79, middle column, the final six lines of the column should have been printed before the penultimate line of the first column (after the word "But . . ."). On page 80, first column, line 27 should read" . . . . . don't have perfect enough transducers to do the . . . ." On page 81, first column, line 5 should read " . . . . did produce essentially coherent . . . . ". Also on page 81 "Magnapan" should be spelt "Magnepan", reference 13 should be deleted, and there should be a note stating that the article was based on a paper presented to the Boston Audio Society (USA) in July 1976. Apologies for these errors.

LONG DISTANCE U.H.F. RECEPTION

I AM one of a number of enthusiasts, both professional and unconnected with radio communication, who are experimenting with consistent long distance u.h.f. reception particularly of television signals and using very high gain receiving systems. We have experimented with arrays of high gain Yagi aerials and have now begun to investigate the characteristics of parabolic reflectors. Unfortunately we are finding it almost impossible to find practical down-to-earth articles on the subject in print and wonder if any of your many thousands of readers around the globe would like to exchange details of experiments, among which are optimum size of dish, optimum focus to diameter ratio, height above ground level, optimum low noise amplifier configuration, etc.

So far with a temporary 25ft diameter dish a few feet above ground we have confirmed the precise focusing effect and very high gain of a parabola but it has been a matter of many hours of tedious experiment. Also tried was diversity at separated sites of reception over a 180 mile path, with the result that the further the separation of aerials the better, at least up to 3 miles so far. Along the coast where we have been experimenting the signal levels of the distant 500kW television transmitter in Cornwall vary tremendously depending on the tropospheric propagation, ranging from a couple of microvolts to tens of millivolts over even short periods of reception, i.e. 24 hours. We would like to hear of similar attempts at long distance reception of u.h.f. signals on the basis of exchange of ideas and results. Someone somewhere must be spending countless hours experimenting on a similar basis.

Des Walsh EI5CD
Ballylynch
Carrick on Suir
Co. Tipperary
Rep. of Ireland

USEFUL CALCULATOR TRICKS

BEING an owner of the CBM 4190 electronic calculator, I have discovered a couple of useful tricks which this excellent machine will do and which are not mentioned in the rather brief CBM handbook.

1. The "integration" function can be used not only to find the area *under* a curve, but also the area *inside* a loop, i.e. a cyclic integral can be evaluated.

This is done simply by entering in the *x* and *y* co-ordinates of a number of points round the loop, in the same way as in the area-under-the-curve method. However, the first point entered must be entered again at the end of the sequence, to complete the loop. The first point can be anywhere on the loop, and the points can be entered either clockwise or anti-clockwise.

This facility will be found extremely useful for calculating the "work done" in pressure-volume diagrams, and for finding the hysteresis loss from B-H and similar curves.

2. A conversion from decimal to degrees-minutes-seconds format is normally performed by entering the decimal number and using F,8. However, even when many numbers need to be converted, the F,8 only needs to be used once, at the beginning of the sequence. This is done as follows: Enter the first number and press F,8. This converts the first number. Now simply enter the other numbers, pressing only the = key after each one.

The only apparent problems with this method are that numbers like .25 must be entered as 0.25, and negative numbers are not permissible at all.

It is worth mentioning that converting 34-24-36 (degrees-minutes-seconds format) into degrees Centigrade gives an interesting answer of the order of 10^{-6}. This is of course completely useless for most applications.

Peter Holy
Worthing
Sussex

AUDIBLE AMPLIFIER DISTORTION

PETER BAXANDALL and Peter Walker clearly set much store by transfer distortion assessments of an amplifier's audible performance. ("Audible amplifier distortion is not a mystery", November 1977 issue). But, despite the subjective experiments Mr Baxandall has devised to ascertain, to his satisfaction, that interaction of sub-threshold distortion with signal does not take place as a result of the complex (and poorly-understood) process of the auditory response, the validity of this technique (in terms of *listening* to the difference signal as opposed to measuring it) rests firmly on the assumption that such interaction does not occur.

The study of binaural beats has clearly shown, however, that this can indeed take place. The threshold of hearing is a psychological rather than physical phenomenon: binaural beat research has indicated that our brains can detect and process sounds down to at least 20dB below threshold. Consequently we have to be careful to define precisely what we mean by "hearing" a sound. It's altogether safer, perhaps, to talk in terms of perceiving sounds when we are conscious of them (which is the meaning in which we normally use "hearing") and monitoring sounds (for want of a better term) when we detect and process them at levels below threshold.

Of course, the fact that we do "monitor" sound and that under certain circumstances it can interact with super-threshold sounds such that their perception is altered does not necessarily mean that sub-threshold distortion in audio amplifiers produces audible degradation of music signals. What it does do, however, is throw a somewhat jaundiced light on Mr Baxandall's conclusion that the "true significance" of amplifiers producing total silence in transfer distortion tests is, "quite inescapably, that such amplifiers are subjectively perfect." You may well believe this to be so, Mr Baxandall, and time may prove you correct but, as yet, the response to your flat assertions can only be — "non sequitur."

K. D. Howard
Oxford

Reference
1. Oster, G. "Auditory Beats in the Brain," *Scientific American*, 229, No. 4 (October 1973), pp 94-102. Offprint No. 1282.

AUDIO is a prolific breeder of folklore, so a reminder of the need for rationalism is always timely; we stand on the slippery slope of superstition once we abandon our belief that audio phenomena are matters of physics, not magic. Mr Peter Baxandall (November 1977, p.63) provides just such a necessary reminder, but unfortunately throws out the baby with the bath water.

The wires going to an electric bell are part of an oscillation-determining circuit involving milli-microsecond transients (they cause radio interference) and it is by no means obviously absurd to suppose that the high-frequency impedence of the wires could affect the action of the bell to an extent that can be heard. On the contrary, it needs calculation based on the mechanisms supposed to be acting before it can be concluded whether or not a significant effect is likely; and even then the conclusion is vulnerable to whether all relevant mechanisms have been correctly identified.

Moreover in audio we are largely deprived of quantitative limits until we have a comprehensive theory of how the ear and brain act. If such a theory exists I have yet to hear of it, and the history of audio might be described as a century of underestimating the sensitivity of perception by the human ear.

It is of course tautologically correct that if linearity and frequency response are the sole significant properties, then all amplifiers will sound alike if they have identical frequency response and are tested under conditions which include "avoidance of overloading". The difficulty is to define, without logical circularity, when all forms of "overload" (i.e. non-linearity) have been avoided, as they were not in early class-B transistor amplifiers, or more recent slew-rate limited ones, that passed all the distortion tests that were initially thought sufficient. In each case our ears told us what we only afterwards learnt how to measure.

Leinonen and Otala[1] have reported measurements on a power amplifier which passed with flying colours total harmonic distortion, SMPTE and CCIF intermodulation and dynamic intermodulation tests but showed unexpectedly large frequency-transference of energy in the noise-intermodulation test. This finding may be connected with the opinion of some listeners, accused in consequence of claiming to have "golden ears", that the subjective performance of this amplifier leaves something to be desired.

Peter Fellgett
Department of Cybernetics
University of Reading

Reference
1. Leinonen, E., and Otala, M., "Correlations of Audio Distortion", AES 56th Convention, preprint 1223 (G-1), March 1-4, 1977; Fig. 9.

Radio on the flight deck-2

Concluding with area navigation systems and landing aids

by Alan Bramson M.R.Ae.S

MOST OF THE radio aids so far described are situated within the airways where they can be of utmost use to aircraft flying within the system. It is not, however, generally realised that business and private aircraft movements outweigh those of the scheduled airlines, and pilots of these smaller aircraft often cover routes not served by conveniently situated v.o.r/d.m.e. facilities or even suitable n.d.bs for use with the radio compass.

Area navigation, as opposed to hopping from beacon to beacon within the airways, entails planning the route using pre-selected turning points, or waypoints, for the purpose, most of them not served by a radio aid. Since the weather may preclude recognition of these waypoints by map reading, other means have to be provided. One such method is known as RNav. It makes use of v.o.r. and d.m.e. information which is fed to a computer provided with the means of off-setting a convenient v.o.r./d.m.e. station from its existing position to where you want it to be. Thus a pilot may "move" the nearest v.o.r./d.m.e. station to, for example, a farmer's field. In its simplest form RNav makes use of the aircraft's existing v.o.r./d.m.e. equipment to which is added a computer with setting knobs for entering the bearing and distance of the shift from the existing to the "ghost" position of the ground facilities. More advanced versions have a readout, with keyboard entry and the ability to store a number of waypoints. At any time the pilot may ascertain distance to run and time to go for the next waypoint. This remarkable navigation aid is, of course, very convenient to use but in moving the v.o.r./d.m.e. facility to a place of the pilot's choosing it takes with it all the errors associated with v.o.r.

Decca Navigator. More accurate than RNav but heavier and far costlier is the Decca Navigator, a system invented by an American who, believe it or not, came to Britain and set up a company to develop it because there was no support for him in the USA. Like v.o.r. the Decca Navigator is a phase comparison aid but here the similarity ends. It operates in the 70-130kHz band and the ground arrangement consists of a master transmitter and three slave stations positioned some 50-100nm from it at roughly 120° intervals (Fig. 4). The complete installation is known as a Decca chain and a number of them cover certain areas of the world.

The method of operation is as follows. The carrier waves of the master and its three slaves are phase-locked and if one imagines wave relationships along the baseline between the master and one slave it will be realised that a number of intersections will exist at half-wave intervals. A phase comparison meter equipped with some form of counter would be able to determine position along the baseline. Looking at the system in plan form the half waves can be imagined as concentric circles based upon each of the four transmitters. This is shown in Fig. 4. The three slave stations are named Red, Green and Purple and the intersection of Red/Master, Green/Master and Purple/Master half-waves creates three hyperbolic patterns in the sense that each hyperbola is the locus of all points with a constant phase difference.* The patterns are known respectively as Red, Green and Purple, and the complete hyperbolic lattice covers a considerable area.

In the aircraft is a receiver capable of accepting transmissions from the three slave stations and their master. Phase comparison units determine the position of the aircraft on the Red, Green and Purple lattice lines so that a fix can be obtained from the intersection of these lines, and the rest of the story is a matter of presentation.

In its earlier forms the information was conveyed on three Decca Meters and readings from them had to be related to special maps overprinted with the Red, Green and Purple hyperbolic patterns in those colours. Now the entire system is automatic, there is a

* For a full explanation see "Hyperbolic radio navigation systems" by F. S. Stringer, *Wireless World*, August 1969, pp. 353-357.

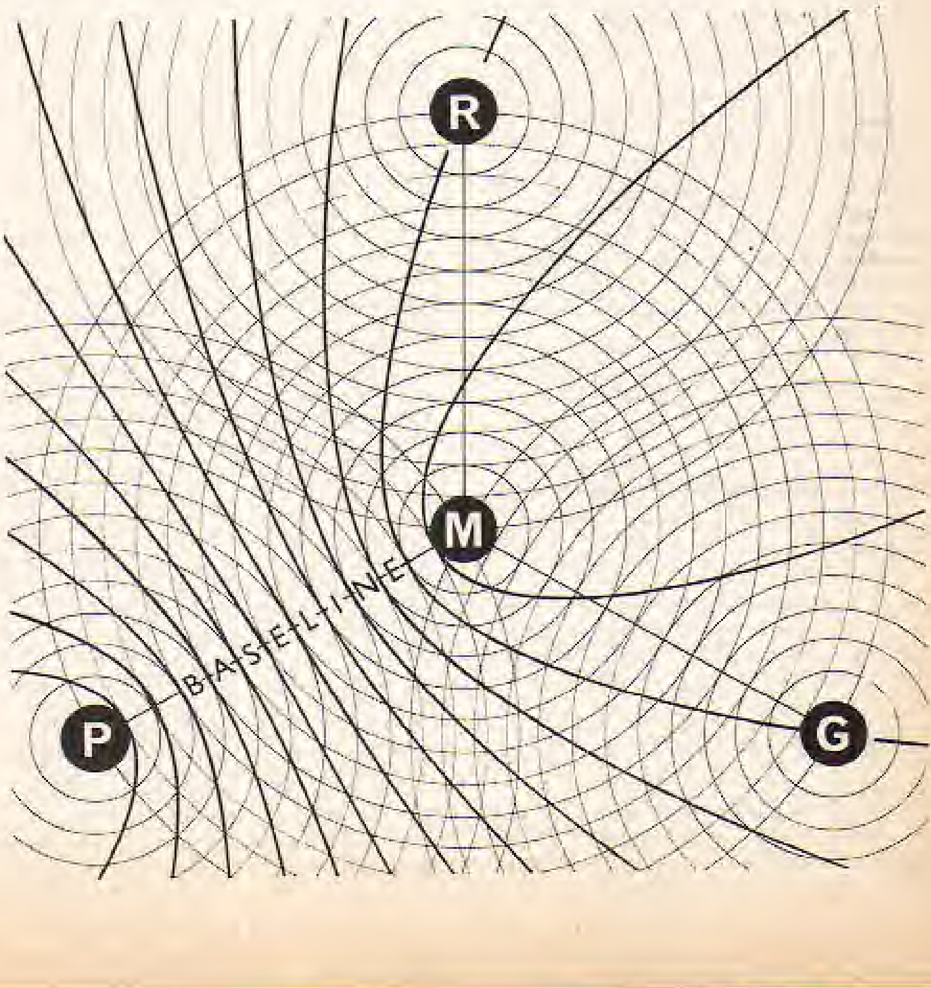


Fig 4. *Decca chain showing the Master station, M, and the Red, Green and Purple (R, G P) slave stations. In the interest of clarity only the hyperbolic phase pattern generated by the Purple/Master baseline is shown. Similar patterns are generated by Red/Master and Green/Master baselines.*

moving map display and the charts are made up in rolls like a large film cassette some 12in wide.

Decca is very accurate, some of the equipment being capable of providing a position to within a few hundred yards. However, it has been a long time attaining its present state of near perfection and events have tended to overtake the aid. Furthermore, there are not many Decca chains, so its coverage is limited.

Doppler. Unlike most of the other aids this equipment requires no ground stations. It measures forward and sideways speed by directing radio signals to the surface, receiving them at the aircraft and computing the resultant frequency shift, which is proportional to speed. The measurements are fed into a computer and displayed as miles flown and drift to port or starboard. The equipment, which for some time found favour with the airlines, is accurate in distance but rather less so when measuring sideways displacement resulting from wind effect. Also it can be troublesome when operating over smooth water. Now inertial navigators are being carried by the larger jet aircraft (two of them at £60,000 each) but these are not radio aids, being based upon accurate measurement of acceleration and deceleration on a gyro-stabilised platform.

Omega. The latest fashion in long range radio navigation is Omega, a v.l.f. hyperbolic aid* comparable with Decca which operates simultaneously on 10.2, 11.33 and 13.6kHz. Eight phase locked stations are situated all over the world and they provide time-synchronised transmissions corrected for ionosphere diurnal changes. Not all stations are available at once but at least three of them may be received in any part of the world. Apart from inserting the time and date into the equipment there is little else a pilot need do. A multi-position switch allows him to obtain more or less instant readouts for such parameters as distance from a particular point, bearing to or from that point, time to run for next waypoint, ground speed, wind velocity, position expressed as a latitude and longitude and so forth. Unlike most other aids Omega does not suffer from cumulative errors with time. It was originally developed jointly by Britain and the USA for long range submarine navigation but since it weighs considerably less than inertial navigation equipment and costs about one fifth of its price, Omega would appear to have a bright future. Marconi have recently won a contract from Pan Am for 105 sets.

Landing aids

At the end of the flight, assuming it is instrument flying weather, comes the moment of truth: the landing, perhaps at a time when cloud base is but a few hundred feet from the ground and visibility might be reduced to 600 metres, a distance covered in about seven seconds at passenger jet approach speeds. Even when aircraft approached at 60-70 knots an instrument landing demanded some radio equipment and the earliest bad weather landings were conducted by flying overhead the airfield using the direction finding service when a lad in the control tower (and I am quite serious about this) stuck his head out of the window and shouted "engines overhead" at the appropriate moment. This being confirmed to the pilot he would fly a timed downwind leg before turning back towards the airfield and setting up a gentle rate of descent. On the way in frequent bearings were obtained by a frantically keying radio operator but fortunately these were the days of 60 knot approaches and there was time to think. V.d.f. (the v.h.f homer already described) has allowed the bearing procedure to be speeded up, although it is only regarded as a cloud break as opposed to a precision landing aid. Very accurate are radar approaches as pioneered by the wartime GCA and developed to today's precision radar.

The charm of radar approaches is that nothing more than a v.h.f transceiver is required in the aircraft. The disadvantage is that radar procedures are relatively slow at the very time when the aim is to avoid stacking over the non-directional beacons and get the aircraft on the runway with a minimum of delay. The key to speed is a matter of moving away from ground monitored procedures and giving the man at the controls pilot-interpreted aids. One of the earliest was standard beam approach, an audio aid where the pilot strained to hear dots and dashes or, when on the beam, a steady note. It was demanding and could be something of a trial at the end of a long and tiring flight.

The present day landing aid in widespread use is instrument landing system (i.l.s.). The ground installation consists of a "localizer" transmitter operating in the 108-112MHz band with aerials situated upwind of the runway being served. The aerials produce two radiation patterns, on the right modulated at 150Hz and on the left at 90Hz. These patterns overlap to form a beam 5° wide centred on the runway. In the aircraft the "nav" receiver (used for v.o.r. reception) feeds the signals to an instrument which is often combined with the v.o.r. indicator except that, in the i.l.s. mode, it senses the tone modulation as opposed to phase differences. Using the vertical needle shown in Fig. 2, this part of the equipment will with great precision guide the pilot along the runway extended centre line, full deflection of the needle left or right representing only 2½°.

Situated within a few hundred metres of the runway threshold is the glide path transmitter operating in the 329.3 to 335 MHz band, its frequencies being paired with those of the localizer so that selection of the i.l.s. for a particular runway automatically sets up the glidepath receiver in the aircraft. The glidepath aerial system radiates two patterns, the upper lobe modulated at 90Hz and the lower one at 150Hz. They overlap to form a beam little more than 1° in depth which is directed down the approach path to the runway like a guiding searchlight inclined at an angle with the horizontal of 2½° to 3½° according to local terrain. Signals from the glidepath transmitter are received in the aircraft and displayed by a horizontal needle which crosses the left/right deviation needle of the v.o.r. indicator when i.l.s. is fitted. If he is above the glidepath the needle will give a "fly down" command to the pilot and so forth. So that he might be aware of his progress towards the runway the ground installation includes two marker beacons transmitting narrow vertical beams on 75MHz. They operate a blue "outer marker" light on the instrument panel at about 4nm from the runway threshold followed by an amber "middle marker" light, the middle marker being at a distance of 3500ft (distances vary slightly from airport to airport). Localizer indications are similar to v.o.r., i.e. "fly left", "on heading" and "fly right" commands are given by the deviation needle or, to use its name when operating in the i.l.s mode, localizer needle. Glidepath arrangements, marker beacons and some of the indications provided are shown in Fig. 5.

The aid is very accurate and relatively simple to use, particularly when the information is presented to the pilot on one of the pictorial displays that these days form part of a modern flight system.

Flight director systems

The flight director is so closely related to radio that brief mention should be made here. Modern flight decks were becoming so cluttered with instruments it was not easy to find room for new radio equipment as it became available. But that was not the only problem. Pity the poor pilot — how much could he watch at any one time. So was evolved the integrated flight system presenting radio navigational information pictorially in conjunction with the gyro instruments that are essential for basic instrument flight, i.e., the control of aircraft attitude, balance and heading. But the scope of the equipment does not end here. The information may be linked via a computer to the autopilot which will then fly the aircraft from radio beacon to beacon and down the i.l.s. guidance system. Current flight systems are cleared to a decision height of only 100ft above the runway while autoland, which incoporates a radio altimeter and

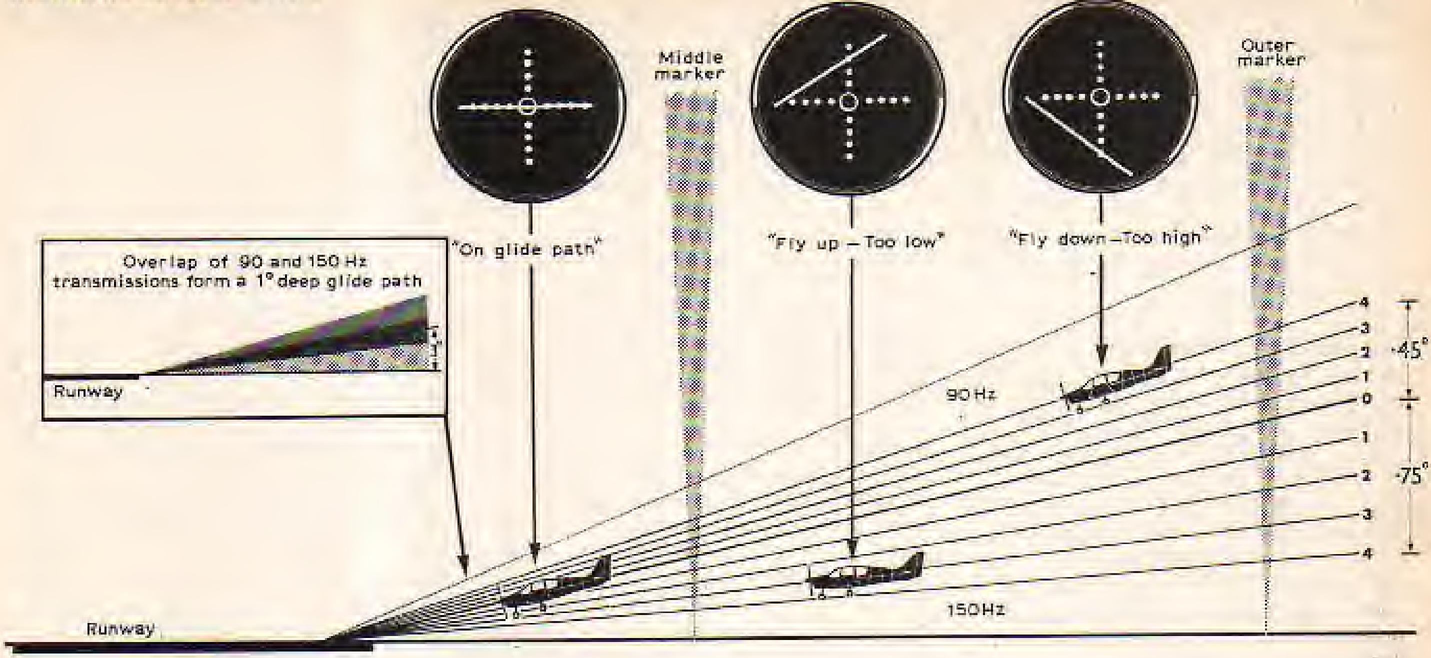


Fig 5. Instrument landing system transmission. Insert shows how the 90Hz (upper lobe) and 150Hz emissions overlap to form a 1.2° beam angled 2½° to 3½° from the horizontal. In the interest of clarity the vertical localizer needle which provides runway centre-line information has been omitted. It is read in conjunction with the horizontal dot scale on the instrument face (Fig 2, January).

autopilot throttle control, is a present day reality capable of landing an aircraft in visibility that makes taxying back to the passenger terminal a problem — but that is another story.

Price of equipment

What does it all cost? Starting with light aircraft, a 720-channel communications set and a nav receiver with v.o.r. would vary in price from £700 to £1,800, while one can pay between £750 and £2,400 for a modern a.d.f. installation. D.m.e. is expensive at £1,900 to £3,000, and a transponder (without encoding altimeter) could add between £400 and £1,800. From personal experience I can tell you that the most reliable avionics are not always the dearest but, bearing in mind a well equipped touring aircraft, light single or twin-engined, would require the navigation and communications sets to be duplicated, one would think in terms of spending some £6,500 minimum. RNav would add another £1,200 to £6,000 according to scope and a good autopilot will set you back £4,000. All this represents a high proportion of the total cost of the aircraft. Higher up the scale large transport jets might carry £200,000 of radio equipment or even more.

Whereas most of the radio designed for smaller aircraft is direct mounted with the cabinets and their controls situated in the instrument panel, large aircraft banish the main installation to radio racks away from the flight deck and control it by indirect switching usually positioned on the central pedestal which carries the power levers and some of the other controls.

The future

It would be a very unwise man who claimed an intimate knowledge of what the future holds for aircraft radio. But certain facts are emerging. For example, there is a continued move away from things mechanical to electronics — v.o.r. displays that dispense with moving needles and display a bearing, say, as a digital readout. I.l.s. is likely to be replaced by a microwave landing system (see November 1977 News) which will allow the pilot a number of approach paths to the runway, not just one. And instruments as we know them, not just those relating to the radio but engine and flight instruments as well, may soon be replaced by cathode-ray displays. A joint Hawker Siddeley-BAC project has produced a very comprehensive VC10 flight deck using seven c.r.t.s in place of all but a few standby instruments. If a c.r.t. fails in flight the display may be switched to one of the others while the tube is removed and replaced like an electric light bulb. The cathode-ray flight deck is lighter in weight and likely to be cheaper than present day instrumentation.

