Wireless World

ELECTRONICS, RADIO, TELEVISION

AUGUST 1963

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NEW MULLARD A.F. PACKAGE

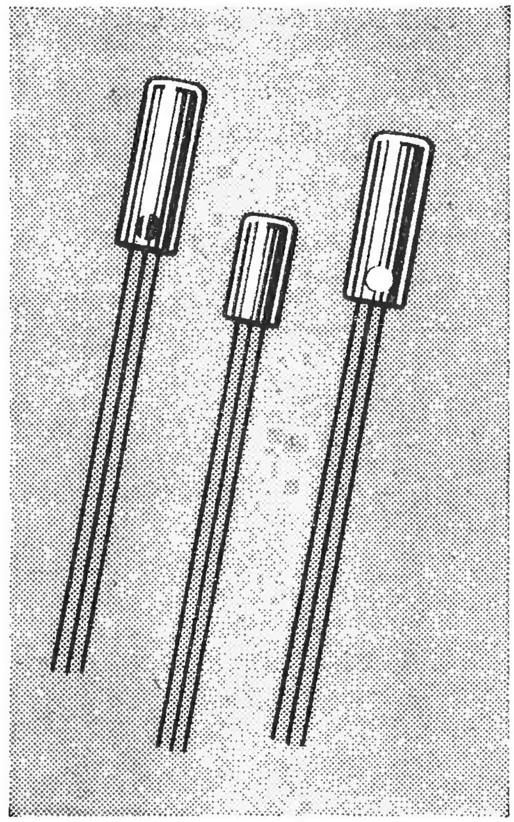
for transistor portables

DESIGNED for use in transformerless audio amplifiers, the new Mullard audio frequency package — the LFK3 — is now to be encountered in modern portable radio receivers.

The output pair of the package consists of the complementary matched p.n.p. and n.p.n. transistors types OC81 and AC127. The p.n.p. driver transistor type OC81D completes the package.

The current amplification factor of the output transistors is greater than 50 at 200mA and 38 at 300mA. The base currents of every pair are matched to within 20% at a collector current of 50mA, and each output transistor is cross-matched with the driver transistor to give reduced circuit gain spreads.

The peak collector current rating of the output transistors is 300mA, which enables output power of up to 500mW to be obtained using a 9V battery. The sensitivity of the package is such that outputs of up to 100mW can be achieved without a pre-amplifier, and outputs of up to 500mW necessitate only a simple single-transistor preamplifier.



PCL86 TELEVISION AUDIO OUTPUT VALVE

The Mullard PCL86 a.f. triode-pentode has been designed specifically for the sound stages of television receivers. The sensitivity of the valve is high enough to allow adequate feedback to be applied in conventional circuits, but is not so high that instability will occur. The high overall gain is achieved partly by a high amplification factor in the triode section, and partly by a high value of mutual conductance in the pentode section. A new cathode material is used in the PCL86 to reduce the likelihood of instability. With this material, there is less deposition of particles from the cathode on other members of the electrode structure.

A special electrode structure — the balcony structure — is used in the PCL86. The triode section is much shorter than the pentode section, and heat can therefore radiate freely from the upper part of the pentode section. Greater dissipation can thus be tolerated, and the anode dissipation rating of the PCL86 is consequently particularly high (9W) for triode-pentodes.

The cathode-to-heater voltage rating of the PCL86 is high (30V), and positioning of the valve in the heater chain is therefore not critical. Screening between the heater and grid leads of the electrode structure ensures a very low level of hum in the valve. The performance to be achieved with the PCL86 is thus very good, and the valve is ideally suited for the sound stages of television receivers.

WHAT'S NEW IN THE NEW SETS

These articles describe the latest Mullard developments for entertainment equipment

ECH84 TRIODE-HEPTODE FOR DUAL-STANDARD TV RECEIVERS

The Mullard triode-heptode, type ECH84, is now appearing in the synchronising stages of dual-standard television receivers in this country. The valve has already been widely adopted by manufacturers producing receivers for 625-line transmission systems using negative vision modulation.

The heptode is generally operated as an interference-cancelling sync pulse separator, and the triode section as a pulse limiter. The heptode function is particularly valuable when interference pulses which are in the same sense as the sync pulses, occur in the video waveform and tend to disrupt synchronisation.

The ECH84 has been designed specifically to supersede the ECH81 in the sync separator application. The earlier type was initially intended for use in a.m. radio receivers and was only subsequently adopted for synchronising circuits, whereas the ECH84 was designed specifically for the television application. Good operation at low voltages is thus ensured. Another consequence of this specific design is that the linearity of the control grid characteristics of the heptode section is markedly better than that of the earlier valve. In the triode section, too, higher values of mutual conductance and amplification factor have been achieved. These improved properties of the ECH84 are reflected by better receiver performance under fringe reception conditions.

MVM 1289

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R.S.G.B.—50 Years

THE Radio Society of Great Britain has just celebrated its jubilee with a round of social events culminating in a Golden Jubilee Dinner in London at which Lord Brabazon of Tara was the guest of honour and which was attended by the presidents of the principal European amateur radio societies, by delegates from the dominions including the Canadian director of the American Radio Relay League, and by distinguished members of the broadcasting organizations, the General Post Office, the learned societies and the radio industry.

The outstanding impressions of this occasion, which will long be remembered by those who were privileged to be present, were first, the easy camaraderie which is so quickly established between radio amateurs irrespective of nationality, social standing or political opinion, and secondly the respect and esteem with which the R.S.G.B. is held in the councils of international amateur radio. It cannot claim to be as big as the ARRL or as old as the Radio Club of America, but its influence today is high because it has been fortunate in having been served by a succession of wise and responsible presidents and by vigilant and energetic secretaries of whom the present holders of these posts, Norman Caws, F.C.A. (G3BVG) and John Clarricoats, O.B.E. (G6CL) are by no means the least.

When it was founded in 1913 there were already national radio amateur organizations in America and Australia, and in England many active clubs in the provinces, notably Derby in 1911, were established before London was shamed into establishing its own Wireless Club by the late Rene Klein. Once formed, the Society rapidly overcame the handicap of its slow start by attracting the support of distinguished scientists like A. A. Campbell Swinton, J. Erskine Murray, Admiral Sir Henry Jackson, W. H. Eccles and Sir Oliver Lodge whose names not only carried weight in negotiation with the Post Office over licensing matters, but whose minds stimulated original thought on the ways in which members might contribute to the advancement of knowledge without detracting from the pleasure they derived from building and using equipment to communicate over long distances.

The outstanding achievement, shared with their American confreres, was the bridging of the Atlantic on 200 metres, a "short" wavelength which had been given to amateurs because it was thought to be of little use as a propagating frequency. What the professionals had missed the amateurs found by patience, persistence and sheer weight of numbers. It is of the essence of amateurism that it need not be efficient in the sense of being under an obligation to show results related to the expenditure of time. It is a leisurely pursuit giving time for thought—which is not to say that it cannot be pushed along at a smart pace when the spirit moves. We can recall many controversies of the early days—"fine wire" coils and reflex circuits, for example—which engendered much heat and resulted in feverish activity between meetings to prove or disprove points raised.

We like to remember also that it was at a meeting of the Wireless Society of London in 1920 that Prof. R. Whiddington described his proximity gauge—one of the first examples of "electronics," or the application of radio-like devices in fields other than communications.

Although the trend has been away from the original concept of a scientific society and towards a more specialized organization of amateur transmitter operators, it is significant that the title of the Society's journal has in recent years been changed from *T. & R. Bulletin* to the more comprehensive *R.S.G.B. Bulletin*. In a message in the July issue this year's president, Mr. Norman Caws, writes: "There are two ways in which we can demonstrate the value of Amateur Radio; first, we should always be sure that the operation of our equipment is of the highest order, both technically and verbally; secondly, we can put all our skill and ability in our experimentation so that it is clear we have sound technical knowledge to add to the sum total of scientific progress."

These are sentiments with which we are entirely in accord, and in offering congratulations to the Society on the occasion of its jubilee we wish its members continued success in their experiments and the deeper satisfaction of strengthening international goodwill through world-wide contacts.

Now as always the amateur is threatened with restriction by the demands for frequencies of other interests, and concerted action is essential if his rights are to be preserved. No one questions his deserts, for he is of the salt of the earth, but some may need reminding of his rights, which he may legitimately claim on the record of past achievement.

LASERS

1.–GENERAL PRINCIPLES: LIGHT AMPLIFICATION IN CRYSTALS

By **AUBREY HARRIS**, A.M.I.E.E., A.M. Brit. I.R.E.

THE past few years have seen a phenomenal rate of technological development in the field of lasers. The reader may well be forgiven for his present confusion as to the method of operation of these newcomers to the field of quantum electronics and just why they promise to be of such value in the future. This review will attempt to explain how these devices work and indicate some of the fields of application.

A brief outline of the history to date is of interest. The first published reference to the theoretical extension of maser operation to the optical region was by A. L. Schawlaw (Bell Telephone Laboratories) and C. H. Townes (Columbia University) at the end of 1958[1] and a practical demonstration that this was possible was reported by T. H. Maiman (Hughes Aircraft Corporation) in 1960[2]. Dr. Maiman's optical maser produced a pulsed output of visible light from a ruby crystal device. Later that year operation of another solid-state device using trivalent uranium was achieved by P. P. Sorkin and M. J. Stevenson (I.B.M.)[3] albeit at very low temperatures. By using a different type of optical maser, a gas discharge tube, A. Javan, W. B. Bennett and D. R. Herriott[4], at Bell Telephone Laboratories in 1961, produced continuous emission at normal temperatures; certain characteristics of this maser were found to be superior to the crystal types.

Perhaps the biggest step forward was made in November, 1962, with the virtually simultaneous announcement from G.E., I.B.M. and M.I.T. in the U.S.A. that an entirely new continuous-output optical maser had been developed. This was a gallium-arsenide semiconductor device of transistor proportions and its efficiency was stated to be in the region of 50%—some 10 to 20 times greater than that of the ruby type.

The term MASER is an acronym formed from the initial letters of the words Microwave Amplification by Stimulated Emission of Radiation. The initial of LASER indicates Light and, usually, includes Infra-red radiation, though it has been suggested that the term IRASER might be used for the invisible radiation at infra-red wavelengths.

The light output of an optical maser differs in several respects from that produced by more conventional generators of light, such as tungsten lamps, discharge lamps or the sun. All these sources

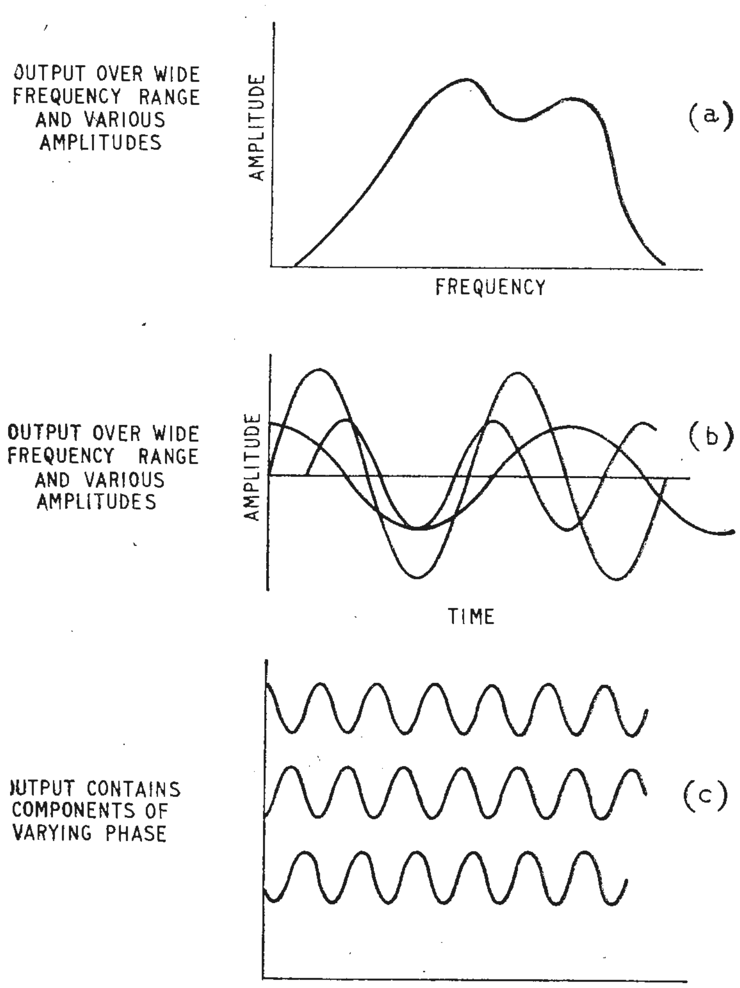

Fig. 1. Non-coherent radiation.

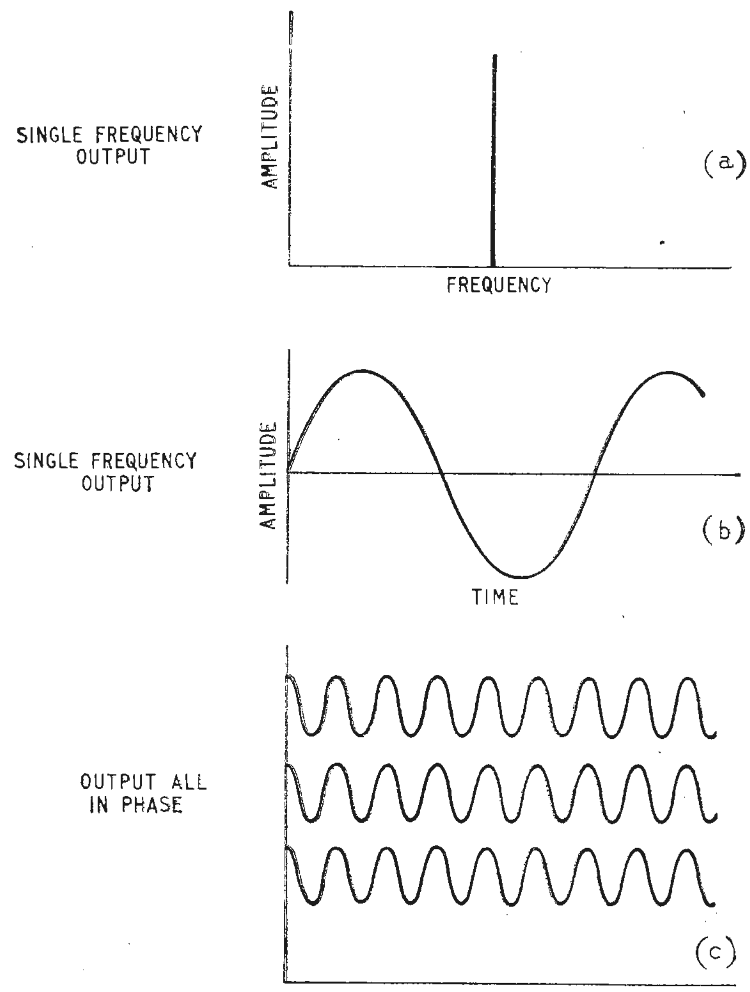

Fig. 2. Coherent radiation.

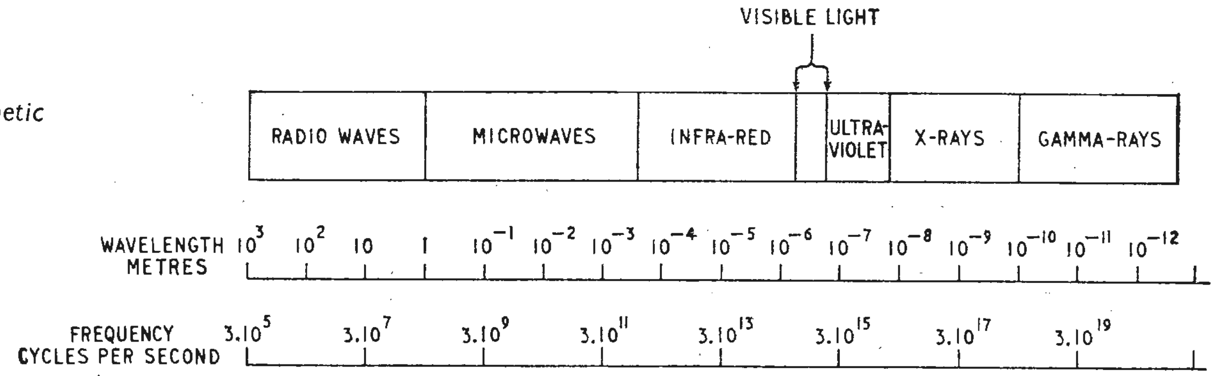

Fig. 3. The electromagnetic spectrum.

produce a relatively wide band of radiation (even a "monochromatic" sodium lamp!). They can be considered to be noise generators as their output contains radiation at a number of different frequencies and also even those components of the radiation which are at the same frequency are of differing phase-relationship, polarization and relative amplitude. (Fig. 1.)

By contrast the laser output is *coherent*. That is, the radiation is at a single frequency, it is completely in-phase and is in the same plane of polarization. (Fig. 2.) It will be appreciated then that the laser output is coherent electromagnetic wave radiation of the same form as that generated by a highly-stable r.f. signal generator. At present, high frequencies, up to 80 Gc/s such as are used for radar systems and microwave links are generated by magnetrons and klystrons, and at low powers frequencies up to 200 Gc/s have been produced by backward wave oscillators. Until the development of the laser coherent electromagnetic waves above these frequencies could not be generated. But now a whole new range of frequencies is available in the electromagnetic spectrum (Fig. 3).

The range of the visible spectrum, from 4,000 to 7,000 angstroms (1 angstrom = 10^{-8}cm) is equivalent to a band of frequencies between 750 million and 430 million megacycles per second. Assuming the likelihood of modulating up to 1/100th of this band, it would theoretically be possible to provide simultaneously over 600,000 5-Mc/s television channels, or about 1,000 million 3 kc/s telephone circuits. Of course, at the moment it is not possible to generate coherent radiation at every frequency in the visible and infra-red spectrum, only at certain specific frequencies in the band. However, as development and research proceeds more and more operating frequencies are being found.

Apart from the advantage of coherence of the output wave the beam is parallel to a high degree, it is extremely narrow in width, and is of a very high intensity. All these factors suggest a whole range of applications for the optical maser. Optical methods may be used to focus and concentrate the output into microscopic dimensions: experiments have been conducted demonstrating how the high-power beam so produced can bore controlled diameter holes of 0.02-inch diameter through ¼-inch industrial diamond—in 200 microseconds. It was estimated that the temperature generated at the surface of the diamond was of the order of 5,500°C.

Basic Necessities

The basic requirements constituting an optical maser are (a) a resonant cavity filled with (b) a suitable active medium (Fig. 4).

The principle of the Fabry-Perot interferometer is almost universally used for the resonant cavity. It consists of two carefully aligned parallel reflecting surfaces, the spacing between which is made equal to an integral number of half wavelengths at the required operating frequency, that is $d = \frac{n\lambda}{2}$ (Fig. 5). A light ray traversing the cavity (A) is reflected at one end (B) in the direction from which it came; it is then reflected at the other mirror (C) in phase with the original ray, which is then reinforced. The process is cumulative and the assembly acts as an optical band-pass filter of very high Q, accepting the required wavelength and rejecting all others.

Where light of more than one wavelength is present in the cavity it is possible to select the desired signal by the choice of the spacing between the reflectors.

The active medium must be one which is capable of possessing at least two distinct energy levels corresponding to the desired output frequency; furthermore the properties of the medium must be such that it is possible to "overpopulate" the upper energy level of the substance with respect to the

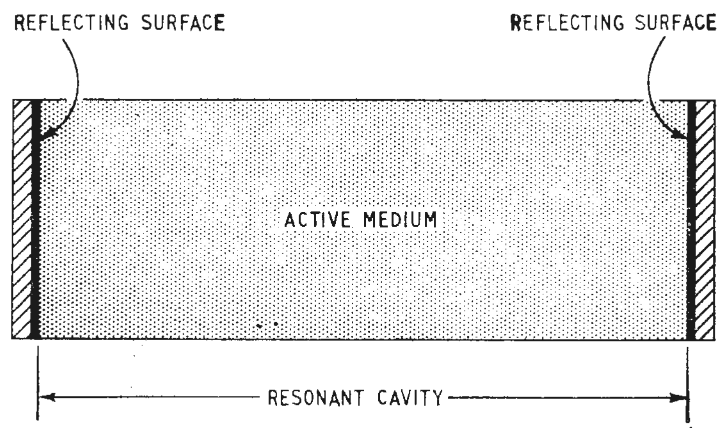

Fig. 4. Basic optical maser.

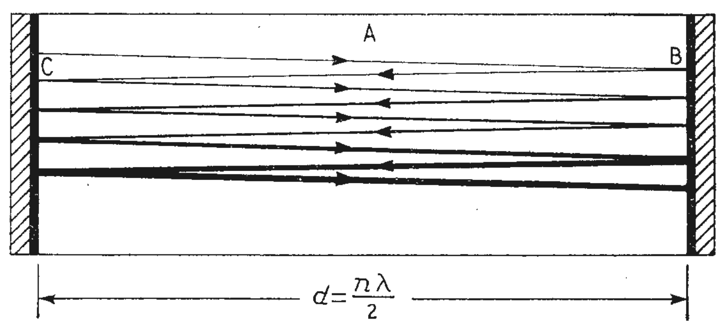

Fig. 5. Fabry-Perot resonator. Rays are successively reflected from end to end of the cavity A, reinforcing each other and producing a strong parallel beam. (Rays are shown slightly non-parallel for clarity.)

TABLE I: THE FOUR MAIN TYPES OF LASER WITH TYPICAL OPERATING CHARACTERISTICS FOR EACH TYPE.

Classification	Typical Material	Input	Efficiency (per cent)	Output		Spectral Width (c/s)	Beam Divergence	Operating Temperature	Emission Mode
				Wavelength (angstroms)	Frequency (c/s)				
Doped crystal	Ruby-chromium	250-1,000 joules	1-3	6,943	4.321×10^{14}	10^7-10^9	0.1 degree	300°K (room temperature)	Pulse (10^{-4} to 10^{-8} sec)
Gas discharge	Helium-neon	80-120 watts	0.01-0.1	6,329 11,530	4.740×10^{14} 2.627×10^{14}	10^0-10^4	0.5 minute	300°K	Continuous
Semiconductor junction	Gallium arsenide	0.05 watts	20-50	8,440	3.554×10^{14}	10^{11}	1-5 degrees	4.2°K (Liquid helium)	Continuous
Liquid	Europium-benzolacetonate	0.01 joules	20-30	6,129	4.894×10^{14}	10^{10}	0.1-0.5 degrees	140°K	Pulse

lower level or levels. This process is often known as population inversion.

A further necessity for successful operation of a laser is the provision of suitable and sufficient power input to the device, in order to raise the energy level and thus obtain overpopulation. The input power may be of light, r.f. energy or just a direct current flow, dependent upon the type of device being operated. " Pumping " is the term normally applied to the process of supplying power to the maser for the purpose of raising the energy level of the active medium.

There are four fundamental types of laser currently under investigation and use. They may be classified under the following heads, primarily indicating their active media:

(a) Doped-crystal
(b) Gas discharge
(c) Semiconductor junction
(d) Liquid

The various types have differing characteristics and properties although they all emit coherent radiation. Output frequency, spectral width, beam width, pumping requirements, efficiencies and other characteristics are summarized for convenience in Table 1.

Even at this early stage of development there are certain pointers indicating the likely application of the different types. For example, it seems highly likely that the gallium-arsenide diode type will be used widely for communications purposes, due to the apparent simplicity of modulation, high efficiency and the continuous mode of operation.

For metal working (spot welding, piercing, etc.) the doped-crystal laser will prove most convenient owing to its compactness and the ease with which the output beam may be collimated and concentrated into high-intensity, microscopic areas. The pulsed output, which is a characteristic of many of the crystal lasers will not prove unduly restrictive for most applications of this type.

The first laser to produce coherent light was Dr. Maiman's, using as active material a crystal of aluminium oxide (Al_20_3); this is a red form of corundum and some specimens are known as ruby. Added to the crystal during preparation was 0.05 per cent of chromium oxide (Cr_20_3).

The ruby crystal is normally in the form of a cylindrical rod, typically $\frac{3}{16}$-in diameter and 2in long. (Sizes vary from between $\frac{1}{8}$-in to 1-in diameter and from 1 to 8in long). With this type of laser the active material, being solid, provides an ideal basis for its own optical cavity. However, careful mechanical work is necessary to ensure that the flatness and parallelism of the end reflectors is adequate for their precise function. Polishing and coating of the ends of the rod provide the reflecting surfaces at the extremes of the cavity. One end reflector is made to have, as nearly as possible, 100% reflectance, the other end is designed to reflect about 95-98% of the internally incident radiation. The small amount not internally reflected passes through the partial reflector as the output.

