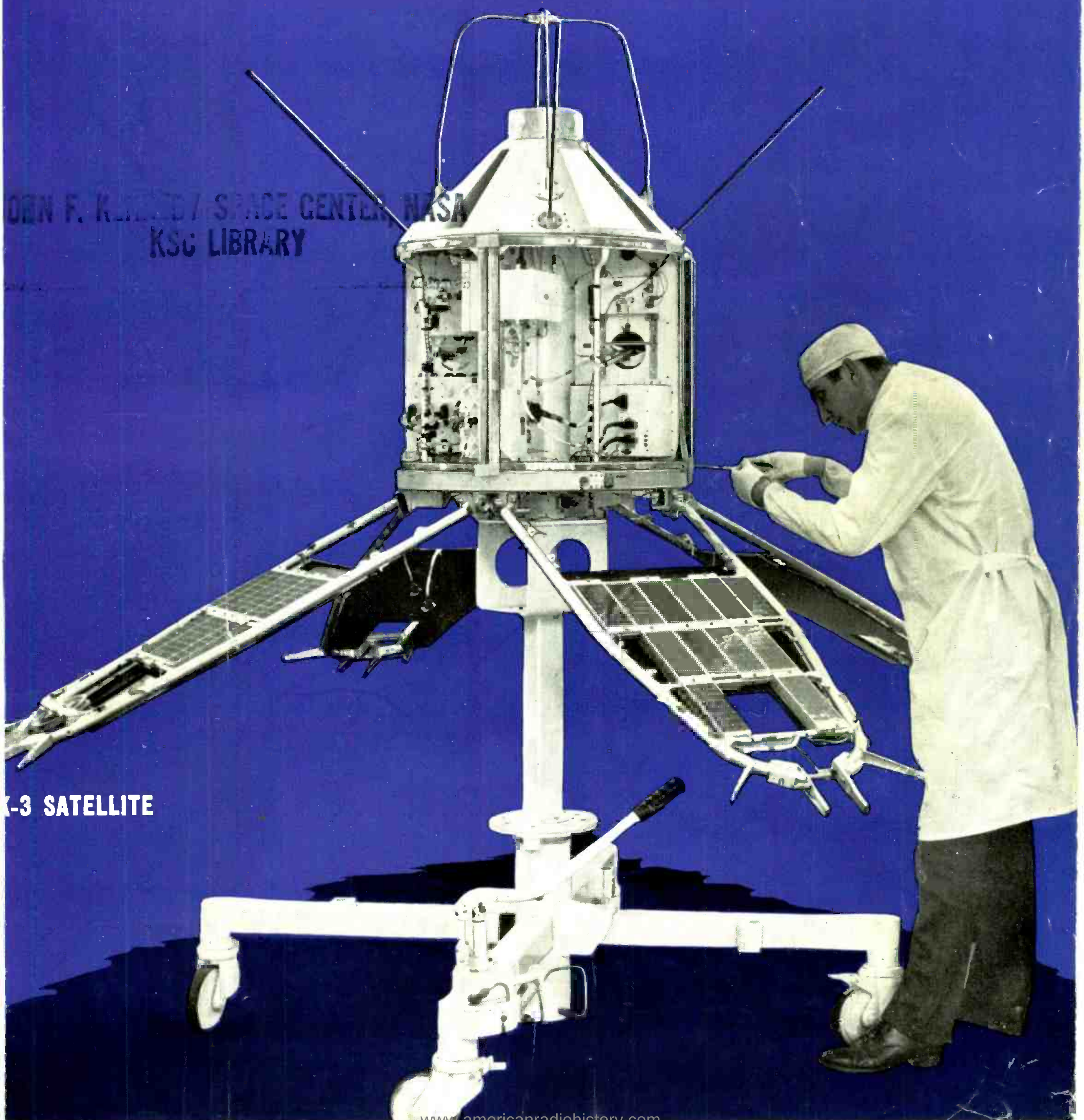
EXPLAINING COLOUR TV RECEIVERS

FEBRUARY 1967
Three Shillings

Wireless World

ELECTRONICS • TELEVISION • RADIO • AUDIO



-3 SATELLITE

RELAYS ex stock in 7 days

***C.S.A. APPROVED IN CANADA**

*MK

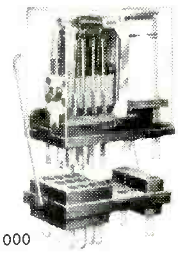
★ 3 pole 7.5 amp
★ 5 million ops. min.
★ **12/4** each per 1000
Single pole **9/7** per 1000

★ 2 pole 5 amp
★ 5 million ops. min.
★ **14/8** each per 1000

MM Contactor

★ 2 pole 15 amps
★ 5 million operations minimum
★ **17/8** each per 1000

*MHP Plug-in relay

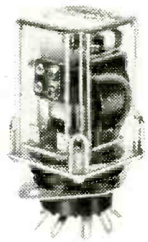


★ 4 pole, 1 amp
★ 100 million operations
13/- each per 1000
SOLDER TERMS
2 pole **8/-** per 1000

1051

★ Snap action microswitch relay
★ 7.5 amp. 1 million operations
Also available in plug-in version
★ **7/5** each per 1000

*MKP Plug-in relay



*MK103

★ Single pole 3 amp
★ 1 million operations minimum
★ **5/11** each per 1000

MK403P *NEW* Plug-in relay

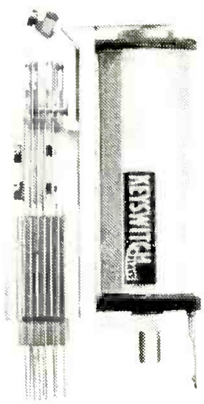
★ 4 pole 3 amp
★ 5 million operations minimum
★ **29/-** each per 1000
SOLDER TERMS
★ **21/9** each per 1000

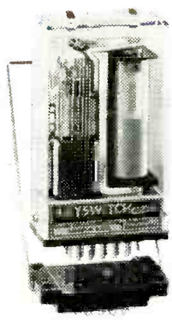
RELAYS made to measure

APPROVALS: C.E.G.B. No. 131 & 92 · B.R. POST OFFICE KRL · U.K.A.E.A.

P.O. 3000 RELAY

★ Manufactured to full G.P.O. specification, also to Industrial Standards
★ Contacts up to 30 amp





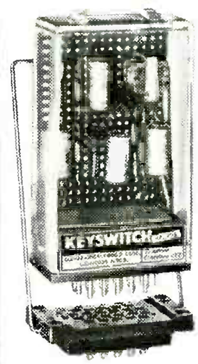
P33 PLUG-IN RELAY

★ Plug-in version to BPO 3000 relay, made to measure for Industrial Applications
★ Contact ratings up to 10A/750V
★ Positive-lock retaining clip
★ 30 million operations minimum

P.O. 600 RELAY

★ Compact version of BPO 3000 relay
★ Contacts up to 10A
★ Sensitivities down to 30mW
★ Up to 18 contact springs

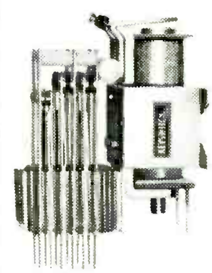
COMPONENT BOARD P304



★ Plug-in component board unit for low cost, easy chassis fabrication
★ **15/-** each per 500
FROM STOCK

CONTACTOR K700 RELAY

★ High-current/high-voltage 3000-type relay
★ Contact up to 30A240V a.c.
★ Sensitivities down to 45mW
★ PTFE armature bar/lifting rods



KEYSWITCH RELAYS

KEYSWITCH RELAYS LIMITED
120/132 Cricklewood Lane · London · NW2 · Tel: Gladstone 3344
Telex: 262754 STD 01-452-3344

WW—001 FOR FURTHER DETAILS.

Iliffe Electrical Publications Ltd.,
Chairman: W. E. Miller, M.A., M.I.E.R.E.
Managing Director: Kenneth Tett
Dorset House, Stamford Street, London, S.E.1

VOLUME 73 No. 2
PRICE: 3s.

FIFTY-SIXTH YEAR
OF PUBLICATION

Wireless World

ELECTRONICS, TELEVISION, RADIO, AUDIO

FEBRUARY 1967

SHORT ITEMS

REGULAR FEATURES

PUBLISHED MONTHLY (3rd Monday of preceding month). *Telephone:* Waterloo 3333 (70 lines). *Telegrams/Telex:* Wiworld Iliffepres 25137 London. *Cables:* "Ethaworld, London, S.E.1." *Annual Subscriptions: Home:* £2 6s 0d. *Overseas:* £2 15s 0d. *Canada and U.S.A:* $8.00. Second-class mail privileges authorised at New York N.Y. BRANCH OFFICES: *BIRMINGHAM:* 401, Lynton House, Walsall Road, 22b. *Telephone:* Birchfields 4838. *BRISTOL:* 11, Marsh Street, 1. *Telephone:* Bristol 21491/2. *COVENTRY:* 8-10, Corporation Street. *Telephone:* Coventry 25210. *GLASGOW:* 123, Hope Street, C.2. *Telephone:* Central 1265-6. *MANCHESTER:* 260, Deansgate, 3. *Telephone:* Blackfriars 4412. NEW YORK OFFICE U.S.A.: 300 East 42nd Street, New York 10017. *Telephone:* 867-3900.

Wireless World

ELECTRONICS, TELEVISION, RADIO, AUDIO

The Compleat Engineer

SINCE the formation of the Council of Engineering Institutions in 1964, and more especially since the granting of its Royal Charter the following year, there has been growing concern, particularly in the electronics and electrical sections of technology, about the image of the "complete engineer being all things to all men" which the Council is seeking to project. This concern has been heightened by the introduction of a common examination for membership of all 13 constituent institutions; and the Council has now set itself up as an examining body.

Commenting on this in his presidential address to the Institution of Electronic and Radio Engineers, Professor Emrys Williams said this function was "neither specified nor precluded in its Royal Charter. In retrospect, it may seem surprising that this extension of powers from certification to examination was not clearly defined before the granting of the Royal Charter.... The present position is that our Institution (in common with all the others) is now expected by C.E.I. to discontinue its own graduateship examination in favour of a C.E.I. examination syllabus which bears a strong resemblance to the syllabuses of thirty years ago—those same examination syllabuses whose inadequacy for the purposes of the radio and electronic engineer led to the formation of our institution."

One of the consequences of this doctrine of the complete engineer considered by Dr. Williams was its effect on recruitment to the profession. The motivation of the schoolboy is inspirational and specialized. As Dr. Williams pointed out "electronics is the greatest intellectual 'nosey-parker' of all time; it has a finger in everybody elses business and is handmaid of all sciences" and although it has no one specific end product or public amenity (as do some of the other disciplines) the ingenuity and versatility of electronic devices have unfailing power to fire the imagination of the schoolboy.

The resulting image of the engineering profession may be immature, but to daub this with wordly wisdom "as is done by some industrialists who visit schools and give the impression that marketing, management and costing are the most important ingredients of engineering practice" and then have a "permanent recruiting poster showing the complete engineer, clad in pre-war clothing and vainly trying to be all things to all men" will make even more of the best sixth-formers opt for higher studies in pure science and arts rather than technology.

The idea of stimulating young people's enthusiasm for a particular kind of technology rather than trying to impress them with the concept of engineering in general has also been stressed by the Schools Council (an independent body). It launched last autumn a pilot project to explore how children can be given through design project work a keener awareness of technology as it exists in the real world.

It has been pointed out by G. L. Viles (who is a member of the Council's project team) that one factor contributing to the enthusiasm for electronics is that children quickly discover that they can buy components like photocells and transistors for only a shilling or two, and in fact often do so, for school projects, with their own pocket money.

No one will deny that there is a growing need for stimulating this enthusiasm and it is to be hoped that the institutions for both professional engineers and technicians will foster it, rather than stifle it as may well happen if the particular electronic "marvel" which inspired the student is lost in a mass of worthy but deadening (and often irrelevant) engineering studies.

VOL 73 NO 2
FEBRUARY 1967

Principles and Practice of Holography

By A. DICKINSON, B.Sc. and M. S. DYE

THREE-DIMENSIONAL LENSLESS WAVEFRONT RECONSTRUCTION WITH VARIED APPLICATION

IN 1948 Professor Gabor of Imperial College described a system of image production[1] called holography, which he hoped to use for microscopy. In this, using no lenses, both the phase and the amplitude of light from an object were recorded on a photographic emulsion. This was done by placing the partially transparent object in front of a monochromatic point source of light, i.e. coherent light. The light diffracted by the object interfered with the transmitted light and the interference pattern was recorded on a photographic plate. When this plate, a hologram, was developed and viewed with coherent light an image of the original object appeared.

Progress in holography has been accelerated greatly in the last two years by the use of lasers. These give a much more powerful source of coherent light, which is needed for this process, than was previously available. This increased power allowed Lieth and Upatnieks[2] to illuminate the plate with a reference beam of light at an angle to the light from the object and not directly behind it as was done by Gabor (Fig. 1). Using a reference beam at an angle to the light from the object has enabled the spurious images, which previously degraded the reconstructions, to be removed and has also allowed holograms to be made of much larger and opaque objects. The good time coherence of lasers has also made it possible to record three-dimensional objects. Because both the amplitude and phase of the light are recorded on a hologram three-dimensional objects are reproduced in three dimensions.

When the hologram is viewed with normal incoherent daylight it bears no apparent relationship to the object which formed it. It seems to be a meaningless mass of whirls and lines (Fig. 2). However when it is illuminated with laser light, on looking through the hologram like a window, an image of the original object is reconstructed in space behind the hologram.

A. Dickinson *joined the Marconi Company in 1964 after graduating at Manchester University. He was working on gas lasers and their applications until a few months ago when he went to the British Aircraft Corporation, at Bristol, where he is now concerned with work on pattern recognition and holography.*

M. S. Dye, *who is 24, spent five years as a scientific assistant and two years as an experimental officer at the Ramsden Laboratory of Ilford Ltd., before joining the Marconi Company in September 1965. He is now in the Applied Physics Group at the Marconi Research and Development Laboratories at Great Baddow, Essex.*

PRINCIPLES OF HOLOGRAPHY

A hologram consists of a very complicated pattern caused by interference between light reflected from the object and the light of the reference beam. Every point of a reflecting object acts as a point source of light radiating spherical wavefronts. At the photographic plate the phase distribution from each point will be a series of concentric circles centred on the normal from the point source to the plate. If, as in the early Gabor system, the reference beam illuminates the plate from directly behind the object, interference between the spherical waves of the object and the plane reference wave will produce concentric fringes on the plate. These fringes are very similar to a Fresnel zone plate and when they are illuminated with coherent light they will focus the light to a real and a virtual image, both on the axis of the system and at the same distance from the hologram as the original object (Fig. 3a). This means that the real image can only be viewed in the presence of an out-of-focus virtual image. If however, the reference beam is not in line with the object point the zone plate produced is asymmetrical and the images produced from this are offset from the axis (Fig. 3b) and can therefore be viewed separately. Each point of an object forms its own zone plate and is reconstructed at its original distance from the hologram. Therefore a three-dimensional object gives a three-dimensional image.

The phase distribution on the photographic plate given by a point source will depend on the distance, x, from P where OP is the normal from the object to the plate (Fig. 4). The phase lag at a point X compared with P is:—

$$= \frac{2\pi}{\lambda} \, . \, SX$$

$$= \frac{2\pi}{\lambda} \, . \, [(x^2 + f^2)^{\frac{1}{2}} - f]$$

where λ is the wavelength of the light used and f is the distance of the object from the plate. For small x this becomes $\pi x^2/f\lambda$. The light magnitude is a function of x, $A(x)$ and therefore the light amplitude can be written as

$A(x)\exp(j\pi x^2/f\lambda)$. The direct or reference beam is usually a parallel beam which gives a plane wavefront at an angle θ to the plate. Its amplitude is $A_o \exp(-j2\pi\theta x/\lambda)$ for small θ. The total amplitude of light on the plate is therefore:—

$$A(x)e^{j\pi x^2/f\lambda} + A_o e^{-j2\pi\theta x/\lambda}$$

The plate responds only to light intensity:

$$I(x) = |A(x)e^{j\pi x^2/f\lambda} + A_o e^{-j2\pi\theta x/\lambda}|^2$$

$$= A_o^2 + A(x)^2 + 2\,A(x)\,A_o \cos\left(\frac{2\pi\theta x}{\lambda} + \frac{\pi x^2}{f\lambda}\right) \quad (1)$$

Provided the linear portion of the density log of the reciprocal of transmission *versus* log exposure curve of the photographic emulsion is used the transmission is related to intensity by:—

$$T(x) \propto I(x)^{\gamma/2}$$

where γ is the slope of the density-log (exposure) curve. If the plate is processed to a γ of 2 the transmission is directly proportional to the intensity of the exposing light.

$$T(x) \propto I(x)$$

$$\propto A_o^2 + A(x)^2 + A(x)\,A_o e^{j(2\pi\theta x/\lambda + \pi x^2/f\lambda)}$$

$$+ A(x)\,A_o e^{-(j2\pi\theta x/\lambda + \pi x^2/f\lambda)}$$

$$= k\,(A_o^2 + A(x)^2 + A(x)e^{j\pi x^2/f\lambda}\,.$$

$$A_o e^{j2\pi\theta x/\lambda} + A(x)e^{-j\pi x^2/f\lambda}\,.\,A_o e^{-j2\pi\theta x/\lambda}$$

The first two terms of this expression are not important as they do not contain information of both the phase and amplitude of the light from the original source but only attenuate the transmitted light. The third term, however, is identical to the light from the source, $A(x)\exp j\pi x^2/f\lambda$, multiplied by a constant term A_o, and diffracted through an angle θ by the phase term $\exp j2\pi\theta x/\lambda$. This means that looking back through the developed photographic plate, called a hologram, at an angle θ, the light appears to come from the original point source.

The image is the same distance from the hologram as the original point source so that when a three-dimensional object is used each point of it is reformed at its original distance from the hologram, i.e. the object is reconstructed in three dimensions. Looking into the hologram a three-dimensional virtual image is visible, showing the properties of the original object such as parallax between near and far parts.

Similarly the fourth term produces a real image between the hologram and the viewer at an angle $-\theta$ to the illuminating light. Because each point of a three-dimensional object is reconstructed at its original distance from the hologram the complete image is inverted and appears to the viewer as though he is looking from inside the object. To overcome this and give a true real image a secondary hologram can be made of the inverted real image of the first hologram. The real image of this second hologram, produced when it is illuminated with laser light, is a true reconstruction.

If the γ used is not exactly 2, extra images are formed. They do not interfere with the main images as they appear at greater diffraction angles.

This theory has been derived using only the x-axis of the photographic plate. Of course, it applies equally well along the other axis of the plate.

Because light from each part of the object covers the whole area of the photographic plate any part of the plate contains information from all of the object. If the

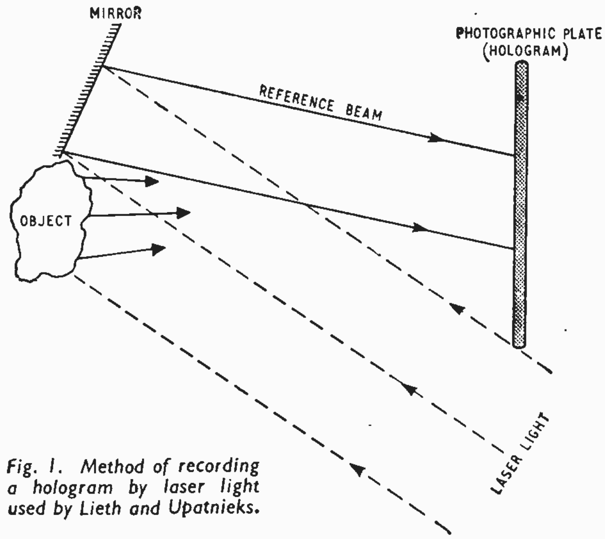


Fig. 1. Method of recording a hologram by laser light used by Lieth and Upatnieks.

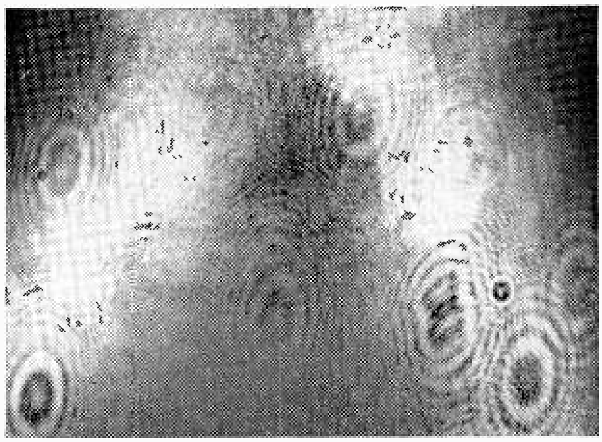


Fig. 2. Appearance of a hologram viewed in daylight and recorded in a set-up similar to Fig. 1.

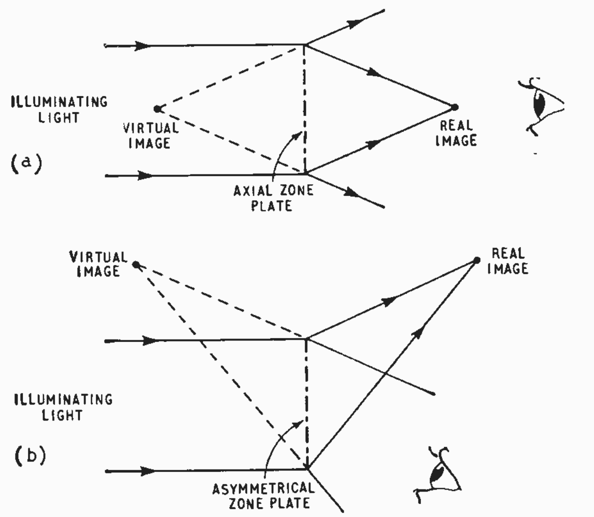


Fig. 3. Offset image at (b) enables separate viewing of real and virtual images.

plate is broken any small piece of it will reconstruct the object completely with only a loss in detail.

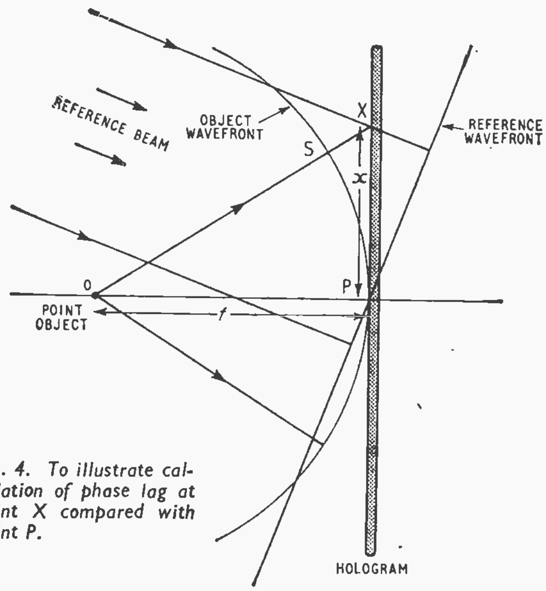


Fig. 4. To illustrate calculation of phase lag at point X compared with point P.

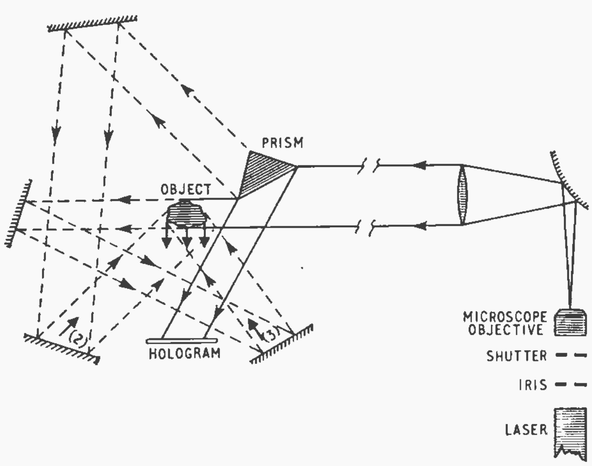


Fig. 5. Apparatus used for producing 3-D Bragg reflection holograms.

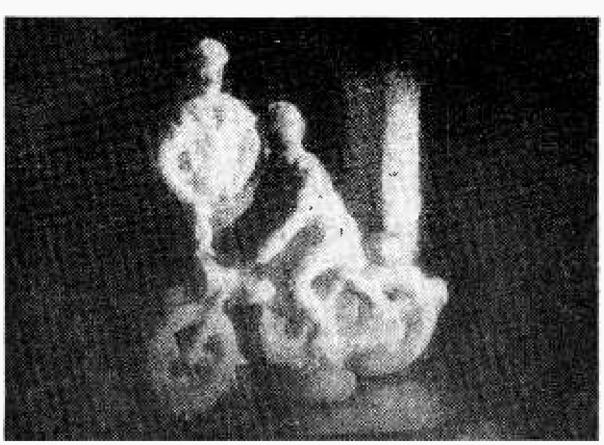


Fig. 6. An image reconstruction from a hologram. The granular appearance is due to the effect of laser illumination.

EFFECTS OF THICK EMULSIONS

If the angle between the light from the object and the light in the reference beam is made large, the fringe width becomes less than the thickness of the emulsion. The 15μ-thick Kodak 649-F emulsion usually used then acts as a three-dimensional medium and the interfering beams set up reflecting planes within the material.

Reconstruction takes place when light from these planes is reflected so that constructive interference occurs. This is exactly the same as Bragg reflection from crystal planes and obeys the same law:—

$$2d \sin \theta = \lambda$$

where d is the spacing between the planes, θ is the angle of incidence of the light and λ is the wavelength of the light. This means that unless the hologram is illuminated at the same angle for reconstruction as the reference beam was on recording, no image is reconstructed, if the same wavelength light is used throughout. If light of another wavelength is used for reconstruction the angle of incidence must be changed to obey Bragg's law.

If light of two different colours is used at the same angle of incidence, the plane spacing will be different. This fact has been used to produce two-colour holograms[3]. The object to be photographed was illuminated with light from two different coloured lasers (red 6328 Å He-Ne and blue 4880 Å argon laser) and the reference beam also consisted of light from both lasers. Each colour set up its own reflecting planes within the emulsion. When the hologram was illuminated at the Bragg angle by both colours, a two-coloured reconstruction occurred. If only one colour was used to illuminate the hologram only those parts of the object which had reflected this colour were reconstructed. There was no " cross-talk " between the colours because the spectral bandwidth of the Bragg reflection is only about 100 Å.

Daylight reconstruction. A very recent advance using interference within the emulsion has enabled holograms to be reconstructed with daylight[4]. Because the Bragg reflection is colour selective, if multicoloured light is incident on the hologram the only colour reflected will be the colour used to produce the hologram. The method used was to cause interference in the thickness of the emulsion, between laser light reflected from the object and the reference beam which now was directed through the photographic plate from the back. When the hologram was illuminated with sunlight from the same direction as the reference beam had been directed the original laser colour was selected by Bragg reflection and the object reconstructed as usual.

This method could equally well be applied to several colours of lasers and therefore multicoloured three-dimensional pictures, visible in daylight, are possible.

PRODUCING 3-D BRAGG REFLECTION HOLOGRAMS

Using the apparatus shown in Fig. 5, the coherent beam from a 6328 Å c.w. laser working in single mode was passed through an iris and a photographic shutter. The iris was used to stop stray incoherent light emerging from the end of the laser and to give a clearly defined beam, free from edge effects. The shutter was placed near the laser so that all other optical equipment was not touched during the exposure, thus avoiding vibration. The beam was then directed through an 8 mm focal length microscope objective and the diverging beam produced, was allowed to fall onto a front-silvered convex mirror of radius 10 cm. The beam, having been further diverged by the convex mirror, was about 6 cm in diameter at the point of entering the 20 cm focal length collimating lens.

The parallel beam emerging was split into two, half the light striking a 90° prism and the other half illuminating the subject of the hologram. The light from the prism, the reference beam, was reflected directly on to the photographic plate and its intensity was approximately 10% of that in the parallel beam. The glass prism was used to direct the reference beam so that the reduced intensity produced was more comparable with the weak scattered light from the object. This gave better fringe contrast at the photographic plate. If an ordinary glass plate had been used instead of the prism, it would have introduced undesirable interference bands across the reference beam dependent on the relevant spacing of the front and back surfaces of the plate. It was found by experiment that the angle between the reference beam and the photographic plate should be about 45° for best results. It was also important to keep the object as near as possible to the edge of the reference beam, so that maximum information was recorded about the points on the object farthest from the reference beam.

The system described so far has produced a hologram, but a disadvantage was that the object was illuminated from one direction only. The system in Fig. 5 shows how this problem was overcome. The otherwise wasted light emerging from the prism, was directed by means of a front-silvered plane mirror to illuminate the object from direction (2). Similarly, light not hitting the object in the incident beam was redirected to fall on to the object from another direction (3).

The photographic plates employed were Kodak 649F Spectroscopic, having a resolving power quoted as 2,000 lines/mm and further claimed to have been used at 10,000 lines/mm. This very good resolving power was attained at the expense of speed. The speed found by experience was about 1/10,000 of Tri-X. Exposure times were consequently long and were of the order of minutes with a 1 mW laser. The exposed hologram plates were developed in total darkness in caustic hydroquinone, diluted in the ratio of two parts developer to one part water, for two minutes. The resulting hologram was arranged by varying the exposure to be of medium density, since a dense hologram merely acted as a heavy neutral density filter in front of the reconstructed image. The long exposure times introduced problems of stability in the apparatus, since both mechanical and thermal vibration could occur and any movement destroyed the fringes.

RECONSTRUCTION FROM THE HOLOGRAM

The developed hologram was replaced at the same position as it was formed and the prism was replaced by a front-silvered plane mirror, placed at the same position and angle as the prism. This gave a reference beam of maximum brightness and area falling on the plate. Looking into the hologram at the first diffraction order the reconstructed object was visible. This reconstruction is shown in the photograph, Fig. 6. Its three-dimensional properties were shown by focusing at different planes in the image, using a short depth of focus camera. The resulting photographs are shown in Fig. 7.

The brightness of the reconstruction was increased by using multi-mode working of the laser. It was possible to use multi-mode since coherence length was no longer important. Because of this, mercury light could also be used to view holograms. Still further brightness could be obtained by partially bleaching the hologram, using the bleach from the Kodak intensifier process. However, brightness was increased at the expense of definition, until when the hologram was completely bleached serious degradation of the image occurred.

RECORDING MULTIPLE HOLOGRAMS ON ONE PLATE

This was carried out in two ways. The first method, a rather trivial one, was to obtain two views of the same object visible at the same time. This was done by taking a hologram of the subject in the normal way, with the reference beam angle at 45°, but with half the usual exposure. Then, leaving everything else the same, the subject was moved to a different position and another hologram exposure taken, again with half the normal exposure time. For the purpose of the experiment the object was rotated through 180° so that the holograms were of the front and the back of the same object. Reconstruction was as before and showed the two clearly defined, separate images, visible at the same time.

The second method was very similar but much more important. For this a normal hologram was taken of a subject but with the reference beam angle altered to 30°.

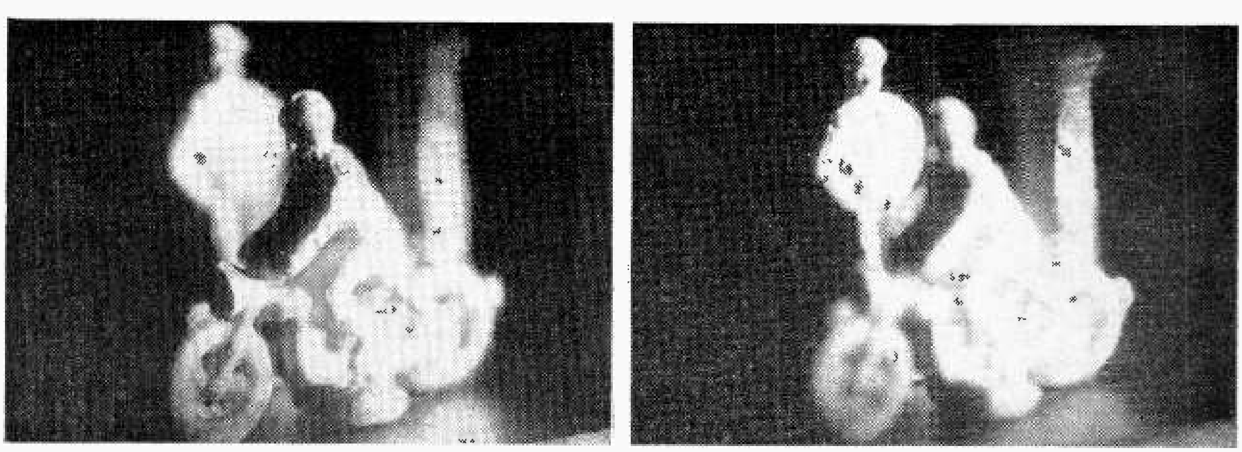


Fig. 7. Same reconstruction as Fig. 6 but showing 3-D nature of image by focusing in front and rear planes with a camera having a small depth of focus.

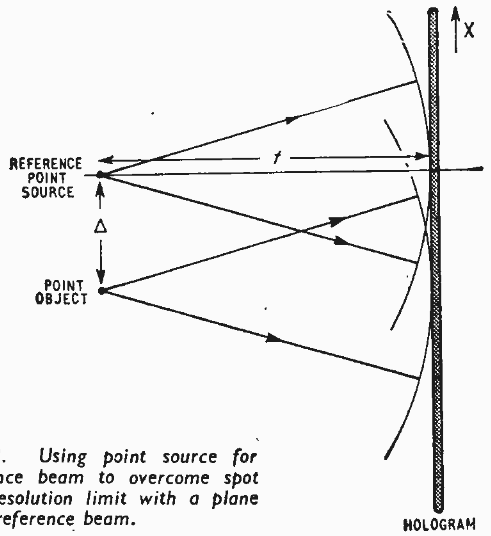


Fig. 8. Using point source for reference beam to overcome spot size resolution limit with a plane wave reference beam.

Another hologram was taken on the same plate of another view of the same object in the same position or of a different object, the reference beam angle being moved to 60°. The reconstruction then gave two separately visible images at the appropriate reference beam angles. This meant that as the hologram was rotated, different images appeared as the corresponding angles were reached and were quite distinctly visible.

HOLOGRAM MICROSCOPY

Gabor originally suggested holography as a means of X-ray microscopy. If a hologram is made with short wavelength radiation, such as X-rays, and then viewed with visible light, the hologram having been enlarged by the ratio of the wavelengths, the image is also magnified by the ratio of the wavelengths. No lenses are used in this process, so the magnification should be free of distortions. Lenses at X-ray wavelengths are very poor.

Further (geometrical) magnification can be obtained by viewing the hologram with divergent light using the hologram like a lens whose focal length, f, is the distance of the plate from the original object. ($M = v/f$, where v is the image distance.)

