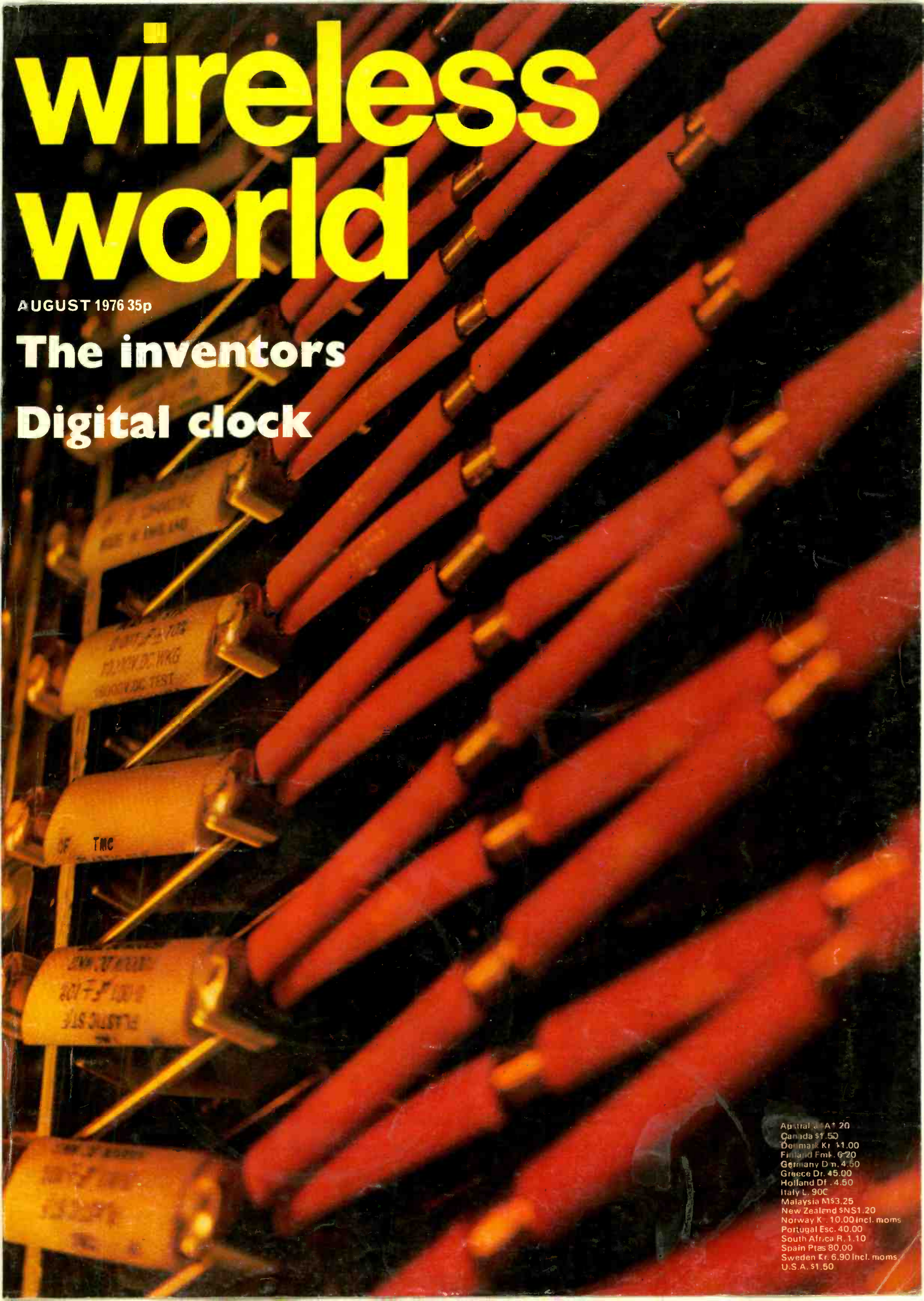
# wireless world

AUGUST 1976 35p

## The inventors

## Digital clock



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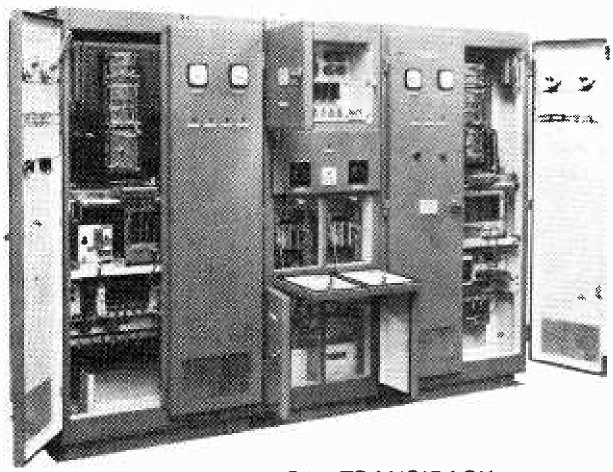

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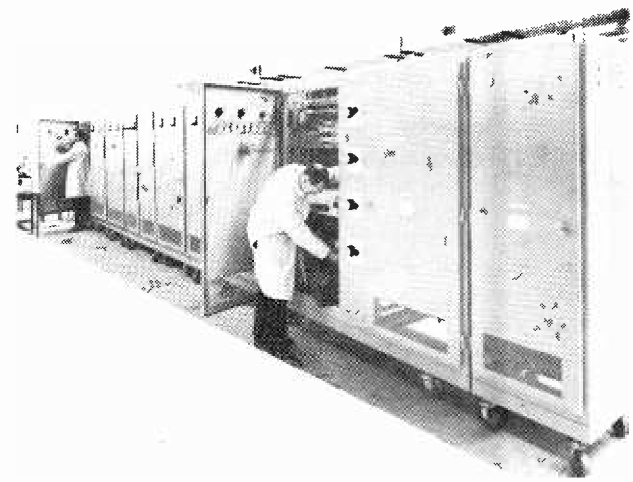

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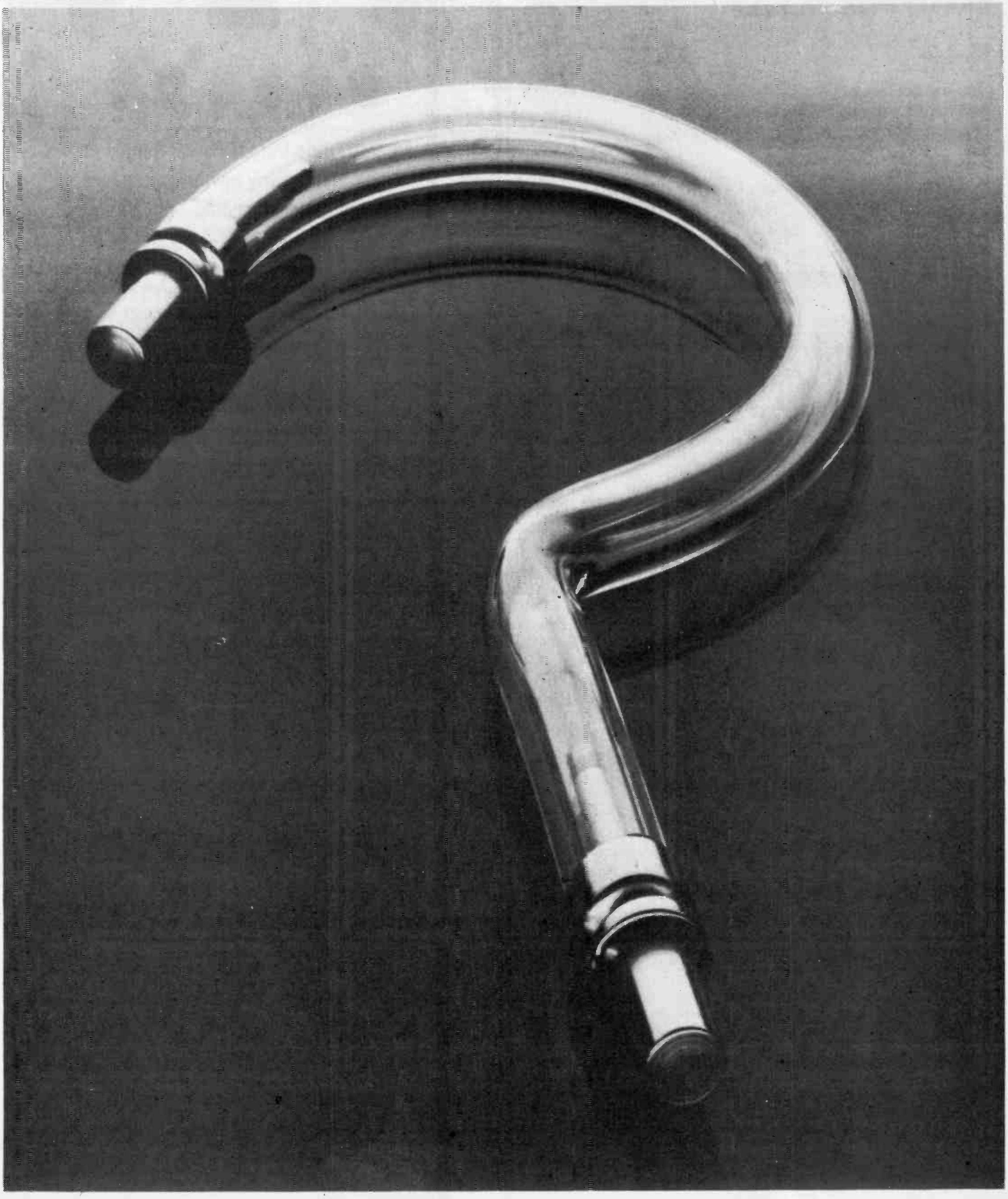

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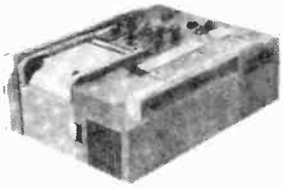
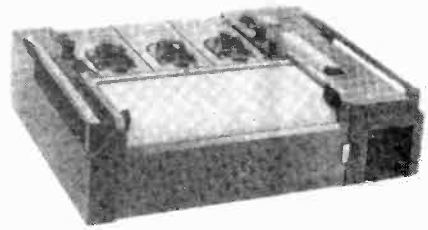
Made in USSR



Type H3020-1
Single pen

Type H3020-3
Three-pen



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Response . . . . . . . . . . . . . . 0.2 sec.
Width of each channel . . . . . 80mm
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**Equipment:** Marker pen, Timerpen, Paper footage indicator, 10 rolls of paper, connectors, etc.

**Dimensions:** H320-1: 285x384x16.5mm
H320-3: 475x384x16.5mm

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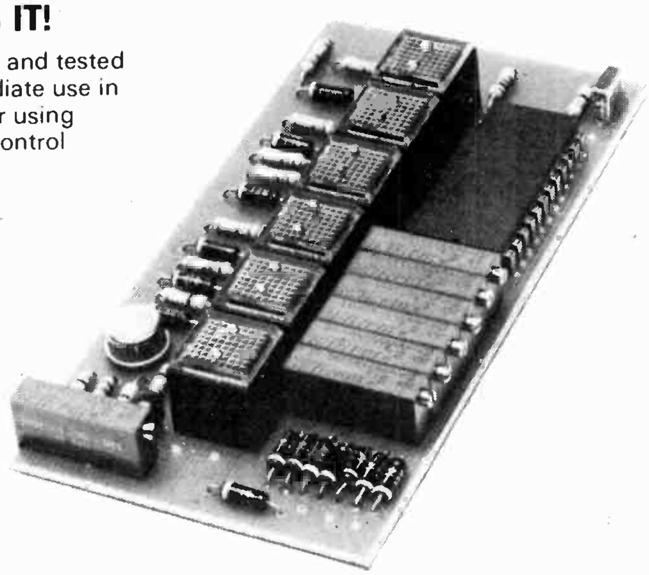

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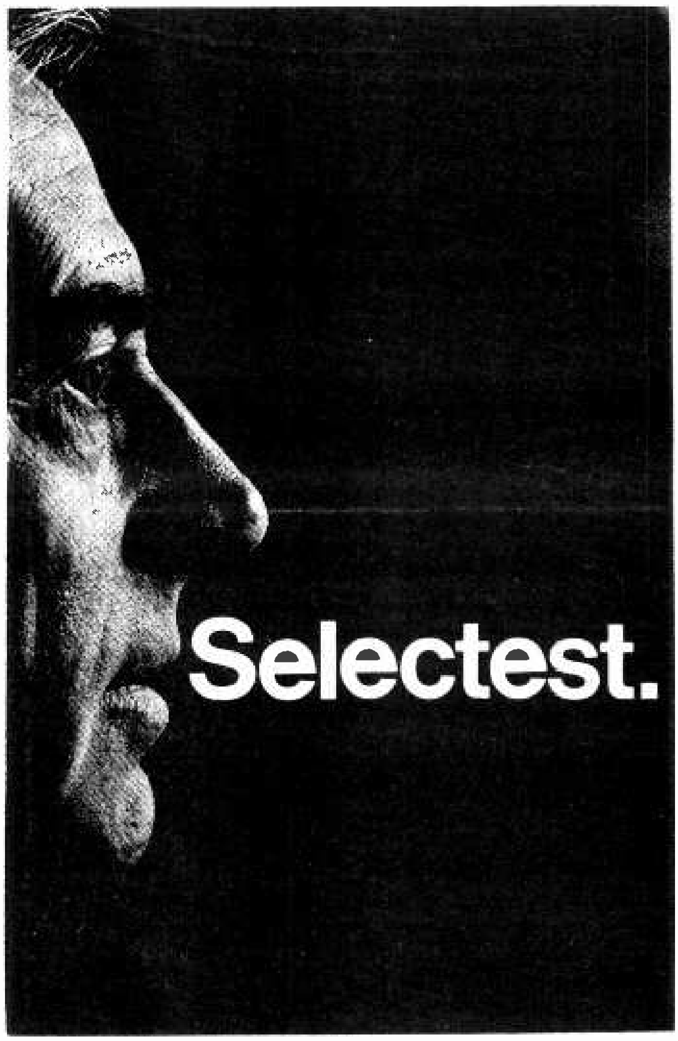
# Everyone just says . . .

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The MK. 3 Selectest has every facility you need built into it, accuracy, sensitivity and robustness.
The case is made of wipe-clean, tough, light-weight melamine. Terminals accept 4mm push-in plugs on the front panel, enabling the Selectest to be used horizontally or vertically.
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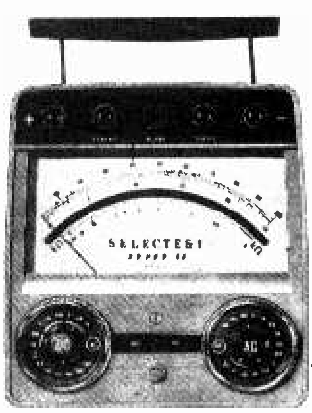


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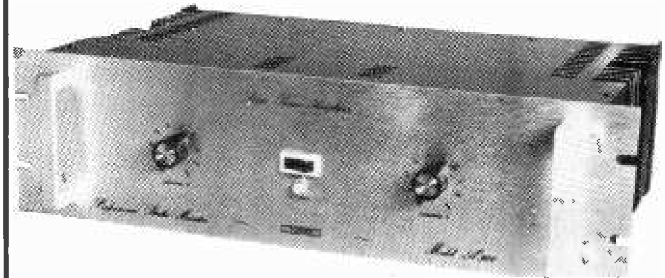
# —TURNER—

STEREO POWER AMPLIFIERS
(from 100 watts to 500 watts)



Professional Stereo Power Amplifiers designed and manufactured to the very highest standard.

TURNER POWER is setting a new standard in the studios for ultra-clean monitoring, and with bands on the road for ruggedness and reliability.

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Our product range comprises:
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Make contacts:
Resistive load. 10 A/240 V AC.
Lamp load: 8 A/240 V AC.
Compensated fluorescent tubes: 3.7 A/240 V AC.

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We resolve your switching problems rapidly and expertly. Please contact us for further details.

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## integrated circuit power amplifier

TPA 50 - D Specification

| | |
|---|---|
| Power Output | 100 watts rms into 4 ohms<br>65 watts rms into 15 ohms |
| Freq Response | ±0·1dB 20Hz to 20KHz into 15 ohms. -1dB at 150KHz |
| Total harmonic distortion | Less than 0·04% at all levels up to 50 watts rms into 15 ohms |
| Input sensitivity | OdBm |
| Noise | -100dB |
| Rise time | 2 u seconds |
| Price | £77 plus V.A.T. |

100V Line (C.T.) and balanced inputs available.

For full technical information contact:

**H||H ELECTRONIC**

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WW—021 FOR FURTHER DETAILS

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## IN-LINE WATTMETER

Measures power output from transmitter and reverse power from antenna.

Compact and light weight (approx. 1 lb)

Frequency range 2MHz to 19Hz.

Measures RF power from 1W to 1KW.

System includes a series of wide range RF elements which can be left permanently in-line in the transmission cable — measurements can then be taken without disconnecting the antenna.

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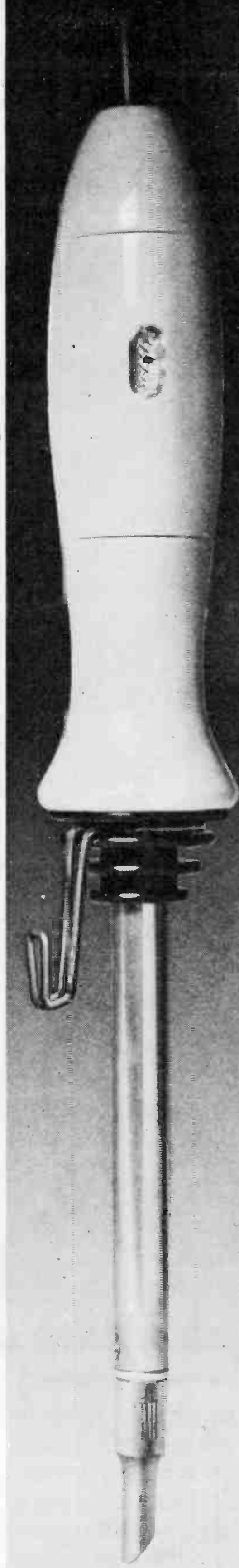

# With our New ORYX SUPER 30

## soldering iron we have a slight problem at £2.95* how do we convince you that it is a precision tool.

Our reputation for professional soldering equipment has been built on our precision products, so we have taken extreme care to see that our new ORYX Super 30 iron at, *dare we repeat it,* only £2.95, is going to be the best at its price.

** plus VAT at 8%*

**Here are some of the features you get as standard:**

A neon Safety Light,
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Iron coated screw-on tip,
Stainless steel shaft,
Styled handle,
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You can have further technical information, or by ordering one now you will see why we call it the Super 30.

*Illustration actual size.*

**Greenwood Electronics**

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Telephone: 0734-595844. Telex 848659

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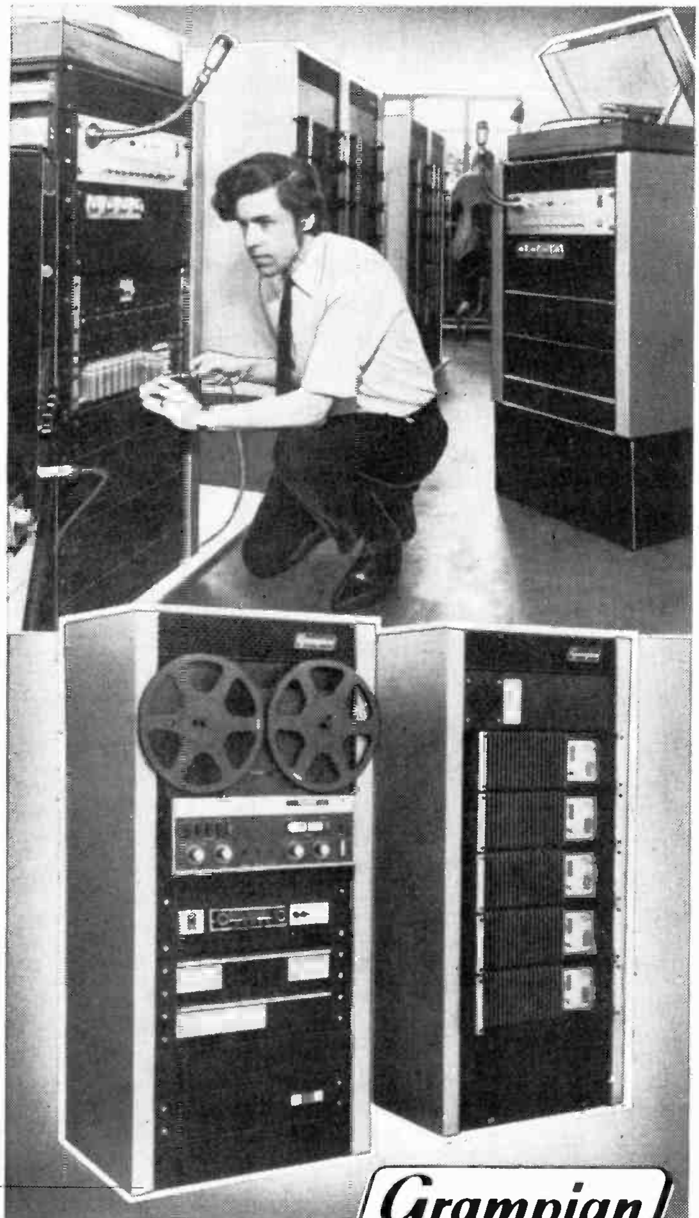
# Series 7 Amplifier Equipment –sound investment




Since Grampian introduced the Series 7 range in 1971 hundreds of satisfied customers all over the world have found it to be a sound investment. The high technical specification has set a new standard in engineering and reliability and the modular construction offers the most comprehensive and flexible system available.

Series 7 — Sound investment

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HIGH INTENSITY 7 SEGMENT READOUTS.
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ATTRACTIVE PROFESSIONAL STYLING
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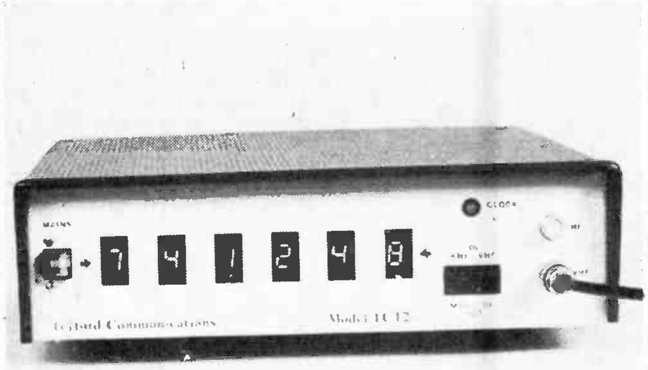
## THE TC12



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## NEW PEAK PROGRAMME METER

A PPM drive circuit with standard performance Manufactured under licence from the British Broadcasting Corporation it is based on the ME12/9 but with the addition of our electronic floating input circuitry which will withstand mains or static voltages on the signal line.

Intended for use in the most critical monitoring applications it possesses excellent temperature and long term stability Meeting BS4297, the proposed revision of BS4297 and the proposed new IEC Type 2 meter specifications, it also fulfills the requirements of the IBA, EBU and BPO

The circuit board is designed to mount on the rear of the meter movement and it accepts balanced or unbalanced signal inputs at line level The sensitivity may be increased by 20dB and the supply requirement is 24V at 30mA, either polarity or earth free

ERNEST TURNER 642 and 643 meter movements stocked with 1/7 and −22/+4 scalings

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*Industrial version* upgraded to studio requirements, with increased signal to noise performance and improved reliability. Four totally independent channels each with sel sync, input mixing, switchable VU's and all the facilities for easy multitracking. This industrial model is in more studios than any other version.

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*(Semi-pro version also available)*
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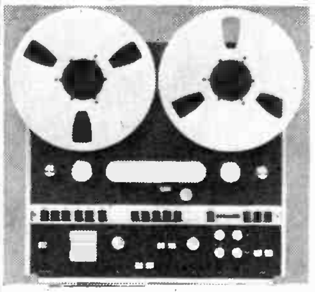
## REVOX A-700 SERIES



The new big Revox — ideal for all studio requirements. Highly sophisticated design features include servo tape tension; full deck logic, crystal controlled servo electronics, 3 speeds, tape footage counter.

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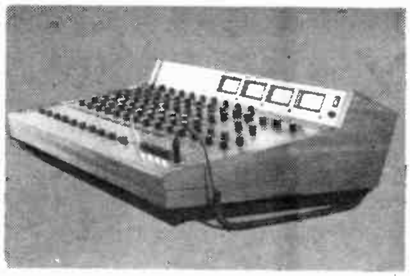

Ten balanced inputs; four output groups, 4 limiters; bass mid and treble EQ, modular construction, headphone monitoring. Extremely high quality construction only matched by mixers costing around £1,000.

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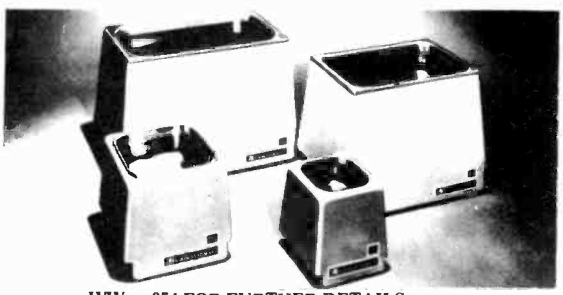

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# * The new Rank WOW & FLUTTER Meter Type 1742

**Fully transistorised**
for high reliability

**Versatile**
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**High accuracy**
with crystal controlled oscillator

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**Two models available:**
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**RANK FILM EQUIPMENT**

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# wireless world

## Electronics, Television, Radio, Audio

AUGUST 1976 Vol 82 No 1488


## Contents




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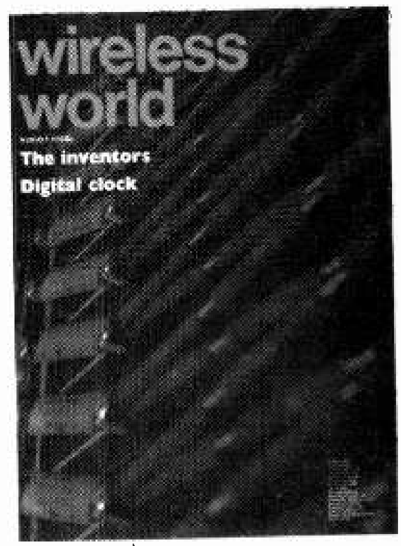


*Photographer Paul Brierley*

**Front cover** this month shows part of a high voltage generating circuit for an electron microscope made by the General Electric Company.

### IN OUR NEXT ISSUE

**Citizens' Band radio.** How CB has developed in the USA, how it is being used, and how the industry and FCC are coping with demand for equipment and channels.

**Projection television.** Technical survey of principles of optical systems used for projection and descriptions of equipment now on the market.

**Non-linear characteristics.** Circuits which need non-linearity for their action. Part 2 of series on characteristics and load lines.

SIXTY-SIXTH YEAR OF PUBLICATION


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wireless world

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## Broadcasting from on high

Direct broadcasting from geo-stationary satellites — for which we are now witnessing the first experiments — will certainly be a boon to the broadcasters. In the first place it allows coverage of enormous land areas, of a million or more square miles, at low cost from a single, sun-powered r.f. source of only 100 watts or so; and this is particularly economical when the population is dotted about in small isolated communities. It eliminates reception problems for people who live in mountain valleys or other places which are in the shadows for terrestrial broadcasting. And in countries which already have highly developed systems of terrestrial broadcasting it offers the possibility of additional services. In the last-mentioned situation, of course, the satellite broadcasting stations must use frequencies which do not interfere with the established terrestrial u.h.f. or v.h.f. transmissions used for existing services, and an article in this issue mentions how the 12GHz bands allocated by the ITU for satellite broadcasting will come into play here. A great advantage of such centimetre wavelengths is that they allow very selective coverage: satellite transmitter aerials of reasonable size can send very narrow beams to illuminate small areas.

One of the interesting, and difficult, problems that has yet to be faced with broadcasting satellites is interference — both in the frequency sense and in the political/social sense. Already there is a possibility of frequency interference occurring between synchronous communications satellites stationed above the Indian Ocean. With broadcasting satellites it is theoretically possible for country A maliciously to send programme signals to a satellite belonging to country B and so attempt to broadcast the programmes to country B, but in practice, of course, this would be pointless because both country A's programmes and country B's programmes would be made unintelligible by mutual interference. But malicious jamming could take place on this principle.

More innocent, but nevertheless potentially troublesome, is the possibility of overlapping service areas. We have already seen that India's television programmes can be received via the ATS-6 satellite in Northern Europe (March 1976 issue, pp.68-70) — though this might be dismissed as a DX-ing activity. A particular problem arises where there are adjacent countries with widely differing political/social/economic systems (e.g. Western Europe and Eastern Europe), and the sustaining of the different ideologies relies partly on the control of broadcast programmes. In such a situation the overlapping of service areas of broadcasting satellites may be seen as adding something new to the techniques of propaganda, even though it is not different in principle to the overlapping that occurs in conventional broadcasting. This problem of "overspill" in satellite broadcasting has already been discussed at the United Nations. For such reasons the development of satellite broadcasting services can never remain purely in the realm of engineering.

# Satellite broadcasting developments

## After India, first steps by Canada, Japan, Russia and Europe

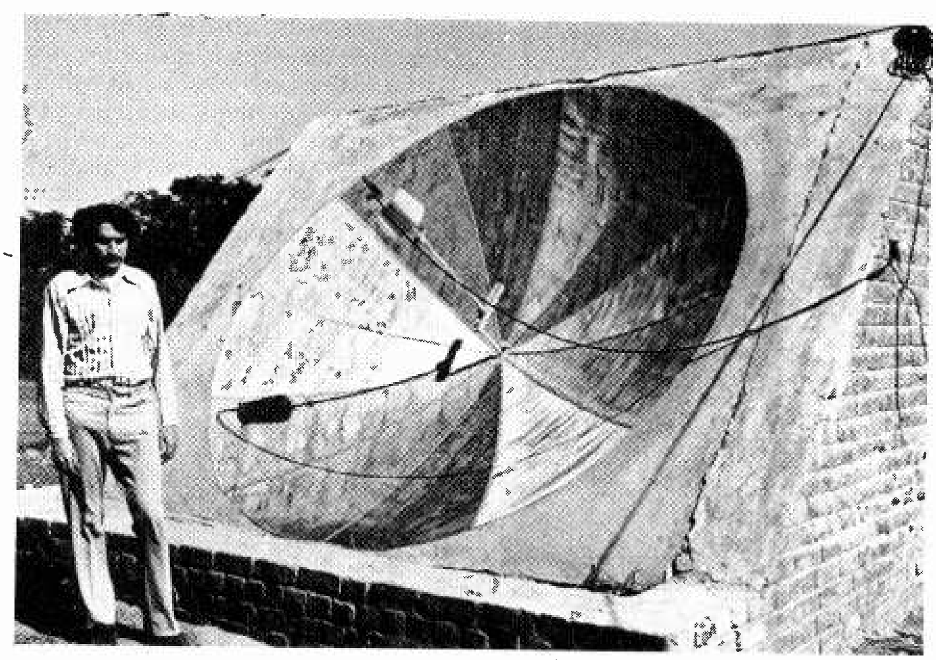
The undoubted technical success of the Indian experiment in direct television broadcasting from a satellite (see March 1976, p.68, Dec. 1975, p.549, Dec. 1973, p.609) has been a great encouragement to all engineers and administrators working in this field of direct broadcasting from synchronous satellites. The social results have yet to be assessed and the indications are that things are not as rosy as on the technical side – we have been told, for example, that the ATS-6 broadcasting experiment in 1975 for isolated communities in North America was considered a failure.

Meanwhile three more such experiments are going ahead, in Canada, Japan and the USSR. The Canadians have built a satellite, the CTS (Communications Technology Satellite) which was launched by NASA in January 1976, and among other things it is hoped to use the high power 12GHz transmitter of this to test experimental receivers for satellite broadcasting. Then in 1978 the Japanese will be broadcasting from a satellite built in the USA and also launched by NASA. The interesting point about these two experiments is that they are the first to attempt to use the 12GHz band allocated by the International Telecommunication Union for satellite broadcasting* and a new era of microwave television receiver technology is about to be ushered in. (D. B. Spencer and K. G. Freeman gave some indication of the nature of this receiver technology in their article "Television broadcasting from satellites" in our March 1974 issue.) Also, in January 1977, the International Telecommunication Union will be holding a planning conference for satellite broadcasting in the 12GHz band. A consultative group of the European Broadcasting Union for this type of service has in fact already stated that within the European broadcasting area it is possible to establish a plan for channel assignment, signal polarisations and positions of satellites in synchronous orbit that will allow each country to have a service of four television programmes and about 15 high-quality sound channels without causing unacceptable interference.

But why 12GHz? One basic reason for the choice of this allocation in the developed countries (e.g. Europe, Japan, North America) is that most of these countries already have established terrestrial broadcasting networks working on u.h.f. and the use of the ITU's satellite broadcasting allocation at u.h.f. would cause intolerable interference with these. By contrast the undeveloped countries (e.g. India, Brazil) have no such u.h.f. terrestrial broadcasting systems. A second reason for the use of the 12GHz band is that the small wavelengths in this frequency region, a few centimetres, make possible narrow beamwidths from the satellite transmitters — about 1° — so that small countries or small regions can be separately "illuminated" without too much overlapping or interference between transmissions. Also, small receiving aerials are possible (e.g. 75cm diameter with a satellite transmitter power of about 500W).

The Canadian CTS satellite — actually Canada's eighth satellite — was built at the Communications Research Centre near Ottawa, with subcontractors Spar Aerospace for the structure and RCA for electronics. It is in synchronous orbit above the equator at 116°W longitude and is maintained in station to an accuracy of ±0.2°, with comparable pointing accuracy, using

*Ancient and modern materials are combined in this receiving antenna used in India for the ATS-6 satellite television broadcasting experiment. Wire mesh dish is supported in a mud and brick structure built to face the satellite*



*At the 1971 World Administrative Radio Conference the ITU authorized a number of allocations for these direct broadcasting services: for Region 1, 11.7 to 12.5GHz, and for Regions 2 and 3, 11.7 to 12.2MHz, on a shared basis between satellite and terrestrial broadcasting and the fixed and mobile services (including fixed services by satellite in the case of Region 2 only); 620 to 780 MHz (u.h.f.) for f.m. television signals, provided these do not unduly interfere with existing terrestrial systems; 2.5 to 2.69 GHz on a shared basis with fixed and mobile services; and two other bands 41 and 43 GHz and 84 to 86 GHz. The Indian experiment, on 860 MHz, is not within the official u.h.f. allocation, and a permanent service in India would have to lie within the 620-780 MHz band or in a higher band.

three-axis stabilization (to which it was transferred from spin stabilization). Electrical power of about 1kW is provided by 27,000 solar cells carried on a pair of 22ft×4ft "sails". The transmitter's maximum r.f. output of 200W at 12GHz is provided by a travelling-wave tube, supplied by NASA, but unfortunately the associated power-supply switching system developed a fault soon after launching. It is hoped nevertheless that the high-power tube can be operated satisfactorily for certain periods. Also on board is a 20 watt 12GHz travelling-wave tube, contributed by the European Space Agency, which can be directly connected to the antenna to provide a lower-power transmission. Signals are sent up to the CTS in the 14GHz communications satellite band.

There are two gimballed antennas on the spacecraft, each being used simultaneously for transmission and reception. Each antenna provides a beam coverage area corresponding to that of a 2.5° circular beam, and can be positioned by command from the ground so that the beam can be aimed at any point within a 15° cone. In the transmission bands (11.843 – 11.928 GHz and 12.038 – 12.123 GHz) the effective isotropic radiated power (e.i.r.p.) capability is 60 dBW (compared with 51 dBW for ATS-6) when using the 200-watt tube.

Although initiated by Canada, the CTS project is a co-operative Canadian/USA experiment and the satellite is being shared by the two countries on a 50-50 basis. The main purpose of the project is to try out various methods of broadcasting and communication to remote areas, and it will act as a relay for over 20 experiments, some of which will be purely engineering and some for social, administrative, scientific, educational, medical, entertainment and other such purposes. One of the broadcasting experiments, conducted by the Canadian Broadcasting Corporation will be to evaluate reception of 12GHz television signals in a metropolitan environment, using a 2-metre diameter dish antenna and a professional receiver. Another is planned to test direct satellite-to-home television broadcasting using a 1-metre dish and ordinary domestic television sets with 12GHz front ends made in Japan and Europe. A further experiment will be in sound broadcasting – sending the programme signals from studios via the CTS satellite to individual sound broadcasting stations. British made 12GHz receiving equipment has already been set up in Canada for evaluation with the transmissions.

Canada's main ground control station for the CTS is in Ottowa and uses a 9-metre diameter dish antenna. The expected life of the CTS itself is about two years.

The Japanese experimental direct broadcasting satellite, called BSE (Broadcasting Satellite Experiment) and made by General Electric in the USA with sub-system by Toshiba, will be launched by NASA in February 1978. It will be placed into synchronous orbit over the equator at about 110°E, approximately over Borneo, and will keep in station with an accuracy of ±0.1° and have a pointing accuracy of ±0.2°. The 12 GHz transmitter will have two travelling-wave tubes, each with an r.f. output power of 100W, and the shaped beam from the satellite's antenna, which has an elliptical reflector, will be adapted as closely as possible to include the Japanese outer islands but to reduce the radiation impinging on China, Korea and Siberia. The maximum e.i.r.p. will be 58dBW. Power for the electronic equipment is provided by two solar cell "sails" with nickel-cadmium secondary batteries, giving a power of about 800 watts.

This experiment will provide two frequency modulated colour television channels, each with a channel bandwidth of 25 MHz, and a number of sound channels. Again the signals will be sent up to the satellite in the 14GHz communications band. Expected life of the experimental satellite is three years.

One of the reasons why Japan needs a broadcasting satellite is that about a million households are located in mountainous areas (about 22% of the population), in remote islands, or in shadowed positions in cities, where normal terrestrial television reception is poor. Also, the Japanese expect an increasing demand for educational television channels in their country, and these could well be provided by a satellite.

As part of this Japanese experiment, four types of ground terminal will be tested. The largest will be a transportable station with a 4.5-metre dish antenna and two-way transmission of television and sound signals. Next in size will be a mobile station with 2.5m antenna and also with two-way television and sound transmission. The third type of terminal will be for reception only with antennas of 2.5m and 4.5m; while the fourth type will be for high quality community reception, using a very rigid, carefully oriented 1.6m antenna and a high quality television receiver. For s.h.f. reception a very neat 12GHz front end has been developed by NHK, the Japanese broadcasting organization, with a very low noise figure (500K noise temperature over a bandwidth of 180 MHz), only one down-conversion frequency change, and housed in a small box of about 3in × 1in. There is also a simplified f.m. to a.m. modulation converter for use with the television receiver.

The service area of the satellite is envisaged as being in two parts. There will be an inner part, including the four main islands of Japan, and for this a medium power electromagnetic flux density (–99 dBW/m$^2$) will be provided, allowing the use of the 1.6m diameter receiving antennas and 500K noise-temperature receiver front ends. The outer part of the service area will extend over the remainder of the country, including the remote islands (such as the Sakishima Islands) and will receive a low power electromagnetic flux density (–110dBW/m$^2$) requiring the use of the 4.5m diameter antennas. The possibility of signal attenuation due to rainfall at 12GHz has been studied, but this proves not to be too serious. Investigations made in Tokyo show attenuations of 1dB for 1% of the time and 7dB for 0.01% of the time.

In Russia a synchronous satellite called Statsionar T for television broadcasting within the territory of the USSR is being launched this year. It will be placed above the equator at 99°E longitude, above the eastern part of the Indian Ocean and will transmit in the official ITU u.h.f. satellite band at 714MHz. Signals will be sent up to it on 6.2GHz from a ground terminal at Gus-Khrustalnyi near Moscow. The first receiving stations will be community reception centres in Siberia, eastern regions beyond the Urals and places in the extreme north of the USSR. Distribution of sound and television programmes will be handled by a second Russian satellite, a synchronous communications type named Statsionar 2, which will be stationed at 35°E longitude over East Africa near to the ATS-6, and this will operate in the well established 4GHz and 6GHz communications bands.

Europe seems to be lagging behind with 12GHz broadcasting satellites, in so far as the broadcasting and other organizations are still only at the talking stage. The EBU consultative group in fact reports that an experimental, pre-operational broadcasting satellite, probably developed by the European Space Agency, could be launched in about 1980. There is less urgency in this part of the world because the European countries are already well served by terrestrial broadcasting systems. As the consultative group says: "It is becoming more and more evident that satellites will in the future form the best means for the broadcasting of national programmes to countries with relatively large surface areas, the terrestrial networks being better adapted to regional local and special programmes (for which there is an increasing need) as well as, naturally, national programmes in smaller or more-easily covered countries." The consultative group points out, however, that it may be advantageous for EBU countries to change eventually to satellite systems for national programmes, in place of the present terrestrial networks. However, even if this were to be done, conventional terrestrial transmitters are still likely to be needed to fulfil requirements for local programmes.

# Teletext at Heda

The appearance at the Birmingham Home Electronics and Domestic Appliances exhibition of a large number of television receivers with teletext and Viewdata decoders built in may have deceived the casual onlooker into thinking that this type of set is almost in the shops. Conversation with the exhibitors, however, made it plain that this is not the case and that most of the equipment on view was not even of pre-production status.

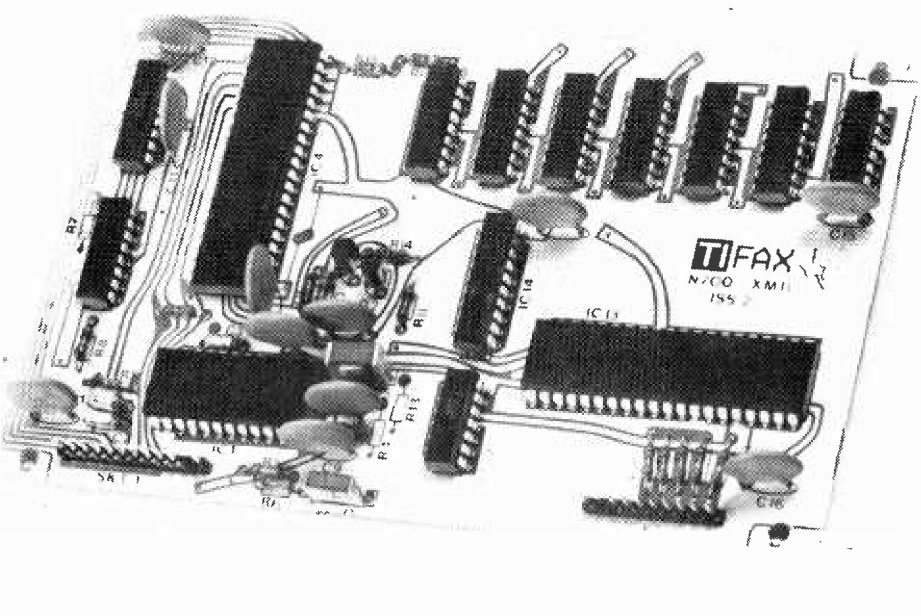
Many teletext receivers shown use the Tifax decoder made by Texas Instruments, for the very good reason that it is the only one available which employs large-scale integrated circuits to achieve a small and reasonably inexpensive unit. Some manufacturers said that they were using their own design of decoder, employing t.t.l. small or medium-scale integration (around 80 packages) but were "considering" Tifax or the Mullard l.s.i. module, when it appears. Most recent or new receivers can cope with teletext, but Rank Bush Murphy have used an acoustic surface wave filter in their i.f. amplifier for improved phase response. Degradation of signal down to the point where eye height (*W.W.* p.59, Mar. 1976) is 15-20% can be tolerated, according to most of the set makers we questioned.

All but one of the teletext demonstrations were by means of integral decoders, many using ultrasonic keypads combined with the ordinary receiver controls in a hand-held unit, but one company — Labgear — were showing an "add-on" decoder which can be placed in the aerial lead. To do this, the signal is processed by low-noise u.h.f. tuner and i.f. strip, passed to a Tifax decoder and the teletext characters (not the data signal) modulated onto a u.h.f. carrier. The performance of the i.f. amplifier in this kind of system should be better than that of the amplifier in a normal receiver, since the character clocking rate is 7 Mbit/s. The data bits normally received are also at 7 Mbit/s, but are of "raised-cosine" form and in a non-return-to-zero code, which gives a bandwidth of 3.5MHz. The Labgear display was not as sharp as that normally seen and it was explained that the response of the amplifiers was such as to turn the rectangular character waveform into a rounded shape.

Decca's teletext receiver uses the Texas X887 r.o.m., which forms part of the Tifax unit, in a decoder of their own design. Facilities provided by Decca include the display of channel number, date and time when changing channels and the possibility of a doubling in height of parts of the display.

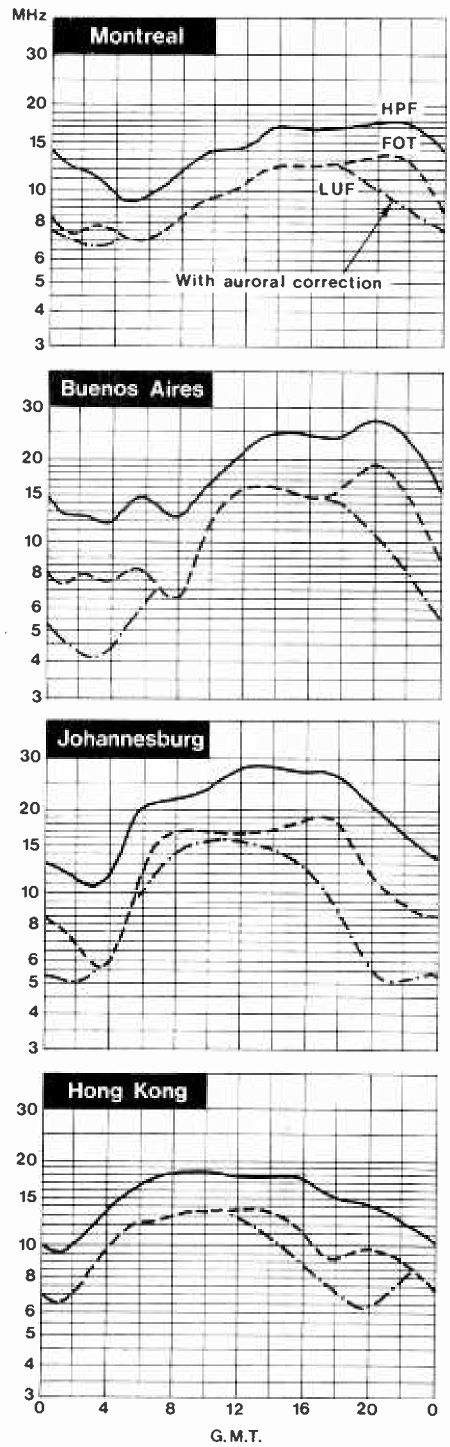
Viewdata was shown by most of the manufacturers, who use the r.a.ms and character generators already present in teletext decoders and use a universal asynchronous receiver/transmitter (u.a.r.t.) or a Post Office modem and microprocessor for the signal-conditioning and organisation of the data. Manufacturers seemed optimistic about the future of teletext and Viewdata, although Michael Butler of Philips did think that more tests of the system in Europe were needed.

*Tifax 14-package teletext decoder by Texas Instruments*




# HF predictions

There is still no sign that solar activity is moving away from the low level experienced for the past two years. Comparison with previous sunspot minimum periods shows that it will be unusual if an increase has not started by the end of August. Sunspot numbers for the next six months are required to confirm that a distinct upward trend exists, but once this has been established a long-range sunspot number forecast using an increase of five per month for the following eighteen months can then be made with confidence.



# The inventors

## Britain never had greater need of innovation and original ideas. Yet, when they do appear, how do we treat the innovators?

by John Dwyer

The traditional picture of the inventor is of one who is bald, bespectacled, and irredeemably dotty. However accurate that may be, it is usually true that the inventor refuses to listen to sensible advice, even that offered by those generally accepted as knowing far more about his chosen field of invention than he does.

But while his deafness may be an embarrassment to the new Royal Chartered aristocracy, the rest of us should be grateful for it. When D. E. Hughes demonstrated, with a telephone earpiece and what would now be described as a primitive copper-oxide rectifier, that he could hear the interruptions in a circuit located hundreds of yards away, the Royal Society were not impressed. He had walked up and down Great Portland Street, London, one day early in 1880 and the clicks in his earpiece could be heard 500 yards from where his "interrupter" was operating, but Sir George Stokes, president of the Royal Society, said the phenomenon was due to induction.[1,2]

Another example of "misguided" persistence was Edwin Armstrong's advocacy of frequency modulation. In this case, Armstrong had a proven record – he had already invented the superheterodyne and had several feedback patents to his credit. He patented f.m. in 1933, but he met with opposition from the radio companies, many of whom were motivated less by any consideration of the technical merit of the system than by avarice, since they and the set manufacturers already had a stake in a.m. According to one account,[3] Armstrong's idea was finally taken up by a rich friend, John Shepard, who owned the Yankee network. Shepard built a station for the new type of broadcasting and public demand did the rest. According to another[4] Jack Hogan of Radio WQXR, which was owned by the New York Times, co-operated with Armstrong, allowing him to present the first regularly scheduled programme on f.m. radio, using music from WQXR on July 18, 1939.

The demand for static-free radio was immediate, large and lasting. By December, 1941, f.m. receivers were being produced at the rate of 1,500 a day.

Despite the evidence available on the other side of the Atlantic it was May, 1955, before an f.m. service began in Britain. Field trials with low powered transmitters had begun ten years before, although, as Geddes[5] puts it, "The results were encouraging, but did not yield a conclusive answer to the question 'a.m. or f.m.?'" Wrotham transmitter was built as an experimental high power transmitter broadcasting both a.m. and f.m. signals. It started that broadcast in July 1950. The official f.m. service began five years later, 22 years after Armstrong's patent.

It is easy now to be critical of the American stations and the BBC because, with hindsight, we know that f.m. was a good idea. Many ideas aren't so good. Eric Laithwaite, professor of heavy electrical engineering at Imperial College, London, and developer of the linear motor used in the Hovertrain, commented: "For every exploitable invention that is worthy there are a thousand that are not, and if you sit in the corridors of power trying to decide, how shall you decide whether there is genius when you yourself are not a genius?"

### An inventive nation

As a nation we seem to have become used to the idea that we will invent the thing and the Americans will make money out of it. The Hovercraft seems a good example, but Britons invented the electric motor, the electromagnet, the telegraph, the computer, radio telegraphy, the radio valve, probably television, certainly radar and the cavity magnetron, to name just those things of direct interest to *Wireless World* readers. Others include Terylene, Rayon, polyethylene, stainless steel, foam rubber, Perspex, silicones, the electric vacuum cleaner(!), the disc brake, the carburettor, various forms of bicycle, Celluloid, the refrigerator, linoleum, the deck chair and the export-spinning miniskirt.

We don't always show inventors the door. Guglielmo Marconi had performed a series of successful experiments in his native Bologna but could extract no help from the Italian Government. So he came to England, and went to see A. A. Campbell Swinton at his home in Victoria Street, London. Swinton gave him a letter of introduction to Sir William Preece, Engineer-in-Chief of the Post Office and himself an experimenter in wireless. Thereafter Marconi prospered.

The site of the house Marconi visited in Victoria Street is now occupied by the offices of the National Research and Development Corporation, a government-backed body set up in 1948 to develop and exploit inventions from universities, companies, government research establishments or private individuals. The NRDC has come in for a great deal of criticism. Its position is, in many ways, untenable; either it is accused of rejecting too many ideas, largely by inventors who have approached the NRDC with an idea and been rejected, or it is accused of spending money on projects that are not a commercial success. In answer to the first, Roland Rosser, who deals with private inventions for the NRDC, echoed what Professor Laithwaite had said. Of all the inventions dealt with by the Corporation about three per cent were those of private individuals, he estimated, and "about 2½ per cent of private inventions are worth looking at." Many good inventions were snapped up by industry for development straight away, so that they never reached the NRDC.