The moving map display and "head up" instrument projections, which appear on the windscreen, are at an advanced stage of development and navigation by satellite opens up exciting new possibilities. But having regard to the astonishing pace of aircraft radio development this past twenty years who is to say what the future holds. □

LITERATURE RECEIVED

Publications catalogue of the Instructional Centre for Theoretical Physics (ICTP) now available from Division of Publications, IAEA, Karntner Ring 11, PO Box 590, A-1011 Vienna, Austria . . . . WW 401

Load cells, pressure transducers and instruments in short brochure from Transducers (CEL) Ltd, Trafford Road, Reading, Berks RG1 8JH WW 402

Connectors, cables, p.c.bs, wire-wrapping and instruments described in o.e.m. catalogue from Carel Components Ltd, PO Box 654, 40/44 The Broadway, Wimbledon, London SW19 1SQ . . . . WW 403

Vibration testing equipment in generally descriptive leaflet (not catalogue) from Derritron Electronics Ltd, Sedlescombe Road North, Hastings, East Sussex TN34 3XB . WW 404

Microwave alternators, including rotary stepped and programmable types, in catalogue from Telonic Berkely UK Ltd, 2 Castle Hill Terrace, Maidenhead, Berks S16 4JR . . . . WW 405

Opto-isolator applications outlined in 20 page handbook from 23 Churchgate, Hitchin, Herts SG5 1DN . . . . WW 406

Telephone call logging (time, number called and duration) is explained in an article in TR Technical, Winter 77 edition, from Telephone Rentals Ltd, TR House, Bletchley, Milton Keynes, MK3 5JL . . . . WW 407

Reliability of small-signal, metal-can transistors is the subject of a report from Motorola Ltd, Semiconductor Products Division, York House, Empire Way, Wembley, Middlesex HA9 0PR . . . . WW 408

Solid-state relays from I.R. are detailed in data sheet E2730A from International Rectifier Co (GB) Ltd, Hurst Green, Oxted, Surrey . . . WW 409

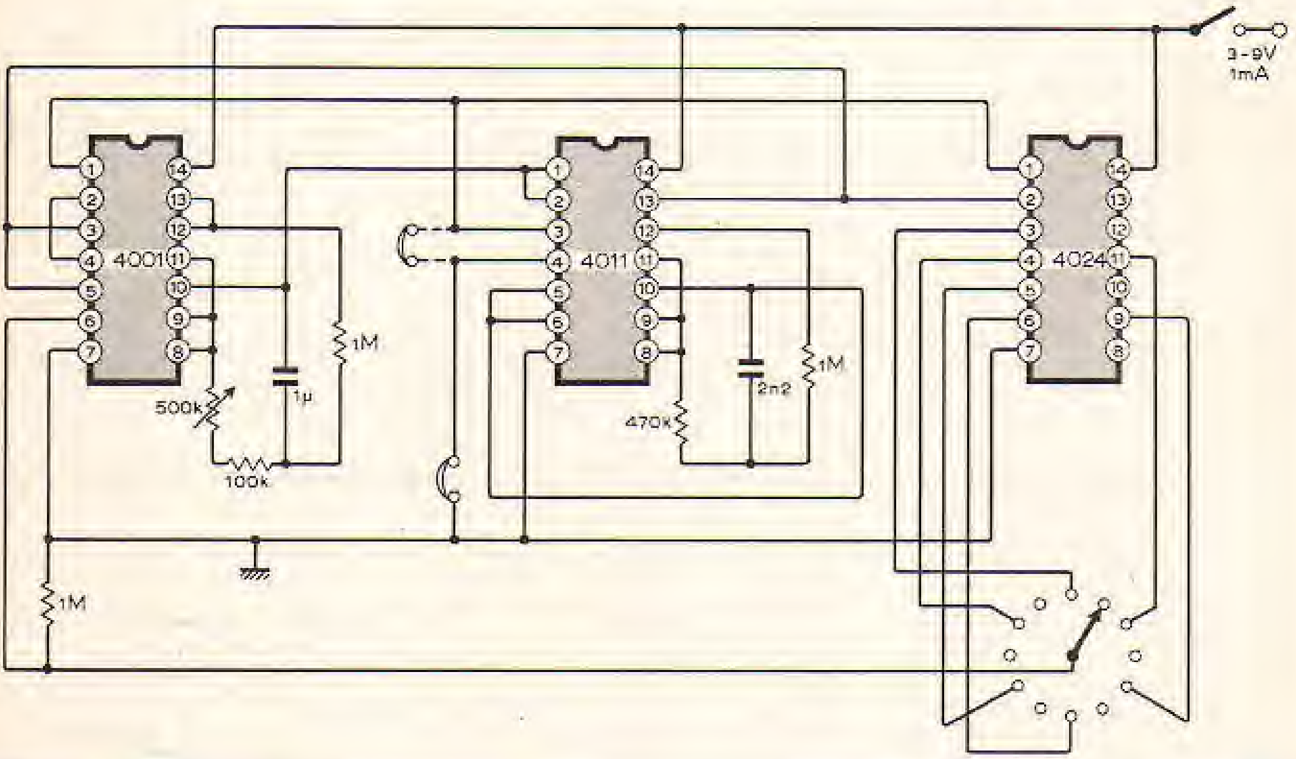
CIRCUIT IDEAS

Precision timer

THIS circuit gives an audible tone lasting half a second at pre-selected times of 2, 4, 8, 16, 32 and 64 seconds. Two gates of the first i.c. are used as a square wave generator. A variable resistor of 500kΩ enables the generator to be set precisely against a known frequency. Where gates are being used as inverters the inputs are connected together. The square wave, via a spare inverter, clocks the binary counter which is advanced one count on the negative going transition of each input pulse. The six outputs of the counter go to the selector switch, the output of which is used to trigger a flip-flop on the positive going edge.

The flip-flop is used to reset the counter to zero and is set itself by the next positive going clocking pulse. Counting from zero then resumes at the next negative going clocking pulse. Two gates of the second i.c. are used as an audio frequency oscillator which drives a crystal earpiece through a spare inverter. The oscillator is normally off and is switched on for the half second that the counter is being reset.

J. M. Osborne,
London S.E.15.

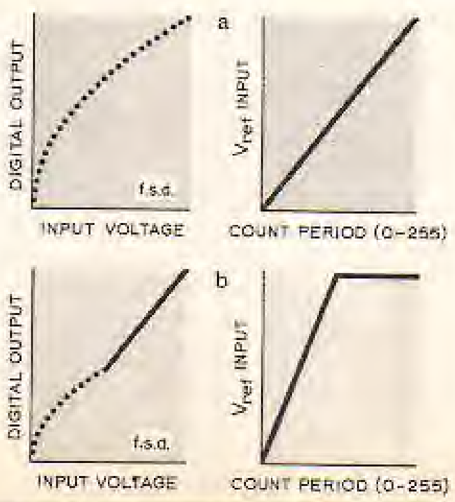


Non linear a-to-d conversion

THE Ferranti ZN425E has become a popular device for low cost analogue to digital conversion. A simple modification to the usual circuit enables the i.c. to perform non-linearly as though preceded by a compression amplifier.

If the internal fixed reference voltage is not used and an external source is connected to the V_{REF} input whose voltage rises linearly from zero at the start of each conversion, the digital output will be proportional to the square root of the analogue input voltages as shown in (a). If the reference voltage reaches a plateau during the conversion period, a linear response will be obtained from that point (b). Either an analogue ramp generator or a second ZN425E can be used with its clock and reset inputs in parallel with those of the main i.c.

J. P. FitzGerald,
London W.5.

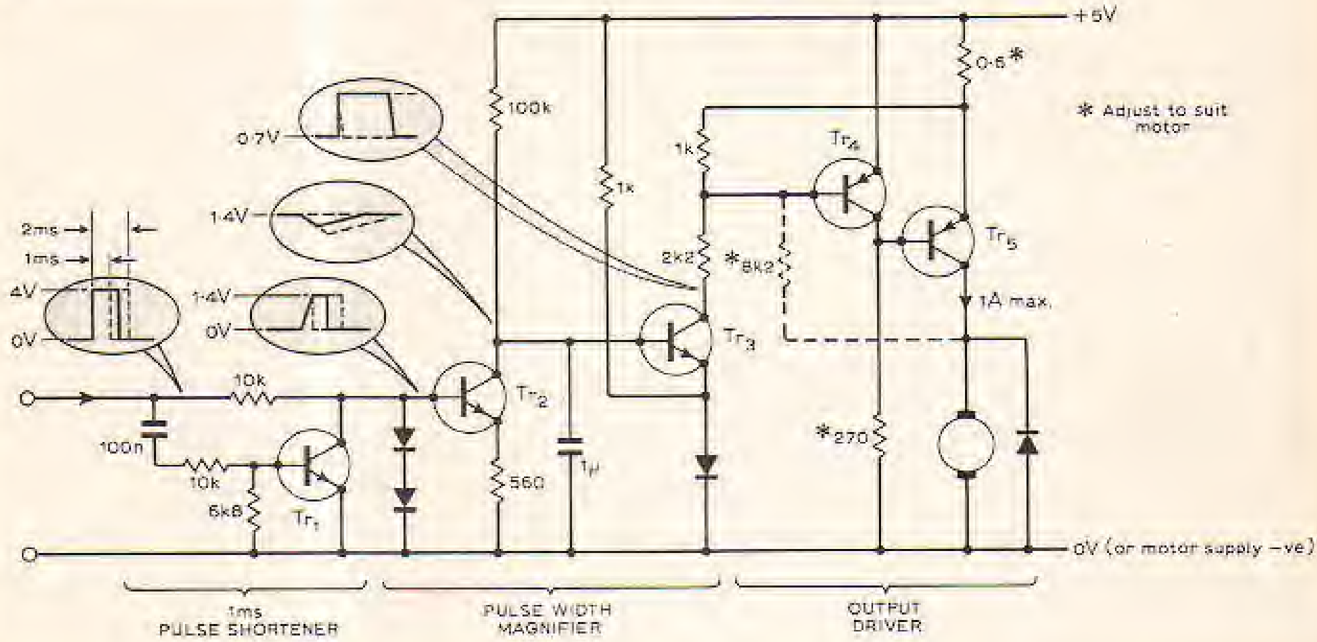


Variable-speed radio control motor

PROPORTIONAL radio control systems produce control pulses every 20ms whose length can be varied from 1-to-2ms. This circuit removes the first 1ms and expands the remaining 0-to-1ms to produce 0-to-20ms pulses which drive the motor. The motor may therefore be driven all of the time, none of the time, or any amount between. Pulsing the motor in this way is more efficient than adjusting series resistors, and gives smoother control, especially at very low speeds.

The rising edge of an incoming pulse turns Tr_1 on via the 0.1μF capacitor. This holds Tr_2 off for the first 1ms. The remainder of the pulse turns on Tr_2 which acts as a current source and removes a controlled amount of charge from the 1μF capacitor. Transistors Tr_3 and Tr_4 turn off allowing Tr_5 to drive the motor until the 100kΩ resistor has recharged the 1μF capacitor and Tr_3 re-saturates. This cuts off the motor drive after a time proportional to the width of the input pulse. The circuit is then ready for the next input pulse. The output circuit includes fold back current/voltage protection as well as limited base drive to the output transistor. These may be adjusted to suit the motor and output transistor by altering the components marked with an asterisk. If full protection is not required the dotted component may be left out. The semiconductor types are not critical: in the prototype an OC28 was used for Tr_5.

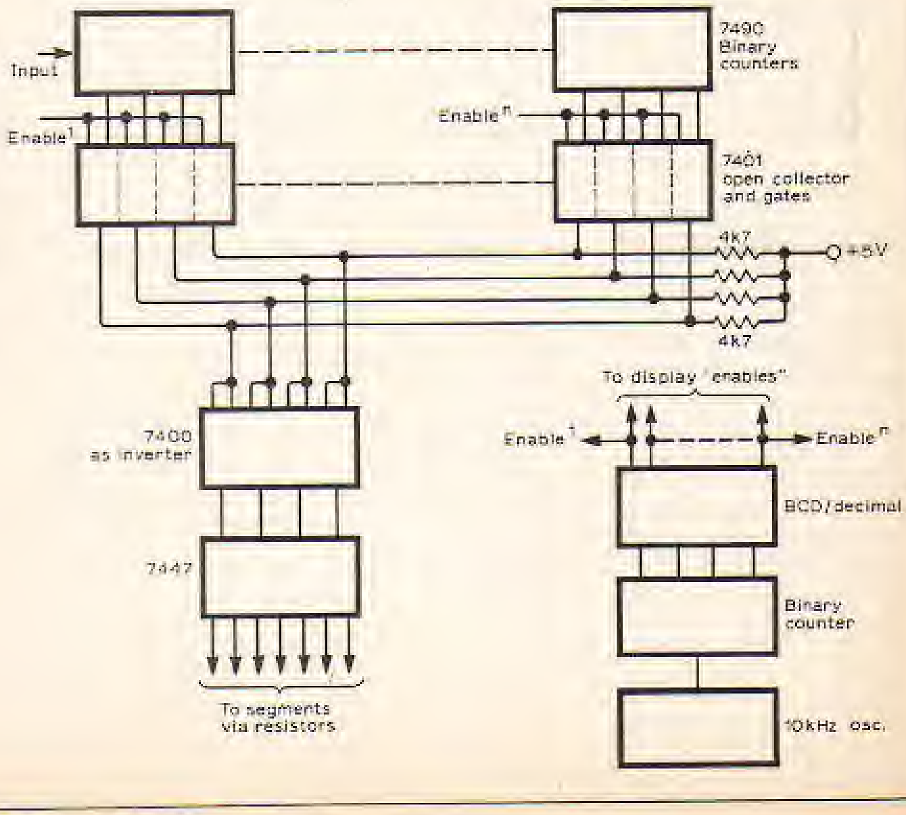
M. Weston,
Epsom,
Surrey.



Simplified multiplexing

A SIMPLE method of multiplexing three or more displays is to gate a 7490 counter output via a 7401, and then wire OR the outputs. The 7401s are switched on in rotation by the positive enable signal which also switches the displays on in turn. If common cathode displays are used the segment and display enable signals must be inverted. The use of 7400s is cheaper than using HEX inverters. If the displays are individual units the segments must be paralleled together.

G. A. Bobker,
Bury,
Lancs.



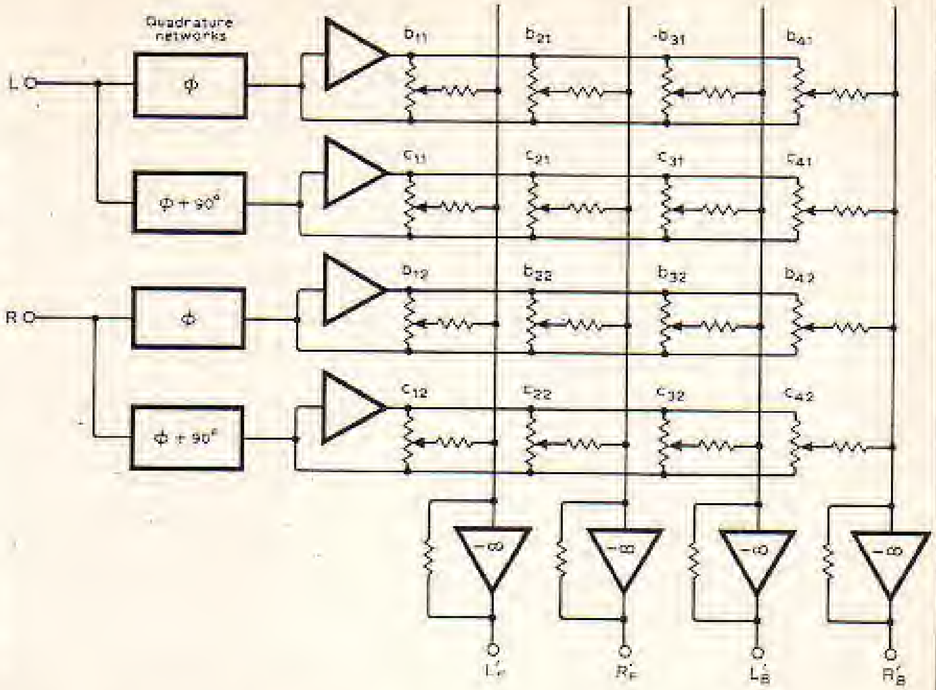
Universal matrix decoder

AN inconvenience when experimenting with matrix surround-sound is that a separate decoder is normally used for each system. However, the decoding is always done by a matrix of the following form,

$$\begin{bmatrix} L_F \\ R_F \\ L_B \\ R_B \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \\ a_{31} & a_{32} \\ a_{41} & a_{42} \end{bmatrix} \begin{bmatrix} L \\ R \end{bmatrix}$$

where the coefficients a_{11} to a_{42} vary in amplitude from 0 to 1 and in phase from 0° to 360°. Rewriting them in the form $a_{rc} = b_{rc} + jc_{rc}$, the decoding equation becomes,

$$\begin{bmatrix} L_F \\ R_F \\ L_B \\ R_B \end{bmatrix} = \begin{bmatrix} b_{11} & c_{11} & b_{12} & c_{12} \\ b_{21} & c_{21} & b_{22} & c_{22} \\ b_{31} & c_{31} & b_{32} & c_{32} \\ b_{41} & c_{41} & b_{42} & c_{42} \end{bmatrix} \begin{bmatrix} L \\ jL \\ R \\ jR \end{bmatrix}$$



If the b and c coefficients are made variable between −1 and +1, any required decode matrix can be set up. The φ and φ + 90° quadrature signals are derived by the well known all pass networks used in commercial decoders. If required, several sets of coefficient potentiometers or fixed resistor dividers can be made on plug-in boards.

D. Hamill,
Hamill Electronics Ltd,
London SW20.

Triple-voltage power supply

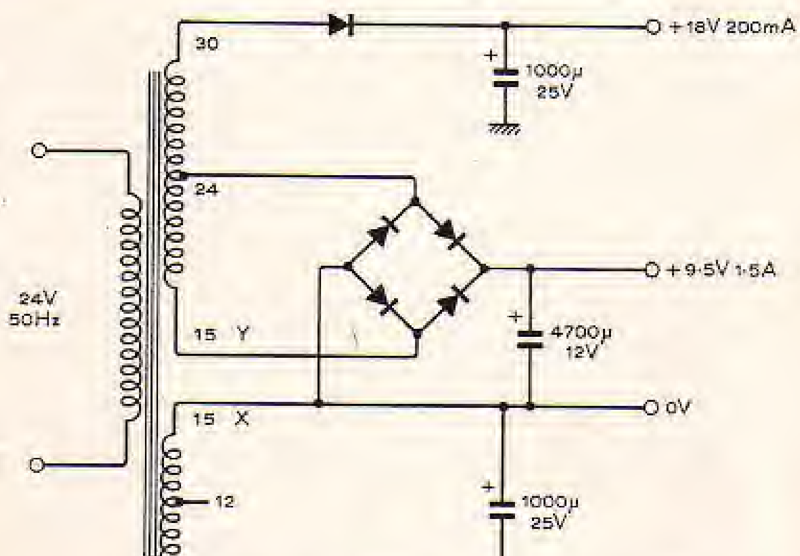
LOGIC systems frequently require ancillary analogue circuitry which cannot be fed from a 5V power supply. This simple circuit is suitable for obtaining ±12V and +5V regulated supplies from a single transformer.

A standard Douglas MT3AT transformer has been modified by isolating half of the secondary winding. This is achieved by unsoldering the ends of the windings at the 15V tapping and connecting them to separate tags.

Three d.c. outputs are provided which are suitable for use with series stabilisers. The current ratings have been selected with a practical circuit in mind, but within the limitations of the transformer they may be apportioned to suit individual applications.

Because the connection of the +18V rectifier is unconventional it is worth noting that purists may wish to isolate the windings at the 24V tapping, and to use bridge rectifiers throughout.

J. A. Hardcastle,
Huyton,
Liverpool.



P.c.b. layout for high-speed Schottky t.t.l.

Requirements of printed-board design for low inductance and effective decoupling

by D. Walton, B.Sc. (Hons), Ph.D.

A great deal has been written on the subject of logic design and quite comprehensive books appear almost monthly. In general, however, the published material neglects an extremely important area and one which probably gives the most trouble to practising engineers. This area, which is dealt with in the present article, is concerned with the layout of logic on printed circuit boards in order to ensure reliable operation. The impetus for writing this article comes from the author's own experience of the lamentable lack of understanding of these basic considerations.

IT SHOULD not be concluded from the preamble that the subject is a difficult one; indeed the mathematics employed in the present paper is extremely elementary. The problems are caused rather by the historical progression from analogue to digital techniques with the consequent carrying out of well-tried analogue practices into the digital environment. Unfortunately, the requirements for digital circuitry are frequently opposite to those needed by the analogue variety and hence there is a need for a complete reconsideration of the requirements.

Low inductance bussing

To understand the criteria which determine how the supply and GND lines should be distributed to the t.t.l., first take the case of a t.t.l. gate driving its output line from low to high. For the gate to drive the output line high it must pass current into it. The output line must be considered as a transmission line of impedance Z_0 if its length exceeds 10cm. In practice, Z_0 will be in the region of 100Ω and for a single logic signal changing from low to high the instantaneous output current will be given by $I_0 = 5/100 = 50$mA. This current must be obtained from the supply rails in a time comparable to the risetime of the signal. If, for Schottky t.t.l., $t_{r(min)} \simeq 1.5$ns, then charge must be transferred from the decoupling capacitor to the gate and hence to the output line in this time. Remember that charge is obstructed from flowing into the gate by the inductance, L, of the loop ABCD in Fig. 1. If this is approximately 2cm square with reasonable track width then, using the formula for parallel wires, $L = \ln(a/r)\,\mu_0/4\pi \approx 30$nH. The e.m.f. dropped across L will then be given by $E = -L\,di/dt$. Therefore,

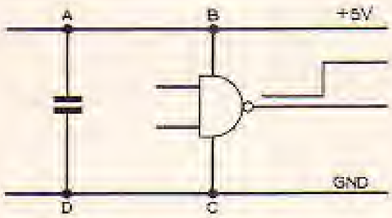


Fig 1. Example of gate, with decoupling, producing a low-to-high transition.

$$E = \frac{30\times10^{-9}\times50\times10^{-3}}{1.5\times10^{-9}}$$
$$= 1 \text{ volt}$$

This is a considerable voltage and it should be remembered that it is the result of a single gate switching. If all four gates in a pack switch together the currents will be additive and the rail will fall by 4 volts.

The first requirement of a power distribution system must therefore be low inductance between the i.c. and the decoupling capacitor. This is achieved by the track layout shown in Fig. 2(b), where a low inductance path from C to the i.c. is provided by keeping the V_{CC} and GND tracks close together.

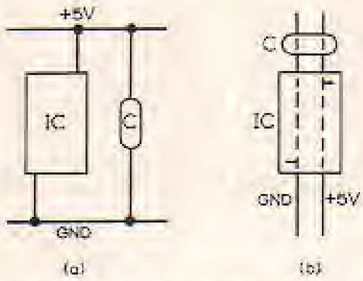


Fig. 2. Two ways of laying out supply lines. Preferred method, giving lower inductance, is at (b).

Manufacturers of i.cs usually specify one decoupling capacitor for every 5–10 i.cs which, with the track layout of Fig 2(a) results in prohibitively high inductance between the capacitor and the worst-case positioned i.c. The safest course is to provide the track layout as in Fig. 2(b) but also to put one capacitor adjacent to each i.c. Clearly, this can be achieved by having one capacitor for each pair of i.cs.

Decoupling capacitors

The foregoing argument shows that the capacitor is better thought of as a reservoir capacitor which supplies the local, instantaneous current demands as i.cs switch. This means that the important parameter for such a capacitor is the instantaneous current which it can supply. Some manufacturers specify capacitors for i.c. decoupling by giving the maximum pulse risetime, which corresponds to a maximum current for a given size of capacitor. For instance, a 47nF capacitor specified at 50V/μs can supply a current given by

$$i = C\frac{dv}{dt} = 47\times10^{-9}\times\frac{50}{10^{-6}}$$
$$= 2.5\text{A},$$

which is adequate in the context of the previous calculation.

The other check to make is that the current drawn from the capacitor does not cause its voltage and hence the rail voltage to fall excessively. If the local demand is equal to 10 gates switching, the current demand will be 500mA; to be safe, assume that this demand lasts for 10ns, and design for a voltage drop at the capacitor of 50mV.

Thus,

$$i = C\frac{dv}{dt}$$

$$0.5 = C\frac{50\times10^{-3}}{10\times10^{-9}}$$

$$C = 100\text{nF}.$$

This suggests that we should provide approximately 100nF for each pair of packages.

It might be thought that radio frequency type capacitors are necessary for t.t.l. decoupling, but this is not so. To show why requires more space than can be spared in an article of this type but essentially it is because the frequently adopted model of a capacitor, which proposes that it possesses a lumped series inductance, breaks down in the case of a single applied step. There is therefore no reason for the designer to be afraid to employ non-ceramic capacitors provided they have adequate V/μs ability. In the author's experience 1μF tantalum beads perform well as decoupling capacitors.

Transmission-line model

The best way to think of the power distribution system is as a transmission line, with each package connected to an ideal voltage source via an impedance equal to the transmission line impedance*. This impedance must be sufficiently low for negligible voltage transients to be produced on the line by gates switching within the package. The impedance of a transmission line is given by $Z_0=\sqrt{L/C}$, where L and C are the inductance and capacitance per unit length respectively. To calculate Z_0 for the case of two tracks close together:

$$L=\frac{\mu_0}{4\pi}\ln\frac{a}{r}$$

where μ_0 is 5. A and r are taken as 2mm and 0.5 mm. Therefore

$$L=0.6\mu H/m.$$

If a 100nF capacitor is placed every 5cm along this line, then:

$$C=100\times 20\text{ nF m}^{-1}=2\mu\text{F m}^{-1}$$

Therefore $Z\approx 0.5\Omega$.

An instantaneous current demand of 200mA – corresponding to 4 gates switching – will produce a voltage transient of 100mV. This is only just acceptable and suggests that the value of C should be increased. Note however, that laying out the tracks with wider spacing and using smaller capacitors – 10nF for every few i.cs, which is not uncommon, will create a situation much worse than this.

Auto-decoupling in t.t.l.

In the context of the preceding remarks some readers may wonder how systems which they have seen or have worked with managed to function at all, since it is common to see most or all of the above design guidelines violated. To see the answer to this, consider the structure of the t.t.l. gate output circuit, when this is driving the following gate input low, as in Fig. 3.

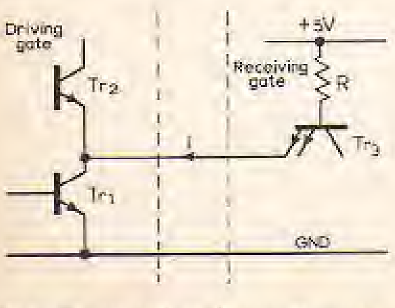


Fig. 3. Totem-pole t.t.l. output stage, driving succeeding gate low.

According to the specification for, say, a 7400 the typical values of i and R are 1.0mA and 4kΩ respectively. When the gate output is low it sinks a current i, given by $i=(V_{cc}-V_{be}-V_{CE(sat)})/R$, where V_{be} is the base-emitter voltage of Tr_3 and $V_{CE(sat)}$ is the collector saturation voltage of Tr_1.