If the hologram is enlarged and viewed in light of a longer wavelength, λ', the total magnification becomes $M\lambda'/\lambda$. Geometrical magnifications of 200 are possible and if the wavelength ratio is 6328, corresponding to laser viewing light at 6328 Å and X-rays at 1 Å wavelength for creating the hologram, the total magnification is over 1 million.

It was hoped that the resolution of this process would be of the order of the X-ray wavelength, i.e. 1 Å. Unfortunately, Baez[5] and more recently Stroke and Falconer[6] have shown that for the system we have described the resolution is limited by the photographic grain size.

In Eqn. 1 the width of the information carrying fringes is given by the 3rd term. Fringe spatial frequency is:—

$$\frac{1}{2\pi}\cdot\frac{d}{dx}\left(\frac{2\pi\theta x}{\lambda}+\frac{\pi x^2}{f\lambda}\right)=\frac{\theta}{\lambda}+\frac{x}{f\lambda}$$

For plates with a resolution limit of N lines/mm, which is the maximum resolvable fringe frequency:—

$$N=\left|\frac{\theta}{\lambda}+\frac{x}{f\lambda}\right|$$

This limit occurs at distances

$$x_1=\left(N-\frac{\theta}{\lambda}\right)f\lambda \text{ and } x_2=-\left(N-\frac{\theta}{\lambda}\right)f\lambda$$

The total range of x is $x_1 + x_2 = 2N\lambda f$.

In the reconstruction process this is the apparent aperture of the hologram of focal length, f, for each point object. From classical optics the diameter of spot to which a lens of aperture A and focal length, f, can focus is $f\lambda/A$. Similarly the hologram will focus the light to a spot of diameter, $d=1/2N$. This spot size is the resolution limit for a hologram and is equal to half the resolution of the photographic emulsion.

This limit can be overcome by using as the reference beam a point source in the plane of the object instead of the plane wave used previously. Of course, this can only be used for plane objects. In this case the total light amplitude striking the plate when making a hologram of a point source (Fig. 8) is:—

$$A_1(x)\exp j\pi x^2/f\lambda + A_2(x)\exp j\pi(x-\Delta)^2/f\lambda$$

The term of interest of the light transmitted by the developed hologram is now:—

$$2A_1(x)\,A_2(x)\cos\left(\frac{\pi x^2}{f\lambda}-\frac{\pi(x-\Delta)^2}{f\lambda}\right)$$

The spatial frequency of these fringes is:—

$$\frac{1}{2\pi}\cdot\frac{d}{dx}\left(\frac{\pi x^2}{f\lambda}-\frac{\pi(x-\Delta)^2}{f\lambda}\right)=\frac{\Delta}{f\lambda}$$

This is independent of x and therefore for a perfect point source reference beam the aperture of the hologram formed by a point source is unlimited. Eaglesfield[7] has pointed out that the resolution is now limited by the diameter of the reference point source. This is apparent since the spatial frequency of the hologram depends only on the distance between the point object and the reference point. When two points on the object are closer together than the diameter of the reference point, light from these points will interfere with two parts of the reference spot and give the same spatial frequency. Two points with the same holographic record must be inseparable so that any points on the object closer together than the reference source diameter will be unresolvable.

Using a plane reference beam the resolution is limited to that of the best photographic plates which is about 5000 Å. When a point source is used, for perfectly coherent light the spot size can be of the order of the wavelength and so for X-rays would be about 1 Å.

Unfortunately, good coherent X-ray sources are not available and the smallest pinhole sources have a diameter of around 5000 Å. This resolution is much too low to be of much practical application for microscopes.

The resolution in the holograms reproduced here is limited by another effect. The objects used were small metal toys which were painted white. It is a well known fact that when many types of objects such as these are viewed with laser light they have a very grainy appearance. This can be seen in Fig. 9. The former is a photograph of the object viewed in daylight, while the object was illuminated with laser light for the second photograph. This granularity is due to interference on a microscopic scale between the light scattered from the many particles of the rough surface of the object.

In practice the resolution of the hologram of many types of object may be limited by this effect and not by the photographic plate. This granularity can be seen in the reconstructions shown (Figs. 6 and 9).

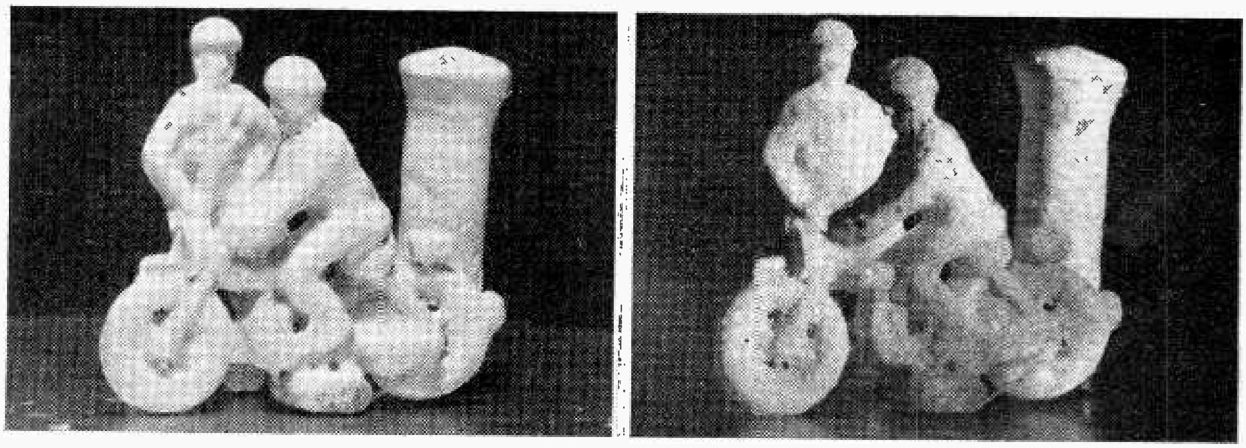


Fig. 9. Resolution in holograms can be limited by grainy appearance caused by laser light. The photographs show the object viewed in daylight (left) and by laser light (right).

APPLICATIONS OF HOLOGRAPHY

A three-dimensional record of an object has many obvious advantages over a normal photograph. One field in which such a record is particularly useful is in the study of moving, three-dimensional objects such as gases or plasmas. If a hologram is made of such an object using a short exposure time the reconstruction can be viewed continuously and is a " frozen " view of the original object. Particle density can be measured, Schlieren photographs taken and all the other interferometric techniques can be used at leisure on the reconstruction.

High speed objects such as bullets have been recorded[8] using a ruby laser with a pulse length of about 60 ns. Because of the short coherence length of ruby lasers great care had to be exercised to have equal path lengths for the reference beam and for the light from the object. This meant that large objects with appreciable depth could not easily be used. However, if better mode control and hence longer coherence length could be achieved this method shows promise for recording moving objects.

Metrology.—A further use for holography arises because of the fact that interference can be obtained between the reconstructed image and light reflected from the original object.* If a hologram is made of an object, and the hologram is replaced in exactly its original position, the object being untouched, the reconstruction and the original object will coincide. Any slight movement of the object will now cause interference fringes to appear across the object and the width of these fringes is proportional to the displacement. By this means accurate strain measurements in three dimensions could be made without disturbing the object by attaching strain gauges or other devices.

This technique might also be useful in precision manufacture of optical components. If the original object was replaced by a copy any differences between the two would be indicated by fringes.

Character recognition.—D. G. Gabor has recently suggested[9] that using holograms it may be possible to solve the problem of machine recognition of handwritten characters. In normal holography two coherent light waves, the reference and the illuminating beams, are combined at a photographic plate. Call these beams A and B respectively. The property of the hologram is that if it is re-illuminated with B then A also appears and vice versa. Let A be a character, typescript etc., readable by human beings and not by a machine and B be a combination of point sources which is coded so that a machine can read it. If a hologram is made of A and B together then when the character subject A is presented to it B will flash out and be recognized by the machine. In other words the hologram is a translator. A large amount of information can be stored on a hologram and it may be possible to record several variants of each letter of the alphabet on one plate so that the correct code will be reconstructed when a letter is presented to the hologram.

Coding.—Information coding can also be carried out using the method explained above. If A is a three-dimensional object or any sort of information to be coded and B is a complicated phase plate the object is only reconstructed when the phase plate " key " is replaced in its original position. Therefore only the person possessing this key can view the object. Several objects can be coded on the same hologram by using a different key for each object.

The future.—Much interest is being shown in holography and rapid progress is being made in the field. Holograms are likely to have many uses in interferometry and metrology and if more powerful lasers are developed they may be used for three-dimensional cinema. However, it is still too early to forecast all the possible uses, but such a technique, with many advantages over normal photography, is certain to be widely used in the future.

Acknowledgement.—The authors wish to thank the Director of Engineering, The Marconi Company Ltd., for permission to publish this article.

*See, for example, *W. W.* May 1966, p.230—Ed.

REFERENCES

(1) D. Gabor. *Proc. Roy. Soc.* A197 (1949).
(2) Lieth and Upatnieks. *J. Opt. Soc. America* Oct. 1962 LII 1123. Dec. 1963 LIII 1311. Nov. 1964 LIV 1295.
(3) Pennington and Lin. *Applied Physics Letters*, 1 August 1965, Vol. 7 No. 3.
(4) Stroke and Labeyrie. *Physics Letters*, 1 March 1966, Vol. 20, No. 2.
(5) Baez. *J. Opt. Soc. America* 42, 756 (1952).
(6) " Optical Information Processing," Stroke. MIT Press 1965, Ed. Tippett.
(7) Eaglesfield. *Electronics Letters*, Sept. 1965, Vol. 1 No. 7.
(8) Brooks et al. *Applied Physics Letters*, 15 Aug. 1965.
(9) D. Gabor. *Nature*, 30 Oct. 1965.

Elements of the Colour Television Receiver

FINDING YOUR WAY EASILY ABOUT A COLOUR TELEVISION RECEIVER BY KNOWING THE MAIN CIRCUIT BLOCKS AND HOW THEY WORK TOGETHER

By T. D. TOWERS,* M.B.E.

ARE you one of the many electronics men who jib at colour television because it *seems* so difficult, particularly when you see it through a haze of forbidding strange terms like "colour killer" and "decoder matrix"? This article is written to give you a chance to grasp the main sections of a colour receiver, as a foundation for later study of individual circuits.

MAIN SECTIONS OF COLOUR RECEIVER

An illuminating way to look at a colour receiver is through the controls that you will operate as a viewer. You find all the familiar "black-and-white" set knobs for "on/off," "channel selection," "fine tuning," "field hold," "line hold," "brightness," "contrast," and "volume." The only unfamiliar knob will be marked something like "saturation," and is used to control the strength of the colouring in the picture.

In Fig. 1 you have a functional block diagram of a colour receiver which shows how the main circuit blocks are connected with the viewer-operated controls mentioned above, and now listed down the left of the diagram. It also shows the paths followed by the television signals from the aerial to the speaker and picture tube.

The *tuner*, with its associated channel selector and fine-tuning controls, selects the desired transmission from the aerial input, amplifies it and then converts it to a standard intermediate frequency. This i.f. signal is subsequently amplified and detected in the fixed-frequency vision i.f. "strip" or amplifier.

Up to this point, the *five* main components of the colour television signal—sound, luminance (or brightness), picture sync, colour (or chrominance), and colour sync—have been handled together, but after this they open out into five distinct streams for separate processing. In the understanding of the colour receiver, the video detector output is therefore a key point, and Fig. 1 attemps to highlight this. Note how it shows the five signal paths leading off separately from the detector. If you master this point you are well on the way to unlocking the mysteries of the colour receiver.

The *sound signal* can be followed in Fig. 1 passing from the video detector, through the sound i.f. amplifier and thence, after detection, through the sound a.f. amplifier to the loudspeaker. The viewer-operated volume control adjusts the gain of the a.f. amplifier.

The *luminance signal* takes another path from the video detector. It passes into the luminance amplifier, where viewer controls are available for adjusting both picture brightness and contrast. The output of the luminance amplifier is applied to the cathodes of the colour picture tube to reproduce the brightness content of the picture.

Picture sync information in the television signal is contained in a stream of line and field sync pulses which keep the receiver timebases in synchronism with the transmitter timebases. In Fig. 1 you can follow the path of these sync pulses through the receiver after the video detector.

First, in the sync separator all information other than the sync pulses is stripped off the signal. Field pulses then pass off in one direction to hold the field timebase in synchronism, with the help of the viewer-operated field-hold control. The field timebase itself, as well as driving the picture tube field deflection coils, also supplies vertical correcting signals to a "dynamic convergence" section.

From the sync separator also, line pulses pass on a separate path to the line timebase, where, with the help of the viewer line hold control, they keep the line timebase too in synchronism with the transmission. Secondary functions of this timebase are to power the e.h.t. supply to the picture tube anodes and supply horizontal correcting signals to the dynamic convergence circuits.

The dynamic convergence circuits thus receive waveforms from both field and line timebases, and shape these before feeding them to the convergence coils on the picture tube. This arrangement is necessary to ensure that the spots from the three electron beams in the colour picture tube remain indexed together, i.e., at the correct spacing relative to each other, as they are swept over the tube face to create the picture.

The *chrominance*, or colour signal, path from the video detector onwards can also be picked out in Fig. 1. It is first handled by a chrominance amplifier section, where a viewer "saturation" gain control sets the strength of the colours in the final display. The amplified signal then passes to the colour demodulator stage, which extracts the separate colour modulations. These modulations are then combined in a "colour decoder" stage to supply separate signals to drive the control grids of the picture tube corresponding to red, green, and blue, the three basic colour components of the displayed picture.

Colour sync information in the television signal is contained in a stream of "colour bursts," one close behind each line sync pulse. Fig. 1 shows how, after the video detector, the "burst amplifier" isolates these

*Newmarket Transistors, Ltd.

colour sync signals from the rest of the carrier signal. The bursts then pass through a discriminator stage to synchronize the colour local oscillator precisely with the colour subcarrier frequency in the transmission signal. As a result, when the colour oscillator is used to drive the colour demodulator, the colour modulation is correctly extracted by the demodulator, and the colour hues come out accurately in the final display.

Another use of the burst discriminator output is to control the "PAL switch" section, which enables the colour demodulator to follow the alternate-line colour phase switching in the PAL system of transmission.

After this brief synoptic look at the main sections of a colour receiver, we will now take a closer look at the individual sections outlined above.

"FRONT END" (TUNER AND I.F. STRIP)

The front end of a colour receiver is not vastly different from its black-and-white counterpart. This can be seen from Fig. 2, which gives more details of this section than was possible in the general diagram of Fig. 1.

On the left of the aerial can be seen a typical signal waveform for one picture line with three distinct parts; the sync pulse, the colour burst, and the mixed signal information. The diagram shows on the right of the aerial the transmission bandwidth covered, for Channel 33 (BBC-2) as an example, and the location of the carrier frequencies in that channel in relation to the vision frequency of 567.25 Mc/s. At the output of the tuner, the diagram shows these frequencies converted down to the standard i.f. frequencies of 39.05 Mc/s for vision, 35.07 Mc/s for colour and 33.50 Mc/s for sound.

The i.f. strip has a response somewhat like that shown below on the right in Fig. 2. Thereafter, the video detector produces three outputs comprising (1) an a.g.c. feedback to control the tuner and first i.f. amplifier gain, (2) a ±100 kc/s-bandwidth intercarrier sound signal, centred on 6 Mc/s for a separate sound section, and (3) a mixed monochrome and colour, wideband, video signal complete with picture and colour sync pulses covering frequencies out to 5.5 Mc/s for the vision output stages.

Nowadays, the whole of the colour receiver front end is transistorized, typically using three or four transistors in

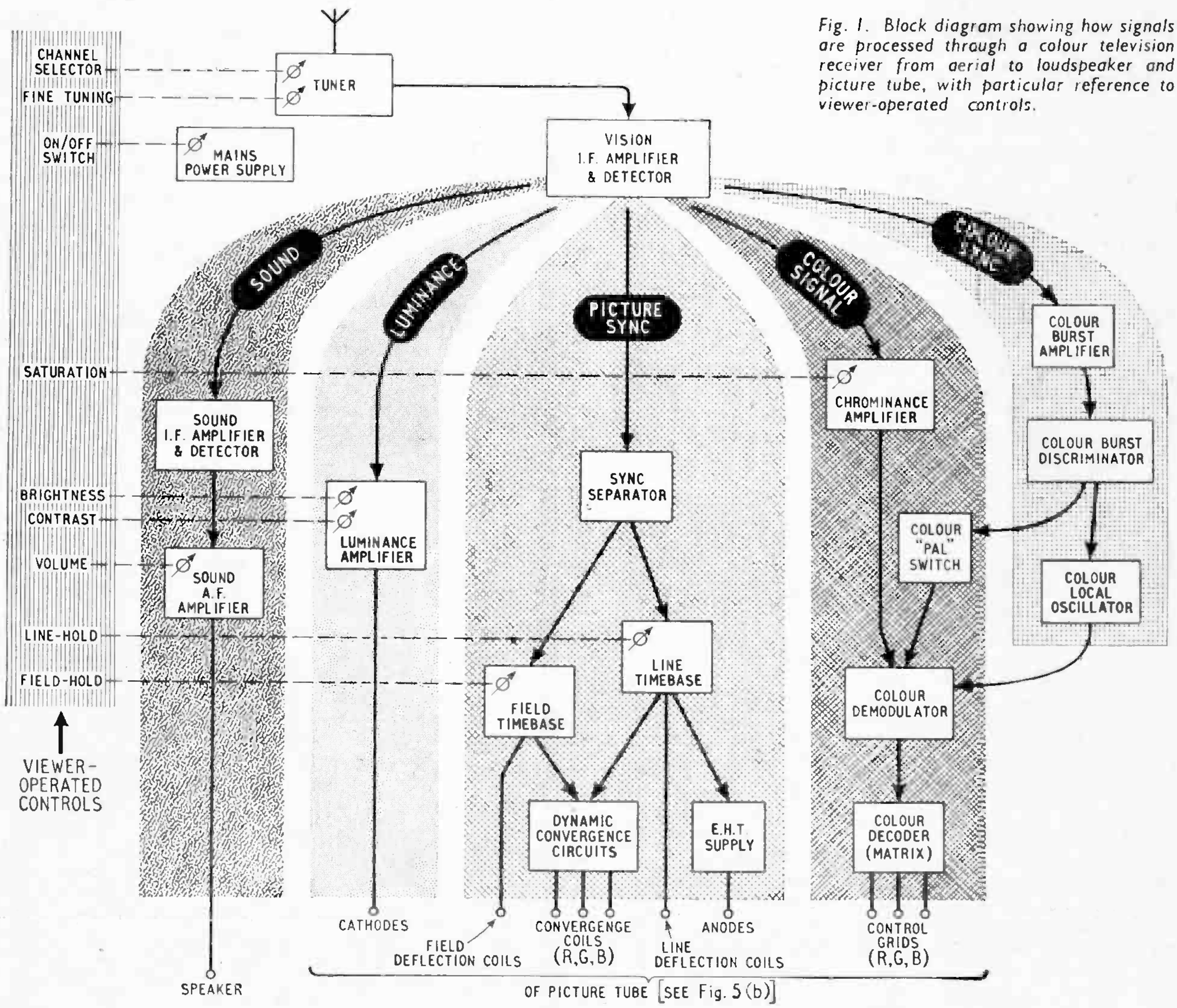


Fig. 1. Block diagram showing how signals are processed through a colour television receiver from aerial to loudspeaker and picture tube, with particular reference to viewer-operated controls.

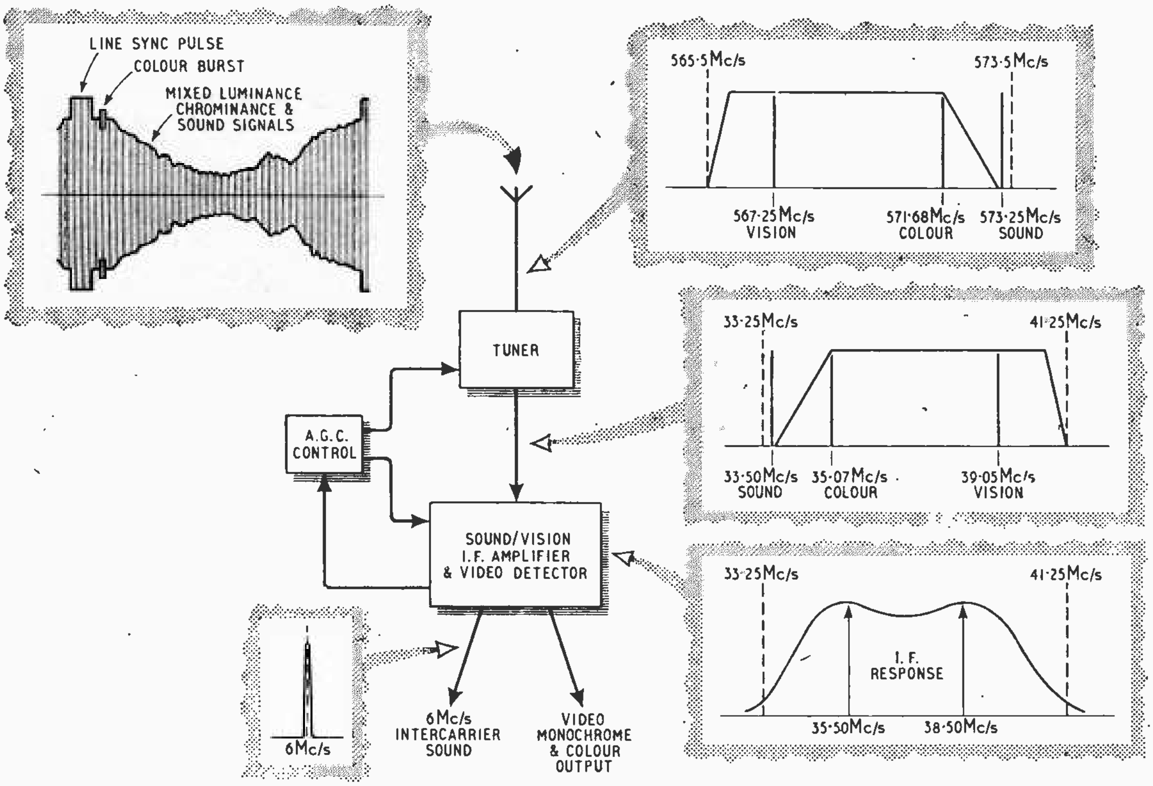


Fig. 2. How U.K. Channel 33 colour television signal appearing at aerial is amplified and frequency-converted in tuner and then fed into common sound/vision i.f. amplifier, where it is finally detected to provide inter-carrier sound and video signals to be processed in later sections.

the tuner, three in the vision i.f., and two in the a.g.c. circuit.

In the front end of a colour receiver, the main differences from a straight monochrome 625-line receiver are that there are more stringent requirements on a.g.c., frequency stability and band response. As a result, designs are tending to use "gated" a.g.c., some form of a.f.c. in the tuner, and a design of i.f. strip that ensures minimum phase shift and a more precisely tailored response across the i.f. band. For example, a dip of 3 dB in the response at the centre of the band was acceptable with black-and-white, but experience suggests that this must be tightened to not more than 1 dB in the colour i.f. strip, if satisfactory colour reproduction is to be achieved consistently.

SOUND SECTION

British 625-line television uses f.m. sound on a carrier spaced 6 Mc/s from the wide (luminance) carrier. Some detail of how sound is processed in the output end of the receiver is shown in Fig. 3. The sound and luminance carriers mixing in the video detector stage give rise to an "intercarrier" 6 Mc/s beat frequency signal carrier, modulated with the sound information. This is fed off into a narrow-band, 6 Mc/s tuned, sound i.f. amplifier, which rejects the amplitude-modulated video output from the detector (which is restricted to a 0-5.5 Mc/s frequency range).

From the 6 Mc/s i.f. amplifier, the sound signal can be seen in Fig. 3 passing to a normal f.m. detector (usually a ratio type). Thence it passes through a volume control and an a.f. amplifier to the loudspeaker. Some form of a.g.c. is usually applied in the sound section as shown. This is additional to the vision a.g.c. discussed earlier.

Nowadays the whole sound section is normally transistorized. The i.f. strip uses two transistors, while the audio amplifier is often a three-stage, complementary-push-pull-output, transformerless design giving between a half and one watt output to the speaker.

PICTURE SYNC SECTION (TIMEBASES)

In Fig. 1 we dealt with the main features of the sync section. In Fig. 4 we go into some more detail.

As mentioned earlier, the sync separator takes the full output from the video detector and strips off the vision information before directing the remaining field and line sync pulse streams into two separate paths.

How the line pulses go on to control the frequency of the line timebase oscillator can be seen on the left hand side of Fig. 4. The synchronized oscillator output then feeds into the line timebase output stage, which in turn drives the line output transformer. We have already mentioned how the main purpose of this transformer is to provide drive for the e.h.t. supply, the line deflection coils and the dynamic convergence section. It also is used (as shown in Fig. 4) to provide line flyback blanking pulses for various stages of the receiver, to supply the boosted h.t. of about 500 V for the line output stage itself and to feed a section providing the 5 kV focus voltage for the colour picture itself.

The separate field sync channel after the sync separator can also be seen on the right hand side of Fig. 4. Here

(*Continued on page* 65)

too the field pulses keep the timebase oscillator in synchronism with the incoming signal. The synchronized oscillator then drives the timebase output and thence the field output transformer. As mentioned in connection with Fig. 1, this output transformer primarily drives the field deflection coils, and supplies correction signals to the dynamic convergence circuits, but Fig. 4 shows that it also supplies field blanking pulses to suppress the light spots on the picture tube during line flyback.

At the time of writing, transistorization of the timebases in colour receivers is only partial. Different models vary. Some use transistors only in the lower level stages such as the sync separator, while others are fully transistorized with the exception of the line output stage for which no suitable transistor type is commercially available at the time of writing.

LUMINANCE SECTION

Fig. 5 (a) gives some details of the luminance section additional to the general points covered by Fig. 1. From the video detector output, the luminance signal passes to the 1st luminance wideband amplifier which passes frequencies up to 5.5 Mc/s, and has traps to reject the sound and chrominance part of the video output. The luminance signal then passes on its own through a 1 μs delay line into the 2nd luminance amplifier, which is coupled to the cathodes of the three electron guns in the picture tube, Fig. 5(b). The gain of the 2nd luminance amplifier is varied by the viewer contrast control, while the d.c. level on the c.r.t. cathode is controlled at the input of this amplifier to set the required brightness level.

The delay line in the luminance channel is not found in monochrome receivers. It is necessary in colour receivers because signals take longer to pass through the 1 Mc/s-response, narrow-band chrominance amplifier than through the 5 Mc/s-wide luminance amplifier. The approximately 1 μs delay introduced in the luminance channel holds back the brightness component of a colour signal so that it arrives at the picture tube at the same time as the corresponding colour signals, and thus prevents misregistration of the colour with the brightness.

Because suitable high-voltage transistors for driving the cathode of the colour picture tube are not yet readily available, the 2nd luminance amplifier uses a thermionic valve at the time of writing, but the 1st luminance amplifier is sometimes a transistor.

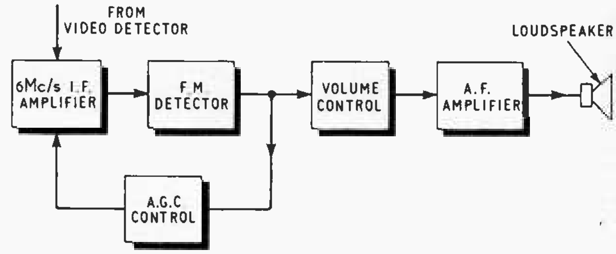
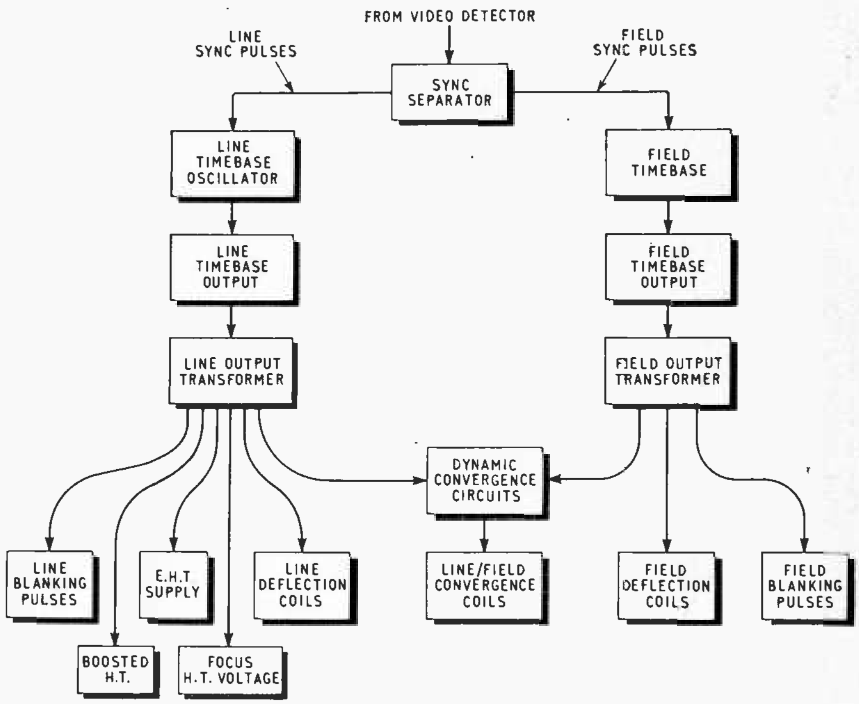
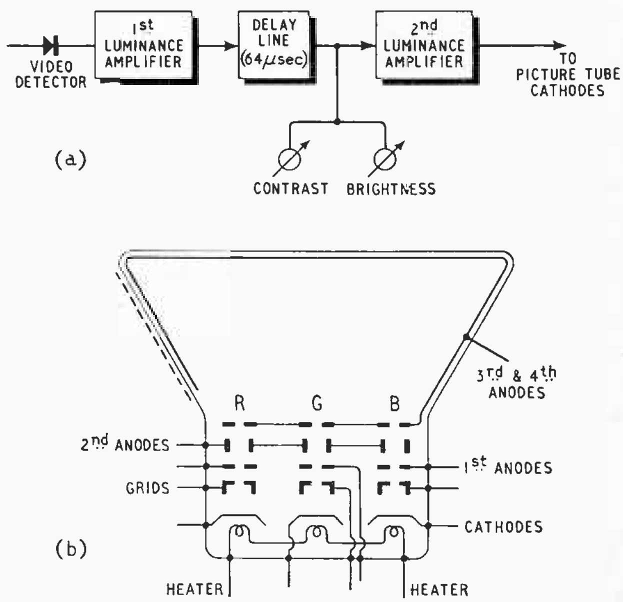


Fig. 3. Diagram of sound section of British, 625-line, colour television receiver, showing how the sound signal is processed from video detector to loudspeaker.



▲ *Fig. 4. Diagram of picture sync section of colour television receiver illustrating how the line and field sync pulses are extracted from the composite video signal after the video detector and used to control the timebases.*



▶ *Fig. 5. (a) Main features of the luminance amplifier which isolates the brightness (black-and-white) information from the composite video signal after the video detector and drives the cathodes of the colour picture tube (British 625-line system). The graphical symbol of the picture tube at (b).*

CHROMINANCE SECTION

In Fig. 6 you will find fuller details of the chrominance section of the colour television receiver than was possible to include in the general survey of Fig. 1.

The full composite, 0-6 Mc/s output of the video detector passes into a 1st chrominance amplifier where filter circuits reject the luminance and sound signals and amplify only the chrominance and colour burst signals. The colour burst signals are then taken off to a separate burst amplifier in the colour sync section.

The chrominance signals (4.43 Mc/s $\pm$1 Mc/s) pass on from the 1st chrominance amplifier into the tuned 2nd chrominance amplifier. In this stage there is a gain control which can be used to set the amplitude of the chrominance signals and thus the "saturation" or strength of the reproduced colours. Line blanking pulses are applied to the 2nd chrominance amplifier to shut off the amplifier during the time of the line sync pulses and the colour bursts, so that spurious colour signals do not pass through to the picture tube from these sources. Finally, a d.c. bias supplied by a "colour-killer" stage in the colour sync section holds the 2nd chrominance amplifier cut off except when a string of colour bursts is being received and indicates that a colour transmission is coming in. The term "colour-killer" is used because the arrangement kills spurious colour on the screen when a monochrome picture is being received. Puristically, it might be more correct to call it a "colour-enabler," as it permits the colour path to open with a colour broadcast.

After the 2nd chrominance amplifier, the chrominance section becomes a little difficult for the newcomer. Up to this point we have deliberately not examined the nature of the chrominance signals too closely, but you must know a little more about them to understand the workings of the colour demodulation stages to which the 4.43 Mc/s signal passes from the 2nd chrominance amplifier.

At the transmitter, two "colour difference" signals, *R-Y* and *B-Y*, are modulated onto a 4.43 Mc/s colour subcarrier with a bandwidth of $\pm$1 Mc/s, where *R* and *B* correspond to the red and blue content of the picture, and *Y* to the brightness (or black-and-white) content. (Note that the colour subcarrier is suppressed before transmission.) A green signal is not transmitted because, as can be shown, it can always be derived from a combination of *R*, *B* and *Y*. The transmitter applies the *R-Y* and *B-Y* signals as subcarrier amplitude modulations with a fixed 90° phase difference, and this enables the receiver ultimately to detect them separately by a system of two synchronous demodulators with a 90° phase difference between them.

In the PAL system, as used by the B.B.C., there are further complications. On every other picture line the phase of the *R-Y* signal is reversed (i.e., 180° added). This is to help balance out phase errors in the path from transmitter colour camera to receiver picture tube, so that colour hues can be accurately reproduced.

To enable the receiver to reconstitute the suppressed colour carrier exactly, the transmitter sends out at the start of each picture line a "colour burst," i.e. some ten cycles of 4.43 Mc/s unmodulated colour subcarrier. This is used to synchronise the receiver colour local oscillator for reinsertion of the exact carrier for synchronous demodulation of the *R-Y* and *B-Y* signals. In B.B.C. PAL these colour bursts are not exactly in phase with the original carrier, but, on alternate lines, their reference phase is $\pm$45° about the mean carrier zero reference—hence the term "swinging burst."

Now, when the suppressed carrier *R-Y*, *B-Y* signals, which we have so far traced in Fig. 6 to the 2nd chrominance amplifier as a group of signals in the bandpass 4.43 Mc/s $\pm$1 Mc/s, leave that stage, they take two courses. First, they go direct to separate "adder" and "subtractor" circuits. Secondly, they pass through a 64 μs (=1 picture line period) delay line, and are then also fed to the same adder and subtractor circuits. Thus the chrominance signals for any line are added to, or subtracted from, the corresponding signals for the previous line which have been held up in the delay line. Now the *R-Y* signal is reversed in the transmission on every line, so the *R-Y* signals cancel out in the adder leaving substantially only the *B-Y* information (still 4.43 Mc/s.).