In certain cases, instead of providing one reflector with partial transmission as just described, both are of maximum reflectance. The output is then emitted through a small clear area purposely left in the coating of one of the reflecting ends.

The emission of light from optical masers is basically due to the phenomenon of fluorescence. A fluorescent material is one which, on exposure to light of a certain frequency or a range of frequencies, gives out radiation at a (usually) lower frequency. An ordinary fluorescent lamp illustrates this: the gas discharge inside the tube produces ultra-violet radiation. This, striking the fluorescent coating on the inner surface of the tube induces the coating to emit lower frequency (visible) light. In the case we are now considering the doped ruby crystal is irradiated with visible light (preferably with peak intensity in the green region) and the emission is obtained at the far-red (lower frequency) end of the spectrum.

The behaviour of the atoms in these fluorescent materials can be explained in terms of the different energy levels or amounts of energy which the atoms

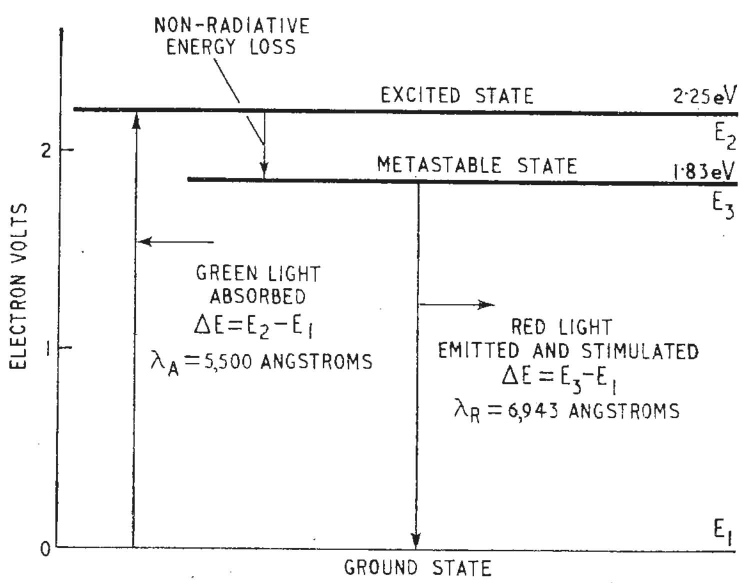

Fig. 6. Energy level diagram for the ruby laser.

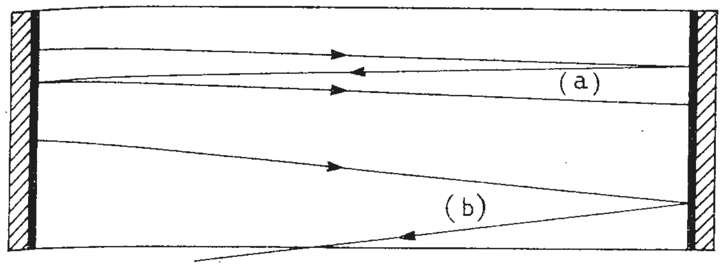

Fig. 7 (a) Light perpendicular to reflectors reinforces and stays in cavity. (b) Light not perpendicular is lost through sides.

possess. Energy can be held by atoms only at certain discreet and fixed levels. In its normal state the atom will have the lowest of its possible energy states—the ground level as it is termed. By absorbing energy (in this case green light) the atom can be raised to a higher level and is then said to be in an excited state. From this excited state the atoms fall back to lower levels and in certain cases emit energy.

The actual energy levels involved together with the frequencies of the incident and radiated energy are bound by the relationship

$$h\nu = \Delta E$$

where h = Planck's constant $= (6.624 \times 10^{-27}$ erg-sec)

ν = frequency of radiation in cycles per second

ΔE = the difference in energy level in ergs

Thus the frequencies absorbed and radiated are proportional to the differences in relative energy levels.

Referring to Fig. 6, the energy level diagram relating to the ruby crystal, atoms in state E_1, are pumped from the ground level by the absorption of green light into the crystal, to a higher energy level E_2

$$h\nu_A = E_2 - E_1$$

The energy level at E_2 is approximately 2.25 electron volts ($= 3.6 \times 10^{-12}$ erg) and that at E_1, the ground level is zero. Thus the frequency of the light absorbed into the crystal is

$$\nu_A = \frac{E_2 - E_1}{h} = \frac{3.6 \times 10^{-12}}{6.624 \times 10^{-27}} = 5.45 \times 10^{14} \text{ c/s which}$$

is equivalent to a wavelength of 5500 angstroms.

At the E_2 level there is a small, but inevitable, energy loss and the atoms quickly drop to an intermediate, or metastable level, E_3, where their life time is of the order of a few milliseconds. From the metastable state the atoms fall back to the original ground state, losing energy and emitting radiation. The energy loss and radiated energy are related by the expression.

$$h\nu_R = E_3 - E_1$$

and as $E_3 - E_1$ is less than $E_2 - E_1$ the radiated frequency (ν_R) is lower than the frequency of the light absorbed during the pumping process (ν_A). The difference in energy between the E_3 level and ground (E_1) is 1.828 electron volts giving the characteristic output wavelength of the ruby crystal maser of 6943 angstroms, equivalent in frequency to 4.31×10^{14} c/s.

With an energy input below a certain rate the atoms falling from the metastable state to ground will do so in a random manner; however, above a particular energy threshold the number of atoms initially raised to the E_2 level and accumulating at the metastable level is greater than that in the ground level. This is a state of population inversion. There is then an accelerated fall of these atoms giving radiation at the output frequency of the device, tending to maintain equilibrium in the crystal. The first atoms to fall radiate spontaneously and in doing so *stimulate* others in the E_3 state to do likewise, these in turn stimulate more atoms and an intense radiation is built up that continues as long as the over-population in the metastable state exists.

Let us recall for a moment that all this action is taking place within an optical cavity with perfectly parallel and accurately spaced reflecting surfaces. These two features ensure that light of a particular wavelength and direction is favoured. Light produced within the crystal by the fall of atoms from the metastable state, which is of the wavelength for which the cavity was designed, is reflected from end to end successively throughout the active material, stimulating the atoms still in the metastable state. Further, only light which is perpendicular to the plane of the mirrors can stay within the cavity (Fig. 7) to help with the stimulation: the stimulating light moves in the same direction, is parallel to, and in phase with, the stimulated light. The fact that the stimulated light is parallel ensures that the output through the end reflectors stays as a non-divergent beam. Light which is not perpendicular to the reflectors is reflected to the sides of the cavity and does not contribute to the output beam.

The ruby crystal laser is normally pumped by a xenon type flash tube giving a burst of light of a

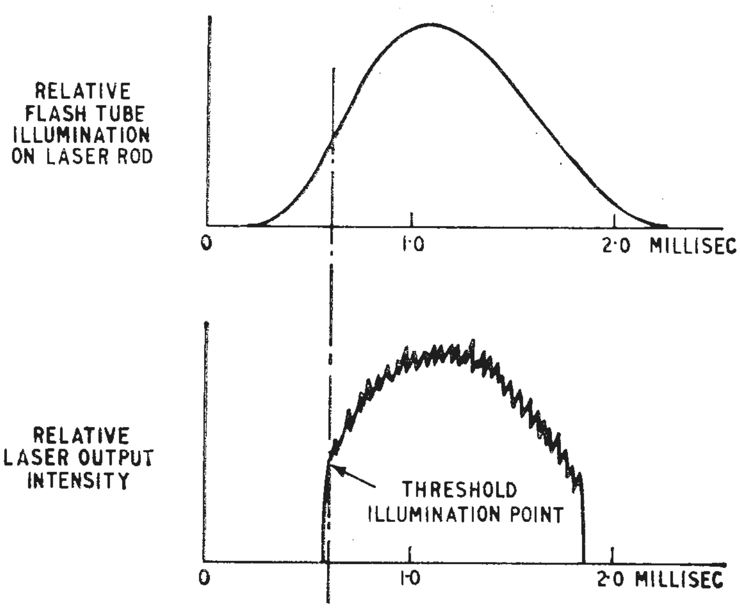

Fig. 8. Spiky output is due to momentary rapid depopulation and repopulation of metastable level.

duration between 0.5 and 2.0 milliseconds. The output from the laser is essentially of the same duration, but consists of a number of spikes each a few microseconds long (Fig. 8). This is thought to be due to the intensity of the light within the crystal building up to the point where emisson is stimulated. The laser action then takes place and the metastable state is then depopulated so rapidly that the pumping light is momentarily unable to maintain a sufficient number of atoms in the metastable state to allow stimulated emission to continue. The radiation abruptly dies away until the exciting source restores the required population level. The extremely rapid pulsing of the light results from the depletion and

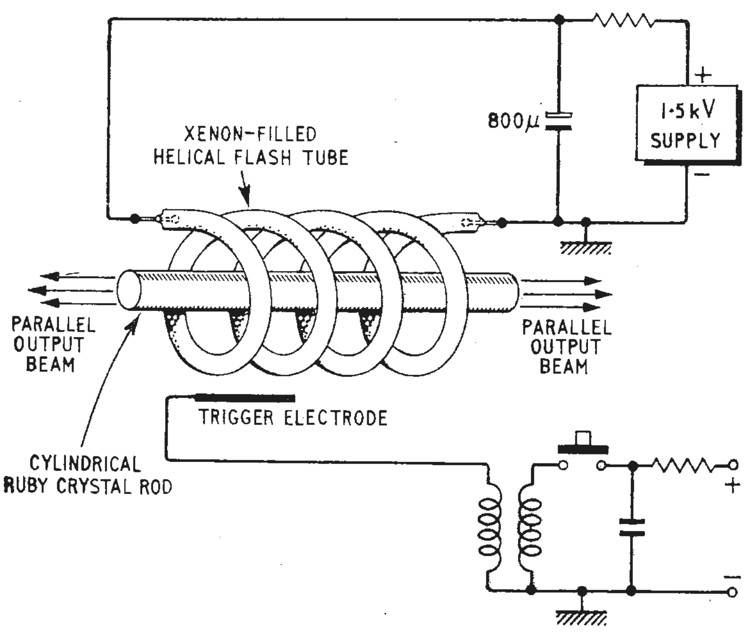

Fig. 9. Ruby crystal laser with helical flash-tube pump.

restoration of the concentration of atoms in the metastable state.

To ensure the greatest overall efficiency of the device close optical coupling is required between the pumping source and the crystal so that as much light as possible is transferred from the flash tube to the laser.

A commonly used arrangement is shown in Fig. 9. The light source is a multi-turn, xenon-filled quartz high energy helical flash tube and the crystal is mounted coaxially in the centre of the helix. Although this is a convenient arrangement, quite a lot of illumination is lost from the outer surfaces of the helix and is not usefully employed.

Fig. 10 illustrates two other rather similar methods of illuminating the crystal. Both use cylindrical type mirrors, one with a circular section (a) and the other with an elliptical contour (c): both utilize linear type flash tubes. With the circular section mirror the crystal and the flash tube are mounted as close together as possible with their long axes parallel to each other and also mutually parallel to, and on the axis of, the mirror. The combination of the lamp and crystal is at the centre of curvature of the mirror and thus all light emanating from this region is reflected back through the same point (b).

A rather more difficult mirror to produce is the one with the elliptical contour, but it does provide greater efficiency. The lamp is placed at one focus of the mirror, the crystal at the other; once again all the long axes are parallel. It will be recalled that light radiating from one focus of an elliptical mirror, after reflection from the surface of the mirror, passes back through the second focus (d), thus virtually all the light from the flash tube is reflected on to the crystal.

The input power required for the flash tube to produce maser action in a ruby crystal is typically 250 to 1000 joules. Coherent light output from the device is often up to 30 joules with maximum efficiencies of 2-3%. The beam width is of the order of 10 milliradians (about ½ of a degree).

At lower power outputs the beam spread is reduced to about one tenth of this figure. Owing to the heating effect of the very large power input it is not possible to operate a laser of this type at any higher rate than one flash every twenty or thirty seconds at room temperatures. However, commercially available devices often provide the facility for air or liquid nitrogen cooling, which permits higher power inputs or greater frequency of operation. It may be of interest to know that a complete laser and power supply equipment of this type, suitable for laboratory use costs in the region of £1,250.

Although the total output of these optical masers is relatively low it is interesting to compare the intensity with that of the sun's visible surface, which behaves much as a black body radiator at 6,000°C and is about seven kilowatts per square centimetre of its surface. This, of course, is over the complete range of wavelengths—visible light, infra-red, ultra-violet, etc., but if only a narrow band sere filtered out, say 1 Mc/s wide (that is, just over 10^{-5} angstroms) in the green light region only, one watt of radiation would be obtained from about ten square *metres* of the surface. By contrast the burst of energy from the ruby crystal maser is over 10,000 watts peak from an area of one square *centimetre*.

The laser output can be concentrated to a spot of light one tenth of a millimetre square (10^{-4} cm^2) In this minute area there will be a power concentration of 10^8 watts cm^2. Densities of this order are, of course, far above that which are produced by the sun or any other source of radiation.

Apart from aluminium oxide there are many other solid materials which with suitable additives

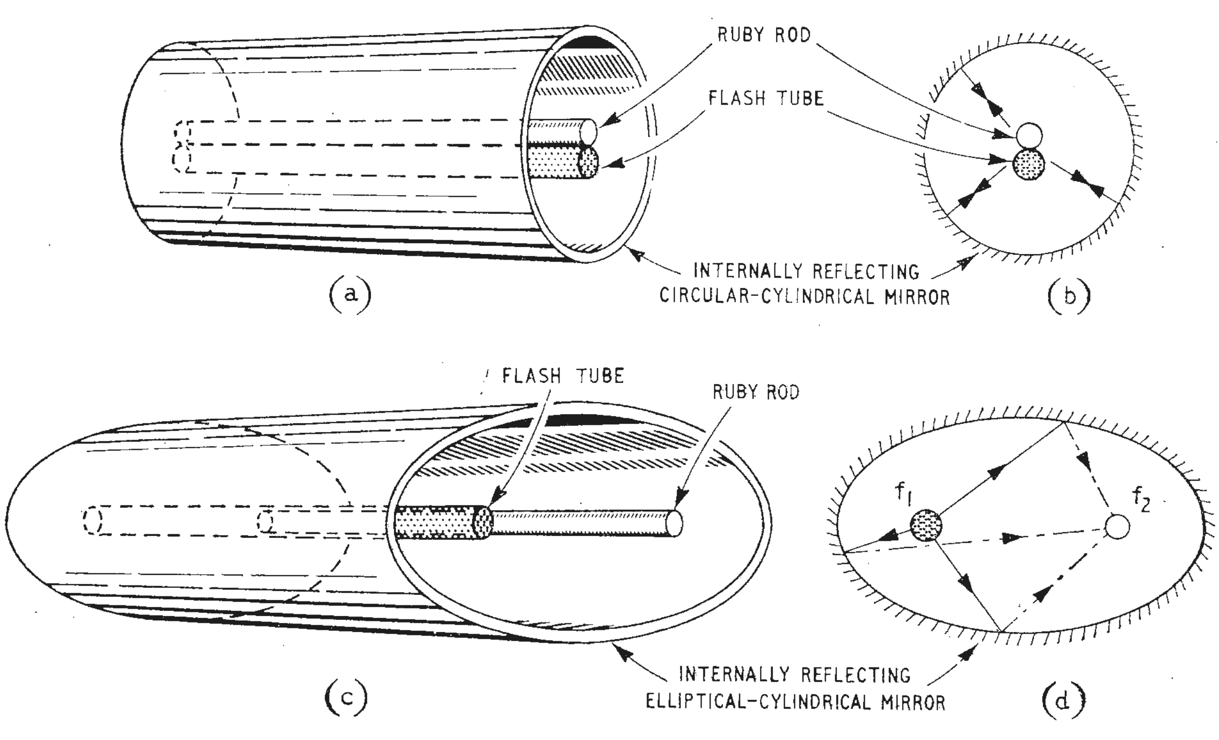

Fig. 10. Two ways of reinforcing the initial illumination.

TABLE II: ACTIVE MATERIALS AND OUTPUT WAVELENGTHS OF VARIOUS TYPES OF LASER.

Class	Active Material	Wavelength (angstroms)
Liquid	Europium-benzolacetonate	6,129
Gas	Helium-neon	6,329
Crystal	Aluminium oxide-chromium oxide	6,943
Crystal	Calcium fluoride-samarium	7,085
Liquid	Toluene	7,463
Semiconductor	Gallium arsenide	8,440
Gas	Neon-oxygen	8,446
Crystal	Glass-neodymium	10,630
Gas	Helium-neon	11,530
Gas	Krypton	16,940
Gas	Argon	16,940
Crystal	Calcium tungstate-thulium	19,110
Gas	Xenon	20,261
Gas	Krypton	21,890
Crystal	Calcium-fluoride-uranium	25,600
Gas	Caesium (vapour)	71,800

have been made to give coherent light. Among the materials used are calcium fluoride with small amounts of samarium or uranium and even glass with neodymium. The wavelengths produced by these lasers range between 7000 angstroms and 26,000 anstroms (in the far infra-red). A fuller list is given in Table II.

Lasers using calcium fluoride crystal have been found to require less pump power than the ruby type and are in fact more efficient, also they have been made to operate in a *continuous* fashion instead of emitting bursts of radiation. The main disadvantage of these at the moment is that they must operate at very low temperatures.

Each crystalline material and its dopant has a particular output wavelength as is shown in the table although it is possible to vary this slightly by a a change in operating temperature[5]. A difference of almost 20 angstroms was detected between the output of a ruby at -180°C (6934 angstroms) and that at 210°C (6953 angstroms). This could prove a most useful feature, for by allowing the frequencies so generated to beat together difference frequencies would be produced, just as with conventional oscillators. In this case " thermal tuning " of one maser would produce a tremendous range of output frequencies. By varying the temperatures appropriately it seems that it may be possible to generate almost any frequency between zero and 10,000,000 Mc/s with one pair of maser crystals.

(To be concluded)

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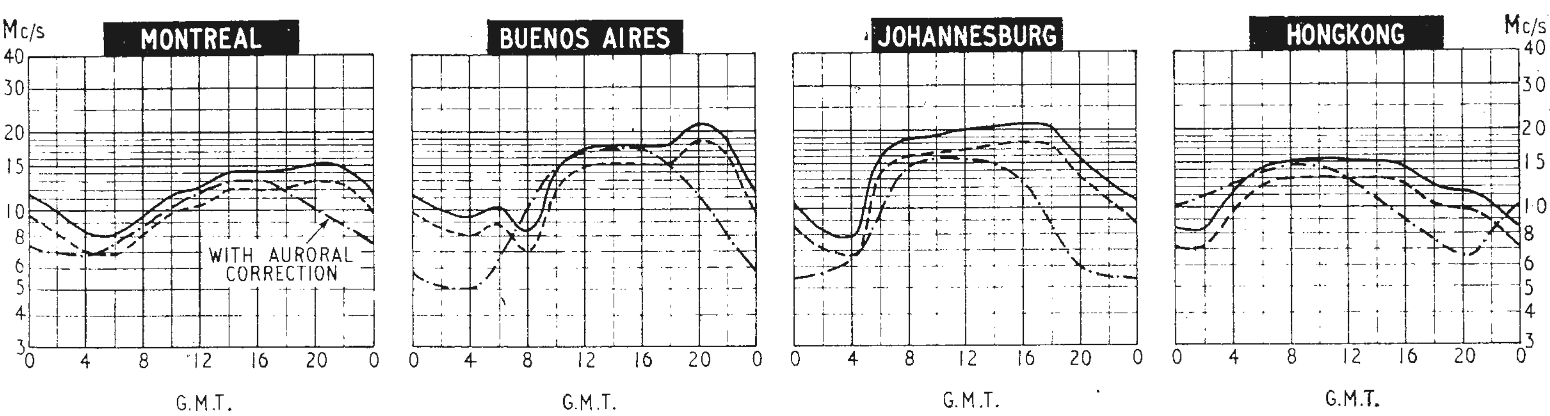
H. F. PREDICTIONS — AUGUST



——— MEDIAN STANDARD MUF
- - - - - - OPTIMUM TRAFFIC FREQUENCY
—·—·—· LOWEST USABLE HF

After hovering around 20 for some months the sunspot number for May leapt to 52. Although month-to-month variations of this magnetitude are not uncommon the figure for May emphasizes that solar activity has now declined very little over a period of 2 years. A slow decline may be expected in coming months but the effect of this will be masked by the more significant seasonal changes.

The prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable high frequency (LUF) for reception in this country. Unlike the MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, local noise level and the type of modulation: it should generally be regarded with more diffidence than the MUF. The LUF curves shown are those drawn by Cable and Wireless, Ltd., for commercial telegraphy and they serve to give some idea of the period of the day for which communication can be expected.

Transistor High-quality Pre-amplifier

SUITABLE FOR USE WITH THE MULLARD 10W CLASS AB, 10W CLASS B AND 5W CLASS A TRANSISTOR AMPLIFIERS

BY E. CARTER* AND P. THARMA,* B.Sc. (Hons.)

THIS pre-amplifier is suitable for most crystal and ceramic pickup heads. In the magnetic pickup position, the circuit gives correct equalization for a pickup head of 500mH inductance. Other values of inductance require a different resistor in the input circuit. In the "radio input" position, the input resistance is 100kΩ and the sensitivity 100mV. Other values of input resistance and sensitivity can be obtained by altering resistor values.

Bass and treble tone controls are provided. A design is also given for simple h.f. and l.f. filters.

The pre-amplifier uses inexpensive germanium alloy transistors, type OC75 and due to the particular design of the input amplifier, the noise is well below typical user requirements. It is hoped to deal with the general problem of noise in audio amplifiers in an article in a subsequent issue.

General Considerations

The number of amplifying stages, the location of volume and tone controls, and the signal levels throughout the pre-amplifier are governed by a number of conflicting requirements.

An important requirement is that all amplifying stages prior to the volume control should be capable of handling signals much greater than the nominal input level. This is necessary because of the wide variations of recording levels and sensitivities of pickups; and it is common practice to design the "pre-volume-control" stages to handle an increase of input level by a factor of at least 10 without excessive distortion. Obviously it is easier to obtain large dynamic ranges if the signal levels are very low. However, too low a signal level would make the noise contributed by the circuit very much more troublesome. Thus the location of the volume control is a compromise between dynamic range and noise.

The noise requirements, which will be discussed in a subsequent article, are as follows. First, the noise introduced by the pre-amplifier should be well below the noise present with the programme material, e.g., record noise. This requires careful design of the input stage and, again, the operating conditions of the input transistor are a compromise between noise and dynamic range. The second requirement is that with the volume control turned down fully, the noise from the system under typical user conditions should be inaudible. To meet this condition, the volume control should be as late as possible in the system. This however conflicts with the dynamic range requirement and in practice a compromise is adopted.

Tone controls generally introduce a loss—a factor of 10 or more being common. Placing the tone controls before the volume control increases the signal handling problems of the pre-volume-control stages. If the tone control is placed immediately after the volume control then the signal level after the tone controls may be so low that the noise of the stage following the tone control becomes a problem. A better solution is to follow the volume control by a single stage of amplification and then the tone control circuits.

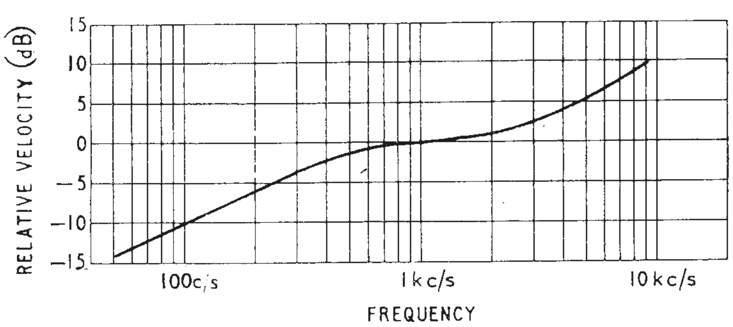


Fig. 1. British standard recording characteristic.