Perhaps the most famous, and certainly the most expensive, private invention sponsored by the NRDC was the Hovercraft, and its sister the Hovertrain. Christopher Cockerell was an electronics engineer at Marconi's for 15 years after he began his career in 1935. Twenty years later he invented the Hovercraft and in January 1959 the NRDC set up a subsidiary, Hovercraft Development Ltd, to exploit the invention. Although the original amphibious vehicle still has the aura of a missed opportunity, perhaps a worse example of official blindness was the abandonment of the Hovertrain. NRDC set up another subsidiary in 1967, Tracked

Hovercraft Ltd, to develop it, but two years after doing so they discovered that the amount of money required to make the train commercially viable was beyond its means.

The Department of Trade and Industry told the National Research and Development Corporation later that no further funds would be advanced, with the result that the Hovertrain project was wound up in 1973.[6] Yet the amount needed was small, particularly when compared with the amounts spent on Concorde.

The NRDC does not have a free hand. It cannot supply money for the setting up of plant or machinery to make a product commercially. Their concern is to develop an invention from an embryo stage to the point at which it is ready for commercial production. Neither is it interested in the development of what it calls gadgets. The excuse is that it is spending public money and so must use the money for projects which they consider will be of public benefit.

The corporation finances itself, and pays off the money the government put in to start it off, by taking over the patents in a project, licensing them to industry and paying the inventor a royalty. The NRDC wishes that more private inventions would prove worthy of exploitation, but the apparent restrictions on the kinds of ideas that the NRDC can involve itself in make it unlikely that the number of exploitable submissions from private inventors will increase.

## Backers lacking

These restrictions have another effect. Mr A. L. T. Cotterell, secretary of the Institute of Patentees and Inventors, said that the total income of his Institute, including a DTI grant of under £2,000 was £18,000 a year. Most of it came from subscriptions. "The institute would like to back inventions but we don't have enough money. The government say the NRDC is there for that."

Tomorrow's World have done a survey showing that only one in five out of 2,350 published items ever saw production at all and of those only one in five hadn't "bitten the dust". These figures also have to be seen in the light of the rejection rate before the programme goes on the air. Many of the letters asking for an appearance on the programme do not reach Michael Blakstad, the editor, and of those that do about one in ten goes on the air, though other items appear which the Tomorrow's World team search out for themselves. The individual inventor usually has preference in the choice between two comparable items. Of the organisations that exist to help inventors he said: "My feeling generally is that it's not a very well organised field and that a really slick entrepreneur could make a lot of money." He also thought too few patent holders tried the simple expedient of advertising for backers in journals.

Professor Laithwaite was in no doubt about one cause of the problem: "Industry won't take on a half-baked project. Industry wants it presented to them on a plate, because their accountants say that it has to be that way."

But Mr Cotterell of the IPI was less critical of manufacturers. "You get inventors who claim that they have something important which nobody seems to be interested in. Usually the idea has no commercial viability or it may be unsuitable for some other reason." I asked him how the IPI could help: "We can hold their hands, and this is particularly important in the beginning." He gave the example of a man who had mortgaged his house and borrowed money from the bank to meet the cost of tooling up for the production of his invention. He ran into trouble with the tooling firm and eventually ended up in the courts. "We could have advised him so that he could avoid all that."

*Professor Eric Laithwaite.*

A characteristic of individual, as opposed to corporate, invention has been that some highly unlikely people have been responsible for the innovating. Legend has it that the dial telephone was invented by an undertaker, the hermetically-sealed refrigerator by a French monk, and the kodachrome process by two music students. Gillette was a travelling salesman in crown corks, Mr Biro, who invented the ballpoint pen, was a painter, and Dunlop was a vet. The parking meter was invented by a journalist, and all the various type of automatic gun that have come into use over the years have come from individual inventors who were also civilians. The phenomenon has led Christopher Cockerell to remark: "I sometimes think that if some competent electronics engineers got into the treasury and challenged their conventional wisdom, we'd probably have an end to stop-go in the economy."

## Pinch or pigeonhole?

No matter how complex your idea it is little use relying on the astuteness of civil servants to perceive its value. Eric Laithwaite's comments about Whitehall would have seemed more than apt to Christopher Cockerell as he tried to persuade various government departments to promote the hovercraft. Were he dealing with anyone else, one would hardly believe the difficulties he faced: "The Admiralty, on the grounds that it was not a proper boat, shuffled the device on to the Minstry of Supply. A demonstration was held in a basement in Whitehall where the little hovercraft, belching diesel fumes, buzzed around the floor at such a speed that one anxious civil servant jumped on to a chair."[7] The craft was put on the secret list, and Cockerell became convinced that officials were trying to pigeonhole the idea.

Sometimes officials seem to be doing rather more pinching than pigeonholing. For example, a tribunal of enquiry was appointed to look into the case of John Hargrave, who has conducted an eight year battle to win recognition for his development of a moving map navigational aid similar to that used in Concorde.

Hargrave, now 81, has documented the history of his autonavigator meticulously. On the afternoon of June 13, 1937, he was invited to Hatfield aerodrome to meet an RAF officer friend, Squadron Leader McKinley Thompson. He was appalled by the primitive way pilots were expected to navigate. The pilot had to draw a pencil line for his course and fold his maps over and over, all the time controlling the aircraft. He thought anout the problem and, according to his own account, the way round it suddenly came to him one evening, seven weeks later. "I stayed up all night," he told me, "and made a model out of bits of cardboard and paper and a child's magic lantern, and it worked." When his wife appeared at breakfast the following morning, July 31, it was ready.

The purpose of the instrument, which in its later form looks rather like a CRO, was to show a map of the land over which the aircraft was flying, with the position of the plane at the centre of the display. The map moved across the screen as the plane travelled. The display rotated as the plane changed direction, and wind-drift was allowed for.

Hargrave and Williams demonstrated the model to Smiths Instruments on February 9, 1939. They wanted Smiths to produce a gyro-controlled model, but Smiths wanted to know the attitude of the Air Ministry before they would do so. At a subsequent meeting with the head of the Air Ministry's navigation department, Wing-Commander P. H. Mackworth, D.F.C. they were told the air ministry had "failed so far to solve the problem of constructing an effective air navigation instrument in the form of a moving map . . . during the last 14 years." He was greatly interested in the instrument and asked that a written specification be submitted "so that the principals and mechanism can be carefully studied by the Air Ministry technical staff and the whole idea be thrashed out between them and my own department."

Next, the head of research department, Squadron Leader May, flight tested the Model II and reported that, in spite of the crudities of the hand-controlled, clockwork driven model the invention was, in his opinion, worth going on with. On the strength of this Hargrave applied for an air ministry development contract, but the war prevented this going further. On May 31, 1940 the device was used on a routine bomber run with the ordinary maps locked away. The pilot reported that he thought the instrument a practical form of moving map and suitable for use in his aircraft.

In October 1941, Hargrave received a letter from the director of technical development of the Ministry of Aircraft Production saying that there was no chance that the autonavigator could be put into production as there was not enough spare production capacity. Nevertheless, Hargrave and Williams pressed ahead. They demonstrated the Model II, in the following months, to an impressive list of defence top brass including Winston Churchil, Lord Beaverbrook and Air Marshall Sir Philip Joubert. As the *Sunday Times* reported in 1973, 'Of the 27 people who were given details of the Hargrave instrument, 23 were either officers or officials of the Crown, a vital point in Hargrave's claim."[8].

In May, 1942 Hargrave received a letter of agreement from instrument makers E. R. Watts & Son of Camberwell, London, to develop the mark III fully automatic model, and to pay a royalty of not less than 10 per cent on each one sold when the model was produced. The agreement was never carried out. According to the *Sunday Times* account, Hargrave never heard from Watts again. Four months later, however, he received a letter from a Group Captain Peter Stewart, who wrote to him from the War Office saying "I cannot too strongly urge you to continue development of this instru ment. . . ." Hargrave says this is the most important of the 19 official communications in his files. By the end of the war, however, his patents lapsed owing to non-payment of the yearly renewal fees.

Over twenty years later, the cover of the February 10, 1967, edition of the *Daily Telegraph Magazine* carried a photograph of the cockpit of Concorde. The prototype of the plane had not yet fully appeared, and the first flight was not to take place until March, 1969, but the photograph showed a section of the instrument panel to which the text referred as follows: ". . . There is even a moving map display, which continuously indicates the aircraft's position in relation to the earth below.".

*Michael Blakstad, editor of "Tomorrow's World".*

There are two main pillars to his case. He realises that his legal rights to the invention ceased with the lapse of his patents in November, 1946. He claims, however, that he is entitled to an ex-gratia payment, and cites the example of Sir Frank Whittle, whose patent on the jet engine expired in 1935, but who subsequently received £100,000 from the government.

The more substantial basis of his claim, however, is contained in the Report of the Royal Commission on Awards to Inventors (Use of Inventions and Designs by Government Departments). Paragraph 117 states that "where the claimant had shown that his invention was communicated to the appropriate Government Department and where in addition it was proved or admitted that an invention similar to that suggested by the claiment had been used in the service of the crown . . . the crown was required to show that the claimant's communication had not contributed to the Crown use . . . Unless it could be shown by the Crown beyond all reasonable doubt that this subsequent development was wholly uninfluenced by the claimant's communication, this residuum of doubt should weigh in the scale in favour of the claimant."*

## Whose transistor?

It often happens that an inventor doesn't get the credit for an idea he has thought up, though we must allow that whenever an invention is made public a horde of innovators descends yelling "I thought of it first." In conversation with Professor Laithwaite, for example, you discover that although Wheatstone invented the concertina, he didn't invent the Wheatstone bridge. He was responsible for producing the first linear motor, the second being made by Henry Fox Talbot, the father of modern photography, of all people, but it was Wheatstone's assistant who devised the bridge; Wheatstone merely gave the lectures.

If you asked most engineers who invented the transistor they will reply "Shockley". Shockley's own detailed account[9] of the discovery seems to confirm that view. "On 29th December 1939 I wrote a disclosure of what in principle was a sound concept of a semiconductor amplifier... Research in my notebook entries show that experiment based on the 1939 disclosure were carried out before Feb 6, 1940. However, my disclosure waited nearly two months, until 27/2/40, before it was witnessed by J. A. Becker, Walter Brattain, supervisor. Two days later on leap year day of 1940, Walter Brattain and I both signed a modification of the earlier disclosure. This disclosure . . . shows a more or less standard copper oxide varistor unit with two lines of metal forming electrodes on the surface of the oxide. It would today be called a Schottky-barrier, field effect transistor. It was prophetic of developments that were to come 20 years later as parts of integrated circuits using field effect transistors."

If Shockley was aware of any previous work he doesn't acknowledge it. The fact that he details the structure of a device which he did not make, and the principles of which he had later to abandon, suggests that he thought the idea original.

So did Oskar Heil. A recent article in *Hi-Fi News*[10] drew attention to the possibility that Shockley had not been first to think up a solid state device which might replace the valve. Heil took out his patent, British Patent Number 439 457 in 1935, a year after the German application. "This invention," states the second paragraph of the specification, "relates to electrical amplifiers and the like and provides novel apparatus adapted to effect alternating current amplification and to perform other functions, e.g. general control functions such as have usually been performed hitherto by thermionic valves. In general terms the present invention, which, as will be seen later, embodies a principle which is believed to be new and is based upon a discovery believed to be new – may be stated to provide a substitute for thermionic valves."

The device Heil describes is based on the theory that "if a semi-conductor be arranged as to form part of a condenser which is subjected to a varying voltage charge the resistance thereof will vary as a function of the said varying voltage and according to this invention this phenomenon or effect is utilised for amplifying or other control purposes." The device is nothing if not an insulated gate field effect transistor. Although the production techniques needed to make the device efficient were not available when Heil devised it, he says in the

*See "News of the Month"

patent that the best way to form the electrodes is by vaporising metal or by depositing metal by cathode dispersion.

The most likely explanation is that Shockley didn't know about Heil's work, and it may well be that more detailed researches would reveal pre-Heil devices which differed little from that which he patented. It is just strange that a *patented* device should so have been overlooked. "The things that humans are worst at doing is communicating with one another," said Professor Laithwaite. "I would not be aware of what my opposite number is doing in Newcastle. He might be doing something which is just the thing I want, I may never know . . . Our communicatiopn is our very worst feature as animals on this planet."

Laithwaite is the model of a good communicator, perhaps because he knows how important communication is. A close associate told me he was always in trouble for saying the wrong things in public, and one acquaintance said he was in danger of becoming 'a bit of a bore', but he seems to thrive on battles with the scientific establishment. "It's like the theatricals will tell you: only no publicity is bad publicity." He has less relish for personal criticisms directed at him by the press, and perhaps the wounds inflicted by the *New Scientist* after a discourse he delivered to the Royal Institution still hurt.

## Jones the gyroscope

To discover what all the fuss was about you have to examine the claims of one of a most remarkable character. Laithwaite, no intellectual slouch himself, described him to me as "a rare man," and said that some of the things he had written showed "the absolute hallmark of a genius." He did admit to grave reservations about the man's experimental method, however, and added that to touch the gems of genius in his correspondence you had to wade through a lot of things which were erroneous and inconsequential.

He speaks of Alex Jones, whose background as a heating and ventilation engineer has served only to allow him the great inventor's traditional freedom from too great a knowledge of his subject. Whatever the value of his thoughts, Jones is a highly original thinker, someone who can take nothing on trust. Conversation with him is stimulating, perplexing and, at times, disturbing.

He says that what set him off was a friend's asking, "Does gravity pull or push?" From that unpropitious beginning he has formulated a theory which, if generally adopted, would turn gravitational physics on its head, and has build a machine which, he thinks, defies gravity itself.

He questions all kinds of assumptions, the most basic being the usual interpretation of Newton's laws of motion. The second law, in particular, he says, has been misinterpreted. Newton's Latin phrase '*mutationem motus*' "is alteration of motion; it mentions nothing of momentum."

Further, he questions the usual account of the Michelson-Morley experiment, which was designed to determine the speed of the earth through the ether. The result, we are told, was null, and it was therefore concluded that the ether didn't exist and, later, that the speed of light was independent of the motion of the observer. This in turn led to the theory of relativity. Altogether the experiment is a crucial one in modern physics, but Jones says we've built the tower on sand. 'The result was very firmly other than null.' He says that the difference or displacement involved was about 0.02$\lambda$, where $\lambda$ is the wavelength of light. The reason the experiment was first thought to fail was that they were using a closed system, they measured phase displacement, and they took no account of Doppler effect. The ether, he postulates, does exist: "I know the shape of it, and what its structure is, even."

*Alex Jones, thinker.*

The existence of the ether is crucial to his theory, which is that gravitation "is a sort of pressure created by the motion of a mass which is going in a straight line." The masses moving through the ether produce a longitudinal displacement wave, he says. Two bodies moving relative to one another experience a mutually repulsive force proportional to their relative speed.

The next step was to demonstrate the theory. "How can I make a machine which has one part of it always moving faster on one side than on the other, which brings you to the gyroscope." A gyroscope spinning on its own axis exhibits no odd effects when its axis is stationary but, when the gyroscope axis is made to precess, the conditions he outlines above, assuming the existence of an ether, are fulfilled.

He devised and built a machine which was shown on Tomorrow's World two years ago. It is explained in a description of the experiment which he wrote in August, 1973. An electrically driven flywheel is mounted at the end of a pendulum hung by a universal joint from a frame which is then mounted on ball bearings. The spinning flywheel is moved to one side of the frame so that the pendulum is at an angle to the vertical. When the flywheel is released it precesses around the point of suspension but there is no reaction on the pivot. Not only that, but the frame in which the apparatus is mounted moves to follow the flywheel, not to go in the opposite direction. The experiment demonstrated, he thought, the creation of a force which could counteract gravity.

He took the experiment to Roland Rosser of the NRDC, who according to Jones saw it move across the floor in the way I've described. "I said 'Did it translate?', and he said 'Yes', and then proceeds to tell me why it didn't work." He also quotes Rosser as saying "My job is much easier if I reject everything." Rosser, naturally enough, is not prepared to discuss this or any other individual case.

Jones had arranged a meeting with Laithwaite and, in Laithwaite's private laboratory, had shown him a machine he had made, though not the one he had shown Rosser which, by this time, had gone to Hawker Siddeley.

Laithwaite has described Jones's experiments to me as "bogus". He told me the floor in his laboratory was not level, it has turned out, and so the experiment proved nothing. "He has made a number of machines and not one of them works. It is not that his experiments are wrong, it's the interpretation he puts on it. He makes the experiment appear to do what he wants it to do . . . Alex has yet to show me the first piece of convincing evidence that an object can lose weight."

I quoted to Jones what professor Laithwaite had said. Had the floor been uneven? "Yes, but he knows damn well that we've shown the machines go uphill because we always run them both ways on his desk."

What about none of the machines working: "Ah, but he accepts the one I showed Rosser." Laithwaite had not actually seen the Rosser machine, which ended up at Hawkers, but Jones had submitted a new explanation to Laithwaite as to why the machine worked and, according to Jones, Laithwaite said "Ah, we have at last a machine which could work." Jones admitted that he hadn't understood, at the time, why the machine did what it did, "But by God I understand now."

What about the "bogus" description? "But it wasn't, you see. Eric is now coming round to this in his maths. I can see it happening now and I know that in a year's time there's going to be one very surprised Eric."

Truth to tell, he may not be far out, though Laithwaite may remain unconvinced about gravitation. "The important thing," said Laithwaite, "is that Alex communicated with me . . . I tried to isolate the effect he'd got and one day

I came across an effect which was readily reproducible which was totally unacceptable to me in terms of conventional physics. And that set me on a road from which I have never turned back."

On the evening of November 8, 1974, Laithwaite gave a discourse at the end of which he presented a machine which he said violated gravity and produced lift without any external reaction. The machine was mounted on a set of kitchen scales. It consisted of two electrically driven spinning tops. The precession of the tops would cause them to rise were it not for a track attached to the frame of the machine. The tops followed the track and caused the machine to move up and down. Laithwaite said there was more upward movement than downward. Gyroscopes of the type used in navigation and direction finding were adequately described by Newton's laws, he said, being supported through their centres of gravity. But the child's spinning top, spinning on a point on its base, was not.

He maintained that the angular momentum of precession about a vertical axis was created out of nothing, so angular momentum about the axis was not conserved about that axis as suggested in Newton's laws.

He also said that the precession was not accompanied by any centrifugal force, that no force was needed to stop the precession, and that if the precession speed were increased the tops rise without there being any corresponding downward reaction at the point of spin.

The needle on the kitchen scales "swing violently between its upper limits and 15 pounds," said the *New Scientist*. The machine weighed 20 pounds at rest, they reported, and if the weight of the apparatus had oscillated between 15 and 25 pounds, showing no average change in weight, it would not have shown on the scales because the pointer had reached the end of its travel at 20 lbs.

Laithwaite replies that if you examined any set of kitchen scales the pointer will travel one and a quarter turns before it reaches its full deflection. "There were pulses of loss of weight," he insists, and adds that he knew a great deal more about it now. The machine had been finished at three o'clock that day, with the discourse due to start six hours later. He saw then that it oscillated. "I knew at once what I'd done wrong but there was no time to change it."

But a greater controversy arose when, a few weeks later, he said more about the subject in a televised Christmas lecture for children. His words were more guarded, but they reached more people. "I'm not saying Newton's laws of motion are wrong. I am merely pointing out that they are restricted to motion in straight lines, and to motion where there is no change of acceleration, just as there is no rate of change of current in Ohm's law . . . Gyroscopes do not exhibit a new force. They show the lack of a force where there should have been one." The force lacking, was centrifugal force.

To show this he made his eight year old son, Dennis, hold a pole, at the other end of which a flywheel rotated. Dennis stood on a turntable and, as the flywheel was speeded up, the boy turned round. The further he held the flywheel out the faster he precessed, but the flywheel did not fly out of his hands, and he had no difficulty holding the machine lightly from the very far end of the pole.

The lecture attracted sceptical comment from the *New Scientist* and 800 letters to Laithwaite himself. "They're from amateur, armchair inventors, and about a dozen of them proposed systems for loss of weight that worked . . ."

The NRDC's annual report for last year says: ". . . Gyroscopic anti-gravity devices have been arousing interest in the press and on television, and we have received a larger than usual number of proposals of this kind.

Roland Rosser said there were about a dozen gyroscope devices on the files which had been received during the year. "It's a very common submission. People think there's something odd about gyroscopes but they're not really peculiar. Lots of them come up to us with a gyroscope and say something strange is happening but it's all to do with the conservation of angular momentum."

Alex Jones said he could not demonstrate his machine as it was in pieces. I leave readers to sift for themselves through the snags with which his theories seem to abound, but they should note that his exploration of the gravitational mechanism has a number of historical parallels. During our conversation he made frequent references to a scientist called Le Sage, who had written a paper in 1782 which asserted that gravitation was caused by the impacts of streams of atoms.

In 1950, 20 years before Jones began to expound his beliefs, Paul G H Voigt, the inventor of the modern loudspeaker, was convalescing from an illness. He began to while the time by thinking about gravitation. As he admitted in the notes he completed three years later, he was not a physicist. He said recently that he had not heard of Le Sage even by 1957, in September of which year a speech he had recorded on tape in Canada was played to a gathering of the British Sound Recording Association. In the speech he stated what he had come to believe about gravitation.

## Either again?

Voigt's idea is that all matter is penetrated by sub-atomic particles travelling at or near the speed of light. They are so small that they may pass easily through the atomic lattice of which all matter is said to be composed yet, unlike Le Sage's particles, which were said to have a mean free path of some 10,000 miles, the Voigt particles are so numerous that they bump into atoms and into one another in a constant exchange of kinetic energy.

Gravity, he says, is the result of an imbalance of forces between those particles acting on a body from space and those that act on it having passed though the earth or another body. The gravitational effect will be proportional to the energy the particles have lost in passing through other bodies, that in turn being a function of what we have called mass. One body, in other words casts a gravitational shadow upon another.

The Voigt particles are travelling in all directions completely randomly. The gravitational shadow will vary as the distance between the bodies in accordance with the inverse square law: If the distance between two bodies is doubled the solid angle is halved and the subtended area reduced to a quarter.

These particles, if they exist, pervade all matter. They swarm through and over everything, and they are the ideal medium for the transmission of light and radio waves. Voigt's particles, in order words, suggest the stuff of which the ether is composed. All we may say with certainty is that none of us knows enough about gravitation to say that Voigt or Jones is wrong.

Almost as certain is that some day someone will build a machine that will demonstrably defy gravity. It may even be Jones or Laithwaite. Whoever it is it will not make them rich. Sir Christopher Cockerell knows more about that side of things than most people. He received a taxable £150,000 for inventing the Hovercraft, about the amount of a modest transfer fee for a professional footballer. "Inventing," he said, "isn't a way of making money. If you want to do that it's better to be a Beatle or an ice-cream salesman."

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# News of the Month

## Dolby f.m. up-date

Dolby Laboratories Inc., report that German stations have been broadcasting encoded B-type signals since mid-1975 with reportedly no adverse comments. As a result they expect full-time Dolby f.m. transmissions in Germany to start in the near future.

Last year, the Institut für Rundfunktechnik (IRT) in Hamburg carried out tests on Dolby B-encoded transmissions both in-house and on-air using the NDR transmitters in Hamburg. With a 50μs pre-emphasis time constant, listeners complained of a change in sound quality; when altered to 25μs – that recommended by Dolby Laboratories – no listener reaction was reported. Further tests, at RIAS Berlin, SR Saarbrucken and WDR Cologne, using a 25μs time constant and B-type encoding have not resulted in any adverse reactions, according to Dolby Laboratories. Results of a re-broadcast test from RIAS were said to be highly impressive, in which a professional receiver in Hof, 250km away, picked up the broadcast, and retransmitted it after decoding. In the WDR test transmissions the same programme (light music) was broadcast from two transmitters, one intermittently encoded and the other non-encoded, to enable direct comparisons to be made. Signal-to-noise ratio was studied in the service area and a report on these measurements is under preparation. The German broadcast authority, ARD, and IRT in Munich have also been making on-air television sound tests using B-type encoding, 25μs time constant and an increased modulation level.

Following FCC authorization of Dolby encoded f.m. transmissions in May 1974, there are now 130 stations using the system in the USA. In changing from 75 to 25μs pre-emphasis, these stations are able to increase their modulation by an average of 4dB, or reduce compression or h.f. limiting by a similar amount. In Canada, the Department of Communications gave approval for B-type transmissions in October last year and five stations have been equipped. Mexico approved the transmissions in 1974, while Brazil have six stations equipped with encoders. Tests are under way in other countries – Australia, Denmark, Ireland, Luxembourg, Norway, Sweden and Thailand.

In the UK off-air tests were undertaken last year by the IBA and authorization for further, on-air, tests is being sought from the Home Office. One proposal is to transmit the same programme from co-sited transmitters working on different frequencies in the London area.

There are now 27 products on the market with capability for receiving and decoding Dolby f.m. transmissions with the 25μs time constant, and 112 products that allow decoding with the 25μs time constant in conjunction with conventional tuners, including the *Wireless World* noise reducer.

## Sound broadcasting in Band I?

The possibility of broadcasting wideband high quality sound programmes in Band I is suggested by the BBC in a submission to the Annan Committee on the future of broadcasting. Hitherto it has been assumed that when the present 405-line television transmissions in v.h.f. Bands I and III are closed down (now expected to be in the 1980s) both these bands would be "re-engineered" for 625-line tv with 8MHz channels, as on u.h.f. The BBC's proposal, however, published in edited form in the April 1976 issue of the *EBU Review (Technical)*, points out that Band I could provide only a limited national coverage for tv. Band III, if extended to 222MHz, could provide a comprehensive national 625-line service in six channels.

For sound broadcasting, the BBC say, Band I could accommodate 12 or more wideband channels providing national or regional coverage for three or more programme services. Modulation could be either f.m., with ± 300kHz deviation using 650kHz channels, or a digital system – p.c.m. with four phase p.s.k. modulating the carrier and channels of 250kHz or 500kHz width. A strong point in favour of four-phase p.s.k. is that it does not require such a high field strength – actually estimated as 27dB(μVm) – as other possible systems to give good national coverage.

Another interesting idea put forward is that part of Band I could be made available for a "dedicated" teletext service with a channel width of 5MHz. All 625 lines would be filled with teletext data instead of just the four non-picture lines as at present. Also, the BBC recommend that extension of Band II to at least 104MHz should be considered.

## TI report world semiconductor slump

The world semiconductor market has dropped by over $900 million from the 1974 level to $4,100 million dollars in 1975, according to the annual report of the chairman of Texas Instruments, Mark Shepherd jr. The US market had declined by $500 million dollars in 1975, but total figures were expected to reach the former figure during 1976 and the semiconductor market would achieve $22 billion by 1980.

Semiconductor memory stores continued to displace magnetic stores because of further reductions in cost, the fastest growing component being the 4k random-access memory, demand for which tripled in 1975 and was expected to double again this year. The leading memory component by 1980, said Mr Shepherd, in terms of bits shipped would be the 16k r.a.m., samples of which were now being delivered. "The development by TI of a new, simplified structure for a charge-coupled device (c.c.d.) has made possible a significant increase in memory cell density. This has the potential of reducing memory costs below that of m.o.s. r.a.ms, enhancing the prospects for c.c.ds to serve in auxiliary memory systems." Pilot production of magnetic bubble devices, which need longer access times than c.c.ds but are non-volatile, has started at TI and samples are being evaluated for their equipment applications. A 100kbit magnetic bubble device was demonstrated last year packaged with bias magnets and drive coils.

## Sales chief calls for import curbs

A call for import controls on consumer electronics has come from the sales manager of Fidelity Radio. Mr Arthur Banford, in a statement issued in May, said that if controls were not introduced on Japanese and Far Eastern imports then large sectors of the industry would go bankrupt. He pointed to the Japanese invasion of the American market, which had forced many American firms out of business. "Now US businesses are beginning to argue, unsuccessfully, that Japanese firms are using their very strong base – over 10,000,000 a year – to cut prices so as to get a stranglehold on the north American market. The irony is that Japan operates one of the most effective import control systems in the world."

Of the one and a half million colour sets and tubes exported to Europe by the Japanese last year, he said, 600,000 came to the UK, even though it was a bad year for colour tv sales. In the year 170,000 music centres were sold in Britain and half were made in Japan. The radio market was worth £30 million last year nearly 85 per cent of which was imported. The Japanese share of the audio market had risen from £58 million out of £131 million in 1973 to £72 million out of £135 million last year. With the market picking up again and at a lower VAT rate, without controls, the Japanese share would increase further.

## Post Office backs large scale integration

The Post Office have approved General Instrument Microelectronics Corporation as the first m.o.s., l.s.i. microcircuit manufacturer to supply m.o.s., l.s.i. microcircuits in their equipment. Their D400 test procedure, under which the m.t.n.s. (metal thick-oxide nitride) process at GIM's factory at Glenrothes, Fife, has been approved, requires a service life for m.o.s., l.s.i. devices of 20 years with no more than 2 per cent cumulative failures. The Post Office has approved the use of the process for telephone exchange equipment.

In a speech at the beginning of the Communications 76 exhibition Professor James Merriman, Post Office Board member for Technology and Senior director, Development, Telecommunications Headquarters, said that by 1980 the British telephone service would be one of the country's largest users of microelectronics. Use of microelectronic devices will grow from four to 12 million devices a year in the next four years, accounting for ten per cent of the country's total consumption.

● Sales of l.s.i. test equipment will be worth over $2.25 million during the next year, according to l.s.i. Instrumentation Ltd, UK representative of the Macrodata Corporation. "Rapid growth in the use of microprocessors is making an l.s.i. test capability almost essential."

## Mobile radio research: Possible solution to fading

A major advance in mobile radio system design was claimed by W. Gosling of Bath University when he presented his paper "A feasibility study for a voice plus data mobile radio system of the future", at the Communications 76 conference held at Brighton in June. Professor Gosling said that since writing his paper, they had succeeded in producing a system which greatly reduced the loss of information due to mobile fading. The system, which used a method called sideband diversity, required two or more fixed stations transmitting the same information but with the modulations phase-shifted relative to each other, using wideband phase-difference networks. This resulted in the peaks and troughs of the upper and lower sidebands occurring in different places, enabling the mobile receiver to hunt at all times for the sideband with the heaviest peak, thus ensuring that the signal was always greater than zero. He stressed that phase-shift angles were not critical and could be as much as ±30°. The system developed for the Bath University project employed three 12W v.h.f. transmitters, sited on a 15 mile triangle, operating in the s.s.b. mode for speech and the d.s.b. mode for data. Sideband diversity is claimed to reduce errors sufficiently for error correcting codes and systems to be used to increase the accuracy still further.

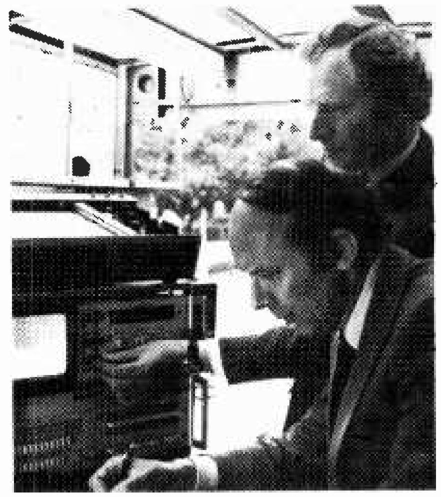
Professor Gosling's lecture created much interest among the conference delegates, and when R. C. French of Mullard Research Laboratories claimed similar results with error-correcting systems only, he pointed out that unlike the diversity system they did not help stationary vehicles located in bad reception areas.

Professor Gosling told *Wireless World* that Britain was certainly ahead of America and Europe in the field of mobile research, and this was a direct result of the Home Office sponsoring work at universities since 1969. "For this we are very grateful", he added (see also Mobile Radio Consortium formed).

## Mobile radio consortium formed

Bath, Birmingham and Bradford universities are to spend £100,000 a year on research into better mobile radio telephones and into linking them with teleprinter machines and visual display panels. The universities, which have been co-operating since 1974, have now formed the Universities Mobile Radio Research Consortium 1976 (UMRRC) to pool information and equipment and make sure their work is not duplicated. The research is backed by the Home Office Directorate of Telecommunications, the Science Research Council, the fuel and power industries and the Ministry of Defence.

The consortium is investigating ways of reducing fading and interference. Birmingham is developing techniques by which aerials on different parts of a vehicle pick up the same signal at different parts of the pattern formed when an incident and a reflected wave cross, so that loss of reception at one place is compensated at the other. They have built an add-on unit no bigger than a small portable radio for v.h.f. amplitude-modulated equipment and a prototype u.h.f. f.m. version. Bradford is examining interference at mobile radio base stations from other co-sited transmitters and from the interference produced by radiation reflected off rusty metal structures.



*E. D. R. Shearman (foreground) and J. D. Parsons of Birmingham University engaged in on-site measurements of the effects of car ignition interference on data communication to vehicles. The work is part of joint research carried out by the Mobile Radio Consortium formed with Bath and Bradford Universities.*

UMRRC says that the number of installations has grown from 1500 in Great Britain in 1950 to 176,000 in April this year. "At this rate", it says in a statement, "there will soon be no vacant channels in our larger cities unless the consortium can succeed in compressing more channels into existing wavebands. This will be one of its prime tasks." Mobile radio presently uses 70-170MHz (v.h.f.) and 425-470MHz (u.h.f.) and with the coming of improved crystal oscillators and synthesizers the Home Office have been able to reduce the intervals between channel allocations from 25kHz to 12.5kHz. The ultimate interval could be as little as 5kHz.

## Computer-aided radio surveillance

A commission placed by the British government four years ago has resulted in the development of CERES, a family of computer-enhanced radio emission surveillance systems. CERES, produced by Redifon Telecommunications Ltd, was first demonstrated at Communications 76 in June.

The operator has complete control over the equipment and, with real-time computer aid, the modular systems enable him to monitor communications traffic with greater efficiency. A typical system could consist of six operator-controlled consoles, each with facilities for remote-manual or computer control of four receivers. Associated equipment includes antenna selection units, two four-channel tape recorders, visual tuning aids for each receiver, and audio selection and control circuits. The receivers, aerial switching, receiver memories, computer, tape recorders, time-code generator and a disc store are all located in a suitable remote environment and can be automatically controlled by the computer. A v.d.u. provides the operator with control instructions and transcribes the received information. This facility enables the equipment to be used by relatively untrained operators. Specific frequencies may be monitored either continuously or at specified times and several frequencies within a selected band may be monitored in sequence at a chosen rate. It is claimed that the main advantage of these systems are that each operator is given the freedom to monitor as many as four frequencies simultaneously, transcribing one transmission in real time and, if necessary, recording other transmissions for subsequent replay and transcription. It is envisaged that these systems will find applications in the monitoring of distress frequencies and in channel utilisation, and in particular in defence and surveillance communication systems.

## Medical scanner prospects

EMI are expected to launch an improved medical scanner at the Radio Society of North America Radiological conference in Chicago at the end of November. Since EMI launched their brain scanner in 1972 with a scan time of four and a half minutes rival companies have tried hard to better the performance of the original design and some prototype scan times have now come down to 5s. Last year in Chicago EMI launched a 20s scanner and it is expected that this year they will unveil a unit with a scan time well below that.

EMI shares went up on the Stock Exchange in mid-June after a report in the *Evening Standard* claiming that EMI were about to launch a "new generation of scanners which use harmless ultra-high-frequency radio waves instead of potentially dangerous X-rays." EMI hastily issued a denial and pointed out that they and their associate companies, particularly Nuclear Enterprises, had been using ultrasonic techniques in medicine for many years now.

An EMI statement in May said it had sold £105m worth of scanners to date, 90 per cent for export. It has sold 538 systems: 384 brain and 154 body scanners. One million patients, they say, have been scanned by the 265 scanners in hospitals and clinics throughout the world. North America is the biggest customer having ordered 400 units, Japan have installed or ordered 37 and the UK 32. EMI won a 1976 Queen's award for exports of the systems, and another for technological achievement.

## Citizens' Band Association formed

A Citizens' Band Association has been formed by Mr James Bryant "to help establish a v.h.f. f.m. Citizens' Band in the UK". As Mr Bryant said in a letter in the June issue, he is opposed to the use of 27 MHz on a.m. for CB because of excessive television interference, audio breakthrough, the disruption of radio controlled models and co-channel interference during high sunspot activity.

The Home Office is still likely to adhere to the view that frequencies are so short that even a small Citizens' Band could not be contemplated. Despite the change in emphasis from 27 MHz a.m. on the part of those advocating CB, the Home Office is still worried that a flood of cheap foreign transceivers would ruin communications in that band, but it might be happier about a CB system which allowed a carefully monitored high quality home market to develop for British made equipment. All the same, potential British CB-ers face an uphill struggle. Home Office decisions will still be based on what they regard as the economic and efficient use of the existing available frequencies.

James Bryant's address is: The Citizens' Band Association, 16 Church Road, St Marks, Cheltenham GL51 7AN.

## Ortofon takeover

Harman International are in the final stages of acquiring the majority of shares in Ortofon, previously jointly owned by David Hafler of Dynaco and his partner Newton Chanin. Harman's announcement at the Chicago Electronics Show on June 14 coincided with news that Ortofon would no longer make loudspeakers. Only a year ago Ortofon took over the Danish Scan-Speak loudspeaker factory, which may now close. Although Harman says there is no connection between the two events, the possible closure may have been precipitated by Harman's reluctance to take on the factory, coupled with a prospective change in the terms of a contract Scan-Speak had with ITT. Since Ortofon took over Scan-Speak in July 1975 it has produced ITT and Pioneer speakers for sale in Denmark.

The discontinuation of Ortofon speakers came as a surprise to Metrosound, Ortofon's UK agents, who issued a statement on June 19 saying they had just received the news from Denmark. A month earlier they and other agents had attended a launch of Ortofon speaker products in Denmark. Unaware that the new range would be dropped, Metrosound showed it at HEDA at the end of May preparatory to launching an autumn advertising campaign.

Harman already own JBL and Tannoy and had no need of the as yet unknown Ortofon range, but for some time they have felt that the acquisition of a pickup manufacturer would be a logical extension of their list of subsidiaries. Newton Chanin was reported to have wanted to withdraw from Ortofon and Harman said they would take over his half if Hafler would surrender some, ideally all, of his shares to give them a majority holding. Some reports have said that the deal, which should be concluded well before the end of Harman's financial year on August 31, may involve a 20 per cent holding for Hafler.

Both Metrosound and Feldon Audio, who now handle Ortofon disc-cutting equipment, have said that they will continue to market Ortofon products. Harman's marketing policy varies, though some have noticed a tendency towards their doing their own marketing. Highgate Acoustics, agents for Harman Kardon electronic products, have just signed a contract to import Altec Lansing speakers, and from August 1 Harman will begin to market Harman Kardon from Tannoy's headquarters in South London instead of through Highgate. On the other hand, last year Harman transferred the JBL agency from Feldon to Colin Hammond.

## Hargrave loses on moving map display

Mr John Hargrave has lost his claim for an ex-gratia payment from the Ministry of Defence who, he said, had stolen his invention of a moving map display device eventually used in Concorde and the MRCA. The president of the tribunal of enquiry into the claim, Mr T. H. Bingham QC, said in his report that two of the necessary seven conditions for granting the payment had not been fulfilled. The two were that a causal connection had to be established between the communication of the details of the invention to the Crown and the subsequent use of the invention; and that before the invention was developed by the Crown there had to be no public disclosure of the information communicated to the Crown.

Mr Bingham added that even had all seven conditions been met the payment would have been in line with awards made by the Royal Commissions on Awards to Inventors, rather than the £1.5 million Hargrave and his colleague Cedric Williams were claiming. The case is described in "The inventors" article on p31.

# Surface acoustic wave devices

## Basic principles and applications as filters, delay lines and oscillators

by J. Heighway, B.Sc., Ph.D., M.Inst.P. *The Plessey Company Ltd*

The basic phenomena of the propagation of waves in materials have been understood for many years. Longitudinal sound waves and transverse waves are familiar enough, but surface wave modes are less well known except, of course, when they propagate on the sea. Surface wave modes are a combination of longitudinal and transverse particle motion and, in the context of occurrence in solids, were explained by Lord Rayleigh in 1885 in relation to earthquakes. Since then, the state of knowledge remained static for nearly eighty years until researchers in the USA achieved efficient generation of surface waves on piezoelectric solids.

This discovery produced an upsurge of interest in the research field, and, more recently, effort has been devoted to systems applications of the devices. Several properties of the devices are of interest to systems designers:

- the devices are of a planar structure and are therefore readily fabricated by establishments with i.c. production facilities
- the wave velocity is non-dispersive (independent of frequency) so linear phase devices can be readily made
- the device performance is almost entirely determined by the geometry of the electrodes, whose structures can be readily and accurately produced by computer-controlled drawing machines
- the waves are accessible over the whole length of the device, hence tapping is straightforward
- the substrates can be chosen to be stable, reproducible, and highly temperature invariant.

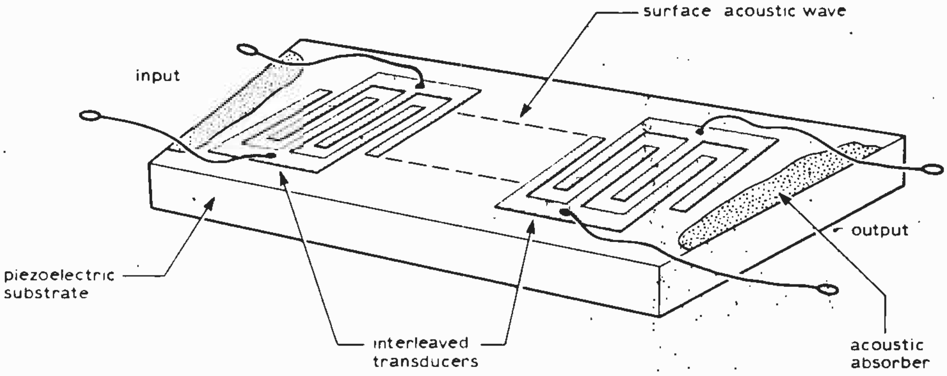
Surface acoustic wave (s.a.w.) devices have been under investigation at the Allen Clark Research Centre of Plessey for five years and units have been typically used as bandpass filters, dispersive delay lines, oscillators and discriminators. This article discusses the basic operation of the devices but more particularly highlights their use in systems and their potential. To this end, a number of specific examples will be given.

### Principle of operation

The basic s.a.w. device is shown schematically in Fig. 1. It comprises a carefully orientated and polished piezoelectric substrate onto which have been deposited an input electrode and an output electrode in the form of a thin film of a good conductor (0.1μm of aluminium is standard). The ends of the crystal substrate are covered with an acoustic absorber and are "angled" slightly to prevent coherent edge reflections. The electrodes are in the form of interleaving metal fingers.

The physical operation of the device relies on efficient use of the piezoelectric effect. In piezoelectric materials the application of a positive voltage to the surface causes a physical expansion and, conversely, a negative voltage causes a contraction. Hence by applying alternately positive and negative voltages to the surface a "corrugation" of the surface is produced (Fig. 2). If the

*Fig. 1. Simplified schematic of the basic surface acoustic wave device. Note angled ends of substrate.*



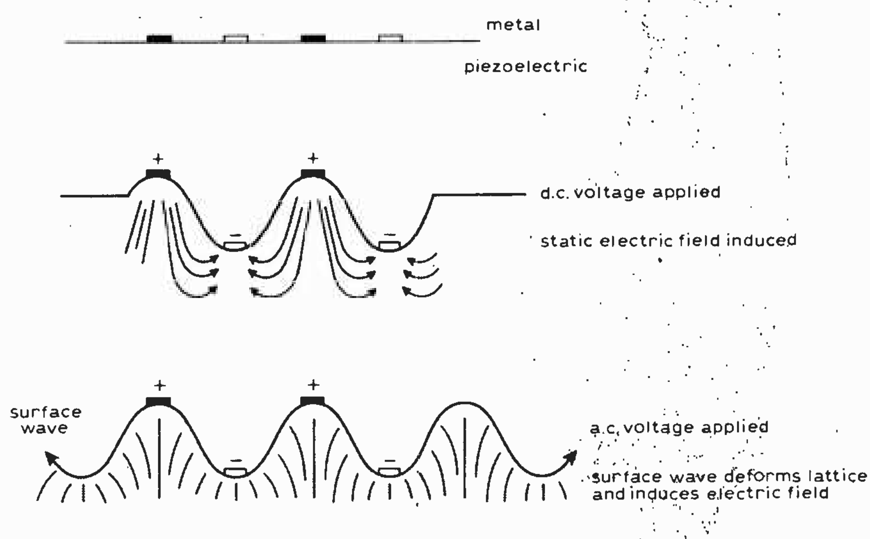




*Fig. 2. Physical operation of the s.a.w. device. Voltages applied to interleaved metal electrodes (black, one set; white, other set) cause disturbances in piezoelectric material surface which travel outwards as waves.*

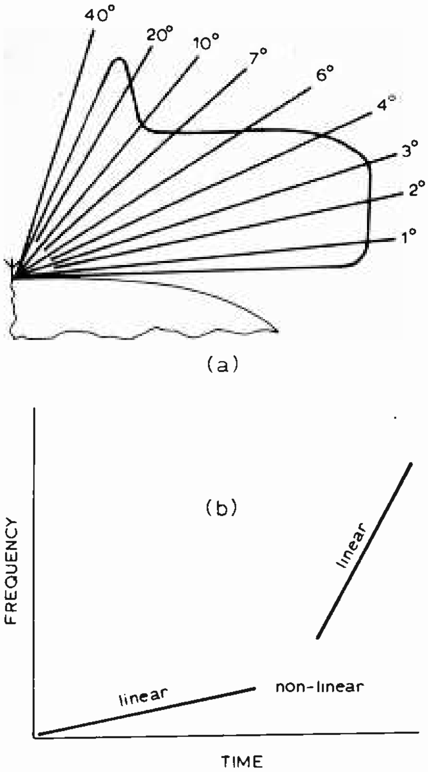



*Fig. 3. (a) Vertical plane coverage of a radar equipment resulting from the frequency sweep shown in (b).*

applied voltage is time varying then the physical disturbance travels both forward and backward along the surface. The acoustic absorbers remove the backward travelling wave and the forward wave is intercepted by the receiving transducer. The action of reception again relies on the piezoelectric effect. In this case the travelling physical disturbance has associated with it a travelling electric field. On passing under the interleaving metal fingers the charges induced on the surface are sensed by the fingers. A signal appears across the load that is the sum of the induced charges in the electrodes.

It is instructive to consider two of the analogous wave motions that are more familiar. For example the waves that are seen on the sea are exactly the same type of motion that is being utilised in the surface wave device. Many swimmers will have observed that gravity waves on the sea are a surface phenomenon and in fact 90% of their total energy is contained within one wavelength of the surface. A second and more sinister example was the recent earthquake damage in Europe where a distinct surface wave effect was detected. It was in fact from early studies of earthquakes by Lord Rayleigh that the wave motion got its name and it is worth emphasising that the surface of the crystal buckles and shakes (in a periodic manner) in an exactly analogous fashion to that experienced in earthquakes.

The basic design of the transducer is such that:

- the width of each finger and the gap between them is one quarter of an acoustic wavelength (typically 8μm at 100 MHz)
- the length of the fingers (overlap) is determined by the power of the source to which the device has to be connected
- the number of fingers depends on the device function.

This demonstrates the fundamental control that the device designer has over the function through its geometrical shape. It also shows clearly that not only is the device highly reproducible but that it cannot be changed once produced — if it does not function correctly it must be redesigned.