Similarly in the subtractor, the *B-Y* signals cancel out, and the alternate-line-reversed *R-Y* signals add to give substantially *R-Y* output on 4.43 Mc/s. Thus we have so far partially separated the *R-Y* and *B-Y* information

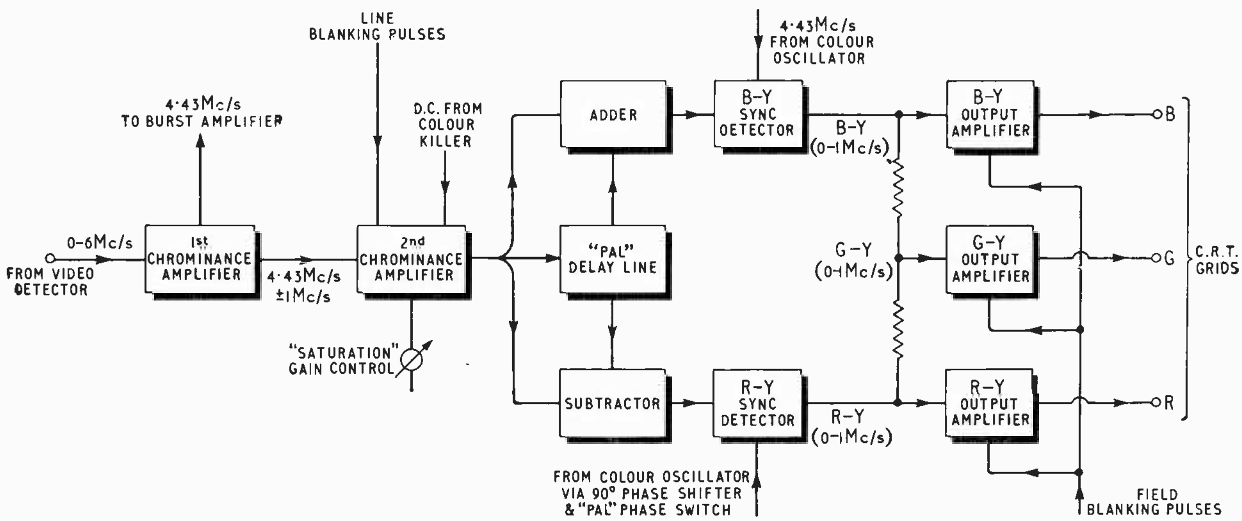


Fig. 6. The chrominance or colour difference section of a British 625-line PAL-D colour television receiver, which extracts the colour information from the composite video signal after the video detector, amplifies it, demodulates it, and reconstitutes (or decodes) the three colour-difference signals to drive the R-Y, G-Y and B-Y picture tube control grids which together with the +Y luminance signals on the cathodes reproduces red, green and blue components of composite picture signal.

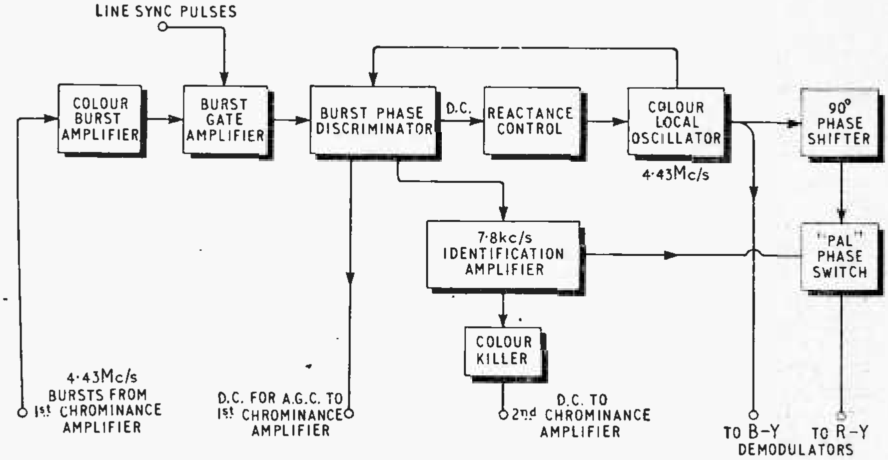


Fig. 7. The colour-sync section of British 625-line PAL colour television receiver. In this section, the 4.43Mc/s colour burst is extracted from the composite video signal after the video detector, demodulated and used primarily to control the phase of the colour local oscillator, to deactivate the colour killer stage and to drive the PAL alternate-line phase reversal switch.

into two streams of 4.43 Mc/s r.f. signals. These have now to be demodulated to recover the original modulation to control the picture tube.

Two separate synchronous detectors are now required, one each for *R-Y* and *B-Y*. A synchronous detector works by feeding a 4.43 Mc/s carrier, in phase with the 4.43 Mc/s suppressed colour subcarrier, into a diode demodulator bridge. Into the same bridge goes the 4.43 Mc/s chrominance signal in the chrominance section at this point. For the *B-Y* adder, the local oscillator signal is fed direct from the oscillator to the synchronous detector, which then gives out a demodulated, 0-1 Mc/s, *B-Y* output. For the *R-Y* subtractor, complications arise from the 90° phase difference of the *R-Y* modulation from the *B-Y*, and the *R-Y* phase reversal on alternate lines. For these reasons, the local oscillator drive to the *R-Y* synchronous detector is first of all phase shifted 90° and then passed through a PAL switch which on alternate lines reverses the phase of the resultant 4.43 Mc/s carrier reinsertion signal before feeding it to the *R-Y* synchronous demodulator. The output of the *R-Y* demodulator then reprduces the 0-1 Mc/s *R-Y* modulation as at the transmitter. (Although the colour local oscillator, the 90° *R-Y* phase shift circuit and the PAL phase switch are discussed here in connection with the chrominance section, they really belong to the colour sync section discussed later below.)

The *R-Y* and *B-Y* demodulated signals now pass to output amplifiers for driving the corresponding control grids of the picture tube. A colour picture tube also requires a green difference signal for a third control grid, and this is obtained by combining certain proportions of the *R-Y* and *B-Y* signals to feed a third, separate *G-Y* output amplifier.

COLOUR SYNC SECTION

Fig. 7 shows in more detail the colour sync section of the receiver that has been surveyed generally as part of Fig. 1, and has been referred to in discussing the operation of synchronous detectors in the chrominance section.

Starting at the input end of Fig. 7, you can follow the colour burst 4.43 Mc/s signal taken off from the 1st chrominance amplifier into the burst amplifier. The burst gate amplifier which follows is held cut off, except when it is triggered open by line sync pulses to pass only the colour burst, and to suppress video information that might pass through and upset the colour synchronisation.

The next stage is the colour burst phase discriminator which compares the phase of the 4.43 Mc/s output from the burst gate amplifier with that of the local colour oscillator, and produces a d.c. correction signal to act on a reactance control stage to bring the oscillator into phase with the burst. From the burst discriminator, we also see derived a d.c. signal proportional to the burst amplitude to provide a colour a.g.c. by controlling the gain of the 1st chrominance amplifier. Finally, the burst discriminator, as a result of the ± 45° phase reference swing on alternate lines, produces a ripple signal at half the line frequency (approx 7.8 kc/s) which is amplified in the "ident amplifier" and rectified to give a d.c. bias to hold the 2nd chrominance amplifier open when bursts are present. The term "ident" comes from the other use of the 7.8 kc/s ripple which is to control the PAL phase switch so that it *identifies* the line being received and switches in the right phase of the oscillator drive to the *R-Y* demodulator for that line.

The colour oscillator is crystal controlled at approximately 4.43 Mc/s, but the reactance control stage can vary this enough to keep the oscillator locked to the transmitted burst frequency and phase. The controlled output from the oscillator drives the *B-Y* synchronous demodulator in the chrominance channel directly, and the *R-Y* demodulator via a 90° phase shift stage and a PAL phase reversing switch controlled by the swinging burst 7.8 kc/s ripple as explained above.

SUMMING UP

This article has shown how all the circuits used in a colour receiver can be largely dissected into six main blocks for ease of understanding. If you have managed to follow the description of these six blocks of the receiver, you are well on the way to understanding how the different circuits actually work in detail.

"Wireless World" Index

The Index to Volume 72 (1966) is now available price 1s (postage 3d). Cloth binding cases with index cost 9s 6d, including postage and packing. Our publishers will undertake the binding of readers' issues, the cost being 35s per volume including binding case, index and return postage. Copies should be sent to Associated Iliffe Press Ltd., Binding Department, c/o 4 Iliffe Yard, London, S.E.17, with a note of the sender's name and address. A separate note confirming despatch, together with remittance, should be sent to the Publishing Department, Dorset House, Stamford Street, London, S.E.1.

WORLD OF WIRELESS

Mobile Satcom Terminals

ONE tends to think of satellite communications in terms of orbiting relay stations and fixed ground stations, but in fact the idea of using mobile terminals, in ships and aircraft, is now being explored and may soon become common practice. The purpose is to overcome the limitations of the h.f. and v.h.f. radio systems in use at present. In the U.K., for example, a shipborne satellite communications terminal is being built by the Royal Navy. It will be used in an inter-Service project, the Interim Defence Communication Satellite Programme, for assessing the effectiveness of global military communications. The satellites—seven are available—are being provided by the U.S. Department of Defence.

The shipborne terminal, constructed jointly by the Admiralty Surface Weapons Establishment and Plessey Radar, has a 6ft diameter aerial with automatic tracking facilities, a transmitter operating in the military band of microwave frequencies and two separate receivers which enable the ship to monitor its own transmitted signals as well as receive those from a distant station. It is due to be installed in *H.M.S. Wakeful* to undergo sea trials, which will include communication with a Ministry of Aviation ground station at Christchurch, Hants, and with U.S. Navy ships. One of the problems peculiar to mobile terminals is that they cause movement of the aerial beam relative to the satellite, and to cope with this in the Navy equipment a specially designed stabilization system using Ferranti gyros is being installed in the ship.

The airlines are interested in air-to-ground communications via satellite as a means of achieving reliable, interference-free v.h.f. communication over large areas such as the Atlantic and Pacific oceans. Tests of two-way teleprinter communication have already been conducted through the Syncom III satellite, using the spacecraft's v.h.f. telemetry equipment, and there have also been listening tests on signals from Syncom III and Early Bird. The latest step is that seven airlines, working through Aeronautical Radio Inc. (ARINC), have started on a test programme of two-way air-to-ground v.h.f. voice and data communications over the Pacific, using NASA's Application Technology Satellite (ATS-1) which was put into equatorial orbit over Christmas Island in December 1966. Specially designed aircraft aerials are needed, and some of the tests will discover how well these perform in conditions of multi-path interference and Faraday rotation in the ionosphere.

British Broadcasting White Paper

THE long-awaited Government White Paper on Broadcasting (Cmd. 3169) was issued on December 20th. Its eight pages contain little, if anything, that was not a foregone conclusion. The main decisions are:—(1) no increase in the receiving licence fee before 1968; (2) no allocation of frequencies to a fourth television service for the next three years; (3) a supplementary licence fee of £5 from those with colour receivers; (4) the introduction by the B.B.C. of a popular music programme to be broadcast on 247 metres for 18 hours a day; (5) for local sound broadcasting the B.B.C. is to conduct an experiment with nine v.h.f. stations "as a venture in co-operation with local interests."

On the question of colour television the Government states "It has always been recognised that the decision to provide colour television on the 625-line definition standard is closely related to the intention to change over the two 405-line services of BBC-1 and independent television to 625 lines. The Postmaster General's Television Advisory Committee has been asked to report as soon as possible on the method of changeover to be adopted. It may well be that this will involve duplicating the existing 405-line programmes on 625 lines in u.h.f."

For each of the proposed nine experimental local broadcasting stations there will be a local broadcasting council which "will have the maximum possible voice in direction and performance of the stations." The stations will come into operation after about a year and the Government will reserve until the conclusion of the experiment of a year or so "any decision on the question whether a general and permanent service should be authorised, and, if so, how should it be constituted, organized and by whom provided, as well as how it should be financed."

Mobile Radio Range Increased

TESTS in London by Pye Telecommunications on their new "synchronous stable relaying" system for mobile radio have proved, say the company, that the system is not upset by reflections from tall buildings nor from aircraft flying over their experimental synchronous relay station on the roof of the Hilton Hotel. (This station relays speech transmissions received from a master transmitter in the Millbank Tower.) The purpose of the s.s.r. system is to overcome the range limitation of mobile radio schemes, without using extra frequencies, by setting up as many synchronous, common-frequency, relay stations as are required. Mobile radio telephony using s.s.r. on long trunk routes is envisaged.

Price Fixing Dropped

THE British Radio Equipment Manufacturers' Association has reluctantly decided to abandon its attempt to secure exemption for domestic equipment from the Resale Prices Act 1964 after carefully considering the position, having been advised by its lawyers that there was virtually no prospect of success. The Association's application in 1964 on behalf of its members was referred to the Restrictive Practices Court in 1965. The Association submitted its Statement of Case and the registrar of the Restrictive Trading Agreements has now delivered his answer. In the circumstances the court will shortly make an order declaring resale price maintenance unlawful in respect of radio and television sets, gramophones, tape recorders and related classes of goods.

A new chair in telecommunications systems is to be established in the University of Essex. The Post Office is to pay the costs of the chair and some supporting staff for ten years. It will be in the Department of Engineering Science and it is hoped that it will be filled by October of this year. Teaching at both undergraduate and post-graduate levels with research into telecommunications systems will be provided. A system of awards for engineering graduates on the staff of the Post Office has been established since December 1965 and a number of these will be placed with the University of Essex. Close ties are expected to develop between the University and the Post Office Research Station, which is to move from London to near Ipswich.

The first elections to the council of the **British Acoustical Society** since its inauguration in May 1966 were held recently. Professor R. E. D. Bishop, Kennedy Professor of Mechanical Engineering in University College, London, was elected president. Professor E. J. Richards, head of the Institute of Sound and Vibration Research, Southampton; Professor E. C. Cherry, Electrical Engineering Department, Imperial College and W. A. Allan, consulting architect were elected vice-presidents. Dr. P. Lord of the Applied Physics Department, Royal College of Advanced Technology, Salford, is hon. secretary and Dr. R. W. B. Stephens, reader in acoustics, London University, is membership secretary. Full particulars of membership can be obtained from Dr. Stephens at the Physics Department, Imperial College, London, S.W.7.

B.B.C. colour test transmissions were extended from January 2nd to include Emley Moor (Ch. 51) as well as Crystal Palace (Ch. 33) and the BBC-2 relay stations at Guildford, Hertford, Reigate and Tunbridge Wells.

Stereo Decoder.—In the article by Mr. Waddington, describing a stereo decoder, published in the January issue, it was stated on p. 4 that Tr6 limits when the input was 60 mV. This should have read 6 mV. Also, in the circuit of Fig. 9 we regret that the centre tap of T3 secondary was shown incorrectly connected to C_{11}. The centre tap should be taken to earth and C_{11} to the emitter of Tr6.

"The Discovery of Television."—The Mullard film with this title, which was transmitted by the B.B.C. on the 30th anniversary of the opening of the British television service, is now available on loan to clubs and other organizations (Mullard, Torrington Place, London, W.C.1). The film shows indubitably that no one person discovered or invented television. The names associated with its development are many and most of them are mentioned. Although some may feel that undue weight is given to Baird, whose system bore little or no relation to present-day techniques, it must in all fairness be said that "he was the first to make it work."

I.T.A. Asynchronous Trade Tests.—Trade test transmissions from all the Independent Television Authority's transmitters are now being broadcast asynchronously, that is the field frequency will be locked not to the mains frequency but to a crystal. Previously, trade tests and many of the programmes were locked to the mains frequency but most of the network programmes have already been crystal-locked and the European standard for 625-line transmission also specifies crystal locking.

The recently formed Industrial Reorganisation Corporation has been asked by the Government to conduct a broad **study of the telecommunications industry.** The evidence the I.R.C. collects will be confidential and the results will not be published.

PERSONALITIES

Lord Bowden of Chesterfield, principal of the University of Manchester Institute of Science and Technology, has accepted the invitation to be president of the Royal Television Society in succession to **F. N. Sutherland,** managing director of the Marconi Company, who completed his two-year term as president on 31st October. A graduate of Emmanuel College, Cambridge, Lord Bowden also studied at the University of Amsterdam, where he received his Ph.D. During World War II he was with the Ministry of Supply, and in May 1943 took a British research team to the Massachusetts Institute of Technology to develop a new naval radar system. In 1950 Dr. B. V. Bowden (as he was then) joined Ferranti and three years later became principal of the Municipal College of Technology, now the University of Manchester Institute of Science and Technology. He was made a life peer in 1963 and was appointed Minister of State for Education and Science in October 1964, but a year later he resigned from the Ministry and returned to the University from which he was granted leave of absence on his Government appointment.

M. J. L. Pulling, C.B.E., M.A., F.I.E.E., deputy director of engineering in the B.B.C. since 1963, will retire in May and will be succeeded by **D. B. Weigall,** M.A., F.I.E.E. Mr. Pulling was educated at Marlborough College and King's College, Cambridge, and after five years in industry, joined the B.B.C. in 1934. He became superintendent engineer, recording, in 1941; senior superintendent engineer, television, in 1949; controller, television service engineering, in 1956, and was assistant director of engineering for a year before he was appointed to his present post. Mr. Pulling was for ten years chairman of the technical body which was responsible for the development of Eurovision. He was also 1959/60 chairman of the I.E.E. Electronics and Communications Section. Mr. Weigall, assistant director of engineering, will become deputy director of engineering, whilst retaining his present responsibilities for the work of the Engineering Specialist Departments. A graduate of Christ Church, Oxford, he joined the B.B.C. Research Department in 1933. He was seconded as chief engineer to the Malaya Broadcasting Corporation from 1940 to 1942 and as Technical Adviser on Broadcasting to the Ministry of Information from 1943 to 1946. He was appointed B.B.C. chief engineer, external broadcasting, in 1962 and became assistant director of engineering in 1963.

J. Redmond, F.I.E.E., B.B.C. senior superintendent engineer, television, since 1963, will become assistant director of engineering and will assume Mr. Pulling's present responsibilities for the operational work of the Engineering Division. Mr. Redmond joined the B.B.C. in 1937 and served in the Merchant Navy as a Radio Officer during the war. He became assistant superintendent engineer (film) in 1956; superintendent engineer (television recording) in 1960; and superintendent engineer, television (regions and outside broadcasts) in 1962.

Lord Bowden

D. B. Weigall

J. Redmond

Bernard Marsden, F.I.E.E., M.I.E.R.E., has been appointed Group Engineering Controller to the A.T.V. group of companies. He has been with Associated Television, the London and Midlands programme contractors, since 1955. Prior to the start of independent television he spent five years in commercial broadcasting and was previously

B. Marsden

in the radio industry—Murphy, Philips and Sugden. In 1960, Mr. Marsden became deputy technical controller and since 1953 has been technical controller.

F. W. Alexander, Ph.D., B.Sc., M.I.E.E., superintendent engineer, sound broadcasting equipment since 1963, is retiring after 31 years' service with the B.B.C. Dr. Alexander joined the Engineering Research Department from the Research Section of the Department of Physics, University of St. Andrews. His successor at the B.B.C., is **J. R. Wakefield,** M.I.E.E., who joined the Recording Department in 1941. Ten years later he transferred to the Planning and Installation Department where recently he has been head of the sound section.

Dr. J. M. M. Pinkerton, research manager of English Electric-Leo-Marconi Computers, is the new president of the European Computer Manufacturers' Association. ECMA, formed in 1960, has some 20 members and an office with a permanent staff of five in Geneva; and its affairs are guided by three elected members. Dr. Pinkerton, a Cambridge double-first and Ph.D., joined Leo Computers Ltd. in 1949 and was for four years a director of the company until its merger with English Electric in 1963, he then became responsible for research in the combined computer company.

Dr. J. M. M. Pinkerton

W. E. Miller, M.A.(Cantab.), M.I.E.R.E., managing director of our publishers, Iliffe Electrical Publications Ltd. since 1962, has been appointed chairman of the company. Mr. Miller, who is a past president of the I.E.R.E., was for many years editor of our associate journal *Electronic & Electrical Trader* (formerly *Wireless Trader*). On leaving Cambridge in 1924 he spent a short time with the Cambridge Instrument Company and joined the editorial staff of the *Trader* in 1925. He was technical editor from 1926, editor from 1940 and later managing editor. Mr. Miller is succeeded as managing director of I.E.P. by **Kenneth Tett** who in 1946 joined Wireless Press Ltd. (an associate company which publishes the *Ocean Times* and other newspapers for ships) as advertisement manager.

NEW YEAR HONOURS

Sir Lawrence Bragg, F.R.S., is appointed a Companion of Honour in the New Year Honours. Sir Lawrence was Cavendish Professor of Physics at Cambridge from 1938 until 1954 when he assumed the directorship of the Royal Institution from which he retired eighteen months ago. Born in Adelaide, S. Australia, in 1890 he was educated at Adelaide University and Trinity College, Cambridge. Sir Lawrence's work on X-ray crystallography is well-known and the phenomenon called Bragg reflection is becoming more significant with the use of lasers and in holography.

Sir Willis Jackson, F.R.S., who received a life peerage for services to technology, has been professor of electrical engineering at Imperial College, London, since 1960. After graduating at Manchester University and lecturing in electrical engineering at Bradford Technical College (now the University of Bradford), he joined Metro-Vick as a college apprentice in 1929. In 1938 he was appointed professor of electrotechnics at Manchester University and eight years later accepted the chair at Imperial College. Sir Willis relinquished his chair at Imperial College in 1953 to become director of research and education of Metro-Vick now part of A.E.I. but returned in 1960. His burning interest is technological education and technical training.

Francis C. McLean, C.B.E., B.Sc., F.I.E.E., who has been director of engineering at the B.B.C. since 1963, is appointed a knight bachelor. A graduate of Birmingham University he was 12 years with Standard Telephones & Cables before joining the B.B.C. in 1937. He headed various groups within the Engineering Division prior to his appointment in 1952 as deputy chief engineer. In 1960 he became deputy director of engineering. Sir Francis, who was for several years a member of the Radio Research Board and has served on many national and international bodies concerned with radio regulations is a member of the Technical Sub-committee of the Government Television Advisory Committee.

The following are also recipients of awards announced in the Honours List.

C.B.E.

L. W. Hayes, who recently retired from the secretariat of the International Radio Consultative Committee (C.C.I.R.) of which he was latterly vice-director. Prior to going to Switzerland he was on the B.B.C. engineering staff.

O.B.E.

A. F. Bulgin, M.I.E.R.E., chairman and managing director of A. F. Bulgin & Company.

L. A. W. Diamond, lately managing director, Broadcasting Company of Northern Nigeria.

A. Kravis, manager, administrative and technical services research division of the Marconi Company.

J. A. Marshall, principal signals officer, Diplomatic Wireless Service.

M.B.E.

A. W. Bailey, head of the economic and statistical department of B.E.A.M.A.

W. A. Bennett, assistant broadcasting officer, British Solomon Islands.

J. C. Curry, manager, public address hire department, S.T.C.

G. M. Evans, chief inspector, English Electric Valve Company.

E. V. Golder, experimental officer, Signals Research & Development Establishment.

I. C. I. Lamb, A.M.I.E.R.E., engineer-in-charge of the I.T.A. station at Emley Moor, Yorks.

L. H. W. Howard-Silvester, experimental officer, Royal Radar Establishment.

D. G. Smith, deputy engineer-in-chief, Cable & Wireless.

IMPERIAL SERVICE ORDER

H. T. Mitchell, F.I.E.E., staff engineer, Post Office Research Station.

BRITISH EMPIRE MEDAL

E. V. Hatswell, assembly superintendent, aircraft navigation instruments, Smith Industries Ltd.

E. R. Patterson, leader of G.E.C. technical information services.

A. Rush, research and development craftsman, S.R.D.E.

A. M. Stark, radio overseer, officer-in-charge, G.P.O. Humber Radio Station.

World Satellite Communications

—including TV, of course

INTELSAT SYSTEM WILL ENCIRCLE THE GLOBE

THE transmission of live television pictures between Britain and Australia via a communications satellite in November last year focused public attention on what is, in fact, the second phase of a global satellite communications scheme planned to be complete by 1968. Telephone, television and teleprinter signals will be carried. This global system is being set up by the International Telecommunications Satellite Consortium (Intelsat), a partnership of 55 nations, and the second phase of the scheme is now under way. The first phase of the project was the coming into service of the Early Bird synchronous satellite in 1965*. Phase II, however, will provide two additional synchronous satellites, one over the Atlantic and one over the Pacific (Fig. 1). Each has the same channel capacity as Early Bird but gives about twice the radiated power and has a larger service area.

The satellite intended for the Pacific was launched in October 1966, but the apogee motor failed to put it into the required geo-stationary orbit 22,300 miles above the earth and the spacecraft is now travelling in an elliptical orbit. It was while this "rogue" satellite was temporarily above the Indian Ocean that it was in a suitable position to allow the Britain-Australia television relay. While it was over the Atlantic it enabled two-way telephone communication to be established between the Cable & Wireless ground station built by Marconi on Ascension Island and the American ground station at Andover, Maine. In the satellite, the receiver operates in the band 6.285-6.405 Gc/s and the transmitter in the band 4.06-4.18 Gc/s.

By the time this article appears in print a replacement for the "rogue" Pacific satellite may well have been launched—modifications having been made to the apogee motor design—and it will be followed shortly by the Atlantic satellite. Meanwhile, Early Bird continues to operate, as television viewers are well aware, and will be in use up to 1968, when the third phase, using Intelsat III satellites, will come into operation. (If Early Bird fails before 1968 it will be replaced.) The combined capacity of Early Bird and the new Atlantic satellite will allow transatlantic television transmission without interruption of other communications.

Phase III will provide three new satellites, one above the Atlantic, one above the Pacific and one above the Indian Ocean. Each will have a capacity of 1,200 voice channels. Their positions are not yet known but the Atlantic satellite will probably be

* "Satellite Communications Service Begins," *Wireless World*, May 1965. See also: "More About Early Bird," *W.W.*, June 1965.

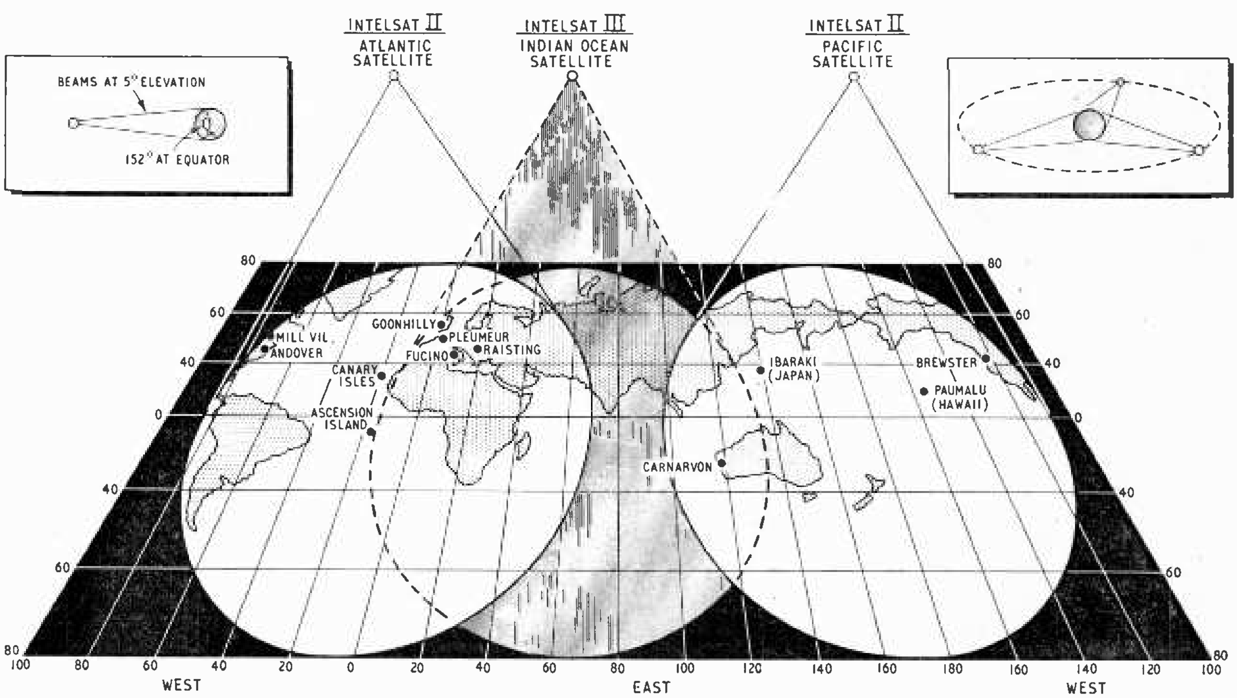


Fig. 1. Estimated service areas of Intelsat II Atlantic and Pacific satellites and probable service area of future Intelsat III Indian Ocean satellite. The Intelsat III Atlantic and Pacific satellites will have roughly similar service areas to those of the Intelsat II satellites shown but the Atlantic service area may be about 20° farther west.

D

farther west than the Intelsat II one shown in Fig. 1. A significant feature of this phase for the U.K. is that the Indian Ocean satellite will allow communication between Britain and Australia, using the Post Office's ground station at Goonhilly, Cornwall, and a ground station to be constructed by the Australian Overseas Telecommunications Commission. As can be seen from Fig. 1, Goonhilly and much of Australia are within the limits of the service area. These limits are described by points on the earth's surface from which the satellite appears to be just above the horizon (see top-left sketch in Fig. 1). More precisely they are points on the globe where the angle of elevation of the ground station's aerial bowl when directed at the satellite is 5° (relative to 0°, the horizon)—an angle which Intelsat have agreed as the lowest economic one for adequate signal/noise ratio.

The capacity of the Intelsat III satellites will be taken up during the 1970s. In general the satellite scheme will be complementary to the existing coaxial-cable long-distance telephone network—satellite communications becoming relatively more economical with increasing distance.

An important factor in the timing of the whole system is the U.S.A.'s Apollo space project for eventual landing of men on the moon. This will require global telecommunication links between the various radio stations tracking the spacecraft, and the Atlantic and Pacific satellites will be needed by N.A.S.A. to supplement existing cables and h.f. radio systems. Ascension Island, mentioned earlier as an earth terminal station, is one of three places at which fixed Apollo tracking stations will be operating (the other two being Carnarvon and Grand Canary Island). A further six tracking stations will be mobile—on land or shipborne. About half of the capacity of the two Intelsat IIs will be used for the Apollo project and the remainder will be available for routine commercial communications.

The two Intelsat II satellites have been constructed by the American firm which built Early Bird (HS303)—Hughes Aircraft Company. These Intelsat IIs are twice as large as Early Bird, have over twice the radiated power, serve a larger geographical area and, unlike Early Bird, provide for multiple-access working (meaning that a number of ground stations can work through a satellite simultaneously). The microwave relay station of the craft (see Fig. 2) consists basically of a receiver operating over the band 6.285 to 6.405 Gc/s, a frequency changer which changes the received signals by 2.225 Gc/s, and a transmitter radiating the frequency-changed signals in the band 4.060 to 4.180 Gc/s. In the transmitter four 6-W travelling-wave tubes are provided. One, two or three of these in any combination may be turned on and operated in parallel, according to the power available from the solar-cell and nickel-cadmium battery power supply (nominally 85 watts). Normally two or three t.w.ts will be in operation, even when the Earth obscures the sun. These transmitter output tubes feed a four-element biconical horn aerial array, which has virtually constant gain across the pass-band, to give an e.r.p. from the satellite of about 25 watts for multiple-carrier working or 35 watts for single-carrier working. Since the aerial array has a toroidal beam it continually illuminates the service area on the earth while the satellite is spinning on its own axis (the spacecraft being spin-stabilized).

Within the 125 Mc/s bandwidth of the relay station, 240 two-way voice channels or one television channel can be accommodated. The cost of operating one two-way voice channel is at present about £14,000 p.a., but this is likely to drop as satellite communications become established. A transmission time delay of 270 ms in each direction is inherent in the system, and this means that two such satellite "hops" used in tandem would make telephone conversations extremely difficult.

The craft's telemetry system, for monitoring and controlling the satellites from the ground, is similar to that of Early Bird and comprises two encoders, two v.h.f. transmitters (which are turned on and off from the ground) and a radio beacon (which radiates continuously). Control of the satellites—positional control through gas jet system and control of the radio system—is the

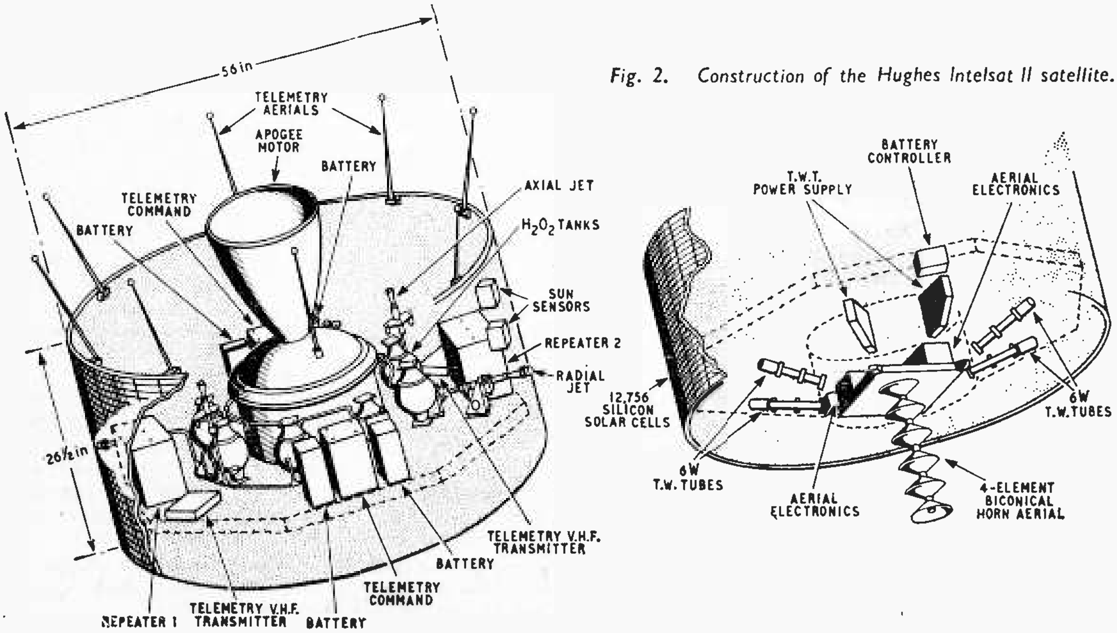


Fig. 2. Construction of the Hughes Intelsat II satellite.