If V_{be} and $V_{CE(sat)}=0.7$ volts, to take a worst-case example, and $V_{cc}=5$ volts

$$\text{then } i=\frac{3.6}{R}$$

Now consider what happens if the rail voltage drops, due to a transient load imposed by the output of another gate switching. When V_{CC} drops there is no change (to a good approximation) in the V_{be} drops. Suppose the rail drops by 10% then:

$$i_1=\frac{5-1.4}{R}$$

$$i_2=\frac{4.5-1.4}{R}.$$

Therefore

$$\frac{i_1-i_2}{i_1}=\frac{0.5}{3.6}=14\%.$$

In other words a 10% change in V_{CC} produces a 14% change in the current load placed on the rail. In effect what is happening is that each gate output which is holding another input low acts as a 'reservoir' of current and when the rail voltage drops as another gate drives its output high all the other gates give up some of their current to assist. This is what I would call the 'good neighbourliness effect' in t.t.l. In general, some gates on a voltage bus will be low and so act as current supplies. The problem arises when none or only a few are in this state – a critical situation for a badly designed system and one which could cause a failure. It should be remembered that a logic system should work for all possible combinations of states which can occur in practice and a hazard of this type could have serious consequences. It is therefore insufficient to demonstrate that a system 'works' because if the power distribution system is badly designed there is always the chance of an untested situation bringing about a failure of the system. It is assumed that in a logic system of reasonable size it is impossible to test all possible combinational situations, and doubly impossible to test all possible changes of situation!

The problem with Schottky t.t.l. is that the increase in speed does not allow time for the 'good neighbourliness effect' to act, consequently one is many times worse off with Schottky than with ordinary t.t.l. Schottky is a less forgiving family than conventional t.t.l. and much more care must therefore be taken with power distribution to ensure reliable performance.

The current spike

As just described, the main cause of transient current demands in a Schottky t.t.l. system is the initial current surge when a gate switches into its transmission line load. The manufacturers' data overlooks the mechanism entirely. There is another cause of transient current demand which results from the 'push-pull' design of the t.t.l. output stage shown in Fig. 4. The current spike is produced because, on the 0 to 1 transition, the upper transistor turns on while the lower transistor is still turning off. This leads to a current surge of 10mA with duration of about 10ns[1]. Provided the design guidelines laid down in the earlier sections with regard to power supply bussing and decoupling have been followed, this small additional hazard will be taken care of. In fact, since a logic gate is driving a transmission line which is a resistive rather than a capacitive load, there is no need to provide a totem pole output and this must be regarded as one of the bad features of the t.t.l. family.

Fig. 4. T.t.l. output configuration leads to current spike at transmission.

Interconnexions

To implement a system successfully using the t.t.l. family it is necessary to interconnect correctly between logic gates.

Transmission lines. The correct model to use for interconnexion between logic gates is a two-wire transmission line. It is impossible to understand how a signal travels from gate to gate without taking the return path into consideration. Indeed it is impossible for a signal to travel without a return path! Consider the two-wire transmission line shown in Fig. 5, in which a zero rise-time is pro-

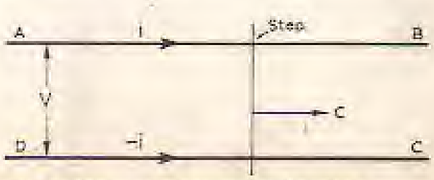


Fig. 5. Two-wire transmission line.

* A package at the centre of a power bus will see two lines in parallel and hence half the impedance. We will adopt the worse figure for the purpose of this argument.

pagating to the right with velocity c. Ahead of the step there is no current in the wires and no voltage differences between them. Behind the step there is a current i in the direction of AB and a current -i in the direction of DC with a voltage difference V between the wires. It can be shown[2] that $V = iZ_o$, where $Z_o = \sqrt{L/C} = \sqrt{\mu/\epsilon}$ where Z_o = characteristic impedance of line, L = inductance per unit length of line, C = capacitance per unit length of line, μ = permeability of medium between wires, ϵ permittivity of medium between wires. The velocity of propagation $c = 1/\sqrt{LC} = 1/\sqrt{\mu\epsilon}$.

These equations are true for any two-conductor system where the resistance of the conductors can be neglected and the medium between the conductors is well-behaved. These conditions are met by tracks on a printed circuit board for any track width which can be manufactured. The step which we have just described is a transverse electromagnetic disturbance. Since the equation relating current and voltage on a transmission line is $V = iZ_o$, it follows that the effect of a transmission line on the driving circuit can be considered in terms of a resistance $R = Z_o$ connected in place of the line. This was the procedure followed earlier in calculating the current drawn from the supply rail by a gate as it switches.

The impedance Z_o depends on the cross-sectional geometry of the conductors employed and its calculation is extremely difficult except for very simple cases. It is, however, a relatively slowly varying function of the geometry[3] (usually logarithmic) and therefore this need not worry us too much. For a track on a printed circuit board laid out according to the design rules evolved in this paper a value of Z_o of around 150Ω can be assumed.

One key feature of a board of logic which distinguishes it from most analogue systems is that there are a multiplicity of signal paths from various points scattered about the board to various other similar points. It is essential that each of these signal routes has an adjacent return path. The simplest way, conceptually, to achieve this is to provide a ground plane on one side of the board. In practice this is difficult since it usually requires multi-layer construction, with the increased cost and complexity which this entails, in order to accommodate the signal interconnexions. With Schottky t.t.l. it is not necessary to go to this extreme; all that is required is a ground grid laid out so that a signal line is never more than one inch away from its return path.

Ground loops. It might be argued that this scheme leads to ground loops which, from our experience with analogue systems (e.g. audio equipment) are to be avoided. The plain fact is though, that on a logic board, ground loops are of no importance. The reasons for this are somewhat complex but it is probably useful to note one simple argument. In a high-gain amplifier, induction of a few millivolts at the input due to ground loop pickup can lead to an output of the same order as the signal. In logic this is not the case; a few millivolts into a gate input make no difference whatsoever. Hundreds of millivolts of noise are required before we will significantly degrade the noise immunity of a t.t.l. system.

It is probably valuable to examine a situation where a logic board has been laid out in order to avoid ground loops. A possible layout of power and ground connexions, which is quite commonly adopted in the industry, is shown in Fig. 6. Now, if circuit A sends a step to circuit B there is no adjacent return path. In practice, since a fast step requires a return path it will simply use adjacent signal lines as returns, resulting in the induction of transient noise on these other signal lines. A further consequence is that the input to B will take a longer time to settle with a consequent reduction in the speed of the system. As was explained earlier, the layout of Fig 6 is also bad from the point of view of placing excessive inductance in the way of charge travelling between i.cs and decoupling capacitors.

Recommended layout

A recommended scheme for laying out a printed circuit board is shown in Fig. 7. The power rails are run as close together as possible along the columns of integrated circuit packages and are interconnected at the top and bottom of the board. These provide return paths for logic signals travelling parallel to them. To provide return paths for signals travelling across the board the ground pins of the packages are connected together from left to right. Thin track, of the same thickness used for signal interconnexions can be used for this. A tantulum bead 10μF decoupling capacitor is provided between each pair of i.cs. Notice also that ground connexions are brought out at regular intervals across the edge connector. These provide return paths for signals travelling on and off the board.

If all these design rules are followed a reliable system will result and the consequent savings in servicing and testing will amply repay a little consideration given to board layout at the design stage.

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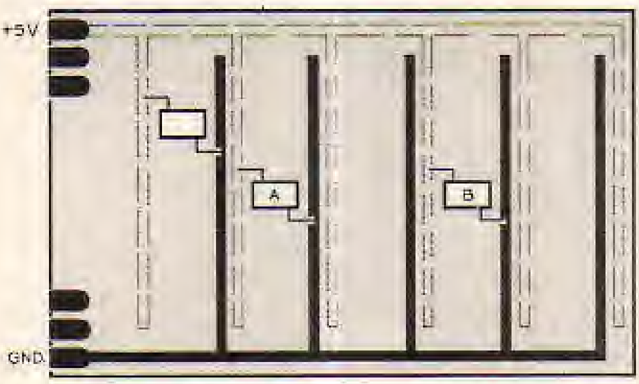

Fig. 6. A bad layout giving high inductance and few adjacent signal return paths, which leads to cross-talk.

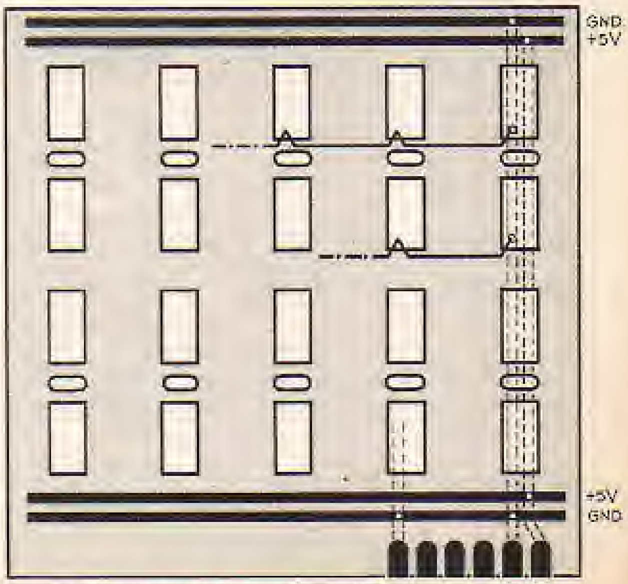

Fig. 7. Recommended layout. o = Through plated hole ⬭ = Decoupling capacitor

Microcomputer design — 4

Practical realisation of a microcomputer system

by **C. D. Shelton,** B.Sc.(Eng.), ACGI, M.Phil., Ph.D., in association with Shelton Instruments Ltd and NASCO Ltd

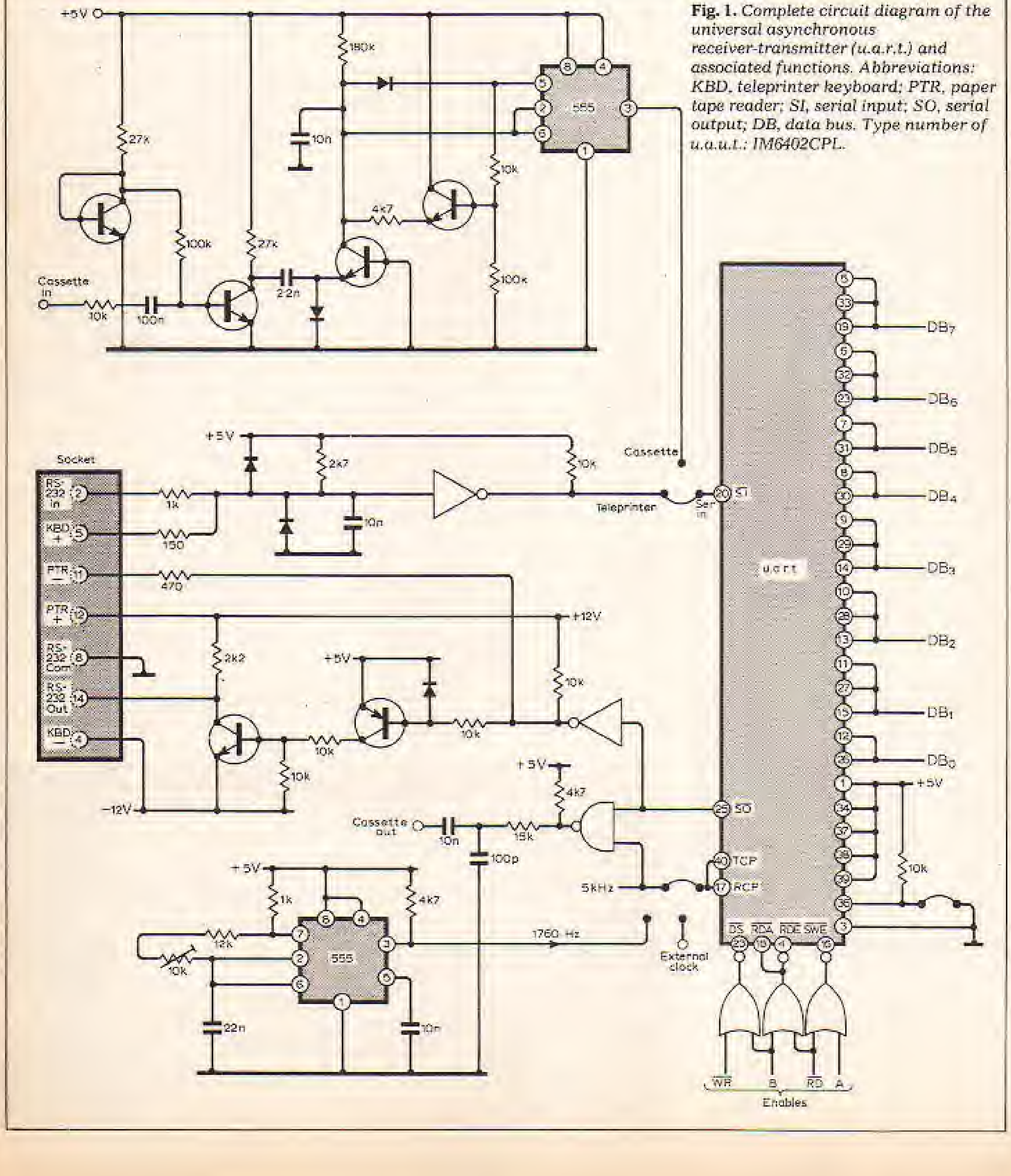

Fig. 1. *Complete circuit diagram of the universal asynchronous receiver-transmitter (u.a.r.t.) and associated functions. Abbreviations: KBD, teleprinter keyboard; PTR, paper tape reader; SI, serial input; SO, serial output; DB, data bus. Type number of u.a.u.t.: IM6402CPL.*

THIS MONTH the description of those peripherals of the microcomputer system outlined in the January issue is completed by a circuit diagram of the universal asynchronous receiver-transmitter (u.a.r.t.). As explained last month, the purpose of the u.a.r.t. is to provide a transformation between the 8-bit parallel data within the computing system and the type of serial digital information which can be handled by peripheral devices such as the audio cassette recorder. The u.a.r.t. is shown in Fig. 1, and it will be seen that this has connections to the 8-bit data bus of the computer system on the right (labelled DB_0 to DB_7) and connections for the serial input and output information on the left (labelled SI and SO, negated).

Clock arrangements

As also mentioned last month, the rate at which the data is shifted into and out of the u.a.r.t. is determined by a clock pulse signal applied to the receiver and transmitter clock connections on the u.a.r.t. (pin 17, labelled RCP, and pin 40, labelled TCP). There are in fact three clock pulse generators available to the system. The first of these is provided elsewhere in the computer by a crystal oscillator and divider chain, which produces a 5kHz clock signal, and this is fed to the u.a.r.t. by a link as shown at the bottom of the diagram. The second clock generator is a circuit at the bottom left of Fig. 1. This is a simple oscillator based on a 555 i.c. which can be adjusted to operate at 1760Hz, and as shown this signal can be fed to pins 17 and 40 on the u.a.r.t. by means of the link. The third clock generator is any external source the user may care to apply, and this again is fed into pins 17 and 40 on the u.a.r.t. by the link as shown at the bottom right.

As already mentioned, since a stop bit and a start bit are added to the byte, there are 10 bits in each word transmitted. This, however, can be increased to 11 bits by adding another stop bit, which can be done by applying +5V to pin 36 on the u.a.r.t. by means of the 10kΩ resistor and removable link.

Serial digital information is recorded on the audio cassette recorder in the form of a modulated tone. This tone is provided by the 5kHz clock signal shown in Fig. 1, which is modulated by gating it with the serial data emerging from $\overline{SO}$ on the u.a.r.t. The resulting modulated 5kHz signal goes to the "cassette out" terminal. The playback signal from the cassette recorder (applied to the terminal "cassette in") is therefore a series of bursts of 5kHz tone corresponding to the serial data stream. To convert these tone bursts back to conventional logic levels there is a tone detector circuit. This is shown at the top of Fig. 1, and is made up from a 555 i.c. and associated components.

The serial input to the u.a.r.t. is connected by a link to whichever source is chosen by the user.

Peripheral 4—visual display

In any computer system of this type it is required that the user be presented with data from the machine. For programme development this may mean the presentation of several hundred characters. At the same time the cost of displaying alphanumeric characters should be minimised. The method chosen for this project is a "memory plane peripheral" and is not sited on ports as conventional i/o but consists of logic which shares a section of the memory. This logic is designed to present a composite video signal to a domestic television receiver in such a way that the contents of this memory section are interpreted as characters. Any possible conflict of access to the memory between the processor and the logic has been resolved by giving the processor absolute priority. As a concession to appearance the video signal is blanked during c.p.u. access. It is as though a section of memory is exactly mapped on to a visible plane.

(To be continued)

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continued from page 50

one alumina substrate. Anodised aluminium capacitors ranging from 2 to 400pF, and nichrome resistors ranging from 4 to 200Ω, are used.

Acknowledgements

The authors would like to thank their colleagues at the Mullard Research Laboratories, whose work has been illustrated in this article. Particular thanks are due in this respect to Mr P. L. Booth, Mr L. W. Chua, Mr K. Holford, Mr R. E. Pearson, Mr S. K. Salmon, Dr H. Sewell and Dr J. C. Williams. The work on the parametric amplifier and the microwave receiver was supported by the Procurement Executive, Ministry of Defence. □

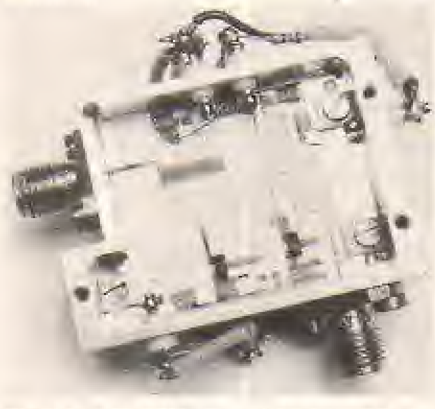

Fig. 10. *A 900MHz transistor amplifer.*

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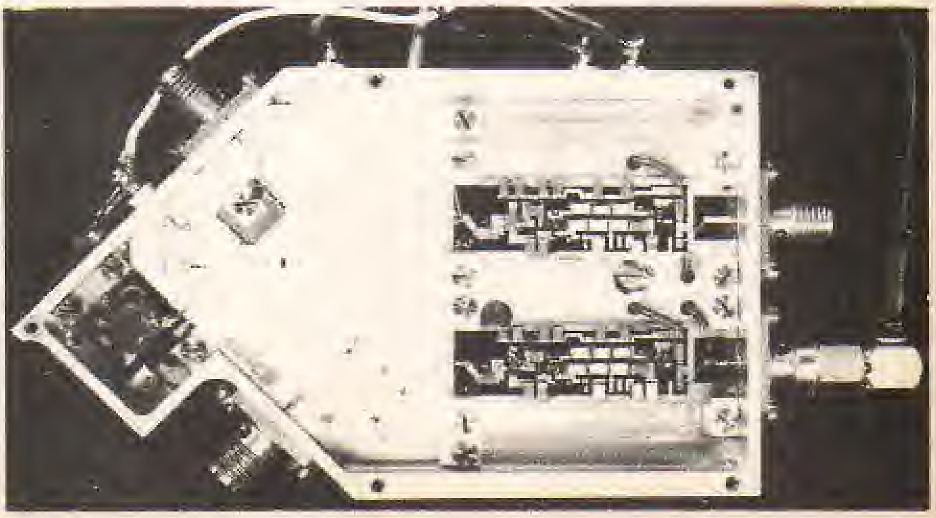
Fig. 9. *An integrated X-band Doppler receiver.*



WORLD OF AMATEUR RADIO

Mysteries of Sporadic E

JUST why and when those curious clouds of ionization form some 100km above the Earth — the Sporadic E (Es) phenomenon — is still one of the unsolved mysteries of radio physics. In the UK, there is a pronounced Es "season", in other countries nearer the Tropics, such as India, the Es paths can open almost daily. Such conditions provide v.h.f. paths up to almost 2000km and very occasionally "two-hop" paths can double this maximum distance. Amateur exploitation of Sporadic E dates back to the 1930s and I remember the sensation when E. Menzies, G5MQ, in Liverpool first worked an Italian station on 56MHz on July 2, 1938 shattering previous conceptions of v.h.f. distances. Today such contacts are accepted as a normal part of the Es and tropospheric scene. But if more was known of the basic mechanisms that give rise to the ionized clouds, it might be possible to predict in advance just when they are likely to occur.

Regular observations made over a number of years by Ron Ham at Storrington, Sussex show that although the 1977 Es season was a little shorter (May 4 to August 5) than in 1976, it was observed more frequently (in the range 65 to 73 MHz) than in any of the previous four years. June 1977 showed 16 disturbances, representing more than half the days of the month. But Ron Ham is still unable to prove or disprove any direct connection between sunspot activity and Es disturbances.

Martin Harrison, G3USF, however, believes there may be a connection between the onset of an Es disturbance and the strange phenomenon of "sweepers"; atmospherics that are observed to sweep rapidly over a frequency spectrum several megahertz wide in a matter of seconds and are heard most frequently between about 25 and 30 MHz (though occasionally as high as 150MHz or as low as 2MHz). Sweepers were first reported by the Americans N. C. Gerson and W. H. Gossard in 1958 and more recent observations have been made by A. K. Sen and S. K. Trehan of the University of Calcutta aided by a number of observers including VU2KX at Berhampore and VU2SA at New Delhi. Both these studies have suggested a firm link between "sweepers" and the sun; but the possible link with the onset of Sporadic E conditions appears to have been suggested for the first time by Professor Harrison, G3USF.

Three European 50MHz beacon stations, ZB2VHF (50.090MHz) in Gibraltar, FX3VHF (50.100MHz) in France and 5B4CY (50.140MHz) in Cyprus should all be in operation by the time these notes are published and should provide an excellent opportunity, particularly for amateurs in southern Africa, for transequatorial propagation.

News and views

"Oscar 6 is dead. Long live Oscar 7" that is the gist of the latest communique from the University of Surrey AMSAT Telecommand. Martin Sweeting, G3YJO reports that following cell failure in the Nicad battery of Oscar 6 last June, the spacecraft was shut down indefinitely. Soon afterwards the downlink telemetry became garbled and the satellite failed to respond to ground command, the transponder falling silent a week later. Although the telecommand station continued to track Oscar 6 it was heard only briefly on two occasions and now, after some 4½ years of operation, must be considered dead. Oscar 7 continues to function well although more orbits are being switched to Mode B where the battery drain is greater, so easing the problem of almost total sunlight at this time of the year. Unfortunately some operators continue to use excessive uplink powers on 432MHz: 100W e.r.p. is recommended, 10W may be enough.

In several West European countries, including Germany and Holland, a number of amateur stations are now using rejuvenated Hellschreiber ("Feldfernschreiber") machines on 3.5MHz producing curious matrix-type tapes of written messages. The Hellschreiber system, which produces a distinctive rhythmic "grinding" signal, was used by the Germans in World War 2 and subsequently by news agencies.

Almost fifty repeater stations are now operational in the UK. The UK FM Group (Western) recently brought two more u.h.f. repeaters into operation on 433MHz. GB3CR operates from Pont-y-Bodkin, Mold, Chester, serving Chester and parts of the Wirral; GB3LI operates from Seaforth serving the City of Liverpool and the whole of Merseyside. It is also hoped to build an amateur tv repeater for the 1.3GHz band and the r.f. equipment for this is already being assembled. The Group secretary is Gordon Adams, G3LEQ (2 Ash Grove, Knutsford, Cheshire WA16 8BB). A man was recently successfully prosecuted in Corwen Magistrates' Court by the Home Office in a case which arose out of jamming and abuse of the Moel-y-Parc repeater. Local amateurs located by direction-finding the unauthorised transmitter. The report (WoAR, December) that the UK FM Group were considering closing down GB3LO is wrong; it appears to have originated in the "dirty tricks department" of an anti-repeater group.

The gigahertz president

ON Saturday, January 21, Lord Wallace of Coslany will install as his successor, the 44th president of the RSGB, Dain Evans, Ph.D., G3RPE.

Dr Evans is known and respected for his tremendous enthusiasm for encouraging more amateur operation in the microwave bands above 1GHz, with the 10GHz band as his own special interest. In October 1970 he launched the first regular monthly column to appear in any amateur journal specifically devoted to the world of the gigahertz. As a result, he has seen interest and activity grow steadily in the UK, and more recently in many countries throughout the world.

But his first experiments with radio, though showing the same ingenuity that led him to examine dozens of different dustbin lids to test their suitability for use as microwave reflectors, was on far more mundane frequencies. As a ten-year-old schoolboy he invested 6d in a pair of government-surplus headphones and made a crystal set using the "blue" on a Blue Gillette razor blade as the detector.

In September 1969 he first contacted a French 10GHz station across the English Channel on Cape Griz Nez while using 15mW s.h.f. power to a 10-inch dish aerial. But he recalls as his most interesting operation "sitting on a beach in Holland chatting to English amateurs while using only 2mW on 10GHz." His ambition is to make some 1000km contacts on this band.

In brief

The ITU has allotted the callsign series P4A to P4Z to Netherlands Antilles . . . Eric Hubbard, G5OX, often known as "Oxo," has died; he was one of the amateurs who in the early 1920s were allowed to operate on 440 metres . . . Another old-timer who has joined the "silent keys" is Reg Radford, G2IM, who began his many years with BBC Engineering in the days of 2LO . . . A television receiver designed to operate without interference in strong r.f. fields has been built for the FCC by Texas Instruments and is attracting considerable interest . . . The Home Office has resumed the issue of "special event" licences, including GB3MSA for the Poldhu station participating in the KM1CC 75th anniversary until January 22.

PAT HAWKER, G3VA

Automatic impedance plotter

Finding impedance variations at 20MHz in surface wave transducers

by **T. F. North,** Physics Department, Chelsea College, University of London

A problem that often arises in electro-acoustical work is the need to know the electrical impedance of a component under specific operating conditions and its variation with frequency. In stimulating nematic liquid crystals with mechanical surface waves in particular, I needed to know how the impedance of an inter-digital surface-wave transducer varied with frequency in the range 18 to 70MHz.