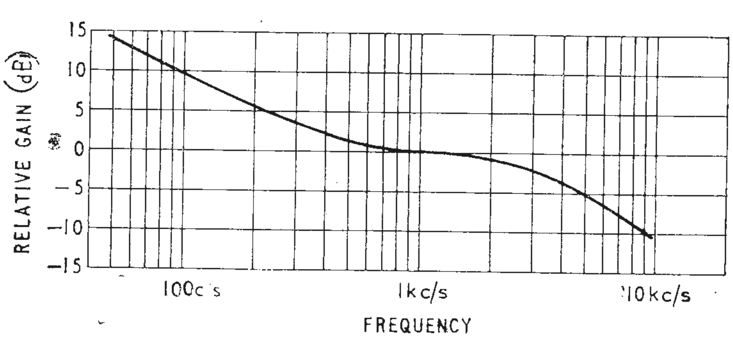


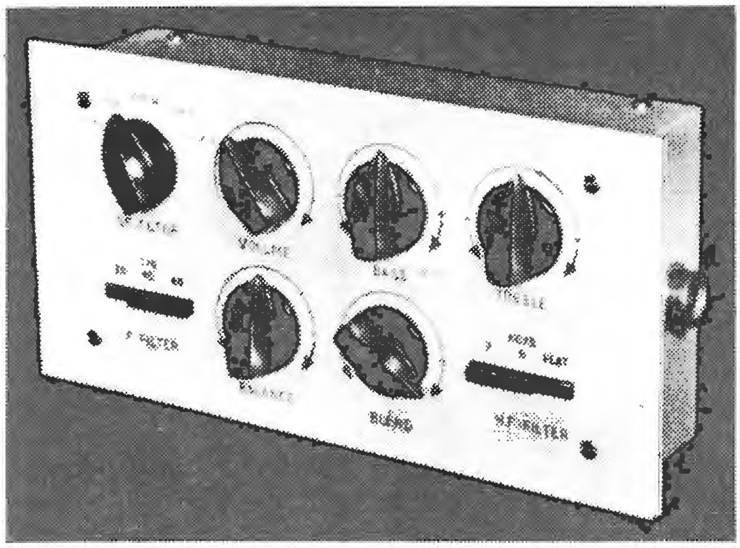
Fig. 2. Equalization required for magnetic pickups.

Equalization for Magnetic Pickups

The recording characteristic (i.e., the relationship between the lateral velocity of the cutter and frequency) in common use is shown in Fig. 1. With a magnetic pickup the e.m.f. is proportional to the rate of change of flux in the magnetic circuit, and therefore the playback characteristic is identical with the recording characteristic. A correction circuit for magnetic pickups should therefore have a response complementary to the recording characteristic as shown in Fig. 2.

With valve amplifiers it is common practice to terminate the pickup with a high resistance (50-100kΩ) and apply the full equalization of Fig. 2. A similar arrangement can be adopted with transistor circuits, i.e., the amplifier can be designed to have a high input resistance and the full equalization

* Mullard Applications Research Laboratory



Controls on the front panel.

applied in the amplifier using suitable networks. A better circuit arrangement which gives improvements in sensitivity and signal-to-noise ratio is shown in Fig. 3. In this the pickup is terminated with a low resistance such that the total resistance in the pickup circuit together with its inductance gives the upper frequency roll-off. Frequency-dependent feedback via R_f, C_s provides the rest of the equalization, i.e., the bass lift part of Fig. 2.

Equalization for Crystal Pickups

The equalization required for crystal pickups is somewhat different. The open circuit voltage from a crystal pickup is proportional to the displacement of the stylus, and the playback characteristic is therefore similar to the amplitude versus frequency recording characteristic. This characteristic, derived from Fig. 1, is shown in Fig. 4. With valve amplifiers the pickup is usually terminated with a high resistance (1-2MΩ) and no further equalization is used. A similar arrangement is possible with transistor amplifiers, a high resistance (1-2MΩ) being used in series with the pickup. A significant improvement in signal-to-noise ratio can be obtained with the circuit shown in Fig. 5. In this, the pickup is connected directly to the input stage. Since the source impedance is capacitive the signal current into the transistor increases with increase of frequency. This rising frequency characteristic is compensated by capacitive feedback via C_s. The playback characteristic will then be similar to the amplitude versus frequency recording characteristic of Fig. 4. The " step " in the playback characteristic can be eliminated if the more complicated feedback network R_2 C_2 C_1 of Fig. 6 is used instead of single capacitor.

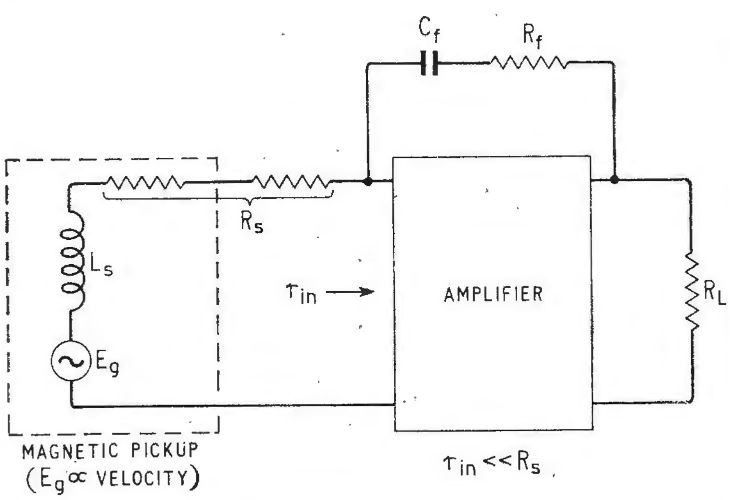


Fig. 3. Equalization for magnetic pickup.

The pre-amplifier circuit is shown in Fig. 6. The transistors Tr1 and Tr2 forming the input amplifier are direct coupled with overall d.c. feedback via R_9 to stabilize operating conditions. The undecoupled emitter resistor R_{12} reflects a high impedance to the collector of Tr1. The voltage gain of Tr1 is therefore high, enabling high impedance feedback networks to be used for equalization.

In the magnetic pickup position, R_6 in conjunction with the pickup inductance gives the h.f. roll-off. The value of R_6 should be chosen to suit the individual pickup—

Ls	R_6
200mH	2.7kΩ
300mH	4.7kΩ
400mH	5.6kΩ
500mH	6.8kΩ
600mH	8.2kΩ
700mH	10kΩ

The bass lift equalization characteristic is provided by the feedback components R_3 and C_3. R_4 across C_3 restricts the otherwise excessive gain at very low frequencies.

In the crystal pickup position equalization is provided by the network R_2, C_2, C_1. The component values are suitable for pickups with capacitances greater than 500pF. The lower cut-off frequency is about 80 c/s—this is equivalent to using a 5MΩ load across the pickup in conventional valve circuits.

In the radio position the gain is determined by the

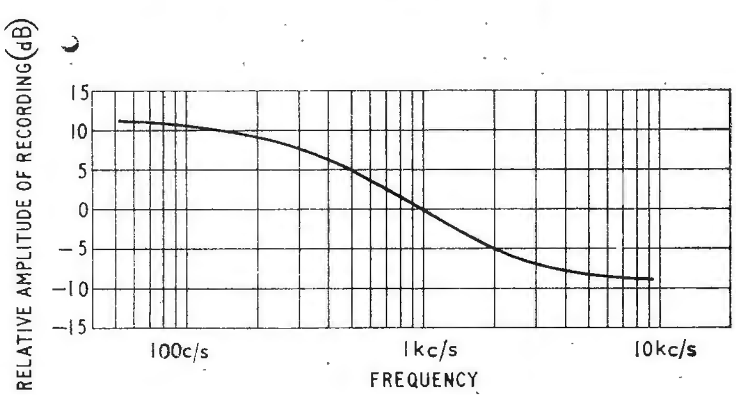


Fig. 4. Standard recording characteristic (amplitude versus frequency).

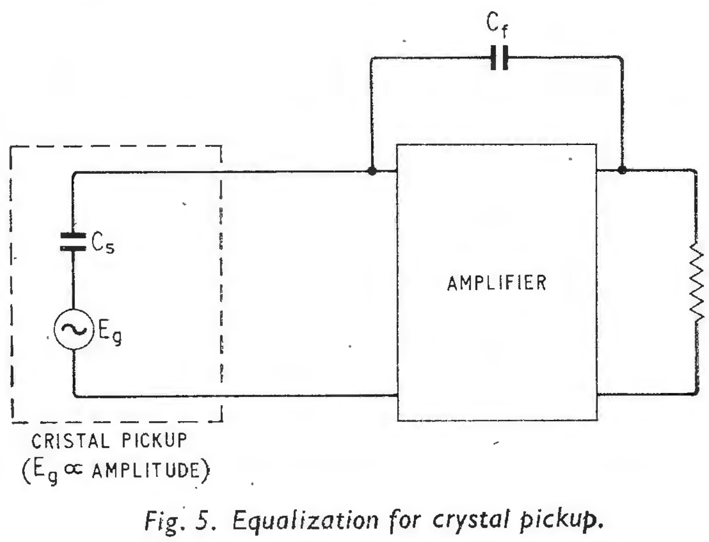


Fig. 5. Equalization for crystal pickup.

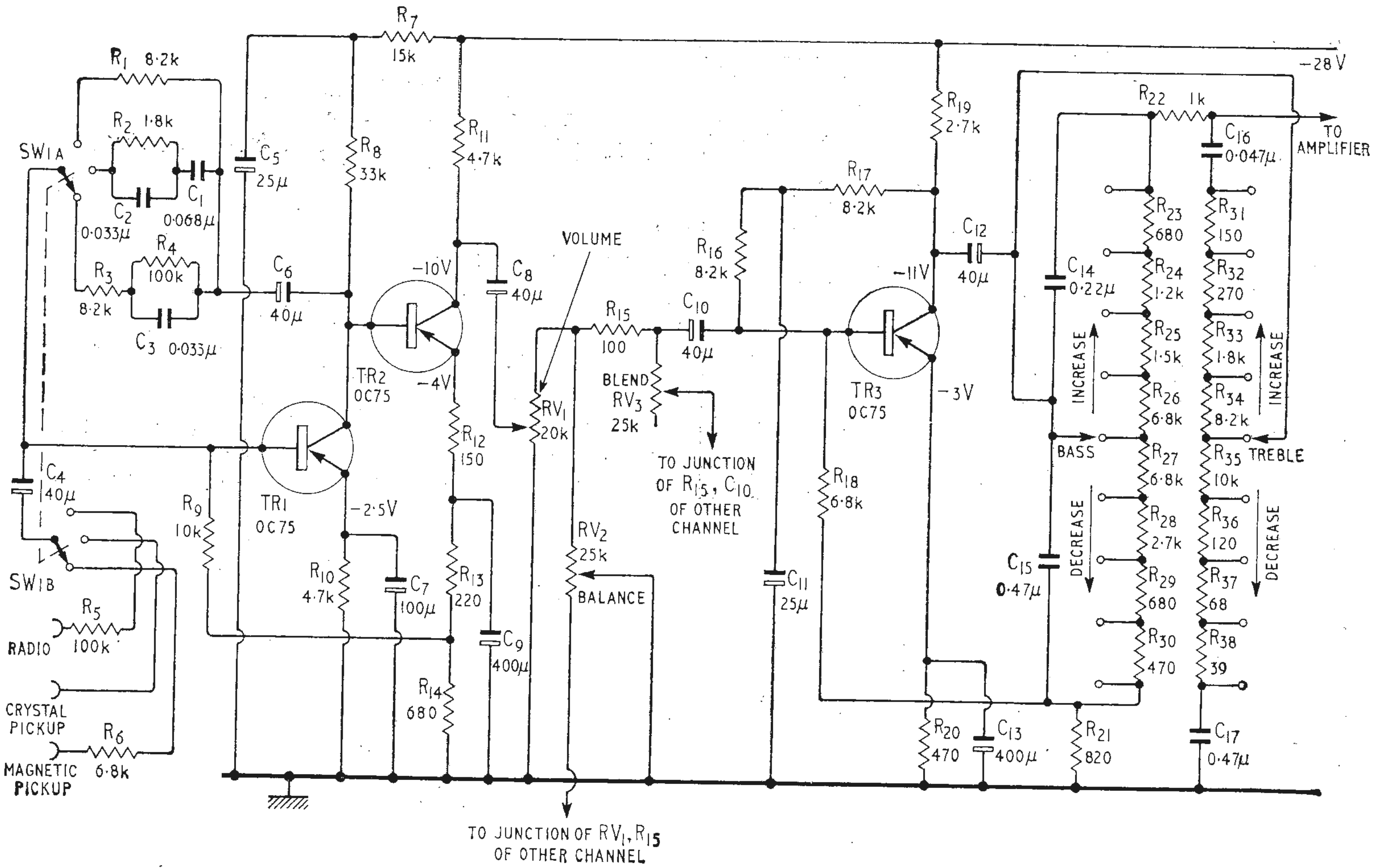


Fig. 6. Complete circuit diagram of pre-amplifier and (below) component list.

Transistors

Tr1	OC75
Tr2	OC75
Tr3	OC75

Resistors Cracked carbon 1/8W ±5%

R_1, R_3, R_{16}, R_{17}, R_{34}	8.2kΩ
R_2, R_{33}	1.8kΩ
R_4, R_5	100kΩ
R_6, R_{18}, R_{26}, R_{27}	6.8kΩ
R_7	15kΩ
R_8	33kΩ
R_9, R_{35}	10kΩ
R_{10}, R_{11}	4.7kΩ
R_{12}, R_{31}	150Ω
R_{13}	220Ω
R_{14}, R_{23}, R_{29}	680Ω
R_{15}	100Ω
R_{19}, R_{28}	2.7kΩ
R_{20}, R_{30}	470Ω
R_{21}	820Ω
R_{22}	1.0kΩ
R_{24}	1.2kΩ
R_{25}	1.5kΩ
R_{32}	270Ω
R_{36}	120Ω
R_{37}	68Ω
R_{38}	39Ω
RV_1	20kΩ log. 1W potentiometer (ganged for stereo)
RV_2	25kΩ linear potentiometer
RV_3	25kΩ log potentiometer

Capacitors

C_1	0.068μF 125V Mullard Type C296AA/A68K
C_2, C_3	0.033μF 125V Mullard Type C296AA/A33K
C_{14}	0.22μF 125V Mullard Type C296AA/A220K
C_{15}, C_{17}	0.47μF 125V Mullard Type C296AA/A470K
C_{16}	0.047μF 125V Mullard Type C296AA/A47K
C_4, C_6, C_8, C_{10}, C_{12}	40μF 16V Mullard Type C426AM/E40
C_5, C_{11}	25μF 25V Mullard Type C426AM/F25
C_7	100μF 4V Mullard Type C426AM/B100
C_9, C_{13}	400μF 6.4V Mullard Type C426AM/C400

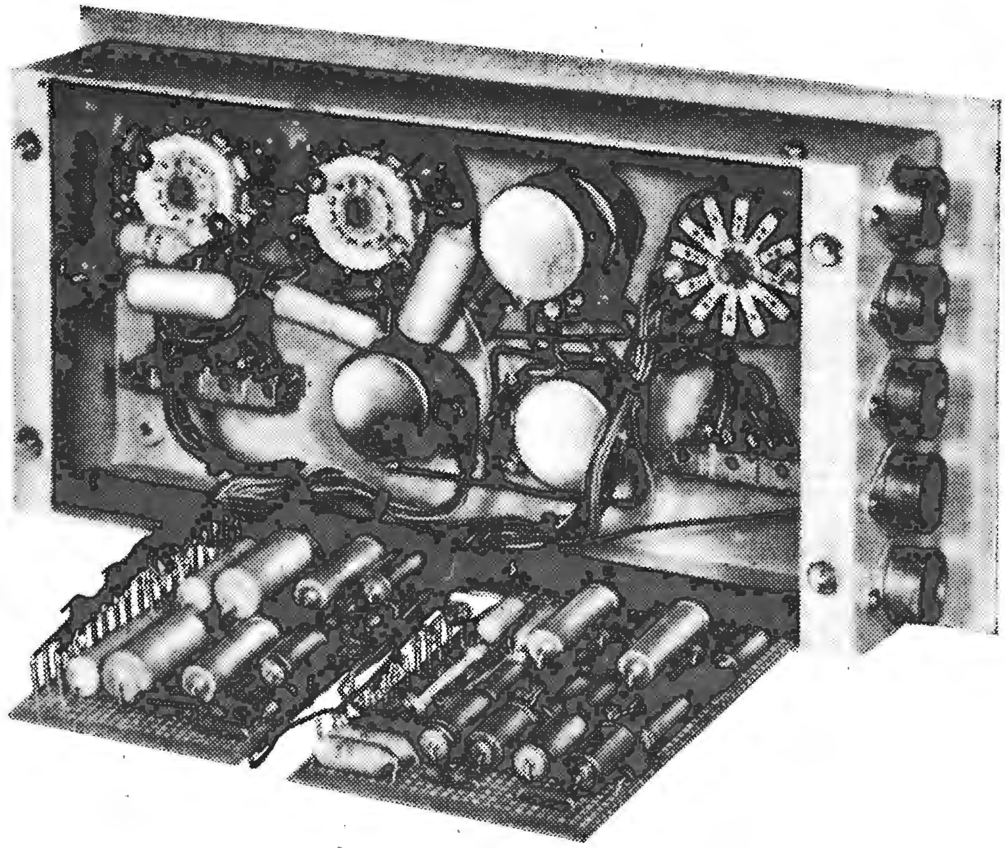
feedback resistor R_1 and the input resistance by R_5. These can be chosen to suit individual requirements.

The input amplifier is followed by the volume control, and by the balance and blend controls (for stereo). These are followed by the amplifying stage consisting of transistor Tr3, which feeds the tone control network. Overall negative feedback is applied via resistor R_{18} to reduce distortion.

Switched bass and treble tone controls are provided. By switching, it is easier to maintain identical responses between both channels of a stereo system. Also the values of resistance for equal increments of boost or cut are such that conventional potentiometers will not be suitable. This is due to the tone control circuit being part of the feedback network. If sufficient feedback is used to reduce distortion and passive tone control circuits with conventional potentiometers used, then the loss of gain will be greater and an extra stage may be necessary.

Simple h.f. and l.f. filters can be added to the circuit of Fig. 6. The lower cut-off frequency of the pre-amplifier is about 20 c/s. This can be

Rear view of prototype pre-amplifier.



increased by decreasing the value of the coupling capacitor C_{12} (Fig. 8). Suitable values are

C_{20} = 0.47μF, lower cut-off frequency 50 c/s

C_{21} = 0.22μF, lower cut-off frequency 100 c/s

The h.f. response can be reduced by shunting the feedback resistor R_{18} with suitable capacitors, thus forming a h.f. filter

C_{18} = 3300pF, upper cut-off frequency 8 kc/s

C_{19} = 2200 pF, upper cut-off frequency 12 kc/s

The sensitivity of the pre-amplifier in the magnetic pickup position is 5mV for an output current of 140μA. This current of 140μA is the input required by the 10W Class AB amplifier for an output of 10W. The corresponding sensitivity in the crystal pickup position is 500mV (source capacitance 500pF), and the sensitivity in the radio position is 100mV.

The total harmonic distortion at 1kc/s in the magnetic pickup position is less than 0.05% for an input of 5mV. If the input is increased to 50mV and the volume control turned down so that the output is 140μA, then the total harmonic distortion increases to about 0.3%.

The tone control characteristics are shown in Fig. 7, and cover the range

Bass +12dB to −13dB at 100c/s

Treble +8dB to −10dB at 10kc/s

The noise spectra with the volume control at maximum and minimum are shown in Fig. 9. The spectrum of acceptable noise is plotted on the assumption that 140μA corresponds to a sound pressure level of 90dB reference threshold. Interpretation of noise spectrum data will be discussed fully in a subsequent article. The noise is well below user requirements. A further improvement of about 3dB can be obtained if AC107's are used instead of the OC75 for Tr1 and Tr3.

The power supply requirement is about 12mA at 24-28V.

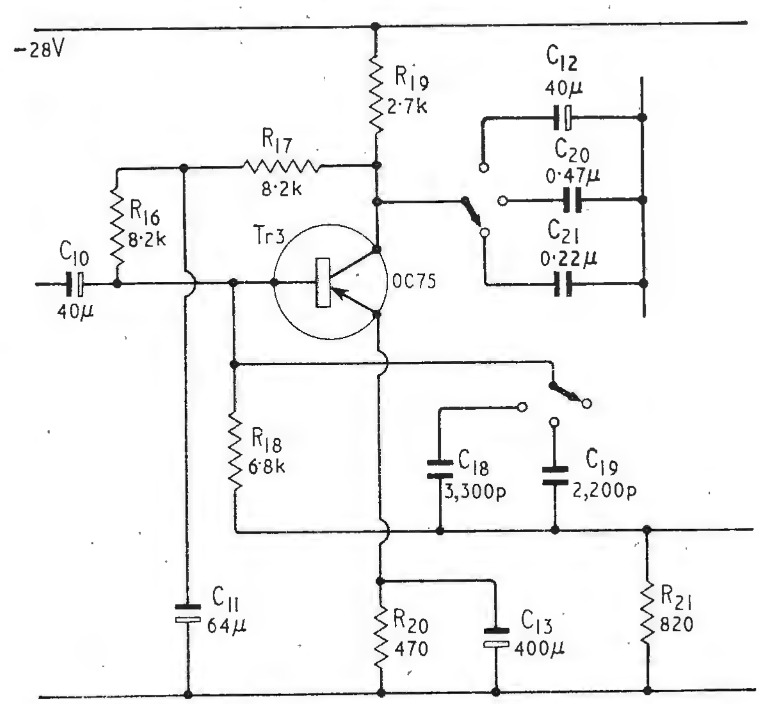


Fig. 8. L.f. and h.f. Filters.

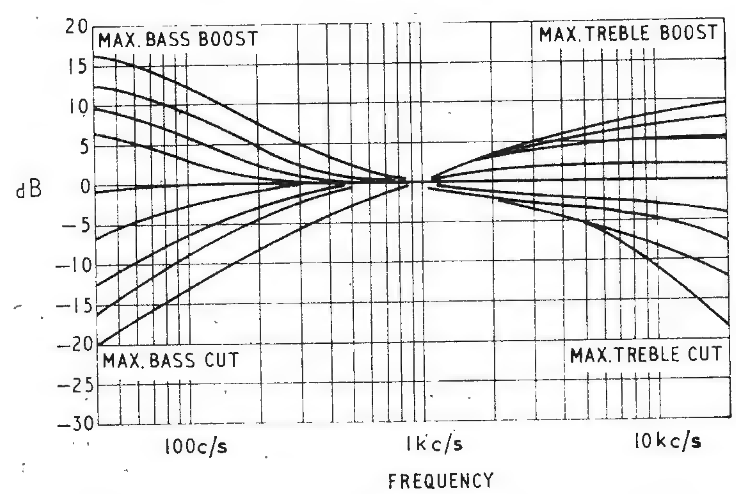


Fig. 7. Pre-amplifier tone control characteristics.

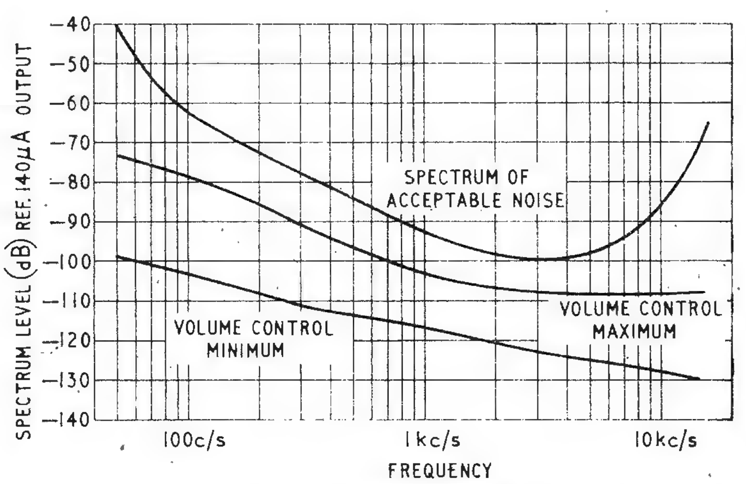


Fig. 9. Noise spectrum of pre-amplifier (magnetic pickup position).

News from Industry

The Ministry of Aviation has placed an order to the value of £1.5M with **Marconi's W/T Company** for the supply of high-frequency mobile radio stations. This order follows a similar contract placed with Marconi's in 1960 and calls for a number of Type D11 and D13 transmitter-receivers, the latter type embodying two receivers for dual diversity operation.

The East African Governments announce that the branches of **Cable & Wireless Ltd.,** in East Africa, are to be taken over from 1st January next. Announcing this in parliament, the Minister of Communications, Power and Works, Mr. Amir Jamal, said a controlling interest is to be acquired by the Posts and Telegraphs Department of the East African Common Services Organisation, with Cable & Wireless retaining the balance of shares.

The Plessey Company which through two of its main subsidiaries, Automatic Telephone & Electric Co. and Ericsson Telephones Ltd. owns a 50% interest in **Telephone & Electrical Industries Pty. Ltd.,** of New South Wales, has now acquired the 25% interest in this company, previously owned by the General Electric Company.