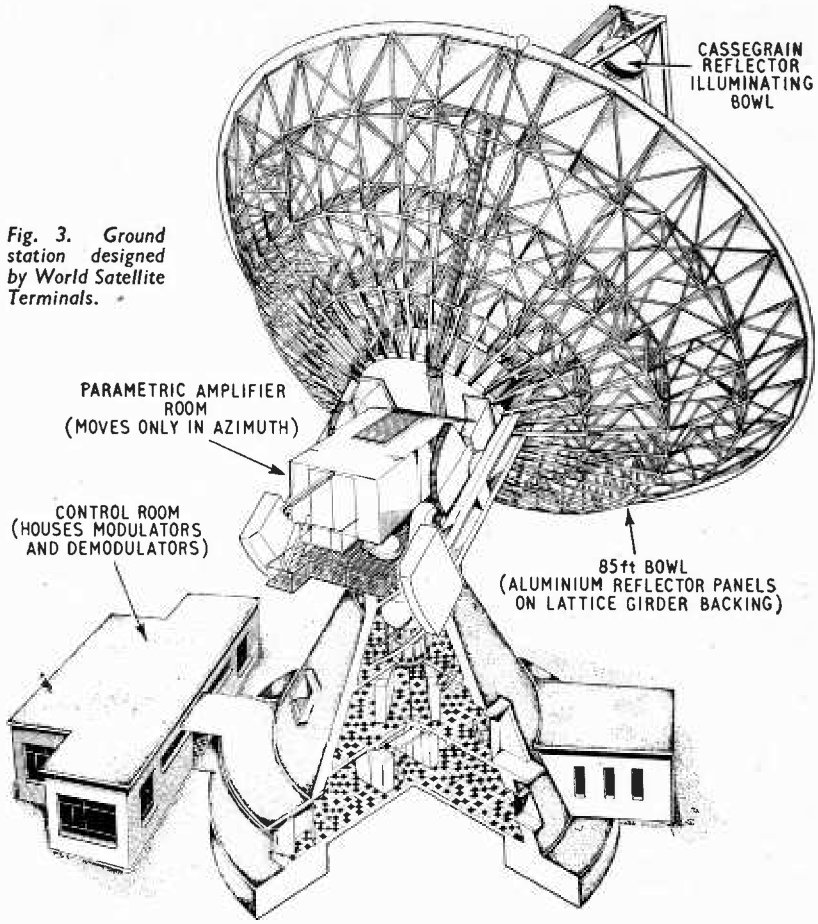
responsibility of the Communications Satellite Corporation (Comsat) in the U.S.A., which acts as manager of the whole scheme for Intelsat. Commands are sent from Comsat's operations centre in Washington, D.C.

The Intelsat III satellites are being constructed by the American company TRW Systems, and six are on order. These will have slightly greater transmitter power than that of Intelsat II but, because the aerial beam will not be an "all-round" toroidal one but have all the radiated energy directed in a cone towards Earth, the e.r.p. will be substantially greater—about 100 W in fact. This directional beam will be achieved by an "electronically de-spun" aerial system which will counteract the effect of the stabilization spin of the satellite by cyclically switching the r.f. energy to the aerial elements as the satellite rotates. The greater capacity of these satellites will be provided by the wider bandwidth of the microwave relay stations—500 Mc/s instead of Intelsat II's 125 Mc/s—the receiving band being 5.925 to 6.425 Gc/s and the transmitting band 3.700 to 4.200 Gc/s.

On the ground a number of stations are, of course, already operating through Early Bird, but many more are under construction and projected. Those already built or in course of construction are: Andover (U.S.A.), Brewster Flat (U.S.A.), Buitrago (Spain), Fucino (Italy), Goonhilly (U.K.), Ibaraki (Japan), Mill Village (Canada), Paumalu (Hawaii), Pleumeur Bodou (France), and Raisting (Germany). Although primarily for use in the Apollo project, the following stations will also be available for commercial communications: Ascension Island (British), Grand Canary Island (Spanish) and Carnarvon (Australia). In addition, there are plans to build stations at Hong Kong, Bahrain (Arabian Gulf), Moorefield (U.S.A.), Moree (Australia), in the Caribbean, and second installations at Goonhilly and Andover. Countries with definite plans to build stations include Thailand and the Philippines, and further possible sites are Nigeria, Ethiopia, the Middle East, Chile, and East Africa.

It has been estimated that 80 to 100 new ground stations will be needed over the next few years. This, of course, represents considerable business for the manufacturers (each station costing £1M or more), and on the strength of it a new company, World Satellite Terminals Ltd., has been set up in Britain to specialize in the building and installation of these stations. Formed as a consortium by A.E.I., G.E.C. and Plessey, W.S.T. have produced a standardized basic design for a ground station and have tendered for the Hong Kong and second Goonhilly terminals. One feature of their design (Fig. 3), which uses an 85-ft Cassegrain aerial reflector system, is that the "pre-amplifier room" containing the parametric amplifier first stage of the receiver is mounted so that it does not move in elevation when the bowl is tilted. This allows the equipment in the room to be continuously accessible to the engineering staff while the station is operating. The aerial bowl, as in other designs, is made steerable to permit tracking of non-synchronous satellites, or of synchronous satellites with slight positional variation (when the orbit is not precisely over the equator), or to allow the station to operate with two different satellites at different times. Maximum rate of movement is 1°/second. The aerial has a beam width of 0.2° and can be positioned with an accuracy of 0.03°.

Fig. 3. Ground station designed by World Satellite Terminals.



Most of the ground stations in use or being built have reflector bowls 85 ft in diameter. This is the minimum size necessary to satisfy a receiving-performance figure of merit recommended by Intelsat:—

$$\frac{\text{Aerial gain}}{\text{System noise temperature in °K}}$$

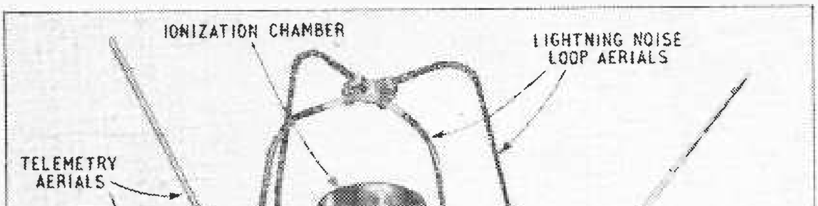
expressed in decibels. In the W.S.T. station, for example, the figure of merit achieved is 40.7 dB with 5° aerial elevation at the reception frequency of 4 Gc/s. The basic problem is, of course, the strictly limited radiated power from the satellite and the irreducible noise level of the system (sky noise plus man-made radio interference plus receiving equipment noise). In practice this means that the aerial bowl should be 85 ft in diameter to collect sufficient r.f. energy from the satellite, the station should not operate with the aerial beam lower than 5° elevation, as mentioned earlier, and the system noise temperature must be brought down to 50° to 60°K.

UK3, Britain's Scientific Satellite

EXPERIMENTS IN RADIO PHYSICS INCLUDED IN FIRST ALL-BRITISH SPACECRAFT

PREVIOUS satellites in the joint U.S.A.-U.K. space research programme were often assumed to be British—perhaps because of the titles they were given, UK 1 & 2 (also Ariel 1 & 2)—but they were in fact American designed and built—only the experiments were British. The third spacecraft in this series is UK3 and has been designed, developed, manufactured and tested in the U.K. (although, of course, the launch vehicle will be American). The work has been co-ordinated in this country by the Science Research Council together with the Ministry of Aviation acting as the design authority. The Royal Aircraft Establishment carried out the research, development and design, and the two main contracts for the construction were given to the British Aircraft Corporation and G.E.C. (Electronics). The spacecraft is due for launch toward the end of March. It will be spin-stabilized in a circular orbit inclined at 80° to the equatorial plane and at an altitude of 525-550 km. Its design lifetime is one year. The design attitude is with the axis normal to the plane of the ecliptic. The satellite configuration (Fig. 1) is the logical result of considering the constraining factors. Amongst these are the need for the folded satellite to fit within the Scout (launch vehicle) payload envelope, the provision of suitable mountings for aerials and sensors, the solar cell layout, thermal balance considerations and the disposal of the various masses to achieve balance and correct moment of inertia ratio for spin stabilisation about the craft's axis.

The equipment on board comprises experiment packages and electronic equipment, which includes the power supply electronics, data handling subsystems, programmer and tape recorder electronics, duplicated telemetry transmitters and a command receiver with decoder and logic circuits (supplied by G.E.C.). The five scientific experiments were the responsibility of the sponsoring bodies —Birmingham University, Manchester University, Sheffield University, the Meteorological Office and the Radio and Space Research Station.



Part of the interior of UK3. Normally the spacecraft is covered with 12 panels of " solar " cells which provide electric power for the vehicle and experiments.

THE EXPERIMENTS

V.L.F. phenomena. The experiment by the Space Physics Group at Sheffield University is designed primarily to study the spatial and temporal characteristics of v.l.f. radiation (1 to 20 kc/s) above the ionosphere and, by means of on-board tape-recording, to provide a wide and uniform coverage in geographic and geomagnetic co-ordinates. This synoptic study of v.l.f. phenomena complements previous v.l.f. satellite studies (e.g. Alouette I, II, Injun III) where real-time observations of the more detailed dispersive and spectral characteristics of the signals have been necessarily limited to the vicinity of Minitrack stations.

One of the two main classes of v.l.f. phenomena is the **whistler**, generated in lightning discharges and observed mainly in medium latitudes. (This phenomenon, which has been known for 50 years, was first understood following the pioneer work of Storey at Cambridge in 1953. He showed that a small fraction of the pulse of energy at v.l.f., released during a lightning discharge, would travel along the earth's magnetic field line through the exosphere to the geomagnetic conjugate point in the opposite hemisphere. Since the higher frequencies travel faster along the field line the signal received is heard as a falling tone—hence the name whistler.) Studies of the dispersion of the whistler signal, at ground stations disturbed over a wide range of latitude, have yielded a great deal of information on electron density profiles at distances up to six earth radii.

Apart from whistlers there is also natural emission at v.l.f. This is a high latitude phenomenon occurring associated with the precipitation of charged particles (mainly electrons) principally in the auroral zones and along the earth's magnetic field lines. The two main classes of v.l.f. emission, **hiss** and **chorus**, are both closely associated with auroral phenomena. Hiss is a slowly varying noise-like signal, whereas chorus† is a complex mixture of discrete rising and falling tones hence its similarity to the sound emitted by a group of birds at dawn ("dawn chorus").

The v.l.f. observations in UK 3 will be made at three representative frequencies: 3.2, 9.6 and 16 kc/s; they are harmonically related to permit calibration from a single square-wave generator operating at the lowest frequency. At the highest frequency a wide (1 kc/s) and a narrow (100 c/s) pass-band centred on the Rugby station, GBR, will make it possible to study the field pattern from GBR as well as whistlers and v.l.f. emissions. On the three wide-band (1 kc/s) channels the peak, mean and minimum signals occurring in each 27-second period ($\approx$ 200 km) around the orbit will be recorded on the satellite tape-recorder. On the narrow-band channel the minimum signal only will be recorded. (In order to facilitate identification of the GBR signal the Admiralty will key their transmission during stand-by periods.

The aerial is a 14-turn screened loop, 3.0 m^2 in area, mounted with its axis along the spin axis of the satellite. The magnetic field sensitivity is approximately 10^{-10} oersted on each channel and each receiver has a logarithmic response with a dynamic range of 75 dB. Power consumption of the experiment is $\frac{1}{4}$ W and the receiver (containing 183 transistors) weighs about 6 lb.

Electron density measurement. Birmingham University has two experiments, one to measure electron density and the other to measure electron temperature. The density measurement is based on the dependence of the permittivity on the presence of electrons and effectively measures the variation in reactive impedance between two rhodium plated grid-type probes (Figs 1 and 2) due to the variation in ionization density.

In this experiment, a probing frequency of 39 Mc/s from a crystal-controlled oscillator is used, and after demodulation to extract the r.f. modulation produced by the interaction of the free electrons in the ionosphere and a chopped ramp signal applied to the sensor electrodes, the data is fed to the high-speed telemetry system. Before this data is suitable for storage on the satellite tape recorder prior to transmission on ground command, it is processed by a data storage unit contained within the module which selects the maximum value of electron density measured in a 27-second period.

Electron temperature measurement. The electron temperature experiment uses two rhodium plated spherical probes (Fig. 2) and relates the ratio of currents to these probes in the electron retarding region to the electron temperature.

Current to the two spherical electrodes is monitored by the circuit which automatically adjusts the potentials applied to the sensor to keep these currents in a fixed ratio. The module contains, in addition to this circuitry, some data processing amplifiers together with a waveform generator and power supply switching circuits, these last two items being common to both experiments. The function of the power supply switching is to operate each experiment alternately on and off for 5.1 seconds in order to reduce the power consumption and reduce the number of telemetry channels required. To simplify data reduction, this switching operation is synchronized to the high-speed encoder by means of a pulse supplied from the satellite encoder.

The density and temperature experiments will yield information on many aspects of the ionosphere which are, as yet, not fully understood. One of the most interesting regions of the upper ionosphere still to be explored is the polar region and the inclination of the orbit is such that investigation of the region can be continued in detail. As well as specific investigations the experiments will yield data on the general structure and behaviour of the upper ionosphere. There is also a need to carry out ionospheric investigations over a complete sunspot cycle and the measurements will extend existing data and will themselves yield information on the period approaching sunspot maximum. The combination of such a survey of density and temperature measurements with other extensive measurements of particle streams and solar radiation, should yield new information on the production, distribution and movement of ionization in the upper ionosphere.

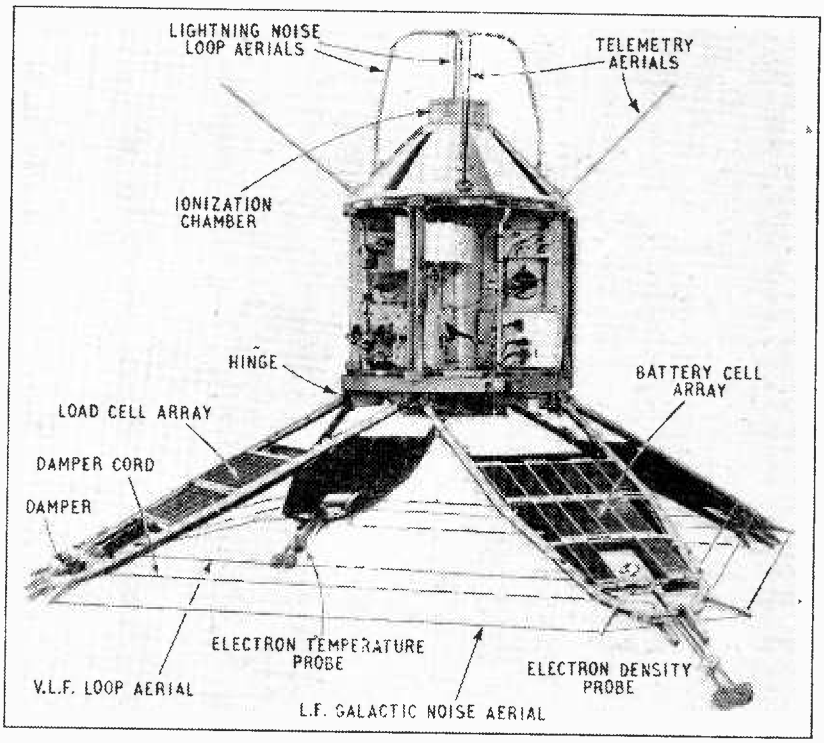


Fig. 1. Overall view of UK3 satellite showing the three loop aerials and other external parts.

† See, for example, "Chorus" by M. Lorant, Jan. 1965 issue p. 51.

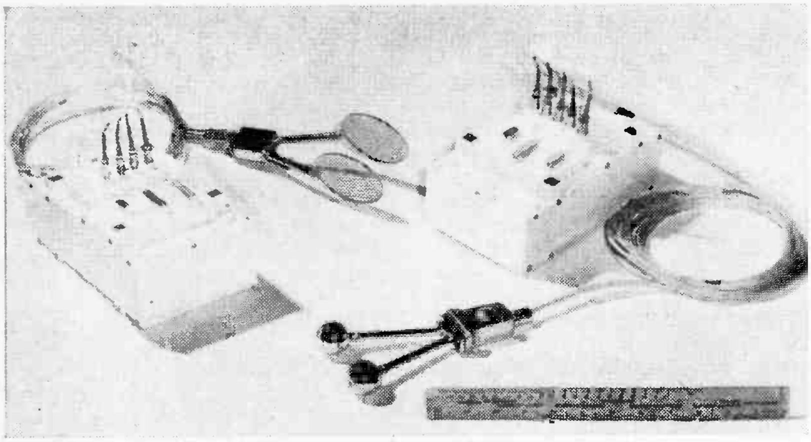


Fig. 2. Instrumentation for measuring electron temperature (spherical probes) and density (Birmingham University). To ensure good electrical connections between screened sections of the two modules, each part which is machined from Duralumin is gold plated to a thickness of 0.0001 in.

Jodrell Bank experiment. The purpose of the Manchester University radio astronomy experiment is threefold:—to measure the general "brightness" of the sky at frequencies too low to penetrate the ionosphere; to obtain low resolution data regarding the distribution of radiation across the sky by ionospheric refraction; and to study conditions within the ionosphere and radio signals originating within the ionosphere and exosphere.

A receiver immersed in the ionosphere, above the layer of maximum density and operating a little above the local plasma frequencies "sees" only a limited region of sky immediately overhead ("ionospheric focusing") thus providing directional information. The beamwidth is necessarily large because of the receiver bandwidth. In practice two plasma resonances occur—one for the ordinary and one for the extraordinary ray (*e*-ray). Only the latter will yield observations of ionospheric focusing since the former is masked by large signals believed to be of local origin.

The receiver sweeps in frequency from 4.7 Mc/s to 2.0 Mc/s. The output immediately above the *e*-ray "cut-off" should exhibit the focusing effect. At somewhat higher frequencies the receiver sees the whole sky.

The aerial is tuned by means of varactor diodes contained in a small matching unit at the tip of one of the booms. In order to ensure accurate tracking the aerial circuit is itself the tuned element in the local oscillator. The receiver is thus of the homodyne type, having the local oscillator in the centre of the r.f. band.

Oxygen measurement.—The Meteorological Office experiment is designed to measure the amount of molecular oxygen in the earth's atmosphere at heights of around 150 km. At heights above about 100 km most of the oxygen is broken up by ultra-violet radiation from the sun into the atomic form but small amounts of O_2 molecules persist to greater heights and by measuring these, and in particular their variation with latitude and longitude on the earth, more may be learnt about the photochemical processes and air movements at the heights concerned.

The technique, which has already been used successfully in the Ariel II satellite for the measurement of ozone (O_3), is to measure the light reaching the satellite from the sun using a detector sensitive in a region of the spectrum absorbed by the gas being studied—around 2800 Å for the ozone experiment in Ariel II and around 1450 Å for the oxygen experiment in UK 3. For most of each orbit, the light reaching the detector will be zero, when the satellite is in the earth's shadow, or a steady value corresponding to full sunlight, but for two short periods in each orbit when the satellite is entering or leaving the earth's shadow, the sun's rays have to pass tangentially through the atmosphere to reach the satellite (see Fig. 3) and the attenuation of the light at these times of sunset and sunrise provides a measure of the absorbing gas in the atmosphere.

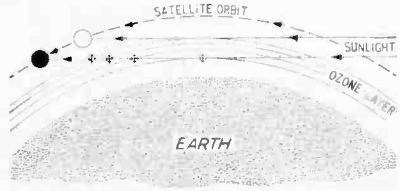


Fig. 3. Attenuation (recorded by ionization chambers) of sunlight through the atmosphere provides a measure of absorbing gas (oxygen).

The detectors used in the UK 3 experiment are small ionization chambers, with sapphire windows about 1 cm dia. filled to a pressure of 2 mm with p-xylene. The short-wave cut-off of the window and the ionization potential of the gas combine to give these chambers a narrow band of sensitivity from about 1425 to 1475 Å coinciding with the region of maximum absorption by oxygen. A disadvantage of these detectors is that the gas is slowly decomposed by sunlight, so that the life of the experiment in orbit is not expected to be more than a few weeks; even this rather short period will be enough to accumulate a large number of observations. Four ion chambers are used, mounted at 90° intervals in a cylindrical unit on top of the satellite, looking out between the satellite antennas with a good field of view fore and aft.

The operating potential (−33 V) for the ion chambers is provided by separate mercury-zinc batteries (duplicated for the greater reliability) encapsulated in epoxy resin. The current drawn is only about 10^{-11} A so that battery life is very long. The outputs from the four chambers are connected in parallel to the input of an electrometer amplifier which delivers 5 V output for an input of 10^{-11} A. The amplifier has an electrometer valve input followed by two transistors, with overall feedback through a resistance of $5 \times 10^{11}\ \Omega$. Some limitation of the open-loop gain at high frequencies is necessary to ensure stability. Individual amplifiers are temperature compensated by selection of components until the change of output over the range −10°C to 50°C corresponds to a change in input current of less than 10^{-13} A. The overall frequency response is limited mainly by stray capacities in the feedback resistors; the effect is minimized by a phase-correcting network and the typical time for 100% response to a current step function is 0.15 sec, with overshoot of about 5%. Current consumption of the amplifier is 20 mA.

The complete experiment, with ion chambers, batteries, amplifier and connecting leads, is assembled in a cylindrical Dural shell 18 cm dia. and 11 cm high (see Fig. 4). Temperature is monitored by thermistors at three points in the unit, on an ion chamber, on the inside of the shell

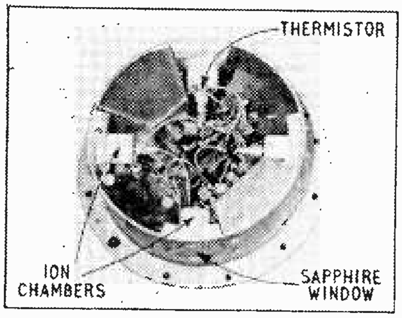


Fig. 4. Meteorological Office experiment showing the four oxygen ionization chambers. The outside of the shell and the lid are gold plated to comply with thermal and electrical requirements of the spacecraft.

and inside the amplifier. The electrometer valve, although inherently quite rugged, has to be specially mounted in foam polythene to avoid damage under vibration.

Terrestrial noise experiment. The aims of the experiment, sponsored by the Radio and Space Research Station, are to measure high-frequency atmospheric noise received in UK 3 and to deduce the distribution of the noise sources (lightning discharges) over the surface of the Earth as a function of time of day and season. These aims may be achieved if atmospheric noise is recorded at an altitude above that of the peak electron density of the ionosphere and at a frequency exceeding the critical frequency of the ionosphere by a known, small amount, so that the atmospherics are received only from storms near the sub-satellite point, since waves striking the ionosphere at oblique incidence do not penetrate. Because the critical frequency varies with geographical location, time of day and season, it is necessary for the measurements to be made at more than one frequency and they will be made at frequencies near 5, 10 and 15 Mc/s.

Operation is in the standard-frequency bands because there are few transmitters in these bands. Even so, it is possible that some interference from transmitters other than those in the standard-frequency service will be experienced. Two receivers will therefore be used in each of the bands, tuned to frequencies slightly above and below the centre frequency of the band so that any sporadic narrow-band interference, which will affect the receivers differently, may be recognized.

Satellite-borne equipment will therefore, during successive specified periods, measure the average voltage of the envelope of the noise received in three pairs of narrow-band channels in the standard-frequency bands near 5, 10 and 15 Mc/s and count the number of atmospherics with amplitudes exceeding a pre-determined threshold in these channels. The two types of measurement should ensure coverage of the wide range of signals expected from the intense thunderstorm areas of the tropics and the quiet regions at higher latitudes.

From these results, the distribution of the sources will later be mapped, using the transmission properties of the ionosphere; ideally, atmospheric noise will be received only from a circular region of the Earth's surface with a radius which increases as the ratio of the frequency of reception to the critical frequency of the F-region of the ionosphere below the satellite increase from unity.

Two orthogonal balanced screened loop aerials, each of effective area 0.12 m², project from the upper cone section of the satellite. The plane of each loop passes through the satellite spin axis so that, as the satellite rotates, a null in reception of signals from the ground cannot occur continuously.

Noise received on these aerials is fed through filter networks to six narrow-band receivers with effective overall bandwidth of 760 c/s and at 4 kc/s the response is 60 dB down.

For each channel, the average voltage of the noise envelope is measured and the number of atmospherics with amplitudes exceeding a specified threshold is counted over integration periods of 25.3 sec synchronized with the timing of the telemetry encoders of the satellite.

POWER SUPPLY SYSTEM

Only brief details of the UK3 power supply system have been discussed previously in *Wireless World* and thus further details are perhaps apposite.

Power for the experiments and the spacecraft generally is provided by silicon photovoltaic cells (Ferranti), commonly known as solar cells. These provide maximum power at about 350-400 mV and with a drain of 50-60 mA. The load power required is 5 W, but due to various factors, the number of cells used for a design lifetime of one year is 7,400. Some of the factors which lead to the use of this large number of cells

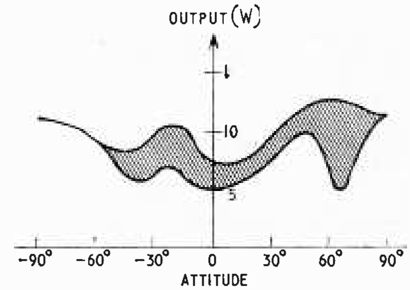


Fig. 5. Variation in output from battery charging cells due to spinning and change of satellite attitude in relation to sun.

are the amount of time spent in darkness (about 1/3rd), the inefficiency of the battery charging process, the varying illuminated array area, the varying cell temperature and electron bombardment, degrading power output. Fig. 5 indicates the variation in output from the charging cells due to spinning and change of satellite attitude in relation to the sun. Random shadowing of the solar arrays during spinning causes power output to vary within the shaded area, so that for an attitude of 60° the available power from the array will vary between 7 and 13 W.

For the **oxygen experiment,** the satellite is required to maintain its design attitude (±45°), but the life of this experiment is only expected to be a fraction of the year, so it is required that the solar cells be capable of powering the equipment whatever the direction of sunlight. (Thus if the design attitude is not achieved, only the m.o. experiment will be affected.) To meet this requirement the cells are mounted on the cylindrical part of the body and on both sides of the four booms.

Two sets of series-parallel arrays are used, one supplying power to the load, and the other to the battery. The system is arranged to permit the battery charging cells to power the load should, for instance, the batteries fail. The battery consists of 12 sealed Ni-Cd cells with a capacity of 3 Ah. Charge is regulated at constant current and then at constant voltage, the characteristic being modified to suit battery temperature. If the battery voltage falls below 14 V, it is disconnected and put on trickle charge. A drop to below 9 V causes permanent disconnection, giving daylight-only operation. Voltage supplies are ±6 V and two ±12 V rails, these being derived by way of six 1% voltage regulators.

LETTERS TO THE EDITOR

The editor does not necessarily endorse the opinions expressed by his correspondents

Television Receiver Sound Quality

I HAVE read your report on the recent B.B.C. seminar on Music on Television, and would like to comment on it.

It is certainly true that the vast majority of viewers do not seem to be greatly concerned with the audio frequency response of their television receivers. The biggest limitation in this frequency response is due to the size of loudspeaker fitted for styling reasons. However, most manufacturers have in their range either larger table models or consoles, with larger speakers and baffles, with a considerably wider acoustic frequency response. Since these receivers cost more to make, their selling price is inevitably higher and unfortunately the number of people who wish to pay this price is so limited that the production of these types is hardly justified.

I would also protest at the suggestion that I was relieved to escape from a hostile situation. I was in fact quite enjoying putting across the commercial facts of life to those who live on the licence payers' money.

M. A. E. BUTLER
(Technical Commercial Manager)

Philips Electrical Ltd.,
Croydon, Surrey.

c/s or Hz?

I WAS interested in the Editorial of your January issue and think that it might be useful to explain the exact situation in the I.T.U. on the use of Hertz for the unit of frequency.

A long discussion on this subject took place at the I.T.U. Administrative Radio Conference which, in 1959, adopted the current Radio Regulations. As a result, it was agreed to use Hertz in documents in French, but to maintain cycles per second in English and *ciclos por segundo* in Spanish. This practice was also followed by the Plenipotentiary Conference—the supreme organ of the Union—in 1965.

As you mention, the Plenary Assembly of the C.C.I.R. recommended that in future Hertz should be used for the unit of frequency, and in fact decided that it should be introduced forthwith in documents published by the Specialized Secretariat of the C.C.I.R.

However, as regards documents published under the provisions of the Radio Regulations, we are obliged to continue to respect the decision of the 1959 Conference until such time as those Regulations are amended by an appropriate conference. We do not yet know when such a conference is likely to be convened.

C. STEAD
(Counsellor)

International Telecommunication Union,
Geneva.

Graphical Symbols

I WAS astounded to read your editorial opinion of BS 3939 (in the January issue) and would like to draw attention to the attitude which you adopted to the transistor symbol. For ten years you obstinately defied the B.S.I. and most of the world by persisting with a non-standard symbol for the transistor, and then you suddenly and furtively changed camps. Are you now intending to repeat this cycle with the proposed resistor symbol?

There is more in this than simply one symbol. There is a great principle here which, I believe, will be upheld by all scrupulous engineers, and it is that a universal standard should be followed even if the majority are against it, because any universal standard at all is better than any other which is not universal.

Your last paragraph is particularly painful to me. If, as you suggest, the B.S.I. exists merely to give formal, unnoticed, ratification of established practices, then what possible reason can there be for its existence?

We all know that if we have two circuits before us, one in familiar and the other in strange symbols, we pick up the familiar one first, and probably don't get round to the other at all. Maybe this is partly why we export only 3% of our sound radio receivers as "Vector" reported last month and perhaps we could all do better for ourselves by becoming accustomed to European standards instead of going slowly bankrupt in splendid isolation.

R. COUVELA

Farnham, Surrey.

Speed Control of Small Motors

WHILE the electronics are impeccable in Mr. Estaugh's October 1966 article on speed control of small motors, the electrical side is open to criticism. He claims (and I suspect that he has been led astray by others in this) that the speed is independent of load in his idealized switching arrangement, and that the efficiency is of a very high order.

This error seems to arise from considering a motor to be a resistive load, whereas it is in fact a source of e.m.f., independent of the current passing (over short periods of time). Speed is by no means independent of the load (such as gradients and curves on a railway) and the efficiency (which broadly is not important for models) at say a 1 : 9 mark space ratio is, however, only 10%!

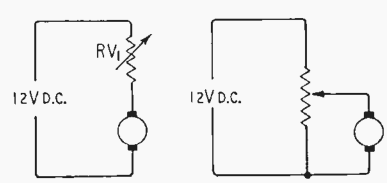


Fig. 1. Left, the control system mentioned by Mr. Estaugh and, right, Mr. Stewart's method.

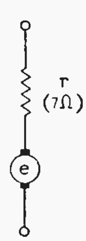


Fig. 2.

Fig. 3.

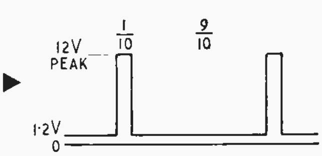
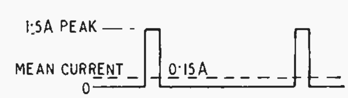


Fig. 4.



Now it is true that the conventional control (his Fig. 1a) is both inefficient and gives the very poor speed regulation he demonstrated, but a much better regulated system is simply the potentiometer as in my Fig. 1.

The potentiometer will be required to dissipate over 12 W with the usual small motor taking up to 1 A starting and about 0.5 A running.

Taking a typical model motor with an armature resistance (r) of 7 Ω (Fig. 2) comparisons are as follows for a pulse lasting 1/10 of a cycle. In practice this would be too short to give adequate *motor* power but it helps in the arithmetic!

The motor inertia must be sufficient to carry over from one pulse to another without significant drop in speed or, which is the same thing, the pulse repetition must be high enough, as stated in the original article.

Let the motor speed be 1/10 of maximum then the back e.m.f. is 1.2V and the current drawn is as follows (we must assume that this current is sufficient to maintain this speed against the load on the motor) (Fig. 3).

Current during each pulse =

$$\frac{\text{Supply volts (12) less back e.m.f.(1.2)}}{\text{Armature resistance (7 }\Omega\text{)}} = \frac{10.8}{7} = 1.5\text{A}$$

and the mean current is 1/10 of this, i.e. 0.15A (Fig. 4).

(This mean current is just an arithmetic value and does not exist as such, being quoted for comparison below with a steady current; on the other hand, the value of 1.2V does exist and the waveform (Fig. 3) could be displayed on a c.r.o.)

Note: That the motor power (that is, the power converted to mechanical form) is 1.2V × 1.5A for 1/10 cycle or 0.18W continuous, but input power is 12V × 1.5A for 1/10 cycle or 1.8W continuous and hence the efficiency is 10%.

Now let an increase in load result in a reduction of speed to half its previous value. Back e.m.f. now falls to half, i.e. 0.6V.

Current is now

$$\frac{\text{Supply volts (12) less back e.m.f.(0.6)}}{\text{Armature resistance (7)}} = \frac{11.4}{7} = 1.63\text{A}$$

and mean current is now 0.163A, an increase of about 10%.

Compare the effect of supply from a low resistance (say 1 ohm) source which could be a regulated supply or the lower end of a potentiometer of high wattage.

Initial conditions:—current as before 0.15A and back e.m.f. 1.2V.

Voltage applied to motor is back e.m.f. (1.2) plus armature resistance drop (7 × 0.15) = 2.25V; and source voltage in a 1 ohm power unit = 2.25V + 0.15V = 2.4V. Now let speed drop to half as before and back e.m.f. consequently to 0.6V. Current is now $\frac{2.4-0.6}{8}$ = 0.22A an increase of 50% which is much better than using the pulse method and will go some way to restore the speed.

It is interesting to note that to maintain truly constant speed, the output voltage of the power unit must *rise* with the increase in current to compensate for the armature resistance.

It might be wondered where the 90% of the energy goes since the transistor dissipation is negligible—it appears as heat in the resistance of the armature winding.

D. R. STEWART

Newport, Mon.

Semi Satellites

RECENT discussions in your columns regarding the future of broadcasting in Britain invariably acknowledge that a synchronous satellite system (costing in the region of £100M) will be the answer to all our problems. Once a quasi-optical path has been established with all its benefits, everything in the frequency spectrum garden will be rosy, and direct broadcasting of various sound and television services can easily be achieved.

A stable platform hovering at 40,000 feet would be in radio line of sight to all areas within a 250 to 300 mile radius. Positioned appropriately this could cover over 90% of the listening and viewing population. With the number of line-of-sight frequencies usable over this area the mind boggles at the many possibilities that this "radio platform" could be used for, in addition to the country's broadcasting services.

Of course, the more down-to-earth reader will want to know who is going to wave the magic wand regarding the "stable platform"? It will be recalled that in the United States an aircraft flying a figure of eight pattern over a predetermined area at the appropriate height, provides educational television programmes to schools in the midwest. However, with the recent discovery of unlimited helium supplies in Canada, an up-to-date version of an airship with station keeping capabilities would probably be more realistic. When the price of a satellite system is so high, and the possibility of failure so great, surely it would be a lot cheaper to concentrate on these "Semi-Satellites" which, incidentally, would be repairable in the event of a fault and not a write off.