**Table 1**

| Application | $f_0$ (MHz) | $\Delta f$ (MHz) | Sidelobes (dB) | Shape | Insertion loss (dB) |
|---|---|---|---|---|---|
| TV vision carrier | 39.5 | 1 | −30 | symmetric | 20 |
| TV transmission | 37.5 | 8 | −40 | square | 20 |
| Radar | 30 | 6 | −25 | symmetric | 24 |
| Radar | 250 | 80 | −25 | flat symmetric | 30 |
| Oscillator | 1000 | single mode | −20 | symmetric | 15 |
| Communications | 23.5 | 0.08 | −40 | symmetric | 15 |

**Dispersive delay lines.** The simple design procedure for a s.a.w. delay line readily lends itself to the design of a

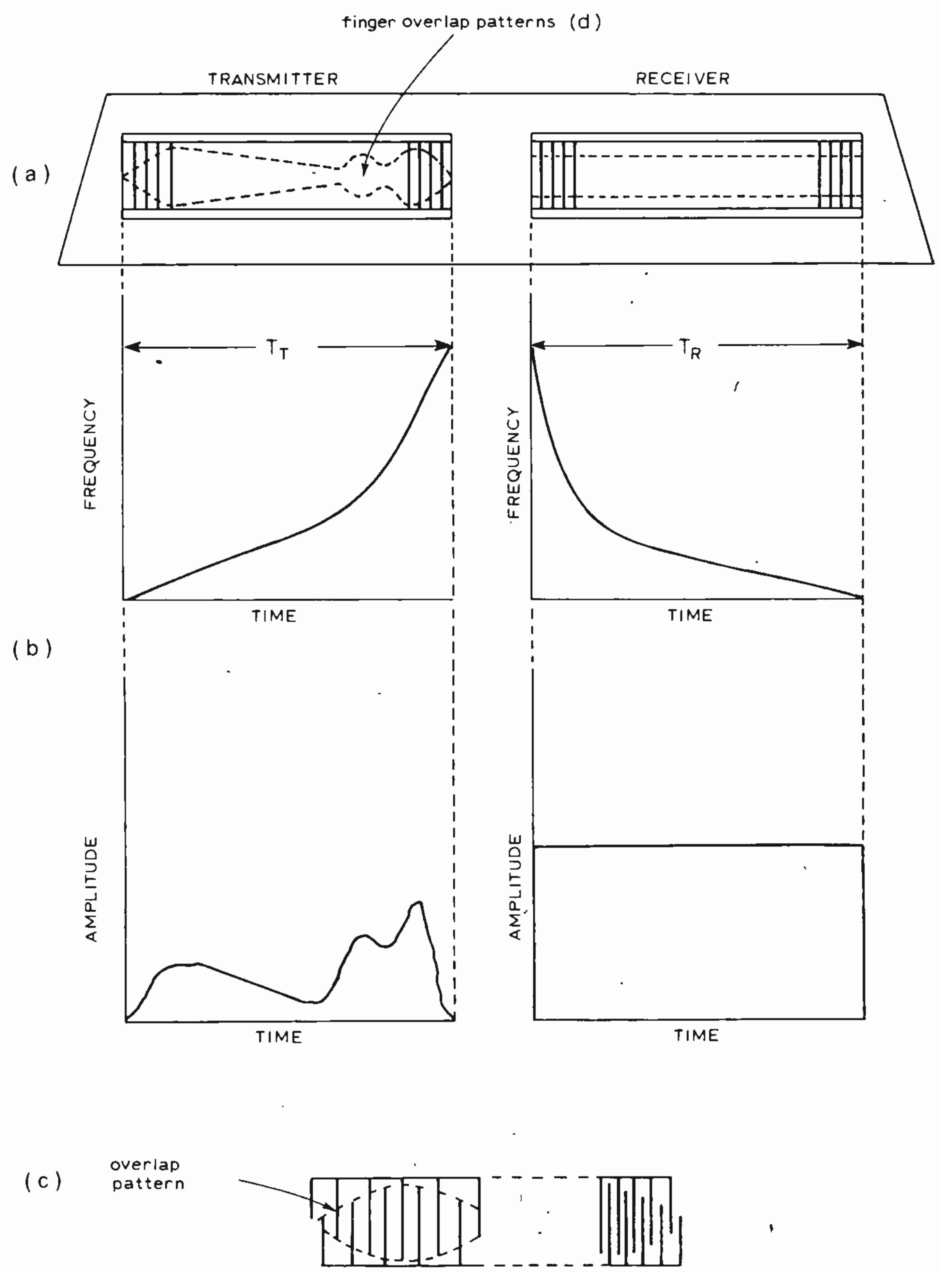



*Fig. 4. Dispersive delay line design: (a) pattern of finger spacing and overlap; (b) frequency/time characteristics of the device and amplitude/time characteristics achieved by (c) variation in finger spacing and/or overlap.*

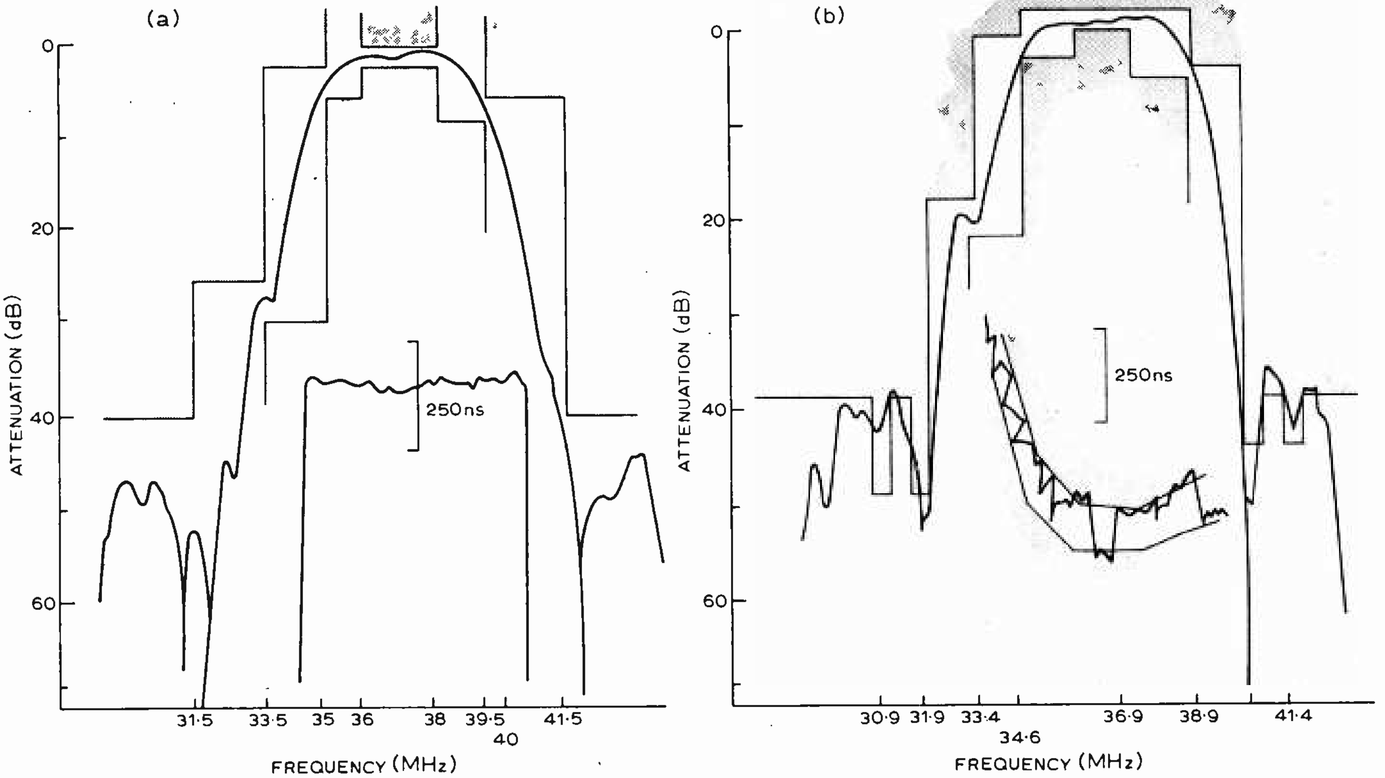



*Fig. 5. (a) Band-pass responses for a UK television i.f. filter: upper curve, amplitude/frequency response; lower curve, group delay response with 250ns interval of time scale marked. (b) Band-pass responses for a PAL i.f. filter: upper curve amplitude/frequency; lower curve, group delay. In both (a) and (b) the shaded areas show tolerances.*

dispersive delay line. It was soon realized at Caswell and the Radar Research Centre that the s.a.w. technology could contribute directly to the development of an advanced radar system. In a previous article[1] on the Plessey AR3D radar, mention was made of the s.a.w. equalizer application. Here the important parameters are stability, linearity of response, and the precision of the response over a relatively large bandwidth.

The s.a.w. devices are sophisticated dispersive delay lines not only because the phase/time characteristic is determined accurately by the device but because the required amplitude/frequency characteristic is provided. The characteristics of the devices for the AR3D are the conjugate of the frequency/time characteristic of the transmitter which is determined by the required coverage diagram of the radar. A typical example is given in Fig. 3 and the plots of the finger overlap weighting required for the two transducers are given in Fig. 4. It is worth noting that the dispersive delay is achieved by the transducer structure and not by the nature of the wave — pairs of fingers close together generate high frequencies, large separations generate low frequencies.

The design of devices to fit given input data is now a completely computer-oriented process. A set of programmes exists, and from inputs of the required phase law, time length, and amplitude/frequency response, the transducer design is produced on magnetic tape and in the correct format for a computer-controlled drawing machine. The programmes include correction routines for a number of second-order effects, including the highly significant diffraction correction. In addition, the basic finger geometry is chosen to minimize inter-electrode interactions and mechanical loading of the wave path.

The type of performance that can be achieved using these techniques is as follows:

| | |
|---|---|
| Time-bandwidth product range | 4 to 1000 |
| Time length | 0.25μs to 50μs |
| Bandwidth (at 75MHz) | 1MHz to 50MHz |

The control of both the amplitude and phase characteristics is sufficient to give 31dB close-in sidelobes. The use of this approach has made temperature-stable dispersive delay lines readily achievable and devices are now fully engineered.

**Bandpass filters.** The successful operation of a dispersive delay line — which is, in some ways, a bandpass filter with a particular phase/frequency characteristic — naturally leads to the design of more complex filter shapes. One range of filters is that comprising the television receiver i.f. filters for the UK, USA and Europe. In this application, the important parameters are:

- cost, as first and foremost the tv industry expects low-cost devices
- no tuning or adjustment — which also reduces cost
- small size
- electrical performance.

In fact, the performance requirements can be quite stringent for such systems as cable tv and data transmission.

The electrical characteristics are best illustrated by diagram, as in Figs. 5 (a) and (b). Here the experimental responses of two devices are shown — the first is the UK tv filter which has linear phase, and the other is the European PAL filter which has a controlled non-linear phase.

The design of these devices is an extremely involved process but basically follows the scheme used for the dispersive delay line. The required input data consists of the amplitude and phase of the filter and, since cost is a parameter, the maximum time length allowed must be an input (the time length relates directly to the physical length because of the non-dispersive nature of the wave). In addition, the tolerancing on both the amplitude and phase must be inserted, and is shown in Fig. 5. In this way, for example, the 6dB point of the vision carrier and the 25dB value of the in-channel sound can be set exactly.

In general, the synthesis of a given filter shape is more difficult than for a dispersive device, but only because the time length has to be minimized. The resulting transducer structures are extremely involved and a typical example is shown in Fig. 6.

These tv filters are now marketed through the consumer division of

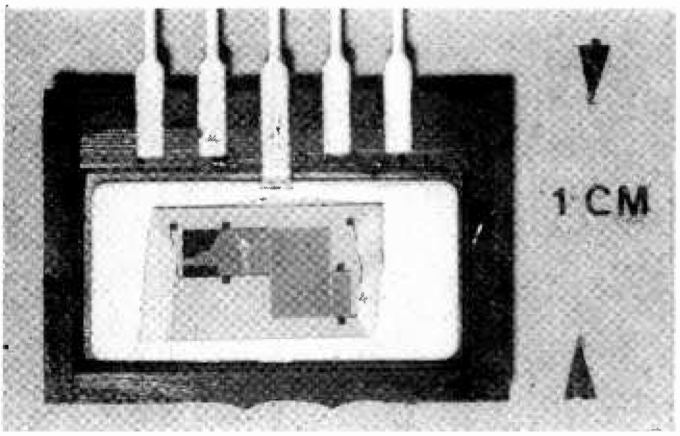



*Fig. 6. Bandpass i.f. filter for television using a s.a.w. device.*

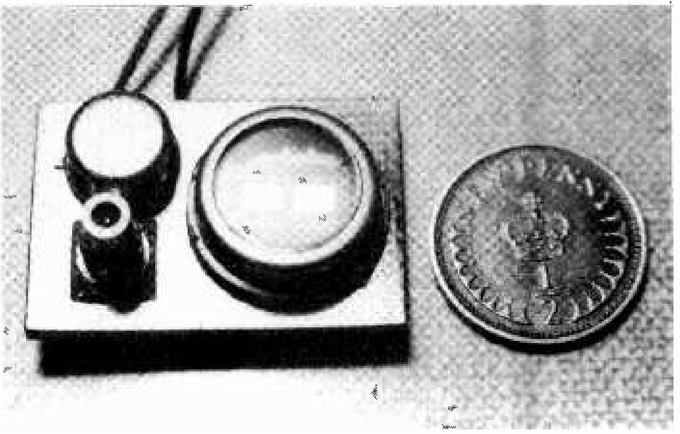


*Fig. 8. Example of a 490 MHz s.a.w. oscillator.*

Plessey Microsystems under the numbers SW150, SW170 and SW200[2]. The devices can be packaged in either a standard TO8 housing or a Plessey design of plastic flat pack.

The tv filters are just one example of the type of filter that can be produced by s.a.w. techniques. A whole range of professional filters is possible and Table 1 lists some examples of typical parameters.

**Oscillators.** The inclusion of a simple bandpass filter in the feedback loop of an amplifier can provide a highly stable oscillator. A schematic of this arrangement is shown in Fig. 7, and Fig. 8 shows a typical device.

A number of advantages is offered to the system designer by these devices:

- high fundamental frequency operation — the device can operate at any frequency within the range of the s.a.w. delay line, namely, 10-1500MHz
- quartz short-term stability — typical figures using the Avantek GPD series amplifiers show 1 part in 10[illegible] over 1 second
- a frequency modulation capability that exceeds 1 per cent — which is a significant improvement over existing alternatives
- a fast warm-up time to reach an operating temperature — the device uses its package as an integral heat-sink
- small, robust and potentially cheap.

A disadvantage of the technique is its medium to long-term drift of, typically, 2 p.p.m./month. It should, however, be attractive to have the short-term stability of the s.a.w. device combined with its f.m. capability and to use this in conjunction with a locking system, either to a bulk wave crystal (normal phase lock loop) or to an atomic standard. Also, there should be a significant market application where cheap, stable oscillators are required for short-term use — for example, in sonobuoys or marine distress beacons.

## S.a.w. sub-systems

The s.a.w. devices discussed above have been used mainly in retrofit applications. The wide bandwidth capability of the devices has been exploited by their incorporation into radar systems, and their reproducibility and low production costs have been used in tv applications. But in a more general way, the devices can be incorporated into novel sub-systems to take advantage of their versatility and, of greater import, may generate new system configurations.

A few of the more significant ideas incorporating s.a.w. devices, and currently available, are briefly outlined in the following paragraphs.

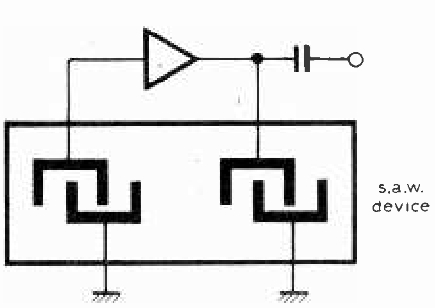
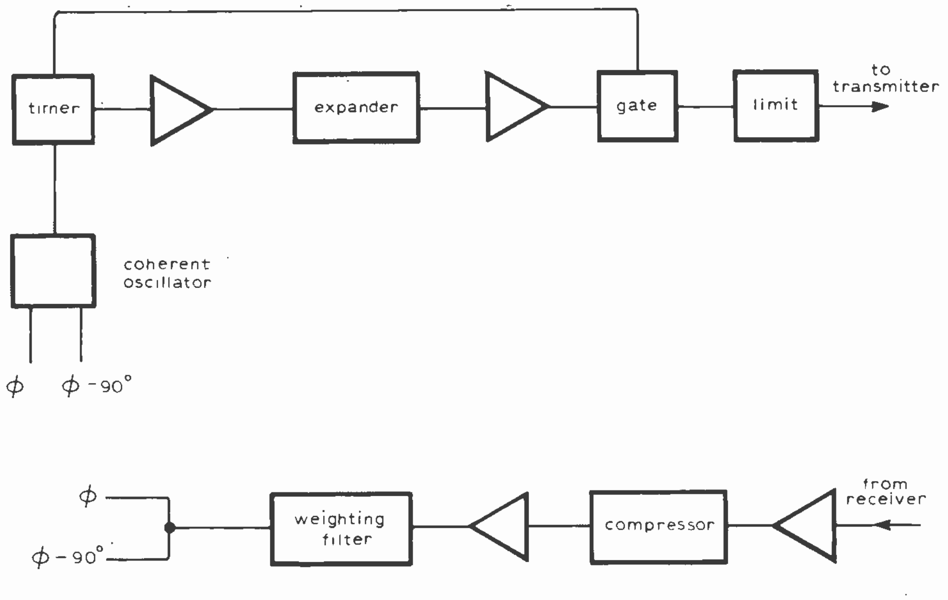



*Fig. 7. Simplified schematic of a s.a.w. oscillator.*

*Fig. 9. Coherent pulse compression system. The blocks with shading around them use s.a.w. devices.*




**Coherent pulse compression units.** The block diagram of a complete unit is shown in Fig. 9. This is an example of how much *can* be done using s.a.w. techniques rather than of how much *should* be done. The shaded units in the diagram use s.a.w. devices. The incorporation of both passive generation and matched pulse compression into a small unit has the advantage of temperature tracking of the devices and ensures a good match over the whole temperature range.

**Compressive receiver.** For a linear frequency/time dispersive delay line the relationship between the delay of the output and the frequency of the input can be used as a fast spectrum analyzer. The relative ease of fabrication of the s.a.w. device has meant that compact units can be fabricated that enable users to identify the frequency components of an incoming pulse after mixing down. The principle is simple and is illustrated in Fig. 10.

The s.a.w. expander is continuously impulsed (and therefore scans a frequency range), the start of the impulse being the reference. If two signals $f_1$ and

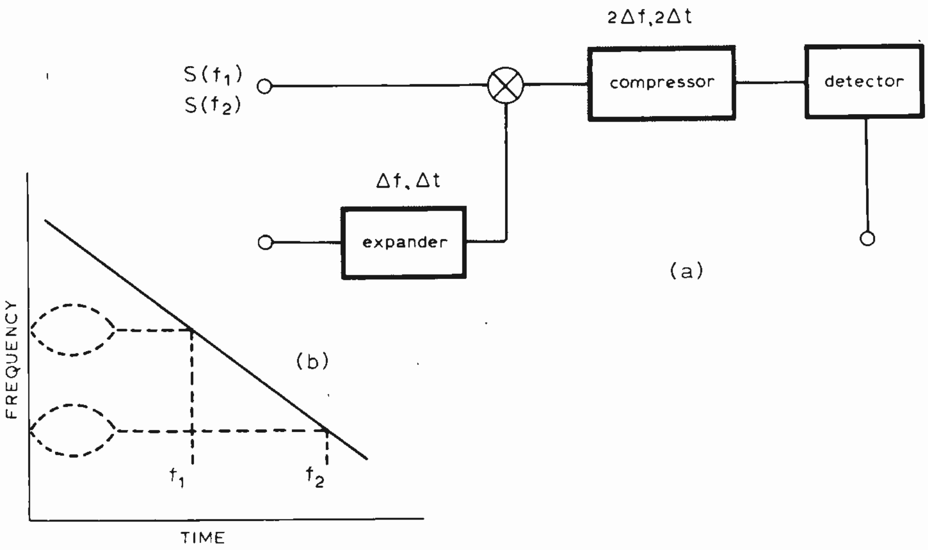



*Fig. 10. (a) Schematic of compressive receiver; the shaded blocks contain s.a.w. devices. (b) Principle of operation of compressive receiver; the bulbous areas in broken line represent the pulse shape after mixing.*

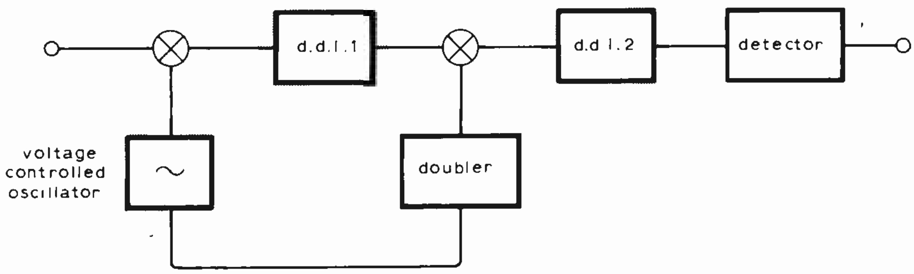



*Fig. 11. Variable delay line. Shaded blocks are those containing s.a.w. devices.*

$f_2$ come into the system at the same instant of time, the frequencies will be resolved by the system into two compressed and distinct pulses. These processes have been discussed in detail by Grasse and Gandolfo in an article[3], in which they conclude that the s.a.w. implementation of the technique offers the best potential for future development.

**Variable time delay.** The dispersive delay line (d.d.l.) can be used very simply to provide a variable analogue delay line[1]. This system, outlined in Fig. 11, operates by delaying the input signal by an amount proportional to the local oscillator frequency. The output from d.d.l.1. is distorted by the phase characteristic of the delay line, but this distortion is readily removed by mixing with the doubled local oscillator output and again convolving the output with d.d.l.2.

The delay can be varied by simply varying the local oscillator frequency, and units have been made which operate over a range of 4 to 60μs, continuously variable. A neat extension of this approach is to vary rapidly the frequency of the local oscillator in such a way that the time length of the input information can be changed and hence data rate modifications made. These techniques are currently undergoing intensive research and show promise in particular applications.

**Synthesizer.** The s.a.w. oscillator has been mainly used in single-mode operation but multi-mode operation has always been possible. In practice, the mode separation is the reciprocal of the time delay, and hence for a 500kHz spacing a 2μs delay is required. What has always been difficult has been the selection of the required mode, but a particularly elegant solution has been proposed and demonstrated by Maines at the Royal Radar Establishment, using a number of the s.a.w. device properties discussed above.

The basic principle is that the s.a.w. oscillator can be injected. The signal for use in this is provided by a voltage controlled oscillator and the system operates as shown in Fig. 12. This synthesizer offers a very economic substitute for what is currently an expensive item. It provides the properties of short-term stability and f.m. capability inherent in a s.a.w. oscillator, outweighing any s.a.w. device disadvantages for systems such as radar where frequency agility is attractive and short-term stability is required.

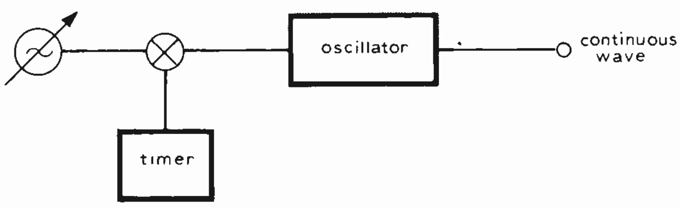



*Fig. 12. Use of s.a.w. device (shaded blocks) in a frequency synthesizer.*

## Conclusion

To sum up, within the last two years surface acoustic wave technology has progressed from being an interesting research project to full system realization in various capacities:

- pulse compression units are being incorporated into advanced radar systems
- television filters are being produced in reasonable volume and gaining acceptance in the industry
- professional filters and oscillators can be designed and are available on a custom-design basis
- novel sub-systems are being developed which should impinge on system design within the next few years.

## References

1. D. L. Motkin. "Three-dimensional air surveillance radar", Plessey *Systems Technology*, No. 21, p.29 (June 1975).
2. J. M. Deacon and J. Heighway. IEEE Spring Conference 1975 (Chicago) on television receivers.
3. C. L. Grasse and D. A. Gandolfo. Ultra. Symp., Boston 1972.
4. J. M. Deacon *et al. Electronics Letters*, No. 10, 1973.

# American CB boom

More than 200 stands at the recent US Consumer Electronics Show in Chicago displayed Citizens' Band radio equipment. CB is now a £300M market in the States. It is estimated that four million units were sold in 1975, which is 25% up on the previous year, and that now about half a million units are being sold each month. This volume of sales has created a licensing jam at the FCC. Sources in the US electronics industry forecast that the sales value of CB equipment will surpass all other consumer electronic products except colour television by 1980. *Wireless World* will be publishing an article on the CB "scene" in the States later this year.

# Letters to the Editor

## LOW NOISE CASSETTE DECK

We should like to take the eminent Mr J. Linsley Hood to task for advising the use of the 70 μs equalisation characteristic for use with normal low-noise ferric cassettes. This is most misleading because one of the most serious problems with these cassettes is their lack of response to high-level, high-frequency signals; the 120μs post-emphasis was adopted to try to alleviate this. Even this results in a fully-saturated recorded level of about 10dB below Dolby level at 10kHz. Adopting the 70μs equalisation characteristic reduces the h.f. overload figure by almost another 5dB which makes an already bad situation intolerable. This would produce severe h.f. intermodulation distortion when recording typical musical material at "normal" mid-band modulation levels.

The reason that the 70 μs equalisation is adopted for chrome cassettes is simply that they are much less susceptible to h.f. overload because of the smaller particle size and higher coercivity of the oxide formulation.

We would, however, endorse Mr Linsley Hood's suggestions for optimising bias and equalization settings. In our opinion too many manufacturers align their machines to attain the ultimate in frequency response (or "specmanship") to the detriment of other aspects of the reproduced quality. One notable exception to this is the British manufacturer NEAL, who quite deliberately align their machines to be −2dB down at 12kHz on ferric tapes. This compromise produces a similar result to that obtained using Mr Linsley Hood's square wave technique.

C. J. Evans,
J. Dawson,
A&R,
Cambridge.

*The author replies:*
The original Philips recommendation for the equalisation of the "Musicassette" was for time constants of 1590 and 120 μs, of which the first was to compensate for anticipated inadequacies in the l.f. response and hum pick-up problems with the circuitry, and the second was to remedy the known shortcomings of recording head and tape characteristics. Improvements in system design have led to the universal adoption of the 3180 μs low-frequency equalisation time constant, to bring the cassette system into line with other reel to reel, recording systems, and the advent of chromium dioxide cassette tapes has prompted the adoption of a 70 μs h.f. time-constant in order to secure some of the advantages which these improved tape types can offer.

As a consequence of this, most modern cassette recorders will offer a choice of h.f. time constants, whose use is at the discretion of the user, when he is making recordings for himself.

However, the design of recording heads and cassette tape materials has not stood still in the intervening years, and it is my belief that there are many ferric tapes which will give an improved signal to noise ratio, without any significant penalty in terms of h.f. overload on typical programme material when used with the "chrome" (70 μs) equalising time constant, and it was this belief, based on a quite substantial number of tests, which led me to make the recommendation to which Mr Evans and Mr Dawson object.

A shrewd friend once observed to me that rules were made for the guidance of the wise, and the blind obedience of fools, so, in this context I would urge, even in the light of hind-sight, which is said to be an exact science, that users try out the available options, and judge the issue for themselves.

J. L. Linsley Hood

## WAS BAIRD FOOLING THE PUBLIC?

In reference to the article on John Logie Baird in the January issue, my letter in April and subsequent readers' letters in June, I would reply as follows:

**D. B. Pitt.** Looking back only to the 1925/1928 period there are many published references to demonstration successes. Claims were supported by unconvincing details. From the journals of the time it is clear that editors were pressed to give publication to reports in the terms of Baird associates. When the 30-line test transmissions commenced (September 1930) both Post Office and BBC disclaimed responsibility for the results. No amateur activity ensued. There were no dealer demonstrations, no receiver sales and no public reaction to the service.

**Dr P. Waddell.** Here is a report of an event, a 3D, 1,000-line, colour demonstration of November 1943. My letter commented only on the earlier claims made in the Falkirk Transmitter article. Other irrelevant events are cited (1938/1939) concerning large screen colour. Much could be said in the context of what was happening at this later time, including the adoption of the Marconi system at the Alexandra Palace now mentioned.

Space was given by the original authors claiming the application of fibre optics to television. This I considered was in no way usefully related to the Baird single channel objective. To digress, therefore, optical cables, with maybe a thousand critically related separate paths, serve to produce small, high definition images over short distances. Contrary to Dr Waddell's advice the video cable is not usually associated with scanning and synchronising devices, particularly of mechanical type.

**Prof G. D. Dawson.** The "Televisor" test report, a single page, did not appear until 12th March 1930, a full six months after the transmissions had started. Styled for domestic use, the "Televisor" was not acceptable for home entertainment and could only be handled by an expert, to doubtful effect. With the transmissions taking place a receiver was described at length in *Wireless World* of 18th December 1929. The normal circuit of lamp and sync winding connected in series, which I believe Dr Dawson implies by his comment, was changed over to a shunt arrangement. This allowed of brightness control and so avoiding the silhouette image caused by the lamp cut-off when adjusting for synchronisation. Without this modification sync arose from random white to black picture changes. Synchronisation was not due to any intended pulse and came accidentally, in the main, from the framing barriers and depending on whether the image background was dark or light at the start or finish of a line scan. The necessary intentional gap of zero signal (blacker than black) was not provided on the completion of each line.

**H. W. Barnard.** My compliments to H.W.B. Baird's use of the "bits and pieces of unrelated discoveries" is apt comment from the writings of P. P. Eckersley (the BBC's first chief engineer). Those fascinating toys of a Victorian physics laboratory, the Kerr electro-optic shutter, the phonic wheel, the Nipkov disc, all developed before the turn of the century, in no way serve as the basic components for the invention of television as Baird clearly proved. To him the thermionic valve was non-existent. It is a matter of wonder that some, who by distinction might have disregarded the Baird adventure, allowed themselves to be sponsors to his plans.

F. H. Haynes,
Overleat,
Bovey Tracey,
Devon

# PHASE—AMOS AND MOIR

The question of whether the end always justifies the means is one that has engaged mankind in perennial dispute. Even education in its most respectable forms, must be admitted to be "a process of diminishing deception." But, with respect, I hold that Fig. 1 in Mr Amos's article "Antiphase or 180° phase shift?" (June, p.47) is an inadmissible deception for the purpose of reaching his legitimate conclusion, viz., that a distinction should be maintained between inversion and 180° phase shift.

Fig. 1 (b) is stated to show the result of phase-shifting Fig. 1 (a) by 180°. But (a) is "a sine wave together with some second harmonic." In (b) the sine wave has truly been shifted 180°, but the harmonic has been shifted 360°! It was to avoid this kind of thing that the British Standards Institution definitions relating to phase* all took care to specify *sinusoidal waveforms, of the same frequency.*

When inversion and 180° phase shift respectively are applied, as they should be for a true comparison, to sine waves, as in Mr Amos's Fig. 2, no difference can be seen between the results. What really matters is which part of the treated waveform corresponds, as effect to cause, to the original. In the case of inversion these coincide in time; in the case of phase shift they differ in time by half a cycle.

Few of your readers are likely to have handy for reference your issues of May and June 1948, in which I went into the whole matter at considerable length, but copies of "Second thoughts on radio theory," in which a revised version appears as Chap. 9, are still to be found in some libraries.

I'm sure it would gratify our curiosity, as well perhaps as emphasizing Mr Amos's point, if he could be persuaded to disclose the nature of the equipment that failed to work because its designer did not distinguish between inversion and phase shift.

"Cathode Ray"

* BS.4727: Part 1: Group 01:1971, definitions 101 1031-1036.

Articles and correspondence about phase have appeared in the last six months issues of *Wireless World* and elsewhere. I am unable to resolve my own understanding of phase with the viewpoints put forward by James Moir and S. W. Amos. If phase is dimensionless (and all the equations I have seen have it so) then it cannot properly be a measure of time.

There is a clear error in Fig. 1(b) of Amos' article. What he describes as a 180° phase shift is, in my view, a time delay of half the period of the fundamental component of waveform (a). Such a delay might be produced by a suitably long piece of lossless transmission line. He asserts that Fig. 1(c) is not a 180° phase shift but concedes that in the case of a symmetrical waveform the result would be indistinguishable. Since my understanding of Fourier analysis is that an unsymmetrical, but zero average, waveform can be constructed by summing symmetrical sine waves then I am sure that his distinction is incorrect.

That referring to phase in terms of time is incorrect is shown by Fig. 3 of James Moir's article in the March issue. Again, Fig. 3 has nothing to do with phase and not even really time. What he shows is the result of feeding his input signal to a dispersive propagating medium. If it were simply a time delay, as he says, then the input waveform would be reproduced exactly.

The debate about linear-phase loudspeakers will undoubtedly go on but perhaps the correspondents could clarify their ideas first.

John Newell,
Workingham,
Berks.

*Mr Amos replies:*

Cathode Ray will, I know, agree that phase shift in reactance-resistance networks is invariably accompanied by signal delay. There is a danger, therefore, that if the signal inversion of an amplifier is interpreted as 180° phase shift, someone will try to make use of the associated (non-existent) delay: this is what happened to my unfortunate designer. In my article I was trying to distinguish between the phase shift in networks (which gives delay) from signal inversion in amplifiers (which doesn't). To highlight the difference I used Fig. 1 to distinguish between the response of a signal-inverting amplifier (c) and the response (b) of a typical network (with 180° phase shift at the fundamental frequency and phase shift proportional to frequency). It is true that I did not mention the 360° phase shift at the second harmonic frequency. In my opinion this omission was justified because it simplified the presentation and clarified the argument e.g. by avoiding any need to introduce considerations of delay and group delay. But Cathode Ray, is of course, entitled to his opinion.

I cannot reply adequately to Mr Newell without introducing delay. To set up a magnetic field around an inductor or to charge a capacitor takes a finite time which is measured approximately by the time constant of the circuit. The phase shift $\phi$ in the circuit is also measured by the time constant and hence phase shift is inexorably associated with signal delay. There is a simple relationship between them: in fact the delay is given by $\phi/\omega$ which has the dimensions of time. Phase shift itself, as Mr Newell says, is dimensionless. To avoid distortion of a wave passing through a network the delay must be constant for all its components and must thus be independent of frequency. Thus for distortionless transmission phase shift must be directly proportional to frequency.

Mr Newell is quite right in his statement about Fourier analysis and it is also true that the effect of inverting each component of an asymmetrical waveform is the same as phase shifting it by 180°. It would not be possible, however, to create an inverted wave such as that of Fig. 1(c) by phase shifting each component by 180° (even if a network could be found which would do it) because the components would be subjected to different delays and therefore would not produce the required result when added. This difficulty does not arise if the components are inverted because there is no delay in this process.

Comments have also been received from Messrs Jefferies, Stancliffe, Evans, Rossiter, Bulmer and no doubt others. The points I would make in reply are all included in my answers to Cathode Ray and Mr Newell above. The fundamental issue is that it is misleading to refer to the signal inversion of an amplifier as 180° phase shift because there is no signal delay. Phase shift in networks (even phase advance) is always associated with signal delay and it is not unreasonable therefore (but quite wrong) to assume that the 180° phase shift of an amplifier is also accompanied by signal delay. Hence my deprecation of the use of the word "phase" to describe signal inversion.

I am grateful to Mr Sargent for his support and for reminding me that phase shift can occur as a result of transit-time effects.

S. W. Amos.

*Mr Moir replies:*

I think that it is unfortunate for communications engineers that the concept of phase was introduced by power supply engineers operating a system at a fixed frequency. As I showed in the contribution in the March issue, in the context of single frequency working a specification of phase shift between two waves can be unambiguous specification of the time difference. In communication circuits the same concept cannot meaningfully be applied. We should be thinking in terms of the differential time delay, the difference between the time of propagation at some reference frequency in the middle of the band and the time of propagation at the extremes of the audio frequency band. It is this differential time delay that produces waveform distortions.

It should be fairly clear that a circuit that has a phase shift of say 360 degrees (one complete cycle) at a frequency of 100 Hz., a phase shift of 720 degrees at 200 Hz (two complete cycles) and a phase shift that continues to increase linearly with frequency will not introduce any differential time delay and is therefore non-distorting (in phase) because all frequency components are delayed by exactly the same time interval (10ms). In consequency waveforms are transmitted without distortion.

The tenor of my March contribution was that waveform distortions due to phase shift (propagation time differences) do not appear to be of any significance in determining the quality of sound signals, provided that the time delays are kept within the CCIF limits which in simple phase shift terms are absolutely enormous.

The waveform shown in Fig. 3 of the March issue certainly shows that the signal is delayed, the start of the 'received' signal occuring 0.0109 secs after the start of the 'sent' signal. The oscillograms were obtained by passing the signal through a simple band pass filter and not in the complicated way Mr Newell suggests. The input waveform would have been delayed and not distorted if the phase characteristics of the filter had met the requirements outlined earlier, but obtaining a linear phase characteristic for such a filter requires the addition of many more elements. The filter used exhibited the usual characteristics, minimum time delay in the middle of the pass band and a delay that increased towards both ends of the pass band. It is this characteristic that results in the amplitude variation and the final "overhang".
James Moir.

## THE CONSULTANTS

As one of the consultants included in John Dwyer's article "The Consultants" in the November 1975 edition of *Wireless World*, I have of course been following the subsequent comment with some interest. Whilst I have been tempted to comment upon the original article and the subsequent correspondence before, Roger Driscoll's letter in June 1976 cannot be left to pass without reply.

In my opinion there are three classes of consultants. There are the variety described by Raymond Cooke, who own "an AVO with a bent needle". There are a few of us who like myself have considerable experience in industry, and have then "gone it alone" and set up their own laboratory facilities. Thirdly there are those like Roger Driscoll who are professional academics, but do some spare time consulting work.

Clearly these three classes of consultants work in very different circumstances – just what has each class to offer? The "AVO with the bent needle" type is clearly to be avoided, but what about the others? The academic type is probably appropriate where a theoretical problem alone is involved, but just how can someone who spends his life in an academic world have experience in practical designs; that is, unless he learns at his clients' expense? I have no disagreement with academic institutions undertaking research projects on behalf of industry on a profit making basis, but individuals making free use of instrumentation and facilities which are public property, for their own benefit is a different issue. Any reasonable laboratory will have at least £50,000 of equipment. If we look at the cost of employing this amount of capital it is at least £5,000 per annum, to which we must add the cost of replacements which allowing for inflation is at least £10,000 per annum and also add overheads at say a minimum of £2,000 per annum. This shows that in the order of £17,000 per annum is involved in purely maintaining a good laboratory – why shouldn't some of this be recovered when academic staff use the laboratory for their personal gain? After all it's the public who own the equipment.

This of course leads to the question of fees. John Dwyer suggested that £100 per day was too high a fee. Well, £17,000 per annum operating cost is about £350 per week which does not leave a £100 per day consultant all that rich!
Hugh Ford,
Sunbury-on-Thames,
Middx.

## CITIZENS' BAND RADIO

In reply to Mr Webber in March "Letters", I am in complete agreement with him as to the practicality and usefulness of CB radio but as to the "Smokey Bear" messages, I fear I must take an opposite stand. Being a professional technician in the music business, I find myself travelling a great deal in America frequently travelling with private and professional CB users, and because of this familiarity I must make two relevant points. Firstly, Mr Webber says "offenders could be charged . . ."; to this I must say that it is "illegal" for police to listen to and act upon any of the CB channels (other than the emergency bands) and also it is common knowledge that a speed violator with a CB unit is liable to higher fines than a speed violator without (the reasoning being than an operator with CB knows about the existence of police patrols/speed traps, and travels over the limit regardless).

One further point regarding Mr Webber's letter re: " . . . impeding the police in the execution of their duty . . ." About a year ago a motorist, being very annoyed about being caught in a police radar trap, positioned himself about a mile from radar trap and posted a sign warning other motorists of its existence. He was apprehended and charged. When brought before the magistrate, the case was dismissed as the court ruled that the motorist was doing more to stop speed limit violators than the police could accomplish by ticketing the occasional offender.
W. T. Penman,
London, W.6.

## COMMUNICATION THEORY

Professor D. A. Bell's excellent article concerning redundancy included an unfortunate half-truth which I feel to be misleading. I refer to the statement on page 75 of *Wireless World* May issue in which are the words "with a sub-carrier placed exactly half-way between line harmonics."

If the sub-carrier was so placed, the interference pattern would build up a vertical bar system which the eye would see. In practice the sub-carrier is placed in a carefully controlled manner, just off this exact half-way position. This results in a more complicated pattern which, while it does in fact repeat, looks like random interference as the repeating time is too long for the eye to realise it.

Another detail, yet an important one, is that the subcarrier is divided into two components, basically in quadrature, and each of these is then modulated, by the I and Q components, in balanced modulators such that only side-frequency components are left. In the absence of colour information, no sub-carrier component is present.
R. L. Hackworth,
The City University,
London

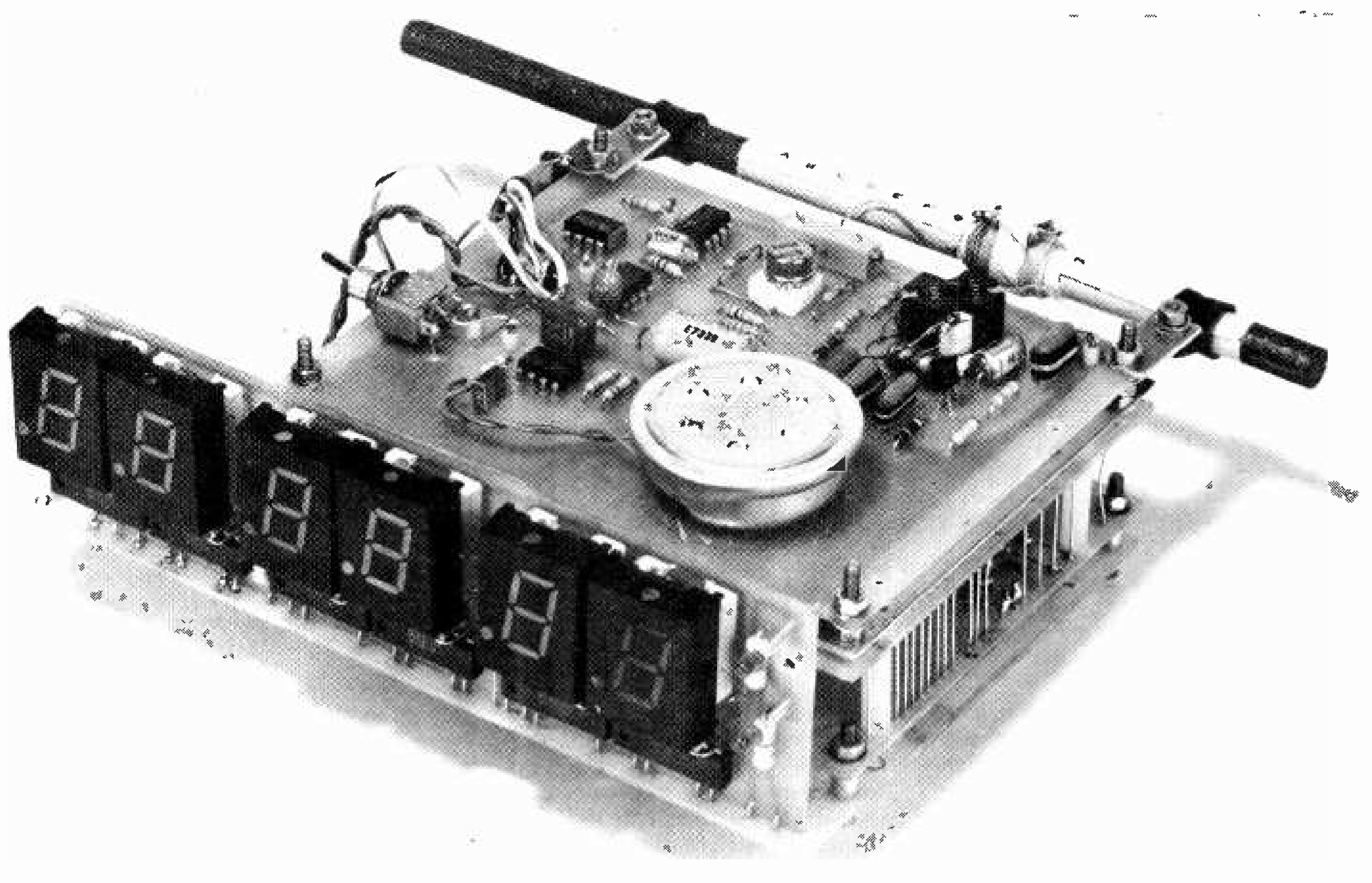
*The author replies:*
The point I wanted to make was that the basic picture signal has most of its energy in sidebands clustered around the line harmonics (and a bias towards the lower frequencies) so that one puts the colour information between a pair of line harmonics. When the frequency of colour sub-carrier is 4433.61875 kHz, it is clearly not exactly in the centre of the gap. But if it were exactly in the centre it would not produce a vertical bar system. Simple Fourier analysis shows that any vertical bar is represented only by exact harmonics of line frequency, the horizontal position of the bar being represented by the phase of the harmonics. Since the separation between line harmonics is a multiple of 25 Hz., the centre point between two of them must be a multiple of 12.5 Hz. The pattern (not bar) produced would be reversed on alternate frames and so minimised by persistence of vision. It would, however, be a stationary pattern and in practice it has proved advantageous to use a frequency which is not related simply to the scanning frequencies. The form of modulation is also of practical value; and if one is going into detail one should include the point that the I component in NTSC has only a vestigial upper sideband, so that the distance between colour sub-carrier and top edge of video band can be less than the maximum colour bandwidth. PAL, however, is different.
D. A. Bell.

# Self-setting time code clock

## Constructional design suitable for domestic use

by N. C. Helsby M.A. University of Essex

**To meet the demand for a fully constructional time-code clock this article describes a modular design comprising five basic functional units. The full circuit receives a time-coded transmission from Rugby MSF and uses this to drive a six-digit display. An optional GMT/BST converter accounts for the one hour discrepancy which exists during the UK summer.**

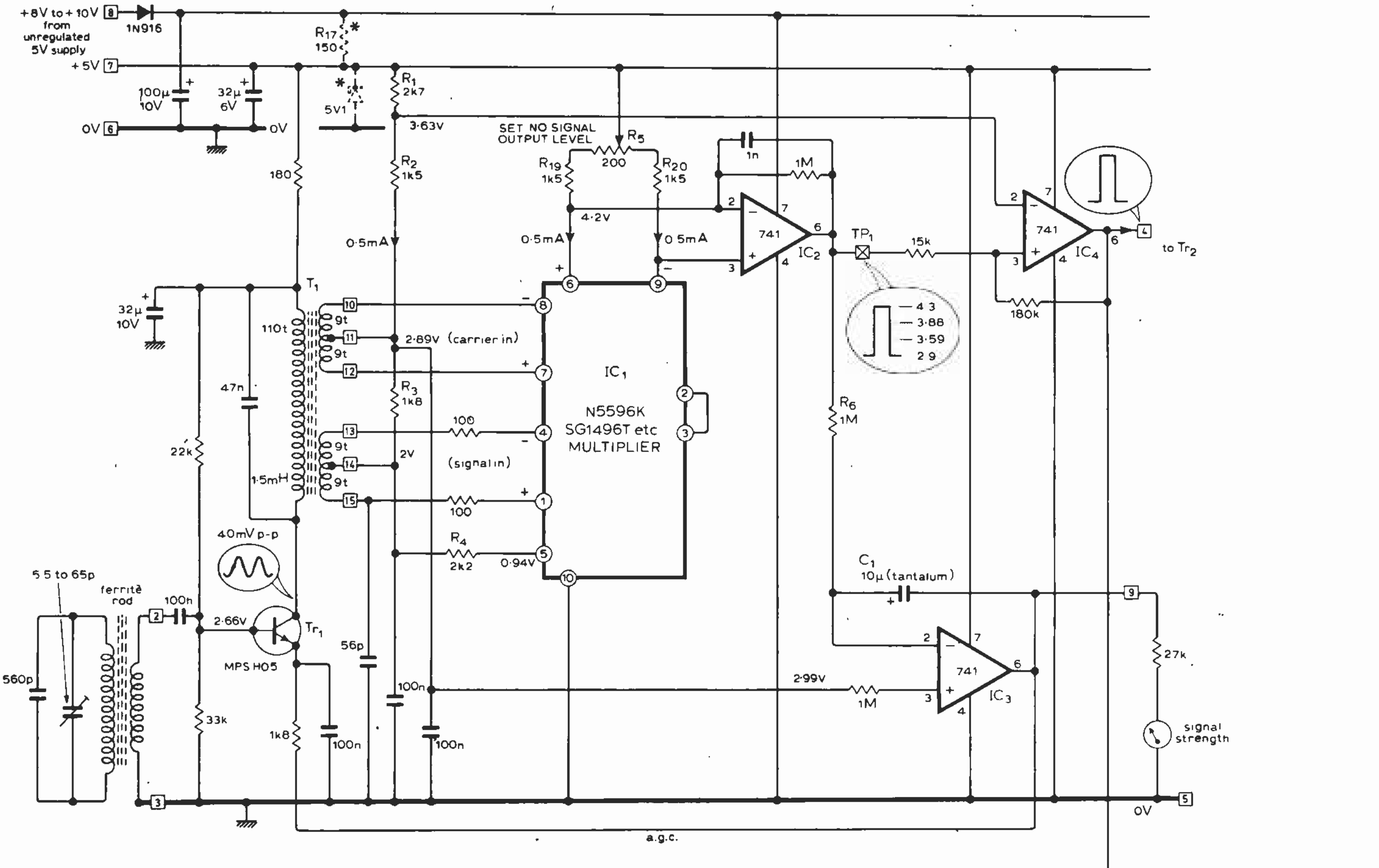


Self-setting digital clocks using coded radio signals have recently been made possible in this country by the introduction of a time-of-day code into the 60kHz transmissions from Rugby, call sign MSF. Until recently only second and minute markers were transmitted in addition to the call sign. This service is maintained as before but the transmission now carries a 13-bit b.c.d. code giving hours and minutes in the UTC time scale.

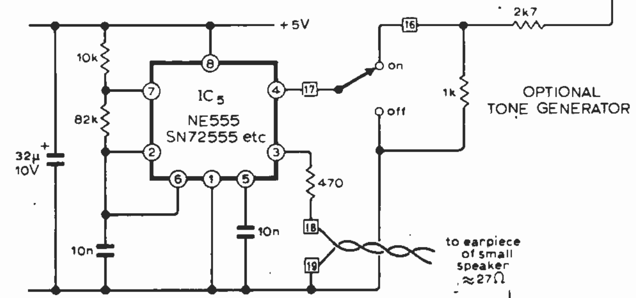
### Receiver

Various receiver designs were considered including a phase-locked loop version. However, it was desired to keep the circuitry simple and a receiver with two tuned stages of amplification followed by a detector was found to work well with a pre-set gain control. With this conventional design it was difficult to obtain more than 12dB extra gain over that required at 100 miles from the transmitter. To obtain extra sensitivity without the danger of regeneration, a low-level detection system was designed using a multiplier as shown in Fig. 1. By operating the multiplier as a frequency doubler a d.c. output is obtained in addition to the double frequency which is removed by filtering. Most of the gain is required at audio frequencies and is provided by amplifier $IC_2$. Using this system, no high levels of 60kHz are present in the receiver which eliminates pick up by the ferrite rod aerial. Although the signal strength has been found consistent, inclusion of a.g.c. and a precision Schmitt-trigger level detector enables best use to be made of the available signal at any moment. The signal strength meter is a useful addition and allows optimum positioning of the aerial.

The multiplier is preceded by a common-emitter gain stage with a tuned collector load, the input of which is fed by the aerial. Current in this stage is set by the a.g.c. amplifier, and reaches a maximum of about 1mA under no signal conditions. Resistors $R_1$ to $R_4$ set the multiplier tail currents, signal and carrier input bias levels via centre tapped windings, the a.g.c. amplifier reference, and a reference for the Schmitt-trigger comparator circuit. Half a milliamp flows in each of the multiplier loads under no signal conditions. Output of $IC_2$ is set to 4.3V by $R_5$ when no signal exists (shorted aerial). When a signal is applied to the input of




* fitted if single supply required



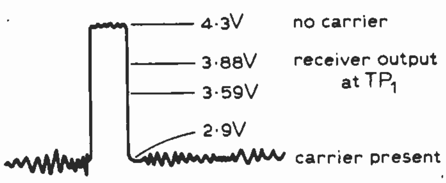

WINDING DATA

| component | core | number of turns primary | number of turns secondary | wire |
|---|---|---|---|---|
| aerial | 7½in. x ⅜in F14 | 380 | 16 | 36 s.w.g. s.s.c. en. |
| $T_1$ | 10mm POT CORE LA 2936 | 110 | (2 off) 18 centre tapped | 40 s.w.g en. |
| $T_1$ | RM6-R LA 4145 | 59 | (2 off) 14 centre tapped | 30 s.w.g. en. |

alternative core

*Fig. 1. Receiver using a multiplier as a frequency doubler to produce a d.c. output. Most of the gain is at a.f. which eliminates aerial interference from high levels of 60kHz.*

*Fig. 2. Typical break in carrier relative to the Schmitt-trigger levels.*




the receiver the negative differential output of the multiplier is amplified and filtered by $IC_2$ (if output is not negative either of $T_1$ secondary windings may be reversed). The a.g.c. amplifier $IC_3$ produces a level of 2.9V at the output of $IC_2$ by controlling the gain of $Tr_1$. The long time constant formed by $R_6$ and $C_1$ ensures that the gain does not change much during the 0.1 to 0.5 second breaks which occur in the carrier. This slow response causes a delay after switch-on for the signal to appear. Schmitt-trigger $IC_4$ has a 0.29V hysteresis and the thresholds are 3.88 and 3.59V. These levels were chosen because most of the noise appears when the carrier is present. A typical break in the carrier relative to the Schmitt-trigger levels is shown in Fig. 2.

The receiver is required to respond to a 60kHz carrier modulated by pulses, the shortest of which is 5ms. Because single tuned stages are used there is no overshoot in the response and the rise time of a stage is $0.7/B$ where $B$ is the bandwidth in Hz between the 3dB points. This expression accounts for the two sidebands of the modulated wave occupying a frequency band that is twice the modulating frequency. If the response determining stages have similar rise times the exponential output of the receiver $V = V_0\,(1-e^{-t/\tau})$ where t is the time after a step of carrier is applied, $V_0$ is the final output after a long period and $\tau$ is the response time constant.