Pye-Goodmans Deal.—The Vibrator Division of Goodmans Industries Ltd., a subsidiary of Relay Exchanges Ltd., has been acquired by Pye-Ling Ltd., a member company of the Pye organization. Pye-Ling, of Royston, Herts., will market the complete range of Goodmans vibration equipment, under the name of "Goodmans" This transaction does not affect the manufacture and marketing of Goodmans loudspeakers.

Amphenol Borg Ltd. has acquired **Electronic Insulators Ltd.,** the manufacturers of cable assemblies and phasing connectors. Electronic Insulators wa formed last year by G. W. Bagshaw, M.Brit.I.R.E , Assoc I.E.E., who was associated with J C. Graves and Co. (the prewar set manufacturers of Sheffield) which subsequently became the Wireless Telephone Company, now part of the Plessey organization.

Standard Telephones and Cables Ltd. has amalgamated its Transistor Division of Footscray, Kent, and its Rectifier Division of Harlow, Essex, to form a single Semiconductor Division. The new division employs some 2,000, and is managed by J M Wilson who was formerly manager of the Rectifier Division.

A new company **Associated Electrical Maintenance Ltd.,** has been formed to take over the duties of Home Maintenance Ltd. which covers the service activities of the Clarke and Smith Industrial Group G. W Aggett, formerly with Magneta (B V.C) Ltd., has be n appointed managing director of the new company, and also of Clarke and Smith Rentals Ltd., an associate company

The **Rank Organisation** have formed a new division to be responsible for the manufacture and marketing of their Xeronic high-speed computer output printers; it will also be responsible for the manufacture of their Copyflo continuous printers. Formerly known as the Electronics Department of Rank Precision Industries, the new division is to be known as the Rank Data Systems Division and will operate under I D. Brotherton at Woodger Road, Shepherds Bush, London, W.12.

A new division, to be known as the **Automation Division,** has been formed by E.M.I. Electronics Ltd. to take over the systems activities of the Industrial and Instrument Divisions.

U.K.-Poland Trade Agreement.—A five-year trade agreement was signed with Poland in June this year. Previous agreements with Poland have been for only three-year periods. Britain is the major trade partner with Poland in the west and in the last trading year, which ended 30th June, the combined value of Anglo-Polish trade totalled £69,000,000. The Polish quota of exports to Britain for the first year of the new agreement includes £150,000 worth of domestic radio, audio and television equipment and parts (including £30,000 worth of transistors and transistor equipment and £30,000 worth of domestic valves and tubes). Industrial valves and parts to the value of £5,000 are also to be admitted. The quota of British exports to Poland includes £440,000 worth of radio, audio and television equipment and components plus £550,000 worth of scientific and industrial instruments and equipment.

Controls and Communications Ltd., formerly known as Radio and Television Trust, announce a profit for the year ended 31st March of £292,888 after taxation of £274,375. This represents an increase of £78,687 on the previous year. Subsidiaries of this company include Thermionic Products, Airmec, British Communications Corporation, and Modern Aerials.

Ferranti Ltd.—Group profit after all charges, including taxation, for the year ended 31st March amounted to £778,772 after taking account of a £368,539 deficit accumulated by its subsidiary companies. The Group profit represents a decrease of £134,245 on the previous year's figure.

Pre-tax profits of **Dansette Products Ltd.** for the year ended 31st March amounted to £251,676. This figure represents a drop of over £170,000 on the previous year's profits. Tax this year amounted to £142,213 leaving a net profit of £109,463 compared with £181,917 the previous year.

Colvern Ltd.—Profit, before tax, for the year ended 31st March amounted to £275,360. Tax for the year took £143,968 leaving a net profit of £131,392—an increase of £7,242 on the previous year's figure.

Ultra Electric (Holdings) Ltd.—Profit after taxation for the year ended 30th March amounted to £161,325. This represents a drop of over £50,000 on the previous year's figure.

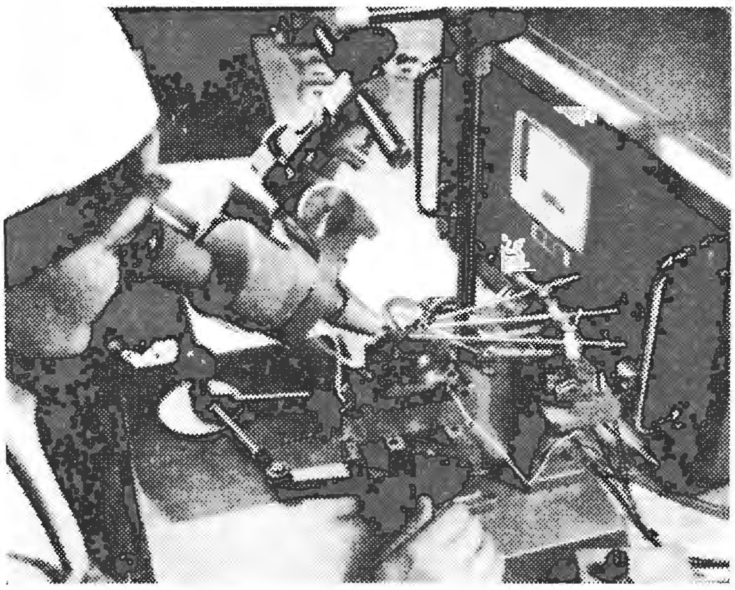
C.S.F.—Compagnie Générale de Télégraphie sans fil, one of the major French electronics companies, announces a net profit of Frs. 12,378,938 for the year 1962. Turnover for the same year amounted to Frs. 880,620,000 of which Frs. 166,889,000 was from overseas trade.

We have received an English edition of the annual report of **A.E.G.** for 1961/62 which records that Telefunken contributed 60% of the DM 1,262,000,000 turnover of the subsidiaries. The parent company's turnover, without subsidiaries, rose to DM 2,067,000,000. The group net profit was nearly DM 52,000,000 (approx. £4.7M).

International Aeradio.—The gross turnover of the company in 1962 amounted to £3,250,000. This represents an increase of £450,000 on the previous year.

Change of Name.—British Electronic Industries Ltd., which was formed about three years ago to acquire the shares of Pye Ltd. and E. K. Cole Ltd., is now to be called Pye of Cambridge Ltd.

Marconi Instruments have asked us to point out that the distortion figure of 0.5% given for their TF 2100 a.f. oscillator in our review of the Components Show, page 329 of July, should have been 0.05%. However, 0.5% does apply for their TF 2101 m.f. oscillator.



Testing microminiature solid circuits at the Caswell Research Laboratory of the Plessey Company. A silicon slice containing over one hundred solid circuits is being checked with point probes.

Georg C. K. Withof, G.m.b.H., of West Germany, who were until recently represented in this country by Thorn Electronics Ltd., are now being represented in the U.K. by Research and Control Instruments, a subsidiary of N. V. Philips of Eindhoven. Withof products include industrial process monitoring, control and allied equipment. Thorn Electronics Ltd. are now marketing the range of temperature indicators and controllers, potentiometric recorders and other instruments manufactured by **Hartmann and Braun A.G.,** of Frankfurt.

Rank Cintel, a division of the Rank Organisation, is to market some of the counter-timers manufactured by the Systron Division of the **Systron Donner Corporation,** of America. These instruments will supplement the range of Rank Cintel laboratory equipment and it is expected that selected models from the Systron range will shortly be manufactured in this country under the trading name Rank Cintel Systron.

Keyswitch Relays Ltd., of 120-132 Cricklewood Lane, London, N.W.2, announce that they are now handling the American **Omron** series of relays.

Stephenson, Mills Ltd. of New Malden, Surrey, have been appointed U.K. agents for **Technical Wire Products Inc.,** of New Jersey, U.S.A., whose products include an extensive range of r.f. interference shields.

R. H. Cole (Overseas) Ltd., of 26-32 Caxton Street, Westminster, London, S.W.1, who for some years have been U.K. agents for **Siemens & Halske** components and test gear, are now also handling their special purpose valves.

Roberts Electronics, of Hitchin, Herts., have recently been appointed agents for three American companies—Ramcor Inc., Melabs Inc., and Paradynamics Inc.

A.E.P. International Ltd., of Hounslow, Middx., the U.K. associates of A.E.P. of Montreal, Canada, are now representing nearly twenty American and Canadian companies in this country. They include Lumatron Electronics Inc., Vidar Corp., Philbrick Researches Inc. and Non Linear Systems Inc.

The **Burroughs Corporation** of America has appointed Walmore Electronics Ltd., of London, as representative in the U.K. for the products of its Electronic Components Division.

Claude Lyons, of Liverpool, have been appointed agents for **Millivac Instruments Inc.** of Schenectady.

Tektronix Inc. of America have formed a British subsidiary, **Tektronix U.K. Ltd.,** to market their range of oscilloscopes and instruments in Great Britain. Harry Sellers, previously commercial director of Livingston Laboratories, has been appointed managing director of the new subsidiary which is scheduled to come into operation next January. Livingston Laboratories are to continue distributing Tektronix equipment until 1st January 1965.

Painton & Co., Ltd., have been appointed exclusive agents in the U.K. for the sale of the entire range of products of **Bourns Inc.,** California, U.S.A. For some time, Painton has held the manufacturing and selling rights for the Bourns Trimpot range of potentiometers.

Electrosil Ltd., up to now a sales organization, is to undertake the manufacture of metal oxide resistors, previously made by James A. Jobling, at its plant in Sunderland.

G. & E. Bradley Ltd. have been awarded an initial contract, worth over £42,000, to supply the R.A.F. with test equipment for pre-flight testing TACAN air-to-air navigational equipment.

Decca Type 424 airfield control radar is to be installed at Jersey airport in the Channel Islands. The equipment will be used primarily in the approach rôle, complementary to the I.L.S. and surveillance radar systems already in use.

Digital Measurements Ltd. have recently supplied the Admiralty with a seaborne digital data recording system. It will be used to evaluate new ship designs in terms of various motion parameters.

A 16mm vidicon tele-ciné unit manufactured by **Automatic Information and Data Service Ltd.** has been supplied to Tyne-Tees Television. The unit, built from standard Vidiaids equipment, is designed for 405-line operation.

British Brown-Boveri Ltd. have moved to Glen House in Stag Place, London, S.W.1. (Tel.: TATe Gallery 9422.)

The new London headquarters of the **General Electric Company** is 1 Stanhope Gate, London, W.1. (Tel. HYDe Park 8484.)

OVERSEAS TRADE

O.B. Television Vehicles.—Masinimport of Bucharest, Rumania, have placed an order with Marconi's W/T Company for a complete four-camera outside broadcast vehicle and a complete three-camera studio for Bucharest. Mark IV 4½in image orthicon cameras will be used in both the studio and O.B. vehicle. Radio Television Belgrade has also ordered a four-camera O.B. vehicle from Marconi, bringing their sales of these vehicles up to 54, of which 32 are for abroad.

The **Belgian Television Authority** has ordered eight camera channels and two 16-channel audio mixing units from Pye T.V.T. Ltd. to re-equip its Brussels studios.

Redifon Ltd. has received a contract, worth £30,000, to supply and install five radio beacon stations for the Ports and Lighthouses Administration of the **United Arab Republic.** The stations to be sited at Alexandria and Rosetta are to operate on 303.4kc/s and those at Damietta, Port Said and El Tor on 310.3kc/s.

Germany's largest independent producers of TV programme material, Riva TV and Film Studios, have ordered four 4½in image orthicon cameras and an 8-channel vision mixer, for a new studio from E.M.I. Electronics Ltd..

The New Zealand Civil Aviation Authority has ordered four **instrument landing systems** from **Pye** Telecommunications of Cambridge. Two of these installations are to be fitted at Auckland's new airport and the other two at Christchurch airport.

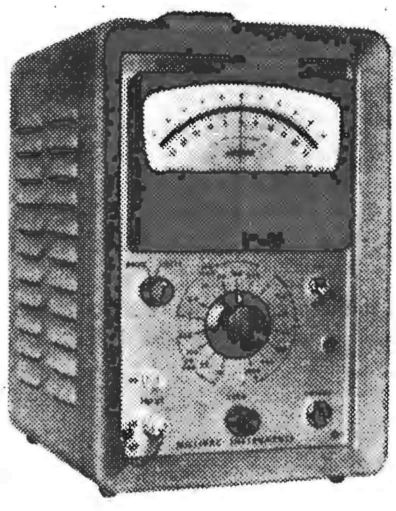
MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

D.C. Micro-Volt-Ammeter

A WIDE-range voltage and current measuring meter the Type MV-07 C manufactured by Millivac Instruments is available in the U.K. through Claude Lyons Ltd., Valley Works, Hoddesdon, Herts. The instrument is capable of measuring direct voltage from 10 μV full scale to 1,000 V full scale and direct current from 10 $\mu\mu$A to 1 mA in seventeen ranges. The manufacturers claim that the greatest error over this range is $\pm 4\%$ of full scale on the most sensitive voltage and current ranges improving to $\pm 2\%$ of full scale on the 100 $\mu\mu$A to 1 mA ranges and $\pm 1\%$ of full scale of the 250 μV to 1,000V ranges.

The low noise characteristic of the equipment, quoted as better than ± 0.5 μV, p-p, referred to the input, is achieved by a low-drift chopper circuit, the use of a double triode in cascode for the amplifier input stage and a twin -T circuit in one of the feedback loops.
For further information circle 301 on Service Sheet.



Millivac Instruments Type MV-07C d.c. micro-volt-ammeter.

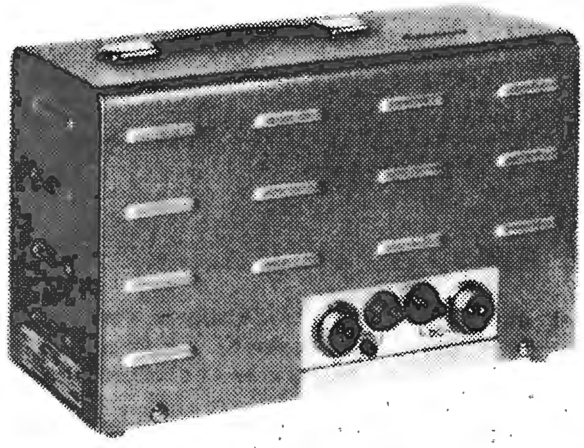
English Electric pulse tetrode Type C1149/1.

Pulse Tetrode

A NEW pulse tetrode, C1149/1, for use in radar modulators has been produced by the English Electric Valve Company. Features of this valve, which is a development of the C1133, include a strengthened electrode assembly, to reduce the chance of short circuits under vibration and a cathode coating which is claimed to be immune to flaking and peeling. The base pins have been made more pliant to minimize glass breakage. The valve is specified to withstand intermittent vibrations up to 50g from 20c/s to 1,500c/s, and each valve is subjected to a shock test of 200g. The pulse output power is rated at 330kW with a maximum anode dissipation of 60W at 20kV and a pulse current of 18A.
For further information circle 302 on Service Sheet.

Transistor Inverters

OPERATION of mains-powered equipments in the field can be achieved by use of two new transistor sine-wave inverters Models ICV80 and ICV150 manufactured by Advance Components of Hainault, Ilford. D.v. inputs range from 12 to 28V with maximum load ratings of

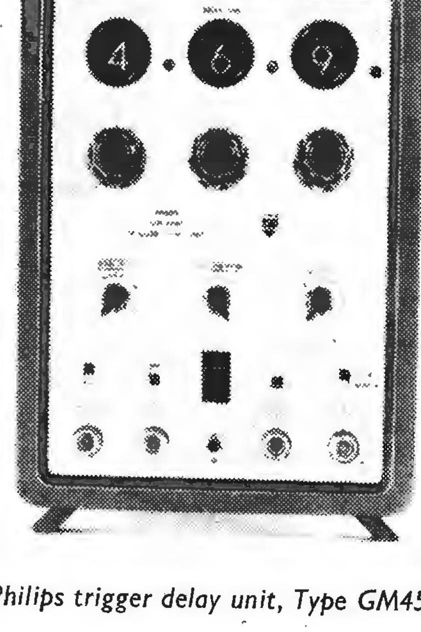


Advance transistor sine-wave inverter, Model ICV80.

80 and 150 W depending on the type. The 240V a.v. output has a frequency stability within $\pm 0.5\%$ and an harmonic content of less than 5%. The efficiency on full load is approximately 70%. The output voltage variation for a fixed load does not exceed $\pm 3\%$. Both equipments may be operated over an ambient temperature range of $-10°C$ to $+50°C$.
For further information circle 303 on Service Sheet.

Trigger Delay Unit

THE versatility of many oscilloscopes can be increased by the use of a trigger delay unit. This enables the triggering of a timebase to be delayed so that the trace begins at any desired point during the period of the signal. Thus, examination in detail can be made of any particular portion of a signal by adjusting the delay unit and the oscilloscope so that that portion occupies the whole width of the display. A single line of a television video signal may be displayed by feeding the frame pulse to the input of the delay unit and using the delayed output pulse to trigger the oscilloscope. The delay time is variable from 2.5 μsec to 100 msec in four ranges and is

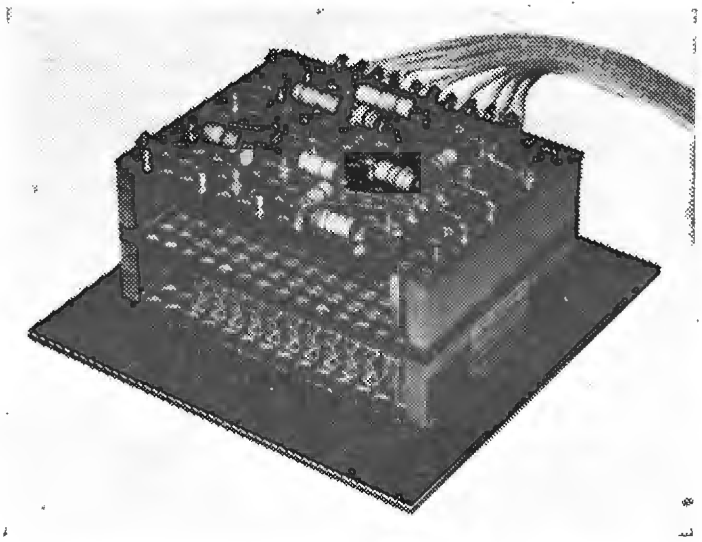


Philips trigger delay unit, Type GM4585.

indicated by digital read-out tubes. Additional facilities include sawtooth and gate-pulse outputs that can be used for x deflection and unblanking of the oscilloscope. A sync separator is also included to aid stable triggering on video frame pulses and to allow the delayed trigger pulse to be locked to line sync pulses. The unit is manufactured by Philips and is designated the Type GM4585. It is marketed in the U.K. by Research and Control Instruments Ltd., 207 King's Cross Road, London, W.C.1.
For further information circle 304 on Service Sheet.

Computer Patch Boards

THE usefulness of the Sealect oboard computer programming board is further extended by the addition of a built-in circuit deck. Turret lugs mounted on a ¼in grid carry circuit elements; input and output ter-

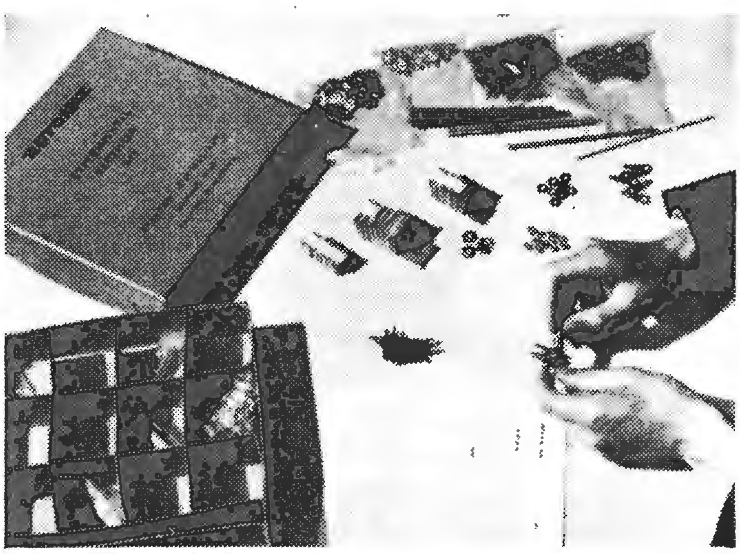


Sealectro programming board with circuit deck.

minations are available in the plane of the circuit deck. The unit is manufactured by the Sealectro Corporation, Hersham Trading Estate, Walton-on-Thames, Surrey.
For further information circle 305 on Service Sheet.

Rectifier Kit

BOTH development engineers and amateur experimenters should find the Electro Automat rectifier kit a useful accessory. The kit consisting of three sizes of rectifier plates, contacts, contact washers, insulation washers, spacing washers, plated steel nuts, insulating tube, mounting spindles, tags and wire enables rectifier stacks of different specifications to be built up. The plates provided are suitable for reverse voltages not exceeding 30V r.m.s. The instruction leaflet provided, lists the



"Automat" experimental metal rectifier kit.

current ratings for the plates when used in common circuit configurations. The standard kit costs £7 7s and may be obtained from Electro Automat Ltd., Swinton, Manchester.
For further information circle 306 on Service Sheet.

Voltage Calibration Source

THE problem of calibrating voltmeters, oscilloscopes and other voltage sensitive devices can be solved by the use of a new precision voltage calibrator Model 420, manufactured by Ballantine Laboratories Inc. The instrument can deliver both alternating (1 kc/s) or direct voltages from zero to 10V. Three different outputs can be selected, d.v., r.m.s. and peak-to-peak. The output is accurate to within ±0.5% of the indicated value but this may be improved to ±0.25% when using the calibration chart provided. The short-term drift is less than ±0.05% per hour after a suitable warm-up time. The total distortion (including hum and noise) of the a.v.

Ballantine Model 420 precision voltage calibration source.

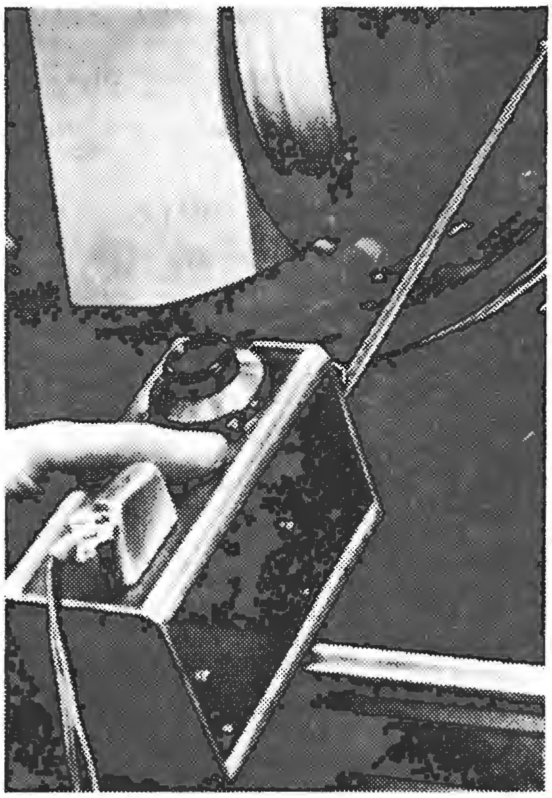
source is less than 0.25%. The price of the instrument is £175, alternatively a rack mounting version can be supplied for £184. The Ballantine agents in the U.K. are Livingston Laboratories Ltd., 31 Camden Road, London, N.W.1.
For further information circle 307 on Service Sheet.

Pressure-operated Switch

A REDUCTION in size by a factor of six compared with previous designs, is the salient feature of a new hermetically sealed pressure switch, the Klixon 2PS, introduced by Metals and Controls Inc., a division of Texas Instruments. This is designed as a pressure limit safety device in, for example, aircraft refrigeration equipment and fuel boost systems. All internal surfaces are of stainless steel and the actuating element is a snap-action disc. The switch is rated to break 5A at 28V d.v. or 110V a.v. in a resistive circuit or 2.5A in an inductive circuit. Actuating pressures (with a tolerance of ±10%) between 20 and 500 lb/in² can be provided for, and it is claimed that the actuating pressure shift over a temperature range of −300°F to +500°F is less than 1 lb/in². The pressure port is designed for ⅛in tubing.
For further information circle 308 on Service Sheet.

Proton Resonance Magnetometer Kit

THE underlying technique involves nuclear magnetic resonance, in which the nucleus of an atom at a given magnetic field strength absorbs radio-frequency energy. The frequencies involved are generally from 10-70 Mc/s. Scientifica, 148 St. Dunstan's Avenue, Acton, London, W.3, have introduced a proton resonance magnetometer kit of all the parts necessary to build the instrument, including a one-valve oscillator and a 3-stage transistor amplifier. A small probe head can be filled with different liquids for nuclear resonance comparisons. If used in



Scientifica proton resonance magnetometer being used to measure the strength of a magnetic field.