MEASURING IMPEDANCE variations of a component is a straightforward procedure using a standard radio frequency bridge. But a large change within a narrow frequency range makes an automatic plotting system more appropriate. In the circuit of Fig. 1 R is a standard resistor of negligible inductance and peak-to-peak potentials V_1 and V_2 at both terminals of the resistor are measured. Provided the phase change across the component under test is small, it follows that its impedance is $|Z| = V_2R/(V_1-V_2)$. As an initial step a method was sought of varying the signal strength to maintain (V_1-V_2) constant. The use of f.e.t. attenuators introduced distortion into the waveform and so an alternative procedure was adopted of attenuating the average signal level by chopping the continuous-wave signal with a variable mark-to-space ratio.

The wideband gate employed to chop the r.f. signal is given in Fig. 2. With the gating input in the up position, the diodes are all reverse-biased and so there is no signal transmission. On putting the gate input down, the diodes become conducting so that the input and output potentials must now both be one diode-voltage drop above and below the respective junctions between the diodes and resistors; hence the gate will allow the passage of the signal.

Such a system of gating the r.f. signal worked satisfactorily but a simpler procedure is to measure V_1 and V_2 and then attenuate both by the same proportionality factor α so that $\alpha(V_1-V_2)$ remains constant; Z is now proportional to αV_2. This proportional attenuation is achieved by chopping both voltages with a variable mark-space ratio of $\alpha(1-\alpha)$ and integrating the resulting wave to produce the voltages αV_1 and αV_2, Fig. 3.

Negative voltages $-V_1$ and $-V_2$ are measured by detection in D_1 and D_2 and the outputs from these diodes fed into voltage follower operational amplifiers IC_1 and IC_2 to provide a high input impedance to the system. There is no need to smooth the detected signal. The frequency range under study being well outside the frequency range of the 741 op-amp. Diodes D_3 and D_4 introduce an offset in the voltages between the inputs and outputs of these voltage followers equal and opposite to the voltage drops across D_1 and D_2. Potentials at the outputs of IC_1 and IC_2 are thus equal to $-V_1$ and $-V_2$.

When the output of IC_5 is saturated negatively diodes D_5 and D_6 are reverse biased and the voltages at points A_1 and A_2 will be $-V_1$ and $-V_2$ respectively. However, when the output of IC_5 is saturated positively D_5 and D_6 will raise the potentials at A and B until D_7 and D_8 conduct. The voltage drops across these diodes are balanced by that across D_9 so that points A_1 and A_2 will now be at zero potential. The voltages at points A_1 and A_2 are integrated by R_9 and C_1 and R_{10} and C_2 respectively to give voltages αV_1 and αV_2. The last-mentioned voltage αV_2 is amplified in the unity-gain voltage follower IC_3 to provide a low impedance output. A constant voltage of 2.7V is added to it by the zener diode, fed by constant-current source, and the resulting voltage compared with $2V_1$ in the differential amplifier IC_4. Capacitive negative feedback across this amplifier limits its frequency response to well below the chopping frequency and renders the system stable. The output of this amplifier is used to vary the chopping mark-to-space ratio, $\alpha:(1-\alpha)$.

Positive feedback through R_{14} causes IC_5 to oscillate at a frequency of approximately 10kHz. Capacitor C_3 is continually charging or discharging through R_{15} so there is a triangular

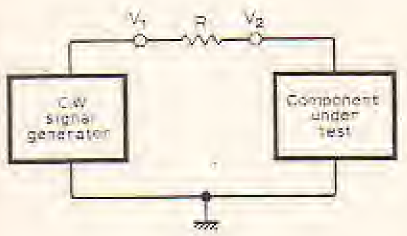


Fig. 1. *Impedance of component is plotted by attenuating average signal level through it. A chopped c.w. signal with variable mark-space ratio can achieve this.*

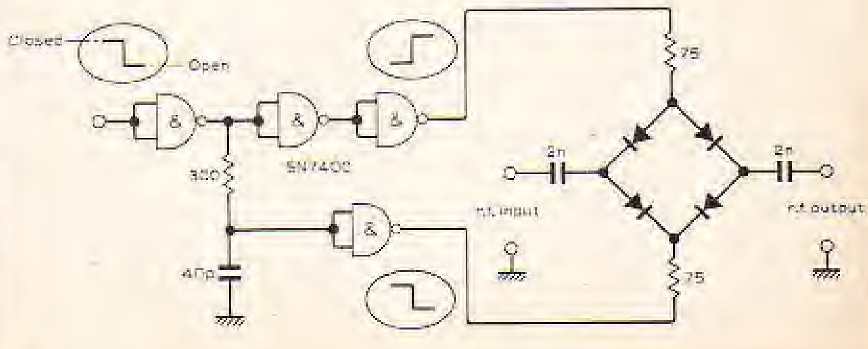
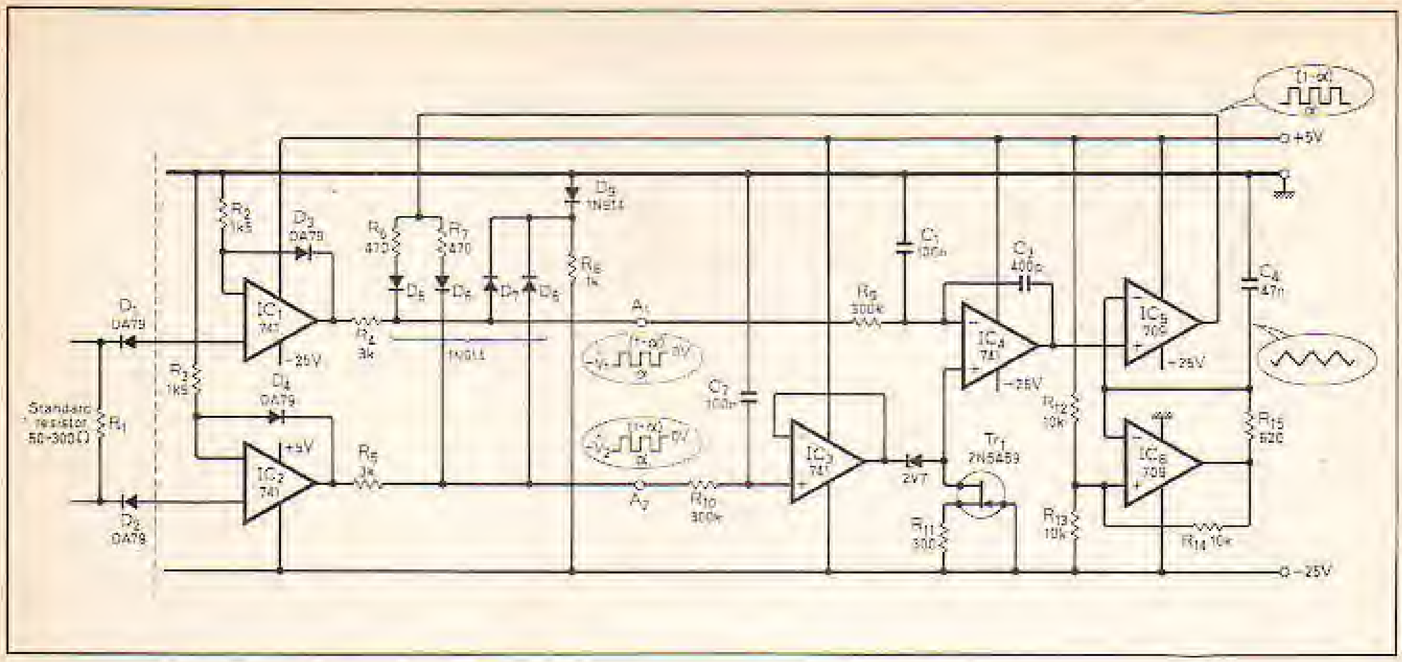


Fig. 2. *A variable amount of r.f. signal can be passed through a standard resistance using a single wideband chopper, avoiding the distortion of an f.e.t. attenuator.*



wave at their junction, which is fed into one input of the saturating amplifier IC_5. The points at which the voltage level at its other input cut this triangular wave determine the moments at which it changes from saturating at one polarity to the other. Accordingly this voltage level determines the mark-to-space ratio of its output.

Procedure for plotting the impedance of the transducers in question is to slowly sweep through the frequency range of interest by changing the output frequency of the signal generators by hand. The X input of an XY plotter is driven by a frequency-to-voltage converter consisting of a commercial 1:100 frequency divider, which triggered a 1µs monostable unit (SN74121). The integrated output of this is proportional to frequency. The Y input of the recorder is driven by the output of IC_3, and point A_1 of the circuit monitored with an oscilloscope. This enables both the detected signal level V_1 and the mark-to-space ratio of the chopping to be seen. In practice the signal level can be set so as to maintain this ratio at about unity. The system is calibrated by using carbon resistors of known value.

Fig. 3. *Same attenuation of V1 and V2 is obtained by chopping both with a variable mark-space ratio of $\alpha(1-\alpha)$ and integrating to produce αV_1 and αV_2.*

Turntable war, first casualties

Garrard and Strathearn are in trouble. Strathearn's autocratic chief executive, Graham Bish, has been relieved of his duties as executive chairman, though he remains a director. The reason given was of ill-health. The company has now swallowed at least £7 million of taxpayers' money, and as the rest of the turntable industry produces ever newer models the Strathearn units are as they were four years ago.

Recently Strathearn asked the Northern Ireland Development Agency for further funds "to develop its marketing operation and future production capacity," according to a spokesman. The NIDA declined, and called for an examination of Strathearn's viability. The subsequent report showed that the company could not survive, and it appears that the Minister of State for Northern Ireland is not prepared to intervene to keep the firm going. However, the directors have been given a period of grace to prepare a case for keeping Strathearn open.

Garrard, by comparison, look like paragons of efficiency. All the same, 480 jobs are to be lost of which 335 are indirect labour, such as cleaners and clerical staff, and 145 are directly employed in making turntables. Of the 145, a large number are working shifts, so the total of direct labour redundancies could be as high as 290. The total workforce is 2,000.

There are several reasons for Garrard's plight. One is the depressed home market. According to BREMA, "There is little sign of the anticipated seasonal pickup." Any disposable income people have left after inflation and wage freezes have taken their toll is being spent on something other than hi-fi.

Even if there had been a normal pre-Christmas rush, however, Garrard say they would not have been ready. Production of the new range, for which they would have had to start taking trade orders at Harrogate at the beginning of September, didn't start until the end of October, two months behind schedule. They blame poor deliveries of components, including some from Japan, and, privately, poor labour relations.

However, there seems to have been very little labour trouble at Garrard's, which the local union representatives say has better wages and working conditions than most factories in the district. The local organiser of the AUEW told *Wireless World* that in the four years he had been in Swindon he could only remember having to go there once, and that was over a small matter that was easily resolved. The unions add that, as soon as Christmas is over they will want to look at the books, but they have little doubt that they will find the main cause of the lay-offs was lack of consumer demand.

That does not appear to have affected the Japanese makers, who, Garrard complain, went on the offensive, taking large ads in the colour supplements. One wonders what was to prevent Garrard doing the same.

Last July Garrard held a press lunch at which they previewed the new range. Managing director Derek Moon made clear his attitude to Japanese imports: "This industry used to employ 48,000 people more than it does now ... Protect your home industries, I say to government, and if that means tariffs for a while then let's have a tariff barrier. I do want a breathing space from Japan Inc. Give us a couple of years and we'll beat the hell out of them too."

Garrard has suffered quite a bit at the hands of the Japanese. In 1972 they had 17½% of the world turntable market. By 1976 that had dropped to 7½%, though they say they have managed to hold their share this year. Together Garrard and Plessey had invested £2.5 million in new products in 2½ years, though they admitted to mistakes. At the July preview they said, "Cosmetically last year's range didn't match up."

There are signs, as we pointed out in our Harrogate report (November 1977, p.57) that this year's don't match up either. The collapse of the home market hardly explains the troubles of a company that exports 70-80% of its production. The European and American markets have not been so depressed. A company that wants relief from the pressures of competition is in trouble, whether it knows it or not. BSR's Roger Allan, who lived in Japan for many years, told us in an interview last year "I'm totally for free trade. If the world went protectionist it would be a disaster."

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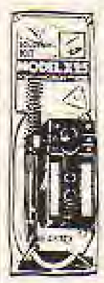
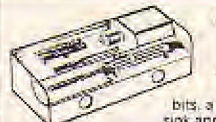


With the model X25 general purpose iron and the S.T.3 stand and its B.E.A.B. safety label, this kit is a must for every tool-kit in the home.



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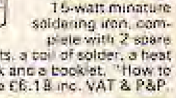

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Topics from Radar 77 — 2

Further extracts from the IEE conference

by Ray Ashmore

The last issue summarized six papers from the international radar conference, Radar 77, which this year was organised by the IEE. The papers included descriptions of a man-portable radar, and radar systems for automatic collision avoidance and the detection of sea states and oceanic winds. The following text is also based on extracts selected from the conference papers.

AT A WAVELENGTH of 10μm, one has the option in radar of using either photodetection or radio-frequency detection using metal-oxide-metal point contact diodes. Comparisons by the Royal Signals and Radar Establishment at Malvern have shown that, assuming all radiation entering these detectors is 'signal', for heterodyne detection the signal-to-noise ratio performance with r.f. detection is 'everywhere better' than with photodetection. For photodetection the signal noise is proportional to the incident field, but for r.f. detection it is proportional to the power. For both systems, performance is greatly improved by using heterodyne detection at the receiver. In practice one can achieve a receiver performance in which background fluctuations are the dominant noise source in the receiver system.

Harmonic radar detection

Plessey Radar Research Centre have been investigating systems using harmonic radar detection[9]. The difference between harmonic radar and conventional radar is that the receiver detects radiation generated by the target at frequencies which are harmonics of the incident radiation frequency. Many man-made objects generate harmonic frequencies when illuminated by a radiation flux, but most natural objects such as vegetation, the ground and the sea do not. However, the frequency conversion efficiency from the man-made objects usually restricts applications to relatively short range detection systems.

The main advantage with harmonic radar is that it is free from environmental clutter. Harmonic generation arises from non-linearities in the electromagnetic transfer characteristics in objects such as semiconductors, and metal-to-metal junctions. Further information regarding the theory of harmonic radiation can be obtained from the May and June 1974 issues of *Wireless World*.

For a semiconductor diode the transfer characteristic is exponential and results in a rich harmonic spectrum. Since it has been found that the conversion loss is less for low harmonics, for the most favourable range law, a second-harmonic receiver should be used. For a typical metallic target, because the transfer characteristics are symmetrical and the power series contains only odd-order terms, the receiver must be a third harmonic type. Results confirm that the third harmonics received from metallic targets are much lower than the second harmonics from electronic targets.

Non-linearity in metal junctions is thought to arise from, among other things, electron tunnelling through the oxide barrier existing at the metal surfaces. This non-linearity, however, is sensitive to small movements of the contact surfaces. This causes the harmonic signals to fluctuate and make it impossible to give a fixed value of harmonic 'cross-section' to the objects, except by using a statistical definition. The observed cross-sections have been found to vary considerably for different types of object.

Applications for harmonic radar include collision avoidance, locating targets close to the surface of the sea and non-destructive testing, to locate the presence of cracks in metal structures.

Radar in geophysical prospecting

The use of radar for detecting and locating subsurface geological strata and man-made artefacts has recently received considerable attention in technical reports, particularly in the USA. For this application, conventional a.m./c.w. has been found to be the most suitable for long range prospecting. For short range prospecting, f.m./c.w. was found to require highly complex receivers, especially at frequencies below about 1GHz, and consequently other modulation techniques had to be developed.

One of these techniques, pseudo-baseband pulse radar, was the subject of a paper[10] presented by the Plessey Radar Research Centre. There are two methods of generating pseudo-baseband pulses. One method transmits a discrete harmonically-related spectrum related to a pulse train, and depends upon a computer processor to reconstruct the received information into the time domain. The other method, which is suitable for portable radars, uses a pulse generator providing a real time pulse train. The latter method was used by the Plessey team investigating subsurface interfaces between strata, and has resulted in a number of short-range high-resolution radars being developed.

In general, the pulse generator produces a cosine squared function having a time duration between 0.5 and 10ns, depending on the application. The return signals from the interfaces are passed through a sampling head and translated from the nanosecond time region to the millisecond time region.

The antenna is a critical element in the design because clutter greatly reduces the system dynamic range. Most applications require the antenna to be operated well clear of the front surface of the radar. The radar is then physically moved to scan the target and the signal return is stored for analysis.

In the field trials a series of laboratory measurements were carried out at frequencies from 100MHz to 15GHz on coal and slate samples from South Derbyshire. From these measurements it was concluded that the attenuation characteristics of UK geological materials tend to be significantly higher than those reported by other authors and that, as expected, water content and impurity level are the functions of material attenuation. In addition the results showed that the antenna design feature used, a successive subtraction technique, has enabled a significant improvement in the dynamic range which can be achieved.

Detection of buried objects

One paper[11] from the Queen Mary College, University of London, proposed the use of f.m./c.w. radar for the detection of buried objects such as pipes and cables, some of which may be plastics. In the latter case conventional metal detectors fail. A prototype radar developed by the investigators at the College operated in a linearly-swept frequency band from 2 to 4GHz. With this system, which is potentially man-portable, small plastic objects were detected at depths of about 25cm in wet sand. For polystyrene foam buried in sand vertical and horizontal resolutions of about 4 and 20cm respectively have been achieved.

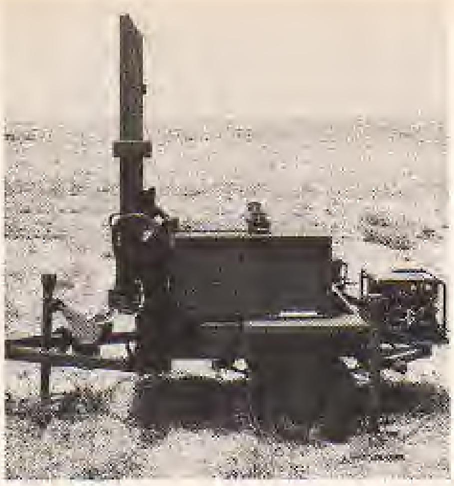
The choice of operating frequency was a compromise. A low microwave frequency improves ground penetration but limits resolution because, for a constant-aperture antenna, the ground illumination increases as the frequency increases, and for a constant percentage swept bandwidth the range resolution decreases as the centre frequency decreases.

The antenna needed to have a radiation pattern with a relatively narrow beam width at the ground surface, and one that remains relatively independent of frequency over the swept band. It also had to have a low input v.s.w.r. which was either frequency independent over the band or exhibited a desired variation. In addition, the antenna pattern needed to have low side-lobes and the antenna had to be compact.

It was concluded that improvements in system performance should be achieved by using a bistatic system having a microwave amplifier following the receiver antenna. Signal processing techniques could also be used to further reduce range side-lobes associated with the ground returns, and, where the antenna is at a constant height above the ground, cancellation techniques could be attempted. These features would certainly be required if the radar is to detect objects buried in clay soil at depths in excess of 20cm.

The detection of electricity pylons and cables

The potential hazard of light aircraft and rotary-wing aircraft striking electricity cables has long been the concern of military aviation authorities in many countries. As a result, the role of such aircraft is severely restricted, particularly in darkness or bad weather conditions. Line cables may be detected by the interference generated by them, but if the cables are not current-carrying they will not be seen by the aircraft. The Research Laboratory of Marconi-Elliot Avionics Systems Limited, on behalf of the Royal Signals and Radar Establishment, has been investigating the possibilities of detecting pylon cables by radar[12]. It is possible by using a simple pulsed radar, generating at short centimetric or millimetric wavelengths for example, to detect a straight power cable at several points along its length. The detection points will be a main return (broadside flash), which is normal to the cable and is due to the cable acting as a cylindrical rod, and a secondary return which is detected on either side of the broadside flash, and is due to the wrapped construction. Tertiary detection points could also be detected at an angle of approximately 40° to normal, but these could be observed only at very short ranges. It was decided that a Q-band, experimental pulsed radar should be used, operating at approximately 35GHz. The radar used a high powered magnetron transmitter with a pulse length of 100ns and a p.r.f. of 200 pulses per second. The aerial system had a flat plate Cassegrain scanner with a 3dB bandwidth of approximately 1° and it could be mechanically scanned over several degrees in both elevation and azimuth planes. Using this radar, targets as close as 150m could easily be detected.



Hughes' US Army Firefinder radar AN/TPQ-36 can locate artillery after only one firing and predict target location before impact.

The field trials showed that it is possible to detect power cables by using pulsed Q-band radar equipment, and that the magnitude of the broadside return is similar to that produced by the supporting pylon. The fact that, in a plan presentation, the secondary returns all lie on the same straight line as the broadside return and the two adjacent pylons, is considered an advantage to a pilot in discriminating between cable returns and those from trees and other more randomly spaced obstacles.

Radar on the battlefield

A radar system has been developed by the US army to determine automatically the location of hostile artillery after it has fired only once[13].

The system, called Firefinder, is designed to locate simultaneous fire from numerous weapons on a battlefield. It employs two different radars, types AN/TPQ-37 and AN/TPQ-36, which both employ electronic scanning antennas enabling rapid repositioning of the antenna beam anywhere over a 90° azimuth sector. They will also scan a few degrees in elevation.

The AN/TPQ-37 has successfully located artillery in live fire tests at ranges beyond 30km. Phase shifter devices in its phase scan system are integrated into modular arrays that include stripline power dividers and dipole radiating elements. The final power amplifier in the system's transmitter is a travelling wave tube controlled by a shadow grid and, in each position, the transmitter is pulsed at a fixed p.r.f. to form a train of coherent pulses. The radar receiver uses a gallium-arsenide, f.e.t. preamplifier for each of the pulse channels. After frequency conversion, the channels are time-multiplexed into a single channel by using s.a.w. delay lines. The train of pulses is then coded by frequency modulation and the f.m. signal transmitted to the operations shelter over coaxial cable at its intermediate frequency.

The AN/TPQ-36, which also scans in azimuth and elevation, has a range approximately half that of the AN/TPQ-37. It used a series end-feed to distribute the r.f. power in the horizontal plane and ferrite phase shifters to electronically scan in azimuth. For elevation scanning, r.f. power is disturbed through individual waveguides which have radiating elements in the form of slots cut in the narrow walls. Electronic scanning is carried out using the frequency dispersive characteristics of the waveguides by changing the radiated frequency. The transmitter and receiver systems are similar to those in the AN/TPQ-37.

Each radar scans the horizon of the surveillance sector, with a single row of beams searching the sector a few times each second. Targets are tracked by updating measurements of range, azimuth, elevation, doppler and amplitude several times each second. When there are multiple targets, each target is tracked for a few seconds and time-related to the search process. The system discriminates between returns to reject those done to birds, aircraft and other sources of clutter.

The weapon-locating process is so rapid that the position of the hostile artillery is usually determined before the projectile impacts. The radar system computer can also extrapolate forward along the trajectory to indicate to the operator the expected impact point as well as the artillery position.

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Single-sideband transceiver design

Underground application uses simple ceramic sideband filter

by **B. A. Austin,** B.Sc. (Eng.)

Research Laboratories, Chamber of Mines, Johannesburg

An investigation of underground radio communication showed the need for a transceiver operating at around 1 MHz and with an r.f. power capability of 1 W. The requirements of such a transceiver are considered and certain circuit details discussed.

For underground use, a suppressed-carrier modulation system must be used to obtain maximum usable transmitter power, and a double-sideband suppressed carrier transmitter is simple to design, adjust and manufacture. Reception of d.s.b. s.c. signals with fairly simple detectors, however, presents a problem. Use of a single sideband, on the other hand, does not require such complication in the receiver but does require a more complex transmitter. Of three commonly-used s.s.b. generation systems, only the filter method does not require careful circuit adjustment. Because filter-type s.s.b. generators are expensive it was necessary to examine other possibilities, particularly in view of the environment.

Transceiver requirements

The transceiver was required for operation in deep gold mines, shielded from surface noise by a mass of rock impervious to electromagnetic propagation. There is no channel congestion in this environment, and this makes it possible to accept transmitter characteristics which would be non-ideal elsewhere. Most important of these is the generation of an s.s.b. signal by the filter method which is of sufficient quality to simplify the receiving circuitry, but does not require excessive rejection of the unwanted sideband. Acceptance of this immediately simplifies the requirements of the sideband filter.

A ceramic filter element appeared to be suitable and the manufacturer's specification for a single-section filter type SFD-455B is shown in Table 1.

Table 1. Single-section SFD-455B filter

Centre frequency kHz	Bandwidth (−3dB) kHz	Loss dB
455 ± 2	4.5 ± 1	9 (max.)

To obtain a reference against which various filter combinations may be compared it is necessary to define the filter shape factor in terms of two meaningful and measurable bandwidths. For this filter, with skirts that are not particularly steep, the shape factor is defined as −30dB bandwith divided by −3dB bandwith. Coupling the two sections of the filter via a 68pF capacitor gave a shape factor of 6.35. Because the shape factor is a measure of attenuation for the unwanted sideband, it enables an assessment to be made of various filter configurations.