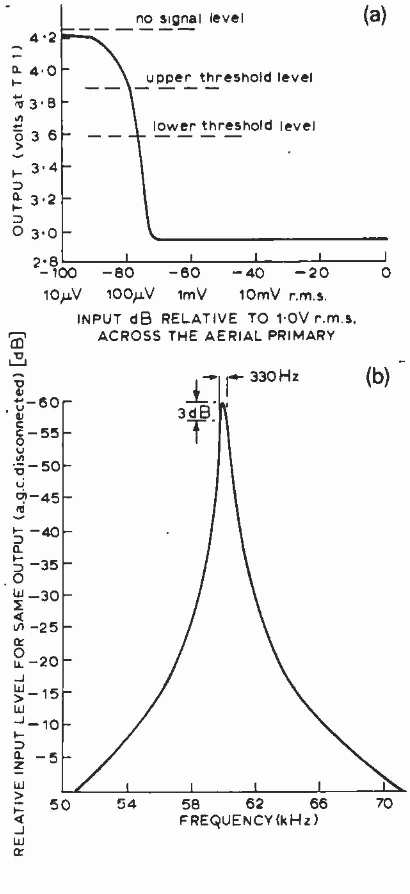



*Fig. 3. (a) Minimum input voltage at aerial to produce a low output from $IC_4$. (b) Frequency response of receiver.*

The rise time ($T$) is the time taken for $V$ in this equation to rise from $0.1V_0$ to $0.9V_0$ and can be expressed as $2.2\tau$. Therefore, $V=V_0(1-e^{-2.2t/RT})$. From this equation the overall rise time which will allow $V$ to reach 99% of $V_0$ in a specified time $t$ may be found; $0.99=1-e^{-2.2t/RT}$ therefore $t/RT=2.0$. Thus if $t=5$ms the overall time required is 2.5ms. Two tuned circuits in the receiver define $RT$ in addition to the filtering capacitor. The transmitter rise time may also be taken into account in this approximate analysis if it is considered to have the same rise time as one of the receiver stages. The overall rise time is approximately proportional to the square root of the number of stages. For these four response determining stages to give an overall rise time of 2.5ms, each stage should have a rise time of $2.5/\sqrt{4}=$ 1.25ms.

For the single tuned stage, rise time is $0.7/B$ hence $B$ is $0.7/1.25\times10^{-3}=$ 560Hz. The loaded Q's of the aerial and the amplifier tuned circuits should be adjusted to give a 3dB bandwidth of this order of magnitude, requiring a loaded Q of 110 (60,000/560) at 60kHz. Note that if two single tuned stages have bandwidths of 560Hz the overall bandwidth, which is given by $B=B_0\sqrt{2^{1/2}-1}$ where $B_0$ is the bandwidth of each stage, is $0.64\times560\text{Hz}=360\text{Hz}$.

The aerial pick-up coil design involves a compromise between Q and output voltage. Tuning is accomplished by means of a fixed capacitor and a trimmer across the primary coil. It was found that 36 s.w.g. single silk-covered wire gave a Q of about 140 with the coil spread over 2in. A signal generator connected across the aerial primary produced the results shown in Fig. 3(a). The minimum level of signal required to register as a low from the Schmitt trigger is 160µV r.m.s. across the aerial primary. The maximum signal picked up from Rugby, 100 miles from the transmitter, was equivalent to 3.5mV r.m.s. which gave about 26dB reserve gain. Inside a reinforced concrete building the signal was 10dB lower which still left 16dB of gain. Frequency response of the receiver is shown in Fig. 3(b). The a.g.c. was removed and $Tr_1$ was operated at a current which would normally give the correct output level from a signal of about 1mV r.m.s. across the aerial primary. It should be noted that the step-down ratio of the aerial transformer is 380:16 or 27dB in terms of signal strength. By buffering the input stage, so that this ratio can be reduced or eliminated, greater sensitivity can be obtained.

## Decoder

The receiver output detector, which appears typically as an inverted form of waveform A in Fig. 5, is fed into the buffer stage $Tr_2$ in Fig. 4. This is

*Fig. 4. Decoder circuit, the charge and discharge action of $C_2$ provides heavy filtering and increases the noise immunity.*

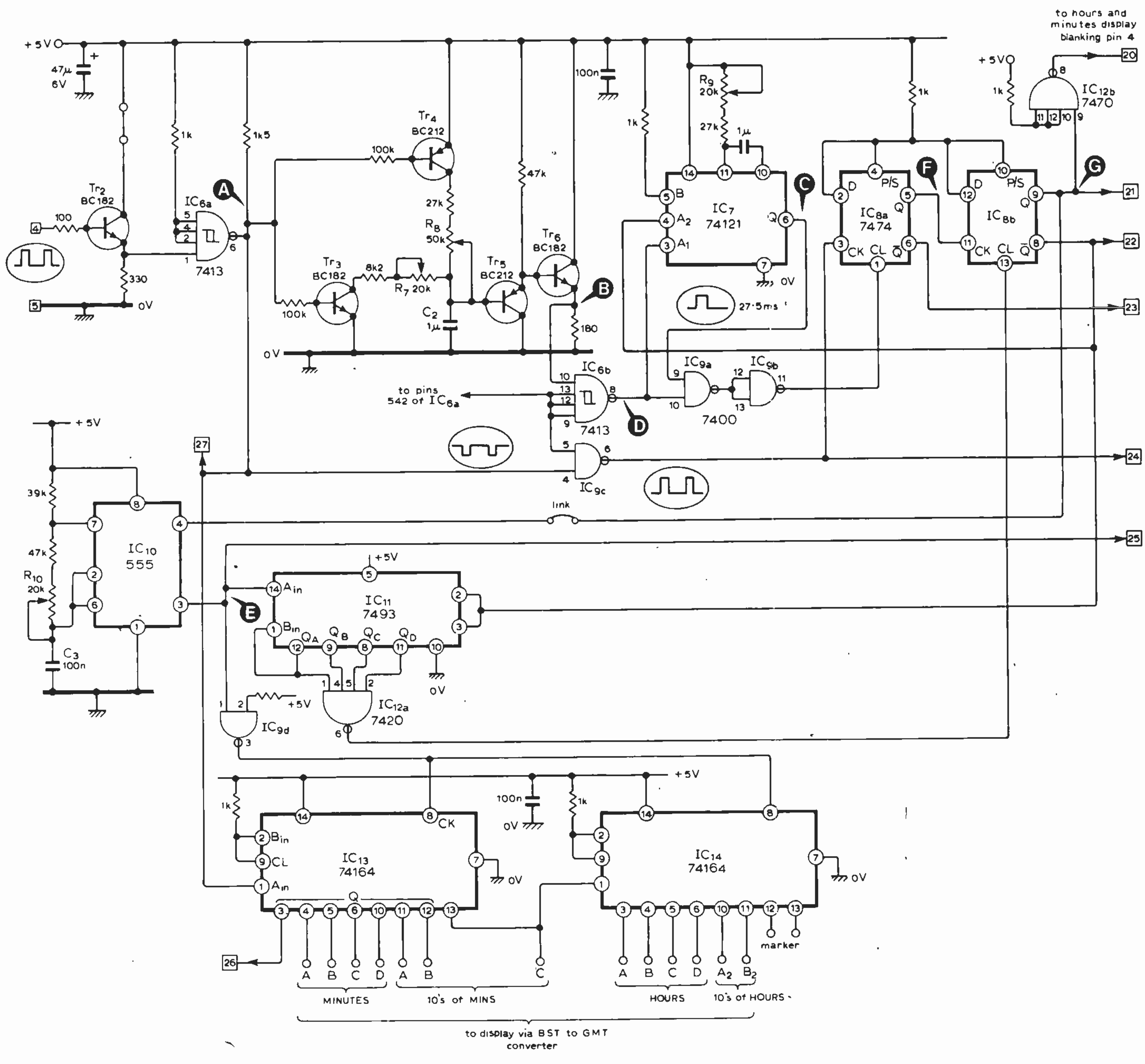
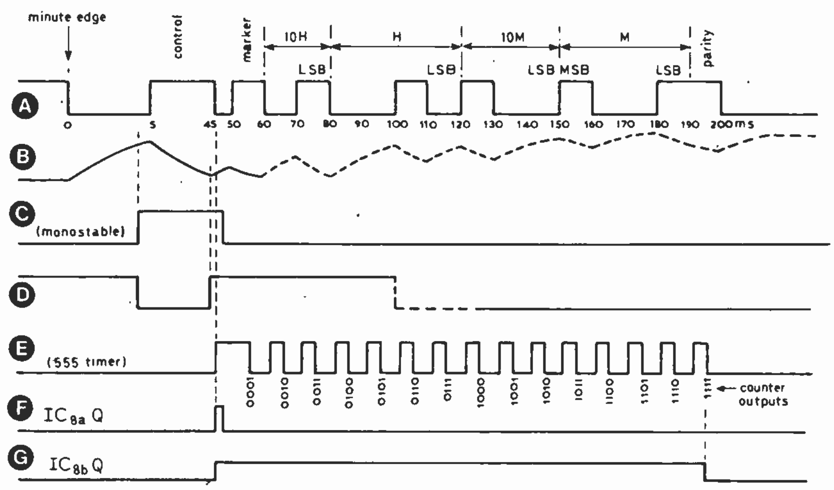


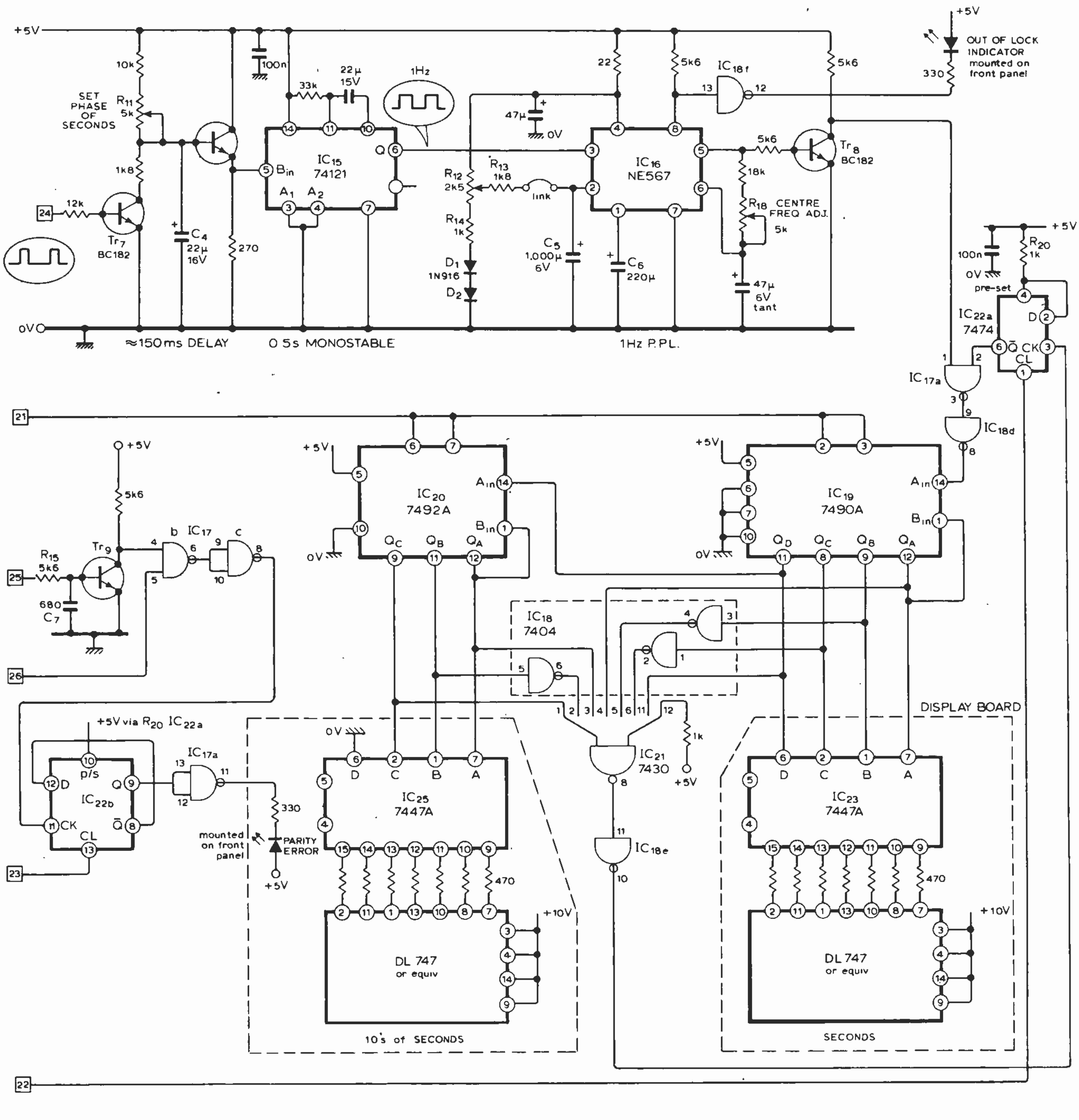
*Fig. 5. Waveforms for various points throughout the decoder circuit.*




followed by Schmitt trigger $IC_{6a}$ to improve noise rejection in the conversion to t.t.l. levels. The output of this gate feeds a circuit which charges and discharges capacitor $C_2$ to produce waveform B in Fig. 5. Transistors $Tr_5$ and $Tr_6$ form a double emitter follower to drive Schmitt trigger $IC_{6b}$.

Resistor $R_8$ is adjusted so that if point A is low for more than 22ms, the positive threshold on the second Schmitt trigger is reached, to produce a low as shown by waveform D, Fig. 5. The output from $IC_{6b}$ triggers monostable $IC_7$ which is adjusted by $R_9$ to give a pulse length of 27ms. Output D is required to be high with output C in order to clear $IC_{8a}$ via $IC_9$. These conditions leave a narrow window during which a negative going edge at A, made positive-going by $IC_{9c}$, can clock $IC_{8a}$. Resistor $R_7$ is adjusted so that if A is high for more than 18ms after the initial 25ms break, $C_2$ is discharged to the negative threshold of $IC_{6b}$. The charge and discharge action of $C_2$ provides heavy filtering and reduces the likelihood of false triggering by noise pulses.

*Fig. 6. Seconds counter using a phase-locked-loop tone decoder.*



Unused inputs of gates which are required to be high are taken to +5V via 1kΩ resistors as a precaution against transient noise on the power supply. The Q output of $IC_{8a}$ clocks $IC_{8b}$ which in turn allows $IC_{10}$ to run in the astable mode with a frequency set to 100Hz by means of $R_{10}$. Simultaneously, the $\bar{Q}$ output of $IC_{8b}$ allows $IC_{11}$ to count the negative-going edges from the timer. On the 15th edge all outputs of $IC_{11}$ go high to give a low out from $IC_{12a}$ which clears $IC_{8b}$. The last-mentioned then resets and holds the timer. The $\bar{Q}$ output of $IC_{8b}$ returning high also resets $IC_{11}$.

The timer capacitor $C_3$ normally charges to 2/3 of the supply and discharges to 1/3 by the internal action of the circuit. This gives the mark-space ratio as shown in Fig. 5 with the component values selected. When held in the reset state, $C_3$ becomes discharged and it is therefore required to initially charge from zero to 2/3 of the supply which produces the first wide pulse as shown. Thus, by choice of resistor values it is possible to place the negative-going edges of the timer output in the centre of the time code bits. This output is then inverted so that the time code is clocked serially into shift registers $IC_{13}$ and $_{14}$ at the middle of each bit; the shift registers clocking on positive-going edges. The registers are not cleared in this design, new information simply pushes out the previous pattern. Although the marker bit can be used as the first received high at the end of the shift registers, to stop the clock, the counter was used because if the marker bit were missed due to noise, the time-code might still be retained correctly.

It is possible that the time code itself contains a pattern similar to the one that indicates the start of the code because it is divided into 10ms-long bits. However, the $\bar{Q}$ output of $IC_{8b}$ is connected to the $A_2$ input of $IC_7$ and this pin therefore goes low just before the end of the monostable pulse. $IC_7$ cannot fire again until the complete code has been received and when this occurs $A_2$ returns high without firing the monostable so good noise immunity of the code recognition circuitry is maintained.

## Seconds counter

Due to the tranmission accuracy, reception and display of seconds is well justified. In this design the Signetics NE567 p.l.l. tone decoder has been used for the seconds counting function as shown in Fig. 6. The device operates from a 5V supply and incorporates a balanced multiplier type of phase detector which, when overdriven, also operates as exclusive-OR gating.

The maximum recommended timing resistance for the p.l.l. current-controlled oscillator (c.c.o.) is 20kΩ. The tantalum timing capacitor may increase in value by as much as 5% for a 20degC rise in temperature but, as the oscillator is not required to accurately run for

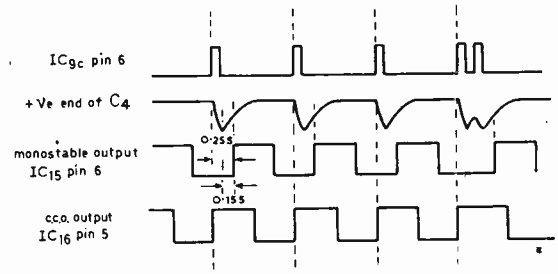


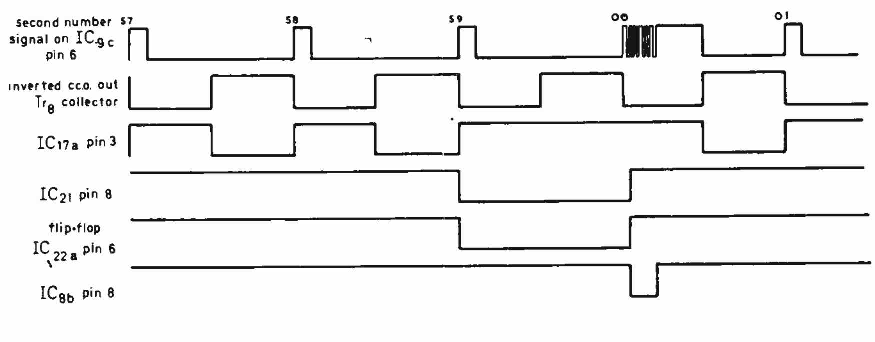

*Fig. 7. Delay of 250ms is created from the positive edge on $IC_{9c}$ by lengthening pulses via monostable $IC_{15}$.*

long periods without an input signal, the effect is not important provided the loop remains locked.

In this application the p.l.l. is required to lock to a single fixed frequency so it is desirable that the bandwidth of the loop is small. Because heavy filtering is used it is necessary to reduce the loop gain which increases damping. This is accomplished by the manufacturer's recommended method of adding $R_{12,13,14}$, $D_{1,2}$. This network reduces one of the internal multiplier collector loads and hence the loop gain. Potentiometer $R_{12}$ enables the correct d.c. conditions to be maintained while the diodes provide temperature compensation. The detection band is reduced from ±7% to about ±4%. Reduction in gain coupled with the value of $C_5$ gives the loop a damped response which prevents overshoot in phase after a disturbance. It also has the advantage of reducing the number of input cycles required before locking occurs, usually less than the maximum of twenty.

To produce the required 1:1 mark-space ratio at the input of the p.l.l., monostable $IC_{15}$ is used to lengthen the input pulses. By delaying the input to the monostable a phase shift brings the c.c.o. output in phase with the second markers. The total delay is 250ms from the positive-going edge, on the second, at pin 6 of $IC_{9c}$ – see Fig. 7. By timing the delay from the negative-going edge the extra amount required is 150ms which is obtained by allowing $C_4$ to charge through $R_{11}$. This capacitor is discharged by $Tr_7$ when the output from $IC_{9c}$ is high for 100ms after the second. The monostable Schmitt trigger input is used and $R_{11}$ adjusted until the necessary delay is achieved. The output-pulse length of the monostable is fixed at about 0.5s and any phase error can be eliminated by adjusting $R_{11}$.

*Fig. 8. Waveforms present in the seconds counter.*




The c.c.o. output is fed via buffer stage $Tr_8$ through $IC_{17a}$ and $IC_{18d}$ to the input of the seconds counter. The outputs of the counters $IC_{19}$ and $IC_{20}$ are inverted where necessary to present all highs to $IC_{21}$ at the count of 59 seconds. This causes the output to go low and clock flip-flop $IC_{22a}$ causing its $\bar{Q}$ output to go low. Further clock pulses via $IC_{17a}$ are inhibited until the flip-flop is cleared by detection of the minute sequence. Thus, if the hours and minutes are not updated the seconds count ceases. When the sequence is correctly received the counters are reset and $IC_{22a}$ is cleared by the output of $IC_{8b}$. Waveforms of this are shown in Fig. 8.

It should be noted that extra decoupling of the supply to the tone decoder is used. This is to prevent the decoder running as a locked oscillator, with no signal at pin 3, due to small 1Hz spikes on the supply rail from other parts of the circuit.

*(To be continued)*

**Printed circuit boards**

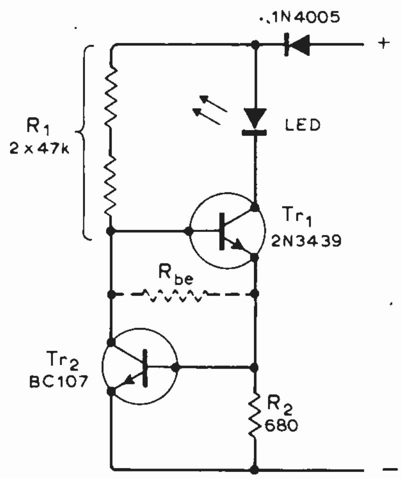
Wireless World has arranged a supply of glass fibre boards for the time code clock. The p.c.bs are available as a set which comprises three double-sided and two single-sided boards for the receiver, GMT/BST converters, decoder, seconds counter, and display. The boards mount on top of each other (see photo) to form a compact module which can be housed in a case approximately 8 × 5 × 3in. The set of boards is priced at £13.50 inclusive or £11.00 undrilled.

A set of special components is also available which comprises an aerial assembly, receiver coil assembly (LA4145) N5596K multiplier, MPS H05 transistor, two 1.5kΩ metal-film resistors, and the NE567 tone decoder. This set is priced at £7.50 inclusive. Available from M. R. Sagin at 11 Villiers Road, London NW2.

# Circuit Ideas

## Voltage probe

This circuit indicates the presence of direct or alternating voltages from 3 to 440V without range switching. The circuit is basically a constant current supply for the l.e.d. Transistor $Tr_2$ regulates the base current of $Tr_1$. As the voltage across $R_2$ rises to $V_{eb}$, $Tr_2$ begins to conduct and reduces the base current of $Tr_1$. The voltage capability of the probe is limited by the $V_{ceo(sus)}$ of $Tr_1$ which is 350V. This value can be increased to 450V by the addition of a suitable base emitter resistor $R_{be}$. If this is a fixed value of 60Ω the low voltage operation of the circuit is impaired due




to the lack of forward bias on $Tr_1$. With the correct selection of $R_1$, $Tr_1$ can be made to act as a variable $R_{be}$, having high resistance at low operating voltages and low resistance at high operating voltages. The power dissipated in $R_1$ can be reduced by increasing its value provided that $Tr_1$ has a $h_{FE}$ above 45 at 1mA. However, $R_1$ must not be so high that $R_{be}$ is significantly increased due to the lower collector current in $Tr_2$.

The prototype was housed in a plastic tube of internal dimensions 100mm × 10mm dia. The probe tip was made from a 4mm plug and the l.e.d. was mounted in the back end plate of the probe. For use on the mains supply a suitable varistor should be used to limit voltage transients.

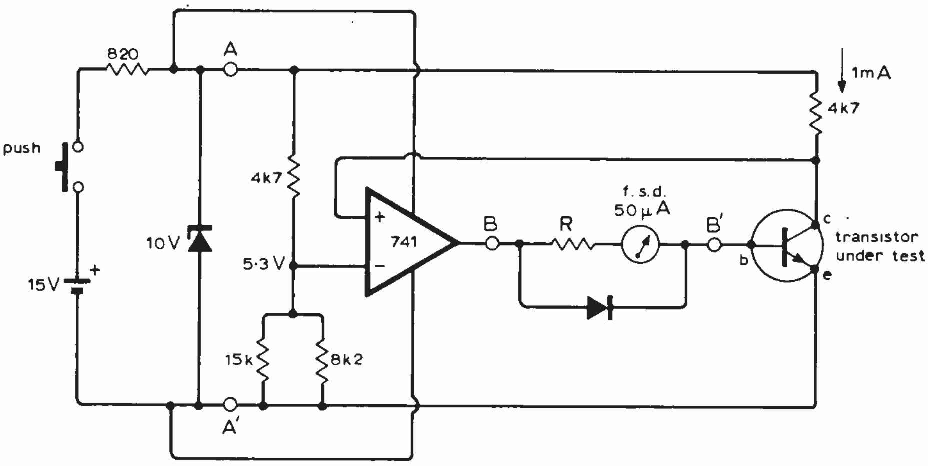
Glyn Jones,
Queen Elizabeth College,
London W.8.

## Direct-reading transistor tester

The op-amp provides base current for the transistor under test whose action causes equal voltages to occur at the op-amp input terminals. If $V_{ref}$ is 5.3V, sufficient base current will flow to provide 1mA collector current. Gain of the transistor is then 1mA/base current, and the meter scale is calibrated. Thus, the 50μA point is marked 1000/50 = 20, and so on. A gain value of 400 is marked at the 2.5μA point. Resistor R and the diode protect the meter against overloading which could occur if a zero-gain transistor were tested. Resistance R in series with the meter should total 5kΩ.

For testing p-n-p devices a switch is fitted to reverse the supply polarity and the meter.

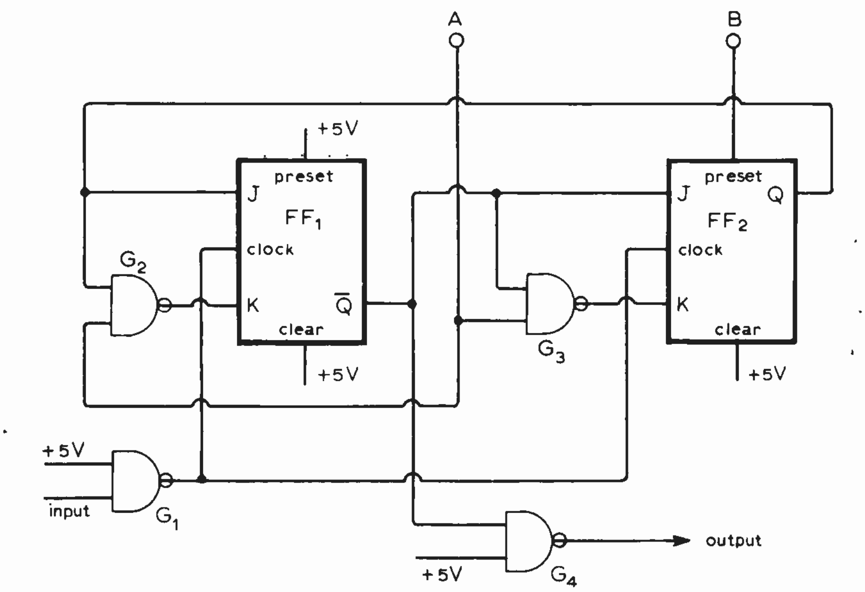
A. Rigby,
Ormskirk,
Lancs.




## Fast modulo-3 counter

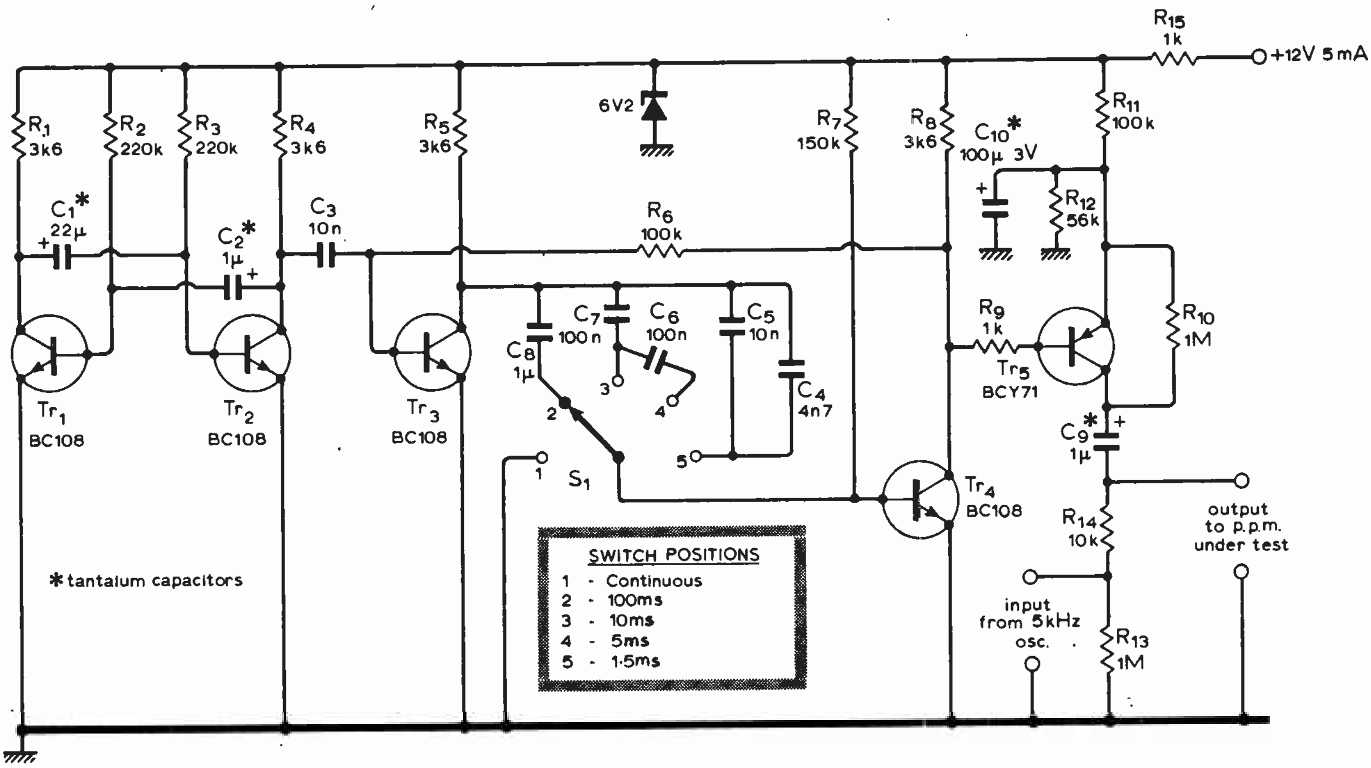
A receiver design required a local oscillator source covering 10 to 30MHz. To avoid a $3^2$:1 capacitance ratio in the oscillator tuner, and to reduce the tuning rate, a 40 to 60MHz oscillator was followed by a circuit which could divide by 2, 3 or 4. $G_1$ and $G_4$ are the input driving gate and output buffer gate respectively. When A and B are both 1, the circuit is a ÷4 twisted ring counter with $G_2$ and $G_3$ acting as inverters between the J & K inputs of each bistable. When A is 0 and B is 1, both Ks go to 1, and the circuit is a synchronous ÷ 3. With both A and B at 0, $FF_2$ is preset, preventing it from switching, and J of $FF_1$ is forced to 1. Input K of $FF_1$ then divides by 2. With the components shown the circuit will operate up to 60MHz.

C. Attenborough,
Emsworth, Hants.




| A | B | division ratio |
|---|---|---|
| 1 | 1 | 4 |
| 0 | 1 | 3 |
| 0 | 0 | 2 |

$G_1$–$G_4$ each ¼ 74S00N
$FF_1$ & $FF_2$ each ½ 74S112N




## Tone burst generator for testing p.p.ms

The rise time of a peak programme meter is defined by BS4297:1968 as the deflection caused by various short duration tone bursts. This circuit can be used with an audio oscillator for producing these tone bursts. Transistors $Tr_3$ and $Tr_4$ form a monostable with switched timing capacitors. The monostable is triggered every five seconds by the astable $Tr_1$ and $Tr_2$. An audio oscillator signal is pulsed by the monostable output via the transistor switch formed by $R_{14}$ and $Tr_5$. This switch is biased to handle the required +8dB output, and is designed to avoid d.c. level changes and spurious transients which could give misleading results. The load impedance should not be lower than 10kΩ which results in a transmission loss of 6dB. If this cannot be tolerated, or the p.p.m. under test has a low input impedance, the switch should be followed by an emitter follower. The residual output in the off condition is adequately low at −26dB, and the minimum input impedance is 10kΩ. Output waveform can be checked on an oscilloscope, in which case $C_1$ can be temporarily reduced in value to increase the pulse repetition frequency. Power requirements are 5mA at 12V but other voltages can be used if $R_{15}$ is adjusted accordingly. Transistors $Tr_1$ to $Tr_4$ can be any silicon n-p-n types but a good quality device is recommended for $Tr_5$.

To test a p.p.m. response time the tone burst generator is connected to a 5kHz oscillator which is adjusted for a reading of 6 on the meter with $Sw_1$ at continuous. On switching to the various pulse lengths the p.p.m. reading should be within the following limits.

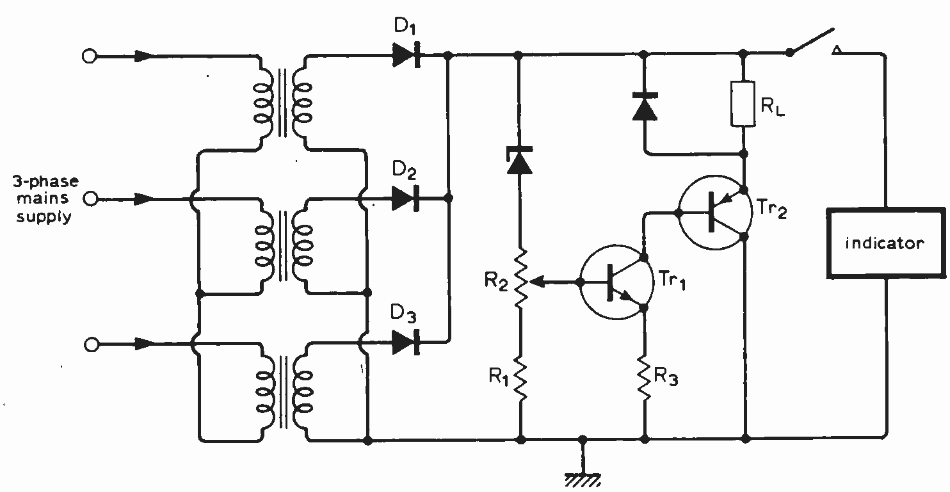
| Burst duration | Meter reading (relative to 6) |
|---|---|
| continuous | 0dB |
| 100ms | 0±0.5dB |
| 10ms | −2.5±0.5dB |
| 5ms | −4.0±0.75dB |
| 1.5ms | −9.0±1.0dB |

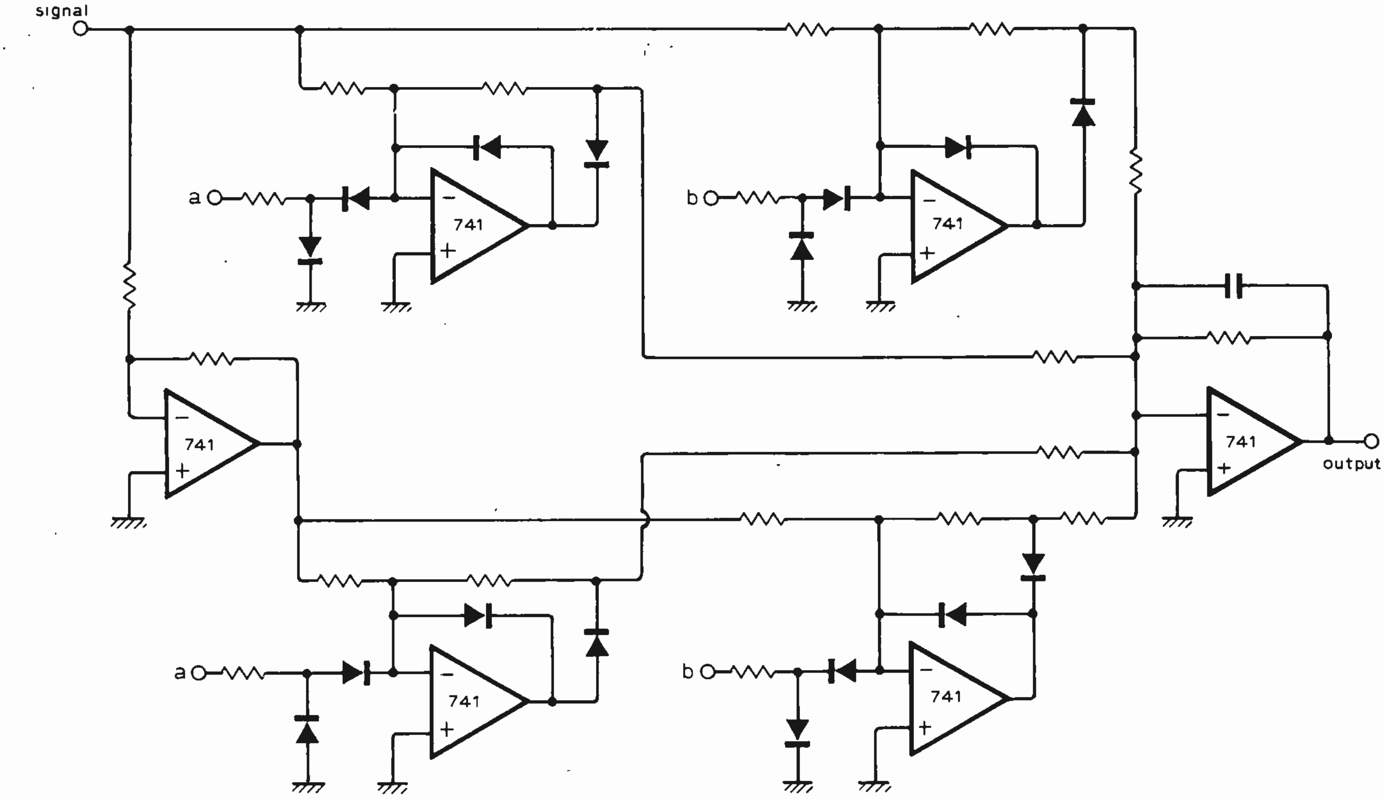
E. T. Garthwaite,
Carlisle.

## Phase failure indicator

The circuit shown will indicate whenever any one of the three phases of a balanced supply is absent. Each phase is separately stepped down to about 9 volts and rectified. The three cathodes of the diodes are joined together and resistor $R_2$ is adjusted so that $Tr_1$ is just conducting when three phases are present. In this condition the relay will operate. If one of the phases is off the average voltage at the base of $Tr_1$ is reduced and the relay is released.

S. K. Sud,
Instrument Design Development Centre,
I.I.T. Delhi,
India.






# Precision phase sensitive detector

Precision phase sensitive detectors are finding an increasing application in experimental environments where a small signal has to be retrieved from background noise, often much greater than the signal itself.

The basis of this detector is four precision rectifiers operating as analogue gates. Each passes signals of one polarity and may be dis-enabled by a suitable signal. At any instant only one of the gates will be passing a signal and a d.c. output is obtained by summing and smoothing the outputs from the individual gates. The phase reference is obtained from two 180° out of phase square waves (a and b in the diagram) which should be symmetrical about zero and have an amplitude greater than the largest expected signal.

Performance of the circuit is good, and no switching transients are present at the output. Overall phase response and rejection of quadrature components in the signal are dependent on all the amplifier elements having unity gain. For the highest quality detector, selection of the gain determining resistors will be necessary.

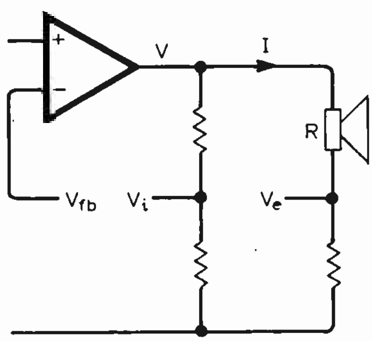
W. Allison,
U.C.L. (Dept. of Physics),
London W.C.1.

# Loudspeaker feedback circuit

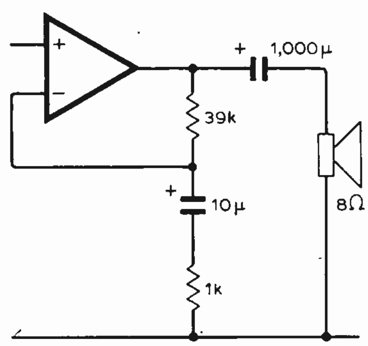
Power dissipated in a loudspeaker is proportional to $V^2/R$ where $V$ is the voltage across the coil and $R$ is the resistive impedance. Modern voltage amplifiers driving into moving coil loudspeakers work successfully on the assumption that the impedance is roughly constant over the entire frequency range. This, however, is not the case and, although damping factors can minimize the effect, this is one of the causes of colouration.

It is possible to obtain a loudspeaker output which is more accurately proportional to the square of the amplifier input voltage by including the speaker in the feedback path of an amplifier. In circuit (a) the resistance in series with the loudspeaker monitors the current, and a potentiometer is used to monitor the output voltage. If the feedback is now made proportional to the geometrical mean of $v_1$ and $v_2$, i.e. $(v_1 \times v_2)^{1/2}$, then the output from the speaker will be proportional to the amplifier input and independent of variations in the speaker impedance. Very complicated circuitry would be needed to obtain such a mean, but for medium differences between $v_1$ and $v_2$ the arithmetical mean approximates closely to the geometrical mean. The simplest way of obtaining an arithmetical mean is shown in circuit (b) where the output and feedback paths of a typical amplifier are shown. Circuit (c) shows a modified arrangement but other configurations are possible and may be more suitable in different amplifier designs. The results, especially in the medium quality loudspeaker range, can be quite impressive.

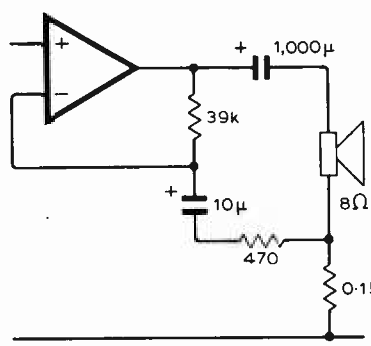
Giles Hibbert,
Blackfriars, Oxford.



(a)



(b)



(c)

# Low-noise, low-cost cassette deck — 3

## Motor control and further notes

by J. L. Linsley Hood

In response to one or two queries, the following notes are offered. Several cassette decks have now been completed, using alternative designs of printed board, and have proved very successful.

### Motor control

Circuitry for the control of the drive motor and solenoid is shown in Fig. 20. It is required to supply or withhold current from the cassette-retaining solenoid and to supply a constant drive to the motor in the presence of supply variations.

**Solenoid control.** $Tr_3$ normally conducts and energizes the solenoid. As the motor turns, the pulse-generating switch in the mechanism (yellow and green leads in the Goldring deck) keeps $Tr_1$ conducting, which cuts off $Tr_2$ and allows current to flow through the solenoid and $Tr_3$. When the motor stops, so does the switch: $Tr_1$ ceases to conduct and, after 3 seconds ($C_2R_5$) $Tr_2$ conducts, cutting off $Tr_3$ and de-energizing the solenoid. The cassette is thereby released. If the "pause" contacts are made, the motor stops, but the cassette is retained in position.

**Speed control.** The motor is supplied with constant current via $Tr_5$. $Tr_4$ is conducting. Back e.m.f. developed by the motor beginning to turn is applied to $Tr_4$ emitter, reducing its forward bias. This reduces the current into $Tr_5$ base and tends to reduce the motor speed — the effect is to stabilize the motor. $Tr_5$ behaves as a constant-current source by virtue of the feedback from its collector to $Tr_4$ base.

### Record input impedance

There are, unfortunately, two conventions on the impedance levels employed for signal handling prior to tape recording. Of these, the older, and I think the

*Fig. 19. Buffer amplifier to match a DIN source to the recording amplifier.*

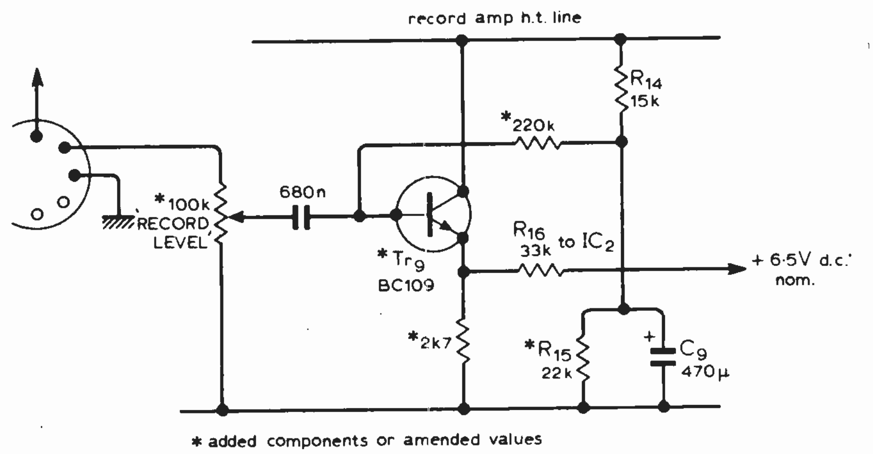
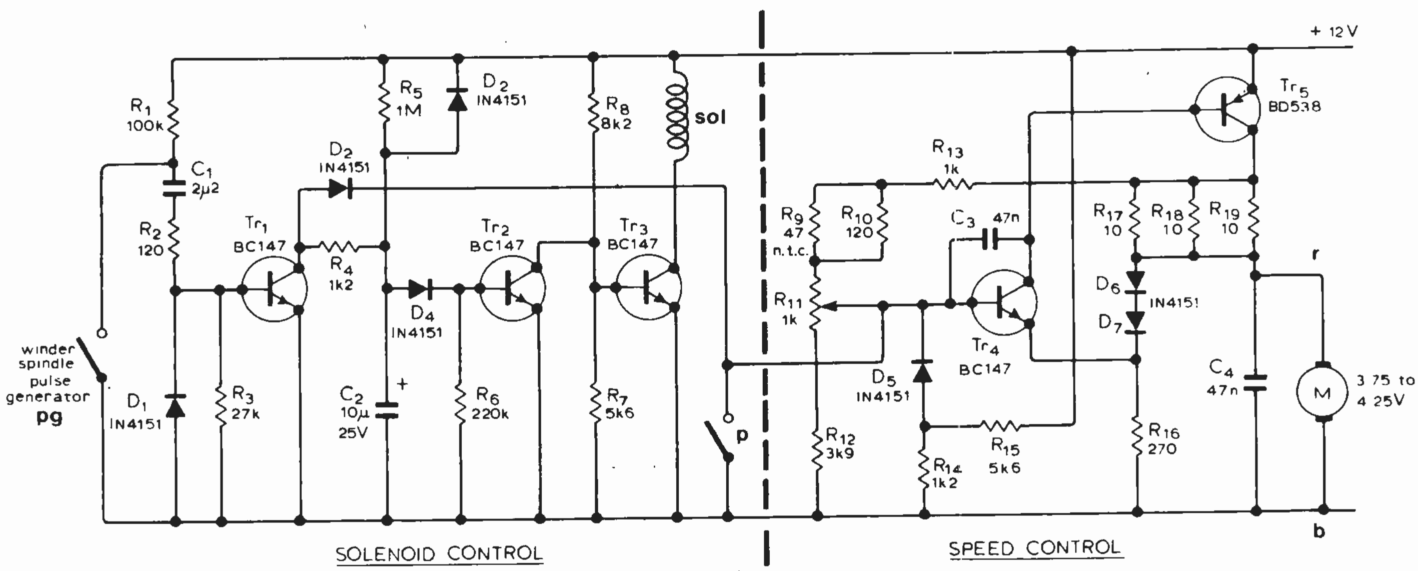
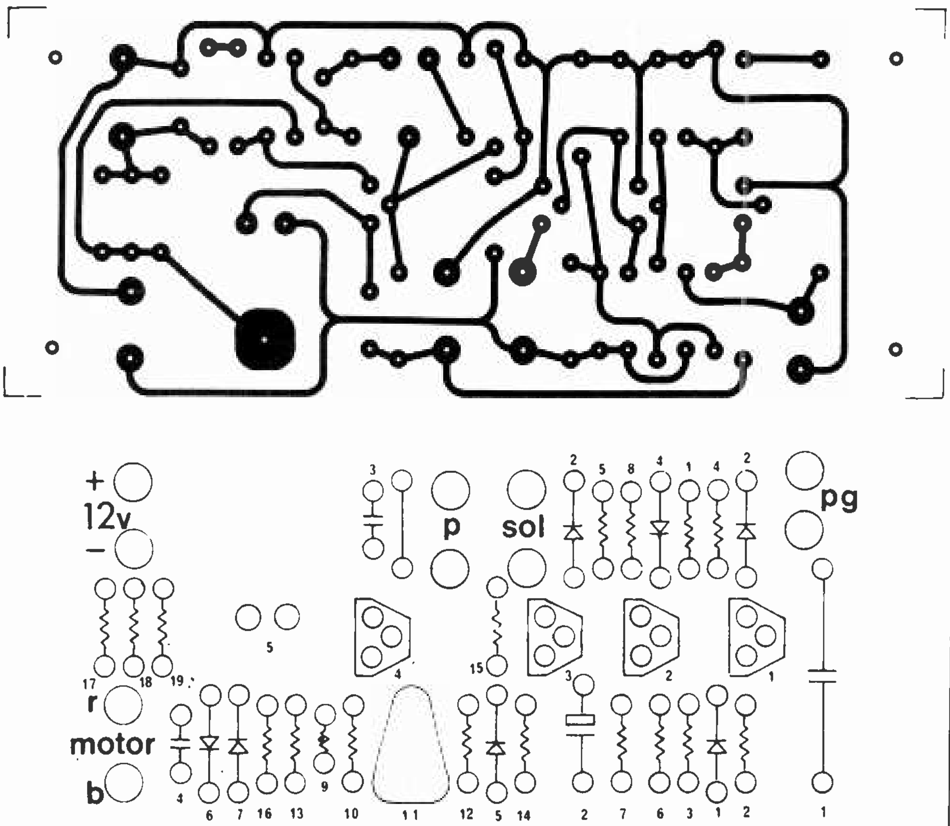



*Fig. 20. Circuit diagram of the motor controller.*






more sensible, is the "600 ohms, 0 VU" (+0 to —60dB, ref. 0.77 V r.m.s.), system which seems to be used by many recording studios, and gives a signal level which can be handled comfortably without problems of degradation due to noise. The other, and the one which is being used increasingly in commercial amplifier "recorder" outputs, is the DIN standard, which implies basically a constant-current source, developing a nominal lmV r.m.s. for each 1kΩ of recorder input impedance. Predictably, this leads to a degradation of signal quality due to thermal noise unless fairly high value input impedance circuits are employed.

The convention for which the recorder described above was designed was the 600-ohm source impedance one although, taken in general terms, this means any range of source impedances in the range zero to a few kilohms, and the system as it stands would probably have inadequate gain if operated from a DIN source. It is, however, not practicable simply to increase the input record level potentiometer to 50kΩ or 100kΩ since the source impedance of $IC_2$ influences the Q of the h.f. pre-emphasis system (see Appendix). While the effect of the existing 10kΩ potentiometer, when driven from a fairly low source impedance, is negligible, this would not be true for a higher value DIN input.

If, therefore, this is to be used with a commercial unit having this convention (as distinct from a home-constructed item, in which it is probably most convenient to take the recorder feed at the pre-amp output, in parallel with the power amplifier input), it is recommended that a small buffer circuit

*Fig. 21. A suggested, actual-size layout for the controller. The layout and modifications to the speed control circuit are due to Mr A. H. Milligan.*

should be attached to the output of the record level potentiometer, as shown in Fig. 19.

## Replay h.f. stability

Proximity of output and input leads may cause instability in the replay amplifier. If this cannot be avoided due to layout constraints, a small capacitor (330pF or so) can be connected across the replay output relay terminals ($RL_1/1$, $RL_1/2$) – across the replay coil output in the replay position – without any adverse effect on the h.f. performance.