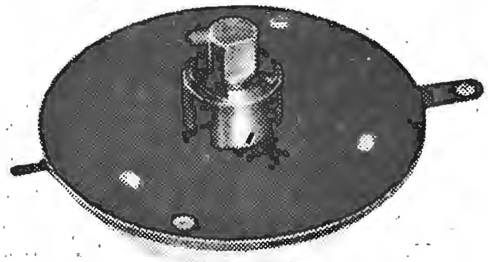
an academic institution the equipment can be easily dismantled after a set of experiments so that other students can rebuild it prior to further experimental work. The instruction manual includes a number of experiments that can be performed including the determination of nuclear magnetic moments. The complete kit costs £22.
For further information circle 309 on Service Sheet.

Magnetic Tape Instrumentation

TWO recording channels are provided in the new Elliott-Tandberg magnetic tape instrumentation system. Three tape speeds are available; frequency modulation or direct recording modes can be selected by push-button switching on either or both channels. At $7\frac{1}{2}$ in/sec and with a 12 kc/s carrier the f.m. system has a frequency response of z.f. to 2.4 kc/s ± 1 dB; at $3\frac{3}{4}$ in/sec and 6 kc/s carrier the response is z.f. to 1.3 kc/s; at $1\frac{7}{8}$ in/sec and a carrier of 3 kc/s the response is z.f. to 600 c/s. When recording directly, the frequency responses for speeds of $7\frac{1}{2}$, $3\frac{3}{4}$ and $1\frac{7}{8}$ in/sec are 40 c/s to 16 kc/s, 40 c/s to 10 kc/s and 55 c/s to 5 kc/s respectively. The complete system costs £550 and is marketed by Elliott-Automation Ltd., 34, Portland Place, London, W.1.
For further information circle 310 on Service Sheet.

Variable Capacitor

A MINIATURE ceramic-dielectric variable capacitor, a special feature of which, is that the vanes are metallized directly on to the dielectric to reduce microphony is available from the Havant Components Division of the Plessey Company. Designated the Type 83, the component is intended for use in medium and long wave receivers and is semi-sealed against dust. Two versions are available, 20-300 pF and 20-500 pF. The power factor at 1Mc/s is less than 0.002. Both the capacitance law (normally linear) and the maximum capacitance can be varied to suit customer applications.
For further information circle 311 on Service Sheet.



Plessey metallized ceramic vane variable capacitor Type 83.

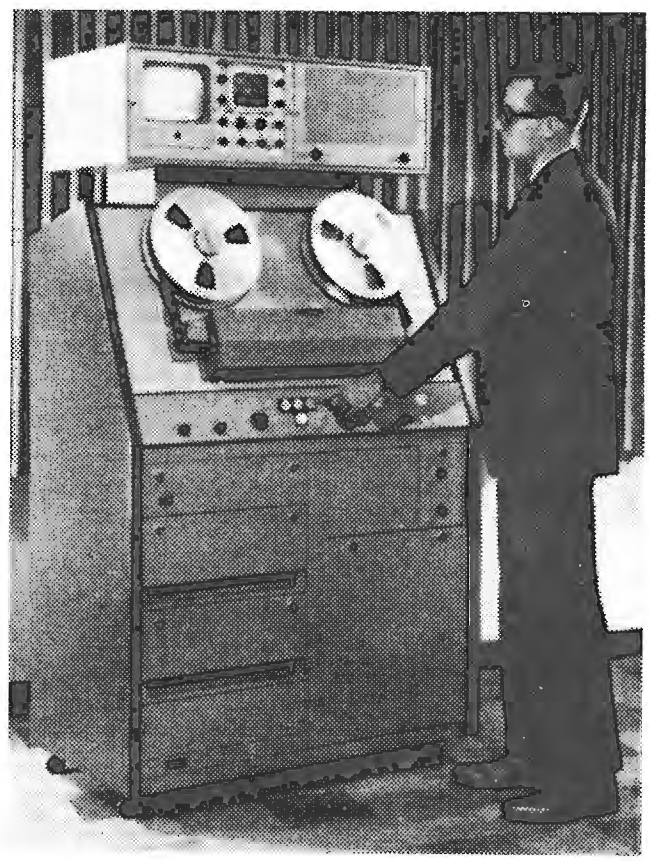
Components for Colour Television

R.C.A. Great Britain Ltd., Lincoln Way, Windmill Road, Sunbury-on-Thames announce that certain receiver parts in kit form can be obtained from them. Designed for 625 line, N.T.S.C. standards operation, the parts available are, a 21in., colour mask, 70 degree, aluminized tube Type 21FJP22 and a kit of parts consisting of a colour-purity ring magnet, deflection yoke, convergence assembly, lateral magnet assembly and line output transformer. The tube is priced at £62; the other parts are sold collectively at £15 9s.

R.C.A. also announce that their new colour television receiver Type 14F61MU will sell at £292 net. Sets will be delivered in the U.K., with Band-I channel aligned for test purposes to vision carrier 55.25 Mc/s, sound carrier 61.25 Mc/s—unless otherwise ordered.
For further information circle 312 on Service Sheet.

Video Recorder

A NEW video tape recorder using transistors throughout is announced by Ampex International. Designated the VR1100, the equipment is thought to be the smallest compatible broadcast recorder available at present. The unit is capable of two-speed operation ($7\frac{1}{2}$ or 15 in/sec) and is housed in a single cabinet $60 \times 24 \times 42$in. in size. Accessories designed for the Ampex VR1000 series may



Ampex International Type VR 1100 video recorder.

be used with this recorder. Specifications include a bandwidth of 10c/s to 4Mc/s$\pm$2dB (525 line), 10c/s to 5Mc/s$\pm$2dB (625 lines), a signal-to-noise ratio of 40dB or better, peak-to-peak video to r.m.s. noise, an input level of 0.5 volts peak-to-peak minimum and a linearity (video response) better than 10%.
For further information circle 313 on Service Sheet.

U.H.F. Television Reception

PROPAGATION PROBLEMS AFFECTING AERIAL DESIGN

By A. C. ROBB,* M.Eng., Ph.D., A.M.I.E.E.

WITHIN a few months a third television programme will become available to a section of the British public. Transmissions will be in the ultra high frequency range of Bands IV and V, and will be based on a 625-line picture standard. No revolutionary technical problems will be involved in starting the service, but there are nevertheless severe practical difficulties to be met. It is therefore quite probable that these difficulties may have an unexpected influence on the popular reaction to the new programme.

It is important to appreciate the circumstances in which the new service will be introduced. They are entirely different from the context in which an altertive British programme first became available. At that time any new and different picture had inherent originality and novelty which easily offset most of the early teething troubles. Moreover at a time when parliamentary feeling was running unusually high, the public was invited to study the controversial profile of a commercial television service. It is also relevant that there were then no particular technical innovations being offered to the public.

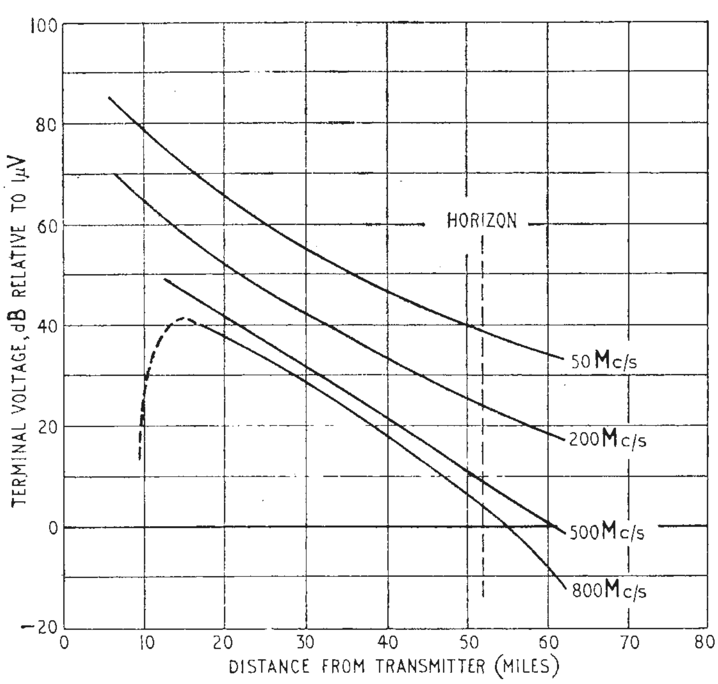


Fig. 1. V.h.f. and u.h.f. propagation characteristics. The transmitting aerial is a half-wave dipole with an e.r.p. of 1 kW.

The present position is very different. Originality has now less to recommend it, and there is less controversy about the character of the new service. Indeed, there seems to be much that will restrict rather than extend its appeal. It has been suggested that evening transmissions will often include programmes of considerable length. Has the domestic viewing public the sticking power of the theatregoer and the concert-goer? The attraction of colour which probably alone could stimulate a wave of interest in the new service, is unlikely to be added for some time. It seems, in fact, as though the main popular attraction of the new service will initially be centred on the new 625-line picture standard. There is, however, little immediate gain in picture quality, and if there are receiving problems which result in an inadequate or a poor signal these will only add to the difficulties in developing a new service which cannot easily achieve striking originality and can only expand as rapidly as the public investment in new receivers.

Frequency Allocations

Bands IV and V cover the ultra high frequency range between 470 Mcs and 960 Mc/s. The allocation of bandwidths and national and regional transmission frequencies is based on decisions covering these transmissions which were reached at the 1961 Stockholm Conference.[1] It was then decided to adopt an 8 Mc/s bandwidth as standard for all channels within the u.h.f. bands, and also to allocate four channels to each service area disposed by number in the series n, n+3, n+6 and n+10. Where this is not practicable, the preferred alternative will be n, n+4, n+7, and n+10.

A British extension to this principle establishes that, wherever possible, all u.h.f. transmitters covering any single service area will be co-sited. In practice this co-siting will frequently be based on the positions of existing lower frequency transmitters and aerials, although where secondary or "satellite" u.h.f. transmitters are required this overall concentration will clearly break down. The general principle involved is, nevertheless, attractive and important, because it encourages the use of single complex domestic receiving aerials, covering either the bandwidth of at least the eleven u.h.f. channels for a locality or a combination of this coverage with channels in Bands I, II, and III.

In order to achieve very wide bandwidth u.h.f. reception, Yagi-type aerials are now almost universally adopted, although a major change in design philosophy has taken place. This involves consideration of the phases velocity of signals received in the aerial directors in conditions analogous to those of a corrugated waveguide.[2] Although relatively complex and bulky, aerials which also accommodate channels in the lower v.h.f. bands are economically attractive; erection and alignment costs are relatively low, with the built-in multiplex coupling to the down lead simplifying the electrical installation.

The area which a Band IV or V transmitter can adequately serve is broadly similar to that which

* Belling & Lee Ltd.

D

can be covered by an equivalent transmitter in the lower three bands. The effect of the higher frequency is, however, to increase the propagation losses and to reduce diffraction at the horizon. This results in rapid deterioration of the available signal beyond line-of-sight distance from the transmitting aerial. An indication of the quantitative range of this effect is provided in Fig. 1.[3]

The effect of this deterioration on the secondary service area will be to concentrate the demand for satisfactory fringe reception into a comparatively narrow annular region only a short distance from the transmitter horizon. In some cases this may bring the problems of fringe reception into areas of high urban concentration.

This contraction of the service area necessarily leads to an increase in the number of stations required to provide adequate national coverage. U.h.f. service areas will be more generously lapped and many low-power secondary stations will be necessary to provide a service where, for topographical reasons, the available signal from main stations is inadequate. Rather more than sixty main transmitter locations are envisaged. Table 1 and the accompanying map, which are based on the decisions reached at Stockholm, show the main station allocations for the British u.h.f. television services. Secondary transmitters are not shown and can only be finally planned as the services develop.

Field Strength and Sensitivity

The relatively small size of Band IV and V dipoles reduces the basic aerial sensitivity, but this is not, in practice, as important as is often made out. The conditions for energy transfer between transmitter and receiver, neglecting propagation losses, are substantially independent of frequency. More impor-

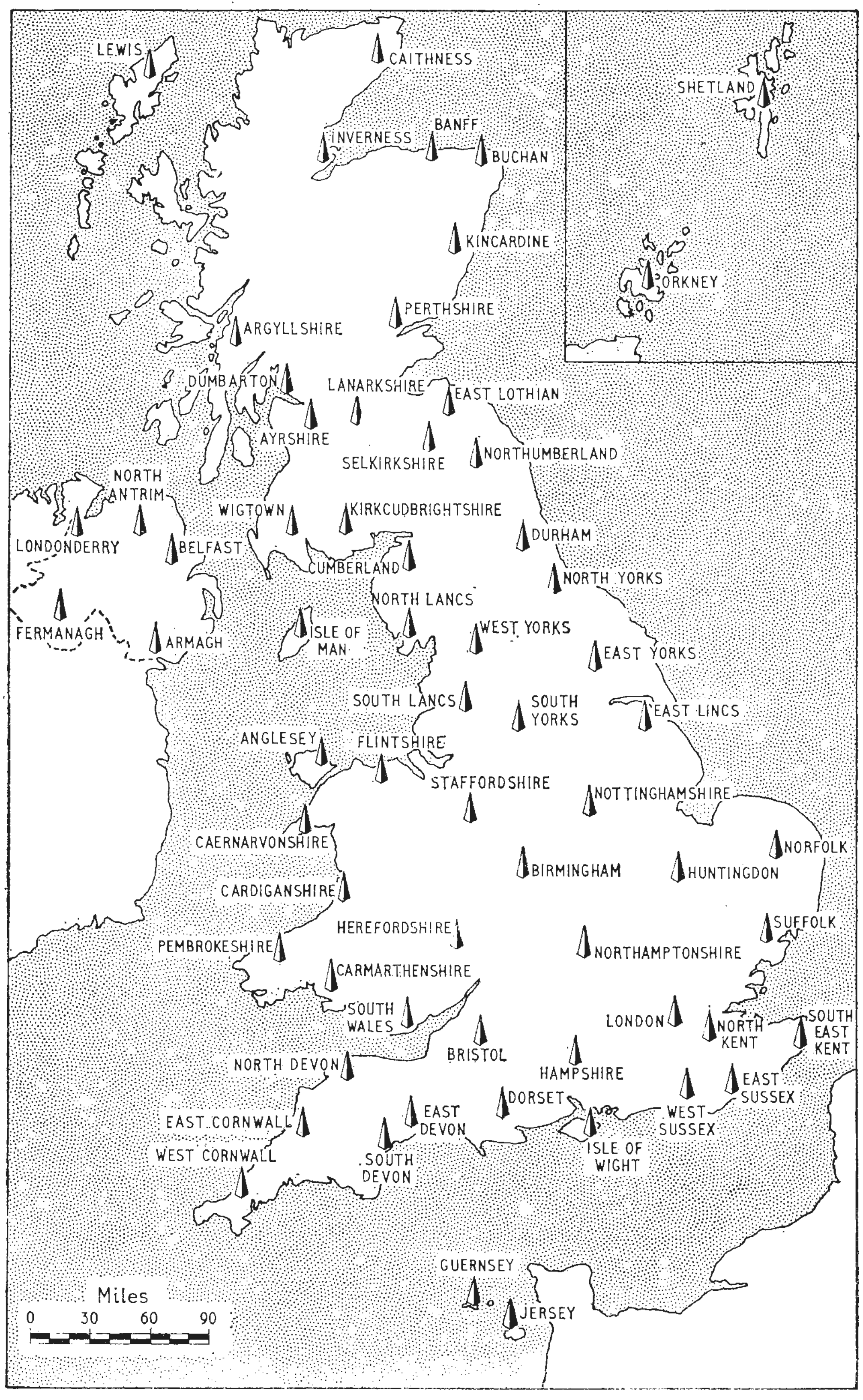


TABLE 1.—The channels allocated at Stockholm to the 64 main stations for the U.K. are listed below and the general disposition of the transmitters is shown on the map. The frequency limits and vision carriers for each channel were given in the December issue of *Wireless World* (p. 592).

Belfast	21	24	27	31
Caithness	21	24	27	31
Cardiganshire	21	24	27	31
East Lothian	21	24	27	31
Huntingdon	21	24	27	31
Isle of Wight	21	24	31	41
West Yorks	21	24	27	31
Argyllshire	22	25	28	32
Cumberland	22	25	28	32
East Cornwall	22	25	28	32
East Lincs	22	25	28	32
Fermanagh	22	25	28	32
Herefordshire	22	25	28	32
Kincardine	22	25	28	32
Ayrshire	23	26	29	33
Banff	23	26	29	33
East Devon	23	26	29	33
Lewis	23	26	29	33
London	23	26	30	33
North Yorks	23	26	29	33
Staffordshire	23	26	29	33
West Sussex	27	55	58	66
Isle of Man	30	34	48	52
Shetland	32	34	45	49
Flintshire	39	42	45	49
Hampshire	39	42	45	68
Inverness	39	42	45	49
Northumberland	39	42	45	49
Birmingham	40	43	46	50
Dorset	40	43	50	67
Lanarkshire	40	43	46	50
North Kent	40	43	46	65
North Lancs	40	43	46	56
Orkney	40	43	46	50
Pembrokeshire	40	43	46	50
Buchan	41	44	47	51
Caernarvonshire	41	44	47	51
Jersey	41	44	47	51
Kirkcudbrightshire	41	44	47	51
Londonderry	41	44	47	51
South Yorks	41	44	47	51
South Wales	41	44	47	51
Suffolk	41	44	47	51
West Cornwall	41	44	47	51
Guernsey	48	52	54	56
East Sussex	49	52	64	67
South East Kent	50	53	56	68
Anglesey	53	57	60	63
Carmarthenshire	53	57	60	63
East Yorks	53	57	60	63
Northamptonshire	53	57	60	63
Perthshire	53	57	60	63
South Devon	53	57	60	63
Wigtown	53	57	60	63
Armagh	54	58	61	64
Bristol	54	58	61	64
Dumbarton	54	58	61	64
Durham	54	58	61	64
Nottinghamshire	54	58	61	64
Norfolk	55	59	62	65
North Antrim	55	59	62	65
North Devon	55	59	62	65
Selkirkshire	55	59	62	65
South Lancs	55	59	62	65

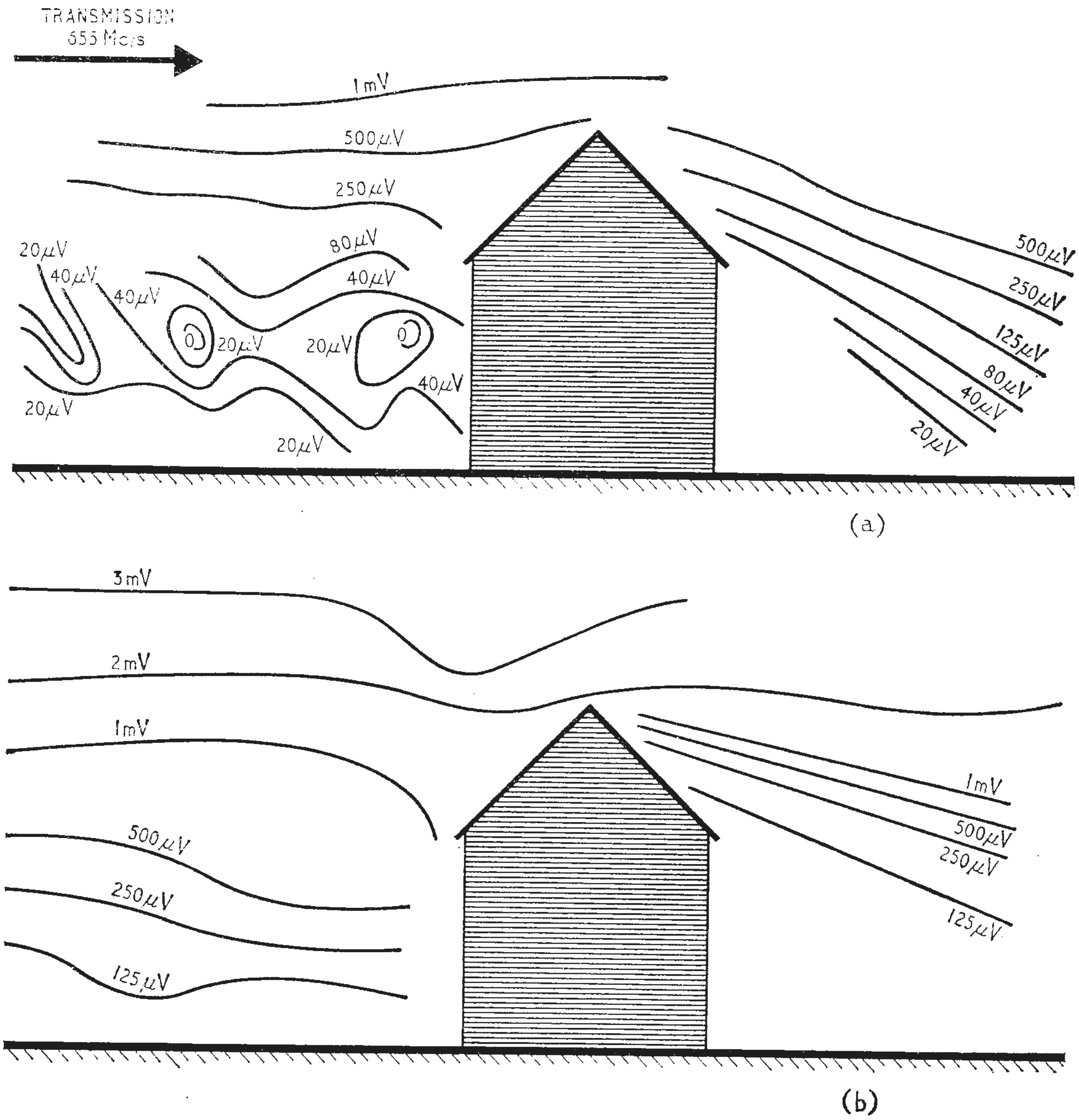


Fig. 2. Terminal voltages from aerial plots adjacent to a suburban two-storey house; (a) using a λ/2 dipole and (b) using a Yagi with a 12 dB forward gain relative to a dipole.

tant considerations are the available input terminal voltage necessary to ensure a high signal-to-noise ratio at the receiver, wide local variations in the available field strength, and effects of shadowing and reflection, already familiar in the v.h.f. bands but appreciably increased at higher frequencies.

For any given signal-to-noise ratio the minimum acceptable input signal to an u.h.f. receiver is determined by the thermal noise of the first stage. This is dependent both on the channel frequency and on its bandwidth. At 600 Mc/s thermal noise on an 8 Mc/s channel is about 9 dB higher than for a 3.5 Mc/s channel in Band I. There is also a greater loss of input signal due to down lead attenuation which, for an average run of 30-40ft, may represent a further 1.5-2 dB. A signal from the aerial generally about 12 dB higher than for Band I is therefore desirable for adequate signal-to-noise ratio in the u.h.f. bands. The necessary aerial gain will depend on the effective radiated power of the transmitter, or the terrain over which propagation is taking place, and on the receiving aerial position and height.

The e.r.p. of the transmitter may be increased by using transmitting aerials of high gain, designed to radiate intensely in the area between the mast and horizon but not significantly above the horizon. The design of such aerials is a sophisticated compromise involving transmitter and mast economics, mast stability, and careful attention to the available field strength in close proximity to the transmitter. Particular attention must also be paid to the tangential radiation at the horizon, which must be unaffected by severe wind loading on the mast. Present technology indicates that a representative economic service may cover a radius of about 25 miles from a 600ft mast, with an e.r.p. of the order of 1 MW. B.B.C. test transmissions on channels 34 and 44, however, have an e.r.p. of only 160 kW.

The transmitter e.r.p. is not alone a criterion of satisfactory propagation; the severe shadowing effects already referred to introduce local variations in the available field strength which are very much more pronounced than at lower frequencies. Fig. 2, for example, illustrates the kind of variation which may be encountered at the front of and in the shadow of a fairly ordinary suburban house, the front effects being due to reflections and standing wave phenomena.[4] More complete shadowing will of course occur behind hills, as indicated in Fig. 3. The comparative results for Bands III and V involve aerials with gains corrected for the differing effective captive areas. Wide variations in the necessary receiving aerial gain will clearly be encountered, but these will be less directly related to propagation distance than at lower frequencies.

Receiving Aerial Performance

Receiving aerial performance involves three basic criteria:—

1. Forward gain,
2. Directivity and
3. Front-to-back gain.

Forward gain will determine the terminal voltage at the receiver for any given circumstances of field strength and down-lead attenuation. We have already seen that wide variations in desirable gain may be involved within quite small physical displacements. It is also clear from Figs. 2 and 3 that an increase of height may well be the most important general means for improving a poor signal.