J. H. KNOX

Plymouth, Devon.

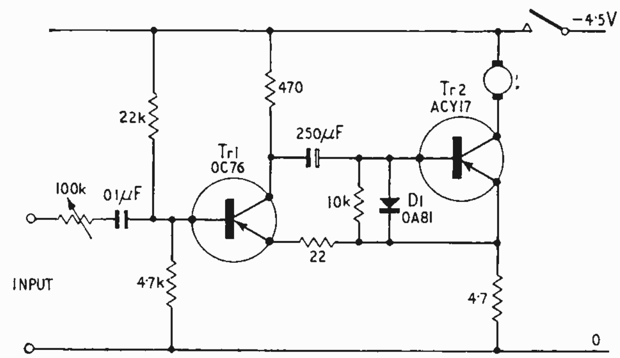
Tactile Recording Level Indicator

AS an alternative to the audible warning device described by Mr. Murray Ward in the July, 1966, issue, it was thought that a description of a warning device which utilizes a blind person's sense of touch might be of interest.

The present device is built into a portable radio case 6in × 4in × 1½in; a large case is obviously cumbersome, too small a case is also awkward. Two-thirds of the case is occupied by a 4½ V battery which has a life of several months and also serves to weigh down the device. The space left is occupied by an electric motor and the circuitry.

The electric motor is the output element and is a "Mighty Midget" type with a reduction drive. A knob fixed to the gear shaft projects through the side of the case where a finger may be conveniently rested on it.

The circuit is a form of monostable with Tr1 conducting and Tr2 cut off. It is unusual in that the first



stage amplifies the input signal fairly linearly until switching occurs. D1 is to shorten the paralysis time on switching back. Without this diode the device remains insensitive for about two seconds after the knob has moved and fails to indicate any overloads during this time. The high sensitivity obtained by this system enables the device to be connected to low level monitor outputs of relatively high impedance.

Setting up is done by adjusting the potentiometer (possibly in conjunction with a fixed resistor) so that the knob just pulses when the tape recorder magic eye shows maximum recording level.

This method of indication is obviously of benefit when a microphone is being used, for example, when a blind person wishes to record a message to send to someone.

G. J. ANDRIESSEN

Downend, Bristol.

Electronics Amateurs

THE British Amateur Electronics Club was formed to enable all those who are interested in electronics as a hobby to get together and communicate through our Newsletter for the furtherance of this most interesting hobby. Unfortunately, the most interesting of modern electronic devices, integrated circuits, are out of our reach with our limited funds.

I am sure that there are many readers, and also contributors to your excellent magazine, who remember the frustrations in the early days of radio when they, as amateurs, were not able to find out for themselves how the valve worked or make that particularly sophisticated radio set due to the extremely high price of newly developed devices. A considerable amount of ingenuity was shown in those days by amateurs.

As chairman of the B.A.E.C. I would like to express my appreciation of the co-operation shown to us by various integrated circuit manufacturers in giving us full details of their devices. I hope you will publish this letter and that one of them will help by allowing us to buy small quantities of their devices at, say, the 1,000 off price, so that we can experiment with them.

C. BOGOD

Penarth, Glam.

FEBRUARY MEETINGS

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

LONDON
1st. B.K.S.T.S.—"The television transmission of cine film" by A. B. Palmer at 7.30 at C.O.I., Hercules Rd., S.E.1.
5th. I.E.E.—"Audio in the home" by Dr. G. F. Dutton at 5.30 at Savoy Pl., W.C.2.
8th. S.E.R.T.—"Amateur Transmitting equipment" by R. G. Shears at 7.0 at the London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.
8th. B.K.S.T.S.—"Holography—third-dimensional pictures of the future" by A. E. Ennos at 7.30 at C.O.I., Hercules Rd., S.E.1.
10th. R.T.S.—"PAL studio operation: a first look at the problems" by Dr. G. B. Townsend at 7.0 at I.T.A., 70 Brompton Rd., S.W.3.
15th. I.E.R.E.—"The remote control of lighthouses and beacons" by A. C. MacKellar & M. J. Dilworth at 6.0 at 9 Bedford Sq., W.C.1.
15th. B.K.S.T.S.—"Magnetic soundtrack duplication" by N. Leevers at 7 30 at C.O.I., Hercules Rd., S.E.1.
22nd. I.E.R.E.—"A dual standard colour television receiver" by P. L. Mothersole, D. S. Hobbs and D. J. King at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.
22nd. B.K.S.T.S—"Colour television for the layman" by H. V. Sims at 7.30 at I.T.A., 70 Brompton Rd., S.W.3.

BASINGSTOKE
9th. I.E.R.E.—"Introduction to digital computers" by E. G. Anderson at 7.30 at the Technical College.

BOURNEMOUTH
22nd. I.E.R.E.—"Development of satellite communications" by J. K. S. Jowett at 7.0 at the College of Technology.

BRADFORD
9th. I.E.R.E.—"Digital logic" by F. Houldsworth at 7.0 at the Institute of Technology.

BRIGHTON
14th. I.E.R.E.—"Flight simulation" by R. A. Marvin at 6.30 at the College of Technology.

BRISTOL
14th. I.E.R.E. & I.E.E.—"Colour television" by H. V. Sims at 7.0 in the Small Lecture Theatre, the University, Clifton.

CAMBRIDGE
2nd. I.E.R.E. & I.E.E.—"A simplified approach to the use of transistors in video, pulse and i.f. circuits" by E. Davies at 8.0 at the University Engineering Dept., Trumpington St.

CARDIFF
8th. I.E.R.E.—"Transmission measuring equipment for telecommunication systems" by H. M. Evans at 6.30 at the Welsh College of Advanced Technology.
10th. R.T.S.—"The colour in colour television" by M. Turner at 7.30 at Llandaff Technical College, Western Ave.

CHELMSFORD
16th. I.E.R.E. & I.E.E.—"High-frequency guided waves in application to railway signalling and control" by Prof. H. M. Barlow at 6.30 at the Tech. High School.

EDINBURGH
14th. I.E.E. & I.E.R.E.—"Computer aided study of character recognition" by J. A. Weaver at 6.0 at the Carlton Hotel, North Bridge.
23rd. I.E.E. & I.E.R.E.—"Some modern advances in scintillation scanners and cameras" by W. G. Walker at 6.0 at the Carlton Hotel, North Bridge.

GLASGOW
13th. I.E.R.E.—"Computer aided study of character recognition" by J. A. Weaver at 6.0 at the University of Strathclyde.
14th. S.E.R.T.—"Video tape recording" by N. Vassie at 7.30 at STV Studios, Hope St., C.2.

LIVERPOOL
22nd. I.E.R.E.—"G.P.O. towers" by S. G. Young at 7.0 at the College of Technology.

LOUGHBOROUGH
9th. I.E.E.T.E.—"Circuits and machines" by A. Draper at 7.0 in the Assembly Hall, Edward Herbert Building, University of Technology.
14th. I.E.R.E. & I.E.E.—"Stereophonic sound reproduction" by J. Moir at 6.30 at the College of Technology.

MALVERN
14th. I.E.R.E.—"Speech synthesis by R.R.E.A.C. digital computer" by P. M. Woodward at 7.0 at the Abbey Ballroom.

NEWCASTLE-ON-TYNE
1st. S.E.R.T.—"Transducers; outlines of types and applications" by G. McEwan at 7.15 at Charles Trevelyan Technical College, Maple Terrace, 4.
8th. I.E.R.E.—"The Stereoscan electron microscope" by I. H. Gordon at 6.30 at Inst. of Mining & Mechanical Engrs., Neville Hall, Westgate Rd.

NEWPORT, I.o.W.
3rd. I.E.R.E.—"M.O.S. transistors" by G G. Bloodworth at 7.0 at the Technical College.

SALISBURY
23rd. S.E.R.T.—"Microwave techniques and applications to radar" by S. V. Judd at 7.0 at the College of Further Education.

SLOUGH
21st. I.E.R.E.—"Pulse code modulation" by J. R. Jarvis at 7.30 at the Lecture Theatre at Slough College.

SOUTHEND
28th. I.E.R.E.—"Adaptive astable/monostable circuits in class D amplifiers" by D. C. Smith at 7.0 at the College of Technology.

STAFFORD
14th. I.E.R.E.—"Railway control and signalling" by J. H. Fews at 7.15 at the College of Further Education, Tenterbanks.

SWINDON
15th. I.E.R.E. & I.E.E.—"Television recording" by P. Leggat at 6.15 at The College.

TORQUAY
21st. I.E.R.E. & I.E.E.—"Automatic landing systems" by R. A. Bailey and J. Meadows at 7.0 at the South Devon Technical College.

Electronic Tachometer

TRANSISTOR INSTRUMENT MEASURING ROTATIONAL SPEED IN R.P.M.

By S. L. V. CHARI, M.Sc., Ph.D., and M. R. K. RAO, B.E.

Low cost and absence of mechanical coupling are features of this electronic tachometer. Range: 0 to 12,000 r.p.m. Uses electromagnetic sensor, standardized pulse generator and time averaging arrangement. Accuracy: not worse than 0.5%.

ROTATIONAL speed may be defined as the time rate of angular motion. A knowledge of the precise time rate of angular motion in rotating machinery is extremely important to the engineer for a variety of purposes, such as, for example, the determination of inertia forces in the reciprocating parts of an engine or the horse-power transmitted by the crankshaft.

Many mechanical and electrical instruments are available for measuring rotational speed, but usually these require positive mechanical coupling with the rotating part. Further, they become expensive if high accuracy is desired. On the other hand electronic r.p.m. indicators have several attractive features such as compactness, elimination of mechanical coupling and high degree of accuracy. However, these instruments also suffer from the handicap of being costly. Therefore, an attempt has been made to develop an electronic tachometer which combines all the above advantages and at the same time is less costly than similar instruments available commercially.

Measurement of frequency or r.p.m. by electronic means can be accomplished by measuring the average value of a train of standardized pulses which are triggered by incoming signals produced by a magnetic pick-up device. Since the pulses are standardized, the time average is directly proportional to the frequency of the pulses.

Dr. S. L. V. Chari, who received his M.Sc.(Wireless) at Andhra University, has for the past six years been in charge of the instruments section of the Internal Combustion Engineering Department of the Indian Institute of Science, Bangalore. He recently received his doctorate from the Indian Institute of Science for research and development of several electronic instruments for engine research. Before joining the staff of the institute he worked for 15 years in the electronics industry both in India and Europe. He is 46.

M. R. K. Rao, who is 54, graduated in mechanical engineering in 1934 at Mysore University, and has since worked in the fields of automobile engineering and internal combustion engines. From 1957 until a few months ago he was in charge of the internal combustion engineering department at the Indian Institute of Science, Bangalore. He is now working in the College of Engineering, Riyadh, Saudi Arabia.

For any given pulse frequency the meter reading is proportional to the standardized pulse width and amplitude as well as to the input frequency. A transistor monostable multivibrator generates standardized pulses and a milliammeter in series with the normally-"off" transistor collector provides a reading proportional to the input frequency. The amplitude of the single-shot pulse used as a standardized pulse is essentially proportional to the supply voltage and, therefore, the milliammeter reading for any given input frequency is nearly proportional to the supply voltage. Since the circuitry is symmetrical in so far as the emitter and collector circuit loads are concerned, the supply drain is independent of the duty cycle of the monostable multivibrator and hence is independent of the input frequency or pulse width of the single shot.

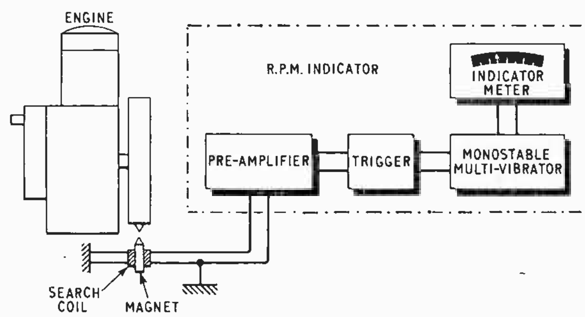


Fig. 1. System used to measure rotational speed of an engine.

A transistor preamplifier coupled to the electromagnetic pick-up with a Schmitt trigger circuit provides adequate sensitivity and allows operation on sinusoidal waves.

Based on the above principle, an electronic r.p.m. indicator, consisting of an electromagnetic pick-up, preamplifier, trigger circuit, monostable multivibrator and power supply unit, has been developed to indicate rotational speed directly on a milliammeter. Fig. 1 is a schematic showing the use of the tachometer to measure the rotational speed of an engine shaft.

The electromagnetic pick-up.—A ferrous pointer is fixed to the rotating part—in our case an engine shaft. A permanent magnet $\frac{1}{8}$in diameter and 4 in long, over which 3,000 turns of 42 s.w.g. enamelled copper wire are wound, forms the pick-up device. The unit is fixed rigidly to the engine framework and close to the shaft so that the rotating pointer comes very near the tip of the magnet once in each revolution and induces an alternating e.m.f. in the pick-up coil. The resulting current in the closed circuit is in such a direction that its own field opposes the original change. The generated pulse varies according to the sharpness of flux linkage, which depends on the speed of rotation of the shaft. The pulse is affected

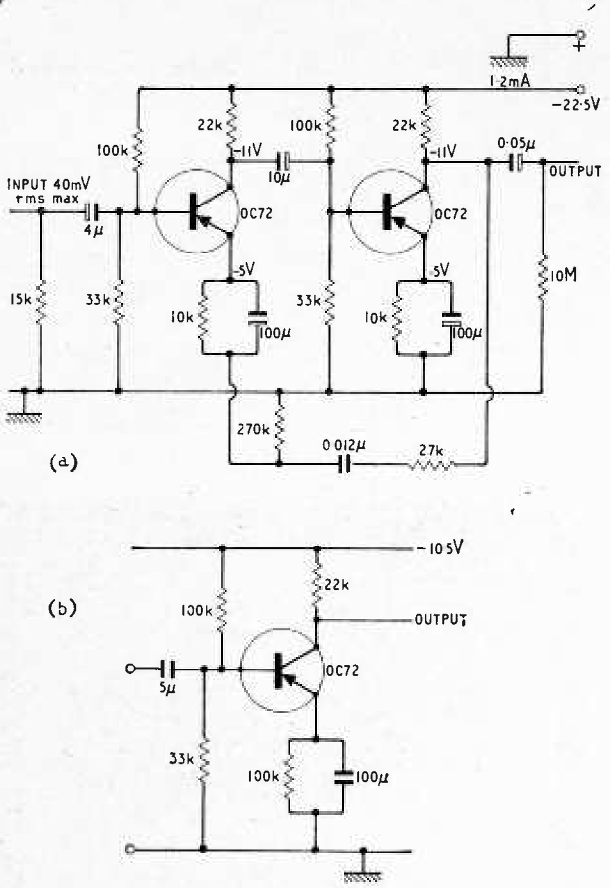


Fig. 2. Pre-amplifier (a) using two transistors and (b) lower-gain version with one transistor.

also by the spacing between the magnet and the rotating pointer. This induced pulse is fed to the pre-amplifier.

Pre-amplifier.—The pre-amplifier is designed to suit the signals from the low-impedance, variable reluctance type of pick-up unit described above. A two-stage amplifier as shown in Fig. 2(a) is constructed with Mullard OC72 transistors, having negative feedback to improve the linearity of the amplifier and stabilize the operating gain. Two identical grounded emitter stages are connected in cascade to operate from a collector supply potential of 22.5 volts. A substantial portion of the battery voltage is dropped in the large emitter supply resistors to ensure good d.c. stability against variations in temperature as well as a high degree of circuit immunity to varying transistor parameters. The battery voltage is limited to the output voltage swing of the amplifier of approximately 4 V r.m.s. with a maximum allowable input signal of 40 mV r.m.s. at 1 kc/s. The feedback circuit can be seen in the lower part of (a).

A stage gain of 40 dB is obtained with the two transistors developing a voltage gain of 75 dB collectively, with the feedback inoperative. When the feedback loop is closed, the total gain at 1 kc/s is nearly 40 dB.

The minimum input signal required to operate the Schmitt trigger circuit (described in the next section) is of the order of 0.3 volts r.m.s. with a small resistance in the input stage of the trigger circuit. Since the high gain mentioned above is not really necessary the pre-amplifier can be modified as shown in Fig. 2(b) by using a single transistor to give the required output. The pre-amplifier is coupled to the trigger circuit by a 1 μF capacitor with a 10 Ω resistor in series.

Trigger circuit.—A Schmitt trigger circuit is used to operate the multivibrator so that an output signal is obtained whenever the input signal voltage is approximately equal to the voltage at the base of the trigger. Two OC 72 transistors are used in the trigger circuit as shown in Fig. 3.

Three series resistors of 10 kΩ, 27 kΩ and 120 kΩ are used so that the transistor Tr3 is kept in the "off" state as long as there is no input signal to transistor Tr2 which would be in the "on" state. When the input signal reaches a value of about 0·5 V, the monostable multivibrator is triggered by the conduction of Tr3. The trigger circuit provides adequate sensitivity with an input signal ranging from 0·5 to 30 volts.

Monostable multivibrator.—The monostable multivibrator circuit shown in Fig. 3 generates the standardized pulse, using two OC 72 transistors. It is coupled to the trigger circuit by a 680 pF capacitor. A milliammeter in series with the normally "off" transistor collector

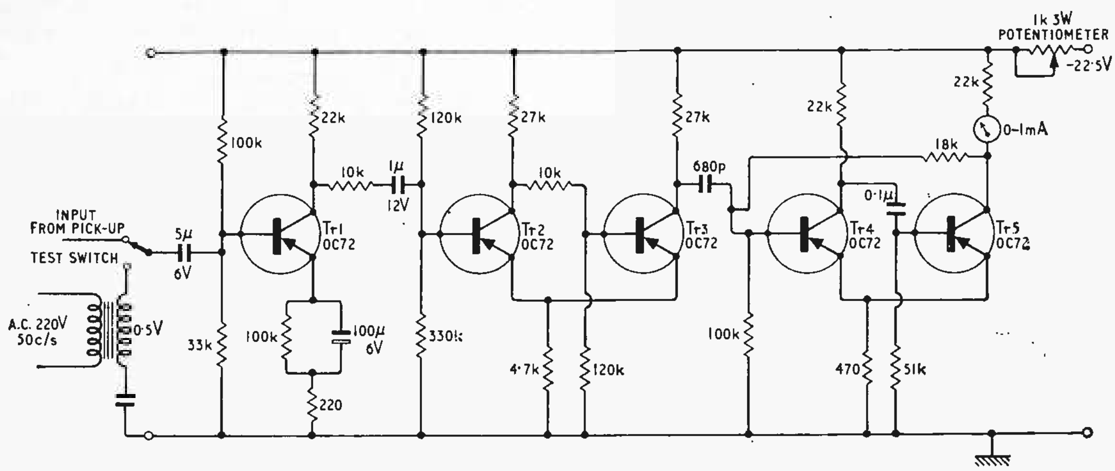


Fig. 3. Complete circuit of tachometer showing Schmitt trigger and standardized pulse generator.

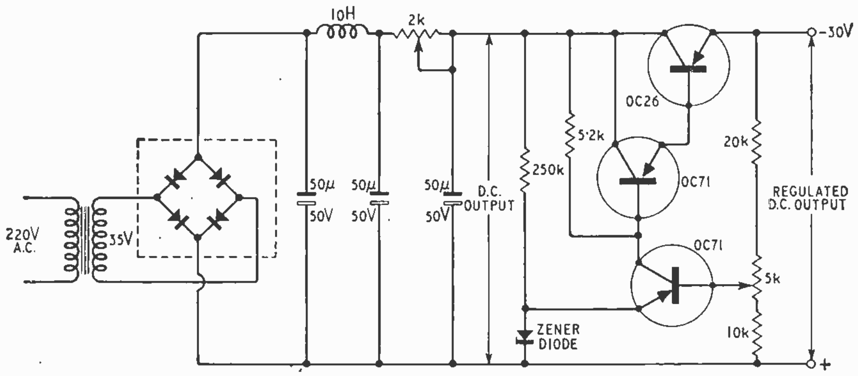


Fig. 4. Power supply unit for the tachometer.

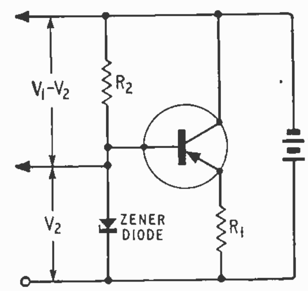


Fig. 5. Stabilization arrangement when power is supplied from a battery.

provides an indicating pointer deflection proportional to the input frequency.

The power supply unit, shown in Fig. 4, can be operated from a.c. mains. A full-wave bridge circuit with four SR 100 diodes and a stabilising circuit, using one OC 26 and two OC 71 transistors, with a zener diode for reference voltage, gives a stable voltage with a stabilizing ratio of 1,000 and an output impedance of 1·0 ohm. It can also be operated with a battery, in which case the current drain is less than 10 mA. Greater accuracy can be obtained by stabilizing the battery voltage, as shown in Fig. 5.

Indicating instrument.—A d.c. moving coil milliammeter of very low internal impedance (70 ohms) with a range of 0-1 mA is used, in series with the collector of the "off" transistor, to read r.p.m. directly. Calibration is carried out by means of a standard frequency meter. The indicator can be checked by feeding a fraction of the 50 c/s a.c. supply (0·5 volts) to the input of the instrument through a test switch as shown in Fig. 3, and this will produce a constant deflection of the pointer corresponding to the supply frequency.

Speed ranges.—The tachometer can be used for any speed range by suitably changing the value of the monostable coupling capacitor. Also, the input pulse rate can be varied by increasing or decreasing the number of ferrous pointers on the rotating shaft. Since the meter reading is proportional to the input frequency, the same instrument can be used for high or low speeds and maintain high accuracy at all speeds by altering the number of ferrous pointers inversely with speed. Tests have shown that the spacing of the rotating pointers and the size of the gap between them and the pick-up unit are not critical. Calibration of the tachometer with a frequency meter shows that the maximum error is 0·5%, as indicated in the table.

Comparison of electronic tachometer readings with other speed indicators, using electric dynamometer up to 5,000 r.p.m. and a.f. oscillator from 5,000 to 12,000 r.p.m.

Electronic tachometer	Other tachometer	Strobotac	Frequency meter	Current (μA)
1,000	1,020	1,024	1,004	100
1,500	1,515	1,520	1,505	150
2,000	2,006	2,007	2,008	200
2,500	2,480	2,475	2,510	250
3,000	2,996	3,006	3,015	300
3,500	3,494	3,498	3,520	345
4,000	4,032	4,006	4,020	390
4,500	4,534	4,510	4,520	435
5,000	5,066	5,008	5,025	480
6,000	—	—	6,030	560
7,000	—	—	7,025	640
8,000	—	—	8,030	720
9,000	—	—	9,025	795
10,000	—	—	10,040	870
11,000	—	—	11,035	935
12,000	—	—	12,040	1,000

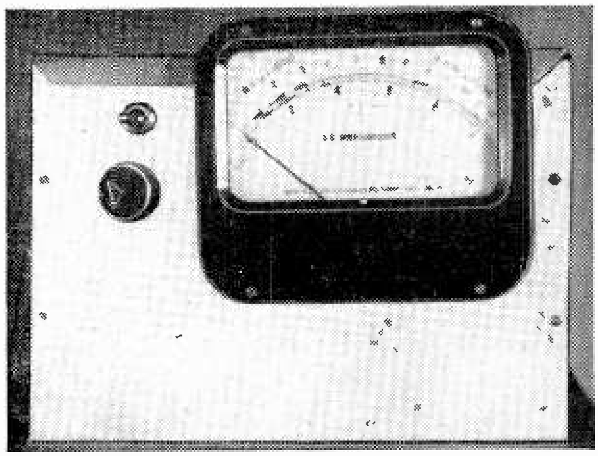


Fig. 6. Complete instrument, with 0—1mA meter calibrated in r.p.m.

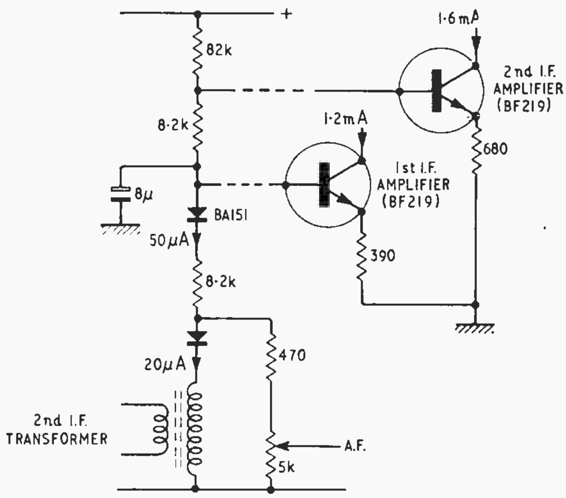
The complete instrument is shown in Fig. 6; its dimensions being 6in × 4in × 4in. It has been used for several hundred hours on an engine and has given good service.

Performance.—The electronic tachometer as described eliminates the need for mechanical coupling with the rotating shaft. The trigger circuit has adequate sensitivity and stability to respond to a wide range of input signals (0·3 to 30 volts). A reading proportional to the input frequency is given by the milliammeter. Power supply drain at 20 volts is of the order of 0·3 watt and the instrument can be worked either with a dry battery or with a transistor regulated low voltage power supply operating from 220 V a.c. mains. Maximum error is ± 0·5%. The response to variations in speed is linear and the deviation from linearity is negligible between specified speed ranges.

SILICON TRANSISTOR BIAS CIRCUIT

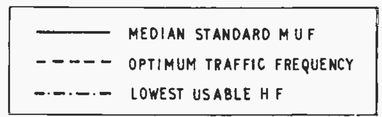
TO ACCOMPANY the recently introduced range of silicon "entertainment" transistors by Thorn-AEI (Mazda brand name), a number of circuits have been developed for domestic equipment. In the receiver designs, special features are employed to minimize the collector current variation with supply voltage in the i.f. stages, necessary because the base characteristic shows a higher forward voltage drop than in germanium transistors, which gives a greater dependence on supply voltage than is the case of germanium transistors, because this voltage is a larger proportion of the supply. One possibility would be to use high value emitter resistors, but this was eliminated since, for one thing, a.g.c. performance would be degraded. A circuit which gives adequate stability against a fall in supply voltage is shown in the accompanying diagram. The circuit is part of a complete a.m. receiver design developed to give a performance equal to that from receivers designed along well-established lines and using post alloy diffused germanium transistors.

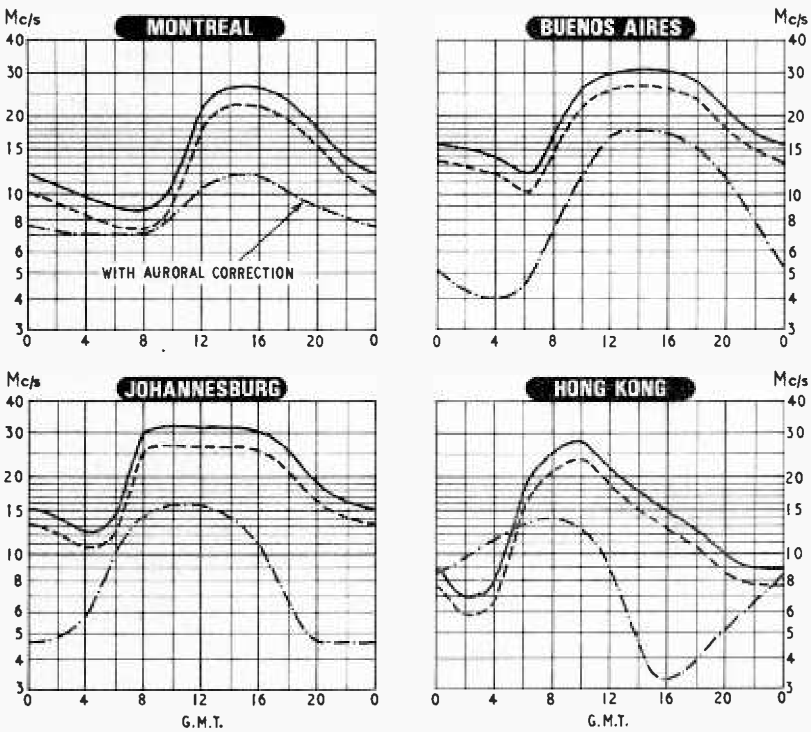
A method of stabilizing base voltage is to use a silicon diode in the lower part of the base potential divider, the diode clamping the base to earth by its forward voltage drop. If a low-value emitter resistor is used giving a base-earth potential of greater than a "diode-worth" of voltage drop, then a further bias diode may be added, either silicon or germanium, or a resistor added, depending on the degree of stabilization and the bias voltage required. Some economy can be obtained by using a diode in this position as a signal and a.g.c. rectifier and the circuit shown uses this technique. Two diodes and a resistor provide the bias for the first i.f. amplifier and a further resistor is added for the second i.f. amplifier. For rectification a germanium diode is preferred, this necessitating the resistor in the lower part of the base potential divider. It was determined experimentally that the least distortion in the detector



was given by a rectifier diode bias of about 20 μA and this accounts for the split in the bias chain, 30 μA passing through the 5 kΩ a.f. gain control. The a.g.c. time constant is determined by the 8 μF capacitor shown.

H. F. PREDICTIONS FEBRUARY





The prediction curves show the median standard MUF, optimum traffic frequency and lowest usable frequency (LUF) for reception in this country. When atmospheric noise at a receiving site is at a high level and/or the signal traverses a region of high absorption, the LUF for a required signal-to-noise ratio increases. When it exceeds the MUF this required ratio is not obtained, the deficiency being very approximately 10 dB for each 1.5 Mc/s difference.

The LUF curves were drawn by Cable & Wireless Ltd. for commercial telegraphy using transmitter powers of several kilowatts and rhombic type aerials, but they indicate when reception of a particular frequency would be difficult or unsatisfactory for any type of service.

An Introduction to Microwave Ferrite Devices

1.—THE DEVICES AND THEIR BASIC THEORY

By K. E. HANCOCK*

IN the face of the recent sensational advance toward higher frequency applications of transistors and specialized diodes, a "quiet revolution" downwards in frequency of another increasingly important group of semiconductors, the microwave ferrite devices, has gone on almost unheralded.

These comparatively new components, which have no real equivalent in the lumped constant, low frequency, field can now be used down to at least 30 Mc/s. The application of microwave ferrites, as the name implies, had previously been restricted to the microwave frequency band, so before we go into detail of the theory and practice of these circuit elements, it might be as well to be a little more explicit as to what is meant by the term microwave ferrite device, and to give a very brief description of the function and application of the basic components.

For the purposes of this article we may define a microwave ferrite device as any component that uses the inter-action between a magnetically biased ferrite material and the incoming signal to modify in any given manner that incoming signal. To clarify that, let us see just what these devices do and how they are used.

The most common component is perhaps the isolator (see table). Basically this may be regarded as a non-reciprocal attenuator.

Another quite commonly used device is the circulator. Again this is a non-reciprocal component and is a three or more port device. Little known in the communications field but very common in radar, where it is used to sweep electronically beamed aerials, is the ferrite phase shifter (in table). It will be shown later that these may be reciprocal or non-reciprocal, tunable or step, latching and non-latching. They are, of course, electronically actuated; this, and the speed of actuation, being the paramount advantages over the simple mechanically variable microwave phase shifter.

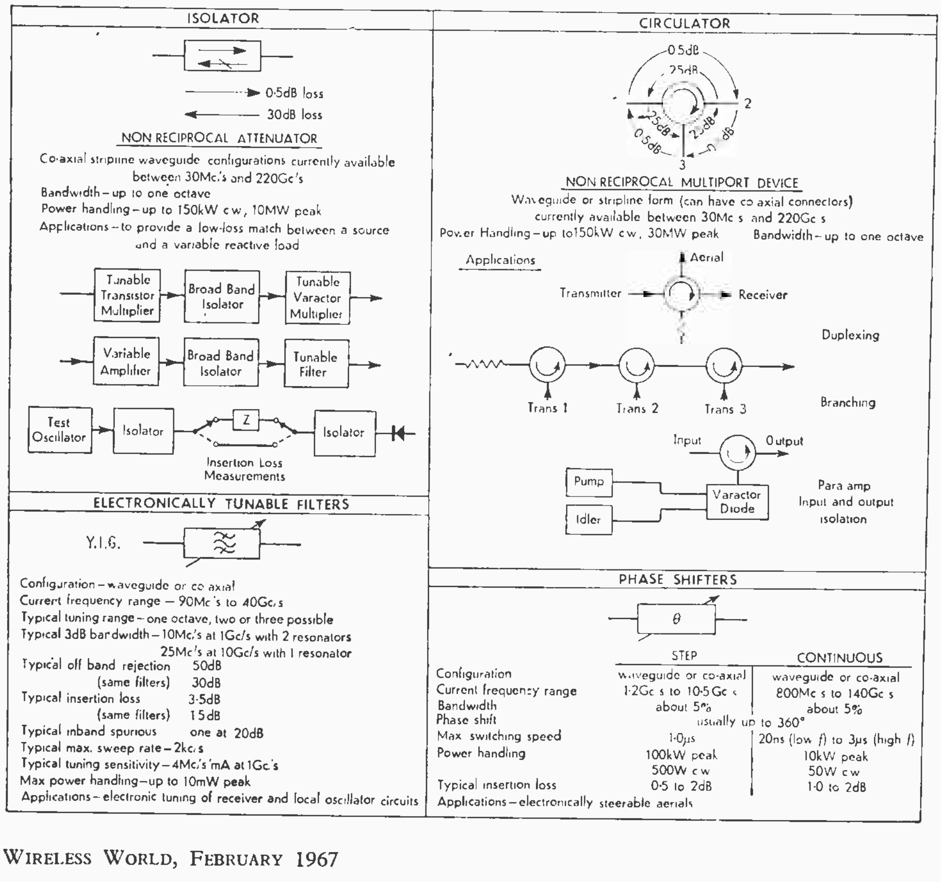
The fourth major ferrite device is the y.i.g. electronically tuned filter, a comparative newcomer (in table). Based on the extremely high Q of a single-crystal yttrium iron garnet sphere and the fact that, like all ferrites, the material's resonant frequency may be changed by varying an applied magnetic field, these devices are beginning to be popular in swept frequency pre-selectors and the like. They can now be considered to be out of the experimental stage, and can be reproduced in quantity.

By appropriate placing of the y.i.g. sphere in relation to the magnetic field the filter may be made reciprocal or non-reciprocal, the great advantage of the latter being that the resultant isolation makes the filter almost insensitive to input and output match.

By variation or switching of the applied magnetic field and by other methods these four basic devices can be modified to yield electronically operated ferrite switches, variable attenuators, a.m. and f.m. modulators, and limiters.

A fifth of new basic device is the ferrite delay line, which uses the phenomenon of low loss acoustic propagation through ferrite combined with spin wave propagation to provide very small and light variable delay lines.

Having briefly covered some of the functions of ferrite devices, let us consider the principles behind their operation. In the second and third parts of this series the individual devices will be dealt with in some detail.