To improve skirt selectivity of the ceramic filter it is necessary to cascade sections with suitable coupling as show in Fig.1. The results of this are shown in Table 2. Six filter elements designated A to F were selected at random and measurements were made as detailed in the table. The centre frequency is $fc=\sqrt{f(-3dB)_{upper}\times f\ (-3dB)_{lower}}$ and the bandwidth (measured 3dB down) is given by $BW = f\ (-3dB)_{upper} - f\ (-3dB)_{lower}$ Comparison between three cascaded filters all coupled by 56pF

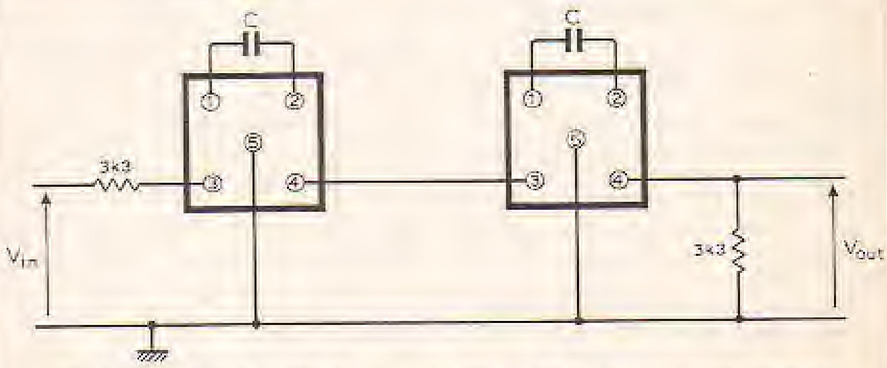

Fig. 1. *Two cascaded 455kHz ceramic filters. This arrangement improves selectivity but increases the insertion loss.*

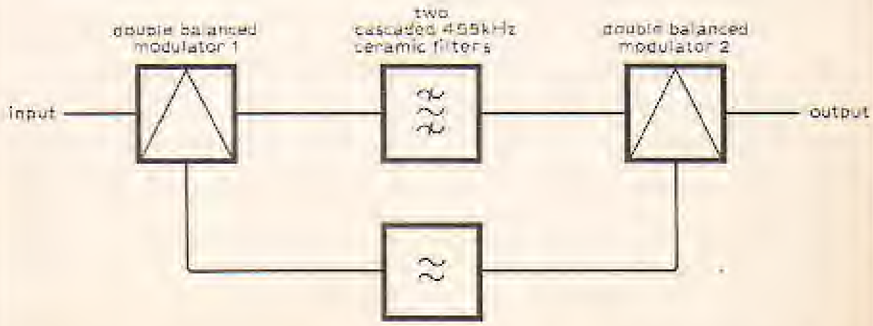

Fig. 2. *903.10kHz s.s.b. module. An oscillator frequency of 451.55kHz was found to provide optimum lower sideband suppression for 1kHz.*

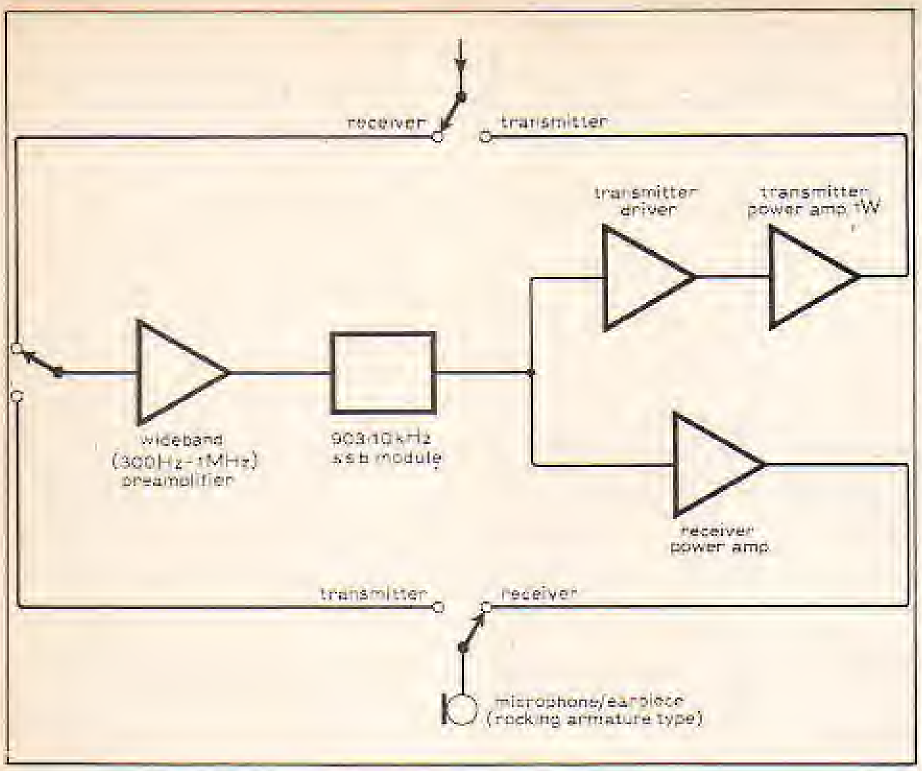

Fig. 3. *Block diagram of transceiver which uses standard units throughout.*

shows slight variation in bandwidth and insertion loss, both of which are within acceptable limits. Decreasing c to obtain a narrower bandwidth achieves this but at the expense of the filter shape factor which increases rapidly.

Transceiver

The system was designed to operate at 1MHz ±100kHz. A block diagram is shown in Fig.3. A crystal oscillator frequency of 451.55kHz was found to produce optimum lower sideband suppression for 1kHz, and also gave acceptable performance when the 1kHz was replaced by speech, band-limited between 300Hz and 3kHz. Lower sideband attenuation is between 20 and 24dB at 1kHz in and varies either side of this frequency, decreasing as the 300Hz limit is approached. The signal at the output of the filter is upper sideband at 451.55kHz. This is mixed with 451.55kHz from the crystal oscillator in the second balanced modulator to produce u.s.b. at 903.10kHz and the original audio frequency components which are easily filtered out. The 903.10kHz signal is then linearly amplified in the following stages.

In the receive mode the incoming u.s.b. signal is fed through the system in the same direction. No switching of signal or oscillator lines is necessary in this generator-detector stage. To provide suitable signal routing around the s.s.b. module a multi-pole push-button switch was used which provided the push-to-talk facility. All circuitry was of standard design with Motorola MC1496 balanced modulators being used in the s.s.b. module. Because low power consumption is important in portable equipment these devices were used in preference to the Plessey SL640, which dissipates approximately twice as much power.

A simple but effective s.s.b. transceiver was designed to fulfil a particular experimental role. This unit, though not generating high-quality s.s.b. has been proved capable of producing excellent results, and has shown that inexpensive ceramic filters have characteristics suitable for this type of application.

Table 2. Two SFD-455B filters in cascade

C pF	Centre frequency kHz	Bandwidth kHz	Loss dB	Shape factor	Sample
68	455.60	3.94	18	2.54	A & B
56	455.20	3.90	11	2.47	C & D
56	455.41	4.20	12	2.50	E & F
47	455.61	3.67	12	2.65	E & F
33	455.87	3.14	11.5	3.84	E & F
22	456.42	1.87	13	4.05	E & F

Maximum stopband attenuation was around 40dB, which could be improved by cascading three or more filter sections at the expense of increased insertion loss. □

Vtr out in the cold

An American study says that the home video tape recorder industry will grow from $90 million in 1976 to $318 million in 1981. According to Steve Cottrell of Creative Strategies Inc. "Unlike others who have been very optimistic about potential consumer sales, our research indicates that substantial penetration of the home market is still years away." Bearing in mind that the market started from zero, a compound annual growth rate of 28% is rather less than might have been expected. Reasons include high prices and competition from other forms of entertainment. □

DMLS succeeds again

The list of successful trials of Plessey's Doppler microwave landing system (DMLS) now includes those carried out at Bern (Belp) airport. Landing systems currently in use are almost useless at Bern, which is surrounded by mountainous country and is said to offer the greatest challenge of any scenario so far investigated. In spite of the fact that the runway under test is only about one third the size of the average runway, 50 automatic landings were made and a further 50 tracked flights. More flying confirmed that the required coverage was obtained and a 30° offset was found to be practicable.

The next set of DMLS trials is scheduled for January at Tehran. □

The year's hi fi and other shows

Before current efforts to put some order into the annual hi-fi exhibition chaos have even begun, several show organisers have announced dates for the coming year. The first will take place at the Excelsior Hotel near Manchester Airport between January 19 and 22. There will, according to the organisers, be 40 exhibitors and lectures and film shows. On the first day the hours from 11a.m. to 4p.m. will be for the trade, and the show will be open to 9p.m. on that and the next two days, closing at 7p.m. on the Sunday.

From May 2 to 6 the Spring High Fidelity Exhibition will be held at the Cunard Hotel, Hammersmith, the last two days being open to the public.

The Harrogate autumn show will be at the exhibition complex instead of the local hotels as in previous years, from August 19 to 22, the first two days open to the public.

The Audio Fair at Olympia will be held between September 12 and 18.

The 59th AES convention goes to Hamburg between February 28 and March 3.

A three day seminar and exhibition on the use of microprocessors will take place at the West Centre Hotel, London, from February 8 sponsored by eight journals run by IPC Business Press, including *Wireless World*.

The All-electronics Show at Grosvenor House, Park Lane, London, is from February 14 to 16, and will be opened by Clive Sinclair, of pocket tv fame. Over 200 stands have been sold.

Another microprocessor show, this time organised by the IERE, will be held at the Old Swan Hotel, Harrogate, on April 11 and 12. The IERE is calling for papers.

At the Metropole Convention Centre, Brighton, the Electrical Research Association is holding a science and security conference between September 12 and 14. It will deal with the application of technology to preventing fire, flood, technical failure, burglary, theft and sabotage.

In 1979 there will be a seven day exhibition starting on September 20 alongside the World Administrative Radio Conference in Geneva. It will be the Third World Telecommunication Exhibition, sponsored by the Swiss Government. The Electronic Engineering Association would like to hear from any British firms wishing to participate in the exhibition as a joint venture.

In November, 1979, the first Electronics Components Industry Fair will be held at Olympia from the 20th to the 23rd, sponsored by the newly formed Electronic Components Industry Federation. This replaces the International London Electronic components Show (ILECS). □

NEW PRODUCTS

Absorption wattmeter

The TE-7 absorption wattmeter introduced by All-M Products Ltd is designed for radio use in the frequency range 1 to 500MHz. It houses a convection-cooled terminating load of 50Ω and allows continuous dissipation up to 15W and intermittent dissipation up to 25W. At 150MHz it has a s.w.r. of

WW301

better than 1.2:1. The unit uses a peak-reading detector and displays r.m.s. power in ranges of 0 to 5W and 2 to 25W. It has a BNC input connector but other types may be fitted. Provision exists for sampling the r.f. for use with frequency meters and in these cases it gives a signal attenuation of 33dB. The case is of robust metal construction and measures only 65 × 120 × 50mm. Price is £24.65. All-M Products Limited, 3 Westhill Close, Highworth, Swindon, Wiltshire, SN6 7BY.
WW301

Distribution blocks

Rail-mounted terminals, in a range from Highland Electronics Limited, fit the DIN rail 46277/1 and are available in grey, brown or green/yellow colours. Half of the range comprises a 6mm pitch block with a 60A busbar, an 8mm block with a 102A busbar and a 10mm block with a 142A busbar. Cable sizes for these terminals are 4, 10 and 16mm² respectively. The rest of the range enables the user to connect onto one or two M8 studs with 1 by 70mm² or 2 by 70mm² cables with either 2, 4, 6 or 8 ways, each way to a maximum cable clamp facility of 16mm². An insulated cover, which is supplied as standard, fits over the main cable stud and allows the cable to be connected in either direction. Highland Electronics Limited, Highland House, 8 Old Steine, Brighton, East Sussex BN1 1EJ.
WW302

Impatt diode bias supplies

Constant-current power supplies, in a series from Avtech Electrosystems, are intended for biasing impatt-diode oscillator and amplifier circuits in low and medium power applications. The outputs from the Model AV-100 may be adjusted from 10 to 50mA for load voltages in the range 0 to 100V. Model AV-100P has an additional facility providing a pulsed output for pulsed-mode impatt diode operation. Model AV-101 is identical to the AV-100 except that it requires a direct input voltage of 15V, instead of a mains supply. These models, which all have meters and short-circuit protection, measure 4.2 × 3 × 2.75in and weigh 1.5lb. Model AV-102 is a smaller, low-cost unit without a meter. It requires a direct input voltage of 115V but otherwise has similar specifications to the other models. The AV-102 measures only 2.25 × 1.38 × 1.13in and weighs only 0.5lb. Prices, without v.a.t. and duty, range from £67 to £198. Lyons Instruments Limited, Hoddesdon, Herts.
WW303

Matched quad op-amps

The OP-09 quad operational amplifier, from Bourns (Trimpot) Ltd, has an input offset voltage of 500μV maximum and a c.m.r.r. of 100dB minimum. It also has a guaranteed matched c.m.r.r. of 94dB minimum and an input offset voltage match of 750μV maximum. The individual amplifiers in the OP-09 are claimed to be as reliable as the OP-02 op-amp, which is in common use. To optimise performance in active filter applications positive-going and negative-going slew rates are equal. Bourns (Trimpot) Limited, Holdford House, 17/27 High Street, Hounslow, Middlesex, TW3 1TE.
WW304

WW303

WW302

Service tool set

A twenty-piece precision tool set, from Jonard Industries Corp., includes the major tools essential for the production, service and repair of electronic equipment.

WW305

The set includes three types of plier, four screw drivers, including a Philips type, two tweezers and two needle files. In addition there is a soldering iron and core, a magnifier, a burnisher, an alignment tool and two nut drivers. The complete set is contained in a leather case measuring eleven inches long by six inches wide. The case, including the tools, weighs only 2lb. Jonard Industries Corp., Precision Tools Division, 134 Marbledale Road, Tuckahoe, New York 10707, USA.
WW305

Low-cost cermet trimmer

The Series 8035 cermet trimmer, from Greenwood Electronics, is a ¾in-long rectangular, multi-turn device having a height of only 0.25in. Resistance values available range from 10Ω to 5MΩ with a resistance tolerance of ±10%. A fifteen-turn slider adjustment enables the trimmer to provide adjustment within ±0.05% of the

full scale. The 8035 is fully sealed and will withstand automated soldering and all known industrial cleaning solvents. Contact resistance is 1% maximum with a variation of less than 0.25%. The temperature coefficient of resistance is ±100 for an operating range of −55 to +125°C. At 25°C the trimmer has a power rating of 0.75W and its maximum input voltage is 300V. Price is 36p in large quantities. Greenwood Electronics Limited, Portman Road, Reading, Berks RG3 1NE.
WW306

D.i.l. ceramic capacitors

Low-profile, multi-layer ceramic capacitors introduced by Sprague are available in 2-, 4-, 8-, 14- and

16-pin d.i.l. packages. The packages, registered as Multi-Comp Monolythic Ceramic Capacitors, permit closer stacking of p.c.bs. Complete details are given in a document Engineering Bulletin No. 6242B which is available on request from Sprague Electric (UK) Limited, 159 High Street, Yiewsley, W. Drayton, Middlesex.
WW307

F.m. tuner head

The first f.m. varactor tuner head from a range to be introduced by Astec Europe Ltd is the UM1171. It is a compact, fully-shielded device intended for f.m. radio applications. The device will cover a frequency range from 88 to 108MHz by applying a tuning voltage of 2 to 20V. Main specifications are 12mA current consumption, 20dB power gain and a noise figure of 7dB maximum. The UM1171 measures only 20 × 37 × 71mm and may be provided with automatic frequency control. Astec Europe Limited, 4A Sheet Street, Windsor, Berks.
WW308

L.c.d. multimeter

Full-scale readings of 19999 on a liquid-crystal display, with a maximum error of 0.05% are provided by the Advance DMM9 multimeter: alternating and direct voltage and current from 10μV and 10nA, resistance from 100mΩ and a separate range of 10a. The a-to-d converter is a true r.m.s. type which can cope with crest factors of 4 at full scale. Additional measurements are possible by the use of a temperature probe for use between −20°C and 120°C, a r.f. probe with detector and a 40kV probe. A printer interface provides a parallel b.c.d. output. Gould Advance Limited, Roebuck Road, Hainault, Essex.
WW309

Paper tape reader

A portable, photoelectric paper-tape reader, available from Data Precision (Equipment) Ltd, has been designed to be used by service engineers for fault diagnosis. The unit, which is based on the recently announced DP203 tape reader, is capable of reading any known five, six or eight-track, punched-paper tapes, including typesetting and advanced sprocket types. Reading speeds are up to 250 characters per second and the feed is bidirectional. Plug-in c.mo.s. i.cs enable output changes to be made, and input changes are implemented by adding or removing soldered bars between p.c.b. tracks. The unit is ruggedly built and the infrared l.e.ds and photosensors are unaffected by ambient light. Data Precision (Equipment) Limited, 81 Goldsmith Road, Woking, Surrey.
WW310

WW 308

WW 309

Close tolerance capacitors

A range of metallised-film polycarbonate capacitors, manufactured by Wingrove & Rogers Ltd, have capacitance value tolerances of ±0.5%. Capacitor values down to 50pF are available in several axial and radial formats. The axial capacitors can be supplied with nylon or sleeved metal cases, sleeved metal cases with glass end seals, or in wrap and end sealed forms. The radial capacitors, which have nylon cases and are epoxy-resin filled, may be of the standard or low profile type. Polar Capacitors Limited, Domville Road, Liverpool L13 4AT.
WW311

Infrared illuminator

The Type RT5A infrared illuminator, from ITT Components, is capable of sharp focus and a very small minimum spot size. Its adjustable lens system allows a focus range giving "spot sizes" from a 0.2m line to a 1.2m diameter circle at 100m range

(N.B. for a sharp focus the "spot" is a line). At a small spot size, the maximum useful range is 1500m. The unit employs a pulsed, double-heterostructure laser and operates in the near infrared wavelength region of the frequency spectrum. Consequently its beam is virtually invisible. In night vision applications the RT5A may be used to illuminate areas which are shielded from natural light sources such as the stars or the moon. ITT Components Group Europe, Electron Device Product Group, Brixham Road, Paignton, Devon.
WW312

Pocket cable stripper

The AB MK02 pocket tool, in addition to its prime function of stripping cables, can also be used for slitting cable insulations longitudinally. It has an adjustable cutting blade which can be set by turning a knurled screw to match the precise thickness of insulation to be stripped. The cable is retained by a spring-loaded clamp such that, by rotating the tool around the cable, the blade cuts through the insulation. The MK02 is suitable for round cable from 4.5 to 28.5mm in diameter. To slit the cable longitudinally the cutting blade is turned through 90°, by depressing a knob on the side of the tool, and the tool is pushed along the cable instead of around it. To assist in peeling off the more-difficult-to-remove insulations, a retracing ripping blade is housed in the handle. AB Engineering Co., Apem Works, St. Albans Road, Watford WD2 4AN.
WW313

Static r.a.ms

A range of n-channel, m.o.s. static r.a.ms in plastic d.i.l. packages has been announced by NEC Electronics (Europe). The 22-pin μPD2101 is a 256-word by 4-bit device having an access time ranging from 450 to 250ns. The r.a.m., which is compatible with the Intel 2101 family, has a power dissipation of 220mW and requires a 5V power supply. The 16-pin μ PD2101 is a 1K by 1-bit r.a.m. having the same access time range and supply require-

ment but its power dissipation is 150mW. This device is compatible with the Intel 2102AL family. The 18-pin μPD2111 is also a 256-word by 4-bit device which is compatible with the Intel 2111 family. It has the same access time range and power requirements as the other devices but its power dissipation is typically 200mW. The 22-pin μPD410 family is compatible with 22-pin dynamic r.a.ms and they have power requirements of +12V, +5V and −5V and power dissipations of 470mW. They have a storage capacity of 4K by 1-bit. NEC Electronics (Europe), 43 Civic Square, Motherwell, ML1 1TH, Scotland.
WW314

Dual-trace oscilloscope

The D12 oscilloscope, manufactured by Dartron Instruments Ltd, is a 17MHz instrument which operates automatically in the chopped or alternate sweep modes according to the sweep speed. The D12 has a sensitivity from 10mV/cm to 50V/cm or, with cascaded amplifiers, 1mV/cm with a bandwidth from 2Hz to 10MHz. The Y amplifier performance is up to 1MHz on both channels and these are calibrated from 10mV/cm to 50V/cm. Triggering is also available on both channels. The c.r.o. has a five-inch, helical post deflection accelerator and is used at an overall operating voltage of 3.6kV. ITT Instrument Services, Edinburgh Way, Harlow, Essex.
WW315

WW 315

WW 317

Photovoltaic cells

A family of silicon photovoltaic cells, introduced by National Semiconductors Ltd, comprises high-stability, high-efficiency devices which, it is claimed, have excellent short-circuit current linearities over a wide range of illumination. Devices in the range have low leakage currents (10μA maximum when reverse biased by only 1.5V) and response rates of typically 8 μs. The cells are normally of n-on-p construction, but reverse polarity p-n cells can be provided with a choice of either a low-capacitance, high-speed 800-type material or a 700-type material giving higher open-circuit voltages. National Semiconductors of Canada, Stamford House, Stamford New Road, Altrincham, Cheshire WA14 1DR.
WW316

WW 316

D.i.l. switches for p.c.bs

The Boss (binary option selection switch) family of low-cost p.c.b. switches, from Molex Electronics Limited, has been designed for applications where manual programming of electronic equipment is required. When p.c.b.-mounted, ribs on the switch bases raise them from the board to allow flux residues to be removed. A double-lever design enables the switch to make low-stress, high-force contacts. Brief electrical specifications include a switching rating at 30V d.c. (open circuit) of 50mA maximum, and a non-switching rating of 100mA r.m.s. at 50V d.c. maximum. Contact resistance, measured with a current flow of 10mA, is 100mΩ. Single-pole, double-throw and double-pole, single-throw versions are available. Molex Electronics Limited, 1 Holder Road, Aldershot, Hants GU12 4RH.
WW317

Heat-pipe power semiconductor

A range of power semiconductors known as "transcalent" devices has been introduced by RCA Electro-Optics & Devices, a division of RCA Solid State Europe. The devices have heat pipes bonded directly to large silicon wafers which are capable of handling currents up to at least 400A. These heat pipes minimize the thermal resistance and increase the radiator fin efficiency, thereby allowing the devices to be significantly smaller and lighter than conventional devices having similar power ratings. Typically, size reduction is by a factor of four and weight reduction by a factor of seven. In addition the devices offer improved resistance against overloads and high-current surges. The first "transcalent" devices available from RCA are the P95000EB series of 250A, 500W rectifiers, which have blocking voltages up to 1200V, the P95400EB series of 400A, 500W thyristors, having blocking voltages up to 1200V, and the P95200EE4 100A, 500W n-p-n transistor. All of these devices can be supplied with radiator structures to accommodate air or liquid cooling. Thermal resistances are about 0.1 to 0.2°C/W and the operating ambient temperatures at full ratings range up to 50°C. RCA Limited, Solid State Europe, Sunbury-on-Thames, Middlesex TW16 7HW.
WW318

T.t.l. latch and flip-flop

Two devices just announced by Texas instruments are a low-power Schottky t.t.l. latch and a flip-flop. The SN54LS/74LS373 comprises eight transparent D-type latches such that when its enable is high the Q outputs will follow its data inputs. When the enable is low the output will be latched at the level of the data (D) that was set up. The SN54LS/74LS374 has eight edge-triggered D-type flip-flops. On the positive transition of the clock, the Q outputs will be set to the logic states that were set up at the D inputs. Integrated Circuit Department, Texas Instruments Limited, Manton Lane, Bedford, MK41 7PA.
WW319

Closed-circuit tv tubes

Two camera tubes, Newvicon types XQ1276 and XQ1442 from Mullard, have high sensitivities and will enable closed-circuit tv cameras to work in dim twilight (1 lumen/metre²). Type XQ1276 has a spectral response in the near infrared region and a screen diameter of 2/3in. It is interchangeable with vidicons such as the XQ1271. The XQ1442 is fitted with a fibre-optic face-plate to enable high efficiency coupling to be achieved when the tube is used with a similarly coupled image intensifier. This tube is mechanically interchangeable with the Newvicon type XQ1440. Mullard Limited, Mullard House, Torrington Place, London WC1E 7HD.
WW320

SIDEBANDS by Mixer

A Jaguar in my boot

No, it's nothing to do with a tiger in the tank or even a nodding dog on the rear window ledge. The Jag. in question was a four-wheeled conveyance, not the motorway equivalent of a set of plaster ducks, and it was desperately trying to get into the boot of my car. It seemed like that, anyway, although since I was blinded by spray from the truck in front and blinded by the Jag's main beam headlights from behind I wouldn't want to swear to it. All I really wanted to do at that moment was to extend a pair of wings and get out of it.

There really ought to be some way of helping incompetents such as the aforementioned Jag. driver to achieve their own, personal set of wings, accompanied by a harp, but since that approach is frowned upon by the Department of Environment somebody must come up with some kind of gadget to repel attack from the rear on wet, foggy days. And, since lunatics often harbour delusions to the effect that they are Napoleon, Albert Einstein or, worse, Stirling Moss, it is no good lighting up a lot of signs saying, "Careful" or even "Watch it, buster." At best they will think you guilty of lèse majesté, or, at worst, think it only applies to the other, bad, drivers.

As a matter of fact, you may be surprised to learn that I have already come up with the answer. There are any number of devices which tell you when there is ice or fog about (though I find I can usually see the fog for myself, thanks very much) but very little has been proposed to actually do anything about it when spotted. The only development to help in a case like this is the car-borne radar connected to the accelerator and brakes, so that if one approaches the car in front too closely and too fast, your anchors are automatically thrown overboard. Sounds fine, but its's not likely to be cheap and most drivers don't like their cars being taken over by machines.

As I said earlier, it isn't a bit of good just warning people. You can do that until you're blue in the face and still have maniacs charging about at 90 m.p.h. in dense fog. So what you've got to do is make it impossible. All you need is a fog and ice detector (photoelectric for fog — temperature and humidity for ice) and something to make the road surface come up like a lot of little mole-hills when you want to slow people down a bit. Inflatable tubes, like aircraft de-icers, would to the trick, but the details of how to make them and how to justify the cost I will have to leave to someone else. I can't be expected to do everything for the D.o.E.

What's in a name?

At an impressionable age, I watched the march of television northwards from Ally Pally, via Sutton Coldfield, to Holme Moss. From S.C., I was able to receive a fairly poor picture (80 miles — 4-stage t.r.f.) but from H.M. the face of Leslie Mitchell was displayed in all its monochrome glory. I went to Holme Moss, which is really the name of a Pennine hill, not a transmitter, and gazed at this new monument to man's progress. There it stood, 750ft tall, on the top of a small mountain near Holmfirth. I could only see the top by lying on my back, a position which was mandatory anyway after pushing my bike up the road to the top.