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The author has pointed out to us that the use of a Doram 207-374 toroidal transformer greatly eases the problems of hum elimination. Doram Electronics Ltd, P.O. Box TR8, Leeds, are the suppliers. Components and metalwork for this design will be available from Hart Electronics Ltd, Penylan Mill, Oswestry, and Powertran Electronics, Portway Industrial Estate, Andover, Hants, also tell us they intend to produce a kit of components. *Wireless World* has arranged a supply of glass fibre p.c.bs based on the author's design. The board accommodates a changeover relay and four present potentiometers for switchable bias and provision has been made for a single time constant suitable for chromium dioxide tape (70μs). The board is priced at £4.50 inclusive. Make cheques or postal orders payable to M. R. Sagin at 11 Villiers Road, London, N.W.2.

# Announcements

Customs and Excise have issued a revised list of electronic components which will attract a **VAT rate of 12½ per cent** from July 1. The announcement supersedes one made on May 22 by the customs and the Electronic Components Board, and the list includes c.r.ts, radio and tv tuners, delay lines, transformers, chokes and coils, valves and voltage multipliers. The full list is available from the nearest VAT office.

**Computer exhibition** COMPEC has been acquired by the publishers of *Wireless World*, IPC Business Press Ltd, from the original promoters Trident Conferences & Exhibitions Ltd. This year it will be held at the new Wembley Conference Centre, November 23 to 25. In May COMPEC Europe was launched in Brussels and plans are in hand for further European shows.

The European Physical Society has awarded the Hewlett Packard Europhysics prize to Professor Wolfgang Helfrich for work on liquid crystals, leading to the discovery of the twisted nematic display.

The Sira Institute, in association with Warren Spring Laboratory, is holding a two-day seminar on **microprocessor applications** in instrumentation and control systems at the City University, London EC1, on September 29 and 30, 1976. Application forms from the Sira Institute Ltd, South Hill, Chislehurst, Kent BR7 5EH.

# Sixty Years Ago

The following, rather untypical piece was published in *Wireless World* for August 1916. Technological prophecies seem to become fact rather quicker than the prophets imagine, but this one was a little too far-seeing. The long-wave trans-Atlantic wireless telephone service was opened on January 7th, 1927.

"According to an American scientific journal, it will not be long before England and America will be able to converse with one another by means of the wireless telephone. There are certain individuals to-day who cling to the conviction that the telephone was simply the invention of a man who had a grudge against humanity. What will they now say of the wireless telephone? There is this much to say. It will be much better than those cheap wire telephones, the wires of which are so apt to snap if you don't pay up your subscriptions. With the wireless telephone it may be that you will receive a second demand note for payment, but there will be not a man with a pair of wire-cutters in his pocket to bring the third and last demand note and cut you off if you do not pay at once. It is getting to be very exciting when we get those wireless telephones in full working order. Just imagine yourself stepping into a call box in Victoria Street and asking for "45678, Broadway, New York City." While the young lady is waking up New York you just sit down and read a few chapters from your Shakespeare or Bacon – according to which school you belong. But it will test your temper when the young lady tells you that you are through, and will you please drop three hundred and sixty-five pennies in the slot and 'turn the handle after each, please'."

# Surround-sound decoders — 3

## Operation of QS Variomatrix decoder

by David Heller, B.Sc. (Eng.)

**The Sansui Variomatrix technique allows decoding of QS records with enhanced separation but without altering the gain of the decoder outputs and consequent loss of subsidiary sounds. It permits decoding of SQ records and provides two alternative ways of reproducing stereo records through four loudspeakers.**

It's well-known that in the basic Sansui QS system crosstalk is distributed symmetrically in that a left-front source, for example, produces crosstalk in the right front and left back speakers, but negligible leakage in the diagonal speaker. The QS Variomatrix (continued next folio) is a technique to increase the interchannel separation and place the reproduced signal more sharply in focus. When a predominant signal is detected, say in the left-front ($L_F$) direction, the Variomatrix circuit varies the $L_B'$ matrix coefficients* as well as the $R_F'$ matrix coefficients. If a signal of a lower level is present at the same time, it will be reproduced with maximum interchannel separation if it is located in the same direction as the dominant signal $L_F$. If it is located in a different direction, it will be reproduced in such a way that its directionality is more and more obscure as it moves further away in direction from the $L_F$ signal.

Sansui claim that their experiments have shown that when a listener perceives a dominant and a secondary sound source simultaneously, the directionality of the secondary sound source is masked by the direction of the predominant sound source, which they call directional masking. This being the case, a listener would hardly be able to detect the ambiguous directionality of the secondary sound source. However for the directional masking to be efficient it is necessary that the secondary sound source should occur within a certain time after the predominant signal. For this reason the Variomatrix coefficients have to respond to primary source changes within 20ms.

In attempting to give a surround effect, matrix systems arrange source information into two, three or four audio channels. Differences between the various approaches arise in the coding and decoding methods used; different relative weights being given to the quality of surround, stereo and mono playback. (In two-channel systems it is not possible to give optimum playback in all three modes.) The defects of early two-channel systems were quickly recognized and widespread use was made of 90° phase difference circuits to distribute the 180° phase error. Codings for these systems, including the Sansui QS, have been detailed many times, see for example "Commercial quadraphonic systems," *Wireless World Annual* 1975 pp.84-9, (for a subjective assessment see "Matrix decoding" *Hi-Fi News,* March 1975, pp. 147-57), and it is known that the maximum directivity of a two-channel system is governed by a cardioid-shaped characteristic relating signal amplitude and direction, no matter how many loudspeakers are used. The Variomatrix technique is a method developed by Sansui to improve directional effect by reducing the gains of signals prior to final decoding, according to detected phase relationships. This allows subsidiary sounds, which would otherwise be attenuated along with undesired crosstalk, to be reproduced. — Tech-ed.

### Variomatrix principles in QS decoding

The QS Variomatrix decodes the coded $L_T$ and $R_T$ signals † as follows

$$L_F' = (1+f)(L_T - R_T) + (1+l)\sqrt{2}R_T$$

$$R_F' = -(1+f)(L_T - R_T) + (1+r)\sqrt{2}L_T$$

$$L_B' = (1+b)(L_T + R_T) - (1+l)\sqrt{2}R_T$$

$$R_B' = (1+b)(L_T + R_T) - (1+r)\sqrt{2}L_T$$

where the Variomatrix coefficients f, l, b and r vary between 0 and $\sqrt{2}$. Fig. 1 shows the relationship between the direction of a sound source and the corresponding value of the Variomatrix coefficients. The centre of each circle represents 0 and the circumference $\sqrt{2}$. For example, when the sound source is located in the $L_F$ direction the Variomatrix coefficients become $f=\sqrt{2}$, $b=0$, $l=\sqrt{2}$ and $r=0$. Fig. 2 shows the internal functions of the HA1328 decoder i.c. The input matrix derives the $L_T+R_T$, $L_T-R_T$, $\sqrt{2}R_T$ and $\sqrt{2}L_T$ signals which are then passed through four gain-controlled amplifiers.

*Primed quantities indicate playback signals.

†$L_T$ and $R_T$ represent signals in the two transmission channels; they are in-phase for front sources and antiphase for back sources.

It is here that any similarity with the SQ logic ends, because in the case of SQ logic the gains of the output amplifiers are varied in such a way that the channel containing the predominant signal is amplified, while the gains of the channels containing crosstalk are attenuated. Hence any secondary sound sources contained in the attenuated channels are largely lost and only appear as crosstalk components in the remaining channels. To quote Sansui's phrase, matrix coefficients are governed according to the "centre of gravity" of the total sound signal.

The QS Variomatrix system allows weak secondary sources to be reproduced, but with ambiguous directionality. To understand how this is achieved, readers are referred to the Appendix.

### Derivation of four-speaker signals from stereo sources

The QS Variomatrix circuitry can be adapted to "synthesize" a surround sound field from a stereo source in two ways.

**Surround mode.** In Fig. 3 stereo signals at the input are blended in antiphase through $S_1$ to yield the following signals prior to entering the matrix i.c.

$$L - 0.414R$$

and

$$R - 0.414L.$$

For a left-only source ($R=0$), inputs to the matrix i.c. are $L$ and $-0.414L$, chosen to correspond to a left-back QS-encoded signal. Similarly a right-only signal produces the equivalent of a right-back encoded signal. If the stereo inputs correspond to a phantom image defined by $L=1.414R$ or $R=1.414L$, this is equivalent to an encoded left-front or right-front signal respectively.

**Hall mode.** In this instance, the stereo signals are blended by the same amount but in-phase and fed to the matrix i.c. However, signals for the left-front and right-front speakers are taken directly from the stereo source signals, while

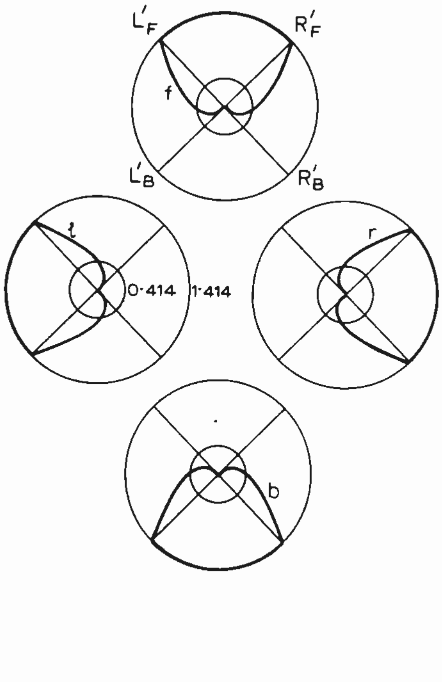


Fig. . Relationship of the four Variomatrix coefficients with encoded direction follows the laws shown.

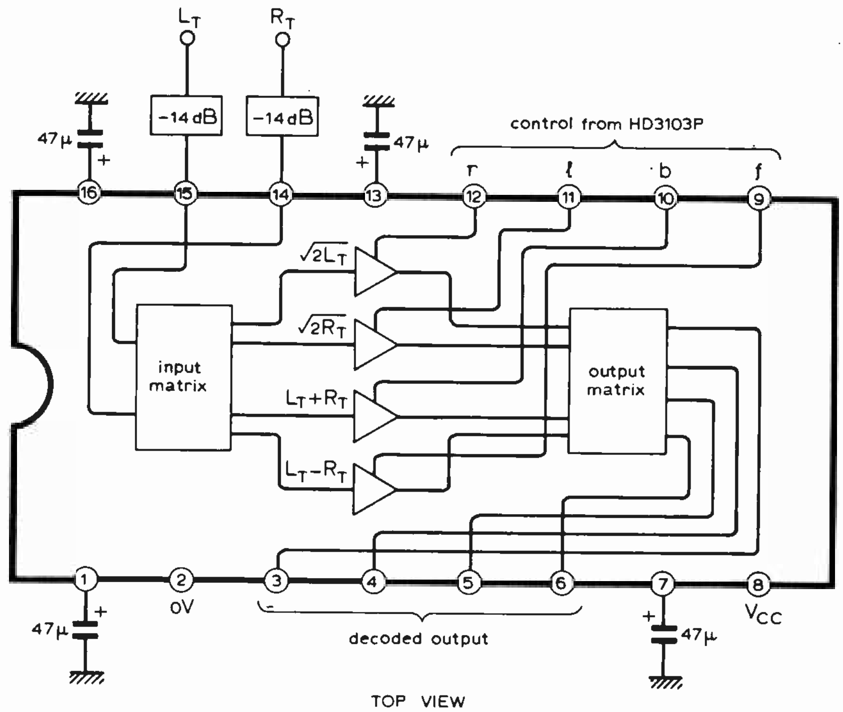


*Fig. 2 Matrix i.c. includes gain-control elements before final matrix.*

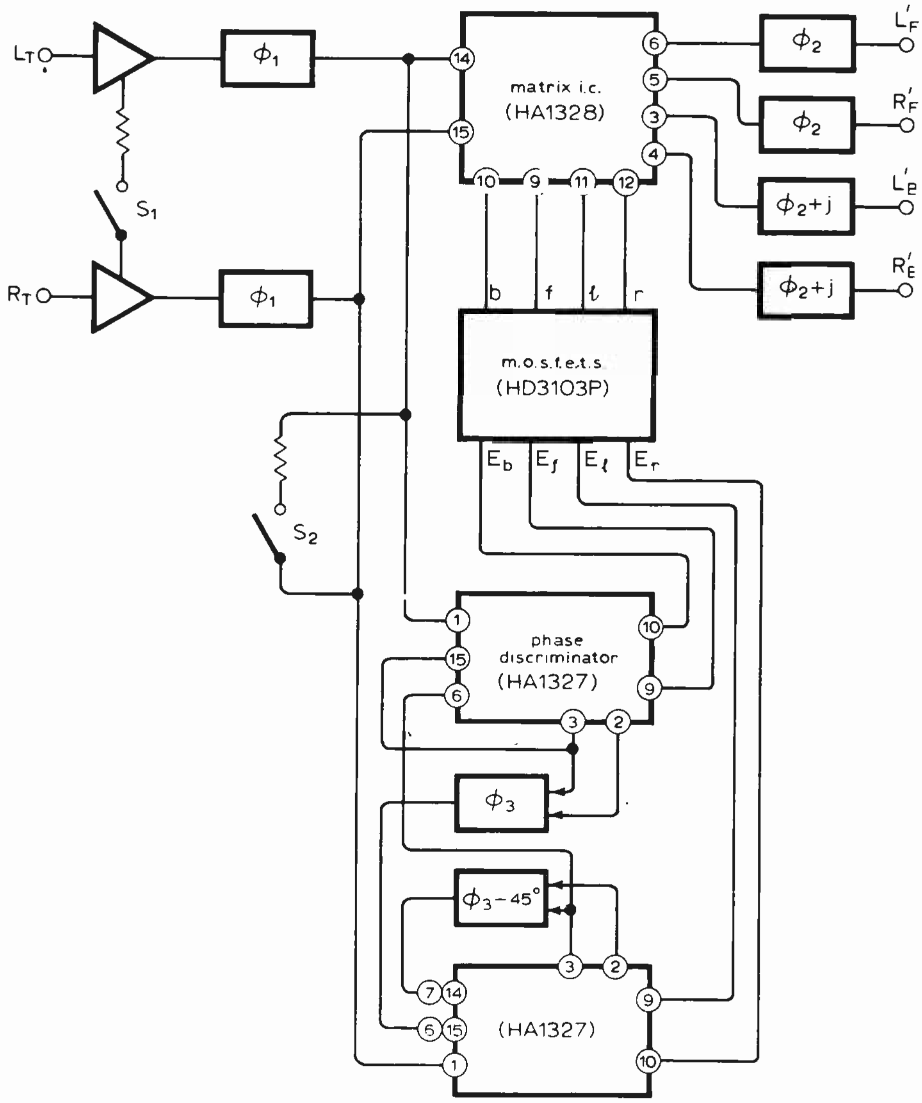


*Fig. 3 Decoder arrangement includes facility for deriving four speaker sound from stereo sources using Variomatrix technique by operating $S_1$ or $S_2$.*

signals for the rear speakers are taken from the appropriate Variomatrix decoder outputs. Referring to the table it is evident that all in-phase stereo signals would appear in the front while antiphase signals result in rear speaker images. Therefore any antiphase information present in a stereo recording will appear from the back speakers and normal stereo from the front.

**SQ decoding**

It is possible to use the Variomatrix decoder to with SQ sources. Like the QS matrix, the SQ matrix distributes the front signals in-phase to $L_T$ and $R_T$, and the back signals in reverse-phase to $L_T$ and $R_T$. In the case of the SQ matrix the $L_B'$ and $R_B'$ signals are 90° out-of-phase with each other. Separation between $L_F$, $L_B$ and between $R_F$, $R_B$ is limited to 6dB, but is theoretically infinite for centre front/back.

The decode equations for playback of SQ encoded signals using the Variomatrix decoder are

$$L_F' = (1+f)(L_T - R_T) + 2R_T$$

$$R_F' = -(1+f)(L_T - R_T) + 2L_T$$

$$L_B' = (L_T + R_T) - 2R_T + jb(L_T + R_T)$$

$$-R_B' = (L_T + R_T) - 2L_T + jb(L_T + R_T)$$

with $0 \leqslant f,\ b \leqslant 1$. The first two terms of the above equations correspond to the original QS decode equations with $l = r = \sqrt{2} - 1$, while the third and fourth equations correspond provided $l = r = \sqrt{2} - 1, b = 0$ and a new term $jb(L_T + R_T)$ is added. Hence, provided the signals $j(L_T + R_T)$ are derived at external circuits to be applied to the b control terminal of the matrix i.c. HA1328, it is possible to decode SQ sources.

**Variomatrix processing** In the block diagram, Fig. 3, of the QS Variomatrix system (without SQ option) the encoded direction of sound sources are detected by discriminating the phases of the $L_T$ and $R_T$ signals. Back and front sound sources are recognized by discriminating phases of $L_T$ and $R_T$, while left and right sound sources are located by subjecting $R_T$ to −45° phase shift and then phase discriminating $L_T+R_T\angle-45°$ with $L_T-R_T\angle-45°$. Fig. 4 shows the relationship between encoded direction of a sound source and the phase difference.

Referring again to Fig. 3 signals $L_T$ and $R_T$ are transmitted through buffer amplifiers and phase shifters $\phi_1$ to the input of the matrix i.c. and to the two inputs of the phase discriminator i.cs HA1327. The last-mentioned i.cs discriminate the phases between $L_T-R_T$, and $L_T+R_T\angle-45°$. and $L_T-R_T\angle-45°$ respectively to obtain control signals $E_f$, $E_b$ and $E_l$, $E_r$. These control signals are applied to the respective gates of four p-channel f.e.ts on the m.o.s. i.c. HD3103P to control the resistance between drain and source of each f.e.t. The drains of the f.e.ts are connected to control terminals 9, 10, 11 and 12 on the matrix i.c. HA1328 to control the matrix coefficients with the result that decoded outputs $L_F''$, $R_F''$, $L_B''$ and $R_B''$ appear at the output terminals. These signals are changed back to the state prior to phase shift when encoding by passing the signals through phase shifters $\phi_2$, $\phi_2$, $\phi_2+j$, and $\phi_2+j$ respectively.

The antiphase blend in the QS synthesizer surround mode is effected by closing $S_1$, while in-phase blend if the hall mode is effected by closing $S_2$.

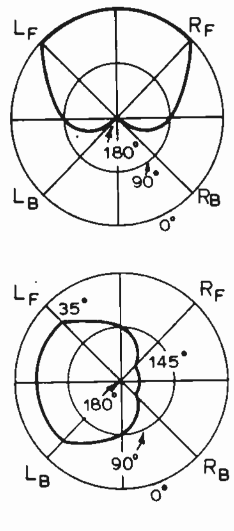


*Fig. 4 Relationship between encoded direction and phase difference of $L_T$, $R_T$ and $(L_T+R_T\angle-45°)$, $(L_T-R_T\angle-45°)$.*

## Appendix

To understand how the QS Variomatrix method of decoding allows both dominant and weak signals to be reproduced simultaneously, consider the Table. Two columns show the encoder and decoder inputs while another column shows the resultant Variomatrix coefficient required to give the correct decoded output. In physical terms, this is equivalent to placing resistors, the values of which are given in the Table, at the respective i.c. pins numbered 9 to 12.

Consider a signal $L_T$, $R_T$ to be present at the decoder inputs consisting predominantly a left-front signal $(L_T^*, R_T^*)$ together with a lesser signal of right-front directionality $(S_l, S_r)$. The $L_T$ and $R_T$ signals may be expressed as

$$L_T = L_T^* + S_l \quad (L^* \gg S_l)$$
$$R_T = R_T^* + S_r \quad (R^* \gg S_r)$$

where $L_T^*=1$, $R_T^*=\sqrt{2}-1$, $S_l=(\sqrt{2}-1)x$ and $S_r=x$ and with $x\ll 1$.

The Variomatrix circuitry recognises the dominant signals $L_T^*$ and $R_T^*$ to be a left-front encoded signal and adjusts the Variomatrix coefficients to $f=\sqrt{2}, b=0$, $l=\sqrt{2}$ and $r=0$. The resulting decoding equations become

$$L_F' = (1+\sqrt{2})(L_T-R_T)+(1+\sqrt{2})\sqrt{2}R_T$$
$$R_F' = -(1+\sqrt{2})(L_T-R_T)+\sqrt{2}L_T$$
$$L_B' = (L_T+R_T)-(1+\sqrt{2})\sqrt{2}R_T$$
$$R_B' = (L_T+R_T)-\sqrt{2}L_T.$$

Substituting $(L_T^*+S_l)$ for $L_T$ and $(R_T^*+S_r)$, and then for $L_T^*$, $R_T^*$, $S_l$ and $S_r$, yields

$$L_F' = 2.83+2x$$
$$R_F' = 0 \quad +2x$$
$$L_B' = 0 \quad -2x$$
$$R_B' = 0 \quad +0.83x$$

The calculations may be redone for different combinations of primary and secondary sound sources. In all cases it can be shown that the Variomatrix decodes the dominant sound source in the correct position, while secondary sounds are reproduced with ambiguous directionality.

*To be continued.*

**Note.** Sansui ask us to point out that QS and QS Variomatrix are trade marks of Sansui Electriclo Ltd. and SQ is a trade mark of CBS Inc. — Ed.

**Matrix coefficients and control resistor values in Variomatrix decoder.**

| Encoder input $L_F$ | Encoder input $R_F$ | Encoder input $L_B$ | Encoder input $R_b$ | Encoded signal $L_T$ | Encoded signal $R_T$ | phase diff (deg) | Matrix coeff. l | Matrix coeff. f | Matrix coeff. b | Matrix coeff. r | Control resistor $R_l$ | Control resistor $R_f$ | Control resistor $R_b$ | Control resistor $R_r$ | Decoded output $L'_F$ | Decoded output $R'_F$ | Decoded output $L'_B$ | Decoded output $R'_B$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | 0.414 | 0 | 1.414 | 1.414 | 0 | 0 | 692 | 692 | ∞ | ∞ | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0.414 | 1 | 0 | 0 | 1.414 | 0 | 1.414 | ∞ | 692 | ∞ | 692 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | j | −j0.414 | 180 | 1.414 | 0 | 1.414 | 0 | 692 | ∞ | 692 | ∞ 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | j0.414 | −j | 180 | 0 | 0 | 1.414 | 1.414 | ∞ | ∞ | 692 | 0 692 1 | 0 | 0 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1.414 | 1.414 | 0 | .414 | 1.414 | 0 | .414 | 2366 | 692 | ∞ | 2366 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | j1.414 | −j1.414 | 180 | .414 | 0 | 1.414 | .414 | 2366 | ∞ | 692 | 2366 | 0 | 0 | 1 | 1 |
| 0 2 | 0 | 0 | 0 | 2 | 0 | — | 1.414 | .414 | .414 | 0 | 692 | 2366 | 2366 | ∞ | 1 | 0 | 1 | 0 |
| 0 | 0 2 | 0 | 0 | 0 | 2 | — | 0 | .414 | .414 | 1.414 | ∞ | 2366 | 2366 | 692 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1.414 +j1.414 | 1.414 −j1.414 | 90 | .414 | .414 | .414 | .414 | 2366 | 2366 | 2366 | 2366 | 1.08 | 1.08 | 1.08 | 1.08 |

# Books Received

**Convolution and Fourier Transforms for Communications Engineers** by R. D. A. Maurice explains the mathematical process of convolution from basic concepts and gives many examples enabling the reader to compare convolution with Fourier transformation. Convolution is rather like correlation in that it is a statistical process which enables relationships between, or possible combinations of, two or more groups of things to be calculated. In communications engineering a method of calculating the effect of a network on a transient signal would be to obtain the final waveform by convolution of the original signal with the waveform of the network's response to a test signal — the unit impulse. If the functions to be convolved are in digital rather than analogue form the process becomes a simple arithmetical operation. All examples in the book are taken from real cases and chosen to show features which predominate in practice. Suitable for broadcasting and telecommunications engineers and also for undergraduate and postgraduate engineering students. Price £7.50. Pp. 198. Pentech Press, 4 Graham Lodge, Graham Road, London NW4.

# Electronics in measurement

## New industrial techniques revealed at 7th IMEKO congress, London

Too often electronics seems to be associated with dangling before the public a succession of new toys and trinkets — digital watches, pocket calculators, radio and television sets, video games and the like — for the main purpose of creating mass consumer markets for components and equipment. To some engineers this seems like a trivialisation of their calling. It is therefore encouraging to be able to report on a field of activity where electronics has a more direct bearing on the quality of our lives — on energy conservation, pollution control, public safety, agriculture, and the efficient utilization of raw materials. Such applications were the dominant feature of the seventh IMEKO congress held in London in May this year. Indeed, the official theme of the congress was "practical measurement for improving efficiency", and this was reflected in most of the papers delivered.

In general the electronic techniques described were used for processing in various ways the electrical signals produced by measurement transducers, thereby obtaining more refined or elaborated information, or quicker results, than would be possible by other means. One of the simplest examples, described by two Indian authors, A. S. Zadgaonkar and M. G. Tarnekar, was an instrument for estimating the ash content of coal samples. This is being used to test coal in India to decide whether it is in fact worth mining. A 1000Hz acoustic signal, produced by a signal generator, amplifier and transducer, is passed through a 5mm cube sample of coal and the received energy is picked up by a microphone, the output of which is amplified and indicated on a voltmeter directly calibrated in percentage ash content. The ash percentage is in fact proportional to $\log_{10}(V_0/V)$, where $V_0$ is the voltmeter reading without the sample and $V$ the reading with the sample.

At the other end of the scale were elaborate instruments including analogue and digital computing techniques, in some cases using microprocessors. The technique of correlation computing is now being widely used, particularly for measuring the flow rate of materials and the velocity of objects. The attraction of this method is that it can be applied to measurement signals obtained from natural features of the material itself, such as particles, grain patterns, turbulences and radiation discontinuities. In flow rate measurement, for example, two transducers are used, spaced at a known distance apart along the flowing material. They produce electrical signals $x(t)$ and $y(t)$. The output from the leading or "upstream" transducer, $x(t)$, is delayed in time by an interval $\tau$ which can be continuously varied, giving $x(t-\tau)$. To obtain the cross-correlation function of the two signals, $x(t-\tau)$ is multiplied by $y(t)$ and the time integral of the product is continuously calculated over a fixed period of time while $\tau$ is varied. All this is done by analogue or digital electronic circuits. When delay time $\tau$ is equal to the time of travel of, say, a particle from one transducer to the other, the cross-correlation function is at a maximum. This gives the time of travel, and since the distance between transducers is known the flow rate can be electronically calculated.

One example of this method of flow measurement was concerned with pollution of the environment by fumes from steel making plant, in a paper by P. J. Webb and co-authors from the British Steel Coporation. To optimise the use of capital in the construction of steel-making plant and to monitor the conditions of service they have developed non-contacting techniques for measuring the flow rate, temperature and composition of exhaust gases. These make use of either emission or absorption of infra red radiation by the fumes. In particular the flow rate of the exhaust gases is based on cross-correlation between the electrical signals from two spaced infra-red detectors "viewing" the gas stream. By arranging these detectors in different viewing configurations it is possible to distinguish information relating to either regional flow rates or to the mean flow rate.

Correlation is also the basis of an instrument, described by G. J. Llewellyn, of Bradford University, for measuring the velocity of jets of high temperature gas and solid material from volcanos. Expeditions have been made to the Etna and Stromboli volcanos to test it, and the applications intended are to provide early warning of volcanic activity and to improve the deployment of rescue services aiding the communities affected by the eruptions. The flow of the volcanic jet is detected by means of infra-red radiation emitted by it, received at a distance. A telescope is focused on the jet, and the infra-red radiation from two points on the jet, one above the other, is directed onto two lead sulphide cells. The output signals from the cells are amplified and tape recorded on site, after which the readings are applied to a cross-correlator, from which the jet velocity is obtained.

When solid materials are transported hydraulically or pneumatically along pipelines they have to be conveyed as slowly as possible to minimise power costs and wear on equipment and to reduce the risk of breakage. R. M. Henry (Open University) and M. S. Beck (Bradford University) presented a paper on an adaptive control system for achieving this which used cross-correlation for conveyer velocity measurement. Two conductivity transducers are placed in the pipeline about 2 pipe diameters apart and the cross-correlation, flow control, adaptive control and flow valve positioning are all done digitally by an on-line digital computer (the Argus 400). The system operates by sampling at a rate of 1300Hz, and 48 points are correlated in about 9 seconds. A modified system under development will use a microprocessor and a l.s.i. correlator.

Two cross-correlation flowmeters for use in open channels were described by R. W. Smith and co-authors of Bradford University. In one, ultrasonic sensing is used. Two transducers transmit beams of ultrasound from one side of the channel through the flowing liquid to pick-up transducers at the other side. Discontinuities in the flowing liquid modulate the received signals in amplitude and phase, and the demodulated signals are processed in the cross-correlator. A second flowmeter works optically, using photocells, and operates on the time of travel of turbulence patterns or floating particles between two points on the liquid surface.

### Speed measurement

Highly accurate measurements of vehicle speeds are often needed as a basis for improving motor vehicle efficiencies. T. Idogawa and T. Ono of Hokkaido University, Japan, described a method, using cross-correlation of random functions obtained from road surfaces, which gives a speed measurement accuracy of 1% for movement both in straight lines and in arbitrary curves. Two semiconductor photocells are mounted in the vehicle and arranged to examine the road surface, one being 20cm ahead of the other in the line of movement. The output signals of these are fed to a digital cross-correlator and the correlation function is read out every 400$\mu$s and indicated on analogue and digital display units.

Another method of speed measurement using cross-correlation was revealed by C. Zimmer and co-authors of Hasler Ltd, Switzerland. This uses a delay locked loop, based on a shift register, which automatically follows the delay time between the two spaced transducer signals. The system is for measuring the speed of trains without using the wheels (which introduce errors because of skidding and slipping) and it works by optically scanning the varying structure of the rail surface with two optical heads spaced 50mm apart. The rail surface is illuminated by solid state light sources and the reflected light is focused through slits onto photodiodes. The output of the leading photodiode is applied to the shift register delay line and the delayed signal is multiplied by the output of the other photodiode. The product is then integrated and, through a voltage controlled oscillator, used to control the stepping speed of the shift register. Each step of the shift register indicates a certain travelled distance, e.g. 1.25mm. The whole delay locked loop operates to automatically adjust the delay time in the shift register to equal the time of travel of a point on the rail between the spaced optical heads. Speed is then obtained by integrating the distance pulses over a given time. Measurement accuracies of better than 1% are obtained.

Correlation technique also has its use in extracting periodic signals from noise which obscures them: the periodic signal is highly correlated but the noise, being random, is not. Y. Dubnistchev and co-authors from the USSR showed how correlation technique can reduce the noise that affects the performance of a laser Doppler velocity meter used for flow measurement. Another noise problem was dealt with by Japanese authors. Flaws in wire rod being made by hot rolling are normally detected by eddy current flaw detectors. The rod passes between search coils as it is rolled and a flaw is detected by the change it causes in the eddy current induced in the rod. A serious measurement problem, however, is introduced by noise created by vibration of the rod. K. Watenabe and co-authors from the Daido Steel Company of Japan showed how this trouble can be overcome electronically by phase discrimination between the flaw signal (at 160kHz) and the noise. This is based on the fact that the phase angle of the noise is continually changing while that of the flaw signal remains constant.

A special purpose m.o.s. integrated circuit digital correlator designed for use in correlation flowmeters was described by J. R. Jordan and B. A. Manook of Edinburgh University. The i.c. executes 12 points of polarity correlation and has a novel output circuit which interrogates only the overload state of the integrating counters summing coincidence between the two, polarity detected, analogue inputs. When used in a flowmeter, the first integrating counter to overload indicates the position of the peak of the correlation function, while a frequency inversely proportional to the peak position (i.e. proportional to flow rate) is obtained directly from the output circuit.

### Thickness and layers

An optical method for measuring the deposition rate and thickness of various layers of material used in the making of microelectronic devices was described by V. N. Chernjaev and co-authors from the Moscow Aircraft Technological Institute, USSR. The principle makes use of optical interference between rays of coherent light. A beam of monochromatic light is directed on to the substrate carrying a deposited layer and the intensity of the reflected light is measured. As the thickness of the deposited layer increases there is a continuous change of phase between the light reflected from the substrate and the light reflected from the layer surface, and this causes a cosine law variation in the intensity of the measured reflected light. From this the thickness is determined electronically and used to control the deposition rate.

In optical range-finders and other stereoscopic instruments, the parallax is a measure of range or altitude. Normally such instruments depend on human perception, but F. Mesch and H. Moll of the University of Karlsruhe, Germany, showed how correlation methods could be applied to obtain parallax measurements. For electrical operation, the two stereoscopic images, which are temporarily constant, have to be transformed into time varying signals by electronic scanning methods using television cameras or cathode-ray tubes.

Examination of layers in the earth's atmosphere associated with temperature discontinuities has been carried on for some time with powerful frequency modulated, continuous-wave microwave radar sets. A development revealed by J. H. Davies of Barringer Research, Toronto, is a small, lightweight (150 lb) f.m.-c.w. radar for this purpose which could be carried in an aircraft. Using a transmitter power of only 20 watts at 5·8GHz with a frequency excursion of 200MHz, it has a receiver sensitivity of -140dBm, a maximum range of 1km and a resolution of 3 metres.

One way of measuring the flow rate of solid granules in pipes or conveyors depends on detecting random fluctuation of the granules in transit: the greater the flow rate the greater the amplitude of the fluctuations. A method described by Y. Tomita and co-aurhors of Keio University, Japan, depends on the audible noise produced by the collision of the particles against each other. The noise is picked up by a microphone mounted in the pipe and the power spectrum of the noise signal is obtained by a wave analyser for bandwidths of 10 and 100Hz. The noise is pink; at lower frequencies the r.m.s. sound pressure is flat but above about 200Hz it falls sharply. Curves plotted show a relationship between particle flow velocity and r.m.s. sound pressure. Other methods, using a similar basic principle, were described by H. K. Kwan and M. S. Beck of Bradford University. One of these employed a capacitance transducer. Random variations in flow cause small changes in the instantaneous concentration of material between two capacitance electrodes and the amplitude of the resulting capacitance changes is measured electronically. The second method uses ultrasonic transducers operating at 40kHz. The granule fluctuations cause variations of ultrasound pressure at the receiving transducer and the amplitude of this modulation of the 40kHz signal is again measured electronically. With the capacitance method, R. G. Green of Bradford College showed that higher sensitivity is obtained with an f.m. transducer (the capacitance changes causing frequency variations in an oscillation) than with an a.m. transducer (the capacitance changes causing amplitude variations in the oscillation).

Speakers from Unilever Research, Netherlands, described the use of microprocessors in conjunction with a nuclear magnetic resonance spectrometer, for measuring the percentage of solid matter in partially crystallized fat, and with a dissolver/sampler for automated analysis of detergent powders. Digital techniques are also used in a system, explained by S. Kun and co-authors of Budapest, for accurately measuring the net mass of hydrocarbons passing along pipelines. The mass flow measurements taken by turbine flowmeters are automatically corrected in digital circuits by measurements of density, pressure, viscosity, temperature and other variables to give accurate measurement of net mass. Also from Hungary, G. Várnai showed how digital computing methods are used for accurate measurement of the mass or volume of liquids stored in tanks. The basic measurements are of liquid level in the tank and of temperature differences which affect the expansion of the liquid. The digital computing operation calculates the volume or weight of liquid using these measurements and the cross-sectional area of the tank stored in a r.o.m.

A method of measuring the quality of printed characters, resulting from multiple copying or other processes, was described by R. J. Hall of Wiggins Teape Research and Development. Its principle is to compare the density distribution of a sample character with that of a master (perfect) character by means of two vidicon television cameras scanning the characters. For each line scan across the characters, the line waveform from the "master" camera is subtracted from that from the "sample" camera and the resulting difference signal represents the error in density between corresponding areas. The integral of this waveform is the total area-density product and is obtained by digitizing the difference signal. Measured results are displayed digitally. A refinement to the digital processing system enables the area due to the "master" to be removed from the "sample" field and as a result only the external dispersion error, or "blur," is measured.

It is useful to be able to monitor the flames used for heating boilers, in one case for the purpose of minimizing fuel consumption (by controlling air/fuel ratios) and in another case to prevent explosions (caused by accumulation of a mixture of unburnt fuel and air). H. C. Lord and co-authors from the Environmental Data Corporation, USA, described a flame monitor used for the first application which works on a spectroscopic principle. The intensity of light emitted from the flame is measured at two wavelengths and the ratio of these two measurements, calculated in a microprocessor, is proportional to the percentage of air in the combustion process and is used to control electronically the burner's air/fuel ratio.

B. G. Gaydon of the UK C.E.G.B. gave a review of flame monitoring techniques for large boilers, one of which was an electronic cross-correlation method now being tried out in England and Australia. Two telescopes spaced 70mm apart are aimed so that their lines of sight intersect at the edge of the flame. When the flame is present the flickering light received by one telescope is very similar to that received by the other telescope. If, however, the flame is absent, either the light level will by very low or the flickering illumination received from different areas of background sources will be dissimilar, i.e. uncorrelated. The monitored flame is presumed to be present only when the electrical flicker signals have sufficient amplitude (determined by a "low signal" detector) and are highly correlated (determined by a cross-correlator). An advantage of this method is its sensitivity to low light levels as the correlation process gives a dimensionless criterion of flame presence, independent of flicker amplitude.

The vibration in lathes and other machine tools known as "chatter" was the subject of a paper by M. A. El Hakim, of Ain Shams University, Egypt, who described a "chatter" detector and control system. Vibration of the cutting tool is detected by an accelerometer and the output signal of this is amplified and passed through a band-pass filter tuned to the natural frequency of the chatter process, then rectified. When the rectified voltage approaches a reference voltage which represents a point just before the onset of chatter, a relay operates an audible alarm and also causes a solenoid to disengage the clutch of the machine-tool feed motion.

A new type of very thin (10 to 50μm) pressure transducer, for measuring pressure fluctuations on aerofoils, was the subject of a paper by M. Chatanier of the French Office National d'Etudes et de Recherche Aerospatiales. Being so thin, it can be attached by simple bonding and no machining of the aerofoil is necessary. It consists of a dielectric film (6 to 25μm), both surfaces of which are metallized. Pressure changes cause corresponding variations in the dielectric thickness and an electrical signal is obtained by measuring the resulting capacitance values. The transducer will operate at temperatures of a few hundred °C and at frequencies up to tens of kHz.

## Aids to agriculture

Agricultural research is greatly benefiting from the use of electronics and several papers reflected this activity. For example, J. D. Lambright of Texas Technical University and co-authors described a digital capacitance meter designed for measuring the foliage yield of plants. This is much quicker in use than the normal method of clipping, drying and weighing samples of foliage to obtain the mass per unit area. The principle is to measure the capacitance of a structure consisting of a specific volume of vegetation enclosed between electrodes. Basically the system measures moisture content, because water has a higher permittivity than other substances. The measured capacitance variations indicate either water content and its alteration with time in a constant mass or total mass in a given region of growth, or both. Essentially, a relationship between water content and foliage mass can be established.

Reducing the heating costs of glasshouses is the ultimate purpose of an electronic meter which measures and records the total heat in joules dissipated by a hot water heating system. Described by W. R. Wignall of the UK National Institute of Agricultural Engineering, it integrates the product of water flow rate and the temperature difference between flow and return circuits. This is done by means of a train of pulses which have an amplitude proportional to the temperature difference and a mark-space ratio proportional to flow rate. The area under the pulses is integrated and the result is shown on an electromechanical counter. Also outlined by this author was an electronic instrument for measuring a rotary digger's "bite length" — or length along the ground surface between successive cuts of the rotor blade. It operates from photoelectric transducers sensing forward speed and rotor blade speed, and these produce pulses which are fed to gating and counting circuits. Forward-speed pulses are counted for a period determined by counting a pre-set number of rotor speed pulses, and from the first-mentioned a direct display of "bite length" is obtained.

*The 7th IMEKO congress was organized by the Institute of Measurement and Control, and the proceedings, consisting of 163 papers in four volumes, can be obtained from the Institute at 20 Peel Street, London W8 7PD, price £20.00 including postage and packing.*

# Announcements

**North Sea orders**

Ferranti will supply £1½ million worth of telemetry and control equipment to the Central and South Platforms in the Ninian field. Each will have a dual Argus 700E computer with paper tape peripherals and an interface which includes two semi-graphic CRTs with digital and analogue inputs and outputs. All systems can be monitored on the displays and the operator will be able to route selected wells to the test separator system automatically. As well as full logging the system will provide constant monitoring for metal fatigue and corrosion in the steel platform.

Marconi has bought Comelit antennae and cable feeders from Hayden Laboratories to establish communication links between oil and gas rigs in the North Sea and the shore. Hayden says all the rigs will now be linked permanently to the mainland telecommunications system. Hayden has also supplied equipment to install on the Occidental Piper and Mobil Beryl A oil platforms 100 miles east of the Shetlands. The four antennae use either line of sight or tropospheric scatter techniques.

**Tanker equipment orders**

The Shell tankers Methane Princess and Methane Progress are to be fitted with a ship telex system, the new vessel Matco Thames has been fitted with radio communications and navigational equipment, and the BP fleet has been supplied with 79 multi-standard colour tv receivers, all orders for Marconi.

# Characteristics and load lines

## 1 — Linear characteristics

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

To use an electronic device successfully information is required on its basic properties and these may be quoted as the input resistance, output resistance, transfer resistance (or conductance) and reverse transfer resistance. This is true whether the device is a transistor, an i.c. or a complete equipment. This article and the next one are concerned with the shape of the transfer characteristic, i.e. the form of the relationship between the input signal and the output signal. For some applications the characteristic is required to be linear, showing strict proportionality between input and output signals: such characteristics are the subject of this article. Other applications require a non-linear characteristic and these are discussed in Part 2.

For a bipolar transistor the input-output characteristic may be given in the form of a curve relating output (collector) current with input (base) current. A typical example of such a curve is given in Fig. 1(a) and this has an almost-linear section showing the output current to be nearly directly proportional to the input current. For a field-effect transistor (and a thermionic valve) the input-output characteristic is generally shown as a curve relating output (drain or anode) current and input (gate or grid) voltage. As shown in Fig. 1(b) this curve also has a near-linear section showing that the output current is proportional to the input voltage (measured from the cut-off point).

In general input-output characteristics have the form shown in Fig. 2 in which BC is the nearly-linear section. The regions of curvature at the ends of the characteristic can be explained by considering a simple single-ended amplifying stage. Linearity cannot continue as the input is decreased towards zero because the output current is cut off, causing the characteristic to become horizontal as shown by section AB. On the other hand linearity cannot continue indefinitely as the input is increased, and at a particular value of input amplitude the device is unable to increase the output current pro rata with the input and the characteristic again goes horizontal as shown by section CD. This may not be due to lack of emission: it is quite likely to be due to the inclusion of a load resistor in the output circuit which limits the output current to a particular value by reducing the supply voltage across the device to zero. For example if the supply voltage is 12 and the load resistor 3 kilohms, the output current cannot exceed 4mA. Thus the curvature at one end of the characteristic arises because the active device runs out of current and at the other end because it runs out of voltage.

The linear part of the characteristic is of interest to the designer of linear or analogue equipment and in general the degree of linearity of active devices is not good enough for most purposes. The linearity must therefore be improved, and some methods of doing this are described later.

In the design of digital equipment the shape of the almost-linear part of the input-output characteristic is of little interest. For most of the time the active device is biased either well beyond point A, i.e. beyond cut off, or well beyond point D, i.e. at maximum current. These two regions are identified in Fig. 3. The device is used in fact as a switch which is either on or off. The only time the linear part of the characteristic is used is during the change from one stage to the other, and this occurs so quickly that the precise shape of section BC is of little concern. The only interest the designer of digital equipment has in this part of the characteristic is that it should be steep so that the change from one state to the other can be as rapid as possible.

### Linear amplification

Let us assume that part BC of an input-output characteristic has been

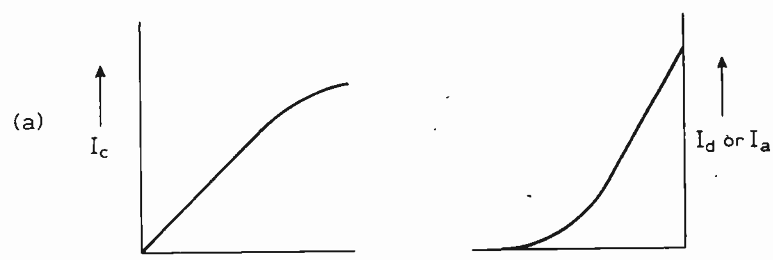

*Fig. 1. Input-output characteristic for (a) a bipolar transistor and (b) a field-effect transistor or a thermionic valve.*

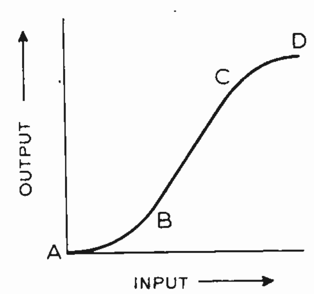

*Fig. 2. General form of input-output characteristic.*

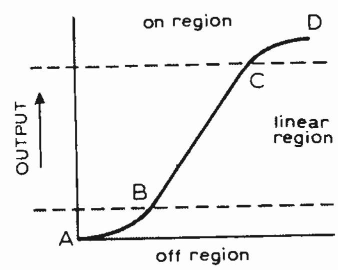

*Fig. 3. Relationship between on, off and linear modes of operation.*

linearised by one of the methods to be mentioned later and suppose a sinusoidal signal of say 1kHz is applied to the input of the device. To avoid using the non-linear sections of the characteristic, which would result in distortion, the amplitude of the signal must not exceed the extent of the linear section of the characteristic and the bias must be chosen to ensure that the signal is centred accurately on the linear section. Amplification is then distortion-free and, if we ignore extraneous signals such as hum and noise, the output of the device consists solely of the amplified 1-kHz signal.

Suppose now a second signal of say 10kHz is added to the input. The two signals when added give the waveform shown in Fig. 4, from which it is clear that the combined amplitude is the sum of the individual amplitudes of the two input signals. This combined amplitude must be accommodated on the linear part of the characteristic if distortion is to be minimised. Thus the individual amplitudes of the two signals must be smaller than that of the 1-kHz signal used originally. Under these conditions the two signals are amplified independently and the output of the device contains only 1-kHz and 10-kHz components: amplification is again distortion-free.

If too large a signal amplitude is used the non-linear parts AB and CD of the characteristic are involved in the amplification process and distortion results: this, of course, is overloading the amplifier and can be avoided by restricting the input-signal amplitude. But even when there is no overloading there is still some residual non-linearity in part BC of the characteristic in spite of efforts to linearise it. Amplification is not quite distortion-free and there is a slight modification to the waveform of the signal during amplification: an example is shown in exaggerated form in Fig. 5. This distortion is equivalent to the addition of new signals (harmonics) at multiples of the original frequency. When the non-linearity is such as to produce a resultant wave which is asymmetrical about the time axis, as shown in Fig. 5, the added harmonics are chiefly even, i.e. are at twice, four times, six times etc. the frequency of the input signal. If the distorted output wave is symmetrical about the time axis (e.g. both peaks equally flattened) the added harmonics are chiefly odd, i.e. at three times, five times, seven times etc. the input frequency. In general both even and odd harmonics are generated, and if the frequency of the input signal is 1kHz, the harmonics have frequencies of 2kHz, 3kHz, 4kHz etc., the amplitude of the harmonic decreasing as the frequency increases. The harmonics are evenly spaced throughout the spectrum, the common frequency difference being 1kHz — the frequency of the input signal.

If the introduction of harmonics were the only consequence of non-linearity

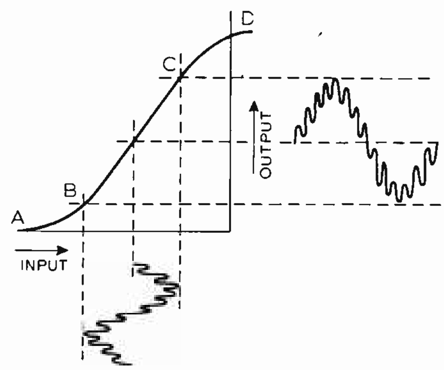


*Fig. 4. Addition of 1-kHz and 10-kHz signals at the input to a device and their application to the linear part of an input-output characteristic. (Time scales are different.)*

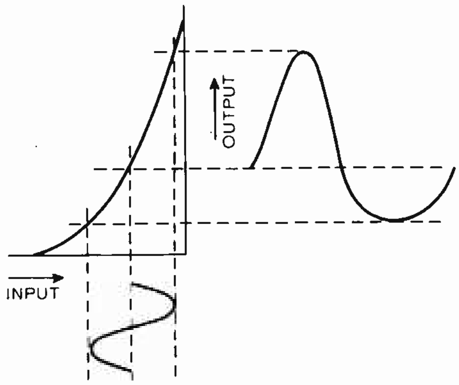


*Fig. 5. Production of even-harmonic distortion by a non-linear characteristic. (Time scales are different.)*

they would not be serious in an audio-frequency amplifier because:

(a) low-order harmonics blend harmoniously with the input frequency and with each other. For example 2kHz is one octave higher than 1kHz; 3kHz forms a musical fifth with 2kHz. The 7th and 9th harmonics do form discords with the original frequency but often the amplitude of these harmonics is too small to be significant.

(b) in audio amplification the input signals are not usually single tones such as 1kHz. Musical instruments and the human voice produce a wealth of harmonics and it is their number and relative amplitudes which give the source its characteristic sound quality. In practice therefore the input is likely to contain a number of harmonics: as a result of the non-linearity of the amplifier the amplitudes of the harmonics will be slightly increased.

Unfortunately non-linearity results in another effect which is far more serious than the introduction of harmonics. This effect occurs when there is more than one input frequency and this, of course, is normal for an audio-frequency amplifier. For simplicity suppose there are two inputs at frequencies of $f_1$ and $f_2$. Each is treated as a single tone and a number of harmonics of each are generated during amplification as just described. In addition, however, new signals are produced as a result of non-linearity with frequencies equal to the sum and difference of the two input frequencies and their harmonics. These new signals are known as sum and difference tones or intermodulation products and their frequencies can be expressed as $(mf_1 \pm nf_2)$ where $m$ and $n$ are 1, 2, 3 etc. Each fundamental component and each of its harmonics gives rise to sum and difference tones with every component of the other signal and thus the total number of tones now generated is very large. Some of these new tones do not blend harmoniously with the others. Discords are produced and it is these which are responsible for the harsh and unpleasant quality from an overloaded amplifier. The difference tones can be low in frequency and probably make a greater contribution to the harshness than the sum tones, many of which lie outside the frequency range of the amplifier or the ear.

The degree of distortion introduced by the use of a non-linear characteristic is measured by the amplitude of the intermodulation terms introduced and this depends on the length of the non-linear section of the characteristic used during the amplification process. In general distortion is very low for very small input-signal amplitudes, increases slowly as the amplitude is increased but increases very rapidly when the overload point is reached. Small input signals, such as those from a high-quality microphone, take up such a small length of the characteristic that its linearity is not so important as for signals of larger amplitude.

The generation of harmonics and combination tones by a device with a non-linear characteristic is not peculiar to electronic equipment. It occurs also in the human ear for sound inputs exceeding about 50dB above the threshold of hearing. It is an interesting thought that if an amplifier generates intermodulation tones we interpret the process as distortion but we do not do so when the ear itself introduces such tones. The brain is evidently able to decide whether the spurious signals are introduced externally or internally. Many of the properties of the ear, e.g. its ability to detect the fundamental frequency of a complex harmonic sound, were at one time thought to depend on the non-linearity of the ear. The theory was that the ear made an analysis of the sound and could assess the common interval between the harmonic frequencies: this interval is the fundamental frequency and determines the pitch of the sound. This explains the ability of the ear to detect the pitch of a note which has no discrete component at the fundamental frequency. However, this theory has been abandoned because of the observation that the ear is linear for very small sound inputs but can still detect pitch accurately. Moreover, recent experiments have shown that the ear still correctly assesses pitch even when the common frequency interval is by electronic means made different from the fundamental frequency. It is now thought that the ear assesses pitch by measuring the repetition frequency of a complex sound and it does so without using the non-linearity of the characteristic.