*Canadian Marconi Company.

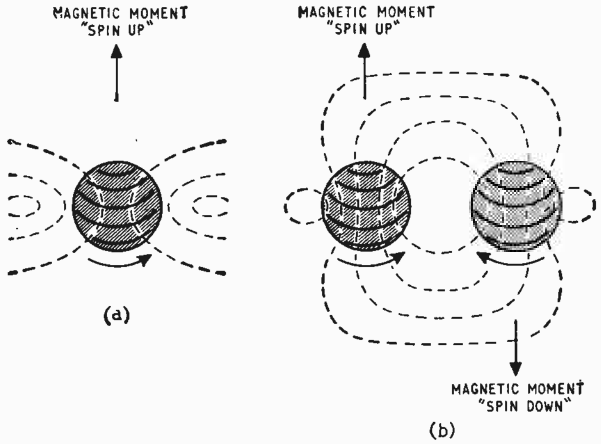


Fig. 1. Magnetic moments of spinning electrons: (a) unpaired electron; (b) paired electrons.

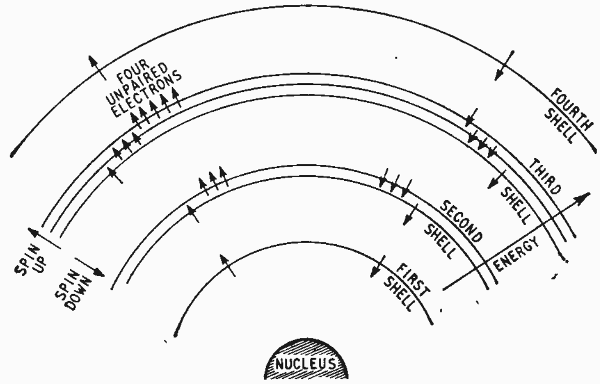


Fig. 2. Showing the relative energy levels of electrons in an iron atom.

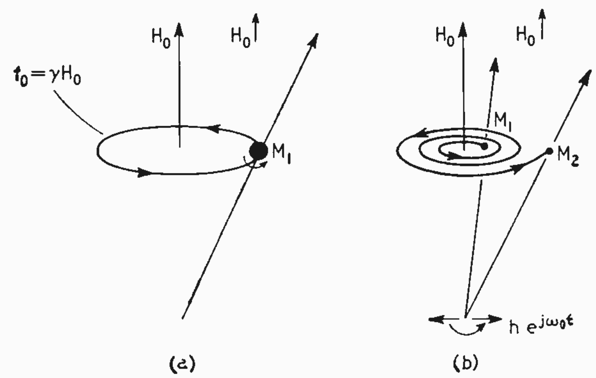


Fig. 3. Precession of an unpaired electron under the influence of external magnetic fields. At (a) is shown the precession with an external steady magnetic field H_0. A clockwise polarized r.f. field will have no effect. At (b) is the precession under the influence of a steady field H_0 plus an anti-clockwise polarized r.f. field $he^{j\omega_0 t}$.

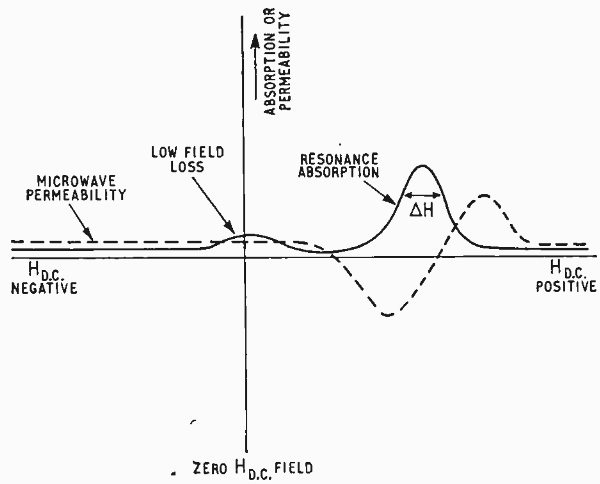


Fig. 4. Microwave absorption and permeability of ferrite as a function of steady magnetic field strength.

First let us go back to basics. The main interaction between the ferrite and the applied signal is magnetic, so we will consider why iron, nickel, cobalt and some other elements have strong magnetic properties.

An atom consists of a nucleus and several electrons arranged in levels or valence bands about it. Each electron can be considered as an electric charge rotating about the nucleus and spinning on its own axis. This creates a magnetic field which has a given direction, termed spin up or spin down, and the electrons will align themselves with other electrons with spins in the opposite direction, like fields repelling, unlike fields attracting, as shown in Fig. 1. The important thing to note here is that with paired electrons the magnetic field does not extend very far beyond the electrons, while that of the single electron is quite far reaching.

Now in any atom the electron population of completely filled valence bands is 2 for the first band, that is the one nearest the nucleus, 8 for the second, 18 for the third and 32 for the fourth. As in each filled band there are even numbers of electrons, they will pair off, spin up, spin down and there will be no residual magnetic field. However in certain atoms not all electrons pair. Let us look at the atomic structure of iron, Fig. 2. The 1st and 2nd bands are full with equal numbers of spin up and spin down electrons; the 3rd band, however, is not full, containing only 14 electrons, and, of these, 4 are unpaired.

The 4th band is also not fully occupied, containing only 2 electrons which, however, are paired off. The four unpaired electrons produce a large net magnetism. Nickel, cobalt, etc., also have unpaired electrons in the 3rd band and thus have large magnetic moments. This is fine if we were concerned only with a magnet, but iron and most other metals are quite conductive, and therefore in any interaction, high current would flow giving high loss. What is required therefore is a compound which is highly magnetic and highly resistive.

Compounds with large magnetic moments can be classed as *paramagnetic* or *ferromagnetic*. In the former the iron or other magnetic atoms are widely spaced so the *H* fields have little effect on each other and are randomly aligned due to thermal agitation (can be aligned by an external field, e.g. soft iron). In a ferromagnetic material the Fe atoms are so closely placed that adjacent atoms in a small cell or domain interact and *spontaneously* line up in the same direction.

Close to the ferromagnetics are the *ferrimagnetics*. In these materials some of the atoms are antiparallel; however, there is still a large resultant magnetic field.

Ferrites fall into this group and have in general high resistivity and high magnetism.

They are generally of the form MO Fe_2O_3 where M is a divalent metal such as iron, magnesium, zinc, nickel or manganese (sometimes small amounts of aluminum, zinc, cobalt are added for special purposes).

In addition to the true ferrites certain other crystalline ferromagnetic oxides, notably yttrium iron garnet ($Y_3Fe_2(FO_4)_3$) and Ba $Fe_{12}O_{19}$ have found use as microwave ferrites.

Having discussed our material, let us consider microwave ferrite interaction and the devices making use of it. When considering the iron atom it was mentioned that the electrons spin on their own axis. Consider an unpaired electron spinning on its own axis (Fig. 3). If a steady magnetic field is applied a gyroscopic interaction takes place and the electron will precess about the axis of the H field. The frequency of this precession in Mc/s is given by $f_0=\gamma H_0$, where gamma is the gyromagnetic ratio of the electron, which for iron is 2.8.

So for a magnetic field H_0 of 1000 oersteds, the frequency of precession would be 2.8 Gc/s. If we now apply an anticlockwise, circularly polarized, alternating, magnetic field $f=f_0$, in other words a microwave signal, along the axis shown in Fig. 3(b), the oscillating component of the torque will be in phase with the precessional motion of the electron, increasing the amplitude of the precession and thus *absorbing* energy from the microwave field. If the alternating magnetic field is changed in polarization or the H_0 field reversed in direction, the r.f. field will not increase the precession but will return it to its original level, having little effect on the r.f. field.

This effect and the associated change of permeability encountered by the clockwise and anticlockwise rotating circularly polarized magnetic fields depend on the action of all the devices to be discussed, so let us examine the effect graphically in Fig. 4. The wavelength, and thence the velocity of propagation through a material, is proportional to its permeability. The permeability curve could therefore also be called a phase shift curve. You will note that the resonance curve is fairly sharply defined. The Q of the resonance curve, or *line width* in ferrite parlance, is determined by the material and the detailed magnetic field therein. Basically, however, the wider the line width the smaller the resonance peak.

I have mentioned two points here that may require a little clarification; first, the statement that the wavelength of an unbounded electro-magnetic field is proportional to the permeability of the medium. This is easily cleared up when the general case of electromagnetic velocity formula is recalled, and the two parameters ξ and μ which are normally left out noted.

$$\lambda = \frac{c}{f\sqrt{\xi\mu}}$$

where λ=wavelength in an unbounded medium; c= velocity of electromagnetic wave in free space; f=frequency; ξ=dielectric constant of medium; and μ=permeability of medium.

The second point is the mention of a circularly polarized r.f. magnetic field. This is fine, you may say, but where in normal microwave work do you get a circularly polarized r.f. magnetic field? The answer briefly is that we have one in standard rectangular waveguide propagating the normal fundamental TE_{10} mode.

It is a viewpoint not normally considered, so let us look into it. Consider the magnetic field pattern shown in Fig. 5. The pattern of the H field travels down the guide at a rate proportional to the frequency. The magnetic

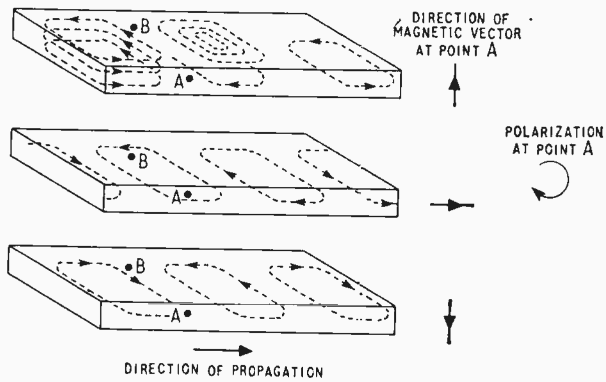


Fig. 5. Magnetic field of the TE_{10} mode in rectangular waveguide.

vector at a point A towards the nearside of the waveguide will, at successive intervals of time, vary as shown, rotating in a clockwise direction. If the point is chosen such that the magnetic vector remains at a constant amplitude, the polarization will be circular; if the amplitude is not constant it will be elliptical. The point for circular polarization is approximately half-way between the centre and the edge of the waveguide and is given by

$$A = \frac{a}{\pi}\sin^{-1}\frac{\lambda}{2a}$$

It should be noted that there is a similar point B on the other side of the waveguide where the polarization is anticlockwise.

In the next article we will discuss how this basic theory is applied to obtain the various types of circulators and isolators.

Domestic Satcom for U.S.A.

A PROPOSAL for a domestic multi-purpose communications system that would integrate satellite and terrestrial communications in the most economical "mix" has been put before the U.S. Federal Communications Commission by the American Telephone and Telegraph Company. Based on studies carried out by Bell Telephone Laboratories, it aims to benefit from the savings that can be achieved by using satellites for the longer distances (1,300 miles is given as an economic cross-over) and to pass these savings on to the customer. The estimated savings would be about 19 million dollars p.a. in 1969, increasing to 41 million dollars p.a. in 1980.

A feature of the scheme is the use of a small number of high-capacity synchronous satellites of advanced design—initially three in 1969-71, then a further four in the 1970s (two of which would replace the initial three). This would provide in the 1980s period 80,000 two-way voice circuits (or their equivalents), 27 television channels and 61 protection and/or occasional television channels. Ground stations would be initially two large transmitting and receiving stations near New York and Los Angeles, with 73 small television receiving-only stations, then later would follow 26 new transmitting and receiving stations in major metropolitan areas. Pulse code modulation would be used for voice circuits and p.c.m. and f.m. for television.

Various other proposals for private and domestic satcom schemes have been put to the F.C.C., and A.T. & T. has made criticisms of some of these, pointing out that proliferation of private special-purpose satcom systems would result in "impairment of economies, waste of the frequency spectrum and unnecessary duplication of facilities."

NEWS FROM INDUSTRY

Television Signal Translator for Jamaica

PROVIDING a television signal translator for communities that lie in propagation shadow areas is a problem in itself when the receiving communities are small, isolated and in rugged, inaccessible terrain. To cope with such conditions a television translator independent of mains supplies, capable of unmanned operation for long periods in isolated conditions has been specially designed by T.I.E. (Communications) Ltd., of 21 Sloane St., London, S.W.1, for operation over eight hours a day in Jamaica. Powered by a solar driven device, in this case silicon cells, limits applications of the B.6402 translator to areas lying within 35° north and south of the equator. A one watt panel is made up of 49 individual cells, and a number of the panels are interconnected to provide the voltage and current necessary to maintain storage batteries at full charge. The Jamaican installation will have a minimum of 92 W in full sunlight from 68 interconnected panels. Connected in series parallel, this network will yield 2.6 A at 36 V. A 360 Ah nickel-cadmium storage battery is constructed of 28 parallel pairs of cells. A sensor included in the equipment regulates the output of the battery supply, and it senses the charge condition of the batteries, disconnecting the solar cells from the batteries when the latter are fully charged. Batteries and sensor are buried to protect them from extremes in environmental conditions and marauding animals. For areas where the television signal is severely attenuated, correct siting of the translator is critical; its propagation range must cover the entire shadow area. A site only a few hundred yards away from, or at a slightly lower altitude than the optimum site may well mean weaker signals. Optimum sites are unlikely to have access roads, for supervision and maintenance, so the elimination of this need is a major advantage. This translator and power supply can be transported to the required site and maintained by helicopter. Long periods of adverse weather do not prevent operation, since battery size and the number of solar panels can be adjusted for local conditions.

A **new components group** is being formed from A.E.I. Semiconductors and Industrial Components. This new single group will be responsible for increasing the use of solid state components in such items as domestic cookers and industrial controls. A wide range of packaged solid state modules for control in the power field are to be produced as "off the shelf" commodities.

Following an agreement with G.E. in the U.S.A., Thorn-A.E.I. have made available a range of **silicon planar transistors** for entertainment use, to be marketed under the brand name Mazda. There are basically two ranges, one for r.f. applications the other for a.f. applications. At the present time, mounting, encapsulation, selection and testing only are carried out at Brimsdown, Middx., the pellets being imported from G.E., but at some later date it is planned to manufacture the complete devices in the U.K. Considerable collaboration between the two companies was necessary owing to the requirements of the British and European markets being different from those of the American market—due mainly to the popularity of receivers using low-voltage batteries on this side of the Atlantic.

Devices available, and in this range of r.f. transistors, for use in a.m. and a.m./f.m. receivers, are **BF216** (Band II r.f. amplifier), **BF217** (Band II mixer), **BF218** (a.m. mixer-oscillator and 10.7 Mc/s amplifier), **BF219** (i.f. amplifier) and **BF220** (oscillator for l.w., m.w. and s.w.). The a.f. range is **BC150** (high-gain low noise pre-amplifier), **BC151** (high gain preamplifier) **BC152**, **BC175** and **BC180** (drivers). A BA151 silicon biasing diode is also introduced. Other devices being produced at Brimsdown for professional equipment, include the 1N4148 and 1N4154 high-speed silicon planar switching diodes, the 2N2926 series, and the 2N3395, 2N3414, 2N3416, 2N3605, 2N3606 and 2N3607 transistors. These are intended for general purpose, small signal and switching industrial applications.

Flying spot telecine and slide scanning equipment made by the Compagnie Francaise Thomson Houston-HB is to be marketed in the U.K. and other territories exclusively by **E.M.I. Electronics Ltd**. Installation, maintenance, and after sales service will all be carried out by E.M.I. Arrangements for the manufacture (under licence) of this equipment in the United Kingdom are also being made.

A 27,500 sq ft factory on the Donibristle Industrial Estate at Inverkeithing, near Edinburgh, has been leased for 20 years by **Varian Associates** as the first step in their plans to manufacture instruments on a large scale in this country. Initially, analytical instruments and ultra-high vacuum equipment will be produced here; including electron spin-resonance spectrometers, and gas chromatographs for chemical, biological, and medical research.

The British-Swiss Chamber of Commerce in Switzerland has announced that as from 1st January **protective tariffs on Swiss imports** of British industrial goods will be removed. These goods include medical and hospital equipment, electronic components, instruments and industrial control equipment. Advice and guidance for manufacturers wishing to export to Switzerland is available from this organization at 1, St. Peterstrasse, 8001 Zurich.

A multi-channel (sixty) **radio telephone link** between Kampala in Uganda, and Dodoma in Tanzania will be supplied by the Marconi Company through a £300,000 contract from the East African Posts and Telecommunications Administration. A tropospheric scatter system with 60-ft diameter parabolic aerials will be employed. The stations linking Kampala and Mwanza (respectively north and south of Lake Victoria), will have 1 kW power amplifiers, duplicated drive equipment, and quadruple diversity receivers. For the link from Mwanza to Dodoma the equipment will be similar except that the power amplifiers will be rated at 10 kW.

A multi-channel (sixty) **radio tele-of 3,000 words per minute** is to be marketed in the U.K. by Bush-Murphy Electronics. It is stated that this teleprinter is 30 times as fast as a standard machine; the high-speed printing is achieved by employing pulses to form characters on electrically sensitive paper. There are no print-out keys, and operation is almost noiseless. A compact, desk size machine, it will accept a variety of input codes, including those used in digital computers, and data processing systems. It is manufactured in the U.S.A. by Motorola Inc.

The Societe des Accumulateurs Fixes et de Traction, of Romainville (Seine), France, has acquired the whole of the capital of **Cadmium Nickel Batteries Ltd.**, Park Royal Road, London, N.W.10, the manufacturers of Voltabloc batteries. S.A.F.T., said to be the largest manufacturer of modern type nickel-cadmium batteries in the world, plans to invest £.05M next year, to gain a large proportion of the nickel-cadmium battery market in Great Britain.

High purity metals such as bismuth, cadmium, indium and tin are to be marketed in the U.K. by Enthoven Solders Ltd., of Rotherhithe Street, London, S.E.16. These metals, available in a variety of physical forms such as ingots, sticks, pellets, granules, washers, wires, ribbons, spheres and single crystals, will have specified standards of purity (in the case of indium, down to one-tenth part per million impurity). Alloys based on these metals can be supplied. The prevention of contamination during storage and dispatch is achieved by the use of specially sealed plastic packaging.

Gyrators - using direct-coupled transistor circuits

By F. BUTLER, O.B.E., B.Sc., F.I.E.E., M.I.E.R.E.

The gyrator is a circuit element with some very useful properties. It can, for example, convert capacitance into inductance, a resistance of one value into another, or a short circuit into an open circuit. Examples of how these properties can be used in practical circuits, such as oscillators, amplifiers and filters, are given in the article. In network theory the ideal gyrator is a theorist's device, an abstraction, which is not physically realizable by a single, simple component like a capacitor. In practical circuit design, however, a very good approximation to the ideal gyrator element can be constructed using transistor amplifiers.

THE ideal gyrator is a linear, passive, non-reciprocal four-terminal network. As a circuit element it is represented by the symbol in Fig. 1. When terminated by an impedance Z_2 at one pair of terminals, the device presents an impedance Z_1 at the other pair, these impedances being related by the expression $Z_1Z_2=R^2$. Here R is a constant, defined as the gyration resistance. The gyrator characteristics can also be described in terms of the gyration conductance G, the reciprocal of R. Thus $Z_1Z_2=R^2=1/G^2$.

The gyrator has some extraordinary properties. For example, if the terminating impedance is a capacitance C such that $Z_2=1/j\omega C$, it is clear that $Z_1=R^2/Z_2=j\omega CR^2$. Thus Z_1 is equivalent to an inductance $L=CR^2$. In effect, the gyrator converts capacitance into inductance, the conversion factor being independent of frequency. The transformation of inductance into capacitance is equally feasible but less generally useful. Furthermore, a resistance of one value may be converted to another. As an extreme example of this, a short-circuit across the output terminals of a gyrator is transformed to an open-circuit across the input terminals. The converse is also true. More generally, it might be said that the network "gyrates" a voltage into a current, or a current into a voltage. A particularly useful property is the ability of a gyrator to simulate a high-Q inductor by means of a capacitor. Resistance-conversion could of course be accomplished in a simpler way by means of an ideal transformer but the conversion rule is different. Moreover, a real, as distinct from an ideal, transformer cannot operate down to zero frequency whereas a gyrator can.

Since a gyrator, when terminated by capacitance at its output end, looks like an inductance connected across the input terminals, it is clear that this inductance could be tuned by another capacitor in shunt with the input terminals. We then have an extraordinary situation in which one capacitor is apparently brought into parallel resonance with another. Series resonance is equally simple to achieve, using the same two capacitors.

Gyrators may be used in the construction of sinusoidal oscillators, selective amplifiers, low-pass, high-pass, band-pass and band-stop filters. They can be used for impedance matching, as d.c. transformers and, on a much higher intellectual plane, they can be used to solve some intractable problems in network synthesis. In what follows we shall touch on some of the simpler applications.

The gyrator concept

The original concept of the gyrator as a new circuit element is due to B. D. H. Tellegen. He described it in a classic paper[1], published in 1948, which is "required reading" for anyone starting work in this field. Tellegen speculated whether there might exist some fifth network element to add to the four conventional elements—the ideal resistor, capacitor, inductor and transformer—normally used in network synthesis. He concluded that there could be no possible two-terminal element to add to the list, but that a four-terminal element might be found provided that one did not insist on it being at once linear, passive, reciprocal and with constant coefficients in its network equations. He considered that, of all these properties, the least important was the reciprocity characteristic and by removing this constraint he was able to specify a new circuit element which he called a gyrator. The choice of name springs from a parallel which he drew between the electrical network equations and some dynamical equations describing the behaviour of certain mechanical systems containing flywheels or gyroscopes.

Tellegen's insistence on a passive element led to difficulties with the actual physical realization of a gyrator, and he was forced to specify two rather esoteric systems. For details of these the original paper must be consulted. If, however, we choose to make use of active circuits it is possible to build an almost ideal gyrator using fairly standard transistor amplifiers, suitably interconnected. We must of course modify our original definition of the gyrator to read "active" instead of "passive" if we use amplifiers in its construction.

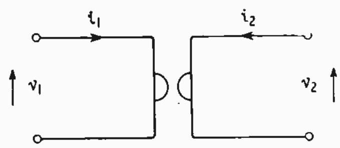
Gyrator theory

Following Tellegen's treatment, one can draw a useful parallel between the circuit equations of an ideal transformer and an ideal gyrator.

For the transformer:—

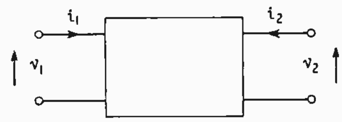
$$\left.\begin{aligned} i_1 &= -Ni_2 \\ v_2 &= Nv_1 \end{aligned}\right\} \qquad (1)$$

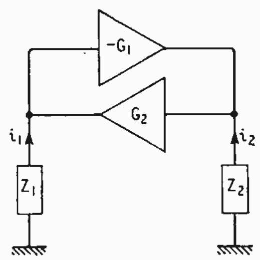
Here i_1 and v_1, i_2 and v_2 are respectively the primary and



(Left) Fig. 1. Graphical symbol for the gyrator.

(Right) Fig. 2. General 4-terminal (two-port) network.





(Left) Fig. 3. Gyrator using back-to-back paralleled ampliers.

secondary currents and voltages and N is the turns ratio.

In passing, it may be noted that $v_1 i_1 + v_2 i_2 = 0$, so that the energy dissipation in the transformer is zero. The transformer also complies with the reciprocity rule.

Fig. 1, as already mentioned, shows an ideal gyrator. The circuit equations which characterize the gyrator are:—

$$\left.\begin{aligned} v_1 &= -Ri_2 \\ v_2 &= Ri_1 \end{aligned}\right\} \quad \ldots \quad (2)$$

Here again, $v_1 i_1 + v_2 i_2 = 0$, so that there is no dissipation but the reciprocity relationship is violated. The resistance R is the gyration resistance previously mentioned.

Simple manipulation of equation (2) shows that the input impedance of the gyrator is given by:—

$$Z_1 = \frac{v_1}{i_1} = \frac{-R^2}{v_2/i_2} \quad \ldots \quad (3)$$

If v_2 is the voltage drop across an impedance Z_2 connected across the output terminals then, with the polarity conventions of Fig. 1, $v_2 = -Z_2 i_2$. Thus:—

$$Z_1 = R^2/Z_2 \text{ or } Z_1 Z_2 = R^2 \quad \ldots \quad (4)$$

This is the basic gyrator equation.

At this point we may make passing reference to another network which has something in common with the transformer and the gyrator. It is the pi-section matching network consisting of a series inductance L with two shunt capacitors C. When operated at the frequency $f = 1/(2\pi\sqrt{LC})$ and when terminated by an impedance Z_2, the input impedance of the section is Z_1, where $Z_1 Z_2 = L/C$. If Z_2 is zero, Z_1 is infinite and conversely Z_1 is zero when Z_2 is infinite. These properties are identical to those of the gyrator but the pi-network acts in this way only at one particular frequency whereas the gyrator is a wide-band device. In a rather loose way we could define the gyration resistance of the pi-section as $R = \sqrt{L/C}$.

Another and more instructive theoretical approach is to make use of elementary matrix methods to examine the gyrator, regarded as a special type of 4-terminal network. The advantage of this method is that it suggests a way in which one might construct an active gyrator of a more general type than that envisaged by Tellegen.

Referring to Fig. 2, let y_{11}, y_{12}, y_{21} and y_{22} be the admittance parameters of the 4-terminal network. Then:—

$$\left.\begin{aligned} i_1 &= y_{11} v_1 + y_{12} v_2 \\ i_2 &= y_{21} v_1 + y_{22} v_2 \end{aligned}\right\} \quad \ldots \quad (5)$$

In matrix notation, these equations may be written:—

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \quad \ldots \quad (6)$$

It may be found helpful in understanding the next step in our argument to recall in words the definitions of the four y-parameters.

y_{11} = input admittance with the output short-circuited,
= i_1/v_1 with $v_2 = 0$.
y_{12} = reverse transfer admittance with the input short-circuited,
= i_1/v_2 with $v_1 = 0$.
y_{21} = forward transfer admittance with the output short-circuited,
= i_2/v_1 with $v_2 = 0$.
y_{22} = output admittance with the input short-circuited,
= i_2/v_2 with $v_1 = 0$.

Returning to equation (2), which defines the gyrator characteristic, and rewriting it in terms of conductance (the real component of admittance), we have:—

$$\left.\begin{aligned} i_2/v_1 &= -1/R = -G = y_{21} \\ i_1/v_2 &= 1/R = G = y_{12} \end{aligned}\right\} \quad \ldots \quad (7)$$

The terms y_{11}, y_{22} which appear in equation (6) are both zero in this particular case and so equation (7) can be written in matrix form:—

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 0 & G \\ -G & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \quad \ldots \quad (8)$$

This equation, which again describes the gyrator, is now seen to be merely a degenerate form of (6), the general 4-terminal, (2-port) network equation.

Thus the gyrator admittance matrix becomes:—

$$Y = \begin{bmatrix} 0 & G \\ -G & 0 \end{bmatrix} \quad \ldots \quad (9)$$

It can be expanded to:—

$$Y = \begin{bmatrix} 0 & G \\ 0 & 0 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ -G & 0 \end{bmatrix} \quad \ldots \quad (10)$$

In physical terms, equation (10) represents the parallel back-to-back connection of two voltage-controlled current sources (two amplifiers with high input and output impedances), one of them being of the phase-inverting type and one non-inverting. An active gyrator can thus be built by paralleling two suitable amplifiers each having a prescribed mutual conductance, the reciprocal of which is the gyration resistance. The output terminals of each amplifier are connected to the input terminals of the other.

Proper gyrator action is still obtained even if the transfer conductances of the two amplifiers are unequal, but we now have a gyrator with unequal gyration resistances or conductances. When terminated by impedances Z_1 and Z_2, its characteristics are described by the equation:—

$$Z_1 Z_2 = R_1 R_2 = 1/G_1 G_2 \quad \ldots \quad (11)$$

The schematic diagram of a gyrator embodying two back-to-back amplifiers is shown in Fig. 3. The requirement previously stated for amplifiers with high input and output impedances is only crucial if the gyrator is being used with purely reactive terminations. In this case the amplifier impedances act as parasitic loss resistances, spoiling the Q-factors of the terminations. With resistive terminations, the amplifier impedances can be absorbed into the loads, leaving the performance unaffected.

Practical gyrator circuits

The central problem in building a high-grade gyrator is to design amplifiers with the requisite high input and output impedances. Figures in the region of one megohm are acceptable but much larger values, say 5 megohms, are desirable. The design is simpler if a.c. coupling is admissible but some gyrator properties are useful down to zero frequency so that direct coupling is much to be preferred. Brief details of two practical circuits have been published. The first[2] is extremely simple, easy to build and to set in operation. The second[3] is much more elaborate but its performance comes closer to the ideal.

Two different circuits will now be described, each of which owes something to the work just mentioned. In Fig. 4 each amplifier has a complementary output stage in which both transistor bases are driven, in phase, by earlier stages. The design difficulty is that there is a standing difference of d.c. potential between the bases of the complementary transistors. The problem is solved by using a special type of complementary driver stage, itself driven from an emitter follower of extremely high input impedance.

The upper amplifier in Fig. 4 is a phase-inverting type in which the base of each output transistor is driven from a tap on the emitter load of the preceding stage. The lower amplifier, non-inverting, takes the drive to the output stage from the collector loads of the earlier stage. Local series feedback in the intermediate and final stages gives a very high output impedance, of the order of half a megohm. In each amplifier the mutual conductance is about 0.6 mA/V, corresponding to a gyration resistance of 1667 ohms. The voltage gain of each amplifier is simply $g_m R_L$, exactly as for a single transistor or pentode valve amplifier, if g_m is the mutual conductance and R_L the load resistance.

Experience shows that some selection or adjustment of components must be made to ensure proper operation of the amplifiers. In each channel, two starred resistors are shown. It is suggested that variable resistors should be used in these positions, set by trial to give the maximum possible undistorted output from each amplifier, treated separately. After adjustments have been completed, the variable resistors should be measured and replaced by selected components or series/parallel combinations very close to the measured value.

The second gyrator, Fig. 5, makes use of much more elaborate amplifiers. The output stage employs a complementary cascode arrangement of four transistors which is believed to be new and original. Its output impedance is of the order of 2 megohms. The intermediate amplifier, or cascode driver, uses an arrangement similar to that of Fig. 4. The input stage is a compound complementary emitter-follower of extremely high input impedance.

Again it is necessary to select certain components to obtain maximum possible output from each amplifier. They are marked with an asterisk on the diagram.

Each amplifier in both circuits requires a well-filtered centre-tapped power supply of 6-0-6 volts, stabilized by Zener diodes. The earthy terminals of the amplifiers (input and output) are connected to the common terminal, which is preferably earthed.

Each channel of the gyrator should be built and tested separately before connecting the amplifiers together. The setting-up process requires an audio signal source, an

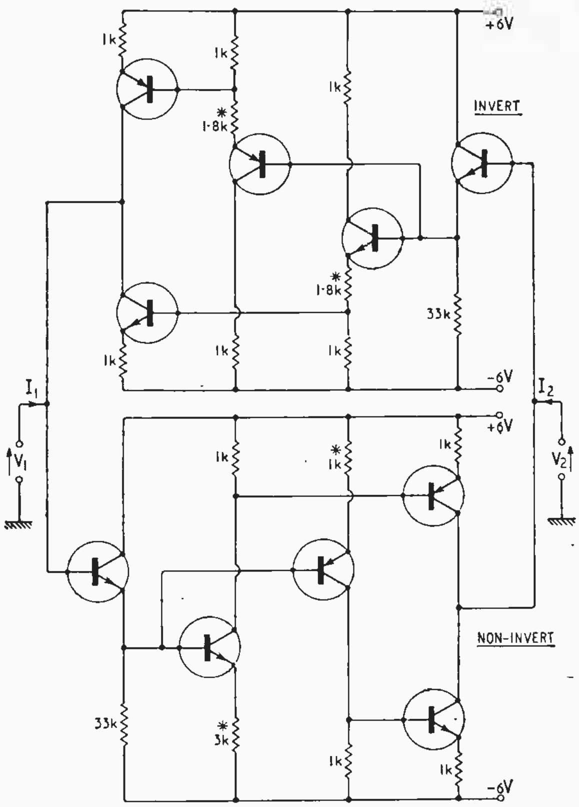
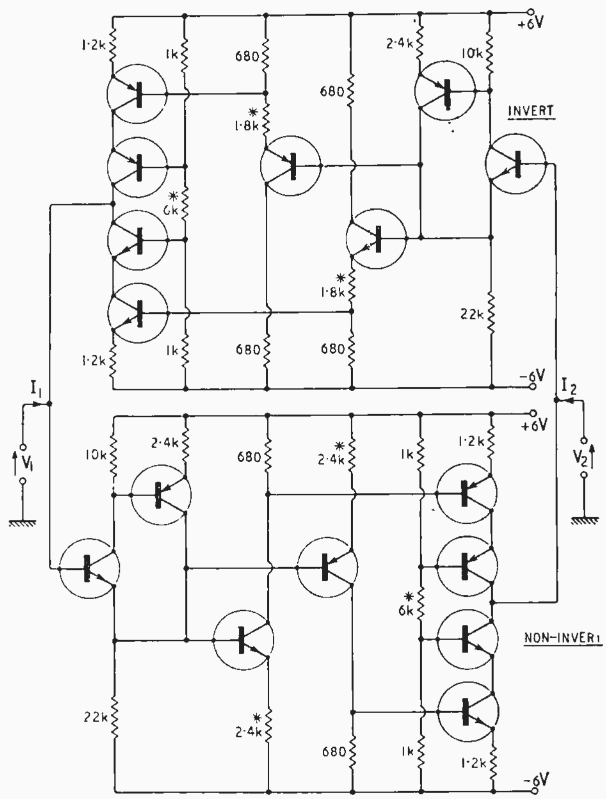


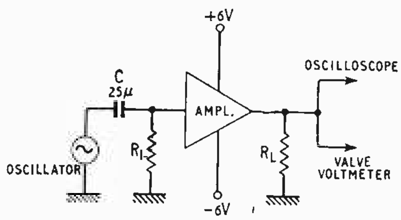
Fig. 4. Simple gyrator. (*Below*) *Fig. 5. High-grade gyrator.*



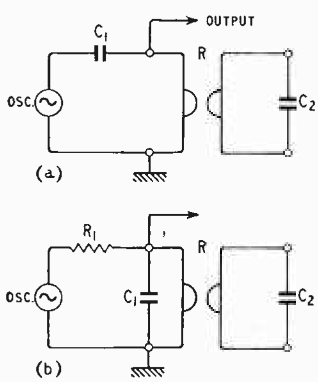
oscilloscope and a valve voltmeter, assembled as in Fig. 6. The audio oscillator is coupled to the amplifier input through a blocking capacitor C (25 μF reversible electrolytic). A low-value resistor R_1, not exceeding 2.2 kΩ, is connected across the amplifier input. A low value is required so that the base current of the input transistor will not set up an unwanted bias voltage across R_1. A load resistance R_L of 10 kΩ is connected across the output terminals. With the remaining test equipment in position and with an audio signal of about 0.5V across R_1 it should be possible to observe an output across R_L. The waveform will probably be distorted but adjustment of one or more of the variable resistors will correct the distortion. When all the adjustments have been properly made, an undistorted output of 3.5V r.m.s. should be available across the 10 kΩ load. A further increase of input signal should result in exactly symmetrical waveform clipping beyond the overload point. The overall voltage gain of one experimental amplifier was found to be 6 with a 10 kΩ load, rising to 60 with 100 kΩ. This corresponds to a mutual conductance of 0.6 mA/V. Assuming an identical, but phase-reversing, amplifier in the other channel the gyration resistance is 1667 ohms.