The names given to these early transmitters were evocative of grandeur — Wenvoe, Pontop Pike, Rowridge, The Wrekin, Caradon Hill and so it remained until the smaller stations were built, with names like North Oldham and Halifax. But the final stage in the debasement of the image is now upon us. A Press Statement from Auntie Beeb last week informs us that a relay station at Wincobank in Sheffield is now on the air. What a sad decline! And how far from the ringing names of yesteryear. Would Kubla Khan have decreed his stately pleasure dome at Wapping Broadstairs or Penge? Of course not. And the screw is turned by the description of the service area which, we are told, encompasses not the plains of East Yorkshire or the mountains of Wales, but Standon Drive, Woodbury Road and Fife Street. If further proof of the BBC's possession of feet of clay is needed, the last sentence of the press release gives it: "The station is at Barrow Road, adjacent to the gasworks."

Remote control

In common with the majority of offices in the Smoke, and probably everywhere else in the country, we're in the middle of the annual rash of days off, on account of a number of variations on the theme of respiratory malfunction. Colds, even.

I've been so afflicted myself, albeit less drastically and for a shorter time than my more vulnerable colleagues, and while I was languishing there at home, pining for the office and supported only by the thought that they were able to go to the canteen for lunch, while I had to content myself with rough, homely fare such as game soup, chicken and the kind of pudding people might commit murder for, it struck me (if I can remember what I was talking about at the start of this sentence) that the day of the commuter must nearly be over. Every dog has his day, so they say, and British Rail has nearly had its.

It's all so illogical. In a period when communication and easy access to computer terminals can be provided, it's a nonsense that all those thousands of official troglodytes should wear their individual little grooves deeper every day to get to the office, simply because the 'paperwork' is there, or because they have to attend a sales meeting. If eyeball-to-eyeball confrontation is essential, then a television method of some sort should suffice.

Think of the rates the big companies could save, too. Instead of a couple of million a year in Central London, a few thousand a year for the hire of the terminals and a suite at Claridge's for the M.D. — he's still got to have somewhere for the drinks cupboard and four walls for his Stubbs-surrogate horses.

Computers + 10^{-6}?

It all depends on where you start from, I suppose. If the little ones had come first, they would now be called computers and the Swansea-type giants megacomputers. It seems rather a shame that, although "Micro" has a precise meaning in electronics, it is often used as a rather vague prefix meaning 'very small', which can change its meaning as time passes. A microcomputer of today could very well be classified as a minicomputer in a couple of years' time without anything about it being changed at all. "It's all a matter of relatives," as someone I know used to say, but then he has some very peculiar relatives indeed. (His Uncle Arthur has been known to eat coal — and he's the bright one.)

Where was I? Oh, yes — computers. Yes, well what I was coming to was the difference between processors and computers — a distinction which seems to become more blurred with every bit of paper that crosses my desk. I tend not to delay these bits of paper very long on their way across, but I have noticed as I pass them on to more technical colleagues that 'computer' seems to hold more attraction as a name than 'processor'. As I see it, a microprocessor can be the central processing unit of a microcomputer and, in the computing field, is incomplete without its programme memory, read/write memory, input/output buffers and latches, input keyboard or whatever and some kind of output display or recorder. Of course, it is usable without some of the peripheral equipment in the process control application, for which it was originally intended, but used in that way it is a controller, not a computer.

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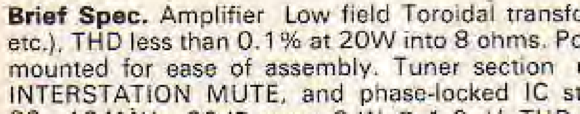

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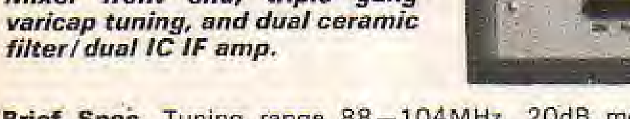

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AF124	0.25	BCY31	0.55	BFW30	1.25	OC170	0.23	2N3771	1.60
AF125	0.25	BCY32	0.60	BFW59	0.30	TIP29A	0.44*	2N3772	1.90
AF126	0.25	BCY33	0.55	BFW60	0.36	TIP30A	0.52*	2N3773	2.10
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AL102	1.45	BCY39	1.15	BFX84	0.23*	TIP41A	0.58	2N4348	1.20
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AU107	3.30*	BCY42	0.30	BFX86	0.25	2N404	0.40	2N4871	0.35*
AU110	1.75*	BCY54	1.60	BFX87	0.20	2N696	0.20	2N4918	0.60*
AU113	1.60*	BCY70	0.12	BFX88	0.20	2N697	0.20	2N4919	0.70*
BC107	0.12	BCY71	0.18	BFX89	0.90	2N706	0.15	2N4920	0.80*
BC107B	0.12	BCY72	0.12	BFY11	1.10	2N1131	0.15	2N4922	0.58*
BC108	0.12	BD115	0.55	BFY18	0.50	2N1132	0.16	2N4923	0.48*
BC108B	0.12	BD131	0.38	BFY40	0.50	2N1302	0.40		
BC109	0.12	BD132	0.40	BFY41	0.60	2N1303	0.40		
BC109B	0.12	BD135	0.36*	BFY50	0.20	2N1304	0.45		
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7412	0.25	7495	0.67
7413	0.40	7496	0.82
7414	0.72	74100	1.07
7417	0.43	74107	0.35
7420	0.16	74121	0.34
7425	0.30	74122	0.47
7427	0.30	74123	0.65
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100V	0.60	0.60	0.70	0.70	0.78	0.78	0.83	0.83	1.01	1.01
200V	0.64	0.64	0.75	0.75	0.87	0.87	0.97	1.01	1.17	1.17
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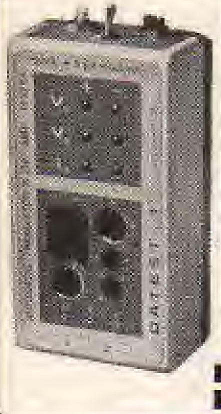

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T20+20 AND T30+30 20W, 30W AMPLIFIERS **

Designed by Texas engineers and described in Practical Wireless, the Texan was an immediate success. Now developed further in our laboratories to include a Toroidal transformer and additional improvements, the similar T20+20 delivers 20W rms per channel of true Hi-Fi at exceptionally low cost. The **easy to build** design is based on a single F/Glass PCB and features all the normal facilities found on quality amplifiers including scratch and rumble filters, adaptable input selector and headphones socket. In a follow-up article in Practical Wireless further modifications were suggested and these have been incorporated into the T30+30. These include RF interference filters and a tape monitor facility. Power output of this model is 30W rms per channel.

Pack	T20	T30
1. Set of low noise resistors	£1.60	£1.70
2. Set of small capacitors	£2.60	£3.40
3. Set of power supply capacitors	£2.20	£2.50
4. Set of miscellaneous parts	£3.50	£3.50
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6. Set of pots., selector switch	£2.80	£2.80
7. Set of semiconductors, ICs. skts.	£7.25	£7.75
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12. Handbook	£0.25	£0.25
13. Teak cabinet 15.4" x 6.7" x 2.8"	£4.50	£4.50

One each of Pack 1-13 are required for complete stereo amplifier. Total cost of individually purchased packs T20+20 £40.90, T30+30 £45.60.

SPECIAL PRICES FOR COMPLETE KITS

T20+20 KIT PRICE £33.10 **T30+30 KIT PRICE £38.40**

WWII TUNER **

Following the success of our **Wireless World FM Tuner Kit** this cost reduced model was designed to complement the **T20+20** and **T30+30** amplifiers and the cabinet size, front panel format and electrical characteristics make this tuner compatible with either. The frequency meter of the more advanced model has been omitted and the mechanics simplified, however the circuitry is identical and this kit offers most outstanding value for money. Facilities included are switchable afc, adjustable, switchable muting, LED tuning indication and both continuous and push-button channel selection (readily adjusted by controls on the front panel).

SPECIAL PRICE FOR COMPLETE KIT £47.70 AVAILABLE AS SEPARATE PACKS – PRICES IN OUR FREE CATALOGUE

POWERTRAN SFMT TUNER **

The requirement was a simple, low cost design which could be constructed easily without special alignment equipment but which still gives a first class output suitable for feeding any of our very popular amplifiers or any other high quality audio equipment. Not finding a suitable published circuit, the requirement was met by design and development work in our own laboratories and this tuner, which uses a pre-aligned front end module can be set up with the aid of nothing more sophisticated than a multi-meter. A phase-locked-loop is used for stereo decoding and controls include switchable afc, switchable muting and push-button channel selection (adjustable by controls on the front panel). This unit matches well with the T20+20 and T30+30 amplifiers.

PRICE FOR COMPLETE KIT £35.90 AVAILABLE AS COMPLETE KIT ONLY

Wireless World Amplifier Designs. Full kits are not available for these projects but component packs and PCBs are stocked for the highly regarded Bailey and 20W class AB Linsley-Hood designs, together with an efficient regulated power supply of our own design. Suitable for driving these amplifiers is the Bailey Burrows pre-amplifier and our circuit board, for the stereo version of it features 6 inputs, scratch and rumble filters and wide range tone controls, which may be either rotary or slider operating. For tape systems a set of three PCBs have been prepared for the integrated-circuit based, high performance stereo Stuart design. Details of component packs are in our free Catalogue.

30W Bailey Amplifier	
BAIL Pk. 1 F/Glass PCB	£1.00
BAIL Pk. 2 Resistors, Capacitors, Potentiometer set	£2.35
BAIL Pk. 3 Semiconductor set	£4.70
20W Linsley-Hood Class AB	
LHAB Pk. 1 F/Glass PCB	£1.05
LHAB Pk. 2 Resistor, Capacitor, Potentiometer set	£3.20
LHAB Pk. 3 Semiconductor set	£3.35
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60VS Pk. 1 F/Glass PCB	£0.85
60VS Pk. 2 Resistor, Capacitor set	£2.20
60VS Pk. 3 Semiconductor set	£3.10
60VS Pk. 5A Toroidal transformer (for use with Bailey)	£8.80
60VS Pk. 6B Toroidal transformer (for use with 20W LH)	£7.25
Bailey Burrows Stereo Pre-Amp	
BBPA Pk. 1 F/Glass PCB (stereo)	£2.80
BBPA Pk. 2 Resistor, Capacitor, Semiconductor set (stereo)	£6.70
BBPA Pk. 3R Rotary Potentiometer set (stereo)	£2.85
BBPA Pk. 3S Slider Potentiometer set with knobs (stereo)	£3.10
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TRHP Pk. 1 Replay Amp F/Glass PCB (stereo)	£1.30
TRRC Pk. 1 Record Amp F/Glass PCB (stereo)	£1.70
TROS Pk. 1 Bias Erase/Stabilizer F/Glass PCB (stereo)	£1.20

SQ QUADRAPHONIC DECODERS

These state-of-the-art circuits developed by CBS are offered as kits of superior quality with close tolerance capacitors, metal oxide resistors and fibreglass PCBs designed for edge connector insertion. Further information on these kits is given in our FREE CATALOGUE.

M1 Basic matrix decoder	£6.90
L1 Full logic decoder	£17.20
L2A Full logic decoder with variable blend	£22.60
L3A As L2A but with high performance discrete component front end	£30.10
(or with carbon film resistors)	£25.90
SQM1 30 Decoder complete with 30W four channel amplifiers. Complete kit matches T30+30 amplifier	£40.75

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2N3442	£1.20	BC109	£0.10	BFR39	£0.30	MPSA55	£0.25	TIP42A	£0.80
2N3711	£0.09	BC109C	£0.12	BFR79	£0.30	MPSA65	£0.35	TIP41B	£0.75
2N3904	£0.17	BC125	£0.15	BFY51	£0.20	MPSA66	£0.40	TIP42B	£0.90
2N3906	£0.20	BC126	£0.15	BFY52	£0.20	MPSU05	£0.60	1N914	£0.07
2N5087	£0.25	BC182	£0.10	CA3046	£0.70	SBA750A	£1.90	1N916	£0.07
2N5089	£0.25	BC212	£0.12	LM301AN	£0.55	SL301	£1.30	1S920	£0.10
2N5457	£0.45	BC182L	£0.10	LP1185	£6.50	SL3045	£1.20		
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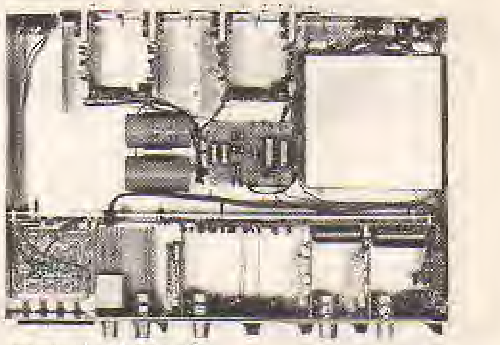

Internal view of De Luxe Kit

SPECIAL PRICE FOR COMPLETE KIT £99.30

The standard model of our kit for Mr. Linsley-Hood's 75 watt design has for a long time offered exceptional performance for a very modest cost (just look at prices for comparable high quality, high power ready built units). Features of the amplifier include very low distortion, less than 0.01%, 75W rms per channel power output, rumble filter, variable slope scratch filter, variable transition frequency tone controls, tape monitoring facilities and individually adjustable inputs. This model is based on 5 circuit boards which not having the controls mounted on them can, if desired, be effectively used separately in high performance audio systems not based on our metalwork.
Our new De Luxe model uses 14 boards which interconnect with gold plated contacts and have the potentiometers and switches fitted to them. There are 3 boards for each power amplifier, 1 board for the power supply and 7 boards for the stereo pre-amplifier. This system almost eliminates internal wiring, making construction delightfully straightforward, and as each board can be easily removed in seconds from the chassis, checking and maintenance is so simple that even newcomers to electronics will be able to cope competently with the kit. Additional features of our new model are inclusion of latest circuit improvements, generously sized heatsinks for heavy duty use, even in tropical climates and metal oxide resistors throughout for long term stability and reliability.

PACK PRICES FOR STANDARD KIT

Pack	Price
1. Fibreglass printed circuit board for power amp	£1.15
2. Set of resistors, capacitors, pre-sets for power amp	£2.50
3. Set of semiconductors for power amp	£6.50
4. Pair of 2 drilled, finned heat sinks	£1.10
5. Fibreglass printed circuit board for pre-amp	£1.90
6. Set of low noise resistors, capacitors, pre-sets for pre-amp	£4.10
7. Set of low noise, high gain semiconductors for pre-amp	£2.40
8. Set of potentiometers (including mains switch)	£3.50
9. Set of 4 push-button switches, rotary mode switch	£5.40
10. Toroidal transformer complete with magnetic screen/ housing primary: 0 117-234 V: secondaries: 33-0-33 V, 25-0-25 V	£10.95
11. Fibreglass printed-circuit board for power supply	£0.85
12. Set of resistors, capacitors, secondary fuses, semiconductors for power supply	£5.40
13. Set of miscellaneous parts including DIN skts, mains input skt., fuse holder, interconnecting cable, control knobs	£6.20
14. Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£8.20
15. Handbook	£0.30
16. Teak cabinet 18.3" x 12.7" x 3.1"	£10.70

2 each of packs 1-7, 1 each of packs 8-16 inclusive are required for complete stereo amplifier. Total cost of individually purchased packs £90.80

STANDARD LINSLEY-HOOD 75W AMPLIFIER

SPECIAL PRICE FOR COMPLETE KIT £79.80

LINSLEY-HOOD CASSETTE DECK

* *

SPECIAL PRICE FOR COMPLETE KIT £79.60

Pack	Price
1. Stereo PCB (accommodates 2 rep. amps, 2 meter amps, bias/erase osc. relay)	£3.35
2. Stereo set of capacitors, M.O. resistors, potentiometers for above	£7.95
3. Stereo set of semiconductors for above	£8.50
4. Miniature relay with socket	£2.90
5. PCB, all components for solenoid, speed control circuits	£3.80
6. Goldring-Lenco mechanism as specified	£18.50
7. Function switch, knobs	£1.90
8. Dual VU meter with illuminating lamp	£6.95
9. Toroidal transformer with E.S. screen prim. 0-117V, 234V. Sec. 15V	£4.90
10. Set of capacitors, rectifiers, I.C. voltage regulator for power supply (Powertran design)	£2.80
11. Set of miscellaneous parts, including sockets, fuse holder, fuses, interconnecting wire, etc	£3.40
12. Set of metalwork including silk screened fascia panel, internal screen, fixing parts, etc	£7.10
13. Construction notes	£0.25
14. Teak cabinet 18.3" x 12.7" x 3.1"	£10.70

One each of packs 1-14 inclusive are required for complete stereo cassette deck. Total cost of individually purchased packs £83.00

Published in Wireless World (May, June, August 1976) by Mr. Linsley Hood, this design, although straightforward and relatively low cost, nevertheless provides a very high standard of performance. To permit circuit optimization separate record and replay amplifiers are used, the latter using a discrete component front-end designed such that the noise level is below that of the tape background. Push button switches are used to provide a choice of equalization time constants, a choice of bias levels and also an option of using an additional pre-amplifier for microphone use. The mechanism used is the Goldring-Lenco CRV, a unit distinguished in its robustness and ease of operation. Speed control and automatic cassette ejection are both implemented by electronic circuitry. This unit which is powered by a toroidal transformer and uses metal oxide resistors throughout offers an excellent match for the Wireless World Tuner and the Linsley-Hood 75 Watt Amplifier.

WIRELESS WORLD FM TUNER

* *

SPECIAL PRICE FOR COMPLETE KIT £70.20

Pack	Price
1. Fibreglass printed board for front end IF strip, demodulator, AFC and mute circuits	£2.15
2. Set of metal oxide resistors, thermistor, capacitors, cermet preset for mounting on Pack 1	£4.80
3. Set of transistors, diodes, LED, integrated circuits for mounting on Pack 1	£5.25
4. Pre-aligned front end module, coil assembly, three section ceramic filter	£8.50
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	£2.90
8. Set of components for channel selector switch module including fibreglass printed circuit board, push-button switches, knobs, LEDs, preset adjusters, etc.	£9.40
9. Function switch, 10 turn tuning potentiometer, knobs	£5.80
10. Frequency meter, meter drive components, fibreglass printed circuit board	£10.35
11. Toroidal transformer with electrostatic screen. Primary: 0-117V 234V, secondary: 15V	£4.90
12. Set of capacitors, rectifiers, voltage regulator for power supply	£2.10
13. Set of miscellaneous parts, including sockets, fuse holder, fuses, inter-connecting wire, etc	£2.05
14. Set of metalwork parts including silk screen printed fascia panel, acrylic silk screen printed tuning indicator panel insert, internal screen, fixing parts, etc.	£8.30
15. Construction notes	£0.25
16. Teak cabinet 18.3" x 12.7" x 3.1"	£10.70

One each of packs 1-16 inclusive are required for complete stereo FM tuner. Total cost of individually purchased packs £81.15

Designed in response to demand for a tuner to complement the world-wide acclaimed Linsley Hood 75W Amplifier, this kit provides the perfect match. The Wireless World (Skingley and Thompson) published original circuit has been developed further for inclusion into this outstanding slimline unit and features a pre-aligned front end module, excellent a.m. rejection and temperature compensated varicap tuning, which may be controlled either continuously or by push-button pre selection. Frequencies are indicated by a frequency meter and sliding LED indicators, attached to each channel selector pre-set. The PLL stereo decoder incorporates active filters for "birdy" suppression and power is supplied via a toroidal transformer and integrated regulator. For long term stability metal oxide resistors are used throughout.

EXPORT A SPECIALITY!

Our Export Department can readily despatch orders of any size to any country in the world. Some of the countries to which we sent kits last year are shown in this advertisement. To assist in estimating postal costs our catalogue gives the weights of all packs and kits. This will be sent free on request, by airmail, together with our "Export Postal Guide" which gives current postage prices.

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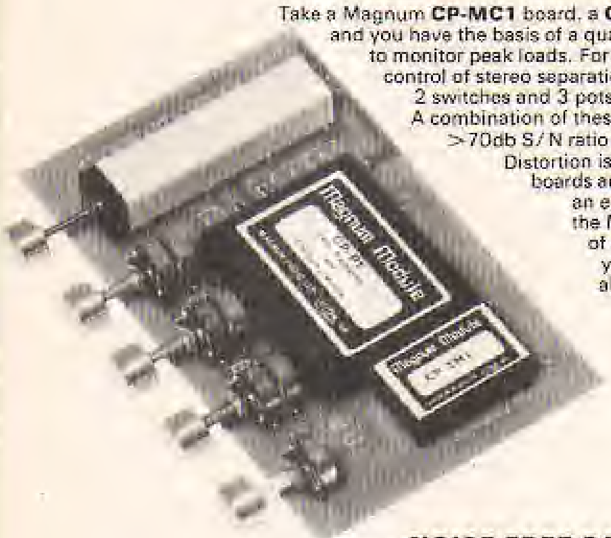

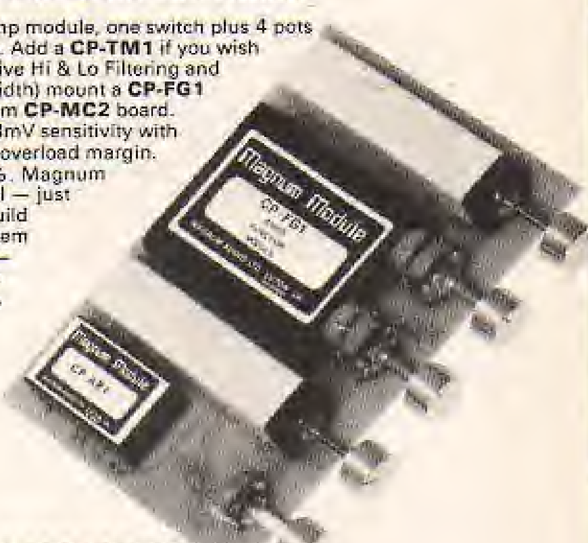

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'UL6 the best budget loudspeakers I've heard' says Philip Mount

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Celestion's UL6s

Up to this point you could say the products described are competent by present standards, or even very good. Celestion's UL6 loudspeakers hooked up to the end are unequivocably the best budget loudspeakers I have heard, or in some particular respects the *best* loudspeakers I have heard without the qualification of price. Around the time of their introduction a small group of audio journalists was asked by an importer of a certain well known Japanese brand to give opinions on the quality of a loudspeaker they were about to import. For comparison, about eight popular British loudspeakers had been assembled and connected to a comparator. At the end of the session there was one point on which everybody seemed agreed, and that was the fact that Celestion's UL6 appeared to sound significantly smoother and more evenly balanced than any of the other makes. Since the difference appeared so great, even against significantly more expensive models, I at least wondered whether the particular listening conditions had by some quirk favoured the UL6's by an unusually large degree.

Now, about one year later I find that it wasn't providence and that the speaker easily beats most others into second place by uncanny ability. It was suggested to me for instance, and I think this is true, that the UL6 can be recommended irrespective of taste. Because it's so completely natural and free from major imbalances or defects I believe most people would admit to 1 — liking it, and 2 — finding that they could live with the unit no matter what they had been previously used to. According to taste, you may prefer another loudspeaker with its own peculiar sound, but you would have to admit that this sounds 'right'.

It is common when describing the sound of a loudspeaker to split the audio band into bass, midrange and treble regions, then deal with each separately. This is often provoked by the loudspeaker itself, because most do the same thing and don't present a coherent picture but a fractured programme where bass output might be, say, soft and distant whilst treble is bright and forward.

This split in quality and relative levels is, as usual, fairly well compensated for by the brain after a short learning and adjustment process. Since it is so common the effect is also tolerated and one does expect to adjust to a speaker's own peculiar sound quality. The most immediately striking feature of the UL6 and the one that caused it to sound superior to all others on that group listening test described earlier is the fact that adjustment hardly seems necessary or called for. There aren't splits, suck-outs or imbalances. The treble doesn't leap out or disappear and you don't have to decide whether you like such-and-such an effect or not. At a broad fundamental level the UL6 just sounds unusually *right*. I cannot say that behind this overall feeling detail criticisms are impossible but the UL6 certainly transcends its price category and cannot be approached, I feel, by most speakers costing around £200 or less.

If you want to hear a speaker with the whole of the audio range present and transmitted as a smooth coherent whole, listen to the UL6. It's as detailed as any of the best speakers but doesn't achieve this by false upper midrange or treble prominence. An ABR (Auxiliary Bass Radiator) is used to augment bass response and for the first time I can recall it doesn't produce soggy, indefinite bass quality. The main weakness I felt was some wooden nasality in vocals, but this was the only form of coloration easily identifiable.

Percussion instruments were astonishingly powerful and realistic for a speaker of the size and perhaps just a small amount of resonant boom contributed to this very large and excellent performance which will, I assure you, make a majority of budget equivalents sound like neutered cats (which they are in spite of belief by some that real bass can be wrought from a tarted up shoe box).