Directivity is related to forward gain, high gain and narrow directional characteristics being generally, for any given bandwidth of performance, directly related. Directivity will be important where reflected signals cause serious "ghosting," and much experience has been gained in Band III on these problems. The effects in Bands IV and V should not be conspicuously different, and from recent small-scale field tests seem, if anything, rather less serious than anticipated.

Clearly, since height is advantageous, a low aerial is likely to be troublesome. In a large urban concentration with many flat dwellers, a considerable proportion of whose premises face away from the transmitter, here are likely to be problems associated with ground floor and basement reception. Many reflections from adjacent buildings are likely to complicate reception, and these reflections may be quite strong compared with a severely shadowed and attenuated primary signal. In such circumstances polar discrimination against reflection paths will be a natural consequence of providing the necessary gain to use any severely attenuated but adequate primary signal. It is therefore probable that much latent "ghosting" trouble has been concealed by the inevitable use of high-gain, and therefore highly directional, receiving aerials. However, this argument becomes less valid in areas of very high field strength—possibly on hill tops, or, in some cases, close to the transmitters. Here, even close to the ground low-gain aerials may be acceptable but may lack adequate angular discrimination against reflections. It may then be appropriate to

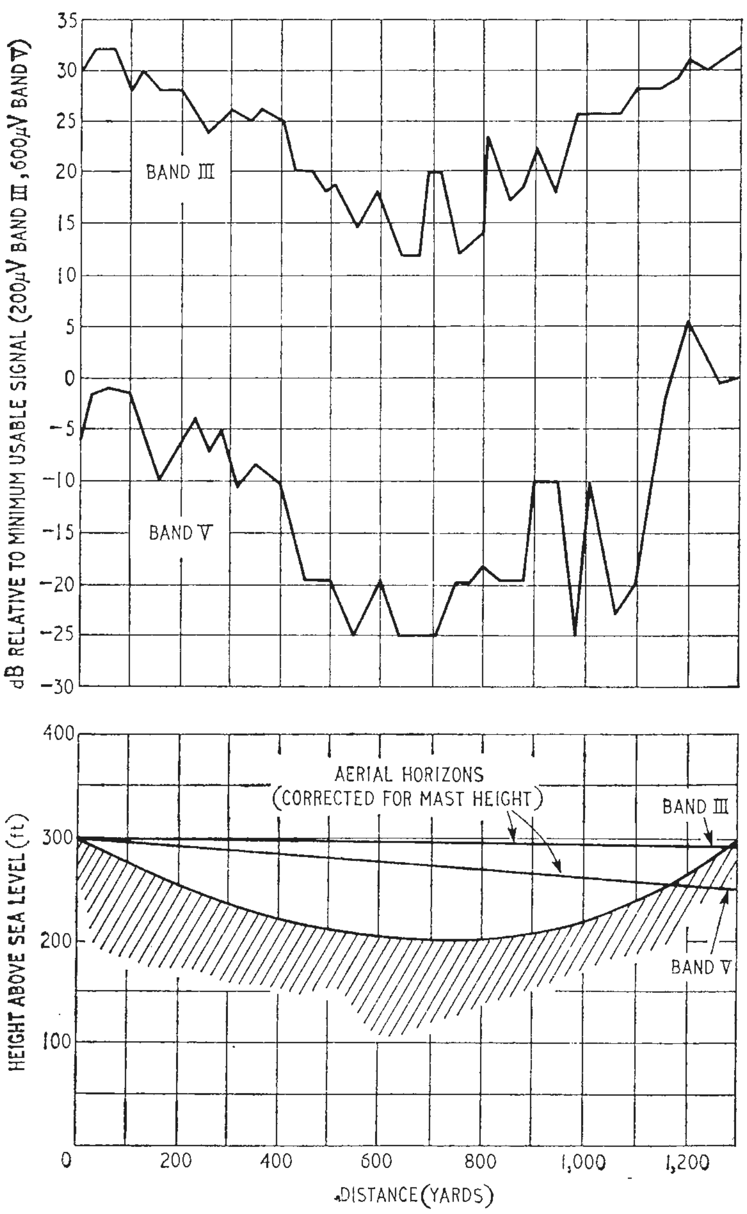


Fig. 3. Field variations within a 100ft. depression.

use an aerial of considerably higher gain than necessary in order to take advantage of its superior directional properties. In very exceptional circumstances this may even be coupled to the receiver through a compensating attenuator, although very close to the transmitter, direct pick-up within the receiver itself may introduce a further complication.

A high forward-to-backward gain is necessary to discriminate against reflections in the immediate vicinity of the aerial mounting. Such signals may be relatively strong and may cause the serious standing wave patterns and field strength nulls illustrated in Fig. 2. They may also cause short time delays which will impair visual resolution. There is a further small chance of co-channel interference from a distant transmitter, or second channel interference from the tenth channel above that which is being received, if receiver selectivity is inadequate; these are, however, unlikely to be troublesome except in particularly unusual circumstances.

Practical Aerial Arrangements

All outdoor aerials for Bands IV and V meet the requirements already set out, in greater or lesser degrees. Fig. 4, indicates the appearance of representative broadband aerials with nominal forward gains relative to a half-wave dipole of 3, 6 and 9 dB, and shows approximate directional characteristics for each. Higher forward gain and greater directional discrimination may be obtained by using longer director arrays or possibly by fitting side rows, as shown in Fig. 5a, but this approach to performance improvement becomes less rewarding as arrays become larger and involves very large structures even to achieve a nominal gain of 12 dB. Where higher gain is necessary, smaller arrays can be more successfully coupled in broadside arrangements as shown in Fig. 5b.

It is, for the reasons already presented, difficult to generalize about receiving aerial requirements, but Table II and the accompanying map, collate a variety of information obtained during recent field tests in the Greater London area[5]. Many viewers will be able to use relatively low-gain aerials at considerable distances from the transmitter—always assuming good roof-top mounting positions are available. It seems, however, that considerable difficulties arise as soon as reception is attempted below rather than above the main topographical irregularities. Once the receiving aerial becomes submerged below the mean surrounding roof level, multiple reception paths are introduced which involve both the attenuation and reflection of adjacent buildings. A particular irritant associated with low aerials is transient reflection from moving vehicles, a far more frequent nuisance than passing aircraft on v.h.f. channels.

There remains the problem of indoor and set top aerials. Attic aerials of comparable gain to outdoor arrays have much to commend them; they are protected from the effects of the weather and are of convenient size for such mounting. The attenuation due to roof cladding is normally only about 1-2 dB but may be worse in some cases when it is raining. A further comparatively new hazard affecting such aerials is the use of metal foil roof insulation. This, of course, renders many of these arrangements virtually useless. Set top aerials are more difficult to generalize about; interior wall reflections may be

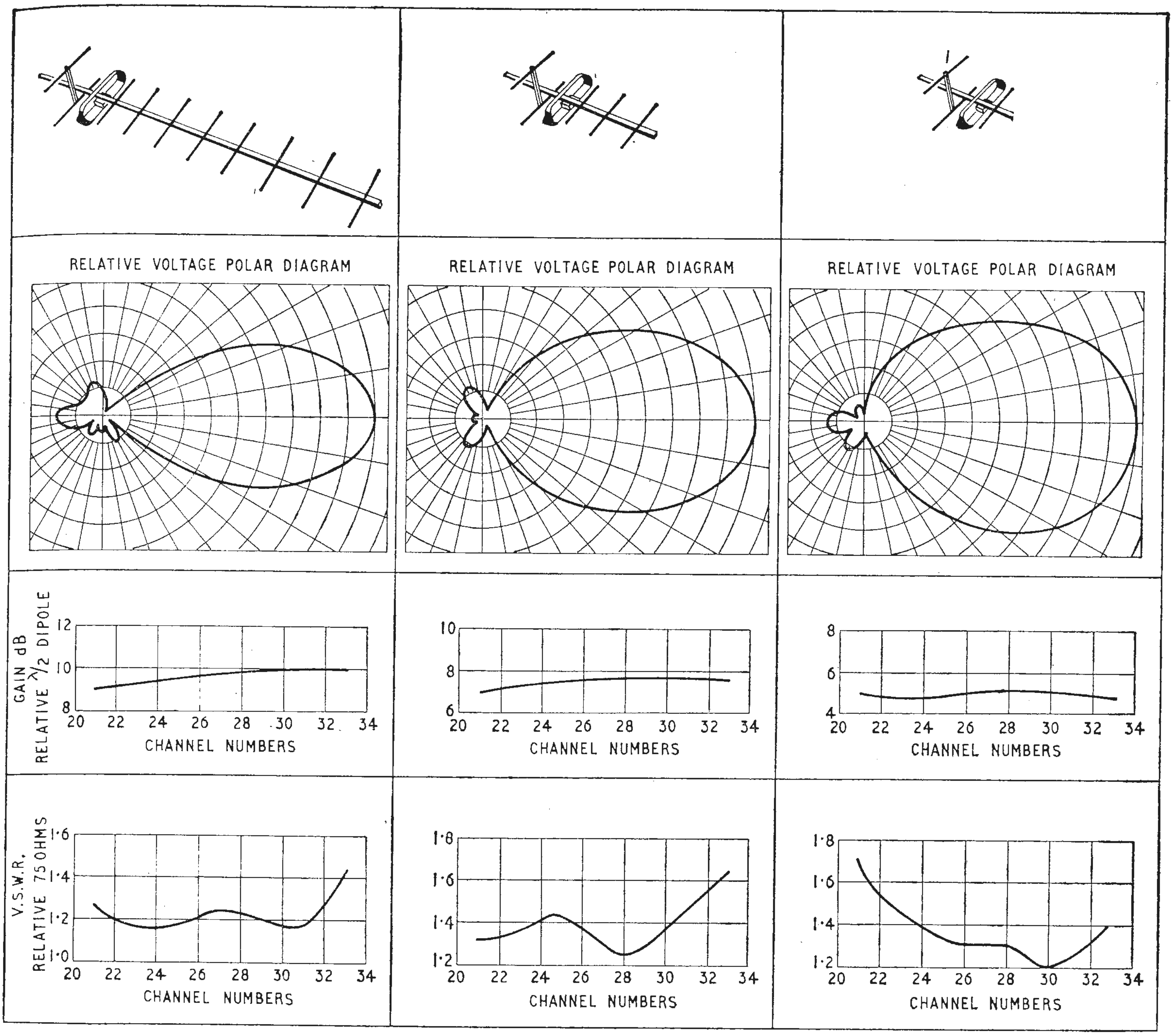


Fig. 4. Typical performance figures for wide-band u.h.f. aerials.

troublesome unless the aerial is carefully positioned, and the movement of people in adjacent rooms may have real nuisance value.

Some recently published American results[6] have tended to confirm the findings of these preliminary tests in Greater London, but have brought out one or two further and important observations. Often when the receiving aerial is below the average roof line, it is extremely difficult to analyse the nature of picture degradation, and the amount of degradation which is acceptable varies considerably with the type of picture content. In this condition of immersion within the building "clutter"—the American term—it is also often preferable to use an aerial of only moderate gain and polar discrimination as the alignment of high-gain narrow-angle aerials is frequently critical and unreliable.

In conclusion a few words about colour. The effects of multiple path distortions and poor signal strength on the quality and character of colour reproduction depend fundamentally on the system in use. They also, in some cases, depend significantly on the transmitter aerial alignment. During the tests described in Table II, temporary transmitter aerials were in

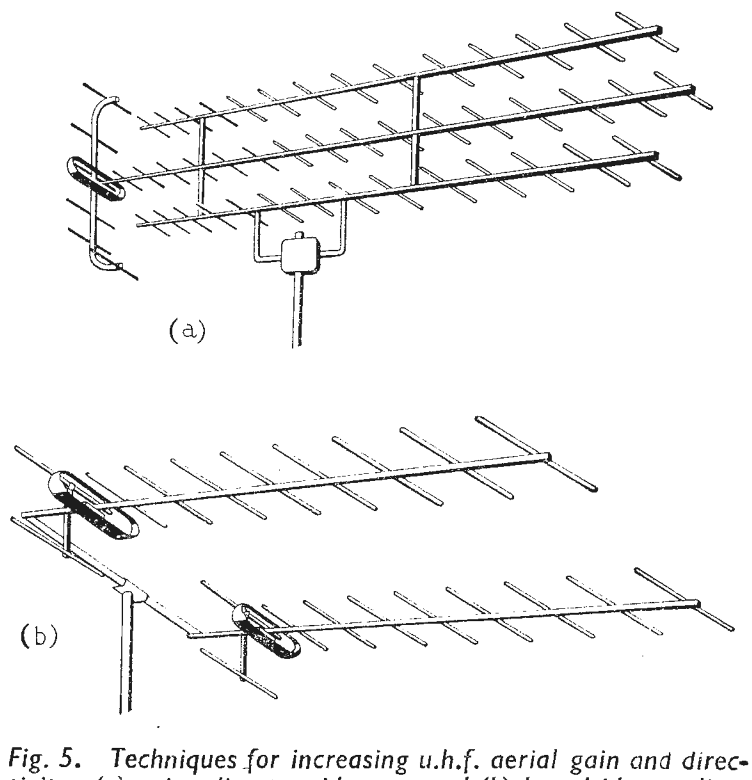
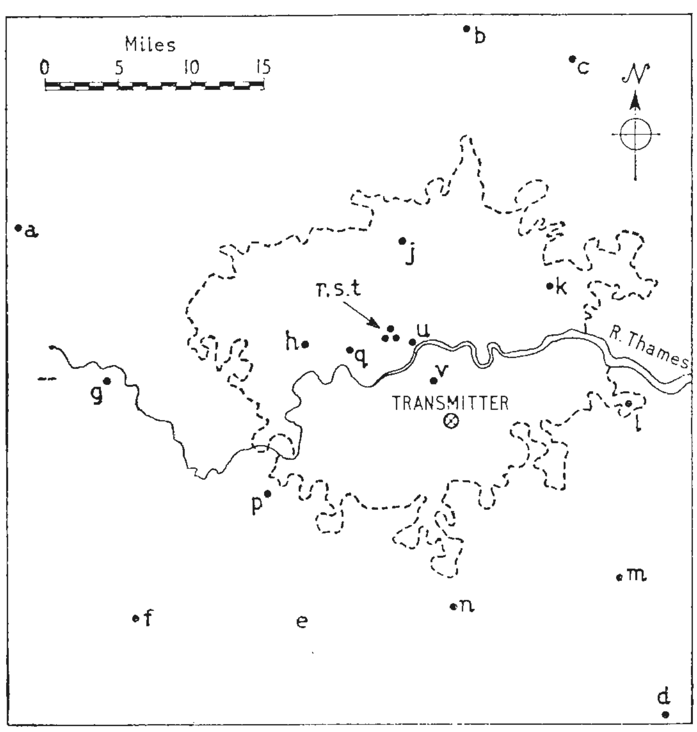


Fig. 5. Techniques for increasing u.h.f. aerial gain and directivity; (a) using director side rows and (b) broadside coupling.

TABLE II.—Summary of results of u.h.f. tests conducted in the Greater London area. The places referred to in the table are indicated on the sketch map. It must be stressed that local results vary widely and that the figures given are random rather than representative. Low tabulated results, therefore, do not necessarily indicate a low average signal in the specified area. All tests were conducted with a 36ft mast.

Test Position and Character					Reception Conditions			Picture Quality			Notes
Map Ref.	Place	Dist. from Transmitter (miles)	Terrain	Buildings	Chan-nel	Aerial Gain Rel. to Dipole (dB)	Average Receiver Terminal Voltage (mV)	General	Noise	Reflections	
a.	High Wycombe	36	Hilly	Semi-open	44	9	0.79	Fairly good	Slight	V. slight	
b.	Ware	28	Low	Residential and light ind.	34	9	0.28	Poor	Moderate	None	Behind hill
c.	Harlow	25	Flat	Urban car park	34	9	0.40	Fair	Slight	Slight	
d.	Tunbridge Wells	24	High	Residential	34	9	0.14	V. poor	V. slight	Moderate	
e.	Dorking	18	Low	Commercial, etc.	34	9	0.16	Fairly good	V. slight	V. slight	
f.	Guildford	22	Mod. high	Commercial, etc.	34	9	0.79	Fairly good	Slight	Slight	
g.	Windsor	25	Low	Residential	34	6	0.71	Fair	Slight	V. slight	Just clear of castle shadow
h.	Ealing	13	Flat	Residential	34	9	11.2	V. good	V. slight	None	
j.	Wood Green	13	Low	Residential	34	6	0.20	V. poor	Moderate	Slight	Behind hill
k.	Ilford	11	Flat	Residential	34	6	0.28	Good	V. slight	V. slight	Behind large building
l.	Dartford	11	High	Residential	44	6	0.25	Fairly good	Slight	V. slight	
m.	Sevenoaks	14	High	Residential	34	9	0.28	Good	V. slight	V. slight	
n.	Godstone	12	Low	Residential	34	9	0.10	V. poor	—	—	Very poor picture synch.
p.	Esher	15	Flat	Commercial	34	9	6.30	Good	V. slight	V. slight	
q.	Shepherds Bush	10	Flat	Residential	34	9	6.30	Good	V. slight	V. slight	
r.	Oxford St.	9	Slope	High commercial	34	9	0.45	Poor	Moderate	Severe	Severely screened
s.	Regent St.	9	Flat	High commercial	34	9	6.31	V. good	Nil	Nil	Clear towards transmitter
t.	Leicester Square	8	Flat	High commercial	34	9	0.45	Poor	Nil	Severe	Severely screened
u.	Savoy Place	7	Low	Riverside	34	9	1.00	Good	V. slight	V. slight	Fairly open
v.	Camberwell	5	High	Residential	44	3	1.12	Fair	Nil	Moderate	



use and it was known that some local peculiarities in colour reception were probably very much influenced by the aerial radiating characteristics. At a time when the selection of a standard colour system is urgent, nothing is to be gained by cluttering the debate with misleading impressions and tenuous deductions. It is probably enough to observe that, in general, the areas where colour reception has been poor have also been immediately recognizable as characteristically difficult areas for monochrome reception, although in some cases colour reception has been very disappointing where monochrome reception has been quite acceptable.

The objective of studies in u.h.f. reception must, in the end, be a practical one. So far field tests have confirmed the wide variations in local field strength associated with these frequencies, and the complexity of the field patterns involved. What we must now develop through our working experience, is a modest range of conventional solutions to a great diversity of particular problems. The time that it will take to acquire this experience and facility will depend on the rate of expansion of the new service; effectively on the attractiveness of the new programmes and the success with which the public can be persuaded to change their receivers.

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WORLD OF WIRELESS

U.H.F. Television

THE areas to which the B.B.C's second television service will be extended following its introduction in London next April have now been announced by the P.M.G. The first eight high-power stations, to be opened by the end of 1965, will be in the Midlands, Lanarkshire, South Wales, Lancashire, South Yorkshire, Northern Ireland, the Isle of Wight and North-east England. A further nine stations, which it is hoped to open in 1966, will be in the Bristol Channel area, Norfolk, Anglesey, Kincardineshire, South-east England, Nottinghamshire, Suffolk, North Yorkshire and Northamptonshire. A list of the frequencies allocated to these stations at the Stockholm Conference, 1961, and a map showing the distribution of the 64 main u.h.f. stations provisionally planned for the U.K. are given on page 386 of this issue.

Seven of the 17 stations will be built at the sites of existing B.B.C. Band I transmitters (Sutton Coldfield, Wenvoe, Rowridge, Pontop Pike, Divis, Tacolneston and Llanddona), and five at or near the I.T.A. stations at Winter Hill, Emley Moor, Black Hill, Durris and Dover.

Extending 405-line Coverage

BOTH the B.B.C. and the I.T.A. have been given the go-ahead by the P.M.G. to build additional Band III stations to extend the coverage of their existing services. The B.B.C. is to have six Band III transmitters, including that already announced for Wenvoe (Channel 13), which will radiate a Welsh programme. The five additional transmitters will be at Moel-y-Parc, near Denbigh (Channel 6), Sandale, Cumberland (Ch. 6), South-west Lancashire (Ch. 12), Mid-Lancashire (Ch 7) and East Lincolnshire (Ch. 13). The Moel-y-Parc transmitter will share the existing I.T.A. site.

The I.T.A. is also to build six additional v.h.f. stations to serve Central Berkshire (Channel 12), Bedford-Peterborough (Ch. 6), East Lincolnshire (Ch. 7), Scarborough (Ch. 12), Dundee (Ch. 11) and Caithness-Orkney (Ch. 8). The East Lincolnshire station will be constructed with a view to its future use by both the B.B.C. and I.T.A. for u.h.f. transmissions. Some of the channels quoted are provisional allocations.

The P.M.G. stated in the Commons that the three transmitters to operate in Channel 6 will for a time have to limit their hours of transmission from noon to midnight to avoid interference with the sky survey of the Northern Hemisphere which is being conducted by the Mullard Radio Astronomy Observatory at Cambridge using frequencies within this channel.

Aviation Electronics

DIPLOMAS and prizes were presented to 114 students at the College of Aeronautics, Cranfield, by the Minister of Aviation, Mr. Julian Amery, on July 5th. Seventy-five of the students were from the U.K., 22 from the Commonwealth and the remainder from ten other countries. The college is a Government-sponsored establishment providing engineering, technical and scientific training in aeronautics. A two-year course is given to selected graduate students leading to the award of the diploma of the college (D.C.Ae.). Students in the final year specialize in the work of one of the six departments (including electrical and control engineering) and produce a thesis.

Of the six recipients of the D.C.Ae. in the Department of Electrical and Control Engineering, Flight Lt. Colin W. Andrews, B.Sc., also won one of the nine special prizes. His thesis was on a 450 Mc/. tunnel diode amplifier in a stripline configuration.

The college also awards a diploma in advanced engineering (D.A.E.) on the completion of a one-year course in one of several subjects of advanced engineering science offered by the various departments. The only recipient of the D.A.E. for the course in aviation electronics was A. K. Majumdar, M.Sc., formerly with International Computers and Tabulators, of India, whose thesis was "The role of radar in air traffic control."

Not Yet

THE proposal put forward by Paul Adorian and referred to in our April issue that this country should adopt a 525-line 60-field/625-line 50-field dual television standard, has been considered by the Television Advisory Committee to be "quite impracticable to introduce . . for at least another 10 years." The committee's advice has been accepted by the Postmaster General.

Although such a dual system "might prove to be worth while in the long term" the committee gave among its reasons for delaying its introduction that, although it might be possible eventually to provide receivers capable of being used on both 625 and 525 lines, it would be wrong to introduce additional complications in receiving sets during the period when definition standards are changing over from 405 to 625 lines; and, that even were it practicable to introduce such a system now (and the Committee is convinced it is not), so drastic a change in plan on the eve of the start of the B.B.C.'s second programme on 625 lines would result in a serious set-back for the radio industry.

This year's **Paris Radio and Television Show,** which will be held from 5th-15th September, will, for the first time, be international. Organized by the F.N.I.E. (Fédération Nationale des Industries Electroniques) it will cover domestic radio and television (819 and 625 lines will be demonstrated) and sound reproduction.

Italy's 29th National Radio & Television Show, to be held in Milan from 7th to 15th September, will this year include the first International Electronic Components Fair to be held in Italy. The organizers, Associazione Nazionale Industrie Elettrotechniche, are also planning to hold a convention during the Components Show.

B.S.R.A.—At the annual general meeting of the British Sound Recording Association, J. C. G. Gilbert was elected president for the year 1963-1964 with M. J. L. Pulling, A. P. Monson, G. A. Briggs and D. W. Aldous as vice-presidents. The Hon. J. Dawnay, R. J. Barton, R. E. Cooke, J. W. Maunder, P. M. Clifford and P. B. Cooper were elected members of the council. S. W. Stevens-Stratten was re-elected hon. secretary.

The **Paul Instrument Fund Committee,** administered by the Royal Society, the I.E.E. and the Institute of Physics and Physical Society, has recently made the following grants:—£15,320 to Professor H. M. Barlow, F.R.S., Pender professor of electrical engineering at University College, London, for the development of a microwave electrostatic wattmeter and the construction of instruments for the measurement of electrical power at very high frequencies by the absorption of the angular momentum of a circularly polarized wave; £950 to K. G. Nichols, M.Sc., lecturer in electronics, University of Southampton, for the construction of apparatus giving an improved method for vacuum deposition of thin films of high melting point materials; and £1,800 to Dr. E. E. Schneider, reader in solid-state physics, King's College, Newcastle-upon-Tyne, for the development of superconducting cavities for use in magnetic resonance spectrometers.