### Video-frequency amplification

We have so far confined this discussion to the effects of curvature of an input-output characteristic on audio-frequency amplification. It is instructive to consider the effects of such curvature on video-frequency amplification. As an example consider a characteristic for which the output is proportional to the square of the input as shown in Fig. 6. Such a characteristic could have a disastrous effect on audio-frequency amplification. The distortion depends on the input-signal amplitude and is small for small signals but for large-amplitude signals the distortion can reach 25 per cent. If a video signal is applied to the input of the squaring device the curvature of the characteristic causes details near one extreme of the input signal (say near white level) to be exaggerated compared with those at the other extreme (i.e. near black level), as shown in Fig. 6. The reproduced picture is still recognisable: indeed it is quite viewable and for some types of picture the effect of the characteristic could be an improvement in tonal balance. The television engineer would say that the signal has been "up-gammed" (gamma for the characteristic in question being, of course, 2). The effect of the characteristic curvature is thus quite different from that experienced in audio reproduction: in television the effect would not be described as distortion but as "white stretching" or "black stretching" depending on the polarity of the signal applied to the input.

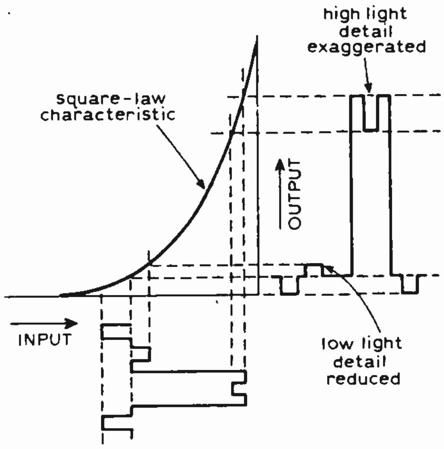


*Fig. 6. Exaggeration of a highlight detail by a square-law characteristic.*

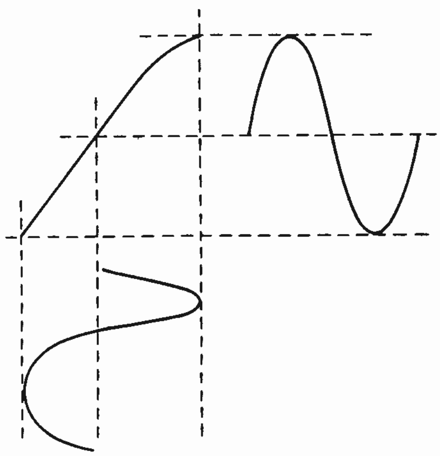

*Fig. 7. Form of characteristic required to correct the waveform distortion introduced in Fig. 5. (Time scales distorted to emphasize effect.)*

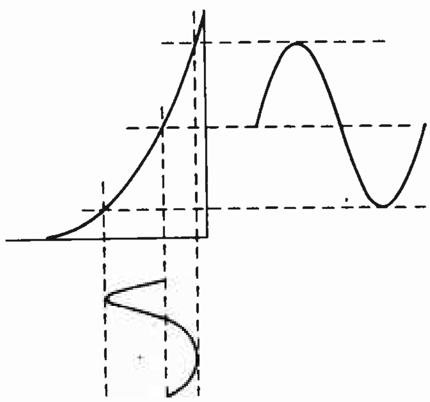

*Fig. 8. Distortion reduced by inverting the input and using the same characteristic as in Fig. 5. (Time scales distorted to emphasize effect.)*

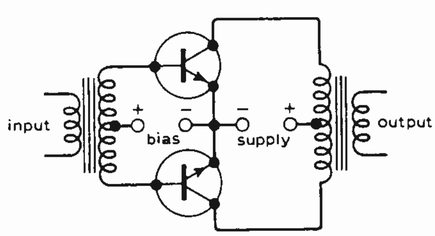


*Fig. 9. Basic form of push-pull amplifier.*

### Methods of linearising characteristics

There are a number of methods of minimising the distortion caused by the curvature of an input-output characteristic. One has already been mentioned: if the signal amplitude can be kept small, distortion can be kept to a low level. This may apply, for example, to an amplifier intended to follow a high-quality microphone. The output of such a microphone is so low that distortion due to characteristic curvature is unlikely to be troublesome. The designer is likely to be more concerned with maintaining a good signal-to-noise ratio than in obtaining a high degree of linearity.

A second method of reducing the waveform distortion caused by a device characteristic is to pass the distorted signal through another stage with a characteristic having complementary curvature to that of the first device. For example, if the output signal in Fig. 5 is applied to a device with a characteristic shaped as in Fig. 7 the final waveform is less distorted than that at the output of the first stage. In practice it is difficult to find two devices with accurately-complementary characteristics but fortunately this is not necessary. A considerable reduction in distortion can be achieved by using two similar devices and by inverting the signal applied to one of them. To illustrate this consider again the output signal in Fig. 5. Let us invert it and apply it to a characteristic identical to that in Fig. 5. This is illustrated in Fig. 8 which shows that a reduction in waveform distortion is possible by this means. Such a reduction in distortion occurs to a limited extent in amplifiers consisting of cascaded common-emitter or other signal-inverting stages but the cancellation is not perfect because:

(a) a characteristic and its mirror image (which we are effectively using here) are not necessarily complementary

(b) the signal input to the second stage is larger than that applied to the first stage: it therefore uses a longer length of the characteristic and so produces greater distortion than the first stage.

If it were possible to arrange that the signals applied to an amplifying stage and to the compensating stage were of equal amplitude a considerable reduction in distortion could be achieved. This can be done for example by using a transformer with a centre-tapped secondary winding to provide two identical signals, by applying these signals to closely-matched devices and by combining the outputs of the devices. The circuit deduced in this way is shown in Fig. 9 and is, of course, a push-pull amplifier.

The way in which the push-pull principle reduces distortion is shown in Fig. 10. In this diagram we have allowed for the fact that the signal applied to one device is inverted with respect to that applied to the other by assuming a common input signal and by laterally-inverting one characteristic with respect to the other. The horizontal spacing between the two characteristics is determined by the bias value which must be located at the same point on both characteristics: the bias value in Fig. 10 is chosen to give class-A operation at (a) and class-B operation at (b). The effective characteristic for the pair of devices can be obtained by simple addition of the individual characteristics and is shown in dashed lines in Fig. 10. It is a better approximation to the ideal straight line than the individual characteristics but there is still some residual curvature. This is to be expected because one characteristic is the mirror image of the other and the two are not accurately complementary. Any curvature in one characteristic on one side of the bias value is repeated in the other characteristic on the opposite side of the bias value: thus when the characteristics are added the result is a characteristic symmetrical about the bias value. A symmetrical characteristic produces only odd-harmonic distortion: even harmonics cancel.

This advantage of the push-pull principle is one reason for its popularity: a second reason is that by biasing the devices to cut off as in class-B operation very high efficiency can be obtained.

A third method of reducing the waveform distortion caused by the non-linearity of input-output characteristics is to include the non-linear stage within a negative feedback loop. In this way distortion can be reduced to any desired extent.

There is a graphical method of demonstrating the improvement in linearity brought about by negative feedback. Fig. 11 shows in solid lines the $I_d$–$V_{ds}$ characteristics for a junction-gate field-effect transistor. We will assume that voltage-derived negative feedback is to be applied to this device and, as a numerical example, we will assume that 20 per cent of the drain voltage is to be returned to the gate circuit. Consider point A: this corresponds to a drain voltage of 10 and lies on the characteristic for $V_g = -2$V. The feedback voltage is 20 per cent of 10, i.e. 2V. Thus when feedback is applied the new input ($V_{fb}$) must be $-2$V to neutralise the feedback and $-2$V to supply the gate input. Thus for this point $V_{fb} = -4$V. Similarly for point B the drain voltage is 15 and the feedback voltage therefore 3V. As B lies on the characteristic for $V_g = -1$V the value of $V_{fb}$ for this point is also $-4$V. Thus A and B are two points on the new characteristic for $V_{fb} = -4$V. By continuing this process it is possible to deduce the new set of characteristics shown in dashed lines in Fig. 11 which apply when 20 per cent voltage feedback is applied.

The new characteristics are more upright than the original characteristics, showing the effective reduction in a.c. drain resistance brought about by the feedback. Both sets of characteristics are drawn for 0.5-V increments in input voltage but the new characteristics are more closely spaced, this illustrating the reduction in gain due to feedback. The improvement in linearity due to feedback is best demonstrated by considering the intercepts on a load line. CD is a load line chosen to cross most of the characteristics and the intersections of this line with the solid curves are plotted in Fig. 12 in the form of an curve of input voltage against output voltage. The intersections of the load line with the dashed characteristics are also plotted on the same diagram to show the effect of the negative feedback on the input-output characteristic. The characteristic with feedback is clearly straighter than the other, showing the improvement in linearity, and also has a lower slope, showing the reduction in gain due to feedback.

*(To be continued)*

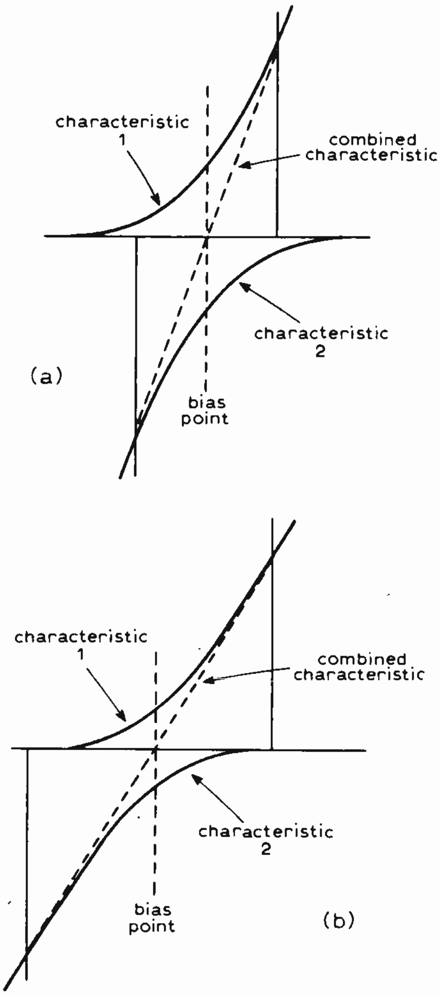


*Fig. 10. Derivation of the shape of the effective input-output characteristic for a push-pull amplifier (a) class-A and (b) class-B.*

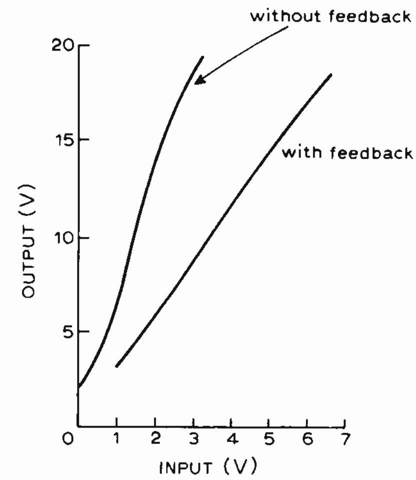


*Fig. 12. Input-output characteristics of the transistor of Fig. 11 with and without negative feedback.*

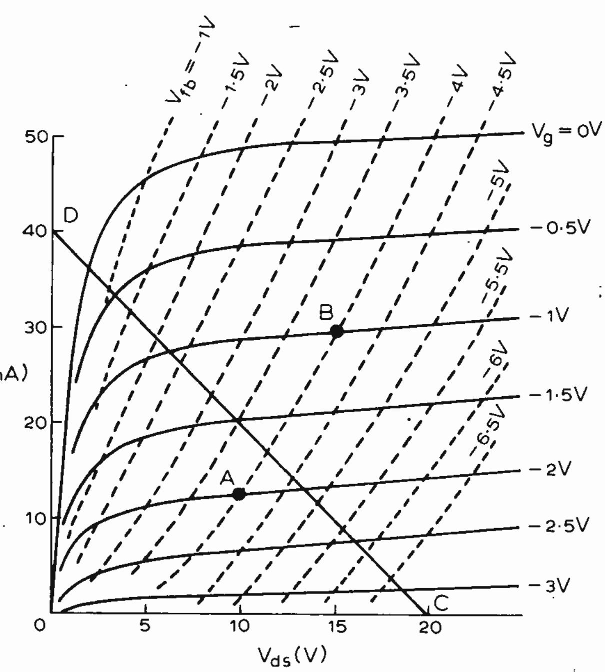


*Fig. 11. $I_d$–$V_{ds}$ characteristics of a junction-gate field-effect transistor in solid lines without negative feedback and in dashed lines with 20% voltage feedback.*

# World of Amateur Radio

## In the air

The month of May brought a big change to the 21 and 28 MHz bands with many Sporadic E openings and some unexpectedly good F-layer conditions. The morning of May 15, for instance, found the 21MHz band full of Japanese signal, while the late evening of May 27 produced an opening to North America that may have been double-hop Sporadic E. On 28MHz the beacons (DLoIGI, 5B4CY, 3B8MS etc) provide very good indicators of these sunspot-minimum openings. In Australia a 28.5MHz "local net" has been organised and the additional activity on the band ensures that opportunity is taken of the long-distance openings that occur most often at the commencement and break-up of geomagnetic disturbances. Openings between Europe and Australia are rare but a few were reported during the past winter season.

A Sheffield amateur, Barry Chambers, G8AGN, has applied for permission to install the country's first 9cm (3456MHz) beacon station, GB3UOS, to the north-west of Sheffield. The 10.1GHz beacon on the Isle of Wight has been received in nine English counties and in Guernsey.

Virtually every country having a significant number of radio amateurs has a national society of its own. There is however one exception: the recognised IARU society for Canada is a division of the American Radio Relay League. The Americans seem determined to keep it that way. At the recent IARU Region 2 conference in Florida there was extensive discussion "of the problems which arise when there are competing societies in a country, and it was agreed to continue with the existing policy, which discourages official IARU contact with such societies". So presumably RSGB contact with Canada should be routed via Connecticut? A thought for the Bicentenary.

An investigation into the future of the Wireless Institute of Australia (the doyen of all national societies, having been founded in 1910) has suggested a change of name on the grounds that "Institute" is felt to be too Victorian sounding.

## Touchy transmitters?

An article on "antennas" by Bill Lowe, GB3UOS, to the north-west of Sheffield. letter of the Association of Sheffield Amateur Radio Clubs makes one reflect on the limitations that we have apparently come to accept in the design of modern amateur transmitters. For he firmly advises amateurs not to attempt to use voltage-fed systems such as the 136ft long-wire that I find a most convenient multiband system (since it uses some salvaged multi-core telephone cable and is slung over a tree it cost me precisely nothing to put up).

Bill Lowe states that "if you squirt your transmitter into a high impedance you wreck your power amplifier . . . even though it can be made to look like a low impedance by the use of an antenna tuner or "Z-match" . . . the slightest tweak on the controls sends the s.w.r. sky high and it is during the microsecond or so of high s.w.r. that the snap, crackle and pop takes place in the power amplifier . . . we concede that experienced operators are adept at the art of tuning up and get away with it but we cannot emphasise strongly enough that for the average chap, an inherently low impedance is essential."

Well, well. Certainly Bill Lowe, whose firm handles many of the popular transmitters using high-perveance and line-output valves in their output stages, should be in a good position to speak from experience, even if his "microseconds" are artistic licence. And one must accept that solid-state power amplifiers, unless protected, are vulnerable to high s.w.r. and that stages using line-output valves need to be tuned quickly since they are seldom intended to operate with a high duty cycle. But should we encourage designers to accept that we are never going to use voltage-fed systems or those with high s.w.r.?

The almost 20-year-old transmitter that feeds my long-wire aerial has an 813 p.a. that loafs along at 150-watts d.c. input and I suspect that if I wished I could spend all day twiddling the knobbs of my a.t.u. without any snap, crackle and pop (except perhaps from the high-efficiency r.f. output). But that's progress!

## Amateurs and the CIA

Little reaction has been forthcoming on the disturbing suggestion in the book "The Real Spy World" by Miles Copeland, a former CIA organiser, that amateur transmissions are sometimes used for clandestine intelligence operations. He suggests that high-speed "squirt" or "screech" signals are sometimes played in the background to ordinary "ham radio messages" since it is no longer possible to pass speeded up transmissions over international telecommunications circuits due to the presence of cut-off filters. Copeland claims that squirt recordings "are still used to good effect on 'ham' radio transmissions". It is much to be hoped that if CIA or any other organisations have ever in the past used amateur radio in this way, the practice has long ceased.

It is if course well known that radio amateurs played a big part in both German and British clandestine radio during World War 2, in very different circumstances. Last September we noted how SOE's suitcase sets (A2, A3, B1, B2, B3 and MCR1) owed much to Major John I. Brown, G3EUR, as a member of the Inter-Services Research Bureau. John Brown has recently joined Avel-Lindberg Ltd to provide a liaison service to handle technical queries on their uninterruptible power supplies. Since considerable emphasis was placed in the SOE-ISRB work on providing novel forms of power supply for use in the field, his wartime experience should stand him in good stead.

## In brief

"We must try to behave like responsible people . . . some recent happenings on 3.5MHz and 144MHz have made me ashamed to be the holder of an amateur licence. Some have been due to inexperience in new licence holders, but I'm sure that the bulk has been deliberate action by old hands who, for reasons best known to themselves, wish us to be all put off the air." — Quoted from a stern warning issued by Dr John Allaway, G3FKM, president of the RSGB. . . . Radcomex 76, the revived RSGB Radio Communication Exhibition for the first time at Alexandra Palace in north London, opens at 10 a.m. on Friday, July 30 (official opening by Lord Wallace of Coslany at noon) and is open to 8 p.m. on the Friday and Saturday, closing at 4 p.m. on Sunday, August 1 . . . the recent steep increase in postage rates for sending printed papers overseas will significantly increase the cost of QSL bureaux. . . . When Bill Bullivant, VK2BC, sent a large packet of QSL cards to Box 88, Moscow (address of the Russian QSL Bureau) it was returned marked "addressee unknown in Moscow, Idaho, USA — apparently the Australian Post Office had not heard of Moscow, Ayr, Scotiand or Moscow Road, Bayswater. . . . The BATC is holding its next amateur television convention on Saturday, September 18 in Parkinson Court, University of Leeds, from 10 a.m. to 5.30 p.m. with demonstrations of both slow-scan and 625-line systems, trade stands and bring-and-buy stall. Further details from A. R. Watson, Somerby View, Bigby, Barnetby, South Humberside . . . Alan Dorhoffer, K2EEK has become Editor of CQ Magazine, taking over from Richard Ross, K2MGA. . . . The French society REF lists "Radio France International" as an intruder on 7085 kHz.

**PAT HAWKER, G3VA**

# Earthing, shielding and filtering problems

## 1 — Unwanted resistance in earth lines

by R. C. Marshall, M.A., M.I.E.E. *Rank Xerox Ltd*

**Problems resulting from ineffective or insufficient grounding, shielding or filtering are not easily anticipated or understood, yet this is one of the least-taught aspects of the electronic engineer's art. Difficulties arise from components not shown on circuit diagrams, modes or operation not contemplated by the designer and, worst of all, several such modes operating at the same time. Cure of one mode may not eliminate the symptom — only when all spurious couplings are removed at the same time will correct operation occur.**

**Grounding and shielding problems often occur only when systems are coupled together, and then may appear only spasmodically. This makes them difficult to locate, and underlines the importance of dealing with them at the design stage. This short series of articles considers the basic effects, setting the scene with first-order numbers, and the cures that can be achieved by changing magnitudes and circuit configurations. Situations will be dealt with in order, firstly those due to unwanted series impedance, then unwanted coupling capacitance, and then more complex situations involving both.**

Unwanted series impedance almost always appears as the source of potential difference between ground point. For example one foot of 16 s.w.g. (14 a.w.g.) wire has a resistance of 2.5 milliohms. Above 3kHz the inductance (0.6μH) will be dominant. Printed wiring has much higher resistance[1], 0.36Ω per foot of 0.015in-wide 1oz copper track. The significance of this depends of course on the circuit. In a small audio amplifier, 1A is a typical reservoir capacitor ripple current which will develop 2.5mV across the above-mentioned foot of thick wire. A mere one thousandth of this voltage transferred to a 1mV input will degrade the signal-to-hum ratio to 52dB!

These notes detail the effect of series resistance in an earth line that is common to both input and output of an amplifier or buffer[2].

### Case 1

*Situation:* Subassembly amplifier or digital buffer with significant output current as shown in Fig. 1 (a). This could be a loudspeaker amplifier, or solenoid or lamp driver.

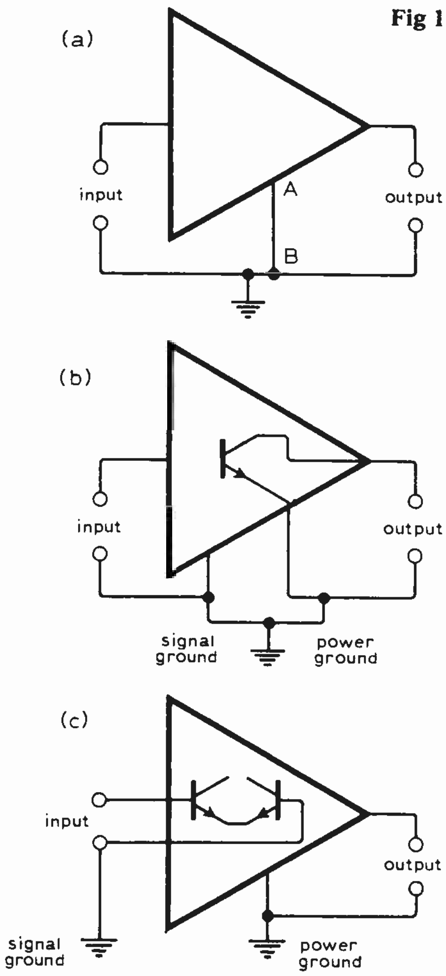


Fig 1

*Symptoms:* Oscillation or unexpected gain characteristic. Input threshold variation with output load. Hysteresis.

*Problem:* Output current flows through AB, developing e.m.f. in series with input circuit.

*Cures:* Reduce resistance of AB.
Separate wiring of the output stage and use distinct signal and power earths, connected only at one point for the whole system, as in Fig. 1 (b).
Isolated or balanced input using transformer or long-tailed pair, as in Fig. 1 (c).

### Case 2

This case is similar, except that the common earth line couples the power supply to an input circuit because of an incorrect sequence of earth connections.

*Situation:* Audio or instrumentation amplifier, line-powered or using a battery and inverter, as in Fig. 2 (a).

*Symptom:* Pulses at twice supply frequency appear in amplifier output.

*Problem:* Smoothing capacitor ripple current flows through wire FG and develops and e.m.f. in series with input, as the common side of the input returns to the amplifier along this wire.

*Cure:* Rearrange sequence of connections to earth, or isolate input circuit from earth. The arrangement of Fig. 2 (b) is one of many.

*Comments:* Use of directly-earthed reservoir capacitors and directly-earthed input sockets is the commonest cause of this problem. A related problem is the e.m.f. between one point of an earthed wire or chassis and another, caused by circulating currents induced by the magnetic field of a supply transformer or motor; 1mV per square inch is typical. This spurious voltage is

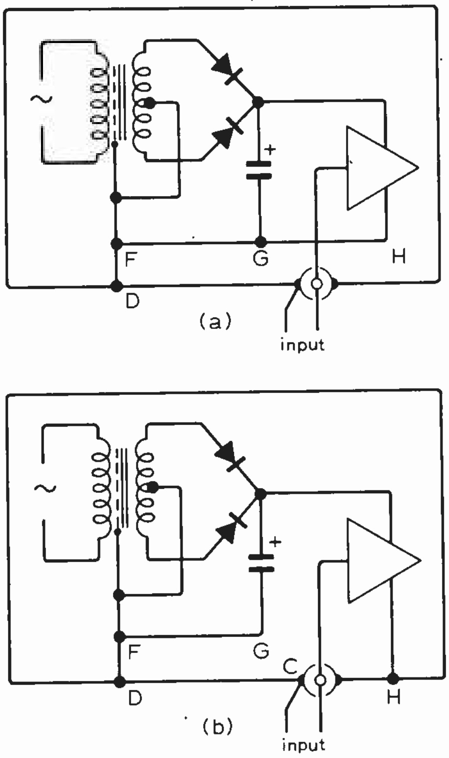


**Fig 2**

approximately sinusoidal, and at supply frequency. Motor sources can be identified by the change of phase when the motor is stalled.

## Case 3

Next for consideration are the common-impedance effects of simple systems.

*Situation:* Two amplifiers in different boxes, at least one mains powered, and both grounded to same ground point. E.g. f.m. tuner and audio amplifier, or instrumentation amplifier and oscilloscope.

*Symptom:* Line frequency and line switching transients appear at amplifier 2 output.

*Problem:* Currents flow through transformer and wiring capacitance shown symbolically as $C_1$ and $C_2$ in Fig. 3 (a) to equipment 2 chassis. The current from primary to interwinding shield (or, if there is no shield, to secondary) is typically 50μA for a 240V 50Hz 60W transformer, but can be substantially less for low capacitance designs. This current returns to source via NM and NJKLM in parallel. The portion developed across JK is in series with amplifier 2 input and causes the symptom.

*Cures:* Break ML or MN, or add series resistance to either – but this may contravene safety regulations.
Isolate amplifier 2, point J and all associated electronics and power supplies from box 2 – this may satisfy safety regulations.
Lower the resistance of JK.
Use twin shielded cable to ground the input return of amplifier 2 at K not J.
Isolate K from L by using a transformer $T_2$, for fairly narrow bandwidth, or optoisolator, for digital systems, as in Fig. 3 (b).
Raise the signal level to swamp interference by reallocating circuits to boxes.
Eliminate the loop, perhaps by combining power and signal along one cable as in the reference oscillator of Fig. 3 (c).

*Comments:* The situation and cures above may be extended to cover other real-life cases. If the supply earth connections are to different distribution points, currents due to leakage elsewhere in the electricity distribution system may contribute to the voltage across JK. Such currents may also arrive via unexpected routes such as structural steel work, or water or air pipes. In some specialized buildings a low-impedance "technical earth" is provided for electronic equipment[3], but continuing vigilance is needed to keep this distinct from the power earth. Between buildings, lightning or power faults may develop 100 to 100,000 volts of differential earth potential, and substantial earth connections, together with zener diodes, spark gaps, or gas discharge tubes, may be needed to protect equipment.[4]

Next article in this series will consider situations involving stray capacitance.

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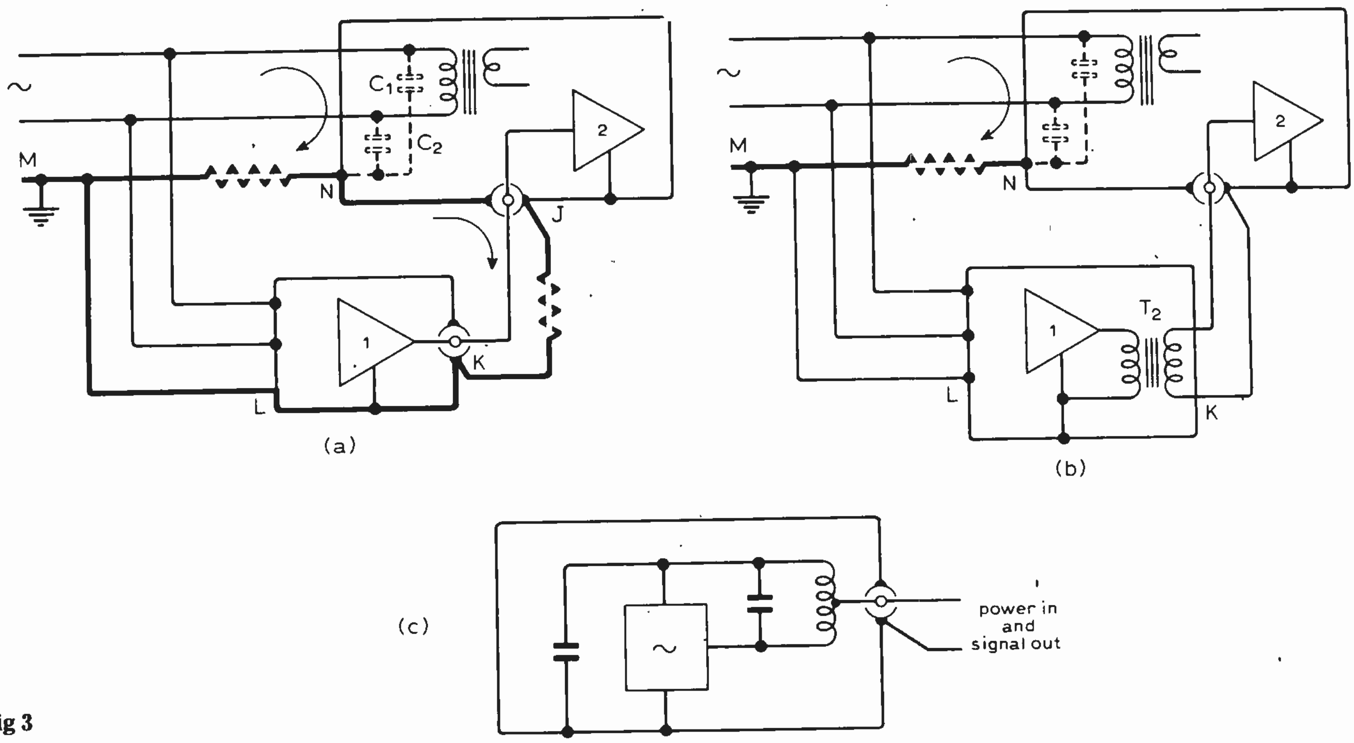



**Fig 3**

# Progress in optical-fibre communications

A field demonstration of a 140Mbit/s digital optical fibre system for a telephone network is to be carried out on the urban route Hitchin to Stevenage in the latter half of 1977. STC, who have been manufacturing and marketing optical cables since September 1975, are to undertake the task to demonstrate, in co-operation with the Post Office, the current state-of-the-art in a non-research environment. Optical-fibre research has shown that system frequencies of between 2 and 560MHz are feasible and can be economical, depending upon the application.

A system, which will have a route length of 9km, will have repeater spacings of 3km and will be capable of handling 1920 speech channels. Some of the lessons to be learned from this demonstration will be: whether the cable can be pulled over long distances, exactly what sort of coding is necessary to control the system, and overcoming practical problems such as cable jointing in the field. Jointing by mechanical alignment is acceptable if close tolerances are met, but fusion, by melting the glass, gives far better results. Although fusion can be carried out successfully in the laboratory, many problems arise when this is attempted in the field. When producing mechanical joints, the fibre must be broken to form a flat normal face so that the joint attenuation is minimized. This can now be done repeatedly by simultaneously marking, tensioning and snapping the fibre, and it is envisaged that small machines could be produced to carry out this job in the field.

Recently, the Nippon Telegraph and Telephone Public Corporation of Japan released a report claiming that they have produced a fibre with a minimum attenuation of 0.47dB/km at a wavelength of 1.2μm, with an overall bandwidth loss of 1dB/km between 0.95μm and 1.37μm. The best fibre previously produced, by Bell Telephone Laboratories in the USA, had a minimum loss of 1.1dB/km at 1.02μm. The new fibre, consisting of a borosilicate cladding and phosphosilicate core, was fabricated using the chemical vapour deposition technique previously used by Southampton University to produce fibres with a minimum loss of 1.9dB/km. Chemical vapour deposition greatly diminishes the transition-metal-ion and OH-ion concentrations in the glass, but the Japanese have improved on this by pre-refining all the materials before fabrication to further reduce the highly absorptive OH-ion component. At present, losses as low as 1.9dB/km are only considered to be "aims" when manufacturing optical cables. In practice, fibre attenuations may be in the region of 3 to 4dB/km with typical increases of about 3dB/km after plastic coating and about 1dB/km after cabling. Cables with 10dB/km attenuations can now be manufactured on a repeatable basis.

*This optical cable being held has a bandwidth greater than the 4800 pair cable or the 18-core 9mm coaxial cable. The space requirement is tiny compared with the other two types of cable.*

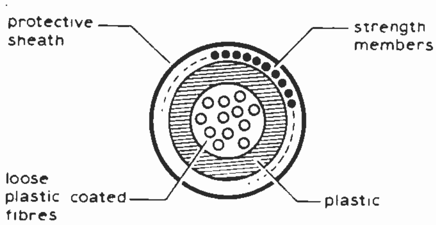



*Fig. 1. Optical fibre cable construction. Note that the fibres are loose in the cable in order to reduce bending strains and radial crushing.*

Manufacturers are primarily concerned with the practical problems associated with systems and cable construction. Glass is extremely sensitive to mechanical strains, especially during manufacture, and small strains can cause high attenuation losses. A plastic coating over the fibre increases both its tensile and radial strength; the first maintains low fibre strain; the second resists crunch stresses, periodic distortions, and improves bend performance, at the same time providing overall mechanical protection. The loose fibre cabling shown in Fig. 1 reduces strain due to bending and also reduces radial crushing within the cable. Cable manufactured in this way can stand reasonably loose knotting – at Communications 76 a representative of STC, R. E. J. Baskett, claimed that a pencil-thick cable could follow a curvature of 1cm radius.

The advantages of an optical system are numerous; the fibres take up relatively little space for a given information load compared to that of conventional systems, they are lightweight and the system does not require an earth return. The transmission line region cannot produce sparks and therefore is suitable for use in hazardous environments. With the exception of the source and receiver sections, the line is completely immune to electrical or magnetic interference of any kind. In security terms these lines are very good, it would be extremely difficult to tap off information without completely disturbing the system, at which point the communication link would be transferred to another line. Because of the saving in space, more fibres may be included in the cable, for little extra cost, for future expansion of the system or for failure replacement.

## SITE solar experiment

Two solar arrays will provide electricity to run two of the television receivers in the SITE project as a result of an agreement between NASA and the Indian Space Research organisation (ISRO) to add a solar energy experiment to the project. The arrays were shipped to ISRO in May. They can produce 260 watt-hours of power each day under Indian sunlight conditions and will be used during the four hours each day that programmes are broadcast to Indian villages from satellite ATS-6. "The experiment," NASA said, "is being conducted to demonstrate the technical and economic feasibility of using photovoltaic power to operate television sets in areas where there is no electricity available." A report on the SITE project will be published shortly.

At the end of May NASA launched a second Maritime satellite (Marisat B) for COMSAT General Corporation. The satellite will provide communications to the US Navy, commercial shipping and offshore industries, and will be in stationary orbit over the equator at 176.5 degrees west, just west of Hawaii.

# Hi Fi market to stay depressed, says report

A market survey of the hi fi market in the United Kingdom predicts that rising unemployment and continuing inflation would depress the market until 1978. The report, conducted for Acoustic Research, the speaker makers, by Research Associates and supplemented for publication, says that a fall of £17.4 million on last year's figures can be expected to the end of this year, when the market will be worth £164.5 million. Small increases may be expected in the following two years, but a rise of £25.9 million on the 1978 figure may bring the 1979 figure to £200 million, and the market will be worth £226.1 million the year after that.

Research Associates also expect the tendency to improved performance and features in amplifiers and tuner amps to slow down. "There will be a move to the modular concept in the electronics and towards making the equipment easier to service." At the same time the appearance of equipment would improve. Turntables would have more complicated motors and drive mechanisms, with servo-controlled assemblies and direct drive, but they would perform better. Automatic turntables would tend to disappear, "but there would seem to be a place in the market for the more expensive automatic deck with true high fidelity specification." The greater use of four channel records would bring about improvements in pickup cartridges. "It is also expected that there will be a movement towards tape systems as against record systems since a tape system is cheaper, more convenient and produces a higher quality of sound. There has been a revival of interest in the conventional reel-to-reel recorder as a result of this trend but the main areas of benefit will be cassette systems and to a lesser extent cartridge systems."

Loudspeaker manufacturers, the report says, would try to improve the look of their product because the consumer wanted a better looking speaker and was more inclined to look behind the front panel. "Speakers which are not well finished behind the gauze are increasingly likely to be rejected by discerning consumers. Another reason for the improved appearance was the effort by manufacturers to make their product look different from that of their competitors. Speaker sales would increase as the market became more sophisticated, and the demand grew for four speakers rather than two.

The survey examines the market by geography, age, marital status, social class and knowledge of the subject. The projections were based on a study of general economic information, a review of published information available in the UK on the development of the sound reproduction market, fourteen executive interviews with manufacturers or retailers, fifteen more extended interviews with senior shop staff, and numerous telephone inquiries.

A 48-page second volume on consumer attitudes is based on 12 group discussions in the Midlands and South with 111 respondents who had spent at least £150 on hi fi in the last three years. "Real high fidelity equipment was thought to cost a minimum of £110-£150 by most. Many would not consider paying more than £250. Beyond this level they considered the improvement in quality was too marginal to justify the extra cost."

The survey said that most buyers did not have a rigid budget but a good idea how much they would spend. "Friends were an important source of advice when choosing equipment. The high fidelity magazines were respected but several found them too technical to understand. Manufacturers' leaflets were criticised for the use of meaningless terms and the lack of standardisation of frequency responses. Price and sound quality were the most important factor (sic) in the choice of system for all income groups."

The report, which is 95 pages long and cost over £7,000 to produce, costs £140 from Research Associates, the Radfords, Stone, Staffs. Title: "High-Fidelity in the United Kingdom".

## Switching component prospects

The Electrical Research Association predicts that over £1,000 million will be spent on switching components in the EEC in 1980. By that time the UK market alone will have increased by half, electromechanical components rising by 24 per cent and semiconductor devices doubling their sales. The information is contained in a £1,200 report which took 14 months to compile and analyses the markets for contractors, relays, sensing switches, timers and their solid state equivalents. The UK and European markets are covered country by country under various application headings and there is also an examination of the structure of the telecommunications market. The price includes an opportunity to discuss the findings with the compilers. ERA Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA.

# Digital colour TV via satellite

Digitized PAL colour television signals on System I have been experimentally transmitted through a communications satellite. This was done in May by the BBC and the Post Office, using the Intelsat IV (Flight 1) satellite stationed over the Indian Ocean. The picture signals were sent from the BBC Designs Department, London, in analogue form to the Post Office earth station at Goonhilly Downs, Cornwall, and back over Post Office s.h.f. links.

A 60Mbit/s signal, generated in BBC equipment, was transmitted. This was split into two 30Mbit/s parallel streams plus a clock signal before being fed to a differentially encoded quadrature phase shift keying (q.p.s.k.) modulator built by the Post Office. The 70MHz i.f. output from the q.p.s.k. modulator was up-converted to s.h.f., amplified, and transmitted through Aerial 1 at Goonhilly to the Intelsat IV satellite and back again, using a transponder with a 36MHz r.f. bandwidth.

The 60Mbit/s signal comprised one video-audio "package". This consisted of a multiplex of one digital colour video signal, with a bit-rate of optionally 44.3 or 53.2 Mbit/s, and one 2048kbit/s multiplex signal for sound channels. The video channel used sub-Nyquist sampling at about 8.9MHz. After quantizing with 8 bits per sample, the bit-rate was reduced optionally to 5 or 6 bits per sample, using a type of differential pulse-code modulation. Resultant bit-rate was 53.2Mbit/s, which, after error-correction coding, was increased to 56.8Mbit/s.

To facilitate reliable recovery of the q.p.s.k. carrier signal in the demodulator (developed by Marconi Research Laboratories), in which only 36MHz r.f. bandwidth was being used for the 60Mbit/s baseband signal, the digital video bits were "scrambled".

The 15kHz bandwidth sound channels were coded using a digital companding technique to enable six such channels to be fitted into a bit-rate of 2048kbit/s (the rate of the first-order multiplex in the new Post Office digital communications network).

Elevation of the Goonhilly aerial above the horizon was necessarily small: about 5°, which is about the smallest elevation for satisfactory transmission. Consequently, careful adjustment of parameters such as group-delay equalization of filters was needed. When this was done a bit-error rate of about 1 in $10^6$ was attained. Subjective assessment of picture and sound quality suggested, according to the BBC, the long-term possibility of obtaining slightly higher quality using digital techniques rather than analogue f.m. techniques, without requiring additional r.f. bandwidth or getting unacceptable interference between channels.

# New Products

## Four-channel cassette recorder

A 4-channel recorder has been made available in this country by North East Audio Ltd. The recorder, designated Model 140, utilizes a 4-track, in-line, full-tape-width record/playback head and is available in standard form with Dolby noise reduction on all four channels and provisions for line or microphone inputs on each channel. This model is intended for professional and industrial applications. Versions of the Model 140 can be obtained to specification: for example, with Dolby on some channels only or with specified input and output levels to suit applications such as dual-sync plus stereo sound audio-visual. Technical specifications of the Model 140 are the same as the forerunning models 102, 103, and 104 and similarly a 3M Wollensak heavy duty mechanism provides the drive. Some of these specifications are as follows: wow and flutter less than 0.09% r.m.s., distortion less than 0.1% from the head to all outputs at 0dB level, and crosstalk better than 40dB. As with the previous models all the outputs have 10Ω impedances, the frequency responses are corrected to 3,180μsec ±1dB from DIN test tape 45513/6, and the signal-to-noise ratio with Dolby is better than 52dB depending upon the tape used. North East Audio Ltd, 5, Charlotte Square, Newcastle-on-Tyne.
**WW 301 for further details**

## Multitester

A portable solid-state multitester, the TMII made by Levell Electronics Ltd, offers 120 basic ranges and 30 optional ranges. Basic ranges have maximum f.s.ds of 500V and 500mA for both a.c. and d.c. Minimum d.c. ranges are 150μV and 150pA. In addition the meter reads decibels, resistance from 0.2Ω to 10GΩ, and d.c. nulls with lin/log scales ±4 decades. The meter, which has a 140mm mirror scale, has an input resistance of 100MΩ on all voltage ranges. Low test voltages on the resistance ranges allow solid-state circuits to be tested without turning on semiconductor junctions, and an i.c. operational amplifier with a m.o.s.f.e.t. balanced input stage is used to obtain a low offset current, high input resistance and wide bandwidth. A selection of optional extras are available with this multitester. Levell Electronics Ltd, Moxon Street, High Barnet, Herts.
**WW 302 for further details**

## Electrolytic capacitors

The 071 series of electrolytic capacitors from Mullard Ltd has been extended to cover the range 3300μF to 4700μF, 63 to 6.3V. Previously this range was provided for by externally linking capacitors in the 072 triple tag series, which is now to be phased out. Series 071 comprises etched-foil polarized capacitors having aluminium electrodes and non-solid electrolytes impregnated into paper. Mullard Ltd, Mullard House, Torrington Place, London WC1E 7HD.
**WW 303 for further details**

## X-band amplifiers

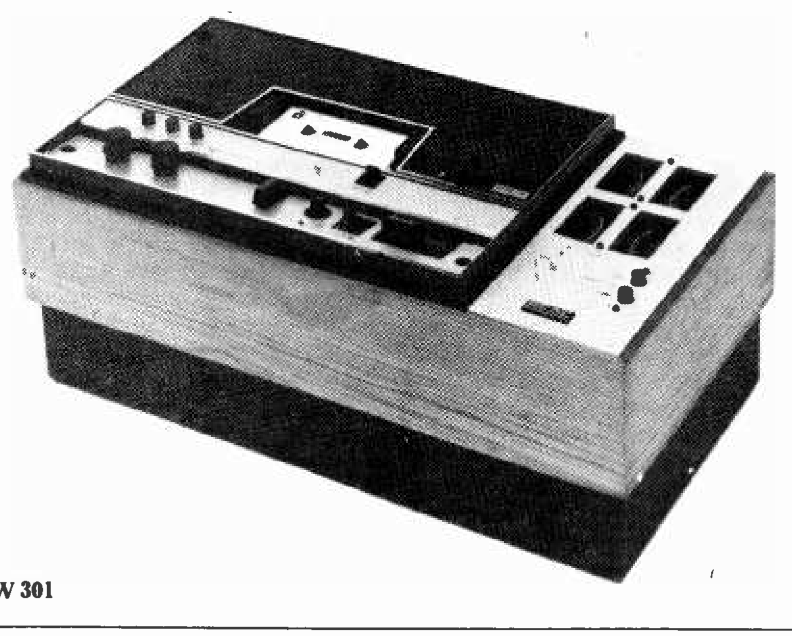
Gallium arsenide f.e.ts are used in a series of wide-band amplifiers by Avantak. The AMT-11000, AMT-12000 and AMT-12400 series are available for gains of 22, 26, 31 and 35dB in frequency ranges of 7-11, 8-12 and 8-12.4GHz. The f.e.ts are passivated with polycrystalline GaAs to reduce gain drift with time and temperature. The mean time to failure is said to be "thousands of hours", during which time performance remains constant. Gain/frequency response is within ±2dB over the quoted range, noise figure is less than 8dB and the balanced mode of each stage reduces even-order distortion. Walmore Electronics Ltd, 11-15 Betterton Street, London W.C.2.
**WW 304 for further details**

## R.f. shielding paste

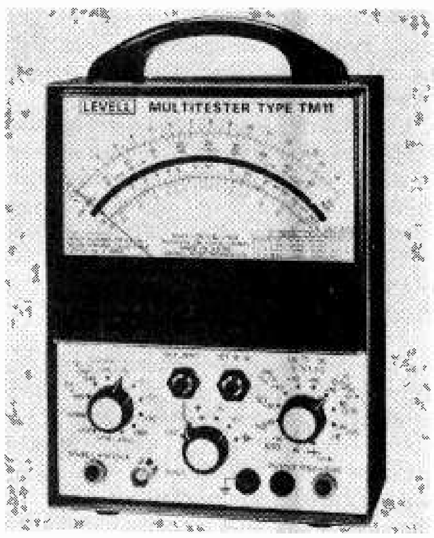
A low-cost, silver-filled adhesive paste by Dage Intersem, Ablebond 26-2 is designed as both bonding agent and r.f. shield. It takes the form of a room-temperature curing adhesive, which can be applied by brushing. The shielding properties are said to be better than those of mesh gaskets. Volume resistivity is 0.005Ω-cm, remaining constant after 100 hours at 85°C and in 85% relative humidity. Dage Intersem Ltd, Haywood House, 64 High St, Pinner, Middlesex.
**WW 305 for further details**

## Electronically tuned magnetrons

Magnetrons which can be tuned electronically are announced by the English Electric Valve Company. Tuning over 100MHz in the X-band at 50kW and over 30MHz in the S-band at 200kW



**WW 301**




**WW 302**

peak power output is claimed. This is achieved in a few nanoseconds by applying a control voltage of 1 to 3 kV to the multipactor cavity electrode. An auxiliary resonant cavity, coupled to the main magnetron anode, is designed so that when an r.f. voltage is applied between its electrodes there is a controlled electron multipactor discharge; this causes a resonance shift and so changes the magnetron frequency. Several of these cavities can be fitted to the same anode to increase the total frequency shift or to give a selection of frequencies. English Electric Valve Company Ltd, Chelmsford, Essex CM1 2QU.
**WW 306 for further details**

## Quartz-crystal filter

A 21.4MHz, 25kHz-channel-spacing filter has been designed within a volume of one and a half cubic centimetres. This quartz-crystal filter, which is the result of studies carried out by Hirst Research Centre of GEC, is claimed to offer performance equal to larger devices previously available. The stopband attenuation is greater than 90dB beyond ±25kHz, providing a ±7.5kHz 3dB bandwidth and ±1dB ripple within the passband. The filter, designed for 1.6kΩ termination, maintains its specified performance from −20 to +70°C and can be provided with impedance matching coils for lower resistances or to include a reactive impedance component. Salford Electrical Instruments Ltd, Times Mill, Heywood, Lancs.
**WW 307 for further details**

## Rotary switch for p.c.bs

A small rotary switch for mounting on p.c.bs has a roller type of indexing mechanism with a pressure spring. It can be made in up to three sections, axially connected. Each section has a stator bearing, linearly placed in two rows, the connecting terminals and a rotor bearing the movable contacts. A sliding type of contact system is claimed to give long life by reducing contact wear. A standard version, suitable for switching currents up to 0.2A at 150V, has silver gilded contacts, while another model, intended for frequent switching of microampere currents, has gold plated contacts. Special versions can be supplied. AB Electronic Components, Abercynon, Glamorgan, CF45 4SF.
**WW 308 for further details**

## Coaxial attenuator

The FA2015 coaxial attenuator covers the range 0 to 2GHz and has a power handling capability of 50W average, 5kW peak. Attenuation is 10 ±0.5dB and is flat within ±0.1dB. Excluding the connectors the FA2015, which has a maximum v.s.w.r. of 1.2:1, measures only 2 × 1¼ × 1in. Each unit is suitable for mounting on the customer's heatsink, or can be supplied with a radiator for cooling in ambient air. REL Equipment and Components Ltd, Croft House, Bancroft, Hitchin, Herts SG5 1BU.
**WW 309 for further details**

## Liquid-crystal multimeter

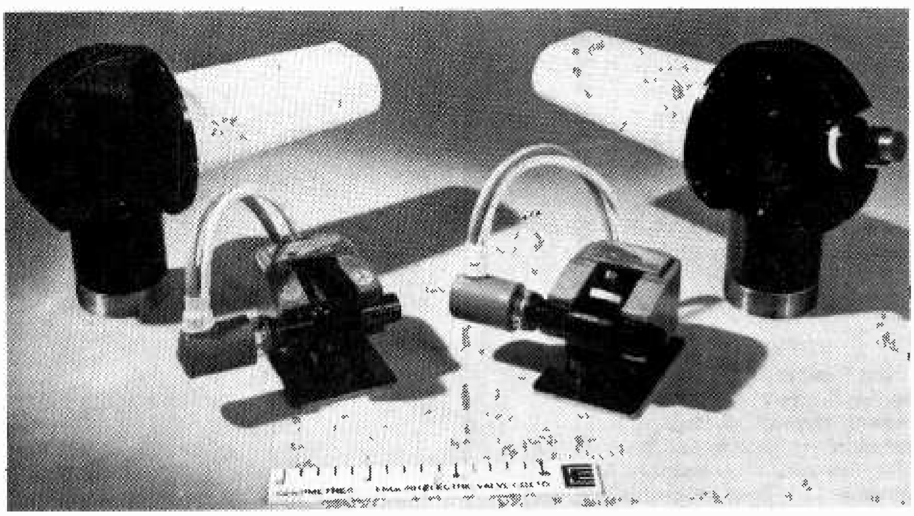
On display at the Leeds Electronics Exhibition was the Beta 3½-digit portable digital multimeter. This multimeter, introduced for the first time in the UK by Gould Advance Ltd, has a high-contrast liquid-crystal display and is battery operated. Voltage ranges are from 200mV to 1kV d.c. and 200mV to 750V a.c. and current ranges are from 200μA to 10A on both a.c. and d.c. The meter also measures resistances from 200Ω up to 20MΩ and offers optional temperature, r.f., and h.v. probes, a battery eliminator and a carrying case. Gould Advance Ltd, Roebuck Road, Hainault, Essex.
**WW 310 for further details**

## 200MHz square-wave synthesizer

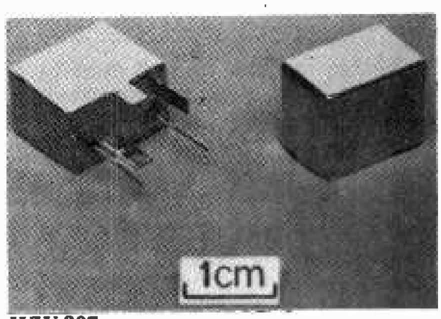
Syntest SI-200 is a frequency synthesizer with, the makers claim, features only found on higher-priced instruments. Output is variable between 1Hz and 200MHz with a stability of 1 in $10^6$. A 6½-digit thumbwheel selection switch sets a divider in the phase-locked loop, whose reference is a 1MHz crystal oscillator. Output attenuator is calibrated in both μV and dBm and covers 0.1μV to 10mV in two ranges. Two fixed-level outputs are provided at −6dBm and at t.t.l. level into 50Ω (usable to 50MHz). Rise and fall times are 2ns. Manufacturer is Syntest Corporation, 169 Millham Street, Marlboro, Mass. 01752. UK agents: Lyons Instruments Ltd, Hoddesdon, Herts. UK price £1,370.
**WW 311 for further details**

## Logic checker

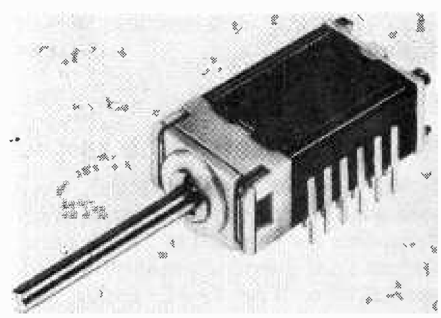
An audible logic checker is now available for testing 0 to 5MHz pulse-rate-frequency logic systems. The LC1, from Lawtronics Ltd, produces a high tone on logic 1 or $V_{cc}$ voltages and a low tone on logic 0 or ground potential. Changes of logic level are indicated by an alternating high-low tone. The presence of a single-shot transient of 200ns or more is shown by a short high tone. This unit, which is not limited by type of logic or size of i.c. package, has a typical input resistance of 1MΩ and can be used on logic voltages from 3 to 18V. Lawtronics Ltd, 139 High Street, Edenbridge, Kent TN8 5AX.
**WW 312 for further details**



WW 306




WW 307



WW 308

# Solid State Devices

**Names of suppliers of devices in this section are given in abbreviation after each entry and in full at the end of the section.**

## Low-noise r.f. transistor

A 5GHz silicon p-n-p transistor, the BFT95, has a noise characteristic of 2dB at 1GHz. The device is constructed using planox-silicon-nitride technology to minimise parasitic capacitances, and is mounted in the common-emitter configuration in a T-plastic package. An improved cross-modulation level is obtained using a copper-alloy frame to withstand high currents. The transistor, which has a forward transmission gain of 10dB at 1GHz and an intermodulation intercept point for optimum bias of +23dBm, is intended for high-volume r.f. applications such as antenna amplifiers, cable TV and up-converter tuners. **SGS-ATES**

## Voltage comparators

A family of monolithic comparators which combine 200V/mV gain, for low-level signal detection, with 50mA or 35V high-level output drive compatability, has been announced by Analog Devices Ltd. The units, AD111, AD211 and AD311 are suitable for use with t.t.l., r.t.l. or d.t.l. loads, lamps, relays, in window or threshold detectors, or free-running multivibrators. Two additional external components facilitate t.t.l. strobing on the AD111. Each comparator is packaged in a TO-99 can. AD311 is also available in an 8-pin dual-in-line package. **Analog Devices**

## High current rectifiers

The Impac series 3S1015-16 miniature high-current silicon rectifiers are cylindrical in design, have insulated cases and axial leads. These general purpose rectifiers, introduced by Semtech, are characterized within the following ranges: p.i.vs from 50 to 600V, r.m.s. voltages from 35 to 420V, and direct blocking voltages from 50 to 600V. Average rectified currents are 3A at 55°C and 2A at 100°C, and surge current limits are 30A if recurrent and 300A if single cycle. **Bourns**

## Radio frequency f.e.ts

Two f.e.ts, the BF244 and BF256L, have been added to the Siliconix range. Both transistors are supplied in TO-92 packages and are intended primarily for r.f. applications. The f.e.ts, which are available in categories to define performances more accurately, feature typical $C_{rss}$ values of 0.85pF and have high $y_{fs}/C_{iss}$ ratios. Type BF244 is in three categories, A, B and C, corresponding to $i_{dss}$ spreads from 2 to 6.5mA, 6 to 15mA and 12 to 25mA respectively when operating at $V_{ds}$ = 15V and $V_{gs}$ = 0. Similarly BF256LA, B and C correspond to $i_{dss}$ spreads from 3 to 7mA, 6 to 13mA and 11 to 18mA respectively under the same conditions. **Siliconix**

## Bi-m.o.s. op-amp

The CA3140 operational amplifier uses a technique called bi-m.o.s., combining a p.m.o.s. input stage with a wide-voltage-range bipolar output stage. It is claimed that this amplifier is suitable for virtually all applications of the 741 series and most applications of other op-amps ranging from the 107 series to the LF356. The p.m.o.s. stage is similar to that used in the CA3130 op-amp but with the added features of internal compensation and a 44V supply-rail capability. Bipolar diodes protect the input so that there is no need for any special handling procedures. The output stage may be strobed, allowing the output to be driven to a low-level independently of the input signal. An output swing to within 0.2V of the negative supply voltage allows power transistors to be driven directly, thus eliminating the need for level-shifting circuitry. The CA3140 has an input impedance of 1.5TΩ, a 10pA input current (at ±15V) and a 5mV input offset voltage. The amplifier, which has an input swing —0.5V below the negative rail, has a 9V/μs slew rate, a 4.5MHz gain-bandwidth product and a settling time of 1.4μs. **RCA**

## High speed analogue gate

A high-speed four-channel analogue switch designed for use in high-speed store-and-hold and general purpose analogue gate applications, is made by Crystalonics Inc. The 16-pin dual-in-line package has a maximum turn-on time of 20ns and maximum turn-off time of 30ns. The typical on resistance is 35Ω, off leakage current is 1nA, and operating voltages and temperatures range from +5 to −15V and from −55 to +125°C respectively. **GE**

**Analog Devices Ltd,** Central Avenue, East Moseley, Surrey.
**Bourns (Trimpot) Ltd,** Hodford House, 17/27 High Street, Hounslow, Middlesex TW3 1TE.
**G.E. Electronics (London) Ltd,** 182/4 Campden Hill Road, Kensington, London W.8.
**RCA Ltd,** Solid State-Europe, Sunbury-on-Thames, Middlesex.
**SGS-ATES (UK) Ltd,** Planar House, Walton Street, Aylesbury, Bucks.
**Siliconix Ltd,** 30A High Street, Thatcham, Newbury, Berks RG13 4JG.