Extremely goo

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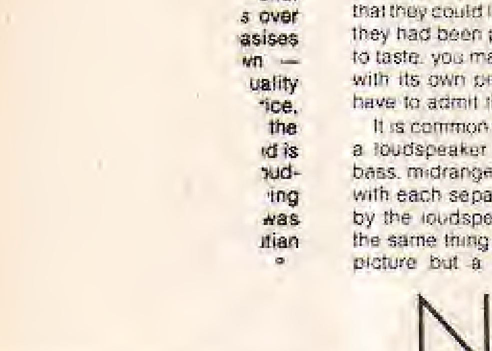

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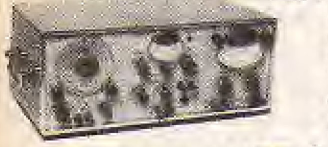

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70dB in 10 dB and 1 dB steps.
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Rise Time < 12nS.
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Full spec. on request

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TUNING: Effective scale length of 145 feet i.e. 6" corresponding to 100KHz.
CALIBRATION: 100KHz signal derived from 1MHz Xtal oscillator accuracy 5 parts in 10^6 provides check points at 100KHz intervals.
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TOTALIZE: 1 to 999999
SENSITIVITY: 25mV, typically 15mV-5Hz to 80MHz
Autoranging, 6 digit LED display. 10:1 attenuator

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Spec 1900A 20Hz-50KHz 3 bandwidths 3, 10 and 50Hz Tracking averages 30mV-300V F.S.D. Input impedance 1M ohm 3 meter speeds
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WAYNE KERR
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1R5	0.50
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6AK6	0.50
6AK8	0.48
6AL5	0.25
6AM5	0.70
6AM6	0.70
6AM8A	0.70
6AN5	0.70
6AN8	0.75
6AQ5	0.70
6AR5	0.70
6AS7	1.50
6AT6	0.50
6AU6	0.50
6AV6	0.60
6AW8A	1.15

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6B8G	0.75
6BA6	0.60
6BC8	0.90
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6BG6G	1.00
6BH6	1.10
6BJ6	0.75
6BK7A	0.85
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6BQ5	0.65
6BQ7A	1.40
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6BW7	0.65
6BX6	0.40
6BY7	0.65
6BZ6	1.50
6C4	0.50
6C5	0.40
6C9	2.00
6C10	1.00
6CB6A	0.65
6C12	0.35
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6F6G	0.70
6F12	0.70
6F14	0.80
6F15	0.95
6F16	1.00
6F18	0.90
6F23	0.70
6F25	0.70
6F26	0.45
6F28	0.65
6F32	1.00
6G6G	0.55
6GH8A	0.80
6GK5	0.75
6GK6	2.00
6GU7	0.90
6H6GT	0.90
6J5GT	0.70
6J6	0.55
6J7G	0.50
6JU8A	0.80
6K6GT	0.90
6K7G	0.50
6K8G	0.50
6KD6	0.50
6L1	2.50
6L6GC	1.50

6L6	0.90
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6PL12	0.60
6P15	0.48
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6Q7GT	0.75
6R7M	0.70
6R7G	0.70
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6SQ7	0.70
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6U8	0.50
6V6G	0.50
6V6GT	1.00
6X4	0.45
6X5GT	0.50
6Y6G	0.55
6Y7G	1.25
7A7	1.00
7B6	1.00
7B7	1.00
7C6	2.00
7F8	2.00
7H7	1.00
7R7	2.00
7V7	2.00
7Y4	0.80
7Z4	0.80
9D2	0.30
9D6	0.52
9BW6	0.90
9D7	0.70
10C2	0.80
10C14	0.70
10DE7	0.80
10F1	0.87
10F9	0.85
10F18	0.65
10L14	0.75
10LD11	0.75
10LD12	0.45
10P13	0.80
10P14	2.50
10P18	0.85
12A6	1.00
12AD6	0.50
12AE6	0.90
12AT6	0.45
12AT7	0.52
12AU6	0.50

12AU7	0.52
12AV6	0.60
12AX7	0.52
12BA6	0.50
12BE6	0.65
12BH7	0.55
12BY7	1.15
12E1	3.50
12J5GT	0.40
12J7GT	0.70
12K5	1.50
12K7GT	0.50
12K8	0.75
12Q7GT	0.50
12SA7GT	0.75
12SC7	0.50
12SG7	0.55
12SH7	0.50
12SJ7	0.60
12SK7	0.60
12SN7GT	0.75
12SQ7	0.80
12SQ7GT	0.80
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20D1	0.70
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20F2	0.85
20L1	1.20
20P1	1.00
20P3	1.00
20P4	0.84
20P5	1.50
25A6G	[illegible]
25L6G	1.00
25Y5	0.80
25Z4G	0.50
25Z5	0.75
25Z6G	0.80
28D7	2.00
30A5	0.75
30C1	0.40
30C15	1.00
30C17	0.90
30C18	2.25
30F5	0.70
30L1	0.35
30L15	0.75
30L17	0.70
30P4MR	0.98
30P12	0.74
30P19	
30P4	0.90
30P16	0.50
30P18	0.50
30PL1	1.25
30PL12	0.62
30PL14	1.30

30PL13	1.50
30PL15	1.20
35A3	1.00
35C5	0.80
35D5	0.80
35L6GT	0.80
35W4	0.65
35Z3	0.60
35Z4GT	0.70
35Z5GT	0.80
50B5	0.65
50C5	0.70
50CD6G	4.00
50EH5	0.65
50L6GT	1.00
[illegible]	1.00
72	0.70
77	0.45
85A2	1.40
85A3	1.40
90C1	1.50
90CV	3.50
150C1	0.40
150C2	0.65
215SG	0.60
301	1.20
305	1.20
807	1.10
956	0.50
1625	2.50
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5763	2.75
6057	2.00
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6067	2.00
6146	4.70
6883	2.00
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BL63	2.00
CL33	2.00
CV6	0.80
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CV988	0.25
CY1C	1.00
CY31	1.00
D1	0.50
D63	0.50
DAC32	0.80
DAF91	0.35
DAF96	1.00
DC90	0.70
DD4	0.80
DF33	0.75
DF91	0.30
DF96	1.00
DH63	0.75
DH76	0.50
DH77	0.60
DH81	1.00
DK32	0.60
DK40	1.00
DK91	0.50
DK92	1.00
DK96	1.00
DL63	0.70
DL82	1.00
DL92	0.65
DL94	1.00
DL96	1.00
DM70	1.25
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EB91	0.25
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EBC81	1.00
EBC90	0.60
EBC91	0.65
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EBF83	0.45
EBF89	0.40
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EC52	1.00
EC81	1.00
EC84	1.00
EC86	0.84
EC88	0.84

EC90	0.50
EC92	1.00
EC97	0.75
ECC32	1.00
ECC33	2.00
ECC35	2.00
ECC40	1.00
ECC81	0.52
ECC82	0.52
ECC83	0.52
ECC84	0.50
ECC85	0.50
ECC86	2.00
ECC88	0.72
ECC91	0.35
ECC189	1.00
ECC804	0.90
ECC807	2.80
ECF80	0.65
ECF82	0.50
ECF86	0.80
ECH35	2.00
ECH42	1.00
ECH81	0.55
ECH83	1.00
ECH84	0.75
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ECL82	0.80
ECL83	1.30
ECL84	0.90
ECL85	0.90
ECL86	0.84
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EF40	1.00
EF41	1.00
EF73	1.75
EF80	0.40
EF83	1.70
EF85	0.45
EF86	0.52
EF89	0.55
EF91	0.70
EF92	0.70
EF93	0.65
EF94	0.62
EF95	0.65
EF97	0.90
EF98	0.90
EF183	0.50
EF184	0.50
EF804	5.25
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EL37	3.00
EL41	1.00
EL81	1.00
EL83	1.00
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EZ35	0.50
EZ40	1.00
EZ41	1.00
EZ80	0.42
EZ81	0.45
EZ90	0.35
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GZ30	0.75
GZ32	1.00
GZ33	4.00
GZ34	2.25
GZ37	4.00
HABC80	0.80
HL13C	0.60
HL23	0.70
HL23DD	0.80
HL41	1.00
HL41DD	1.00
HL42DD	1.00
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HVR2A	1.00
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KT8	3.00
KT32	1.00
KT41	1.00
KT44	1.00
KT63	0.70
KT66	3.00
KT71	1.00
KT81	2.00
KT88	6.75
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N308	0.98
N339	1.25
N379	0.50
N709	0.48
P61	0.66
PABC80	0.45
PC86	0.50
PC88	0.80
PC92	0.55
PC95	1.00
PC97	0.75

PC900	0.85
PCC84	0.38
PCC85	0.47
PCC88	0.61
PCC89	0.49
PCC189	0.60
PCC805	0.75
PCC806	0.70
PCF80	0.40
PCF82	0.45
PCF84	0.70
PCF86	0.57
PCF87	0.90
PCF200	1.35
PCF201	1.00
PCF800	1.00
PCF801	0.49
PCF802	0.80
PCF805	1.35
PCF806	0.70
PCH200	1.00
PCL82	0.62
PCL83	0.75
PCL84	0.46
PCL86	0.72
PCL88	1.50
PCL800	1.00
PCL801	1.25
PCL805/85	0.65
PEN4DD	2.00
PEN25	1.00
PEN45	1.00
PEN45DD	1.00
PEN46	1.00
PEN453DD	2.00
PENA4	1.00
PENDD/4020	1.00
PFL200	1.12
PL33	1.00
PL36	0.80
PL81	0.49
PL81A	0.75
PL82	0.50
PL83	0.50
PL84	0.50
PL95	1.00
PL302	0.80
PL304/500	1.05
PL508	1.30
PL509	2.55
PL519	2.80
PL802	0.74
PL805	3.20
PM84	0.75
PY33/2	0.50
PY80	0.50
PY81	0.60
PY82	0.40
PY83	0.40
PY88	1.12
PY500	0.50

PY500	1.50
PY500A	1.50
PY800	0.60
PY801	0.60
PZ30	0.50
QP21	1.00
QQV03/10	2.00
QS75/20	1.00
QS95/10	1.00
QS150/15	1.00
QV03/12	2.75
QV04/7	2.00
QV06/20	4.70
R10	5.00
R11	1.00
R16	2.00
R17	1.50
R19	0.75
R20	0.89
R52	0.75
RK34	1.00
S24	1.50
SP61C	0.75
TH4B	1.00
TH233	1.00
TP2620	1.00
TP22	1.00
TP25	1.00
UABC80	0.45
UAF42	0.70
UBC41	0.70
UBC81	0.55
UBF80	0.50
UBF89	0.39
UBL21	2.00
UC92	0.50
UCC84	0.90
UCC85	0.45
UCF80	0.80
UCH21	2.00
UCH42	1.00
UCH81	0.52
UCL82	0.70
UCL83	1.00
UF41	0.70
UF42	1.00
UF80	0.40
UF85	0.70
UF89	0.52
UL41	0.90
UL46	1.00
UL84	0.85
UM80	1.00
UR1C	1.00
UU5	1.35
UU9	1.00
UU12	0.45
UY41	0.70
UY85	0.70
U10	1.00
U12/14	1.35
U16	1.00
U17	1.00
U18/20	1.50
U19	4.00

U21	0.85
U25	1.00
U26	0.90
U31	0.50
U33	1.75
U35	1.75
U37	2.00
U45	1.20
U47	1.00
U49	0.90
U50	0.85
U52	0.50
U76	0.80
U78	0.85
U150	1.00
U153	0.80
U191	0.50
U192	0.40
U193	0.60
U251	1.00
U281	0.75
U282	0.70
U291	0.50
U301	1.00
U329	1.00
U339	0.50
U381	0.70
U403	0.80
U404	0.75
U801	1.00
VLS492	9.50
VP2	1.50
VP4(5)	2.00
VP41	0.60
VP23	0.65
VP6	0.90
VR105	0.50
VR150	0.75
VT61A	0.75
VU111	1.00
VU120	1.00
VU120A	1.00
VU133	1.00
VX8020	1.00
W76	0.80
W81M	1.00
W107	1.00
W719	0.45
W729	1.20
X24	0.60
XFY12	0.60
XH15	0.60
XSG15	1.20
X41	1.00
X61	2.00
X63	1.40
X65	2.00
X66	2.80
X76M	0.75
X119	0.52
X142	1.00
X150	1.00
Z319	0.85

Z145	0.67
Z152	0.40
Z329	0.70
Z719	0.40
Z729	0.52
Z749	1.00
Z759	0.50

Transistors and Diodes

1N1124A	0.61
1N4744A	0.16
1N4002	0.58
1N456	0.21
1N914	0.16
2N1756	0.58
2N2147	0.99
2N2297	0.26
2N2369	0.16
2N2613	0.45
2N3053	0.38
2N3121	2.00
2N3703	0.23
2N3709	0.23
2N3866	1.16
2N3988	0.58
2N404	0.55
AA119	0.15
AA120	0.18
AA129	0.18
AAZ13	0.21
AC107	0.18
AC113	0.30
AC114	0.47
AC126	0.14
AC127	0.20
AC128	0.26
AC132	0.23
AC154	0.30
AC156	0.23
AC157	0.30
AC163	0.30
AC165	0.30
AC166	0.44
AC169	0.28
AC176	0.54
AC177	0.21
ACY17	0.30
ACY18	0.23
ACY19	0.23
ACY20	0.30
ACY21	0.18
ACY22	0.18
ACY28	0.21
AD140	0.50
AD161	0.53
AD162	0.53
AF102	1.04
AF106	0.58
AF114	0.30

AF115	0.30
AF117	0.23
AF121	0.35
AF124	0.36
AF125	0.35
AF139	0.76
AF178	0.79
AF180	0.56
AF186	0.44
AF239	0.44
ASY27	0.50
ASY28	0.38
ASY29	0.58
BA102	0.25
BA115	0.16
BA116	0.21
BA129	0.14
BA130	0.14
BA148	0.20
BA155	0.18
BCY10	0.58
BCY12	0.58
BCY33	0.28
BCY34	0.26
BCY38	0.28
BC107	0.14
BC108	0.14
BC109	0.14
BC113	0.30
BC115	0.18
BC116	0.28
BC118	0.26
BF154	0.28
BF158	0.21
BF159	0.28
BF163	0.23
BF173	0.44
BF180	0.33
BF181	0.47
BF185	0.47
BFY50	0.26
BFY51	0.23
BFY52	0.23
BYX38/400	1.31
BY100	0.21
BY101	0.18
BY105	0.21
BY114	0.21
BY126	0.18
BY127	0.21
BYY20	1.16
BYZ11	0.30
BYZ12	0.30
BYZ13	0.30
BYZ15	2.03
CG12E	0.23
CG64H	0.23

FSY11A	0.26
FSY41A	0.26
GD4	0.38
GD5	0.32
GD6	0.32
GD8	0.23
GD9	0.23
GD11	0.23
GD12	0.23
GD14	0.38
GD15	0.47
GD16	0.23
GET119	0.29
GET373	0.44
GET367	0.58
GET872	1.11
GET873	0.18
GET882	0.58
GET887	0.26
GET889	0.26
GET890	0.26
GET897	0.26
GET898	0.26
GEX13	0.21
GEX36	0.26
GEX45	0.34
GEX33	0.87
[illegible]	0.14
[illegible]	0.18
MAT100	0.43
MAT101	0.50
MAT120	0.45
OA5	0.14
OA47	0.12
OA70	0.18
OA73	0.18
OA79	0.18
OA81	0.11
OA85	0.11
OA86	0.23
OA90	0.14
OA91	0.11
OA95	0.11
OA200	0.11
OA202	0.12
OC16	1.06
OC22	0.44
OC23	0.44
OC24	0.44
OC25	0.69
OC26	0.44
OC28	1.00
OC35	0.50
OC41	0.58
OC42	0.73
OC43	1.37
OC44	0.12
OC45	0.12
OC65	1.31
OC70	0.14

OC71	0.13
OC72	0.13
OC74	0.28
OC75	0.13
OC76	0.18
OC77	0.32
OC78	0.18
OC78D	0.18
OC79	0.47
OC81	0.13
OC81D	0.13
OC82	0.13
OC82D	0.13
OC83	0.23
OC84	0.28
OC123	0.28
OC139	1.11
OC169	0.30
OC171	0.40
OC172	0.41
OC200	1.00
OC204	0.50
OC206	1.05
ORP12	0.41
ST237	0.50
SM1036	0.58
ST1276	0.58
SX1/6	0.21
U14706	0.30
XZ8C	0.30
XA1	0.21
V24	0.21

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LP15 (AC113, AC154, AC157, AA120), 61p per pack.
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1/OC44 and 2/OC45, 50p.
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Realistic Throttle and Crash sound effects from the TV Loudspeaker.

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Super Stunt Cycle · Drag Race · Stunt Cycle · Motocross

HOW MANY BUSES CAN YOU JUMP?

This simple to assemble (1 hour) TV Game Kit comes complete (No extras needed) — just simple soldering. Expected retail price (when available in shops) — over £55.00. SAVE 50% by building it yourself. Be one of the first in Europe with this new stunt cycle craze at £28.50 (inc. VAT) + 25p P & P.

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For further Details and Technical Help — phone 01-441 2922.
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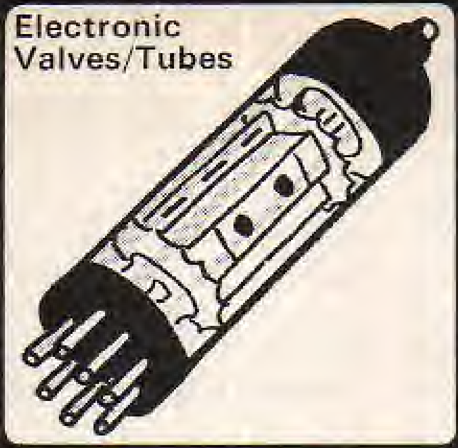
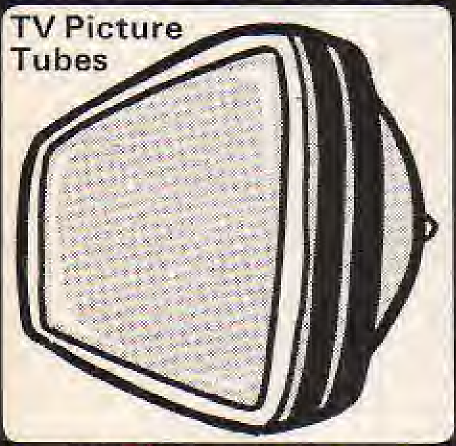
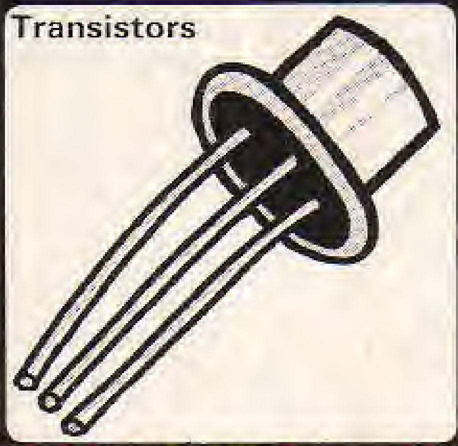


Resistors and Capacitors

TV Picture Tubes



Transistors



CR Gun Assemblies

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TF329G circuit magnification meter **£125**
TF455E Wave analyser. New. **£135**
TF1101 RC oscillators. **£65**
TF1099 20MHz sweep generators
TF1041B & C. VT Voltmeters
TF1102 Amplitude modulator. 500MHz
TF1020A Power meter. 100W. 250MHz. **£85**
TF1152A/1 Power meter. 25W. 500MHz. **£75**
TF890A/1 RF test set. **£425**
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TF1400 Pulse generator
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TF1370 Wide-range RC oscillator **£125**
TF2904 Colour gain delay test set
TF1058 UHF/SHF signal generator
Zenith 8 Amp variacs. £28.50 (carr. 150p)

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Input 190-260V AC. Output constant 220 Volts. 250W. £25 (£2 carriage)

POLARAD TYPE TSA. SPECTRUM ANALYSER. C/w type STU/2M plug-in unit covering from 950 to 4500 MHz.

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Carrier Frequency Level Meter

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SOLARTRON CD1400. DC-15MHz oscilloscope	
AIRMEC 254 High-power oscillator/amplifier	
BOONTON 80 Signal generator. 2-400MHz.	£105
BOONTON 230A RF Power Amplifier	£325
BPL Capacitance decade (5) CD133. 100pf-1uF.	£45
GERTSCH Frequency meter and deviation meter 20-1000MHz	£250
GR Standard sweep generator. 400KHz-230MHz	£485
HEWLETT PACKARD 693D sweep oscillator	£350
DERRITRON. Digital Wheatstone Bridge	£110
MUIRHEAD K-134-A Battery op. wave analyser	
PYE EHT scalamp voltmeter 0-40KV	£125

RADIO CORPS PB1 pulse & bar generator	£45
SIEMENS Level oscillator 12-160KHz	
SCHNEIDER type cf252 100MHz counter (red)	£200
SCHOMANDL type FD1 frequency meter	£125
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Bruel & Kjoer type 3301 Automatic Frequency Response Recorder 200Hz-20KHz	
Airmec 201A Signal Generator 30KHz-30MHz.	
MUIRHEAD-PAMETRADA D489EM Wave Analyser	
TEKTRONIX 555 scope with plug-ins types CA (2 off), 21 and 22	
TEKTRONIX 545 main frames. £210. Choice of plug-in units extra.	
TEKTRONIX 585A oscilloscope with '82' P.I. DC-80MHz	
TEKTRONIX type 526 Vectorscope	£580
TEKTRONIX type 180A Time-mark generator	£110
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NOTICE. All the pre-owned equipment shown has been carefully tested in our workshop and reconditioned where necessary. It is sold in first-class operational condition and most items carry our three months' guarantee. Calibration and certificates can be arranged at cost. Overseas enquiries welcome. Prices quoted are subject to an additional 8% VAT.

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AMF TV. Demodulator 470-790MHz.
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Selectomat. RF Voltmeter. USWV. BN 15221. £450
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UHF Signal generator type SCH. £175
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POLYSKOP SWOB I.

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Supplied in first-class condition complete with types 3A1 and 3B3 plug-in units. DC-10MHz double-beam 10mV/div. Calibrated sweep delay and single-shot. Time-base 0.5us/div. £350.00

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Made by Rotron Holland. These are very high quality, quiet running fans, specially designed for the cooling of all types of electronic equipment. Measures 4.5x4.5x1.5". 115V.AC. 11 Watts. The list price of these is over £10 each. We have a quantity available brand new for only **£4.50 each**

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Philips studio quality precision colour monitors and Pye monochrome 405/525/625 lines

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MUIRHEAD DECADE OSCILLATORS type 890A.
1Hz-110kHz in four decade ranges. Scope monitored output for high accuracy of frequency. Excellent generator.

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LINE advertisements (run on): £1.10 per line, minimum three lines.
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PHONE: Eddie Farrell on 01-261 8508
Classified Advertisement Rates are currently zero rated for the purpose of V.A.T.

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If you're thinking of a shore-based job, here's where you'll find interesting work, job security, good money, and the opportunity to enjoy all the comforts of home where you appreciate them most – at home!

The Post Office Maritime Service has vacancies at Portishead Radio and some of its other coast stations for qualified Radio Officers to undertake a wide variety of duties, from Morse and teleprinter operating to traffic circulation and radio telephone operating.

To apply, you must have a United Kingdom Maritime Radio Communication Operator's General Certificate or First Class Certificate of Proficiency in Radio-telegraphy or an equivalent certificate issued by a Commonwealth Administration or the Irish Republic. And, ideally, you should have some sea-going experience.

The starting pay at 25 or over works out at around £4093; after three years' service this figure rises to around £5093. (If you are between 19 and 24 your pay on entry will vary between approximately £3222 and £3732). Overtime is additional, and there is a good pension scheme, sick-pay benefits, at least 4 weeks' holiday a year, and excellent prospects of promotion to senior management.

For further information, please telephone Andree Trionfi on 01-432 4869 or write to her at the following address: ETE Maritime Radio Services Division (L690), ET17.1.2, Room 643, Union House, St. Martins-le-Grand, London EC1A 1AR.

Post Office Telecommunications

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(Male or female) for a department responsible for the repair of the Laboratories' professional electronic equipment. This involves the maintenance of oscilloscopes, precision high power magnet controllers, digital equipment such as D.V.M.'s, counters, pulse generators and analysers of various kinds.

Experience of servicing this type of equipment is required and it is hoped to gradually extend the maintenance capability to include microprocessors, computers and associated peripherals.

Please apply for an application form to: Mr. M. L. Malpass, Personnel Manager, Philips Research Laboratories, Cross Oak Lane, Salfords, Redhill, Surrey. Tel: Horley 5544. Quoting reference: 102.

PHILIPS Research Laboratories

PHILIPS

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M.Sc./DIPLOMA COURSE IN ELECTRONICS

Applications are invited for places in the full-time one-year MSc/Diploma course in Electronics, commencing 27 September 1978.

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Headlines like these are only possible when you're acknowledged internationally as one of the world's leaders in avionics. To keep us at the forefront we need highly motivated design/development engineers keen to make their mark. And at Ferranti there's plenty of opportunity to do just that. On projects like the Tornado, Sea Harrier, Jaguar and Lynx.

And headlines like these also mean expansion. Which explains why we're looking for more graduate mechanical and electronic engineers to join our airborne radar and inertial navigation teams. They must have the design/development experience to spearhead the progress of equipment from drawing board through to production.

We are particularly interested in talking to engineers with backgrounds in the design of:-

- **Digital/analogue circuitry.**
- **Microwave and laser techniques.**
- **Small digital computers.**
- **Advanced instruments.**
- **Optics.**
- **Airborne structures and light mechanisms.**

So if you're keen to make your mark on avionics, you'll find you're very much on our wavelength.

Think about it. Then ask the family how they'd like living in Edinburgh, freely acknowledged as one of Europe's finest cities.

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For an application form, write to John McPhee at the address below:

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EDINBURGH EH5 2XS
Tel: 031-332 2411.

These posts are open to both male and female candidates.

(7000)

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Candidates should have a wide experience of video systems engineering and preferably be familiar with EMI type 2005 cameras, AVR2 Ampex recorders and Rank Cintel film scanning equipment. Working to the Superintendent Engineer, he will be responsible for the general supervision of all television studio operations.

Two Training Officers

One officer will be required to train local staff in all aspects of audio operations in both radio and television, while the other will be responsible for video operations. In addition to wide experience in television technical operations, candidates with some teaching experience will be given preference.

Salaries are in a scale equivalent to £8870-£9505 pa, tax free including special allowance, and attract 25% gratuity.

Benefits include first-class air travel for the officer and his family, subsidised housing, generous paid leave, education allowances, outfit allowance, interest free car loan and free medical attention. Appointment is on contract terms for 2 or 3 years.

For full details and application form write quoting MT/832/WD.

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Formal application and request for job description should be made in writing to:

Miss E. Fairclough, Personnel Department, St. George's Hospital, Blackshaw Road, SW17. Tel. 01-672 1255 ext. 4121.

Closing date: 3rd February, 1978. (7855)

UNIVERSITY OF WARWICK

ELECTRONICS TECHNICIAN

(Psychology)

A Technician is required for a wide range of electronics development work in the expanding Department of Psychology. There is a particular emphasis on interfacing microprocessors to a variety of measurement and control systems. Applicants are expected to have some experience of logic circuitry. Qualifications to HNC level or equivalent relevant experience are desirable. The post is permanent and pensionable and appointment will be on the Technician Grade 5 scale: £2,889-£3,367 p.a. (under review). Further particulars are available from the Secretary, Department of Psychology (Tel. Coventry 24011 extn. 2565). Letters of application giving full details should be sent to the Academic Registrar, University of Warwick, Coventry CV4 7AL quoting Ref. No. 18/T/77. Closing date for receipt of applications is 30th January, 1978. (7807)

BRIGHTON POLYTECHNIC
LEARNING RESOURCES

VIDEO RECORDING & STUDIO ENGINEER

£3,678-£4,407 p.a. plus up to £17.38 a month supplement

To supervise work in new recording and editing area with colour tele-cine and V.T.R.s, some to broadcast standard, and to assist with operations in two adjoining studios which include a video 80 colour system and a post production area with multi-track sound.