E.E.A. Space Committee.—The Electronics Engineering Association's co-operation in looking into the communication/electronics aspects of the proposed U.K. satellite has been requested by the Minister of Aviation. The Association has, therefore, formed a space committee to "enable the industry to co-ordinate its efforts and speak to the Government with a single voice on space communications." The members are:—W. D. H. Gregson (Ferranti) who is chairman, W. S. Graff-Baker (A.E.I.), Gp. Capt. E. Fennessy (Decca), W. R. Thomas (Elliott), Air Vice-Marshal W. E. Oulton (E.M.I.), R. A. G. Dunkley (G.E.C.), A. W. Cole (Marconi's), S. J. Robinson (Mullard), J. M. C. Dukes (Plessey), T. C. B. Talbot (Rank-Bush Murphy) and P. H. Bourne (S.T.C.).

Technology, life and leisure is the subject of the Thomson lecture, to be given by Dr. Dennis Gabor, F.R.S. (professor of applied electron physics at Imperial College), on 24th October at the Royal Institution. Admission is by ticket obtainable from the Society of Instrument Technology, 20 Peel Street, London, W.8.

Trawler Radio Jubilee.—The fiftieth anniversary of the first fitting of wireless in fishing vessels was celebrated by Marconi Marine in June. Vessels equipped for this "interesting experiment . . . with a view to determining the extent to which wireless telegraphy could effectively and economically be applied to steam fishing vessels" were the trawler *Othello* and the carrier *Cæsar* owned by Hellyers of Hull. Following the lead set by these vessels we stated in our January 1914 issue "it is not improbable that wireless will be generally adopted by the fishing industry"!

Results of the **Radio Amateurs' Examination** held in May have just been announced by the City and Guilds of London Institute. A total of 1,229 sat for the exam. and 861 passed. Eleven blind students, who were examined separately, are included in the total and of these nine were successful.

A symposium on a **multi-standards studio centre** is being organized jointly by the Television Society and ABC Television Ltd. for 30th October. It will be held at the I.E.E. headquarters, Savoy Place, London, W.C.2. Further details are obtainable from the Television Society, 166 Shaftesbury Avenue, London, W.C.2.

A.P.A.E. Symposium.—The Association of Public Address Engineers is holding a symposium at the Queens Hotel, Manchester, on 22nd September. Admission will be by ticket obtainable free from the A.P.A.E. at 394 Northolt Road, South Harrow, Middlesex.

The **Iraqi Ministry of Guidance** has now been given the go-ahead by the government to put out tenders for five, 15 to 25 kW, television stations and five sound relay stations, for use in the provinces. The scheme designed to provide 80% of Iraq with a television service, includes stations at Musol, Kirkuk, Alemara, Elsamawa and Basra.

The **Ministry of Education** has approved increases in the salary scale of the more senior teachers in Colleges of Advanced Technology. The increases take effect from 1st April, 1963, and add £150 to a senior lecturer's salary bringing it up to £2,150 (max.). At the other end of the scale, a Grade VII departmental head receives an additional £325 bringing his maximum salary up to £3,400.

TECHNICAL EDUCATION

A lecture course on **u.h.f. television techniques** is to be given by the Television Society this autumn. This course is of particular interest to those on the servicing side and will be held for five successive Friday evenings at the London School of Hygiene and Tropical Medicine, Keppell Street, London, W.C.1, starting 4th October. The fee for non-members is £1 15s and enrolment forms are available from the Television Society, 166 Shaftesbury Avenue, London, W.C.2.

Two courses leading to the graduateship of the Brit.I.R.E. are listed in the 1963/64 prospectus of the **Northern Polytechnic,** London, N.7. One is a three-year, full-time course in electronics and telecommunications and the other a six-year, part-time day release course. Special short advanced evening courses being provided in the Department of Electronics and Telecommunications during the coming year include pulse circuit analysis, colour television, network theory and microwave techniques. The four-year Dip. Tech. sandwich course in the physics and technology of electronics carries exemption from examination requirements for Grad.Inst.P. and Grad.I.E.E.

In addition to the normal courses in preparation for the C. & G. exams in radio and telecommunications, the **Norwood Technical College,** London, S.E.27, conducts a four-term full-time course for the P.M.G.'s marine radio certificate and a three-year course in telecommunication engineering which covers the syllabi of the Brit.I.R.E. graduateship examination. Short courses listed in the 1963/64 prospectus include v.h.f./u.h.f. techniques, transistors, colour television and medical electronics.

Telecommunication Technicians' Course.—The complete four-year syllabi, plus supplementary studies, in preparation for taking the examination for the City & Guilds Telecommunication Technicians' Certificate, has been prepared as a home study course by C.R.E.I. (London). A brochure covering the course is available from C.R.E.I. (London), 132/135 Sloane Street, London, S.W.1.

National Certificate, block release, two-year course for mechanical, electrical and civil engineers is being conducted by the Twickenham (Middlesex) College of Technology in the coming session. The course is common to the three branches except for the choice of two alternative subjects in the second year. Students are alternately at college and in industry for six-week periods. Fee £12 17s.

Part-time day and evening courses in preparation for the various radio and electronics examinations of the City and Guilds of London Institute are being offered by the **Weston-Super-Mare Technical College** during the coming scholastic year.

CLUB NEWS

Halifax.—During August the Northern Heights Amateur Radio Society has undertaken to provide demonstration stations at three local functions; at a charity gala at Warley (3rd), Halifax Agricultural Show (10th) and at Forest Cottage, Illingworth (17th).

We have been notified of the following **Mobile Rallies:—**

R.A.F. Stradishall, near Newmarket, July 28th (details from Flt. Lt. G. C. Moore (G3MCY), R.A.F., Stradishall, Newmarket, Suffolk).

Derby, Rykneld School, August 18th (F. C. Ward (G2CVV), 5 Uplands Ave., Littleover, Derby).

M.A.R.S. (American Military Affiliate Radio System) is organizing a "Hamfest" in Heidelberg for August 3rd and 4th to which British amateurs visiting the area are invited. Details from Russ Lawson (DL4BS), Postfach 3049, 6100 Darmstadt.

Personalities

G. L. Hutchinson, Ph.D., recently appointed head of the Electronics Group of the Physics and Electronics Department at the Royal Radar Establishment, is a graduate of King's College, London, where he also obtained his doctorate. In 1939 Dr. Hutchinson joined the Air Ministry Research Establishment at Dundee, and was later seconded to the R.A.F. to assist with the installation of the coastal radar chain. In 1943 he joined the staff at the Telecommunications Research Establishment, Malvern, and from 1948 until 1954 he was at the Royal Aircraft Establishment, Farnborough. Dr. Hutchinson was posted to the British Joint Staff Mission in Washington in 1954 and returned to the R.R.E. in 1957.

G. B. Townsend, B.Sc., A.K.C., F.Inst.P., M.I.E.E., has joined the Rank Organisation as technical manager of the Professional Television Equipment Division of Rank Cintel. Mr. Townsend was formerly with the G.E.C., having joined their Research Laboratories at Wembley in 1940 where he worked on radar and secret weapons and was subsequently responsible for the research work on television problems. In 1961 he transferred to G.E.C. (Electronics) Ltd., as manager of the new Television Equipment Department. He is joint author, with P. S. Carnt, of the book "Colour Television." Mr. Townsend is president of the British Amateur Television Club and chairman of the Council of the Television Society.

Lord Hill of Luton has been appointed the new chairman of the Independent Television Authority in succession to Sir Ivone Kirkpatrick. Lord Hill, as Dr. Charles Hill, was Postmaster General from 1955 to 1957.

The guest of honour at this year's Radio and Electronic Industry dinner, which is to be held at the Dorchester, London, on 12th November, is to be the Rt. Hon. **Julian Amery,** M.P., Minister of Aviation. **Lord Brabazon** of Tara, who has been president of the Radio Industry Council since 1957 and has agreed to serve for a further year, will preside at the dinner.

B. V. Northall, A.M.Brit.I.R.E., has received from the City and Guilds of London Institute the Insignia Award in Technology (C.G.I.A.). His thesis was entitled "Factors affecting the design of an audio-frequency magnetic recording system." The Insignia Award in Technology was instituted in 1952 since when 245 awards have been made of which 54 have been to those in the electrical and telecommunications fields. Mr. Northall, who is 44, is senior executive engineer at the Post Office Research Station. He joined the Post Office Engineering Department as a youth-in-training in 1937 and during the war served in the Royal Signals.

Leon A. Smulian, B.Sc., A.M.Brit.I.R.E., has joined the Elliott-Automation Group as joint general manager of Elliott-Litton Ltd. After the war, during which he served as a signals officer (radar) in the R.A.F., he joined Ultra Electric as senior engineer in charge of the special products division, and when he left the company in 1955 he was chief engineer radio and television and assistant chief engineer of the company. In 1955 he started his own company, Gate Electronics, and since 1961 has been with the British Aircraft Corporation on a special assignment as industrial products officer.

R. S. Chadwick, a draughtsman apprentice with the Marconi Company in Chelmsford, has been selected by the City and Guilds of London Institute as one of 31 apprentices to represent the United Kingdom in the twelfth International Apprentice Competition, which this year is being held in Dublin. Mr. Cadwick, who is 21, joined Marconi's in 1958 and is at present studying for his Ordinary National Certificate.

John A. Saxton, D.Sc., Ph.D., M.I.E.E., who has been deputy director of the D.S.I.R. Radio Research Station, Slough, since 1960, has been appointed director of the United Kingdom Scientific Mission in Washington, D.C., and Scientific Attaché at the British Embassy in Washington. He succeeds **Dr. Harry Hookway** and will take up his new appointments early next year. Dr. Saxton, who is 49, joined the Department of Scientific & Industrial Research in 1938. He has been active in the affairs of the International Scientific Radio Union (U.R.S.I.) and the International Radio Consultative Committee (C.C.I.R.) for a number of years and has on three previous occasions worked in the U.S.A. In 1945, and again in 1950, Dr. Saxton undertook a tour of duty as radio physics liaison officer in the United Kingdom Scientific Mission, and at the invitation of the University of Texas, he recently spent a year there as a visiting professor of electrical engineering.

Dr. J. A. Saxton

J. A. Clark

John A. Clark, managing director of The Plessey Company, has taken over the chairmanship of Ericsson Telephones in succession to **J. H. Reed** who has recently retired from this position. Mr. Reed, who joined Ericsson's nearly sixty years ago and was appointed managing director in 1947, will continue as a director of the company.

J. F. Watkinson, Ph.D., B.Sc., has been appointed manager of the Magnetic and Materials Division of Standard Telephones and Cables Ltd. Dr. Watkinson, who is 34, graduated in metallurgy at Sheffield University in 1950 and for four years he carried out research on the torsional fatigue strength of steels at Sheffield. For this work he received his doctorate in 1954 and was awarded the Brunton Medal for Metallurgical Research. Prior to this appointment, Dr. Watkinson was general manager of B.S.A. Metal Powders Ltd.

R. de B. McCullough, Assoc.Brit.I.R.E., is to fill the newly created B.B.C. post of Superintendent, Television Technical Operations, in which he will have overall responsibility throughout the Corporation for the work of the television technical operations staff. Mr. McCullough joined the B.B.C. in 1939 as a maintenance engineer at the London television station at Alexandra Palace. In 1953 he became a senior television engineer at the Lime Grove studios and since 1957 has been head of technical operations (television studios).

E. G. Chadder, O.B.E., senior superintendent engineer of the B.B.C., retired in June after completing 40 years' service. Mr. Chadder joined the B.B.C. as an assistant maintenance engineer, at Cardiff, and was promoted to engineer-in-charge of the Aberdeen station two years later. After holding several superintendent engineering posts he was appointed senior superintendent engineer in 1950. This title lapses with the retirement of Mr. Chadder. Following this move the post of superintendent engineer (transmitters), held by **W. E. C. Varley,** M.Brit.I.R.E., Assoc.I.E.E., has been changed to chief engineer (transmitters), and the post of superintendent engineer (lines), held by **G. Stannard,** B.Sc., M.I.E.E., A.C.G.I., re-designated superintendent engineer (communications).

Air Cdre. J. C. Millar, D.S.O., Commandant of the Central Signals Establishment at R.A.F. Watton, Norfolk, for the past two years, has been appointed Provost Marshal of the Royal Air Force. Air Cdre. Millar joined the R.A.F. in 1934 and has held a number of appointments in the signals field throughout his career including two-and-a-half years as Command Signals Officer of Bomber Command in the mid-fifties.

Gp. Capt. John Goodman, M.Brit.I.R.E., who has for the past year commanded the Radio Engineering Unit at Henlow, has been appointed Commandant of the R.A.F. Central Signals Establishment with the acting rank of air commodore. He joined the R.A.F. in 1932 as an apprentice at the Electrical and Wireless School, Cranwell, and was commissioned in the Technical Branch in 1940. **Gp. Capt. T. C. Imrie,** Assoc. Brit. I.R.E., who succeeds Air Cdr. Goodman at the Henlow Radio Engineering Unit, joined the R.A.F. in 1939 as a wireless operator/air gunner and was commissioned two years later. After taking a technical signals conversion course, he transferred to the signals branch of the R.A.F. in 1948. Prior to his new appointment, Gp. Capt. Imrie was officer commanding 30 Group, (Maintenance) R.A.F. Sealand.

P. E. Axon, O.B.E., Ph.D., M.Sc., D.I.C., A.R.C.S., managing director of Ampex Electronics Ltd. and Ampex Great Britain Ltd., has been assigned several additional responsibilities and now directs all the Ampex manufacturing, engineering and marketing activities in Europe, Africa and the Middle East. Dr. Axon, who joined Ampex in 1958, was previously head of the recording group in the Engineering Research Department of the B.B.C.

The Governors of the Borough Polytechnic have made the following appointments to the academic staff:—**D. D. Randall,** B.Sc., Ph.D., A.Inst.P., senior lecturer in physics; **B. Graham,** M.Sc., A.Inst.P., senior lecturer in electrical engineering; **J. G. Hargrave,** B.Sc., D.C.Ae., lecturer in electrical engineering; **L. F. Spence,** B.Sc., B.Sc.(Econ), A.M.I.E.E., promoted to principal lecturer in electrical engineering; and **G. R. Arney,** B.Sc., promoted to senior lecturer in electrical engineering.

G. C. Pope, M.Eng., A.M.I.E.E., has been appointed general manager of Advance Components, of Hainault, Essex. Educated at Liverpool University, where he specialized in electronics, Mr. Pope was a sales manager in the Radio and Electronic Components Division of Associated Electrical Industries, prior to joining Advance.

Major J. H. T. Fairhurst appointed chief engineer for W. H. Sanders (Electronics) Ltd., was for 5 years in the Radar Development Laboratory of Decca Radar Ltd. which he joined after nearly 20 years military service.

The name of **Chung Lian Fatt,** Assoc.I.E.E., deputy chief broadcasting engineer of Radio Sarawak, should be added to those listed in our last issue who were appointed M.B.E. in the Queen's Birthday Honours. Mr. Chung joined the Government service in 1939.

Dr. B. Y. Mills, F.R.S., is no longer in the Division of Radiophysics of the C.S.I.R.O., Australia, as stated in the Royal Society's announcement mentioned in our May issue (p. 220), but is a reader on the staff of the School of Physics of the University of Sydney which he joined in 1960.

OUR AUTHORS

Dr. A. C. Robb, who writes in this issue on the problems associated with u.h.f. television reception, has been technical manager of Belling & Lee Ltd. for the past two years. A graduate of Liverpool University, where he obtained his M.Eng. degree for post-graduate work, he received his Ph.D. as a result of work on the design of high-voltage particle accelerators when a research fellow at Glasgow University.

Mrs. Elsie Carter, who with **P. Tharma** contributes the fourth of the series of articles on the design of transistor amplifiers in this issue, spent several years as a laboratory assistant in the Mullard Valve Quality Control Laboratory at Mitcham. Since 1959 she has been in the Applications Research Laboratory working on problems associated with transistor audio amplifiers.

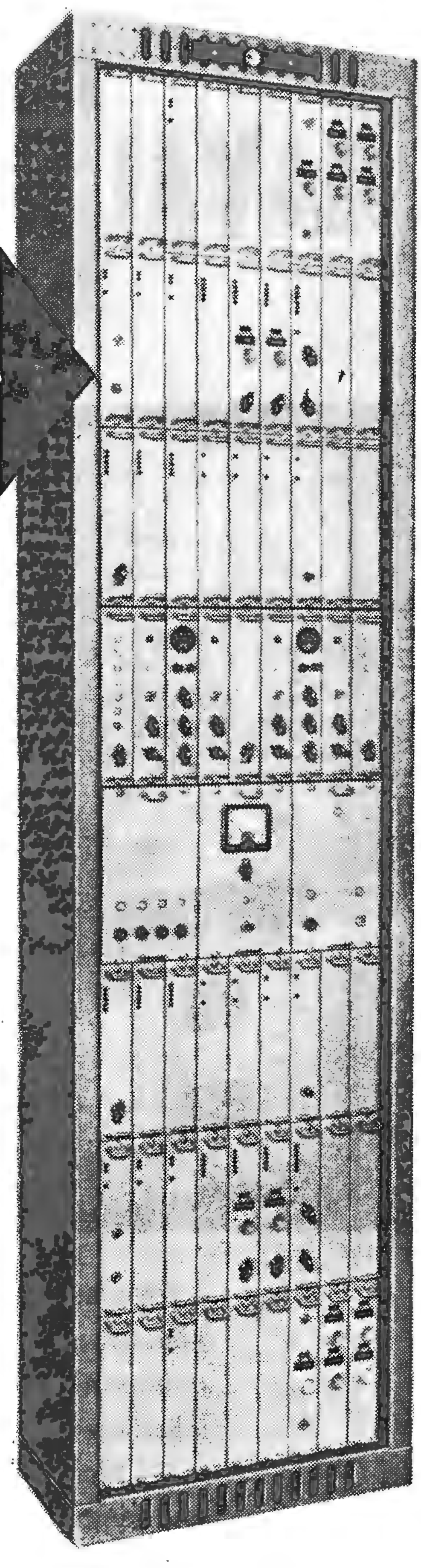
OBITUARY

Dr. Ernest Metzler, head of the radio section of the Swiss P.T.T. and, since 1956, director of the International Radio Consultative Committee (C.C.I.R.), died on 20th June at the age of 63. Dr. Metzler, who received his doctorate from the Federal Polytechnic School in Zurich for a thesis on aerial radiation, joined the Swiss P.T.T. in 1929 and became head of the radio section in 1953. An international figure in the world of telecommunications, he undertook special technical assignments for the United Nations in several middle east countries.

Ernest G. Rowe, O.B.E., M.Sc., A.C.G.I., D.I.C., M.I.E.E., died on 6th July at the age of 54. Following engineering training at Devonport dockyard and the City & Guilds Engineering College, London, he joined the M-O Valve Company in 1933 as a development engineer and was appointed chief development engineer in 1939. In 1948 Ernest Rowe joined the Brimar Valve Division of S.T.C. at Footscray as chief receiving valve engineer where he initiated the programme of development of "special quality" valves on which he contributed articles to *W.W.* His appointment in 1958 as manager of the Valve Division gave him responsibility for engineering, manufacturing and sales of all S.T.C. valves until July 1960 when he transferred with the Brimar valve and c.r. tube division to Thorn Electrical Industries. Since this merger Mr. Rowe had been senior executive of the new company Thorn-A.E.I. Radio Valves & Tubes Limited.

Horace B. Dent, who was on the editorial staff of *Wireless World* from 1927 until his retirement two years ago, died on 17th June aged 67. He came to *Wireless World* from Igranic Electric which he joined after spending a few years in Yugoslavia following service in World War I during which he transferred from the Army to the Royal Flying Corps for special radio duties. During the last war Wing Commander Dent served in the R.A.F.V.R. first at Fighter Command Headquarters, where he was closely associated with the operation of the radar chain and fighter control, then in the Ministry of Aircraft Production and from 1943, until his return to *W.W.* in 1945, in the Air Ministry Directorate of Signals. "H.B.D's" wide knowledge and experience enabled him to contribute to all sides of this journal's work but his particular interest was in the amateur field and his call sign G2MC is well known.

George Earnshaw Partington, B.Sc., A.M.I.E.E., chief engineer of Marconi's Broadcasting Division, died in St. Andrews Hospital, Billericay, on 13th June at the age of 47. George Partington, a graduate of Manchester University, joined the Marconi Company in 1938 and after a year at Marconi College, entered the Research Division. He started work on the development of television equipment in 1947, was appointed deputy chief television engineer in 1956 and became chief engineer in 1959.



A.C. Meter Calibration

A PHOTOMETRIC METHOD FOR LOW-VOLTAGE INSTRUMENTS

By JOHN F. SUTTON, M.Sc.(Eng.)

THIS article deals with the problem of obtaining specified values of a.c. by direct reference to a d.c. indicating instrument of known calibration. It describes a precise method of setting up an a.c. potential divider, making use of the relation between the brightness of, and the current through, a filament lamp. Since brightness is independent of the direction of current through the filament, and depends upon the r.m.s. value of an alternating current, a relation can be established between direct and alternating currents of the same r.m.s. value. The method is especially suitable for radio workshop or servicing use.

Nearly all alternating-voltage meters for radio workshop use are now of the moving-coil-with-rectifier type. While these have the advantage of great sensitivity, reliability, and low current consumption, a difficulty arises in checking their calibration unless they can be compared with a standard instrument on a.c. Moreover, since moving-coil instruments with a permanent magnet indicate the mean and not the r.m.s. value of a fluctuating current, attention must be paid to waveform of the supply. That is to say, if they are to be fitted with a rectifier and calibrated directly against a standard a.c. instrument, the supply voltage should be of simple sine-wave form. The house mains will be good enough in this respect for providing the a.c. supply, but it is worth noting that if a moving-coil instrument without a rectifier is calibrated on d.c., a battery supply should be used and not rectified a.c., unless this is effectively smoothed. The scale divisions of a moving-coil-plus-rectifier alternating-voltage meter will not be uniform over the whole scale and will depend upon the rectifier characteristics; they may therefore need revision with a renewal of rectifier.

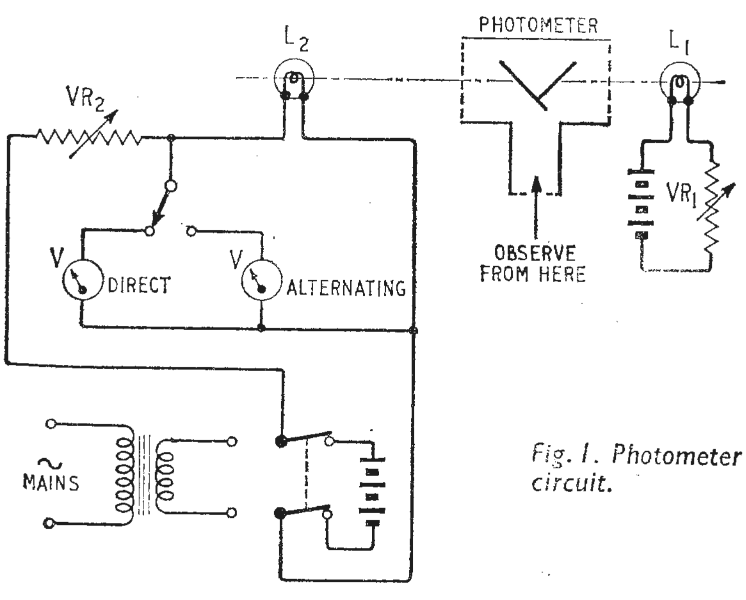


Fig. 1. Photometer circuit.

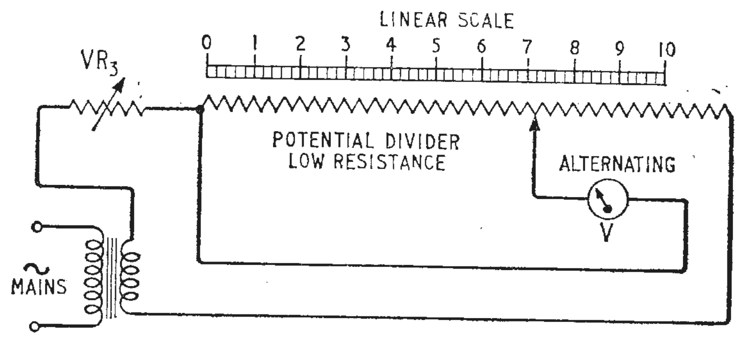


Fig. 2. Calibration of scale divisions.

For radio servicing a voltmeter is used frequently in the 0-10V range, and on this range the characteristics of the rectifier have a large influence on scale divisions; therefore a method of calibrating over the whole of this range is necessary. In a well-equipped laboratory a standard instrument would be available for direct comparison, but it is unlikely that the service workshop would have this facility.