# APRS

## The ninth exhibition shows increases in foreign interest and British confidence

The number of visitors at this year's Association of Professional Recording Studios exhibition was up by 11% to 1,926. Foreign visitors from 36 countries accounted for 14% of the total, 270 compared with 148 last year. The exhibition drew visitors from Jordan, Iran, Iceland and Indonesia as well as the European countries to see the 82 exhibitors, 15 per cent up on last year.

These figures coincide with a welcome upsurge in the number of British manufacturers anxious to compete in one of the fussiest yet most whimsical markets there is. Two reasons for their increased confidence are the fall in the pound and the necessity for buyers to look a little further down the market than their resources would have required a couple of years ago.

A good example is Leevers Bias, who introduced their Proline Professional **tape machine** for the first time at APRS. For under £2,000 they make a machine which has a good chance of attracting those buyers who are unable to afford the established stereo and two track machines at more than twice the price. The Proline supersedes the Bias B1000 and is the result, say Leevers Bias, of analysing faults and spares orders over the past four years. The design has a toroidal mains transformer and plug in capstan and spool motors. All the adjustments are accessible from underneath except for the record and replay electronics.

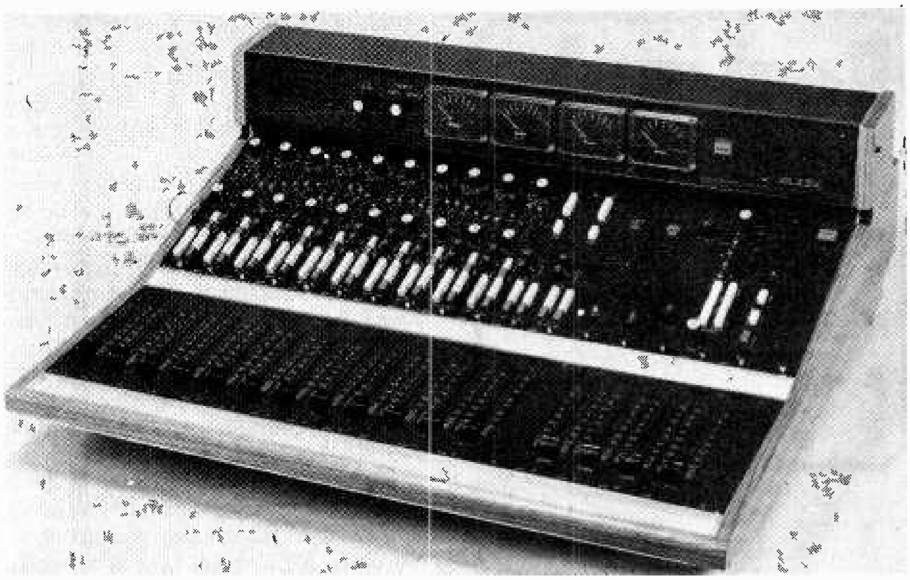
*The Ampex ATR100 recorder, which is available in 1, 2 or 4 channel table top, floor standing or rack mounted versions. It has servo controlled tape handling and a new matrix control panel. Ampex also showed the MM1200 multitrack machine.*

Another British firm launched a new **tape machine** at APRS. Brenell's Mk 7S deck offers stereo half or quarter track to add to their range of stereo and multitrack tape transports. Brenell has also changed ownership, having joined Allen & Heath in the Batiste group of companies a little while ago. Neither company has designs on the money-no-object end of the market but Allen & Heath seems to have a solid group of adherents in the sound reinforcement and small studio fields. A & H launched a ten-channel **production mixer** S6-2 consisting of two stereo gram, two stereo tape, and two mic input channels and a master stereo output channel with VU metering. The unit is intended "for the production of tape collages for radio, television and film broadcast."

Raindirk is a fairly new British firm which seems to be doing well in foreign markets. It is competing in the high cost **mixer** market but produces a range of smaller modular units, such as the Mini Mixer, as well as the bigger custom built models. The latest addition to the Raindirk range is the Quantum system. Each channel has circuits normally associated with separate input, output and monitor modules, and sections of the circuitry are used for more than one function. A master status module is provided to determine whether the channel modules are being used in the record, overdub, remix or track jump modes. This reflects a tendency noted elsewhere, such as on the Harrison console shown by Scenic Sounds Equipment, for even the biggest desks to become smaller. It is evident that the prestige afforded by being able to show customers acres of knob-speckled console has been tempered by the reduction in studio budgets and the unchanging length of engineers' arms. The Quantum comes in three frame sizes, for 24, 32 and 40 channels. Further modules can be added as needed. The 24 channel frame with 24 channel costs about £15,475. The 40 channel frame with 32 channels costs £19,355.

Audix says Thames Television has already ordered five or six of its new MXT 1000 audio **mixers** aimed at the small radio and recording studio, mobile and theatre market. Customers may build up a two or four group system from a pre-designed range of channel modules. "Technical features," says Audix, "include a compressor in the microphone/line channels and the talkback module, two auxiliary outputs from each channel and stereo monitoring facilities." It also offers a choice of VUs or p.p.ms and a selection of faders. The preliminary specification lists 12 modules, including two and four group mic/line channels, two and four group line input amplifiers, two and four group monitors, talkback module, meter panel in two or four groups, and an oscillator.

3M (UK) is marketing a new **autolocator** and a tape timer made by a British firm better known, perhaps, for making acoustic screens. Sonaplan designed the XT14 autolocator for 3M's M79 machines. It consists of a display and control unit and a logic unit normally hidden inside the tape machine. The counter operates in minutes and seconds and accuracy, says 3M, is better than plus or minus two seconds over 30 minutes playing time at 15 i.p.s., with no overshoot. The unit, which can be hand held, also has a full tape machine remote control unit on the same panel. Among its 11 functions, including a memory, the most basic is to find the point on the tape at the elapsed time set on the preset counter. The unit can also make the machine go to zero, which is normally set automatically when the tape is loaded.



*Audix MXT1000 four group p.p.m. metered mixer with ten mic/line and 2 stereo line inputs. See text.*

The tape timer is a real time **digital timer** for use with all the 3M professional range and derives its drive pulses from two sensors mounted below the reversing idler at the front of the 3M tape transport. The accuracy is as quoted for the autolocator.

F.W.O. Bauch was showing a new **wow and flutter meter** by EMT. The unit has a frequency deviation sensitivity of 0.1% f.s.d., and works to linear, DIN/IEC, low pass, high pass or band pass curves, with provision for an external filter. Three lamps indicate the performance of a given unit under test. A green lamp shows that the wow and flutter is well within limits, the amber that it is adequate and the red that it is outside limits. The limits are set by a programme plug in the front of the unit which is supplied along with a dummy plug for making up individual programmes. At the moment the price is £453 based on an exchange rate of 4.5DM to the pound. Bauch also showed a new micro-ohmmeter from EMT with suppressed zero facility, at £507.

Ferrograph, part of the reorganized Wilmot Breeden Electronics group, showed their professional **audio response analyzer** ARA1. The oscillator provides automatic, continuous and single sweep modes in the ranges 20Hz to 30kHz or 200Hz to 200kHz. The long persistence c.r.t. displays a gain v frequency plot, and a permanent record of the response can be obtained by connecting an X-Y plotter to the machine. "The receiver frequency display is derived from the incoming signal and not from the oscillator," says Ferrograph, so the unit can be used to test systems with time delay, such as tape recorders, systems using separate sources, such as test records or tapes or where there is a distance between oscillator and receiver, as in telephone line checks. The graticule has a log frequency scale from 20Hz to 20kHz with a ×10 range. Vertical ranges are 10, 25 and 50dB.

The Digital Audio special **effects unit** provides simple delay and echo effects, phasing, frequency shift and octave up and down signals mixed with the main signal. The unit uses a 40kbit r.a.m. store to hold up to 200ms of audio information which is released to the output under the control of an arithmetic processor. All functions can be remote controlled. There is a line and a low level input and all terminations are on XLR connectors. The unit can be rack mounted or free standing. The sole agents are Philip Drake Electronics.

Lockwood showed a new range of three professional **disc turntables**. The PDR1 has a Russco turntable, PDR2 a Garrard 401 and PDR3 a Thorens TD125. The last two have Ortofon F15E arms, but the Russco has a Grays 12in arm and Stanton cartridge. Alternatives can be provided for all three. Each has a 12 transistor amplifier offering a maximum output of 18dB into 600 ohms with a distortion of not greater than 0.3%. At 0dBm and 1kHz the distortion is 0.1%. The output is on two XLR connectors and there is a headphone jack at the front. PDR1 costs £750, PDR2 £530 and PDR3 £575 plus VAT.

# Real and Imaginary

by "Vector"

## ELECTRONICS CAN BE FUN

Just in case any reader, on scanning the heading, is wondering whether his subscription has been transferred to *Reader's Digest*, a hasty glance at the front cover will reassure him. His second natural assumption, namely that Vector is mentally deranged, is equally invalid. *(I wouldn't put money on that! — Ed.)*

What I really wanted to talk about is "do-gooders" of various kinds. Do-gooding covers a wide spectrum, from the flamboyant gift of a hundred thousand or so to a hospital, with the Press fully alerted beforehand, to those earnest souls who rouse us from our Sunday afternoon nap to press a tract upon us and to assure us that their particular brand of dogma washes whitest of all. There is a great variety of do-gooders and it has been said that you can always tell the people who are being done good to by the hunted expressions on their faces.

But do-gooding, even when performed with the highest of motives in view, does not always work out in the way intended. I have in mind a certain electronics factory whose employees included two brothers by the name of Miller. One was chief of Goods Inward and the other chief of Finished Components Store. Now, if you happened to be in Goods Inward, its chief would be referred to as "Dusty" and the chief of Finished Comps as "Dusty's Brother". So far so good, except that the personnel of Finished Comps, to a man, regarded their chief as the only genuine Dusty and the Goods Inward usurper as "Dusty's Brother". I daresay you find that confusing and so did new arrivals in the factory, but they either contracted a nervous breakdown or got the hang of it after a while.

There was a young and enthusiastic curate in the area who conceived the idea (basically a good one) that he could best get to grips with the problems of his parishioners by working alongside some of them, and to this end he bludgeoned the management into allowing him to work in the factory for three days a week. (I don't know how the union aspect was overcome, but it evidently was.)

News of the impending arrival swept through the factory grapevine at the speed of light and on the works floor a book was made as to which department would be selected to take the curate under its wing. "Goods Inward" was firm favourite, for that particular Dusty Miller, being a thorough-going Plymouth Brother, was considered a natural for the honour; in fact, a supplementary book was envisaged as to who would convert who. The Dusty Miller of Finished Comps, on the other hand, was at the tail-end of the field at astronomical odds; for although he was a chap with a heart as big as a barn door he subscribed only to one of those churches run by the Licensed Victuallers Association and was, moreover, possessed of a lurid vocabulary, with every other word an adjective of four-letter derivation.

Now, some say it was malice aforethought on the part of the management, while the more charitable hold that the hierarchy were genuinely confused as to which Dusty was which. Be that as it may, when the news broke that the cleric had been assigned to Finished Comps, the Works was in a ferment. The bookmaker, in particular, was contemplating suicide until a providential last look at his list showed that not a single client had backed the winner.

Not the least surprising aspect of the affair was the seriousness with which Dusty Miller of Finished Comps took his assignment. The clergyman was due to start on Tuesday; on Monday afternoon Dusty paraded his workforce before him.

"Now look here, you bleepers," he began. "As you may know, the bleeping management have wished a bleeping sky-pilot on me. And I want to say, right here and now, that I want some bleeping respect for the cloth from you lot. The first of you bleepers who says a bleeping word out of place, gets his bleeping cards! Savvy?"

It would be pleasant to conclude by saying that in the fullness of time Dusty might have been seen taking up the collection on Sundays. Life, however, is not always what we would wish it to be. Truth compels me to say that the alliance foundered after three weeks when the curate resigned, being distressed to find that he was acquiring the habit of uttering certain undesirable expletives in moments of trial. By doing so, he saved Dusty from certain apoplexy, for the discipline of saying, "Sorry, mate, we're out of stock" in place of his erstwhile "Wot the 'ell d'you bleeping fink this is — bleeping Marks and Spencers?" had become all but intolerable. Honours, it was generally agreed, were just about even.

But I would particularly like to recall to you a little-known category among those who do good — and, furthermore, do it by stealth. I'm thinking of those anonymous Works humorists who put a little leaven into the flour-and-water of everyday existence. You are walking along the corridor, let us say, feeling Monday-morningish and with a particularly dull chore ahead. You pause at a notice-board and one sheet sticks out from the rest. It's typed on official Head Office paper and runs as follows:

> **NOTICE TO ALL EMPLOYEES**
> *It has come to the attention of the Management that personnel are becoming increasingly in the habit of dying in the company's time. This practice must cease forthwith.*
> *(Signed) F. M. Tuner,*
> *Managing Director*

Another that I recall was handwritten at the foot of a Samaritan's poster. It stated simply: "My mother made me a homosexual." Underneath, in (apparently) another hand, was the comment: "If I send her the wool, will she make one for me?"

You read, and all of a sudden the prospect of the chore doesn't seem nearly so grim. Why do they do it, these chaps? It's an interesting problem in psychology. It can't be for public acclaim, because, by the way nature of things, the author must remain anonymous. The cynic may say that it's for kicks; the thrill of filching Head Office notepaper and pinning it up unseen in a busy corridor. I prefer to think it's done in the hope of relaxing a few taut faces, but perhaps I'm being naive.

Sometimes, however, these efforts come unstuck. Some years ago — in the same Works I spoke of earlier — an "official" document was circulated to the technical staff. It purported to be a description of two new types of radar equipment, one a transmitter and the other a receiver. The tone of the document was that of a preamble to a technical handbook; the uninitiated could easily read the first couple of paragraphs — or, as it transpired the whole of it — without realising that the "new radar system" was in fact a description of that biological process which, initiated by Adam and Eve, has enjoyed universal popularity ever since. The author as usual, was our old friend Anon.

His offering brought joy to the staff, and then someone decided to push the joke a stage farther and sent a copy to a well-known journal (not, I hasten to add, *W.W.!*) which promptly took it at face value and published it. On the morning of publication somebody must have rung the editor, for the edition was whistled off the book-stands at high speed.

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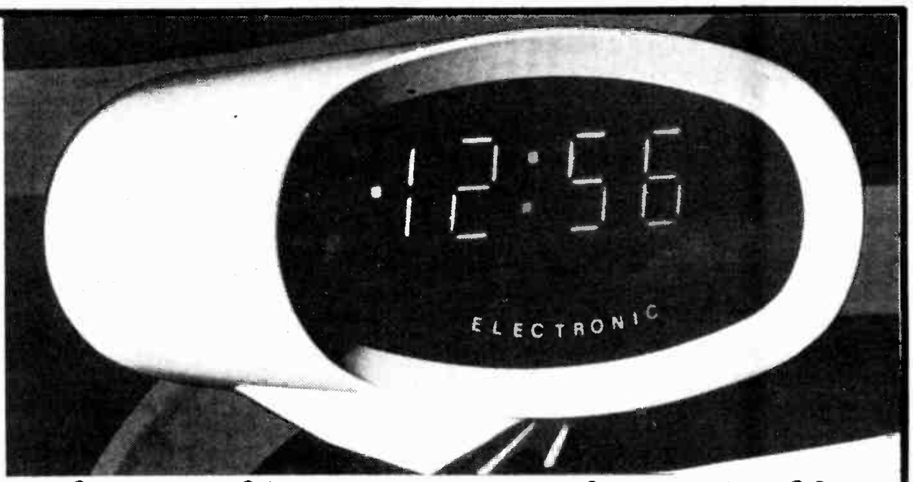


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| BC338 | 0.17* |
| BCY70 | 0.12 |
| BCY71 | 0.18 |
| BCY72 | 0.12 |
| BD115 | 0.55 |
| BD131 | 0.36 |
| BD132 | 0.40 |
| BD135 | 0.36 |
| BD136 | 0.39 |
| BD137 | 0.40 |
| BD138 | 0.48 |
| BD139 | 0.58 |
| BD181 | 0.86 |
| BD182 | 0.92 |
| BD183 | 0.97 |
| BD232 | 0.60* |
| BD233 | 0.48* |
| BD237 | 0.55* |
| BD238 | 0.60* |
| BD184 | 1.20 |
| BDY20 | 0.80 |
| BDY38 | 0.60 |
| BDY60 | 0.60 |
| BDY61 | 0.65 |
| BDY62 | 0.55 |
| BF178 | 0.28 |
| BF179 | 0.30 |
| BF194 | 0.10* |
| BF195 | 0.10* |
| BF196 | 0.12* |
| BF197 | 0.12* |
| BF224J | 0.18* |
| BF244 | 0.17* |
| BF257 | 0.30* |
| BF258 | 0.35 |
| BF337 | 0.32 |
| BFW60 | 0.17* |
| BFX29 | 0.26 |
| BFX30 | 0.30 |
| BFX84 | 0.23 |
| BFX85 | 0.25 |
| BFX88 | 0.20 |
| BFY50 | 0.20 |
| BFY51 | 0.18 |
| BFY52 | 0.19 |
| BFY64 | 0.35 |
| BFY90 | 0.65 |
| BR100 | 0.20 |
| BRY39 | 0.40 |
| BSX19 | 0.16 |
| BSX20 | 0.18 |
| BSX21 | 0.20 |
| BSY95A | 0.12 |
| BT106 | 1.00 |
| BT107 | 1.60 |
| BT108 | 1.60 |
| BT109 | 1.00 |
| BT116 | 1.00 |
| BU105 | 1.80* |
| BU105/02 | 1.90* |
| BU126 | 1.60* |

| | |
|---|---|
| BY206 | 0.15 |
| BY207 | 0.20* |
| BYX36-300 | 0.12* |
| BYX36-600 | 0.15* |
| BYX36-900 | 0.18* |
| BYX36-1200 | 0.21* |
| BYX38-300 | 0.50 |
| BYX38-600 | 0.55 |
| BYX38-900 | 0.60 |
| BYX38-1200 | 0.65 |
| BZX61 Series Zeners | 0.20 |
| BZX83 or BZX88 Series Zeners | 0.11 |
| C106A | 0.40 |
| C106B | 0.45 |
| C106D | 0.50 |
| C106F | 0.35 |
| CRS1/05 | 0.25 |
| CRS1/10 | 0.25 |
| CRS1/20 | 0.35 |
| CRS1/40 | 0.40 |
| CRS1/60 | 0.65 |
| CRS3/05 | 0.34 |
| CRS3-10 | 0.45 |
| CRS3-20 | 0.50 |
| CRS3-40 | 0.60 |
| CRS3-60 | 0.85 |
| MJ480 | 0.80 |
| MJ481 | 1.05 |
| MJ490 | 0.90 |
| MJ491 | 1.15 |
| MJE340 | 0.40* |
| MJE371 | 0.60 |
| MJE52D | 0.45 |
| MJE521 | 0.55 |
| OA5 | 0.50* |
| OA90 | 0.08 |
| OA91 | 0.08 |
| OC41 | 0.15 |
| OC42 | 0.15 |
| OC44 | 0.12 |
| OC45 | 0.10 |
| OC70 | 0.10 |
| OC71 | 0.10 |
| OC72 | 0.22 |
| OC84 | 0.14 |
| SC40A | 0.73 |
| SC40B | 0.81 |
| SC40D | 0.98 |
| SC40F | 0.65 |
| SC41A | 0.65 |
| SC41B | 0.70 |
| SC41D | 0.85 |
| SC41F | 0.60 |
| ST2 | 0.20 |
| TIP29A | 0.44 |
| TIP30A | 0.52 |
| TIP31A | 0.54 |
| TIP32A | 0.64 |
| TIP34 | 1.05 |
| TIP41A | 0.68 |
| TIP42A | 0.72 |
| 1N2069 | 0.14 |
| 1N2070 | 0.16 |
| 1N4001 | 0.04* |
| 1N4002 | 0.05* |

| | |
|---|---|
| 1N4003 | 0.06* |
| 1N4004 | 0.07* |
| 1N4005 | 0.08* |
| 1N4006 | 0.09* |
| 1N4007 | 0.10* |
| 2N696 | 0.14 |
| 2N697 | 0.12 |
| 2N706 | 0.10 |
| 2N929 | 0.14 |
| 2N930 | 0.14 |
| 2N1131 | 0.15 |
| 2N1132 | 0.16 |
| 2N1304 | 0.20 |
| 2N1305 | 0.20 |
| 2N1711 | 0.18 |
| 2N2102 | 0.44 |
| 2N2369 | 0.14 |
| 2N2369A | 0.14 |
| 2N2484 | 0.16 |
| 2N2646 | 0.50 |
| 2N2905 | 0.18 |
| 2N2905A | 0.22 |
| 2N2926R | 0.10* |
| 2N29260 | 0.09* |
| 2N29267 | 0.09* |
| 2N2926G | 0.10* |
| 2N3053 | 0.15 |
| 2N3054 | 0.40 |
| 2N3055 | 0.50 |
| 2N3440 | 0.56 |
| 2N3442 | 1.20 |
| 2N3525 | 0.75 |
| 2N3570 | 0.80 |
| 2N3702 | 0.10* |
| 2N3703 | 0.10* |
| 2N3704 | 0.10* |
| 2N3705 | 0.10* |
| 2N3706 | 0.10* |
| 2N3707 | 0.10* |
| 2N3714 | 1.05 |
| 2N3715 | 1.15 |
| 2N3716 | 1.25 |
| 2N3771 | 1.60 |
| 2N3772 | 1.60 |
| 2N3773 | 2.10 |
| 2N3819 | 0.28* |
| 2N3904 | 0.16* |
| 2N3906 | 0.16* |
| 2N4124 | 0.14* |
| 2N4290 | 0.12* |
| 2N4348 | 1.20 |
| 2N4870 | 0.35 |
| 2N4871 | 0.35 |
| 2N4919 | 0.70* |
| 2N4920 | 0.50* |
| 2N4922 | 0.58* |
| 2N4923 | 0.64* |
| 2N5060 | 0.20* |
| 2N5061 | 0.25* |
| 2N5062 | 0.27* |
| 2N5064 | 0.30* |
| 2N5496 | 0.65 |

## DIGITAL DISPLAYS & LED'S

| | | | | | |
|---|---|---|---|---|---|
| DL704 | 99p | DL747 | £1.75 | 2 RED LED ONLY | 13p |
| DL707 | 99p | DL750 | £1.75 | GREEN CLEAR | 15p |

## THYRISTORS

| | .8A (TO92) | 1A (TO5) | 3A (C106 type) | 6A (TO220) | 8A (TO220) | 10A |
|---|---|---|---|---|---|---|
| 50 | 20 | 25 | 35 | 41 | 42 | 47 |
| 100 | 25 | 25 | 40 | 47 | 48 | 54 |
| 200 | 27 | 35 | 45 | 58 | 60 | 68 |
| 400 | 30 | 40 | 50 | 87 | 88 | 98 |
| 600 | | 65 | 70 | 1.09 | 1.19 | 1.26 |

## TRIACS (PLASTIC TO-220 PKGE. ISOLATED TAB)

| | 4A | | 6.5A | | 8.5A | | 10A | | 15A | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (a) | (b) | (a) | (b) | (a) | (b) | (a) | (b) | (a) | (b) |
| 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 | 0.87 | 0.87 | 1.17 | 1.17 |
| 400V | 0.77 | 0.78 | 0.80 | 0.83 | 0.97 | 1.01 | 1.13 | 1.19 | 1.70 | 1.74 |
| 600V | 0.96 | 0.99 | 0.87 | 1.01 | 1.21 | 1.26 | 1.42 | 1.50 | 2.11 | 2.17 |

N.B. Triacs without internal trigger diac are priced under column (a) Triacs with internal trigger diac are priced under column (b) When ordering please indicate clearly the type required.

## 74 TTL mixed prices

| | 1-24 | 25-99 | 100+ | | 1-24 | 25-99 | 100+ | | 1-24 | 25-99 | 100+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7400 | 14p | 12p | 10p | 7445 | 85p | 71p | 57p | 7493 | 45p | 40p | 32p* |
| 7401 | 14p | 12p | 10p | 7447 | 81p | 75p | 65p | 7495 | 67p | 55p | 45p |
| 7402 | 14p | 12p | 10p | 7448 | 75p | 62p | 50p | 74100 | £1.08 | 89p | 72p |
| 7403 | 15p | 12½p | 10p | 7447A | 95p | 83p | 67p | 74107 | 35p | 28p | 22p |
| 7404 | 16p | 13p | 11p | 7470 | 30p | 25p | 20p | 74121 | 34p | 28p | 23p |
| 7408 | 16p | 13p | 11p | 7472 | 25p | 21p | 17p | 74122 | 47p | 39p | 31p |
| 7409 | 16p | 13p | 11p | 7473 | 30p | 25p | 20p | 74141 | 78p | 63p | 53p |
| 7410 | 16p | 13p | 11p | 7474 | 32p | 26p | 21p | 74145 | 68p | 58p | 48p |
| 7413 | 29p | 24p | 20p | 7475 | 47p | 39p | 31p | 74154 | £1.62 | £1.48 | 86p |
| 7417 | 27p | 22½p | 20p | 7476 | 32p | 26p | 21p | 74174 | £1.00 | 83p | 67p |
| 7420 | 16p | 13p | 11p | 7482 | 75p | 62p | 50p | 74180 | £1.06 | 88p | 71p |
| 7427 | 27p | 22½p | 18p | | £1.30 | £1.09 | 87p | 74181 | £3.20 | £2.50 | £1.90 |
| 7430 | 16p | 13p | 11p | 7486 | 32p | 26p | 21 | 74192 | £1.35 | £1.14 | 90p |
| 7432 | 27p | 22½p | 18p | 7489 | £2.92 | £2.80 | £2.10 | 74193 | £1.35 | £1.14 | 90p |
| 7437 | 27p | 22½p | 18p | 7490 | 49p | 40p | 32p | 74196 | £1.64 | £1.34 | 99p |
| 7441 | 75p | 62p | 50 | 7491 | 65p | 55p | 45p | | | | |
| 7442 | 65p | 55p | 43p | 7492 | 57p | 46p | 36p | | | | |

## LINEAR IC'S

| | | | | | |
|---|---|---|---|---|---|
| 301A 8 pin DIL | 35p* | 3900 14 pin DIL | 70p* | 565 14 pin DIL | £2.00* |
| 307 | 55p* | 709 8/14 pin DIL | 35p* | 566 8 pin DIL | £1.50* |
| 309K | £1.60 | 741 8 pin DIL | 28p* | 567 8 pin DIL | £2.00* |
| 380 14 pin DIL | 90p | 741 14 pin DIL | | CA3046 14 pin DIL | 50p* |
| 381 14 pin DIL | £1.60* | 748 8 pin DIL | 36p* | CA3045 | 85p* |
| | | 555 8 pin DIL | 45p | | |

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**VAT — Please add 8% except items marked * which are 12½%**

**P&P 20p. Overseas 80p**

## SINCLAIR, CBM AND NOVUS CALCULATORS*

**Sinclair:** Cambridge Scientific **£11.45.** Oxford 300 **£13.30.** Programmable Scientific **£24.95.** Mains adaptors for all models **£3.20.**
**CMB:** SR7919D 8 digit/memory/trig/log/pi/powers/sci. notation **£11.90.** 796MD 8 digit/%/memory **£5.98.** Mains adaptors **£3.20.**
**Novus:** 750 6 digit **£5.45.** 835 8 digit/%/const/sq. root/4 funct. mem **£7.60.** Mains unit **£4.20.**

## SINCLAIR BLACK WATCH*

Fully assembled with black strap **£20.95.** Bracelet **£2.00.**

## SINCLAIR IC20

IC20 10W+10W stereo amp kit with printed circuit **£4.95.** PZ20 Power supply for above **£3.95** — VP20 Control and preamp kit **£7.50.**

## SINCLAIR PROJECT 80

FM tuner **£13.25.** Q16 **£9.50.** PZ5 **£3.95.** PZ6 **£8.70.** PZ8 **£9.10.** Trans for PZ8 **£5.60.** Z40 **£5.75.** Stereo 80 **£11.95.** Project 805Q **£18.95.**

## BATTERY ELIMINATORS

**STABILIZED POWER UNITS**
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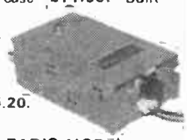
**6-WAY SPECIAL**
Switched output of 3, 4½, 6, 7½, 9, 12V at 500mA **£5.20.**



**6-WAY DOUBLE RADIO MODEL**
Switched output 3+3, 4½+4½, 6+6, 7½+7½, 9+9, 12+12V at 250mA. Also 15, 18, 24V single **£6.20.**

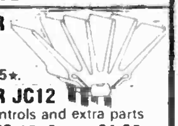
**3-WAY MODEL***
Switched output of 6, 7½ and 9V at 250mA with 4-way multi-jack connector and free matching socket **£2.95.**

**RADIO MODELS**
50mA with press-stud battery connectors for radios etc. 6V **£3.45.** 9V **£3.25.** 4½+4½V **£4.45.** 6+6V **£4.45.** 9+9V **£4.45.** Also 9V 300mA **£3.95.**

**CASSETTE MAINS UNITS**
7½V output with 5 pin DIN plug. 50mA model **£3.45.** 300mA model **£3.95.**

**CAR CONVERTERS**
Input 12V DC. Output 6, 7½, 9V DC 1A regulated **£4.75***.

## JC12 AMPLIFIER

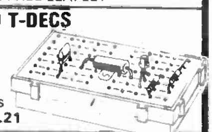


6W IC audio amp with free data and printed circuit **£1.95***.

**DELUXE KIT FOR JC12**
Volume and tone controls and extra parts for the pcb. Mono **£2.16.** Stereo **£4.66.**

**JC12 POWER KIT**
Supplies 25V 1Amp **£3.25.**
SEND SAE FOR FREE LEAFLET

## S-DECS AND T-DECS



S-DeC **£2.24**
T-DeC **£4.05**
u-DeCA **£4.45**
u-DeCB **£7.85**
16 dil IC carriers with sockets **£2.21**

## BATTERY ELIMINATOR KITS

Send sae for free leaflet on range.
**100mA radio type:** with press stud terminals. 4½V, 6V or 9V **£1.95.**
**100mA double radio type:** with press stud terminals. 4½+4½, 6+6 or 9+9V **£2.60.**
**100mA cassette type:** 7½V din plug. **£1.95.**
**Stabilized 8-way types:** transistor stabilized to give low hum. 3 / 4½ / 6 / 7½ / 9 / 12 / 15 / 18V 100mA model **£3.15.** 500mA model **£4.65.**
**Heavy duty 13-way types:** 4½ / 6 / 7 / 8½ / 11 / 13 / 14 / 17 / 21 / 25 / 28 / 34 / 42V. 1A **£4.10.** 2A **£6.80.**
**Car converter kit:** Input 12V DC. Output 6 / 7½ / 9V DC 1A regulated **£2.95.**

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### TRANSISTORS

| | | |
|---|---|---|
| **Small Signal** | | |
| (2–5B) | | |
| 2SA 561 | PNP | 13p |
| 2SA 562 | ,, | 12p |
| 2SA 493 | ,, | 17p |
| 2SA 495 | ,, | 12p |
| 2SC 372 | NPN | 9.5p |
| 2SC 373 | ,, | 9.5p |
| 2SC 382 | ,, | 26p |
| 2SC 383 | ,, | 24.5p |
| 2SC 388A | ,, | 22.5p |
| 2SC 733 | ,, | 6p |
| 2SC 734 | ,, | 11.5p |
| 2SC 735 | ,, | 11p |
| 2SC 1000 | ,, | 16p |
| 2SC 1681 | ,, | 16p |
| (TO–92) | | |
| BC 451 | NPN | 11p |
| BC 452 | ,, | 11p |
| BC 453 | ,, | 11p |
| BC 454 | PNP | 11.5p |
| BC 455 | ,, | 11.5p |
| BC 456 | ,, | 11.5p |
| **Plastic Power** | | |
| (2–7) | | |
| S1234 | NPN | 33.5p |
| (TO–126) | | |
| BD 135 | NPN | 33.5p |
| BD 137 | ,, | 36.5p |
| BD 138 | PNP | 40p |
| BD 139 | NPN | 40p |
| BD 140 | PNP | 44p |
| (TO–220AB) | | |
| *2SA 473 | PNP | 40p |
| *2SA 489 | ,, | 75p |
| *2SC 790 | NPN | 50.5p |
| 2SC 1173 | ,, | 35.5p |
| *2SC 1447 | ,, | 50.5p |
| *2N 5296 | ,, | 59p |
| **Metal Power** | | |
| (TO–66) | | |
| 2SC 515A | NPN | 48.5p |
| 2SC 782 | ,, | £1.08 |
| (TO–3) | | |
| *2SC 643A | ,, | £2.05 |
| 2SC 1434 | ,, | £14.30 |
| *2SC 1576 | ,, | £2.43 |
| 2SC 1617 | ,, | £1.29 |
| *2N 3055 | ,, | £0.86 |
| *S 2530A | ,, | £3.48 |
| S 1299 | ,, | £4.09 |
| **Integrated Circuits** | | |
| TA 7093P | | £1.49 |
| TA 7109AP | | £1.57 |
| TA 7117P | | £2.36 |
| TA 7205P | | £1.55 |
| **F.E.T.** | | |
| (2–5J) | | |
| *2SK12 | | £1.04 |
| 2SK30A | | 27p |
| *3SK35 | | £1.45 |

### DIODES

| | |
|---|---|
| **Zener** | |
| 05Z5.6 | 14p |
| 05Z6.2 | 12p |
| 05Z6.8 | 13p |
| 05Z7.5 | 13p |
| 05Z8.5 | 13p |
| 05Z9.1 | 13p |
| 05Z10 | 13p |
| 05Z11 | 13p |
| 05Z12 | 13p |
| 05Z13 | 13p |
| 05Z15 | 13p |
| **General Purpose** | |
| S5089A (IN4001) | 7.5p |
| S5089B (IN4002) | 8p |
| S5089F (IN4006) | 11p |
| **Vari Cap** | |
| 1S1658 | 25p |
| **Switching** | |
| 1S1554 | 4p |
| **Pulse Rectifier** | |
| 1S2755 | 23.5p |
| **Diac** | |
| 1S2093 | 25p |
| **Thyristors** | |
| SFOR 2B41 | 52.5p |
| **Triac** | |
| *SM6G14 | £1.61 |
| **Uni Junction** | |
| *2SH21 | 57p |
| **Light Emitting Diodes** | |
| TLR 102 | 21.5p |
| TLR 103 | 21.5p |
| TLR 104 | 21.5p |
| TLR 105 | 21.5p |
| TLR 106 | 21.5p |
| TLR 114 | 30p |
| TLG 102 | 35.5p |
| TLG 103 | 35.5p |
| TLG 105 | 35.5p |
| **Seven Segments** | |
| TLR 301 | £1.08 |
| TLR 302 | £2.22 |
| TLR 306 | £3.08 |
| TLR 307 | £3.08 |

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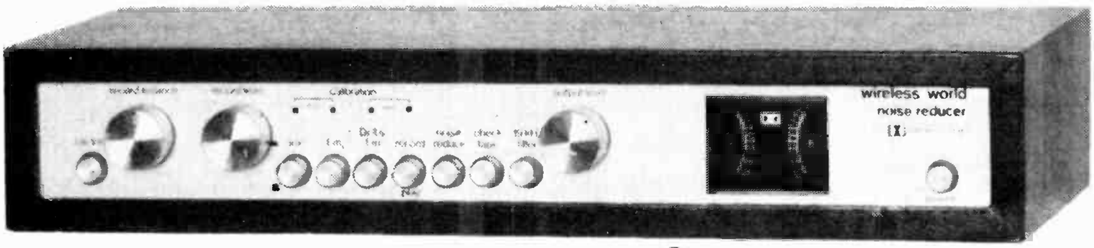


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**We are proud to announce the latest addition to our range of matching high fidelity units.**

Featuring:

- switching for both encoding (low-level h.f. compression) and decoding
- a switchable f.m. stereo multiplex and bias filter
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- no equipment needed for alignment
- suitability for both open-reel and cassette tape machines
- check tape switch for encoded monitoring in three-head machines

The kit includes:

—complete set of components for stereo processor
—regulated power supply components
—board-mounted DIN sockets and push-button switches
—fibreglass board designed for minimum wiring
—solid mahogany cabinet, chassis, twin meters, front panel, knobs, mounting screws and nuts

## Typical performance

Noise reduction: better than 9dB weighted

Clipping level: 16.5dB above Dolby level (measured at 1% third harmonic content)

Harmonic distortion 0.1% at Dolby level typically 0.05% over most of band, rising to a maximum of 0.12%.

Signal-to-noise ratio: 75dB (20Hz to 20kHz, signal at Dolby level) at Monitor output.

Dynamic Range > 90dB

30mV sensitivity.

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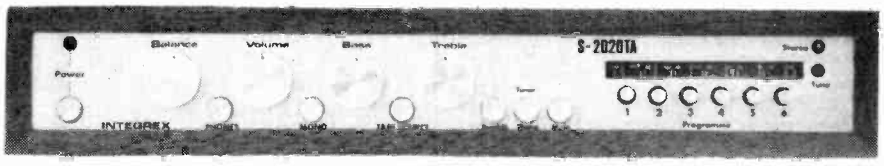
## S-2020TA STEREO TUNER/AMPLIFIER KIT

**SOLID MAHOGANY CABINET**




***A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.***

**Brief Spec.** Amplifier: Low field Toroidal transformer, Mag. input, Tape In/Out facility (for noise reduction unit, etc), THD less than 0.1% at 20W into 8 ohms. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section: uses Mullard LP1186 module requiring no RF alignment, ceramic IF, INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.8µV.THD typ. 0.4%

**PRICE: £53.95**+VAT

## NELSON-JONES STEREO FM TUNER KIT

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


**Brief Spec.** Tuning range 88—104MHz. 20dB mono quieting @ 0.75µV. Image rejection — 70dB. IF rejection—85dB. THD typically 0.4%
IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.

*Compare this spec. with tuners costing twice the price*

**Mono £29.15**+VAT
**With ICPL Decoder £33.42**+VAT
**With Portus-Haywood Decoder £35.95**+VAT

## STEREO MODULE TUNER KIT

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

Sens. 30dB S/N mono @ 1.8µV
THD typically 0.4%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

**PRICE: Mono £26.85**+VAT
**Stereo £29.95**+VAT

## S-2020A AMPLIFIER KIT


***Developed in our laboratories from the highly successful "TEXAN" design. PC mounting potentiometers, switches, sockets and fuses are used for ease of assembly and to minimize wiring***

**Type Spec.** 24+24W r.m.s into 8-ohm load at less than 0.1% THD. Mag. PU input S/N 60dB. Radio input S/N 72dB. Headphone output. Tape In/Out facility (for noise reduction unit, etc.). Toroidal mains transformer.

**PRICE: £31.95**+VAT

**ALL THE ABOVE KITS ARE SUPPLIED COMPLETE WITH ALL METALWORK, SOCKETS, FUSES, NUTS AND BOLTS, KNOBS, FRONT PANELS, SOLID MAHOGANY CABINETS AND COMPREHENSIVE INSTRUCTIONS**

**BASIC NELSON-JONES TUNER KIT** . **£14.28**+VAT
**BASIC MODULE TUNER KIT (Mono)** . **£14.75**+VAT
**BASIC MODULE TUNER KIT (stereo)** . **£16.75**+VAT
**PHASE-LOCKED IC DECODER KIT** . . . **£4.47**+VAT
**PUSH-BUTTON UNIT** . . . . . . . . . . . . . . **£4.50**+VAT

**PORTUS-HAYWOOD PHASE-LOCKED STEREO DECODER KIT** . . . . . . . . . . . . . . . . . . . . **£8.00**+VAT

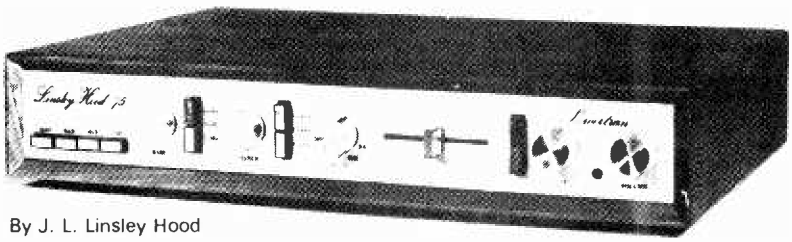
WW—020 FOR FURTHER DETAILS

Bahrain Singapore Thailand Iceland Brazil Sweden Germany Iran Jamaica St. Kitts Tunisia

# POWERTRAN ELECTRONICS

INCORPORATING AMBIENTACOUSTICS

## HI-FI NEWS 75W/CHANNEL AMPLIFIER



By J. L. Linsley Hood

In Hi-Fi News there was published by Mr Linsley-Hood a series of four articles (November 1972-February 1973) and a subsequent follow-up article (April, 1974) on a design for an amplifier of exceptional performance which has as its principal feature an ability to supply from a direct coupled fully protected output stage, power in excess of 75 watts whilst maintaining distortion at less than 0 01% even at very low power levels. The power amplifier is complemented by a pre-amplifier based on a discrete component operational amplifier referred to as the Liniac which is employed in the two most critical points of the system namely the equalization stage and tone control stage, positions where most conventional designs run out of gain at the extremes of the frequency spectrum Unusual features of the design are the variable transition frequencies of the tone controls and the variable slope of the scratch filter There is a choice of four inputs, two equalized and two linear each having independently adjustable signal level The attractive slimline unit pictured has been made practical by highly compact PCBs and a specially designed Toroidal transformer

| Pack | Price |
|---|---|
| 1. Fibreglass printed-circuit board for power amp | £1.15 |
| 2. Set of resistors, capacitors, pre-sets for power amp | £2.15 |
| 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 | £1.75 |
| 6. Set of low noise resistors, capacitors, pre-sets for pre-amp | £3.40 |
| 7. Set of low noise, high gain semiconductors for pre-amp | £2.40 |
| 8. Set of potentiometers (including mains switch) | £3.15 |
| 9. Set of 4 push-button switches, rotary mode switch | £4.50 |
| 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, semi-conductors for power supply | £4.60 |
| 13. Set of miscellaneous parts including DIN skts, mains input skt, fuse holder, inter-connecting cable, control knobs | £5.35 |
| 14. Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc. | £7.30 |
| 15. Handbook | £0.30 |
| 16. Teak cabinet 18.3" x 12.7" x 3.1" | £9.85 |

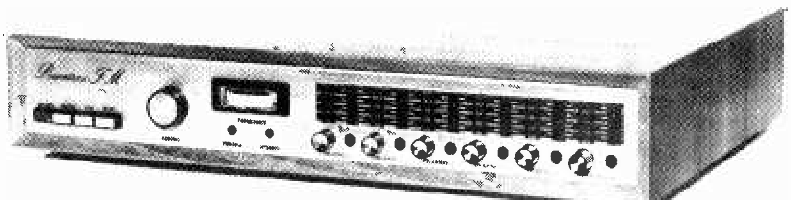
2 each of packs 1-7 inclusive are required for complete stereo system. Total cost of individually purchased packs .......... £83.75

**FREE** TEAK CASE WITH FULL KITS

KIT PRICE ONLY **£73.90**

## WIRELESS WORLD FM TUNER

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 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



| 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 | £4.30 |
| 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. | £8.80 |
| 9. Function switch, 10 turn tuning potentiometer, knobs | £5.30 |
| 10. Frequency meter, meter drive components, fibreglass printed circuit board | £9.45 |
| 11. Toroidal transformer with electrostatic screen, Primary: 0—117V—234V | £4.45 |
| 12. Set of capacitors, rectifiers, voltage regulator for power supply | £2.95 |
| 13. Set of miscellaneous parts, including sockets, fuse holder, fuses, inter-connecting wire, etc. | £1.50 |
| 14. Set of metal work parts including silk screen printed facia panel, acrylic silk screen printed tuning indicator panel insert, internal screen, fixing parts, etc. | £7.50 |
| 15. Construction notes (free with complete kit) | £0.25 |
| 16. Teak cabinet 18.3" x 12.7" x 3.1" | £9.85 |

One each of packs 1-16 inclusive are required for complete stereo FM tuner. Total cost of individually purchased packs .......... £76.85

# NEW KIT!

## LINSLEY-HOOD CASSETTE DECK


A full kit has been prepared for this excellent new design. The above illustration is of Mr. Linsley-Hood's own unit but the Powertran kit is, though not identical, very similar and of course in the same cabinet (that used for the outstandingly successful 75W Linsley-Hood Amplifier design).

| | |
|---|---|
| Goldring-Lenco mechanism, as specified | £19.10 |
| Stereo P.C.B. (accommodates 2 rep. amps, 2 rec amps, 2 meter amps, bias/erase osc, relay), 7.3" x 3 7" | £3.35 |
| Stereo set of capacitors, M.O. resistors, potentiometers for above | £9.80 |
| Stereo set of semiconductors for above | £8.90 |

Further details of above and additional packs given in our FREE LIST

**FREE** TEAK CASE WITH FULL KITS

KIT PRICE only **£66.75**

PRICE STABILITY!

Order with confidence! Irrespective of any price changes we will honour all prices in this advertisement for two months from issue date provided that this advertisement is quoted with your order E&OE VAT rate changes excluded

All components are brand new first grade full specification devices All resistors (except where stated) are low noise carbon film types All printed circuit boards are fibre-glass, drilled, roller tinned and supplied with circuit diagrams and construction layouts.

U.K. Orders. Subject to 12½%* Surcharge for VAT. Carriage free MAIL ORDER ONLY (*or at current rate if changed)

Securicor Delivery For this optional service (Mainland only) add £2 50 VAT inc per kit

Overseas Orders No VAT Postage charged at actual cost plus 50p packing and handling.