Operational experience of sound and colour video systems, preferably in a broadcasting or educational institution, and an HNC or equivalent educational qualification are desirable.

Application forms and details from the Personnel Officer, Brighton Polytechnic, Moulsecoomb, Brighton BN2 4GJ. Tel: Btn. 693655, Ext. 2536

Closing date: 27th January, 1978. (7825)

The Polytechnic of North London

(Readvertisement)

ELECTRONICS TECHNICIAN

We are looking for a well qualified electronics technician with a keen interest in video, audio and audio-visual. As a member of the Educational Development Service, the technician would be responsible for:

* establishing servicing routines and records.
* establishing technical standards and assisting production staff in video and audio recordings.
* training and supervising technical staff,
* developing and building ancillary equipment.

HNC or equivalent qualifications required and minimum of nine years' relevant experience.

Salary Scale: £3621-£4227 (including London Weighting) plus 5% earnings supplement (minimum £2.50 per week, maximum £4 per week).

Application form from Educational Development Service, Polytechnic of North London, Holloway Road, N7 8DB. (7801)

CAPITAL APPTS.

29, Windmill St. London, W.1.

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We are looking for skilled men and women with experience of fault diagnosis, alignment and testing of electronic equipment, preferably communications equipment. Formal qualifications are desirable, but less important than sound practical ability. Armed Forces experience would be particularly acceptable.

We can offer you job security and long term employment prospects.

We have openings at Haverhill in Suffolk (where there is the possibility of local authority housing) and at Cambridge, both being attractive places in which to live. Relocation expenses are available.

Write or phone (reversing charges if necessary) to: **Catherine Dawe, Pye Telecommunications Ltd, Colne Valley Road, Haverhill, Suffolk CB9 8DU Tel: Haverhill 4422 or Clare Barton, Pye Telecommunications Ltd, Elizabeth Way, Cambridge. Tel: Cambridge 58985.**

PYE

Pye Telecommunications Ltd

7832

UNIVERSITY OF KENT AT CANTERBURY

RESEARCH FELLOW IN NETWORK DESIGN

Applications are invited for a Post-doctoral Research Fellowship to work on an SRC supported project involving the application of state-space techniques to the analysis and synthesis of microwave circuits and digital filters, including the development of mathematical models and computer-aided procedures for the design of distributed-parameter networks. Candidates should have a Ph.D. Degree in Computing, Electronics, Physics or a related subject and relevant experience in computer-aided design techniques would be an advantage. Salary will be in the range £3333-£4403.

Application forms and particulars may be obtained from the Senior Assistant Registrar, Faculty of Natural Sciences, Chemical Laboratory, The University, Canterbury, Kent CT2 7NH. Closing date for applications 31st January, 1978. Please quote ref. A52/77

(7851)

UNIVERSITY OF EAST ANGLIA NORWICH

TECHNICIAN

required in the Music Centre from as soon as possible. The successful applicant will assist the Sound Engineer in the operation and maintenance of the sound-recording and electronic music equipment which includes a Synthi 100 synthesiser, and professional-quality mixers and tape recorders. Some experience with mini computers would be an advantage. Salary on the Grade 4 scale £2689 to £3087.

Applications, giving details of age and experience, and the names of two referees, should be sent to Professor P. Aston, School of Fine Arts and Music, University of East Anglia, Norwich NR4 7TJ, not later than 31st January, 1978.

7824

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Courses start in September 1978. For further details, ring or fill in the coupon and send it to the Principal of any of the following colleges: Garnett College, Downshire House, Roehampton Lane, London SW154HR. Tel:01-7896533; Bolton College of Education (Technical), Chadwick Street, Bolton BL2 1JW. Tel: 0204 22132; The Polytechnic, Huddersfield, Holly Bank Road, Lindley, Huddersfield HD33BP. Tel: 048425611; Wolverhampton Polytechnic, Faculty of Education, Compton Road West, Wolverhampton WV3 9DX. Tel: 0902 24286.

Please send me further details and an application form for your one year course to train as a lecturer.

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Address ....

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(535)

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If you are interested, please write with full career details or phone for an application form to: Anne Dare, IBM United Kingdom Limited, 389 Chiswick High Road, London W4 4AL. Tel: 01-995 1441. Ext. 4786. Quoting ref: WW/93452

IBM (7833)

THE OPEN UNIVERSITY

Faculty of Technology

RESEARCH TECHNICIAN

(Electronics and Telecommunications)

A Technician is required to join the Electronics Discipline. His or her main duties will be to contribute to the Discipline's research programme in telecommunications, digital processing, instrumentation and control. This will involve the construction and testing of experimental and prototype electronic equipment, the maintenance and updating of documentation and drawings and the general maintenance of the technical facilities in the electronics research laboratory.

The required qualification is ONC in electronics T5, or equivalent, with, preferably, two years' experience of laboratory or prototype development work.

The person appointed will be expected to live within 20 miles of the University. We do offer assistance with removal expenses to make this possible. There is a wide variety of corporation and private housing, and we have an Accommodation Officer to advise and help new appointees.

The appointment is at Technical Grade 3, for which the salary scale is £2455-£2788 per annum (under review with effect from 1.10.77). We offer generous holidays and excellent social and sporting facilities.

Application forms are available, by postcard request please, from The Personnel Manager (IT2), The Open University, P.O. Box 75, Walton Hall, Milton Keynes, MK7 6AL, or by telephone from Milton Keynes 63868. Closing date for applications: 30.1.78. (7821)

THE UNIVERSITY OF LEEDS

A vacancy exists in the School of Chemistry Electronics Workshop for an

ELECTRONICS TECHNICIAN (Grade 5)

The successful applicant will develop, construct and maintain a wide variety of electronic equipment. Experience in modern analogue and digital circuit techniques and in the use of test equipment is essential. Minimum qualifications HNC or equivalent plus 7 years' experience. Salary on the scale £3186-£3720 p.a. (under review). Applications giving age, experience, qualifications, state of health and the names and addresses of two referees to **Mr. G. Spink, School of Chemistry, The University, Leeds LS2 9JT.** (7822)

MAINTENANCE ENGINEER

A young person is required to assist in the maintenance of Recording Studios and Visual Aid Equipment.

Stating experience, please apply to:

Nigel Adams
Sound Developments Limited
Spencer Court, 7 Chalcot Road, London NW1 (7828)

ELECTRONICS TECHNICIAN Grade 5 required for an establishment engaged in research and teaching based on a nuclear research reactor. Must be capable of constructing and maintaining a variety of electronic equipment to be found in a nuclear establishment. Applicants should have at least eight years experience and a qualification to ONC level is desirable. A knowledge of digital circuitry would be an advantage. Salary in range £3186-£3720 per annum. Excellent conditions, superannuation scheme. Four weeks annual holiday, plus additional days at Christmas and Easter. Applications, by 14 February 1978, to: The Reactor Supervisor, University of London Reactor Centre, Silwood Park, Sunninghill, Ascot, Berkshire, SL5 7PY. Telephone Ascot 23911, ext 272. (7837)

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We can offer exciting opportunities to Engineers who can operate and maintain R.C.A., Ampex, Quad Machines and all types of Helical Scan as well as T.B.Cs. and colour Telecines.

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SOUND ENGINEER

The Royal Opera House Covent Garden requires Assistant Sound Engineer. The post will probably suit someone with a studio or broadcasting background who is prepared to work unsociable hours. The work is very varied and requires an engineering bias and some musical knowledge.

Replies to: Phil Leaver, Royal Opera House, Floral Street, London WC2E 7QA. (7858)

Appointments

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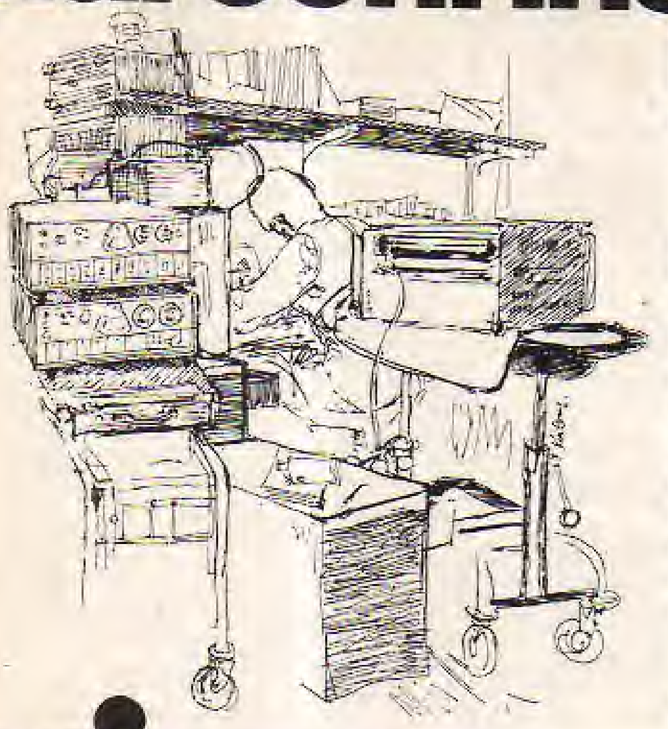

ELECTRONIC TECHNICIANS

Opportunities for the experienced and sometimes inexperienced in St. Albans and Luton.
Work situations range from fault finding on PCB's and components, to batch product testing of equipment that utilise very advanced techniques including microprocessors and the repair/calibration of all manner and types of test instruments.
Attractive salaries and, where appropriate, relocation are offered for the right candidates.
Further information may be obtained in confidence from John Prodger
Marconi Instruments Limited,
Longacres, St. Albans, Herts. tel: St. Albans, 59292

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(7848)

mi

WIRELESS TECHNICIANS

There are a limited number of vacancies at the following Home Office Depots: Andover and Hannington Hants, Bridgend Mid Glamorgan, Guildford Surrey, Hinchingbrook Hunts, Lewes East Sussex and Romsley West Midlands for Wireless Technicians to assist with the installation and maintenance of VHF and UHF systems.

Applicants must be able to drive a car and be in possession of a current UK driving licence.

Salary

is £2,010 (at 17), £2,450 (at 21) and £2,905 (at 25) rising to £3,385, plus a 1976 pay supplement of £313.20 a year and a 1977 pay supplement of 5% of total earnings, subject to a minimum of £101.79 a year and a maximum of £208.80 a year.

A Secure Future

with a non-contributory pension scheme, good prospects of promotion and a generous leave allowance. There are opportunities for day release to gain higher qualifications.

Qualifications

Candidates, male or female, must hold a City and Guilds Intermediate Telecommunications Certificate or equivalent and have practical experience of maintenance and construction of VHF and UHF wireless equipment and a working knowledge of workshop techniques.

Applications from Registered Disabled Persons will be considered.

Interested?

Then write or telephone for further details and an application form: to Mr C B Constable, Directorate of Telecommunications, Horseferry House, Dean Ryle Street, London SW1 2AW. Telephone: 01-211 6420.

7803

Home Office

RADIO TECHNICIANS

The Home Office has vacancies for Radio Technicians to carry out maintenance, modification and construction of specialised equipment including mechanical construction. Applicants must have a good understanding of radio fundamentals and be familiar with commonly used radio components and test equipment. The vacancies will be located at Stanmore, Middlesex, Central London (near Waterloo Station) and Baldock, Herts.

Qualifications and Experience

Applicants must possess either a City and Guilds Intermediate Telecommunications Technicians Certificate, a relevant ONC or equivalent qualification plus 1 year's practical workshop experience.
Applications from Registered Disabled Persons will be considered.

Salary

is £2,010 a year at 17, £2,450 at 25 or over on entry, rising to a maximum of £3,385, plus a 1976 pay supplement of £313.20 and a 1977 pay supplement of 5% of total earnings, subject to a minimum of £101.79 a year and a maximum of £208.80 a year. A London Weighting Allowance of £465 a year is payable in Central London and £275 a year at Stanmore.

A Secure Future

with a non-contributory pension scheme, prospects of promotion, generous leave allowance, further education facilities and a 5-day week of 41 hours in London and 42 elsewhere.

Interested?

Then write or telephone for application forms (for return by 8th February 1978) to: Mr J J Willis, Directorate of Radio Technology, Room 514, Waterloo Bridge House, Waterloo Road, London SE1 8UA. Telephone: 01-275 3006.

(7799)

Home Office

Project Engineers
Electronic Control Systems

Johnson Matthey & Co. Ltd., world leaders in refining and fabricating precious metals have vacancies for experienced Electronic Engineers to join our small, specialist team at Wembley. With an HNC/HND or degree level qualification, you'll be involved in the design, production and installation of electronic control systems to the individual requirements of our manufacturing centres.

Systems Engineer

Drawing on your management abilities, you'll detail the systems and equipment design and organise their manufacture and installation. There will be some travel involved and a clean driving licence is essential.

Electronic Engineer

You'll need to be able to think creatively for you will design the analogue and digital circuits to their pre-production stage from stated functional requirements and assist in the design of production equipment.

We are offering competitive salaries, according to age and experience, for a 37½ hour week. In addition, we offer free lunches, 4 weeks' annual holiday and a contributory pension scheme.

To apply, please write or telephone I.I. Middleton-Stewart, Staff Officer.

(7847)

JM JOHNSON MATTHEY
100 HIGH STREET • SOUTHGATE
LONDON N14 6ET • 01-882 6111

Electronics Engineer

We require an Electronics Engineer at our Research Laboratories at Alderley Park to strengthen a team involved in the design and development of Biological and Research instruments.

Ideally candidates, male or female, should be qualified to HNC/HND or equivalent standard and have had four or more years experience of electronic design. A good knowledge of anologue and digital circuit design using the latest component technology is essential.

Age: 25 years plus.

Please apply in writing to:

ICI

Mr M. J. Higgins
Personnel Department
ICI Pharmaceuticals Division
Mereside Alderley Park
Macclesfield Cheshire

7810

Radio Engineers

Opportunities exist for several additional experienced radio engineers to join this leading firm of Consulting Engineers.

Vacancies exist both in our Brighton Offices and for engineers to serve on contract in the Middle East.

Chartered Engineers who have experience in several of the following fields are invited to apply; h.f. transmitters and receivers, sound broadcasting, m.f. and h.f. antennas, m.f. and h.f. propagation.

Salaries for engineers based in Brighton will be in the range £5,500 to £7,500 p.a. with the usual fringe benefits including assistance with removals.

Salaries for engineers contracted abroad will be about double the above range and these salaries are normally payable tax-free usually with free travelling and local accommodation.

Degree Engineers with extensive experience who are not Chartered may also be considered.

Please write or telephone:

G. E. Tedder, Group Personnel Manager,
PCR Service Company,
Paston House,
165/167 Preston Road,
Brighton, Sussex.
(0273) 507131

PCR

(7811)

The Polytechnic of North London

Department of Electronic and Communications Engineering

TECHNICIAN GRADE IV or V

Applications are invited for the appointment of a Grade IV or V Technician in the Department of Electronic Communications Engineering.

This interesting post involves the operation and maintenance of high grade test equipment, together with the general responsibility for students' day-to-day requirements with experiments and projects in the laboratory.

Important participation in research work in liaison with academic staff for the right applicant, leading to promotion prospects.

Educational level for Grade IV ONC/OND and Grade V HNC/HND in appropriate subjects.

Experience: Grade IV at least 7 years (including training period).
Grade V at least 8 years (including training period).

Salary Scales: (inclusive of London Weighting).
Grade V £3216-£3672 plus 5% earnings supplement
Grade IV £3024-£3450 (Maximum £4 per week)

Application forms obtainable from the Establishment Officer, Polytechnic of North London, Holloway Road N7 8DB. Further details from the Departmental Laboratory Superintendent Mr. S. Elliott 607 2789 extn. 2176.

(7853)

BRUSSELS

The Technical Centre of the European Broadcasting Union is seeking an

EDITORIAL ASSISTANT

for duties entailing the processing of English editions of the E.B.U.'s technical periodicals from source material to publication.

This post would suit an Engineer or Technician of English mother-tongue, with training and experience in telecommunications — preferably broadcasting — and the ability to produce documents in faultless English from English and French material, as well as precise translations of technical reports and correspondence. A higher-than-average proficiency in the French language is evidently essential.

The salary will be in the vicinity of 550 000 Belgian francs per annum, depending upon age and experience, with good prospects of advancement.

Candidates should write giving details of education and experience to:

The Director, Technical Centre of the European Broadcasting Union
Avenue Albert, Lancaster 32, B-1180 Bruxelles (Belgium)

(7800)

DESIGN ENGINEER

BBC Recording

BBC requires an engineer with special responsibility for audio recording in its Designs Department in central London. Much of the work is appraising or modifying commercial audio recording equipment and advising those responsible for audio operations and installations. There is also a substantial amount of original design, both mechanical and electronic, for auxiliary equipments and specialised recording systems.

Preference will be given to applicants having an appropriate University degree or professional qualification. The successful candidate is likely to have a substantial knowledge of the theory of magnetic recording, a wide experience of types of recorders, media and formats, and be skilled in operational alignment and laboratory measurement of audio recording systems. He/she will be experienced in the design of electronic circuits and mechanical devices, and familiar with digital techniques, logic and process control, and the use of time code signals for editing.

The post involves liaison with a wide range of engineers and managers in Radio, Television and External Broadcasting, and in industry. The post-holder must be able to establish effective communication with them and provide expert advice including technical reports and the recommendation of alternatives.

Salary according to experience in the range £5050 – £5430 rising to £6000, opportunities for promotion. Pensionable post.

Write for application form to **The Engineering Recruitment Officer, BBC, Broadcasting House, London, W1A 1AA**, quoting reference 77.E.4094/WW and enclosing a self addressed envelope at least 9" x 4".

Closing date for completed application forms is 14 days after publication.

BBC

AMPEX

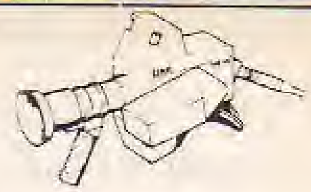
Ampex International recherche un ingénieur bilingue experimenté pour l'élaboration de systèmes de télévision destinés à la France, la Belgique et aux pays d'Afrique francophone.

Sa fonction consistera en l'élaboration d'offres techniques en français, au sein d'une équipe depuis longtemps implantée sur les marchés internationaux. La connaissance des deux langues est indispensable.

Please reply, in French or English, to:

D. J. Lambert
AMPEX ELECTRONICS LTD.
Acre Road
Reading RG2 0QR

LINK



CHECK OUT NEXT GENERATION'S COLOUR TV CAMERAS

Just about to go into production is our multi-mode colour camera which supplements our well known type 110 studio/OB version, now selling in increasing quantities.

Test Engineers are needed who can cope with high technology designs covering the whole spectrum of studio broadcast equipment. A background of circuit theory up to HNC/D/degree standard is essential, although knowledge is more important than a piece of paper.

You must have spent at least a year or two in industry and the experience you have will dictate the complexity of equipment you can work on initially. Domestic TV experience alone is, regrettably, insufficient.

You would be joining a young team in a successful operation, offering salary and benefits normally associated with a much larger company, plus financial help in relocation, where necessary.

Our modern factory in Andover is well placed for a good selection of housing and there is easy access to London and many major towns in the south and Midlands.

Please phone Jean Smith at 0264-61345 for an application form or write to Mic Comber at the address below, giving enough detail of qualifications, experience and salary progression, to make a form unnecessary.

LINK ELECTRONICS — North Way, Andover, Hampshire, England — Telephone: Andover (0264) 61345

(7836)

SITUATIONS VACANT

RADIO TECHNICIANS

Government Communications Headquarters has vacancies for Radio Technicians. Applicants should be 19 or over.

Standards required call for a sound knowledge of the principles of electricity and radio, together with 2 years experience of using and maintaining radio and electronic test gear.

Duties cover highly skilled Telecommunications/electronic work, including the construction, installation, maintenance and testing of radio and radar telecommunications equipment and advanced computer an analytic machinery.

Qualifications: Candidates must hold either the City and Guilds Telecommunications Part I (Intermediate) Certificate or equivalent HM Forces qualification.

Salary scale from £2,230 at 19 to £2,905 at 25 (highest pay on entry), rising to £3,385 with opportunity for advancement to higher grades up to £3,780 with a few posts carrying still higher salaries. Pay supplements total between £443 and £522 per annum.

Annual Leave allowance is 4 weeks rising to 6 weeks after 27 years' service.

Opportunities for service overseas.

Candidates must be UK residents.

Further particulars and Application forms available from:

Recruitment Officer
Government Communications Headquarters
Oakley, Priors Road
CHELTENHAM, Glos GL52 5AJ
Tel. Cheltenham 21491 Ext. 2270
(STD 0242-21401)

(7741)

DEVELOPMENT ASSISTANT. Rank Video Centre is a fast expanding broadcast television facilities house, located in the centre of London, operating state-of-the-art technology. A vacancy has occurred within the Research and Development Department for an enthusiastic Engineer having a good basic knowledge of the PAL colour TV system and who is conversant with the latest analogue and digital techniques. The successful applicant will be responsible to the R & D Supervisor for manufacture and testing of prototype equipment for final installation and operation within the various facilities departments of the company. This post offers a unique opportunity for an Engineer, ideally aged 22-28, having an aptitude for design and construction work, to join a small, active team providing specialist back-up to a busy commercially oriented company. Starting salary will be c£4,000 plus p.a. with automatic progression over 5 years. Application, in the first instance, should be in writing to:— Garry A. Duguid, C.Eng., MIERE, Chief Engineer, Rank Video Centre, Film House, 142 Wardour Street, London, W1V 4BU. (7850

THE UNIVERSITY OF LEEDS. A vacancy exists in the Department of Electrical and Electronic Engineering for an Electronic Technician (Grade 5) to work in the Electronics Workshop. This workshop undertakes the development and construction of prototype electronic equipment used in teaching and research together with the modification testing and maintenance of an extensive range of electronic equipment used in the teaching and research laboratories. The minimum qualifications required are ONC, OND or City and Guilds certificates in Electronic Engineering together with at least 7 years relevant experience. Salary on the scale £3,186-£3,720 a year. Applications should be sent to Mr. C. S. Petch, Department of Electrical and Electronic Engineering, The University, Leeds LS2 9JT. (7826

THE UNIVERSITY OF LEEDS. Electronics Technician Grade IIIE required. Will be responsible, under the head of the Department and the Departmental Electronics Engineer, for the construction, modification and maintenance of electronic equipment associated with research and teaching of biological studies. Must be capable of working from precise instructions, circuit diagrams, sketches and manuals. Applicants should hold ONC or equivalent qualifications in relevant subjects. Salary on the scale £2,688-£3,060 according to qualifications and experience. Applications stating age, qualifications and full experience together with the names and addresses of 2 referees should be addressed to Mr E. French, Departmental Superintendent, Department of Physiology, Medical Multipurpose Building, Mount Preston Street, Leeds LS2 9NQ. (7854

BROADCAST V.T.R. ENGINEERS

Due to expansion vacancies exist for experienced engineers with suitable qualifications. Depending on the successful applicants' experience, the posts will be substantive engineers or senior engineer (ACTT/ITCA salary grades). Duties will involve operation + Maintenance of TR70c + AVR 2 machines together with a (CDL timecode) editing suite, so knowledge of these would be an advantage.

Please write: Graham Saych, Ewart & Co. (Studio) Ltd., Wandsworth Plain SW18 1ET.

(7836)

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Receiving:
CASSETTE A For Amateur Radio examination preparation. Speed slowly increasing from 1-12 w.p.m.
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Sending:
Morse Key and Buzzer Unit for sending practice and own Tape preparation. Phone output.

Prices: each cassette, including booklets, £4.50
Morse key and buzzer unit, £4.50

Prices include VAT, postage, etc. Overseas Airmail £1 extra

M. H. ELECTRONICS
12 LONGSHORE WAY, MILTON, PORTSMOUTH PO4 8LS

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Offers are invited for the following equipment which has been made redundant by the re-engineering of the Council's Communal Television System.
VHF Distribution Equipment consisting of a complete head end with AGC Amplifiers.
12 Repeater Amplifiers of Teling type 6301
Communal Television Mast and Aerials.

All enquiries should be addressed to
H. Davies, A.R.I.C.S., Valuer to the Council, Borough of Milton Keynes, Sherwood House, Sherwood Drive, Bletchley, Milton Keynes MK3 6QE.
Tel: Milton Keynes (0908) 71171 Ext. 427.

7808

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VHF/UHF MONITOR RECEIVERS, air, marine and business bands, all crystal controlled, from £50. Send 15p PO, not stamps. Radio Communications Ltd, St Sampsons, Guernsey, C.I. (7739

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300,000 MULLARD C 280 & C 281 for sale, valves from 01UF to above 1 UF 250/400 V/W price per mixed pack, 100/£150, 500/£7.00 P&P (export 50p). Electronic Mailorder Ltd., Ramsbottom, Bury, Lancs. (7312

THE FABULOUS D2 MICROPROCESSOR EVALUATION KIT FROM MOTOROLA

Featuring '24 key keyboard 'Seven segment display 'Cassette interface 'Erom & Ram Expandable 'Interface Capability 'Full Documentation '5 Volt power supply required 'One year's FREE membership of The Amateur Computer Club with every purchase' **£176** + £1.50 P&P + 8% VAT

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SWG	1 lb	8 oz	4 oz	2 oz
14-19	2.80	1.40	.66	.55
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30-34	3.00	1.70	.95	.70
35-40	3.35	1.90	1.10	.79
40-43	4.50	2.50	1.80	1.25
44-46	5.00	3.00	2.10	1.65
47	8.00	5.00	3.00	1.76
48	15.00	9.00	6.00	3.30

Tinned Copper, Even Gauges 14-30 £3 per lb. Multicore 60/40 Solder 18SWG £3.24 per lb. Prices include P&P and VAT.
SAE brings list of copper and resistance Wires.

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NEOPRENE SHEET, RUBBER AND PLASTIC EDGING, WINDOW RUBBERS. Write or Phone List MELFLEX, 934 Wimborne Road, Bournemouth Tel: 0202 527934

(7844)

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