The best transistors for use in the amplifiers are of the silicon planar epitaxial type, with gain-bandwidth products in excess of 300 Mc/s. Types BSX 28 (n-p-n) and BSX 29 (p-n-p) made by SGS-Fairchild are particularly suitable. Experimental amplifiers have been built using unselected transistors of various types by different manufacturers. The most noticeable difference between them was the upper frequency limit of operation. Typically, the 3 dB point was at 300 kc/s, the response being almost flat from d.c. to over 100 kc/s.

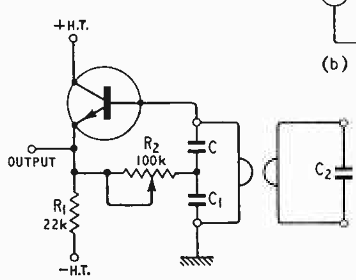
Distortion is low due to the large amount of feedback.



(Left) Fig. 6. Amplifier test circuit.



(Right) Fig. 7. Selective amplifier using gyrators (R is the gyration resistance).



(Left) Fig. 8. Colpitts oscillator making use of a gyrator.

Though there is considerable phase shift through each amplifier, the differential shift is small. Accurate phase splitting is observed up to 250 kc/s with normal transistors and to well above this figure with the v.h.f. types.

When setting up the amplifiers, care must be taken not to reduce the setting of the variable resistors to a dangerously low value. It is safest to include a 1 kΩ fixed resistor in series with each.

Practical applications of gyrators

Fig. 7(a) shows a selective amplifier using a gyrator to convert the capacitance C_2 into an inductance $L = C_2R^2$, where R is the gyration resistance. When driven from a low-impedance signal source, the output is a maximum when C_1 is in series resonance with L, i.e. at a frequency given by:—

$$f = \frac{1}{2\pi\sqrt{LC_1}} = \frac{1}{2\pi\sqrt{R^2C_1C_2}} = \frac{1}{2\pi R\sqrt{C_1C_2}}$$

Fig. 7(b) is a corresponding circuit exploiting parallel resonance of L and C_1. It must be driven from a constant-current generator or through a very high resistance R_1.

Operation at very low frequencies is possible if C_1 and C_2 are large (reversible) electrolytic capacitors. If $C_1 = C_2 = 100\,\mu$F and if the gyration resistance $R =$ 2,000 ohms, the simulated inductance is 400 henries and the resonant frequency is about 0.8 c/s.

The transmission characteristic of a selective amplifier of this type is exactly that of a normal LC circuit and is very different from that of the usual type of RC circuit using a Wien bridge or parallel-T network. The 3 dB bandwidth of the gyrator circuit is broader and the skirt selectivity is much better than in the other circuits. Another advantage is that there is no requirement for accurately matched components as in the twin-T circuit.

A gyrator oscillator is shown in Fig. 8. This too is most suitable for very low frequency operation. It is a variant of the Colpitts circuit. Again, the gyrator is used to simulate the tuning inductance. The emitter-follower is operated from the same supply as the gyrator. R_1 is its normal emitter load, say 22 kΩ, while R_2 is a regeneration control, set to give a sinusoidal output waveform.

A fairly recent communication[4] gave design details of a gyrator RC low-pass filter. The basic circuit is shown in Fig. 9. Its measured transmission characteristic agrees accurately with theory.

Fig. 10 shows a corresponding high-pass section which can be designed by standard image-parameter filter theory. The gyrator merely simulates the shunt inductance.

A standard T-section high-pass filter to work between 600 ohm terminations and to cut off at 1 kc/s requires two series capacitors of 0.2652 μF and a shunt inductance of 47.74 mH. Assuming a gyration resistance of 1,500 ohms, the capacitance C_1 required to simulate this inductance is given by:—

$$C_1 = L/R^2 = \frac{47.74 \times 10^6}{1000 \times 1500 \times 1500} = 0.02122\mu\text{F}.$$

The filter thus consists of two series-connected capacitors, each of 0.2652 μF and a shunt gyrator terminated by a capacitance of 0.02122 μF. The gyrator-capacitor combination simulates an inductance of 47.74 mH.

One method of making a gyrator low-pass filter has been briefly mentioned. Another possibility is to include a high-pass filter in the negative feedback path of a wide-band amplifier. A low-pass LC filter section employs a series inductance of which neither side can be earthed. It is difficult to synthesize such an inductance using a single gyrator since one side of the simulated element is necessarily earthed. However, the basic gyrator equation $Z_1=R^2/Z_2$ suggests a way out of the difficulty. If the gyrator is terminated, not by a single impedance Z_2 but by a number of parallel-connected impedances Z_2, Z_3, Z_4, each of these is separately converted so that the input impedance of the gyrator becomes:—

$$R_1=R^2/Z_2+R^2/Z_3+R^2/Z_4=Z_a+Z_b+Z_c$$

Thus R_1 becomes the sum of three series connected impedances of calculable values. In a similar way, a number of series-connected impedances across one port of the gyrator appear as a parallel group across the other port. More generally, a network across one port is transformed to another network which is the dual of the first. This idea, expressed in different terms, has been exploited by A. G. J. Holt and J. Taylor in order to replace ungrounded inductors by grounded gyrators. Low-pass filters can be synthesized by this technique.

Band-pass transmission characteristics can be secured by using cascaded selective amplifiers with staggered centre frequencies.

When synthesizing some of the more complex networks it may be helpful to note that gyrators can be used in conjunction with transformers or other gyrators. A gyrator and a transformer in cascade are equivalent to a gyrator with new characteristics. Two gyrators in cascade behave like an ideal transformer.

If a gyrator is terminated by a quartz vibrator of which the equivalent circuit is an inductance L in series with a capacitance C, the pair being shunted by a capacitance C_1, the reactance of the network is changed by gyrator action to an entirely different value as seen from the input terminals.

It is not difficult to show that the gyrator input impedance is given by:—

$$Z_1=j\omega C_1R^2\left\{1+\frac{C}{C_1(1-\omega^2LC)}\right\} \quad .. \quad .. \quad (12)$$

Here R is the gyration resistance.

Provided that the whole term in brackets is positive, Z_1 is a pure inductance and can be tuned to resonance by a suitable value of shunt capacitance.

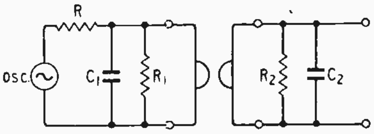
Experiments made with a particular 100 kc/s GT-cut plate show that controlled oscillations can be generated, using the circuit of Fig. 8, with $C=0.007\,\mu$F and $C_1=0.001\,\mu$F, and with the quartz plate substituted for C_2.

The frequency of oscillation involves the gyration resistance R which is not exceptionally stable. The circuit is principally of interest as a demonstration of the remarkable properties of a gyrator but it has one practical advantage over conventional circuits in that the crystal frequency can be pulled away from its nominal value. The circuit cannot be recommended where high frequency-stability is a prime requirement.

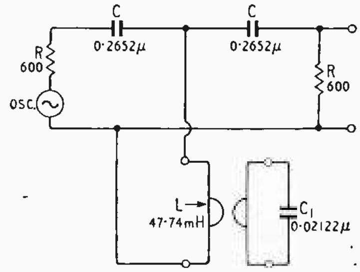
In all these applications it is essential to avoid overloading the gyrator or extremely misleading results will be obtained. The standing collector current in each gyrator output stage of Figs. 4 and 5 is about 1 mA. The maximum current which can be delivered to an external load is no more than 0.35 mA r.m.s. Thus it is unreasonable to expect more than 0.35 V output across a 1 kΩ load, rising to just less than 4 V on open circuit. The conditions are equally, if not more, stringent with reactive loads such as large capacitors.

Advantages in use

A gyrator built with discrete components might seem an expensive method of inductance simulation but in this connection it is worth remembering that "clock-spring" toroidal ribbon-wound cores of high grade magnetic material may cost as much as £10 each. An integrated-circuit gyrator could be produced in quantity at a unit price much less than this.



(Right) Fig. 9. Gyrator low-pass filter.



(Left) Fig. 10. Gyrator high-pass filter (cut-off frequency 1 kc/s).

In earlier articles[6, 7] the writer has described other active devices for inductance simulation. These, and some related devices described by other writers, all suffer from the basic defect that they first simulate a lossy inductance and subsequently improve its Q-factor by some process of resistance-cancellation. Essentially this is a positive-feedback technique which is bad practice where stable Q-factors are required. The gyrator, which employs strong negative feedback, is inherently more stable and is no more difficult to design and construct.

As regards future developments and applications of gyrators, it would seem to be fairly simple to design them with manually or electronically variable gyration resistances. Tunable filters and oscillators, phase-locked oscillators, parametric amplifiers and frequency dividers would then become practical possibilities.

Acknowledgement.—The writer is particularly indebted to J. R. Murray, I. R. Pearson, M. E. Carter and P. M. J. Webster for constructing, testing and evaluating a number of individual amplifiers and several complete gyrators of different types leading to the final versions shown in Figs. 4 and 5.

REFERENCES

1. "The Gyrator; A New Electric Network Element," by B. D. H. Tellegen. *Philips Research Reports*, Vol. 3, April 1948, pp. 81-101.
2. "Direct Coupled Gyrator Suitable for Integrated Circuits and Time Variation," by T. N. Rao, R. W. Newcomb. *Electronics Letters* (I.E.E.), Vol. 2, No. 7, July 1966, p.250.
3. "High Quality Transistorized Gyrator," by D. F. Sheahan, H. J. Orchard. *Electronics Letters* (I.E.E.), Vol. 2, No. 7, July 1966, p. 274.
4. "RC Gyrator Low-Pass Filter," by S. S. Hakim. *Proc. I.E.E.*, Vol. 113, No. 9, September 1966, p.1504 (correspondence).
5. "Method of Replacing Ungrounded Inductors by Grounded Gyrators," by A. G. J. Holt, J. Taylor. *Electronics Letters* (I.E.E.), Vol. 1, No. 4, June 1965, p. 105.
6. "Active Impedance Converters," by F. Butler. *Wireless World*, December 1965, p. 600.
7. "Impedance Converters Using Wideband Feedback Amplifiers," by F. Butler. *Electronic Engineering*, October 1966, p. 639.

ELECTRONIC ORGANS—"Why do so many sound vaguely but indisputably wrong?"

By J. W. MACHIN, B.Sc., M.I.E.E., A.M.I.E.R.E.

IN every stratum of society there are certain topics upon which it is unwise to speak, and a particular instance of such folly is to comment, other than unfavourably, upon the performance of electronic organs when in the presence of a pipe organist. If he is able to speak calmly upon the subject the most that he will concede in their favour is their undoubted advantage where cost is of paramount importance. That anyone could be deceived, even for a moment, into mistaking the sound they make for that of a pipe organ is to him unthinkable.

It is true, of course, that many electronic organs make no pretence to pipe organ imitation, but claim to be musical instruments in their own right. Whether an offspring with so strong a family likeness can disclaim its parents is a question outside the scope of this article, which is a consideration of those electronic organs which claim to be, and are sold as, substitutes for pipe organs.

Before proceeding further it may be an advantage to consider a typical block diagram of an electronic organ (Fig. 1), which has been reduced to its simplest form. Most of the units shown do their bit towards the production of un-pipe-organ-like sounds, but when allocating blame and seeking remedies it is only fair to exonerate the one which is, or should be, practically innocent. This is the voicing unit comprising the various filters used to produce the three basic tones of flute, string and reed, and whose outputs often come in for a good deal of undeserved criticism inasmuch as the majority of organ sounds can be simulated with reasonable accuracy by means of quite simple circuits. It should be borne in mind that pipe organ builders themselves permit a great deal of latitude in their interpretation of the legend on the drawstop knob, and even a casual acquaintance with their instruments will show that one man's salicional is another man's gamba, and one man's trumpet is another's cornopean. To take a further example, it is often said that the reed tones of an electronic organ tend to be flutelike in the upper register; if however one examines a pipe organ it is quite usual to find that the top notes of a reed stop are unashamedly flue pipes, since the builder knows that the ear is uncritical of quality at high frequencies, tending to judge merely by relative volume. It must of course be admitted that some organ stops, for example the celeste, cannot be imitated by simple filters but in the main there is no reason why a suitable harmonic mixture of the raw signals (usually sawtooth or square), may not with filtering produce a wide variety of organesque tones, sufficient for all normal purposes.

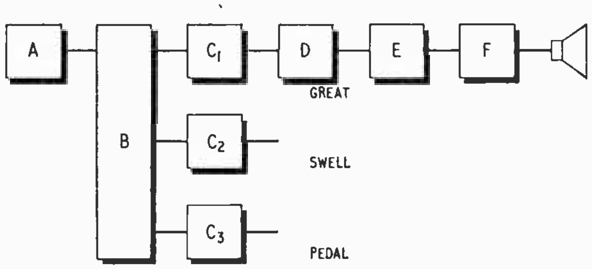


Fig. 1. Block diagram of an electronic organ, A, main oscillators; B, dividers; C_1 C_2 C_3, keying systems; D, voicing networks; E, summing system and pre-amplifier; and F, power amplifier.

J. W. MACHIN is senior lecturer in electrical engineering at the North Staffordshire College of Technology where he has been a member of the staff for the past eight years. Aged 43, he was a radar mechanic in the R.A.F. during the war after which he studied at Manchester University where he graduated in 1949.

If the voicing is not to blame where then does the trouble lie, and why do so many electronic organs sound vaguely but indisputably wrong? In effect there are three main points of variance with the pipe organ which may be set down in the order in which they occur in the instrument shown in Fig. 1.

1. Chorus effect
2. Transient generation
3. Summation of voices

Let us consider these factors in some detail with a view to the possible improvement of the instrument.

THE CHORUS EFFECT

The problem here is one of coherence. Different voices at the same pitch must inevitably be in a fixed phase relationship to each other if they are to emerge from a particular output channel. If it were otherwise then there would be a time when signals of identical pitch and similar amplitude would be antiphase as regards their fundamentals, giving partial or sometimes total cancellation. This basic coherence of output contrasts with that of the pipe organ where every note is an individual and the output is incoherent, sometimes, in a very resonant building, to the point of unintelligibility.

Seeking to improve the chorus effect in the electronic instrument leads to a consideration of the method of note generation. Here one is confronted with the choice between twelve oscillators followed by a system of frequency dividers, or an entire rank (at least 61 and usually 85) of individual "free-phase" oscillators.

The advantage of the latter method is that the octaves are not phase related, and therefore a played octave sounds more like two notes and less like a fundamental and a strong second harmonic. This benefit seems how-

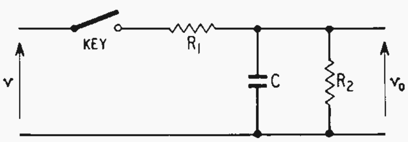


Fig. 2. Equivalent keying circuit.

ever to be outweighed by the following considerations:

(i) To have really good frequency stability an oscillator, specially a transistor type, should operate in class A sinusoidally, and since such an output is usually unacceptable, suitable non-linear shaping circuits have to be provided for each oscillator.

(ii) To simulate many open pipe tones it is essential that at least some second harmonic is added to the fundamental waveform. With a divider system this may be obtained from the octave above, but with the separate oscillator system this octave is not phase related to the fundamental, and the ear tends to hear two notes again. Thus the feature which is held to be an advantage can in fact turn out to be a nuisance.

(iii) The free-phase system is costly by reason of the large number of oscillators required, particularly if separate ranks are provided for the various pitches, e.g. 16 ft, 8 ft, 4 ft, etc.

Neither the divider nor the free-phase system simulates one of the most obvious characteristics of a pipe organ, namely the continuous random variation in the pitch and amplitude of a note about a mean position, which is due to slight variations in wind pressure caused by turbulence in the wind chest, and in and around the pipe itself. This random variation may be observed when the note from an organ pipe is displayed on an oscilloscope. Now there seems to be no reason why a similar effect should not be produced electronically by modulating each oscillator with a signal similar to that of wind noise, and it so happens that the internal noise signal of a transistor fits the requirements fairly well. If a noisy transistor is used as a signal source and its output amplified, the result sounds very like the low pressure wind noise associated with a pipe organ.

If a rank of dividers were driven by twelve oscillators, each frequency modulated by its own individual noisy transistor, all notes that were not octaves would have separate random phase variations and, in the case of sawtooth divider circuits, amplitude variation also. This might provide a much richer chorus effect than hitherto, even to some extent in unison playing, particularly in a reverberant building.

It seems feasible to carry this technique a stage further. Most electronic organs have a separate output channel for each manual and the pedal section, and of course if there are separate generators for each section this is essential. But where all tones are derived from a single rank of dividers the main purpose of the multiple channels is to give distinction between, say, Swell and Great sections by bringing them out through separate (and separated) speakers. Let us suppose, however, that the Swell output as a whole is phase modulated by a further transistor noise generator. The original random variations of the twelve notes will now be further modulated, giving twelve new sets of variations distinct from the original twelve. It should now be possible to distinguish aurally when the Swell output is added to the Great section without the necessity for two channels and amplifiers, assuming that the power handling ability of the one amplifier is adequate.

In passing it may be mentioned that a similar device is in use in some commercial organs where the output, or part of it, is phase modulated with a mild vibrato signal and then mixed with the unmodulated output producing an enhanced chorus effect.

The foregoing does not imply that a multi-channel output is not an advantage, but it may well be that the usual system of horizontal division of the organ into sections is not the best possible. This topic will be referred to again when the summation of voices is considered.

TRANSIENT EFFECTS

Both pipe and electronic organs can produce transients when keyed. Pipe organ transients vary enormously, some being mainly noise known as a "chiff," and others a faint starting note at some harmonic of the fundamental. Their formation is complex and does not yield readily to analysis. On the other hand, the transients produced in an electronic organ are of a comparatively simple type, and their nature can be analysed mathematically without much difficulty.

To illustrate the formation of a transient, let us assume that a sinusoid from a generator of low internal impedance (as is usual in transistor circuits), and having no d.c. component, is keyed by perfectly clean contacts. If the succeeding circuitry is purely resistive (apart from stray capacitances), the effect at the loudspeaker is a click coincident with the start of the signal, which is itself extremely abrupt. Purely resistive circuitry is not, however, the norm since filters of one sort or another are employed to produce the desired voices. In the case of a flute tone, for example, the key is followed by a resistive network to give correct scaling, and then by an RC filter with a load resistance across its output terminals. The whole arrangement may be approximately represented by the circuit of Fig. 2.

If the input signal is given by $v=V\sin(\omega t+\phi)$ then it can be shown that the output signal is:

$$v_o = \frac{V}{\sqrt{\left(1+\frac{R_1}{R_2}\right)^2 + \omega^2C^2R_1^2}}\left[\sin(\omega t + \phi - \psi) - \sin(\phi - \psi)\,.\,e^{-t/CR}\right]$$

$$\text{where } R = \frac{R_1R_2}{R_1+R_2} \quad \text{and } \psi = \tan^{-1}\omega CR$$

The transient term in this expression will be zero only when the instant of switching on is such that $\phi=\psi$, and it will be noted that this is never at the moment when the sinusoid passes through zero. If it is now supposed that C becomes progressively smaller, the rate of decay of the transient will increase and the term outside the square bracket will also increase; in other words as the circuit becomes resistive with residual capacitance the transient takes the form of a large amplitude spike, which is the key click previously mentioned. It can be seen from this that the RC networks designated "click-filters" in some instruments in fact do nothing to remove the transient, but merely change its shape and hence its sound, giving a thud or a pop which is less objectionable to the ear than the click.

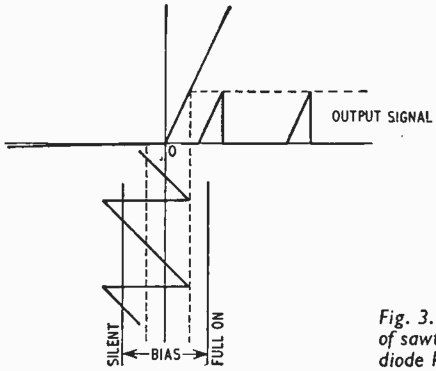


Fig. 3. Distortion of sawtooth during diode keying.

Reverting to the flute type *RC* filter with the long time constant, the input signal is usually of square or sawtooth form containing many harmonics each of which can produce its own transient, giving in theory a very complex effect. In practice however the final output from the filter may be very close to a sine wave, the higher harmonics and their transients being very small and leaving only the transient due to the fundamental to be reckoned with. The approximate analysis above is therefore still applicable to flute tones, though not to reed tones which employ resonant circuit filters, of which the transients though more complex are less objectionable.

The flute tone transient which, as mentioned above, resembles a pop or a thud is more noticeable in the upper and lower than in the middle register. In some instances, specially in the case of stopped diapason tones, the middle register transient is not unlike that produced by some organ pipes, but there is this difference; that with a pipe the transient is over before the normal tone reaches full strength, whereas with the electronic circuit the tone and the transient start together and this destroys the illusion to some extent. A similar transient is produced when the key is released, and this can be objectionable in a more or less anechoic building being specially noticeable since there is no pipe organ effect which corresponds to it. If the building has a reasonable reverberation period however this transient is fairly well masked.

It is clearly desirable to use some means of reducing or controlling the keying transients and this implies some form of variable resistance keying. Special variable resistance contacts have ben devised by one American company, and there have been many attempts to use liquid or semi-liquid resistance elements. The most elegant method from the electronics engineer's point of view is some form of controlled static switching using semiconductors, usually diodes. The diode is caused to pass from the non-conducting to the conducting state by variation of the applied bias voltage, which may be made to occur at any desired rate both making and breaking by the use of suitable *RC* networks. This system has the further advantage that numerous signals may be keyed simultaneously by a single pair of contacts, and both octave and inter-manual coupling is easily provided. The disadvantage of diode switching is that all waveforms other than square are distorted during switching, the effect upon a sawtooth being shown in Fig. 3. This distortion means that the voices of all the stops will be degraded during keying, and unless the time delay is very short this degradation will be audible and a slow break or "sustain" effect will be out of the question. A circuit for the controlled keying of a sawtooth without undue distortion is a more difficult proposition (if considerable complication is to be avoided) and the problem does not yet appear to have ben satisfactorily solved, though investigation is in progress.

The mention of sustain brings up the whole question of artificial reverberation, so popular with the "entertainment" type of organ and so rarely fitted to the church type. It is true that most religious or public buildings have sufficient natural reverberation of their own—some have too much—but now and again one finds a building which, by ill-luck or bad design, is very dead acoustically. In these circumstances an electronic organ might benefit from some judicious artificial reverberation, which could take the form of a slight sustain effect if it were desired to save the expense of the more sophisticated electro-mechanical unit. The illusion might be heightened by making the sustain progressively longer as the pitch increased, although this method would not work too happily in the case of, say, a pedal reed tone where the higher harmonics should reverberate but the fundamental should not.

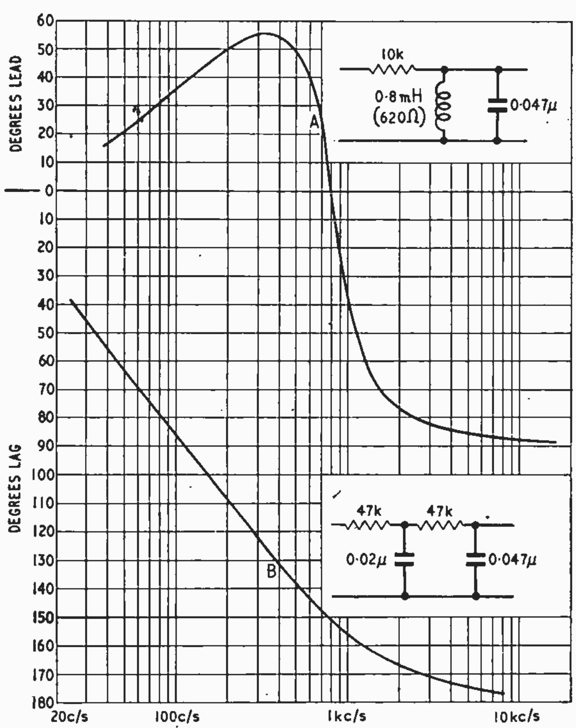


Fig. 4. Phase shift over the normal operating frequency range of two filter circuits.

SUMMATION OF VOICES

The final stages of an electronic organ, in which the stop filter outputs are summated and amplified, are often responsible for much destruction of realism. This is because in a pipe organ each stop voice has in effect its own output channel, but in the electronic instrument many voices are combined in a single circuit and this can produce curious and unwanted effects. A single example will serve to illustrate this point.

The curves of Fig. 4 show the phase shift (with sine wave input) over the normal operating frequency range of two typical filter circuits, "A" reed tone and "B"

(*Continued on page* 97)

flute tone. The curve of Fig. 5 shows the angular separation of the two outputs, and it can be seen that over the vital frequency range of 270 to 700 c/s (roughly from middle C♮ to F_1) the two signals are more or less antiphase. It follows that if they are of similar amplitude there can be almost complete cancellation of the two fundamentals between these two frequencies. Thus the addition of reed stops to a diapason chorus, though increasing the volume, can produce a change of tonal quality giving a sound which is neither reed nor diapason though reminiscent of both. This effect has frequently been noted by musical critics of electronic organs as a telling point against them.

It would seem from the foregoing that the present practice of dividing the organ output into Swell, Great and Pedal sections, each with its individual amplifier, is in fact less satisfactory than to divide it into Flue and Reed sections with the speakers reasonably well separated. Some extra complication would be introduced by the necessity for the duplication of the expression control (and also the vibrato if this is by phase modulation), but this could be offset by the saving of a power amplifier. If cost were not of primary importance the string tone stops might be improved by being brought out through an independent channel.

A further characteristic of the summing circuits is often the production of thermal noise, due to the high impedance terminations of the filters. This noise can reach quite alarming proportions, and in some current models the fact that the organ is switched on is unpleasantly apparent, and compares unfavourably with the wind noise of the equivalent pipe organ. Some control of the noise is possible if the stops are switched off by earthing the signal rather than by open-circuiting it, but a better method is to terminate the filters by emitter followers and then to combine their outputs. This gives constant loading of the filters with true arithmetic addition of the stop voices no matter how many stops are drawn, and a low impedance output which is quiet and relatively insensitive to outside electrical disturbances. The latter point is often overlooked, and a surprising number of commercial instruments respond sympathetically—and noisily—to thunderstoms, and give a faithful rendering of the ignition systems of passing vehicles.

Of the power amplifiers there is little that needs to be said except that they should be of generous proportions and capable of handling full organ without distortion, bearing in mind the tendency of some organists to augment a composer's chording and to play octaves in the left hand.

Of loudspeakers the great deal that has already been written elsewhere applies to organ outputs also, but it is perhaps worth making the point that better results seem to come from the use of a large number lightly loaded than from two or three heavily loaded. The vibrating area in a pipe organ is after all very large, and it is advisable for the electronics engineer to use a similar technique as far as possible.

In conclusion perhaps a word should be said about reliability, as this is the aspect which appeals strongly to those who pay for the organ as well as those who play it; this is also the point at which the maximum unfairness and discrimination exist between electronic and pipe organs. It is expected that an electronic organ shall be fully operational at all times with practically no maintenance, and there is much adverse criticism if a fault develops more than once or twice a year. Yet a pipe organ normally requires quarterly maintenance and tuning, and even so it is a queston whether five per cent of the organs in this country could be said to be in perfect order with all systems going at any particular time.

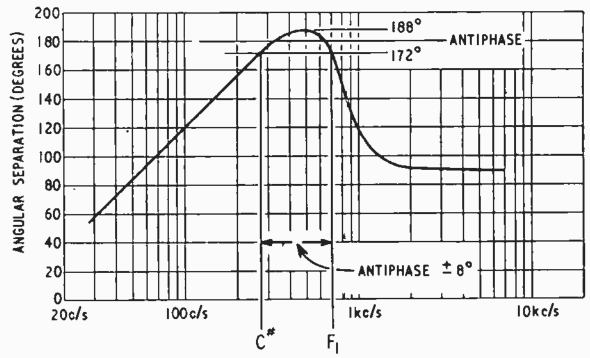


Fig. 5. Angular separation of the outputs of the two filters of Fig. 4.

It therefore behoves the manufacturer of electronic organs to pay great attention to reliability, bearing in mind that a pipe organ is expected to go for upwards of 20 years without a major overhaul. If the electronic job is ready for scrapping after this period—and many of them are—then at least the replacement cost should be no greater than the cost of rebuilding the pipe organ. It would seem however to be possible using all available modern techniques, to produce an electronic instrument which would require the re-tuning of twelve oscillators once a year, and practically no other attention for a decade or so. The life of a transistor, given fair treatment, appears to be between twenty and forty thousand hours, and this is a very long time to play an organ! It is a sad comment on the British electronics industry when a builder of pipe organs can say that he heartily approves of electronic organs, as their unreliability is responsible for a great deal of his business!

In view of the mounting cost of even small pipe organs, and the strange reluctance of modern architects to provide adequate accommodation for an organ in a new church, there ought to be a bright future for the electronic instrument with built-in reliability. It will be a pity if the industry does not rise to the occasion.

Electronic Telephone Exchange

AN electronic telephone exchange installed at Ambergate, Derbyshire, is the first of about fifty similar units to be installed during the next eighteen months, as part of the Post Office programme for modernising the telephone system. Known as the P.O. TXE II, this exchange system has been developed by Ericsson Telephones in co-operation with the Post Office Engineering Department and will be used for all new or replacement exchanges in the capacity range 200 to 2,000 lines.

The key component of this system is the miniature dry reed relay. (Absence of background noise in this system is said to be the result of using these reeds with gold plated contacts sealed in an atmosphere of inert gas.) The reed relay is used as a cross-point switch for speech path switching, and other control functions. The electronic section of the exchange is built up from silicon semiconductors, tin oxide resistors, and ferrite cores for storing the information produced by the calling number generator.

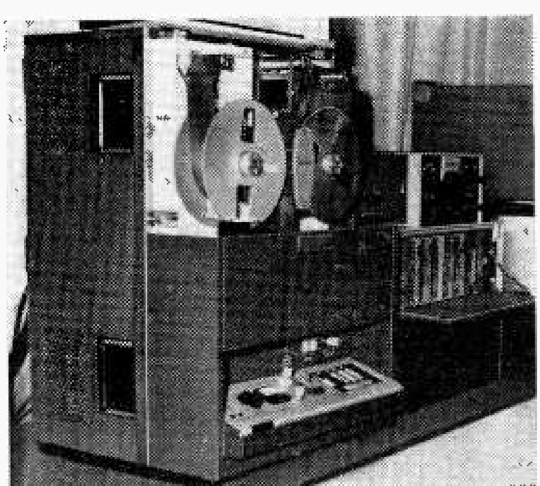
NEW PRODUCTS

equipment systems components

V.T.R. SYSTEMS

THE Sony BV 120E/120 Video Tape Recorder system is a compact design intended for applications in education, laboratories, industry, outside broadcasts, rehearsal of broadcast programmes, etc. The specifications and performance are stated to be compatible with N.A.B. or C.C.I.R. broadcasting requirements. The system consists of a portable v.t.r. (PV-120U/PV-120UE) main equipment for the system; a tv signal stabilizer (TIS-1/TIS-1E) and a waveform monitor (WFM-1). Solid-state circuitry permits operation on normal a.c. supplies from 110 V to 240 V 50 to 60 c/s. The BV-120 system is for recording/reproducing E.I.A. (60 c/s field frequency 525 lines) standard signals, while the BV-120E (50 c/s field frequency 625 lines) is for C.C.I.R. signals. Two audio channels are provided with audio dubbing possible on one channel. There are variable speed slow motion (1/5 to zero of normal speed) in both forward and reverse directions, and stopped picture facilities. Vertical phase lock is available to synchronize the phase of the reproduced vertical-sync with a reference signal. Operating functions—play, record, fast forward and rewind, stop, slow and still can be initiated by a remote control unit (PVR120). Normal tape speed for the BV-120 system is 4·25 in/s (10·79 cm/sec), and for the BV-120E system it is 4·94 in/s (12·56 cm/sec). Maximum recording time for the BV-120 is 90 minutes and for the BV-120E is 80 minutes. Both systems use SONY video tape of 2 in (50·8 mm) width, type V-21. The following specifications are common to the two systems: video input composite signal of sync negative 0·4 to 1·4 V pk-to-pk, 75 Ω unbalanced; sync input, negative sync signal or vertical drive pulse, 4 V p. to p., 75 Ω unbalanced; video output, composite signal of sync negative 1 V p. to p., 75 Ω unbalanced; sync output, negative composite sync signal 4 V p. to p., 75 Ω unbalanced. Horizontal jitter is less than ±0·15 μs, and the video signal to noise ratio is better than 40 dB. Audio signal to noise ratio is better than 40 dB on channel 1 and better than 36 dB on channel 2. Wow and flutter is less than 0·3 % rms. Audio frequency range on the BV-120 for channel 1 is 50 c/s to 8 kc/s, and channel 2, 50 c/s to 7 kc/s; on BV-120E channel 1 it is 50 c/s to 10 kc/s, and on channel 2, 50 c/s to 8·5 kc/s.

The television signal integrated stabilizer unit enables the head drum motor to synchronize to the incoming vertical sync and this sync is recorded on the control track; on replay, the head drum motor is locked to the control track. A servo system with suitable clamping minimizes jitter in the reproduced signal. A recorder without this unit operates locked to the vertical sync.



The waveform monitor is available for observing input/output, and servo signals. To be marketed in the U.K. by E.M.I. Electronics Ltd., Hayes, Middlesex.

WW 301 for further details

E.E.G. Calibration Unit

FOR fault finding and routine maintenance of electro-encephalographic (e.e.g.) appliances Triumph Electronics Ltd. have designed a low frequency, inexpensive (£26 5s 0d) oscillator with the following specifications. The balanced output gives a true bipolar signal similar to that obtained from two e.e.g. electrodes with a ground connection elsewhere on the patient. A calibrated attenuator switches down to 10 μV, essential for low level checks. An unbalanced (multiplying factor 1000) output gives an instantaneous indication of the true discrimination factor at any e.e.g. frequency. It also provides a high level signal (up to 1·0V) referred to ground, which is useful for fault finding in the later stages of an amplifier. A balanced square wave output applied to two electrode leads can be used as a continuous calibration signal to replace the continuous operation of the "Calibrate" key when setting up the gain levels of the channels. A sine wave output can be used to check the effect of the time constant and h.f. filter circuits at various frequencies. A compact, self-contained, battery operated unit enables the operator to place the calibrator in its most convenient position (e.g. behind the pillow on the e.e.g. couch) without any fear of introducing mains frequency interference due to ground loops, etc. It can be used in series with the patient in perfect safety. The output range available (balanced) is 10 to 500 μV, 1 mV, and the unbalanced output is 10 to 500 m, 1 V. The sine wave distortion is less than 5% and the square wave function has a rise time of less than 10 μs. The frequency range is 1 c/s to 100 c/s—variable. Battery operated by PP6 or equivalents gives 50 hours continuous use. Triumph Electronics Ltd., 118 Brighton Road, Purley, Surrey.