DEPT. WW08

## POWERTRAN ELECTRONICS

PORTWAY INDUSTRIAL ESTATE
ANDOVER, HANTS SP10 3NN

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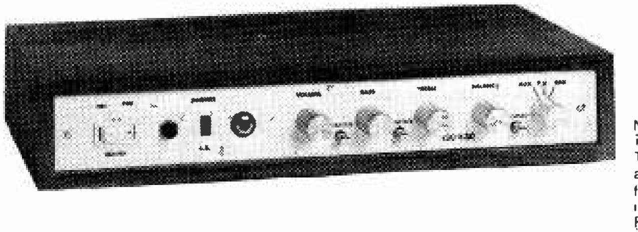
Hong Kong Jersey Australia St. Lucia India Barbados Antigua Jordan Spain Israel Mauritius St. Vincent Uganda Ascension Island Malta Sierra Leone Somalia New Guinea Italy Kuwait Netherlands Canada Trinidad Malaya Austria

# AUDIO KIT SUPPLIERS TO THE WORLD



## T20+20 and our new 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 slimline T20 + 20 delivers 20W per channel of true Hi-Fi at exceptionally low cost. The 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 head phones 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 new model is 30W per channel.

| Pack | T20 | T30 |
|---|---|---|
| 1. Set of low noise resistors | 1.40 | 1.50 |
| 2. Set of small capacitors | 2.20 | 2.80 |
| 3. Set of power supply capacitors | 1.90 | 2.30 |
| 4. Set of miscellaneous parts | 3.20 | 3.20 |
| 5. Set of slide, mains, P.B. switches | 1.20 | 1.20 |
| 6. Set of pots, selector switch | 2.80 | 2.80 |
| 7. Set of semiconductors, ICs, skts. | 7.25 | 7.75 |
| 8. Toroidal transformer — 240V prim. e.s. screen | 4.95 | 6.80 |
| 9. Fibreglass PCB | 3.20 | 3.60 |
| 10. Set of metalwork, fixing parts | 4.20 | 4.80 |
| 11. Set of cables, mains lead | 0.40 | 0.40 |
| 12. Handbook (free with complete kit) | 0.25 | 0.25 |
| 13 Teak cabinet 15.4" x 6.7" x 2.8" | 4.50 | 4.50 |

## SPECIAL PRICES FOR COMPLETE KITS!

T20+20 KIT PRICE only **£28.25**

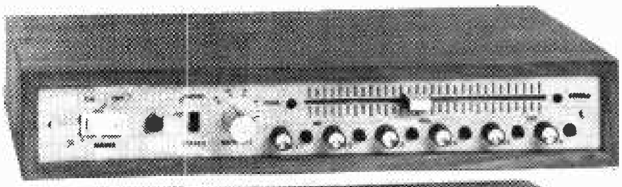
T30+30 KIT PRICE only **£32.95**

## 2 NEW TUNERS!

### WW SFMT II

Following the success of our Wireless World FM Tuner kit we are now pleased to introduce our new cost reduced model, designed to complement the T20 and T30 amplifiers. The frequency meter of the more advanced model has been omitted and the mechanics simplified, however the circuitry is identical and this new kit offers most exceptional value for money. Facilities included are switchable afc, adjustable, switchable muting, channel selection by slider or readily adjustable pre-set push-button controls and LED tuning indication. Individual pack prices in our free list

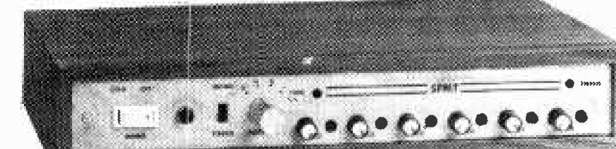
KIT PRICE **£45.50**



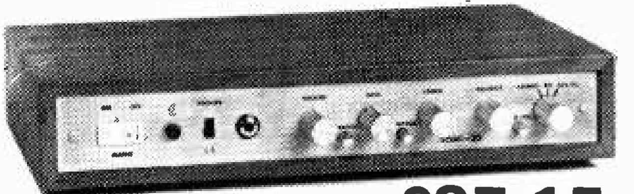
### POWERTRAN SFMT

This easy to construct tuner using our own circuit design includes a pre-aligned front end module, PLL stereo decoder, adjustable, switchable muting, switchable afc and push-button channel selection. As with all our full kits, all components down to the last nut and bolt are supplied together with full constructional details.

KIT PRICE **£32.60**



## CONVERT NOW TO QUADRAPHONICS!



**SQM1 — 30** KIT PRICE **£37.15**

With 100s of titles now available no longer is there any problem over suitable software. No problems with hardware either. Our new unit the SQM1-30 simply plugs into the tape monitor socket of your existing amplifier and drives two additional speakers at 30W per channel. A full complement of controls including volume, bass, treble and balance are provided as are comprehensive switching facilities enabling the unit to be used for either front or rear channels, by-passing the decoder for stereo-only use and exchanging left and right channels. The SQ matrix decoder is based upon a single integrated circuit and was designed by CBS whilst the power and tone control sections are identical to those used in our T30 + 30 amplifier which the SQM1-30 matches perfectly. Kit price includes CBS licence fee.

**Special offer to T20 + 20 and Texan owners!** Owners of T20 + 20 and Texan amplifiers, which have no tape monitor outlet, purchasing an SQM 1-30 will be supplied on request, a free conversion kit to fit a tape monitoring facility to the existing amplifier. This makes simple the connection to the highly adaptable SQM 1-30 quadrophonic decoder/rear channel amplifier.

**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 those intending to get the best out of their speakers, we also offer an active filter system, described by D. C. Read, which splits the output of each channel from the pre-amplifier into three channels each of which is fed to the appropriate speaker by its own power amplifier. The Read/Texas 20W, or any of our other kits are suitable for these. 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 list

| | |
|---|---|
| **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 |
| **Regulator Power Sypply** | |
| 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. 6A 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 | £2.80 |
| BBPA Pk. 2 Resistor, capacitor semiconductor set | £6.70 |
| BBPA Pk 3R Rotary Potentiometer set | £2.85 |
| BBPA Pk. 3S Slider Potentiometer set with knobs | £3.10 |
| **Active Filter** | |
| FILT Pk. 1 F/Glass PCB | £1.40 |
| FILT Pk. 2 Resistor, Capacitor set (metal oxide 2%, polystyrene 2½%) | £4.20 |
| FILT Pk 3 Semiconductor set | £2.25 |
| 2 off Pks 1, 2, 3 rqd for stereo sctive filter system | |
| **Read/Texas 20W Amp** | |
| READ Pk. 1 F/Glass PCB | £1.00 |
| READ Pk. 2 Resistor, Capacitor set | £1.20 |
| READ Pk. 3 Semiconductor set | £2.30 |
| 6 off pks 1, 2, 3 required for stereo active filter system | £2.30 |
| **Stuart Tape Recorder** | |
| TRRP Pk 1 Replay Amp F/Glass PCB | £1.30 |
| TRRC Pk 1 Record Amp F/Glass PCB | £1.70 |
| TROS Pk 1 Bias/Erase/Stalilizer F/Glass PCB | £1.20 |

Further details of above and additional packs given in our FREE LIST

## SQ QUADRAPHONIC DECODERS

Feed 2 channels (200-1000mV as obtainable from most pre-amplifiers or amplifier tape monitor outlets) into any one of our 3 decoders and take 4 channels out with no overall signal level reduction. On the logic enhanced decoders Volume, Front-Back, LF-RF balance, LB-RB balance and Dimension controls can all be implemented by simple single gang potentiometers

These state-of-the-art circuits used under licence from CBS are offered in kits of superior quality with close tolerance capacitors, metal oxide resistors and fibre-glass PCBs designed for edge connector insertion. All kit prices include CBS licence fee.

M1. Basic matrix decoder with fixed 10-40 blend. All components, PCB .......... £5.90

L1. Full logic controlled decoder with "wave matching" and "front back logic" for enhanced channel separation. All components PCB .......... £17.20

L2A. More advanced full logic decoder with "variable blend" for increased front back separation. All components, PCB .......... £22.60

L3A. Decoder similar to L2A but with discreet component front end with high precision 6-pole phase shift networks for increased frequency response. All components (carbon film resistors), PCB .......... £25.90

Also available with M.O. resistors, cermet pre-set — add .......... £4.20

## SEMICONDUCTORS as used in our range of quality audio equipment.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2N699 | £0.20 | 40361 | £0.40 | BD529 | £0.55 | MJE521 | £0.60 | TIP29C | £0.55 |
| 2N1613 | £0.20 | 40362 | £0.45 | BD530 | £0.55 | MPSA05 | £0.25 | TIP30C | £0.60 |
| 2N1711 | £0.25 | BC107 | £0.10 | BDY56 | £1.60 | MPSA12 | £0.35 | TIP41A | £0.70 |
| 2N2926G | £0.10 | BC108 | £0.10 | BF257 | £0.40 | MPSA14 | £0.30 | TIP42A | £0.80 |
| 2N3055 | £0.45 | BC109 | £0.10 | BF259 | £0.47 | MPSA55 | £0.25 | TIP41B | £0.75 |
| 2N3442 | £1.20 | BC109C | £0.12 | BFR39 | £0.30 | MPSA65 | £0.35 | TIP42B | £0.90 |
| 2N3711 | £0.09 | BC125 | £0.15 | BFR79 | £0.30 | MPSA66 | £0.40 | 1N914 | £0.07 |
| 2N3904 | £0.17 | BC126 | £0.15 | BFY51 | £0.20 | MPSU05 | £0.50 | 1N916 | £0.07 |
| 2N3906 | £0.20 | BC182 | £0.10 | BFY52 | £0.20 | MPSU55 | £0.50 | 1S920 | £0.10 |
| 2N4062 | £0.11 | BC212 | £0.12 | CA3046 | £0.70 | SBA750A | £1.90 | | |
| 2N4302 | £0.60 | BC182K | £0.10 | LP1186 | £6.50 | SL301 | £1.30 | | |
| 2N5087 | £0.25 | BC212K | £0.12 | MC1310 | £2.20 | SL3045 | £1.20 | FILTERS | |
| 2N5210 | £0.25 | BC182L | £0.10 | MC1351 | £1.05 | SN72741P | £0.40 | FM4 | £1.00 |
| 2N5457 | £0.45 | BC184L | £0.11 | MC1741CG | £0.65 | SN72748P | £0.40 | SFG10 7MA | £1.50 |
| 2N5459 | £0.45 | BC212L | £0.12 | MFC4010 | £0.95 | TIL209 | £0.20 | | |
| 2N5461 | £0.50 | BC214L | £0.14 | MJ481 | £1.20 | TIP29A | £0.40 | | |
| 2N5830 | £0.35 | BCY72 | £0.13 | MJ491 | £1.45 | TIP30A | £0.45 | | |

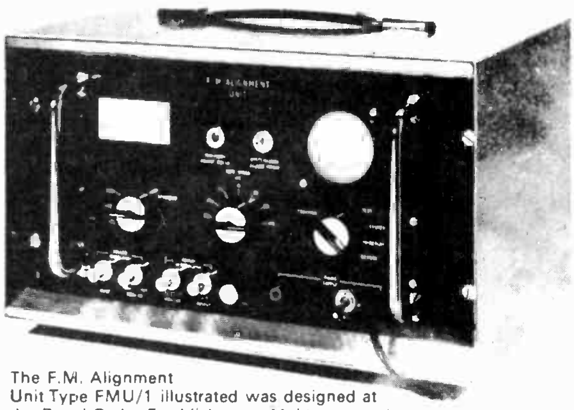
# EXPORT NO PROBLEM

Our Export Department will be pleased to advise on postal costs to any country in the world. Some of the countries to which we sent kits in 1975 are shown surrounding this advertisement.

Kenya France St. Martin, Java New Zealand Borneo South Africa Denmark Nigeria Anguilla Finland

# "Ampex and WHAT?..."

# The JAMES SCOTT Alignment Units for D.R. and F.M. Multi-Channel Tape Recorders.



The F.M. Alignment Unit Type FMU/1 illustrated was designed at the Royal Radar Establishment, Malvern, to suit Ampex Recorders working on the IRIG intermediate band specification (using ES 100 Electronics) e.g. Model Numbers FR 1200, FR 1260, FR 1300, FR 1800L, FB 400, PR 500

If you have a sophisticated Ampex Recorder—Align it to the Manufacturers specification using our Alignment Units for D.R. & F.M. Systems.

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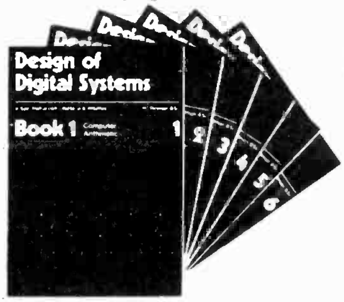
Design of Digital Systems.

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*or ....... combined set(s) at £10.50 each, p & p included

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WW8

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**A Re-BUILDABLE KEYBOARD. In addition to the conventional keyboard layout there are 21 separate push-button function switches. Circuits of the internal logic and core system are provided. £10 each.**
**As above but requiring push buttons etc. to be replaced. All parts provided for you to fit. £6 each.**

**MARCONI TF1094 SPECTRUM ANALYSER**
Late Model, 3MHZ to 30 MHZ. Resolution down to 6 HZ. Nice condition with copy of manual. Cost new in excess of £2,000. **Our Price £75.** Carr. £2.50. **SPECIAL OFFER TO FIRST TEN PURCHASERS** a FREE L.F. Adaptor extending the range down to 100HZ. Further purchases of the L.F. Adaptor enables us to continue our free offer.

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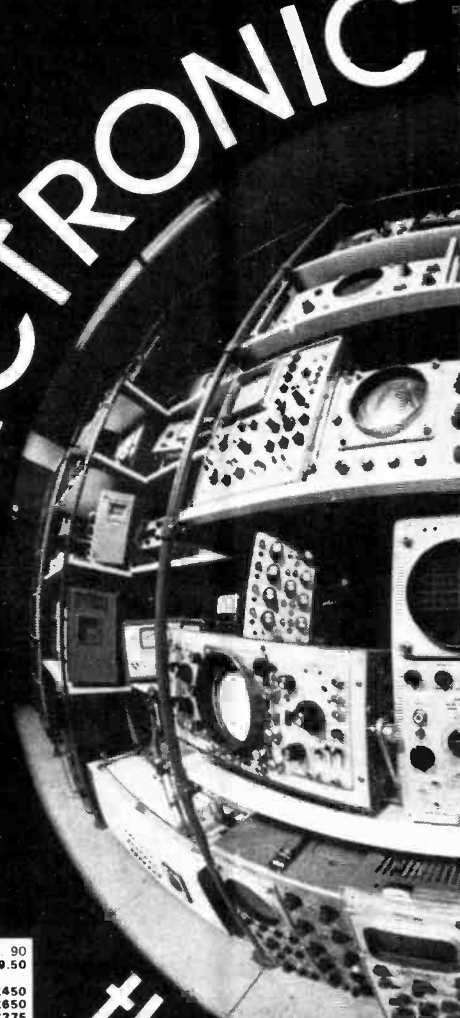

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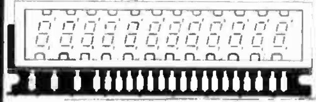

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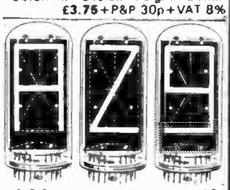

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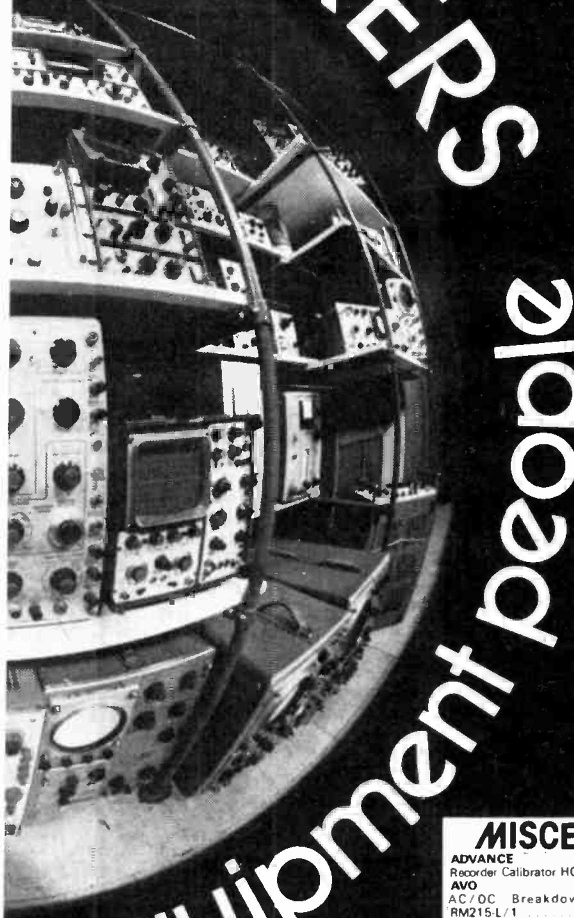

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**RHODE & SCHWARTZ**

Polyscop Swob II .......... £1250
Attenuator type DPR Z = 60 ohms BN 1E042 .......... P.O.A.
Frequency Indicator FKM-BN 47D51 .......... P.O.A.

**SIGN ELECTRONICS**

D.F.M. Type DN 344A .......... £115

**TELONIC**

Band Pass Filter TBA 140-60-5CC. 5 Section. TNC to INC connector. ¾" tubular. 60MHz bandwidth 140MHz centre freq. Brand new .......... £20
Sweep Generator SM 2000 c/w Plug Ins E 3M, S-6 & S4M .......... P.O.A.

**TEKTRONIX**

Sq. Wave Gen. 105. Risetime — 13m secs. Freq. range — 25Hz-1MHz continuously variable. Freq. Meter — Direct reading. O/P Amplitude 0-100V max .......... £30

**TEKTRONIX**

Constant Amplitude Generator 190A. 350KHz-500MHz. O/P 40mV 10V pk-pk .......... £30

**WAYNE KERR**

Current Ratio Transformer T102C .......... P.O.A.

## VOLTMETERS

**ADVANCE**

Differential Voltmeter M500 c/w AC/DC Converter M501 .......... P.O.A.
AC Millivoltmeter 77B .......... £30

**HEWLETT PACKARD**

DC Vacuum Tube Voltmeter 412A 1MV-1000V 1% Accuracy. Can also be used as Ohmeter & Ammeter .......... £75
VTVM. 400D 1mV to 300V FSD. 12 ranges 10Hz to 4MHz. 2% accuracy. Input Impedence 10Mohms £35
VTVM. 400L. Logarithmic version of 400D Reads RMS value of sine wave. Log. voltage scale 0.3 to 1 & 0.8 to 3, Linear dB scale. Input Impedance 10Mohms .......... £30
Vacuum Tube Voltmeter 410B. Freq. Range 20HZ-700MHz. AC1-600V (6 ranges). DC 1V-1KV ohmeter 0.2 ohms to 500Mohms (7 ranges). Accuracy ± 3% .......... £35
Vacuum Tube Voltmeter 400H. Freq. Range 10Hz-4MHz. Volts: 1.0mV-300V F.S. (12 ranges). Accuracy: ± 1% (50Hz-500KHz) ± 2% (20Hz-1MHz) .......... P.O.A.
AV Voltmeter 400E. Solid state. AC volts mV-300V FS (12 ranges). Freq. 10Hz-10MHz. Accuracy: 1% .......... P.O.A.
R.M.S. Voltmeter 3400A .......... £285
AC Voltmeter 400F .......... P.O.A.

**MARCONI**

Sensitive Valve Voltmeter TF.1100 100µV-300V AC Freq. coverage 10Hz-10MHz. Meter has dB scale facility .......... £25
Valve Voltmeter TF.1041B. General Spec. 0-300V Ac. 0-1KV DC Resistance up to 500Mohms .......... £60/£95
Voltmeter No. 3 CT.208 TF.958. AC 100mV-150V. multiplier extends AC range to 1.5KV. DC 50mV-100V. Freq. Range 20Hz-100MHz .......... £55
Valve Voltmeter TF2600. AC 25mV—300V (7 ranges). DC 10mV—1000V (8 ranges). Ohms 0.2 to 59M (7 ranges). 20Hz to 1500MHz. Brand new condition .......... £175

**PHILIPS**

L.F. Millivoltmeter GM.6012. 12 ranges-1mV-300V. dB scale on meter. Accuracy. 2Hz 5% 5Hz-100KHz 2.5% 100KHz-1MHz 0.5% Amplification available 50-70 .......... £65
H.F. Millivoltmeter GM 6014. Measuring Ranges 1mV-300mV in 6 ranges. Accuracy at 30KHz: 3% of FSD = Amplitude Char. 1KHz-30KHz flat within ± 5% .......... £55
DC Microvoltmeter GM6020. 10µV-1KV. Current 10pA-10µA. Accuracy 5% (FSD) 0-100µV. 3% (FSD) AU other ranges. Recorder o/p facility .......... £65

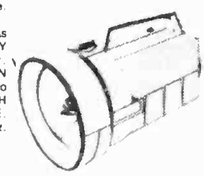
## NEW PRODUCTS DIVISION

**E.B. import and distribute high-grade products from World-renowned manufacturers including:**

### STROBOSCOPIC TACHOMETER

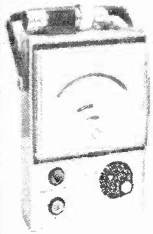
**Two units in one**

STROBOSCOPIC FLASH RATE — 200 to 6,000 flashes per minute. TACHOMETER SPEED RATE — As above. ACCURACY — 3% better. FLASH DURATION — Approx. 10 to 25 µ sec. HIGH IMPACT CASE. WEIGHT — 27 oz. 22 Volts.



**£49.50**

### "TOUCHLESS" RETRO-REFLECTIVE TACHOMETER



Reads RPM from as far as 24 in. away! Four ranges: 0-1,000, 3,000, 10,000, 30,000 RPM. Battery powered. Mirror Scale. Accuracy 1½% of full scale. Push-button reading.

**£89.50**

Carrying Case .......... £12.50 extra. Send for full literature.

### *The New* 'TAK-ETTE' Digital Hand-Held Tachometer

Batteries 4 HP7 cells. £99.50. P&P £1. Complete with leather carrying-case.

**RUSSIAN**

AC Clamp Volt-ammeter. U.91 Brand New .......... £13.75
Spec: Current 10-25-100-250-500 Amps. Voltage 300, 600V. Accuracy 4%. Used for measurements of AC Voltages and currents without breaking the circuits. Ranges are selected by means of a Rotary Selector Switch
Megohmmeter Type M4100/3 Brand New .......... £37
Nominal o/p Voltage (open cct.) 500V. High measurements Range (at 500V) 500MΩ (Mid Scale 5MΩ). Low measurements Range 1000KΩ. Portable (7lbs.) and Hand operated c/w carrying case.

***SEE INSIDE BACK COVER FOR DETAILS OF ICE SUPER RANGE OF MULTIMETERS!***

Shown on these pages are just a few samples of our huge stock. If the item you require is not shown please give us a ring


# BROKERS LTD

**Carriage and packing charge extra on all items unless otherwise stated**

**Please note: All instruments offered are secondhand and tested and guaranteed 12 months unless otherwise stated**

## TTLs by TEXAS

| | | | |
|---|---|---|---|
| 7400 | 16p | 7486 | 34p |
| 74H00 | 28p | 7489 | 270p |
| 74S00 | 39p | 7490 | 40p |
| 74LS00 | 25p | 7491 | 75p |
| 7401 | 17p | 7492 | 48p |
| 7402 | 17p | 7493 | 40p |
| 7403 | 18p | 7494 | 80p |
| 7404 | 21p | 7495 | 70p |
| 74H04 | 28p | 7496 | 84p |
| 7405 | 23p | 7497 | 270p |
| 7406 | 43p | 74100 | 120p |
| 7407 | 36p | 74104 | 55p |
| 7408 | 20p | 74105 | 55p |
| 7409 | 20p | 74107 | 32p |
| 7410 | 17p | 74110 | 45p |
| 74H10 | 28p | 74118 | 84p |
| 7411 | 24p | 74121 | 30p |
| 7412 | 25p | 74122 | 46p |
| 7413 | 36p | 74123 | 68p |
| 7414 | 75p | 74126 | 70p |
| 7416 | 33p | 74132 | 70p |
| 7417 | 36p | 74136 | 75p |
| 7420 | 17p | 74141 | 75p |
| 7421 | 40p | 74145 | 85p |
| 7422 | 22p | 74148 | 160p |
| 7423 | 37p | 74150 | 140p |
| 7425 | 30p | 74151 | 72p |
| 7427 | 37p | 74153 | 85p |
| 7428 | 36p | 74154 | 150p |
| 7430 | 17p | 74155 | 90p |
| 7432 | 27p | 74156 | 90p |
| 7437 | 28p | 74157 | 90p |
| 7438 | 30p | 74159 | 190p |
| 7440 | 17p | 74160 | 104p |
| 7441 | 75p | 74161 | 104p |
| 7442 | 70p | 74162 | 104p |
| 7443 | 140p | 74163 | 104p |
| 7444 | 140p | 74164 | 120p |
| 7445 | 90p | 74166 | 126p |
| 7446 | 95p | 74173 | 160p |
| 7447 | 75p | 74174 | 120p |
| 7448 | 80p | 74175 | 85p |
| 7450 | 17p | 74176 | 120p |
| 7451 | 18p | 74177 | 100p |
| 7453 | 18p | 74180 | 110p |
| 7454 | 18p | 74181 | 298p |
| 7460 | 18p | 74182 | 82p |
| 7470 | 30p | 74185 | 150p |
| 7472 | 28p | 74190 | 165p |
| 7473 | 30p | 74191 | 165p |
| 7474 | 34p | 74192 | 120p |
| 7475 | 45p | 74193 | 120p |
| 7476 | 32p | 74194 | 120p |
| 7480 | 50p | 74195 | 95p |
| 7481 | 95p | 74196 | 120p |
| 7482 | 80p | 74197 | 120p |
| 7483 | 90p | 74198 | 210p |
| 7484 | 95p | 74199 | 210p |
| 7485 | 120p | | |

## C-MOS I.Cs

| | |
|---|---|
| CD4000AE | 18p |
| CD4001AE | 18p |
| CD4002AE | 18p |
| CD4006AE | 104p |
| CD4007AE | 18p |
| CD4009AE | 67p |
| CD4011AE | 18p |
| CD4012AE | 18p |
| CD4013AE | 55p |
| CD4015AE | 90p |
| CD4016AE | 50p |
| CD4017AE | 120p |
| CD4018AE | 175p |
| CD4019AE | 52p |
| CD4020AE | 250p |
| CD4022AE | 170p |
| CD4023AE | 19p |
| CD4024AE | 120p |
| CD4025AE | 19p |
| CD4026AE | 196p |
| CD4027AE | 75p |
| CD4028AE | 140p |
| CD4029AE | 175p |
| CD4030AE | 55p |
| CD4042AE | 137p |
| CD4043AE | 202p |
| CD4046AE | 140p |
| CD4047AE | 154p |
| CD4049AE | 63p |
| CD4050AE | 52p |
| CD4054AE | 196p |
| CD4055AE | 196p |
| CD4056AE | 135p |
| CD4060AE | 229p |
| CD4069AE | 37p |
| CD4071AE | 27p |
| CD4072AE | 27p |
| CD4081AE | 19p |
| CD4082AE | 27p |
| CD4510AE | 130p |
| CD4511AE | 200p |
| CD4516AE | 112p |
| CD4518AE | 100p |
| CD4528AE | 120p |

## TEXAS 75 SERIES

| | |
|---|---|
| 75107 | 160p |
| 75450 | 120p |
| 75451 | 72p |
| 75452 | 72p |
| 75453 | 72p |
| 75454 | 72p |

## TEXAS DTLs

| | |
|---|---|
| 930 | 36p |
| 936 | 40p |
| 946 | 40p |
| 955 | 60p |
| 962 | 36p |
| 963 | 40p |

## MEMORIES

| | |
|---|---|
| 26028 1024 bit RAM | £2.50 |
| 2513(UC) Character Generator | £8.50 |
| 2513(LC) Character Generator | £8.50 |

## LOW PROFILE DIL SOCKETS BY TEXAS

8 pin 13p, 14 pin 14p, 16 pin 15p, 24 pin 50p, 40 pin 75p, 28 pin 60p

## VOLTAGE REGULATORS — FIXED — PLASTIC

| 1 Amp Positive | | | 1 Amp Negative | | |
|---|---|---|---|---|---|
| 5V | 7805 | 140p | 5V | 7905 | 200p |
| 12V | 7812 | 140p | 12V | 7912 | 200p |
| 15V | 7815 | 140p | 15V | 7915 | 200p |
| 18V | 7818 | 140p | 18V | 7918 | 200p |
| 24V | 7824 | 140p | 24V | 7924 | 200p |

LM309K 1 Amp 5V TO3 140p
LM323K 3 Amp 5V TO3 700p

**DUAL VOLTAGE REGULATOR**
1468 ±15V 100mA 16 pin DIL 300p. (Adjustable by resistors from ± 8V min. to ± 20V max.)

**VARIABLE VOLTAGE REGULATOR**
723 2V to 37V 150mA 14 pin DIL 45p
LM305H 4.5V to 30V 20mA TO5 120p
Basic Data Sheets on Vol. Regs. at 10p each + SAE

## OP. AMPS

| | | | |
|---|---|---|---|
| 1458 | Dual Op. Amp. Int. Comp | 8 pin DIL | 70p |
| 301A | Ext. Comp | 8 pin DIL | 36p |
| 3130 | COSMOS/Bi-Polar MosFet | 8 pin DIL | 100p |
| 3900 | Quad Op. Amp. | 14 pin DIL | 70p |
| 536T | FET Op. Amp. | TO-99 | 275p |
| 709 | Ext. Comp. | 8/14 pin DIL | 30p |
| 741 | Int. Comp | 8/14 pin DIL | 22p |
| 747 | Dual 741 | 14 pin DIL | 70p |
| 748 | Ext. Comp | 8/14 pin DIL | 36p |
| 776 | Programmable Op. Amp. | TO-5 | 140p |

## LINEAR I.C.s

| | | | |
|---|---|---|---|
| *CA3028A | Diff. Cascade Amp. | TO5 | 95p |
| *CA3046 | 5 Transistor Array | 14 pin DIL | 60p |
| *CA3048 | Quad. Low Noise Amp. | 16 pin DIL | 200p |
| *CA3053 | Diff. Cascade Amp. | TO5 | 52p |
| *CA3089E | FM IF System | 16 pin DIL | 200p |
| *CA3090AQ | FM Stereo Multi. Dec. | 16 pin DIL | 400p |
| ICL8068BC | VCO Fun. Gen | 14 pin DIL | 550p |
| ICL8038CC | VCO Fun. Gen. | 14 pin DIL | 340p |
| *LM380 | 2W Audio Amp | 14 pin DIL | 95p |
| *LM381 | Stereo Preamp | 14 pin DIL | 160p |
| *M2S2 | Rhythm Generator | 16 pin DIL | 800p |
| *MC1310P | FM Stereo Dec. | 14 pin DIL | 175p |
| *MC1351P | Lim/Det. Aud Preamp | 14 pin DIL | 97p |
| MC1495 | Multiplier | 14 pin DIL | 300p |
| *MC1496L | Bal. Mod/Demod. | 14 pin DIL | 100p |
| *MFC4000B | 1/4W Audio Amp | PCB | 70p |
| MFC6040 | Electronic Attenuator | PCB | 140p |
| *NE540L | Audio Pwr driver | TO99 | 140p |
| NE555 | Timer | 8 pin DIL | 40p |
| NE556 | Dual 555 | 14 pin DIL | 100p |
| NE561 | PLL with AM Demod. | 16 pin DIL | 375p |
| NE562 | PLL with VCO | 16 pin DIL | 375p |
| NE565 | PLL | 14 pin DIL | 200p |
| NE566 | PLL Fun. Gen. | 8 pin DIL | 150p |
| NE567 | PLL Tone Dec. | 8 pin DIL | 200p |
| 2567 | Dual 567 | 16 pin DIL | 370p |
| SN72710 | Diff. Comparator | 14 pin DIL | 50p |
| *SN72733 | Video Amp. | 14 pin DIL | 120p |
| *SN76003N | Pwr Aud Amp with int HS | | 245p |
| *SN76013N | Pwr Aud Amp with int HS | | 140p |
| *SN76023N | Pwr Aud Amp with int HS | | 140p |
| *SN76033N | Pwr Aud Amp with int HS | | 245p |
| *TAA621A | Aud Amp for TV | QIL | 225p |
| *TAA661B | FM IF Amp-Limiter/Det. | QIL | 120p |
| *TBA641B | Audio Amp. | QIL | 250p |
| *TBA800 | 5W Audio Amp. | QIL | 90p |
| *TBA810 | 7W Audio Amp | QIL | 100p |
| *TBA820 | 2W Audio Amp | QIL | 80p |
| *TDA2020 | 20W Audio Amp | QIL/DIL | 325p |
| XR2240 | Prog. Timer/Counter | 16 pin DIL | 370p |
| *ZN414 | TRF Radio Receiver | TO-18 | 110p |

Basic data sheets on above at 10p each + S.A.E.

## OPTO-ELECTRONICS

| Phototransistors | | L.D.Rs. | |
|---|---|---|---|
| OCP70 | 30p | ORP12 | 60p |
| OCP71 | 120p | ORP60 | 75p |
| 2N5777 | 40p | ORP61 | 75p |

## LEDS

| 0.2" | | | |
|---|---|---|---|
| TIL209 Red | 14p | Red | 16p |
| TIL211 Green | 30p | Green | 28p |
| TIL32 Infrared | 75p | Yellow | 30p |

## SEVEN SEGMENT DISPLAYS

| | | |
|---|---|---|
| 3015F | Minitron 0.3 in | 160p |
| DL704 | Com. Cathode 0.3 in | 140p |
| DL707 | Com. Anode 0.3 in | 140p |
| DL747 | Com. Anode 0.6 in | 225p |

## OPTO-ISOLATORS

Phototransistor: TIL 112 (IL 12) 6 pin DIL 140p
Photodarlington: ILCA-55 6 pin DIL 250p

## DRIVERS

75491 Quad. Segment Driver 14 pin DIL 78p
75492 Hex Digit Driver 14 pin DIL 90p

## SCR-THYRISTORS

| | | | |
|---|---|---|---|
| 1A 50V | TO5 | 40p | |
| 1A100V | TO5 | 42p | |
| 1A400V | TO5 | 45p | |
| 1A600V | TO5 | 70p | |
| 3A100V | Stud | 65p | |
| 3A400V | Stud | 75p | |
| 7A100V | TO5+HS | 84p | |
| 7A400V | TO5+HS | 90p | |
| 8A 50V | Plastic | 130p | |
| 12A400V | Plastic | 160p | |
| 16A100V | Plastic | 160p | |
| 16A400V | Plastic | 180p | |
| 16A600V | Plastic | 220p | |

| | | |
|---|---|---|
| BT106 1A/700V | Stud | 110p |
| C106D 4A/400V | Plastic | 63p |
| *MCR101 0.5A/15V | TO-92 | 25p |
| 2N3525 5A/400V | TO-66 | 99p |
| 2N4444 8A/600V | Plastic | 185p |
| *2N5060 0.8A/30V | TO-92 | 34p |
| *2N5062 0.8A/100V | TO-92 | 37p |
| *2N5064 0.8A/200V | TO-92 | 40p |

## TRANSISTORS

| | | | | | |
|---|---|---|---|---|---|
| AC125 | 18p | BFY50 | 16p | 2N3439 | 67p |
| AC126 | 16p | BFY51 | 15p | 2N3442 | 140p |
| AC127 | 16p | BFY52 | 16p | *2N3702 | 12p |
| AC128 | 14p | *BU105 | 140p | *2N3703 | 12p |
| AC141 | 18p | BU108 | 250p | *2N3704 | 12p |
| AC142 | 18p | *MJE340 | 45p | *2N3705 | 12p |
| AC176 | 18p | MJ2955 | 100p | *2N3706 | 12p |
| AC187 | 18p | MJE2955 | 99p | *2N3707 | 12p |
| AC187K | 25p | MJE3055 | 65p | *2N3708 | 12p |
| AC188 | 18p | *MPS6534 | 25p | *2N3709 | 12p |
| AC188K | 25p | *MPSA06 | 30p | 2N3773 | 250p |
| AD149 | 49p | *MPSA12 | 50p | 2N3866 | 90p |
| AD161 | 36p | *MPSA56 | 32p | *2N3903 | 18p |
| AD162 | 38p | *MPSU06 | 62p | *2N3904 | 16p |
| AF114 | 20p | *MPSU56 | 78p | *2N3905 | 20p |
| AF115 | 20p | OC28 | 90p | *2N3906 | 16p |
| AF116 | 20p | OC35 | 90p | *2N4058 | 15p |
| AF117 | 20p | OC36 | 90p | *2N4059 | 10p |
| AF127 | 25p | *OC71 | 20p | *2N4060 | 13p |
| AF139 | 43p | *TIP29A | 40p | *2N4123 | 22p |
| AF239 | 48p | *TIP29C | 55p | *2N4124 | 22p |
| BC107/B | 9p | TIP30A | 48p | *2N4125 | 22p |
| BC108/B | 9p | *TIP30C | 60p | *2N4126 | 22p |
| BC109 | 10p | TIP31A | 52p | *2N4289 | 20p |
| BC109C | 12p | TIP31C | 52p | 2N4347 | 130p |
| *BC117 | 22p | TIP32A | 58p | 2N4348 | 160p |
| *BC147 | 7p | TIP32C | 82p | *2N4401 | 27p |
| *BC148 | 7p | TIP33A | 90p | *2N4403 | 27p |
| *BC149C | 8p | TIP33C | 115p | *2N5089 | 27p |
| *BC157 | 11p | TIP34A | 115p | 2N5296 | 60p |
| *BC158 | 10p | TIP34C | 160p | *2N5401 | 50p |
| *BC159 | 11p | TIP35A | 225p | 2N6034 | 160p |
| *BC169C | 12p | TIP35C | 290p | 2N6107 | 70p |
| *BC172 | 11p | TIP36A | 270p | 2N6247 | 190p |
| BC177 | 18p | TIP36C | 340p | (Comp to 2N3055) | |
| BC178 | 17p | TIP41A | 65p | 40360 | 40p |
| BC179 | 18p | TIP41B | 70p | 40361 | 43p |
| *BC182 | 10p | TIP41C | 70p | 40362 | 45p |
| *BC183 | 10p | TIP42A | 70p | 40364 | 120p |
| *BC184 | 11p | TIP42B | 76p | 40409 | 65p |
| BC187 | 30p | TIP42C | 82p | 40410 | 65p |
| *BC212 | 11p | TIP2955 | 70p | 40411 | 225p |
| *BC213 | 10p | *TIS93 | 30p | 40594 | 81p |
| *BC214 | 14p | *ZTX108 | 10p | 40595 | 92p |
| BC478 | 30p | *ZTX300 | 13p | | |
| BCY70 | 18p | *ZTX500 | 15p | | |
| BCY71 | 22p | *ZTX502 | 18p | | |
| BD124 | 90p | 2N457A | 190p | | |
| BD131 | 36p | 2N697 | 22p | | |
| BD132 | 40p | 2N698 | 30p | | |
| *BD135 | 43p | 2N706 | 20p | | |
| *BD136 | 43p | 2N708 | 20p | | |
| *BD139 | 63p | 2N918 | 40p | | |
| *BD140 | 70p | 2N930 | 18p | | |
| BDY20 | 100p | 2N1131 | 18p | | |
| BDY56 | 160p | 2N1132 | 18p | | |
| BF115 | 22p | 2N1304 | 36p | | |
| BF167 | 23p | 2N1305 | 36p | | |
| BF170 | 23p | 2N1306 | 40p | | |
| BF173 | 25p | 2N1307 | 40p | | |
| BF177 | 26p | 2N1308 | 40p | | |
| BF178 | 28p | 2N1309 | 40p | | |
| BF179 | 33p | 2N1613 | 25p | | |
| BF180 | 33p | 2N1711 | 25p | | |
| BF184 | 22p | 2N1893 | 30p | | |
| *BF194 | 10p | 2N2219 | 20p | | |
| *BF195 | 9p | 2N2222 | 20p | | |
| *BF196 | 14p | 2N2369 | 14p | | |
| *BF197 | 15p | 2N2484 | 30p | | |
| BF200 | 32p | 2N2904/A | 25p | | |
| BF257 | 32p | 2N2905/A | 25p | | |
| BF258 | 36p | 2N2906/A | 24p | | |
| *BFR39 | 30p | *2N2926R | 7p | | |
| *BFR40 | 30p | *2N2926B | 7p | | |
| *BFR79 | 30p | *2N29260 | 9p | | |
| *BFR80 | 30p | *2N2926Y | 9p | | |
| *BFR88 | 30p | *2N2926G | 9p | | |
| BFX30 | 34p | 2N3053 | 18p | | |
| BFX84 | 30p | 2N3054 | 50p | | |
| BFX85 | 30p | 2N3055 | 50p | | |
| BFX86 | 30p | BRY39 | 40p | | |
| BFX87 | 30p | BSX19 | 20p | | |
| BFX88 | 30p | BSX20 | 20p | | |

**FETs**

| | |
|---|---|
| *BF244 | 25p |
| *MPF102 | 34p |
| *MPF103 | 34p |
| *MPF104 | 34p |
| *MPF105 | 34p |
| *2N3819 | 22p |
| *2N3820 | 63p |
| 2N3823 | 57p |
| *2N5457 | 34p |
| *2N5458 | 34p |
| *2N5459 | 34p |

**MOSFETs**

| | |
|---|---|
| 3N128 | 85p |
| 3N140 | 85p |
| 3N141 | 85p |
| 3N187 | 180p |
| 3N202 | 120p |
| 40603 | 58p |
| 40673 | 58p |

**UJTs**

| | |
|---|---|
| *TIS43 | 34p |
| 2N2160 | 95p |
| 2N2646 | 45p |
| *2N4871 | 34p |

**PUJT**
*2N6027 48p

## DIODES

**SIGNAL***

| | |
|---|---|
| OA47 | 7p |
| OA70 | 9p |
| OA81 | 15p |
| OA85 | 15p |
| OA90 | 7p |
| OA91 | 7p |
| OA95 | 7p |
| OA200 | 8p |
| OA202 | 10p |
| IN914 | 4p |
| IN916 | 9p |
| IN4148 | 4p |

**RECTIFIER**

| | |
|---|---|
| *BY100 | 25p |
| *BY126 | 12p |
| *BY127 | 10p |
| IN4001 | 5p |
| IN4002 | 5p |
| IN4004 | 6p |
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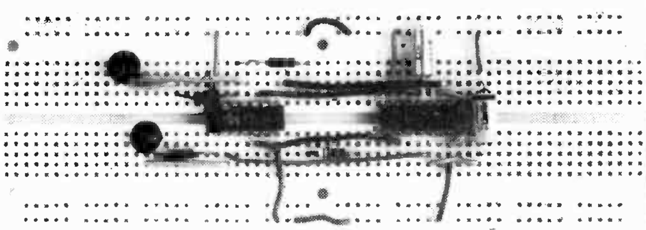

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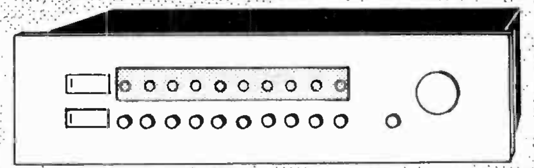

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**Canada H3A 2R2**

# TELEVISION ENGINEERS

Doric Radio is a fast growing member of the Rediffusion group of companies, selling monochrome and colour T.V. receivers to the retail trade through an increasing network of dealers. A small but effective team is being established to provide a technical service to our customers at home and overseas. This team provides service back up facilities by direct contact with our Doric dealers, helping to solve their problems and completing the link back to our factories where necessary.

Attitude, ability, thoroughness, tact and a willingness to get involved are essential requirements for these positions. This is a challenging opportunity for experienced engineers who wish to become important members of a small successful team working on the latest receivers employing advanced electronic techniques. Prospects for promotion are excellent. Formal qualifications, whilst desirable, are not essential where adequate practical experience on modern colour television receivers can be demonstrated.

Successful applicants will be based at our Chessington laboratories, with their excellent facilities and equipment, but occasional visits to our factories in the North of England and to our dealers' premises, both at home and abroad, may be necessary.

Salaries will depend on ability and experience, but will reflect the importance of these new posts. Assistance with relocation expenses will be given where appropriate.

Interested? then write to:-

H. Brearley,
Head of Technical Services,
Doric Radio Ltd.,
Fullers Way South,
Chessington,
Surrey. KT9 1HJ.

Telephone 01-397-5411

**DORIC RADIO** (6049)

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01-242 7773

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required in the Computer Centre for construction, testing and maintenance of electronic equipment, mainly in the area of data transmission. HNC or equivalent. Knowledge of digital devices an advantage. Salary sale £2,751-£3,207 p.a. Ref. 660/C/143.

Applications from: Assistant Secretary, Personnel Office, University of Birmingham, P.O. Box 363, Birmingham B15 2TT.

(6034)

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## Test And Support

To support our design teams we need engineers with qualifications from C & G to HNC, preferably with Test and Quality Assurance experience.

They will become involved in a range of work covering automatic test equipment, fault diagnosis and building special-to-type test equipment.

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Development across all our projects requires parallel expansion in our Technical Publications Group.

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**Apply in writing, quoting reference WW/1, with particulars of qualifications and experience to:**

**Staff Appointments Officer,**
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**Edinburgh EH5 2XS.**

FERRANTI

(95)

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With the increasing sophistication of today's aircraft, the role of the Service and Test Engineer on the ground is of the utmost importance if the electronic systems and equipment are to be kept at a high level of efficiency.

We are engaged in an expanding programme of work covering the provision of spares and the repair, maintenance and overhaul of airborne electronic equipment, and we need Engineers to service and test a variety of British and American equipment, both in the aircraft and in the workshop.

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Write with details of experience to Mrs. L. J. Elborn, Marconi-Elliott Avionic Systems Limited, 22-26 Dalston Gardens, Stanmore, Middlesex HA7 1BZ. Tel: 01-204 3322.

(6032)

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**CITY OF LONDON POLYTECHNIC**
**LIBRARY AND LEARNING RESOURCES SERVICE**

## TECHNICAL MANAGER (MEDIA SERVICES) TECHNICIAN GRADE 7

Applications are invited from qualified and experienced electronics engineers for the post of TECHNICAL MANAGER (Media Services) in the Library and Learning Resources Service.

This is a new post to meet the continuing development in the Polytechnic's Media Services.

The successful applicant will have had at least 10 years' experience as an electronics engineer (preferably in the education field) and will be familiar with all types of TV and audio visual equipment. Proven management ability is desirable as well as flair and imagination. A genuine desire to contribute to this developing area is essential.

Salary £3,666 - £4,122 per annum plus £465 p.a. London Allowance.

Application forms and further details from the Assistant Secretary, City of London Polytechnic, 119 Houndsditch, London EC3A 7BU.

(6053)

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## TECHNICAL OFFICER

An Electronics Engineer with B.Sc. or equivalent qualification is required to assist in the design and construction of an automated system for recording isopotential electrocardiographic surface maps. The project will be conducted jointly with the Engineering in Medicine Laboratory at Imperial College and the appointment is for three years and is available immediately. Salary according to qualifications and experience on scale up to £3,699 per annum.

**Applications to the Personnel Officer, RPMS, 150 Du Cane Road, London W12 0HS (01-743 2030, Ext. 93), quoting ref. no. 2/WW.** (6026)

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Application forms from:
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**Birmingham B15 2TT**

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**University of Reading**

## ELECTRONICS TECHNICIAN

required in the Department of Chemistry. Duties include the maintenance of a very wide range of electronic instruments and help with the design and construction of electronic devices. Salary in scale £2751-£3207 p.a. (Grade 5). Apply in writing, quoting Ref. TZZ.28B, with full details and names of two referees, to Assistant Bursar (Personnel), University of Reading, Whiteknights, Reading RG6 2AH.

(6052)

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# INTERNATIONAL FIELD SERVICE ENGINEER

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(5592)

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**UNIVERSITY OF EDINBURGH**

## ELECTRONICS TECHNICIAN

Required for the DEPT. OF RESTORATIVE DENTISTRY. The work is mainly concerned with medical electronics and electromyography. The successful candidate will be concerned with maintenance and modification of a wide range of medical electronic and allied equipment, and with research and development in electronics as related to dentistry. The post offers challenging and rewarding work in a new and expanding field. Applicants should hold HNC or equivalent in appropriate subjects. Salary will be on scale £2751-£3207 p.a. Assistance with relocation expenses is available if necessary. Applications, quoting post reference No. A188, and giving full details of age and qualifications, together with the names and addresses of two referees, should be submitted by 23rd August, 1976, to the Personnel Office, University of Edinburgh, 63 South Bridge, Edinburgh EH1 1LS. Telephone 031-667 1011, ext. 4510-3. (6021)

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**Radio Society of Gt. Britain**

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The candidate should ideally possess the following qualifications:

At least five years' executive experience.
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Hold an amateur radio transmitting licence

Salary will be commensurate with qualifications.

Applications should be made before 30 September 1976 to Mr C. H. Parsons, 90 Maesycoed Road, Heath, Cardiff, Glamorgan. (6062)

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**BURY AREA HEALTH AUTHORITY.** We need an ASSISTANT IN THE INSTRUMENT SURVEILLANCE DEPARTMENT at Bury General Hospital. Salary scale £1,635-£2,226 p.a. Junior Medical Physics Technician or £2,346-£3,267 p.a. Medical Physics Technician IV — according to qualifications and experience +£312 non-enhanceable supplement on each scale. For further information please contact Mr Brian Taylor at Bury General Hospital. 'phone 061 764 0511. Applications in writing giving full details of age, qualifications and previous employment together with the names and addresses of two referees to the Area Personnel Officer. Bury Area Health Authority, 22a Union Arcade, Bury, Lancashire, BL9 0QF. Closing date for receipt for applications 22 July, 1976.

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## APPOINTMENTS

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Electronic Technician required to organise maintenance service of equipment in the Physics Department Intensive Care Unit and Operating Theatre.

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Further details from the Principal Physicist (01-807 3071 Extn. 581).

Applications to the Sector Administrator, North Middlesex Hospital, Sterling Way, Edmonton, London N18 1QX. Closing date 2nd August, 1976.

(6078)

**MEDICAL PHYSICS TECHNICIAN GRADE II** for Guy's Hospital Department of Clinical Physics & Bioengineering. He/She will be a member of a team of Physicists and Technicians engaged in a variety of clinical instrumentation projects. ONC/HNC or higher qualification required, plus 2 years electronics experience in NHS Technicians Grade III. Salary scale £3,558-£4,581 plus £312 London Weighting plus £6 per week. Apply to Personnel Department, Guy's Hospital, St. Thomas Street, London SE1 9RT. Tel. 01-407 7600. Ext 3462. (5578

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(6072

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**Royal Holloway College**
**(University of London)**
**Egham Hill, Egham, Surrey**

# EXPERIENCED ELECTRONICS TECHNICIAN (GRADE 5)

required in the Physics Department for three years, preferably with experience in digital and computer electronics. Salary on the scale £2,751 - £3,207 plus £275 London Allowance.

Applications together with the names and addresses of two referees should be sent to the Personnel Officer (WW) as soon as possible.

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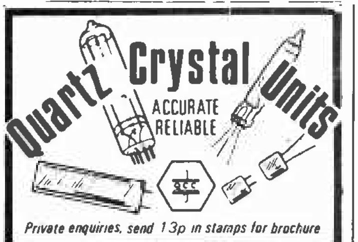


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