WW 302 for further details

VARACTORS

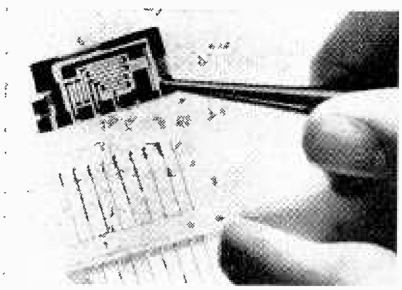
HIGH-POWER multiplier varactors from Microwave Associates Ltd., Cradock Road, Luton, Beds., are being offered in the MA4960 series, covering the frequency range 100 to 250 Mc/s at 30 W to 25 Gc/s at 0.050 W. One particular example of these silicon epitaxial diffused junction devices is the MA4964, which operates in the 2 to 3 Gc/s range. This device has an output power of 5 W and a breakdown voltage at 10 μA minimum of 70 V. The junction capacitance at 1 Mc/s is 3 pF (min), 5 pF (max). The storage and operating temperature range for the MA4964 is −65 °C to +175 °C. Cut-off frequency is 50 Gc/s.

WW 303 for further details

THIN FILM CIRCUITS

THE Plessey TFC thin film resistor networks are intended for passive circuits in commercial equipments which require tolerances ranging from 1% to 10% at temperature coefficients of 50 p.p.m./deg C. The evaporation technique deposits the resistor and interconnection patterns on to a glass substrate. The assembly is in a container designed for mounting on printed circuit boards, with the connections arranged on the 0.1 in grid. TFC 1002 (available as resistor or resistor and capacitor networks) has, however, been designed for either passive or active circuits over a wide range of environments. With a temperature coefficient of 10 p.p.m./deg C resistor tolerances of 0.1% are available. The complete package is a ten-lead hermetic encapsulation with glass to metal seals. Resistor Division, Plessey Components Group, Cheney Manor, Swindon, Wiltshire.

WW 304 for further details



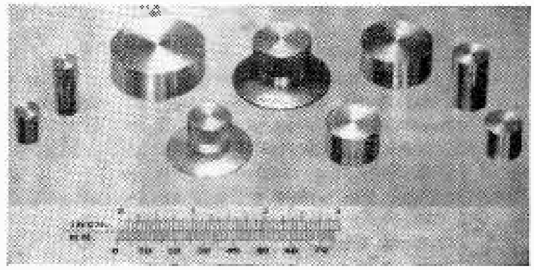
Rationalized Transistor Range

THE Silind range of silicon transistors by Newmarket Transistors Ltd. is an attempt to rationalize the thousands of transistor types which are available with JEDEC, Pro-Electron, and house code specifications. These specifications, say Newmarket, have given rise to too many transistors, with marginal differences which often have little or no influence in a given circuit. The 12 silicon devices in the Silind range have been chosen to cover the majority of conventional circuit requirements in the low-to-medium power industrial field from d.c. to 100 Mc/s. They will be supplied in 0.5 in, three-lead (v.h.f. four-lead) standard TO-18 welded metal encapsulations, gold plated for humidity requirements. TO-5 cans are available for some power dissipation requirements. Ten of the devices are n-p-n types. Maximum and minimum samples are available. Newmarket Transistors Ltd., Exning Road, Newmarket, Suffolk.

WW 305 for further details

ALUMINIUM KNOBS

SOLID, turned aluminium knobs are available in a basic range of five sizes from A. F. Bulgin & Co. Ltd., Bye-Pass Road, Barking, Essex. These circular knobs are 0·5 in (12·7 mm) high, and vary in diameter from $1\frac{7}{16}$ in (36.5 mm) to $\frac{3}{8}$ in (9·5 mm). There are two additional knobs in matching design with a height of $\frac{7}{8}$ in (22·2 mm).



All models have smooth polished sides, turned spin finished top faces, are fitted with Allen set-screws as standard, and have a component nut recess in the base. Two additional models possess "skirts" and finely ribbed sides for positive grip. The integral skirts are normally supplied plain, but can be engraved to individual requirements. These knobs are intended for electrically dead or earthed shafts.

WW 306 for further details

Light Craft Radar

A THREE-UNIT radar for small craft such as tugs, fishing vessels and launches, is being manufactured by Decca Radar Ltd. and was recently seen at the International Boat Show, Earls Court. This radar equipment, the Decca 101, is designed to meet in full the radar performance standards agreed by the 1960 Conference on the Safety of Life at Sea (SOLAS). The scanner unit has a 3 ft wide aerial, rotating at 36 revolutions per minute, and a transceiver with a peak power of 3 kW. A single cable runs from the scanner unit to the display unit, which houses a 7-in diameter c.r.t. Range rings on the screen, spaced at equal intervals, represent $\frac{1}{2}$ or 2 miles, depending on the range in use. The display unit carries the operating controls for the system, and these are identified by a series of conventional symbols. Multilingual explanations of each control function in operational sequence are on the back of the display cover. Mountings for bulkhead, deckhead, or table top can be provided for the display unit. The power unit is a solid-state static inverter supply, with good stabilization and freedom from mains transients. Silicon transistors are used in the display unit and transceiver.

The Decca 101 has a maximum range of 15 nautical miles, and can also be set to cover $\frac{1}{2}$, $1\frac{1}{2}$, or 5 miles. It is suitable for 12, 24, 32, 110, 220 V d.c. and 115 or 230 V a.c. 50/60 c/s single-phase operation. A typical installation will cost about £830. Decca Radar Ltd., Decca House, Albert Embankment, London, S.E.1.

WW 307 for further details

MICROWAVE DIODES

FAST switching diodes for use at microwave frequencies are available from Sylvania International, 21, rue du Rhone, Geneva, Switzerland. The D5720 series of p-i-n diodes has a breakdown voltage of 200 V and a switching time as low as 10 ns. An isolation of 20 dB is attainable at C-band frequencies in a shunt tuned configuration. It is stated that stability over a long life is good. V_B at 10 μA for the 5720 is 200 V; for the 5720A and B it is also 200 V. C_T maximum at -25 V at 1 Mc/s for the 5720 is 0.1 pF; for the 5720A it is 0.2 pF, and for the 5720B it is 0.35 pF. R_t maximum for all three devices in this series is 400° per watts. These diodes operate as a voltage dependent variable resistance when biased in the forward direction, and as a relatively small and nearly constant capacitance when reverse biased.

WW 309 for further details

Zener Diodes

ONE watt Zener diodes in the Zecon range introduced by International Rectifier Co., Hurst Green, Oxted, Surrey, are available in voltages from 3.9 V to 30 V at $\pm$ 10% tolerance. These are wire ended Zeners (VASCA outline SO-16, JEDEC DO3) with a hermetic glass-to-metal seal.

WW 308 for further details

Equi-tempered Scale Generator

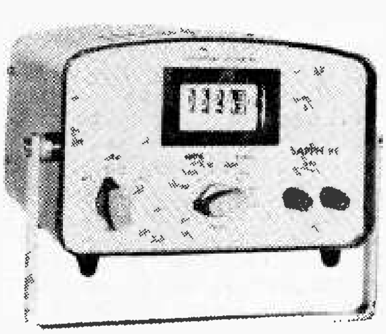
THE solid-state musical scale generator by R. Penny, 58, Sandalwood Avenue, Chertsey, Surrey will produce any one of a series of notes that are precisely related to one another in the form of an equi-tempered scale. The range of the instrument is from middle C to second octave B, and any note may be held indefinitely. By means of a single tune control, the whole scale may be varied in pitch, while preserving the equi-tempered relationship, thus enabling a scale to be obtained at any pitch. The generator may be used for tuning instruments, such as pianos and harpsichords, without reference to fourth, fifth or other intervals as only fundamental (unison or octave) comparison need be made. Adjustment is made until there are no beats between the instrument and the generator. The use of fundamentals only in the comparison helps tuning work in noisy environments, especially as the generator emits a continuous note of adjustable loudness, and it is of great benefit when working with harps which have little harmonic content. The equi-tempered scale generator is provided with only four controls. A combined on/off and volume control provides precise control of loudness. A twelve-position switch selects the note to be produced and a separate octave switch raises all the notes by exactly an octave. The tune control is also used to set the base note accurately to the desired pitch. Any note may be used as a base note, and once set, a true equi-tempered scale is automatically obtained relative to that base note. The scale is based nominally on A440 with range of adjustment from 430 to 450, and it is usual to set the scale to a good A440 fork if a scale at British Standard pitch is required. The scale is accurate, relative to the base note to within ±0·03% which is about one beat in eight seconds at A440. The generator will function over the temperature range 40°F (5°C) to 80°F (27°C) with no loss of accuracy. The base note may be easily set to a fork to within ±0·02% thus giving absolute pitch to within ±0.05%. Another version of this generator can be set to any temperament required such as equal, just, meantone and cyclic.

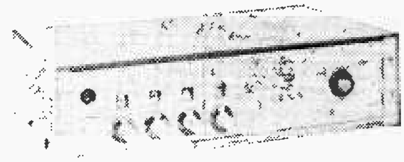
WW 310 for further details

Digital Voltmeter

A DIGITAL voltmeter model 250 by Sapphire Research & Electronics provides both d.c. and a.c. ranges from 1 kV and 500V r.m.s. respectively, and in addition a.c. and d.c. current ranges. It can resolve voltage differences as small as 200 μV. From 10 c/s to 60 kc/s the standard of accuracy is 0.25% full scale on the a.c. voltage ranges. The accuracy on the d.c. voltage ranges is stated to be 0.1% full scale. The Company's sales office is at Rainham, Kent.

WW 311 for further details





Batch Counter

AN AUTOMATIC batch counter comprising four ELMA single decade read-out counters and other modules by Radiatron, 7, Sheen Park, Richmond, Surrey, can be preset to give a relay operation at any number. Then it will either stay set or reset automatically to zero and recommence counting—giving a relay operation at the end of each batch. As long as there is a minimum pulse length of 28 ms and a minimum pulse interval of 12 ms this counter will operate from sources such as micro switches, etc. The contacts for external operation have a rating of 50 W.

WW 312 for further details

WIDE RANGE MICROWAVE GENERATOR

CLAIMED to be the widest range microwave signal generator, the 6459 by the Sanders Division of Marconi Instruments Ltd. has the following characteristics. Frequency range, 3·5 to 12·0 Gc/s, direct reading frequency dial, direct reading attenuator, calibrated in voltage and dBm, high stability and accuracy, internally generated f.m., c.w., pulses or square wave modulation, optional conversion to rack mounting. The instrument has facilities for the application of external modulations. The pulse repetition rate is variable from 40 to 4,000 p.p.s. and the pulse width from 0·5 to 10 μs. Synchronizing signals are simultaneous with the r.f. pulse, or between 3 and 300 μs in advance of the r.f. pulse. The internal pulse generators can also be synchronized by means of external signals.

The signal generator incorporates a plug-in klystron oscillator in an external coaxial line cavity. Frequency is determined by the position of a movable non-contacting piston, which is coupled to the frequency scale, and an automatic tracking network, and the output level is read in dBm and μV from the directly calibrated, internal, high precision attenuator. Temperature compensation, applied to the power meter bridge, ensures virtual freedom from the effects of ambient temperature changes. The power output is (a) direct—an insertion probe couples out power to 80 mW, max. (b) indirect—via attenuators 0·223 V to 0·1 μV (0 to −127 dBm) between 4·5 Gc/s to 11·0 Gc/s and −6 dBm to −127 dBm between 3·5 and 4·5 Gc/s. For the measurement of receiver sensitivity, selectivity or rejection signal-to-noise ratio, aerial gain and transmission line characteristics, in addition to numerous specialized applications, the 6459 is a suitable instrument for single band operation in the 3·5 to 12·0 Gc/s frequency range.

WW 313 for further details

Calibration Standard

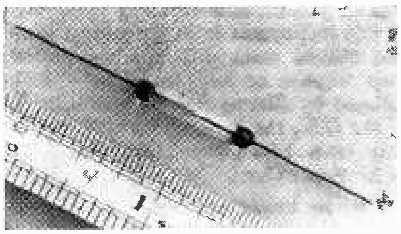
CALIBRATION of analogue and digital voltmeters, ammeters, and wattmeters can be carried out with the Model 300 Instrument Calibration Standard by Radio Frequency Laboratories Inc., U.S.A. A precision source of a.c./d.c. voltage and current, it has an accuracy of 0.1% d.c. and 0.15% a.c. Voltages available range from 0.01 mV to 1 kV a.c. and d.c. Six-digit readout is provided for all d.c. functions and also for a.c. volts and milliamperes. There is a five-digit display for the a.c. ampere and millivolt ranges. The sinewave oscillator and power amplifier permits calibration from 50 c/s to 1 kc/s to be carried out with less than 0.05% distortion. The internal reference source has a stability of better than ±0.01% per year. Logic circuits protect this solid-state instrument against overloads and abuse. Sole U.K. agents are Wessex Electronics Ltd., Royal London Buildings, Baldwin Street, Bristol 1.

WW 314 for further details

REED SWITCH

A DRY reed switch with a maximum d.c. contact rating of 3 W is produced by Flight Refuelling Industrial Electronics, Flight Refuelling Ltd., Wimborne, Dorset. Maximum voltage (switched) across the rhodium plated contacts is 28 V d.c. and maximum permissible current is 100 mA d.c. The overall length including leads is 2.25 in.

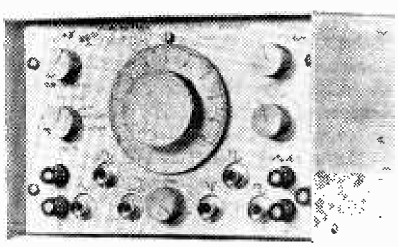
WW 315 for further details



Waveform Generator

THE "Wavetek" voltage controlled generator by General Test Instruments Ltd., Gloucester Trading Estate, Hucclecote, Gloucester, produces ramp, sine, square, triangle waveforms and sync pulses simultaneously. The dial spread allows a 20:1 frequency sweep, the total frequency range being 0.0015 c/s to 1 Mc/s. Further claimed performance figures are: dial accuracy 0.5% of reading, amplitude change with frequency <0.1 dB; amplitude stability 0.1% of maximum pk-to-pk values for 30 minutes short term and sine wave distortion <0.5%.

WW 316 for further details

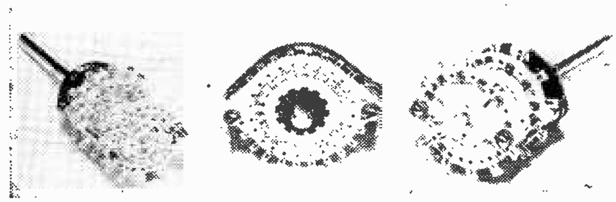


LASERS

RUBY lasers announced by System Computers Ltd., of Fossway, Newcastle-upon-Tyne 6, provide, in three types, R1, R5 and R10, outputs up to 80 joules. R1 gives a low output from a 2-in dry ruby element and is capable of cutting or welding very fine wires, thus making it useful for general demonstration and research purposes. R5 and R10 give 25 and 80 joules respectively from $6\frac{1}{2}$-in long rubies. Besides these lasers five helium-neon types are available.

WW 317 for further details

Rotary Wafer Switches



MANUFACTURED by A.B. Metal Products Ltd., 119/127, Marylebone Road, London, N.W.1, is the range of rotary wafer switches. MINI-12 (12 positions), MINI-24 (24 positions) and PY (22 clips/12 positions). The newly designed index mechanism employs a sintered iron index wheel and hardened detent pin to give reliable performance. The indexing arm can be fitted to one or both sides of the index wheel, which, when coupled with a variety of tension springs, can provide an extremely wide range of spindle operating torques. Contact clips and rotor blades are made of good quality non-ferrous spring material and are heavily silver plated, giving the low contact resistance of 4 to 6 milliohms. Moulded stators and rotors offer a resistance of 50,000 MΩ. Wafers are of self spacing design with full depth castellations, which offer complete support to the clips. The proof voltage at normal temperature and pressure is 2 kV between electrical contacts and normally earthed components; between electrical contacts insulated from each other it is 1 kV. Current switching capacity (resistive loads) is 50 mA at 300 V a.c./d.c. or 500 mA at 30 V a.c./d.c. This range is intended for both military and professional applications.

WW 318 for further details

Low-resonance Speaker

A $6\frac{1}{2}$-in circular cone loudspeaker is available from the Plessey Components Group. The speaker, used in conjunction with a Plessey $3\frac{3}{8}$in "tweeter" and in a suitable enclosure, is said to give a very high quality of sound reproduction. The frequency response of the unit is stated to be flat from 40 to 1 kc/s when correctly loaded. The low nominal resonance of less than 60 c/s is achieved by a flexible bellows-type cone surround of plasticised linen. The sensitivity of this speaker results from the combination of a 10,000 line ferrite magnet with an exceptionally light, stiff cone assembly. The 1-in voice coil, which is dustproofed, has beryllium copper flexible leads that will not fracture with large cone excursions. Output is 12 W. Standard voice coil impedances are 8 Ω and 15 Ω. The recommended enclosure is 14in × 9in × 9in or larger, with internal damping of long-fibre wool. This $6\frac{1}{2}$in speaker is available from the Plessey Acoustics Division, New Lane, Havant, Hants. The same Division can also supply the matching $3\frac{3}{8}$in "tweeter" to extend the frequency range up to 20 kc/s.

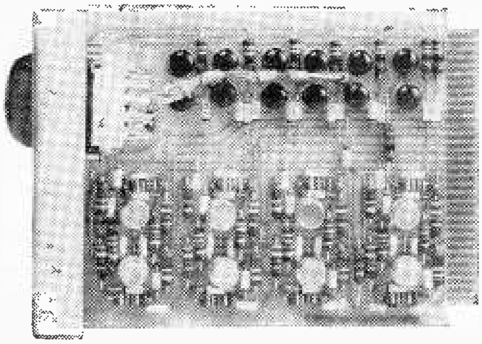
WW 319 for further details

Portable Wattmeter

A PORTABLE peak and average power wattmeter developed by Bird Electronic Corporation is designed to measure almost any type of r.f. transmission in 50 Ω coaxial systems. This instrument, available from Livingston Laboratories, North Watford, Herts., makes use of an integrated circuit amplifier together with other solid state circuitry. Plug-in elements enable power ranges to be selected for given frequency bands. Average power measurements over the frequency range 450 kc/s to 2.3 Gc/s can be made from 1 W to 10 W using suitable elements. Peak power can be read over the frequency range 25 Mc/s to 1.26 Gc/s. The average power plug-in elements used in a previous instrument by Bird, the model 43 Thruline wattmeter, can be used in this new instrument.

WW 320 for further details

Decade Counter Module



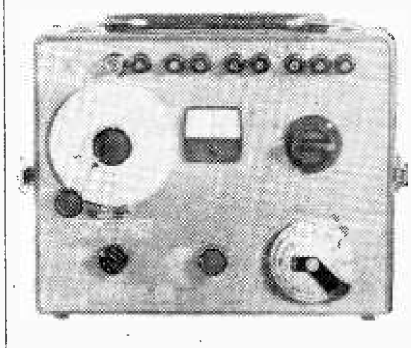
DESIGNATED DCM703 a decade counter module by Quarndon Electronics Ltd., Slack Lane, Derby, utilizes four saturating binary flip-flops with feedback to provide a 1-2-4-8 binary coded decimal counter. Displayed by a numerical indicator tube the b.c.d. outputs are also available at the 32-way 0.1 in. pitch conector. Input requirements over a frequency band of 0-1 Mc/s are 3 V-5.5 V negative pulse amplitude, 300 ns minimum pulse width and 200 ns maximum risetime. Noise rejection is 1.5 V. The power requirements are +6 V ±10%, 60 mA; −6 V ±10%, 3 mA; +200 V ±20%, 2 mA. Output level voltages are +6 V and 0 V with rise time 100 ns and propagation delay 150 ns.

WW 321 for further details

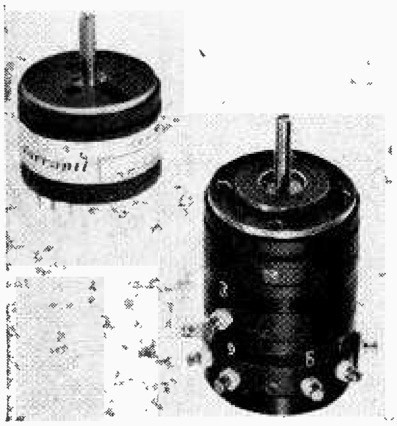
IMPEDANCE BRIDGE

THE impedance bridge Type 250DE, weighing 12 lb, has been designed for field use. It is capable of measuring a wide range of resistance, capacitance and inductance values with accuracies of 0.1 %, 0.2 % and 0.3 % respectively. A greater accuracy is claimed for comparative measurements. The solid-state circuitry, which is operated from four 1.5 V cells, consists of an a.c. generator and an a.c.-d.c. null detector. A feature of this instrument is its patented Dekadial coaxial main dial which provides easy adjustment and readability. Developed by Electro Scientific Industries of the U.S., the portable bridge is available from Livingston Electronics Ltd. of Watford, Herts.

WW 324 for further details



Precision Potentiometers



RESISTANCE values from 50 Ω to 50 kΩ per quadrant over the temperature range −65°C to +150°C are available in the Ferranti 11HL precision wire wound potentiometer. Sine/cosine functions can be provided, on single and multi-ganged units up to six gangs. Precious metal alloys are used for all wipers, slip rings, and most windings for maximum resolution and low noise. Taps are welded to single turns. Torque is 3 gm cm per gang, and law conformity better than ± 10% peak to peak. Ferranti Ltd., Thornybank, Dalkeith, Midlothian.

WW 322 for further details

Semi-rigid Cable

A SEMI-RIGID coaxial cable designed for 50 Ω operation uses a solid drawn tubular outer conductor. Claimed to be completely noise free at all signal levels, this cable, by the R.F. Components Division of Sealectro Ltd., has attenuation characteristics of 3.42 dB/100 ft at 100 Mc/s and 44.30 dB/100 ft at 10 Gc/s. Cable assemblies can be tailored to customers' specifications, a range of subminiature r.f. connectors being also available from the makers.

WW 325 for further details

LOGIC MODULES

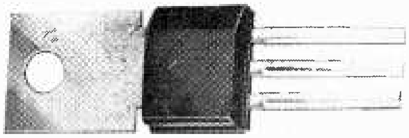
MACHINE tool and process engineering have been the subject of automatic control for many years now, and contributing to this field is the E.M.A. range of RT (resistor-transistor) plug-in logic modules. Available singly or in custom designed systems, they include Emablocs (logic), Emamems (memory), fan-out multipliers, binary units, permanent memory units, and 5A thyristors. The Emabloc functions as a basic AND, OR, NAND or NOR gate, and it has a fan-in of 5. The alternative fan-outs can be 6 Emablocs, 6 double Emablocs, 6 Emamems, 1 fan-out multiplier, 1 power amplifier, 2 binary units, or two timers etc. The switching speed is 1 kc/s. The supply is a negative 24 V d.c. ±5% at 5 mA, and a positive d.c. supply of 24 V ±5% at 0.25 mA. Electronic Motivated Automation Ltd., 88-90 Pall Mall, Leigh-on-Sea, Essex.

WW 323 for further details

Matched Thermistor Pairs

THERMISTORS by Radon Industrial Electronics Co. Ltd., designated G-112, G-126 and G-128, are specifically designed for use in gas chromatographic equipment and other thermal conductivity gas analysis instruments. These thermistors are matched pairs with each head mounted on a hermetically sealed stem. For maximum sensitivity, the higher resistance units should be used at higher ambient temperatures. The resistance characteristics for the G-112 are 23.2 kΩ at 0°C, 8 kΩ ± 20% at 25°C and 3.2 kΩ at 50°C. The temperature coefficient at 25°C is −3.9 % per deg C; the power rating is 45 mW in air, 140 mW in helium. The maximum operating temperature is 300°C at a resistance of 25 Ω.

WW 326 for further details



HIGH VOLTAGE TRANSISTORS

A RANGE of General Electric (U.S.A.) high-voltage silicon n-p-n transistors 2N4054-2N4057 made available in the U.K. by Jermyn Industries, Sevenoaks, Kent, have a total dissipation each, of 4 W at 70°C. The V_{CEO} values available range from 150 to 300 V and the transistors have a continuous current rating of 100 mA. At an I_C of 50 mA their forward current transfer ratio is ≥ 50. They are intended to be used in Class A audio output stages being able to deliver I watt to a loudspeaker, although they can be used in high voltage video amplifiers. In small quantities they cost 16s 11d for the 2N4054, 15s 6d for the 2N4055, 10s 6d for the 2N4056 and 11s 8d for the 2N4057.

WW 327 for further details

Disc Capacitors

CERAMIC disc capacitors in the Erie 801 series have a finished diameter of 0.36 in. At a working voltage of 500 V d.c. the 801 series Ceramicon is available in twenty-four individual ceramic bodies for different applications. The capacitance range is 6 pF to 7,000 pF and 10,000 pF at 100 V d.c. working. The temperature range is −55 to +85°C, and the 801 series has been submitted to a flash test of 1,500 V d.c. Tolerances vary from ± 5 % to −20 + 80 % depending upon the dielectric employed and the value of the capacitor. The 801 series is available in conventional wire termination or "pluggable" for printed circuits.

WW 328 for further details

INFORMATION SERVICE FOR PROFESSIONAL READERS

To expedite requests for further information on products appearing in the editorial and advertisement pages of *Wireless World* each month, a sheet of reader service cards is included in this issue. The cards will be found between advertisement pages 16 and 19.

We invite professional readers to make use of these cards for all inquiries dealing with specific products. Many editorial items and all advertisements are coded with a number, prefixed by WW, and it is then necessary only to enter the numbers on the card.

Postage is free in the U.K. but cards must be stamped if posted overseas. This service will enable professional readers to obtain the additional information they require quickly and easily.

OVERSEAS CONFERENCES AND EXHIBITIONS

Latest information on events abroad during the next six months, is given below. Further details are available from the addresses in parentheses.

Feb. 15-17 — Philadelphia
Solid-state Circuits Conference
(L. Winner, 152 W. 42nd St., New York, N.Y. 10036)

Mar. 1-3 — Washington
Particle Accelerator Conference
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

Mar. 5-14 — Leipzig
Spring Fair
(Leipziger Messeamf, Post Box 329, Leipzig)

Mar. 9-14 — Paris
Festival du Son
(S.I.E.R.E., 16 rue de Presles, Paris 15e)

Mar. 20-24 — New York
I.E.E.E. International Convention & Exhibition
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

Mar. 22-24 — New York
Symposium on Modern Optics
(Polytechnic Inst. of Brooklyn, 333 Jay St., Brooklyn, N.Y. 11201)

Apr. 5-7 — Washington
International Magnetics Conference
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

Apr. 5-10 — Paris
Electronic Components & Audio Equipment Shows
(F.N.I.E., 16 rue de Presles, Paris 15e)

Apr. 10-15 — Paris
Electronics and Space Conference
(F.N.I.E., 16 rue de Presles, Paris 15e)

Apr. 14-21 — Paris
Mesucora—Measurement & Automation Exhibition
(Mesucora, 40 rue du Colisée, Paris 8)

Apr. 17-19 — Bad Nauheim
Semiconductors, Metals & Magnetics
(Deutsche Physikalische Gesellschaft, 645 Hanau Heraeusstr 12-14)

Apr. 18-20 — Atlantic City
Joint Computer Conference
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

Apr. 19-22 — Bad Nauheim
Semiconductor Device Research Conference
(Dr.-Ing. H. H. Burghoff, VDE-Haus, Stresemann Allee 21, 6 Frankfurt/Main 70)

Apr. 24-26 — Atlantic City
Frequency Control Symposium
(M. F. Timm, Electronic Components Lab., U.S. Army Electronics Command, Fort Monmouth, N.J. 07703)

Apr. 29-May 7 — Hanover
Hanover Fair
(Schenkers Ltd., 13 Finsbury Sq., London, E.C.2)

May 3-5 — Washington
Electronic Components Conference
(Electronic Industries Ass., 2001 Eye St., N.W., Washington, D.C. 20006)

May 3-5 — Palo Alto
Human Factors in Electronics
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

May 8-11 — Boston
Microwave Symposium
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

May 16-18 — San Francisco
Telemetering Conference
(L. Winner, 152 W. 42nd St., New York, N.Y. 10036)

May 18-19 — West Lafayette
Symposium on Circuit Theory
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

May 22-25 — Ottawa
U.R.S.I. Spring Meeting
(R. S. Rettle, National Res. Council, Ottawa 2, Ontario)

May 22-26 — Montreux
Television Symposium & Exhibition
(Secretariat, Case-Box 97, 1820 Montreux)

May 29-June 2 — Montreal
Congress of Canadian Engineers
(R. H. Tanner, Eng'g Inst. of Canada, 2050 Mansfield St., Montreal, Que.)

June 6-9 — Washington
Laser Engineering & Applications
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

June 12-14 — Minneapolis
International Conference on Communications
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

June 25-28 — New York
Consumer Electronics Show
(Electronic Industries Assoc., 2001 Eye St., N.W., Washington, D.C. 20006)

June 28-30 — Philadelphia
Joint Automatic Control Conference
(L. Winner, 152 W. 42nd St., New York, N.Y. 10036)

July 3-8 — Warsaw
IMEKO—International Measurement Congress
(Society of Instrument Technology, 20 Peel St., London, W.8)

July 3-11 — Warsaw
IMIS—International Measurements & Instruments Show
(IMIS, Muzeum Techniki, Palac Kultury i Nauki, Warsaw)

July 10-14 — Columbus
Nuclear and Space Radiation Effects
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

July 18-20 — Washington
Electromagnetic Compatibility
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

U.K. CONFERENCES & EXHIBITIONS

Additions to the list published on p. 27 of the January issue. Further details can be obtained from the addresses in parentheses.

Mar. 1-2 — Savoy Place, London
Colour Cameras and Colour TV Production Techniques
(I.E.E., Savoy Pl., London, W.C.2, and Royal Television Society, 168 Shaftesbury Ave., London, W.C.2)

May 2-4 — Eastbourne
Integrated Circuits Conference
(I.E.E., Savoy Pl., London, W.C.2)

Nov. 21-23 — Savoy Place, London
Servocomponents Conference
(I.E.E., Savoy Pl., London, W.C.2)

ADCOLA
PRODUCTS LIMITED
(Regd Trade Mark)

SOLDERING EQUIPMENT

TOTAL PERFORMANCE

ILLUSTRATED
R300 BENCH STRIPPER

ILLUSTRATED
L64 IN PROTECTIVE SHIELD L700

For full information
and sales apply direct to

HEAD OFFICE SALES & SERVICE

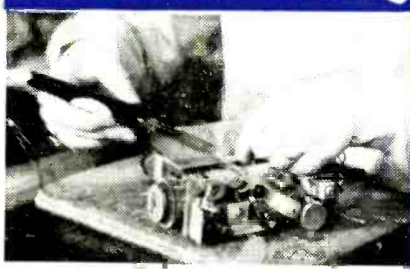
ADCOLA PRODUCTS LTD
ADCOLA HOUSE, GAUDEN ROAD,
LONDON, S.W.4.

Telephones: Macaulay 0291/3 *Telegrams: SOLJOINT, LONDON, S.W.4*

AUSTRALIAN ASSOCIATES: ADCOLA PRODUCTS PTY. LTD., 673 WHITEHORSE ROAD, MONT ALBERT, MELBOURNE
AGENTS IN ALL LEADING COUNTRIES

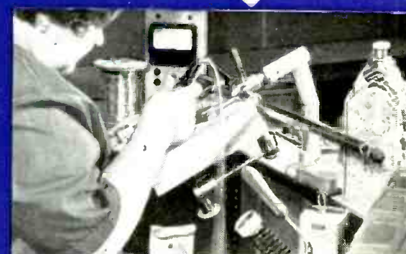
Why do leading overseas electronic manufacturers use Ersin Multicore Solders ?

Because they realise that their reputation can rest upon the quality of the solder they use. For utmost reliability they use Ersin Multicore, the *only* solder containing the purest tin and lead, plus 5 cores of extra-active, non-corrosive Ersin flux. Whatever the application – the speedy soldering of miniature components or the individual production of large units – there is an Ersin Multicore Solder which is exactly right for the job.

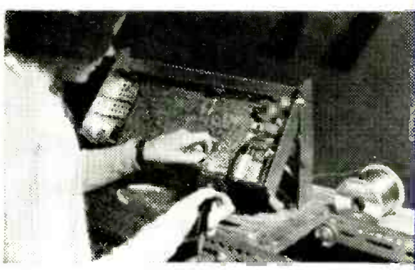


CANADA
Ersin Multicore 5 Core Solder being used to solder Philco Auto Radios at the Philco factory, Don Mills, Ontario, Canada.

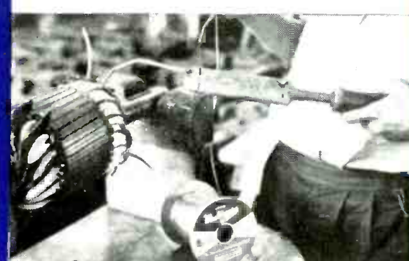
HOLLAND
Ersin Multicore 5 Core Solder is used for soldering printed circuit boards by N. V. Eminent, Bodegraven, Holland.



DENMARK
Ersin Multicore 5 Core Solder being used for the manufacture of high quality electronic instruments at the factory of A/S Brüel & Kjaer, Naerum, Denmark.



NEW ZEALAND
Ersin Multicore Savbit Alloy is seen being used at the factory of the Bell Radio Television Corporation Ltd., Auckland, New Zealand.



INDIA
A motor being assembled with Ersin Multicore 5 Core Solder in the factory of M/S A.E.I. Manufacturing Co. Ltd., Calcutta, India.

FINLAND
Ersin Multicore 5 Core Solder being used in the hand soldering of printed circuit boards for Television Receivers on an assembly line at a factory in Finland.

THE QUEEN'S AWARD TO INDUSTRY 1966

ERSIN Multicore 5 CORE SOLDER

reliability

Engineers and technicians are invited to write on their Company's letter heading for the booklet "MODERN SOLDERS" containing data on melting points, alloys, etc.

MULTICORE SOLDERS LTD.,
Hemel Hempstead, Herts.
Telephone: Hemel Hempstead 3636. Telex: 82363.

WW—002 FOR FURTHER DETAILS.