However, if precise readings can be made at a few voltages or even at one selected voltage the remaining values can be obtained from a potential divider of suitable current-carrying capacity. It is assumed that a reliable direct-voltage meter is available, since one must start somewhere, and moving-coil voltmeters or milliammeters are readily obtainable and can be expected to be within the limits of accuracy required for workshop use. They can be converted to the required voltage range with high-stability carbon resistors.

If a good quality moving-iron, thermo-junction, or hot-wire voltmeter of unknown accuracy can be obtained, this can be calibrated direct from d.c. and used on a.c., giving r.m.s. indications. Such instruments are not readily available and in any case certain precautions must be taken with each type. A moving-iron instrument will of necessity have an inductive coil in its circuit, and will therefore be sensitive to frequency; and the older types of hot-wire instruments may have inductive ballast resistors. Moreover, both types need a fair current for operation and this affects their use with a potential divider.

The method outlined below is described because it requires no other indicating instrument than an accurate m.-c. voltmeter and is capable of precise results. The principle is simply that of using metal filament lamps as hot-wire meters to indicate a single reading of current. A lamp does not suffer from the disadvantages of the conventional hot-wire meter, which are (a) that it needs frequent zero setting, and (b) that it is sensitive to air currents and external temperature changes. The hot-wire meter can be made independent of frequency up to the megacycle range and it has no hysteresis error. A special advantage of the filament lamp method is that brightness, when operating at full voltage, is very sensitive to voltage changes; a 1% change of volts across the terminals corresponds to about 15% change in brightness. The accuracy obtainable is in effect dependent only on the degree of refinement with which the apparatus is set up and measurements made. Fig. 1 shows the circuit and layout. The method is to use a lamp L_1 in, say, the 3-6V range, operated from a battery and variable resistor, as an unknown but constant comparison standard. A second and similar lamp L_2 is operated alternatively from a d.c. or a.c. source, in conjunction with a d.c. instrument of known accuracy and the a.c. instrument to be calibrated. The former is adjusted to a given value by VR_2, and then L_1 and L_2 are balanced on a simple photometer by adjusting VR_1.

The supply is then switched to a.c. and L_2 is adjusted by VR_2 to balance the photometer. The alternating volts across the meter will have the same r.m.s. value as the original d.c. meter reading. The construction of the photometer is simple. The illuminated surfaces are made from thin white card with a smooth *matt* surface, fitted into a dark cardboard tube about 2 inches in diameter to exclude unwanted light. The front or dividing edge between the two illuminated areas of white card must be sharp and thin so that it becomes invisible when optical balance is obtained. The two lamps can be 3.5V torch bulbs in batten holders, both being fixed on a board with the photometer, roughly equidistant from it and well shielded from direct light. When operating it is as well to work in semi-darkness and take voltmeter readings with the aid of a torch. The eyes should, of course, be well shielded from direct light.

After calibration at one or more spot readings a potential divider can be set up, Fig. 2, to check the meter over its whole range. This can be made from the 1kW wire-wound bar element of an electric fire, which will have a resistance when cold of about 50Ω and can be arranged to give, say, 1 volt per inch of length. As the element wire has an appreciable temperature coefficient of resistance, and will warm up slightly with 10 volts across it, the circuit should be given time to settle before taking readings.

Various minor precautions are necessary to obtain stability and these will become obvious when the sequence of readings is repeated a few times. An occasional requirement in the radio workshop is to calibrate a high frequency probe unit which is generally made in the form of a rectifier and resistance capacitance network, in a small shielded tube connected by external leads to the d.c. indicator. This can be checked on the mains-frequency potential divider by removing the small capacitor in series with the probe, and substituting externally a low voltage capacitor of 1μF or greater.

THE MAGNETIZATION CURVE

By E. V. SMITH,* M.Sc.

AN EQUIVALENT DERIVED OPTICALLY FROM FERRIMAGNETIC DOMAIN PATTERNS

THE interpretation of magnetism in materials has of recent years been made in the light of domain theory (see, for example, the article by Dr. D. H. Martin, *Wireless World*, January 1958). The importance of new materials and the explanation of their function in the light of this modern theory is obvious and was fully stressed in the above article.

Since this publication the existence of transparent ferrimagnetic garnet materials has been discovered[1] and the interest aroused in these important materials has been enhanced by the fact that domain photographs are readily observed, without the necessity for the difficult and tedious process of electrolytic polishing. The garnets are of the very highest fundamental importance as has clearly been shown by the recent developments of ferrimagnetic resonance experiments and combined microwave-optical experiments which have been carried out with them.[2]

The aim of this note, however, is to emphasize their importance in domain theory interpretation, and to show that the growth and decay of domains, when measured by transmitted light, do in fact trace out a curve of similar shape to that of the magnetic hysteresis curve.

The garnets have the chemical formula $M_3Fe_2(FeO_4)_3$ where M represents any one of the rare earth atoms, samarium, yttrium, erbium, or gadolinium. The specimens photographed here are gadolinium iron garnet, chosen because comparatively low fields are required to produce saturation.

The photographs show clearly that in low magnetic field conditions a number of preferred directions of magnetization exist (a) but as the field increases one group of domains (the dark ones) grows at the expense of neighbouring domain areas (the light ones). In this case the first group are favourably directed with respect to the field in comparison with the second group. The field is applied axially, i.e., perpendicular to the surface of the specimen which is mounted on an ordinary microscope slide and is of about ⅛in diameter and 1/1000in thick. Notice that at first the pattern changes rapidly for comparatively small field change, (a) to (b). (150mA through the field coil gave a field of about 40 oersteds.) This rapid pattern change corresponds to a steeply sloping region of the magnetization curve and it is seen that the "black" domain regions have grown considerably. Beyond point (d) the pattern changes less rapidly, and at (e) and (f) obviously saturation is near. Reduction of the field (g) restores the pattern, the black areas now decreasing (g) to (j) and this process continues as the field is reversed (k) to (m) until saturation is again

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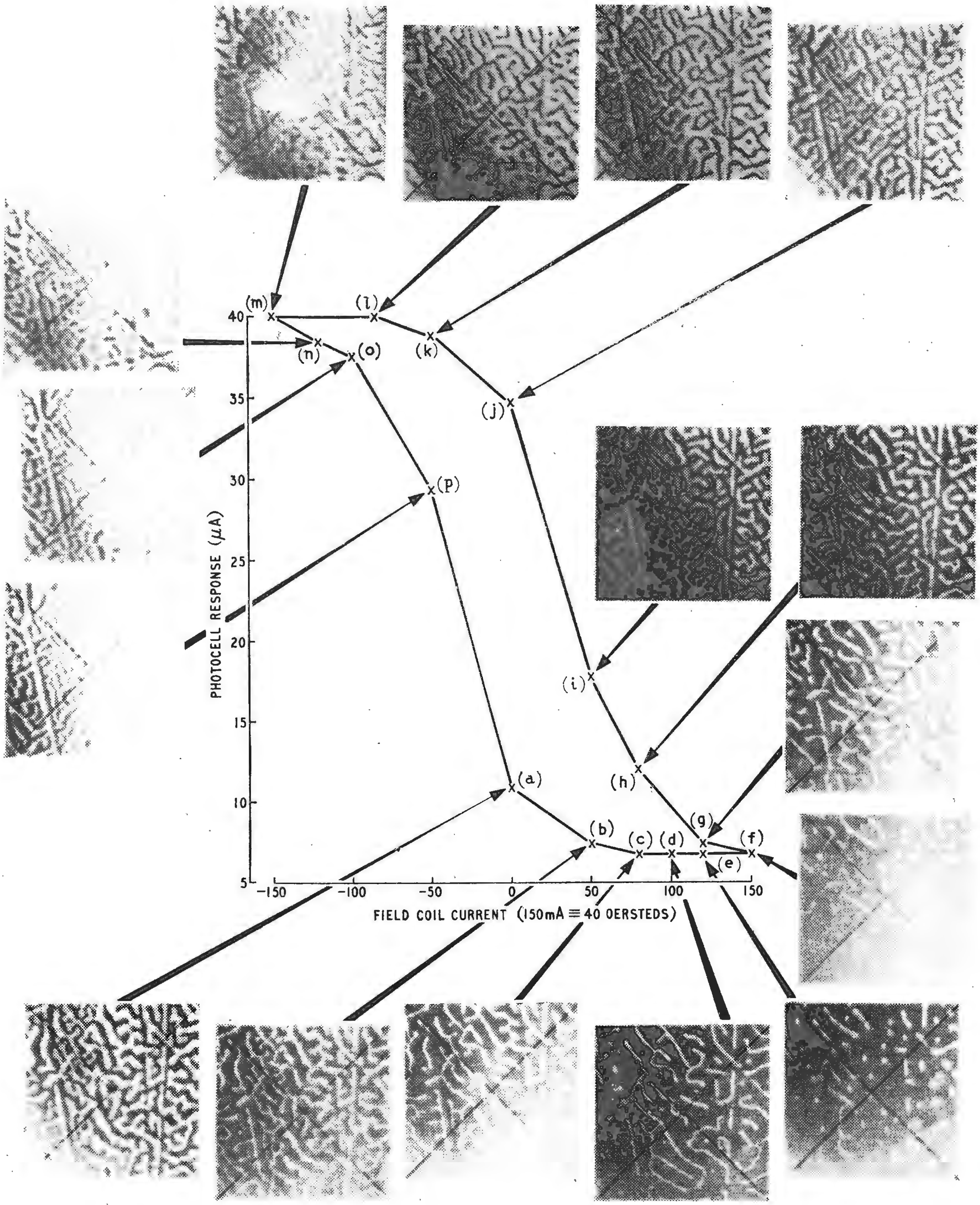
*Rugby College of Engineering Technology.

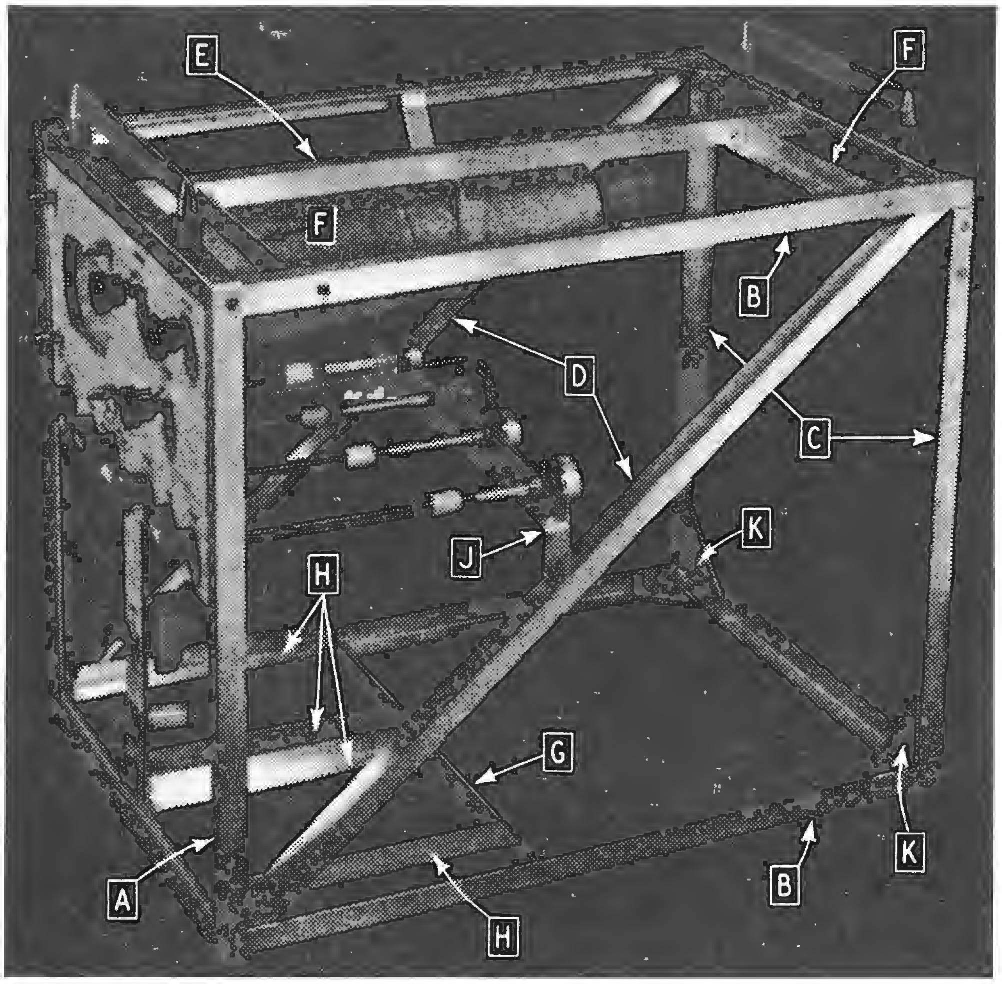
1. Dillon, J. F. *Bull. Am. Phys. Soc.* Series 2, Vol 2, p. 238, 1957.
2. Dillon, J. F. *J. Applied Physics*, Vol. 29, No. 3, pp. 539-541. March, 1958.



Hysteresis curve derived from the light transmitted by a translucent specimen of ferrimagnetic garnet with variation of field strength and direction.

approached in the opposite direction. The final three photographs, (n), (o), (p), show the dark areas once again growing at the expense of the "light" ones and the series of photographs give a striking demonstration and explanation of the well-known experimental phenomenon of hysteresis in terms of ferrimagnetic domain structure. The observation of the domains was made possible by the use of polarized light, the polarizer being placed between the mirror and the stage of the microscope and the analyser between the objective and the eye-piece.

All the photographs shown were taken by R. T. Hoffmann, a senior year student at the Rugby College of Engineering Technology.



Completed frame and tube mounting. Corner brackets are as originally made, but drawing should be followed. Nuts on tube-mounting screws are cycle valve caps. References are to frame drawing.

Wireless World OSCILLOSCOPE

6.—FINAL ASSEMBLY

THE constituent circuits of the oscilloscope are now completed, and it remains to construct a frame to carry them and install the inter-unit wiring. The material is the ½in aluminium angle used for the plug-in units. The drawings are self-explanatory, and only a few words of discussion are needed.

The front panel is made in the same way as those of the plug-in units. That is, sheet aluminium is faced with "Formica" or "Warerite," the bond being made by "Evostik," although a cheaper way would be to use "Contact" or "Fablon" plastic covering, or even a coat of paint. This liberal use of trade names does not imply that they are the only suitable materials; they are merely suggestions. If the front panel is given a slight bend during the facing process (aluminium on the concave side) this will help to avoid deformation, which is probably something to do with shrinkage of the adhesive and plastic face.

The graticule is made from a piece of celluloid, with horizontal lines scribed at 4mm intervals over 4cm, and short vertical lines at 6mm intervals over 6cm. Increased trace contrast is obtained by the use of green-tinted material, which cuts down reflections from the tube face and allows the green light of the tube to pass freely.

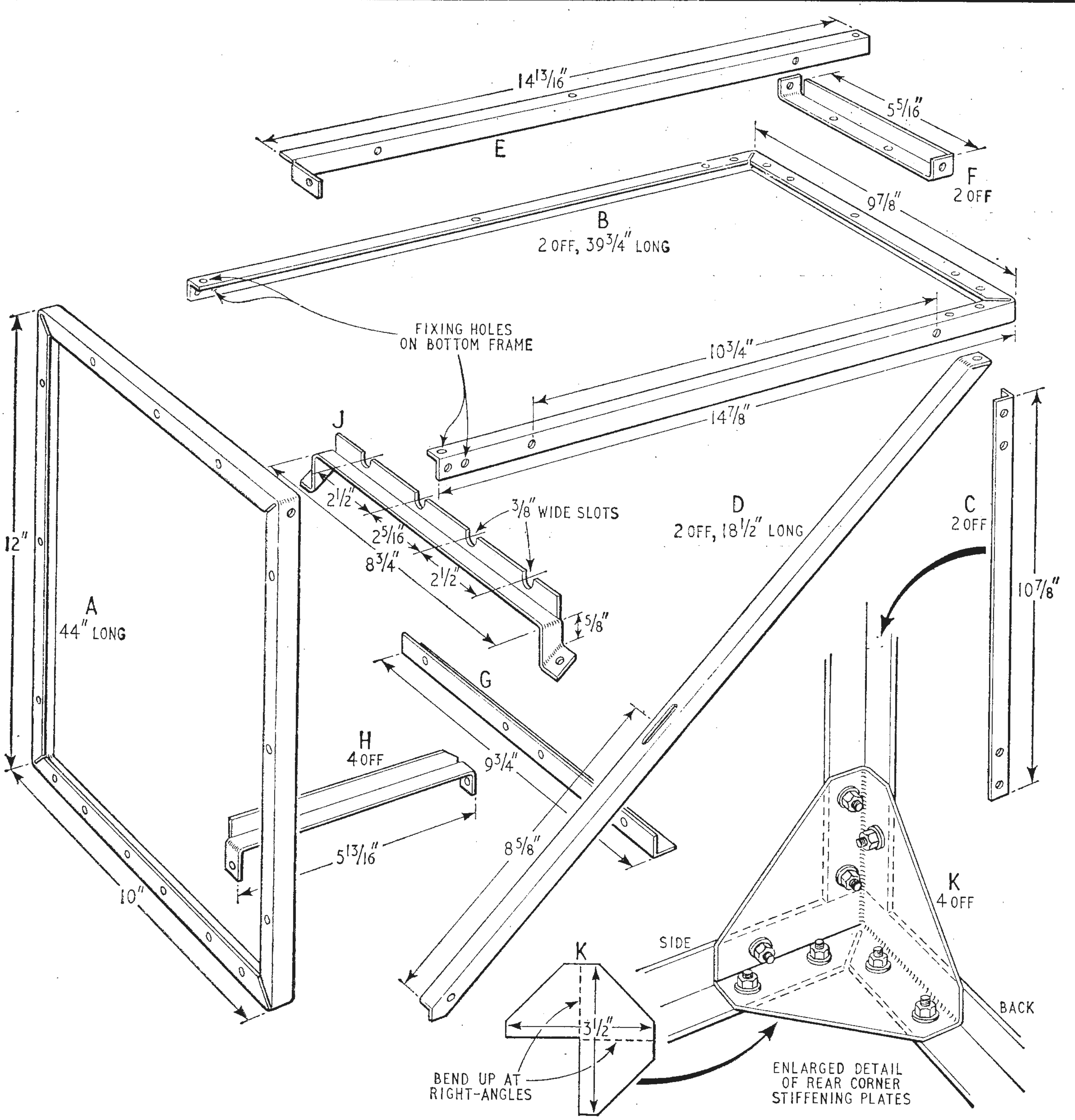
Tube Circuit

Fig. 1 shows the circuit of the tube supplies. The ± 900V supply is the "floating" output previously mentioned. Into the "bottom" end of this goes the blanking pulse from the timebase, emerging from the brightness control superimposed on a direct voltage of −850V, or thereabouts. This cuts the tube off during the timebase flyback but, due to stray capacitances, would not do this quickly enough but for the presence of C_2, which allows the high frequencies contained in the blanking pulse to pass straight to the tube grid.

It is recommended by the manufacturers that the final anode is held at or about the same potential as the average of the deflection plates. If this is not observed, the spot tends to become astigmatic, that is, it is defocused in either a vertical or horizontal direction and the trace is thickened. For best results, the final anode potential is made slightly variable about this point, and the adjustment potentiometer is made a front panel control, labelled "ASTIG." The function of the focus control is obvious, and the two controls should be adjusted together to obtain the finest trace.

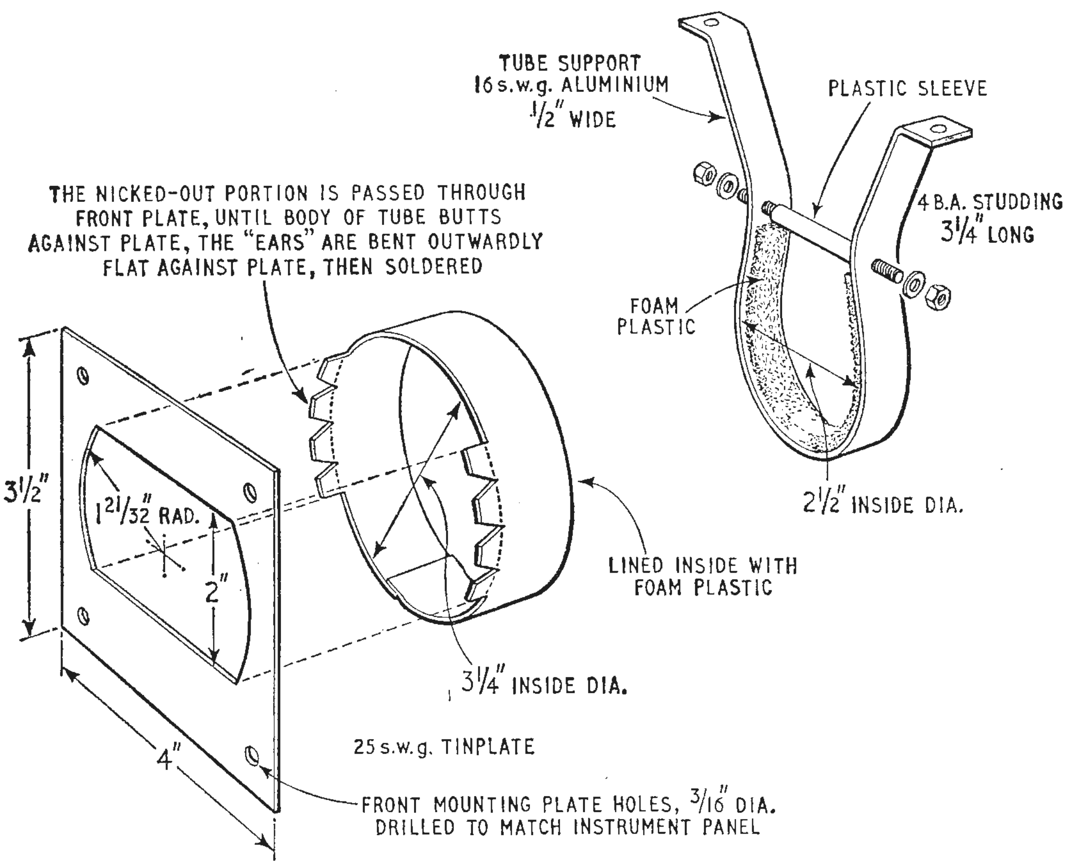
It is possible that some tubes may suffer from pincushion or barrel distortion. We have not experienced this trouble, but if it is found, the interplate shield, pin 5, may be disconnected from the final anode and fed by a similar variable potentiometer to the astigmatism control. The Mu-metal c.r.t. screen was found to be necessary, but if the constructor wishes, a sheet steel screen can be tried. We have no experience of this, but it seems to be worth a try.

R_1 and R_2 are made fixed resistors, but should be selected for best results, as the determining factors are somewhat variable. R_1 should be selected so that the neons in the e.h.t. unit never extinguish under maximum brightness conditions, so taking into account variations in e.h.t. transformers. Our

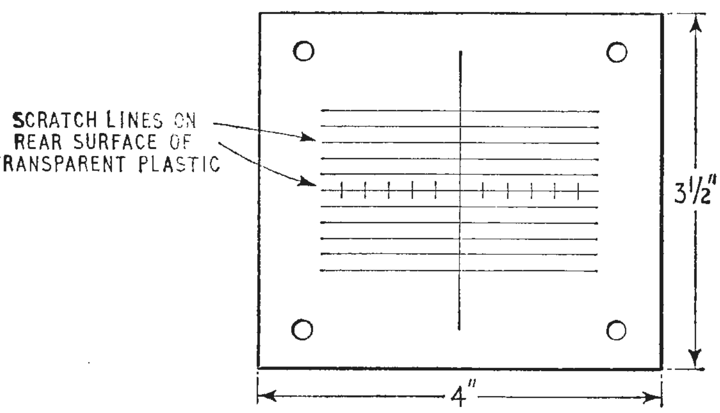


Chassis members made from ½ in aluminium angle.

Tube supporting components.



Graticule cut from transparent green plastic $\frac{1}{8}$in thick or as convenient. Scribed lines should face tube.



value was 680kΩ. R_2 is set so that the trace is evenly illuminated along its length, our value being 27kΩ.

Modifications

Since the instrument was first made, several alterations have been made which improve performance and enhance reliability.

Under certain conditions, it was found that external fields could interfere with the operation of the *y* amplifier, and an aluminium screen was made to shield it. If it is found that interference from the timebase or e.h.t. oscillator shows up on the c.r.t. the screen will get rid of it. It may be found that this is not necessary, and, in any case, all earth connections and screens should be checked for tightness before going to the trouble of making it.

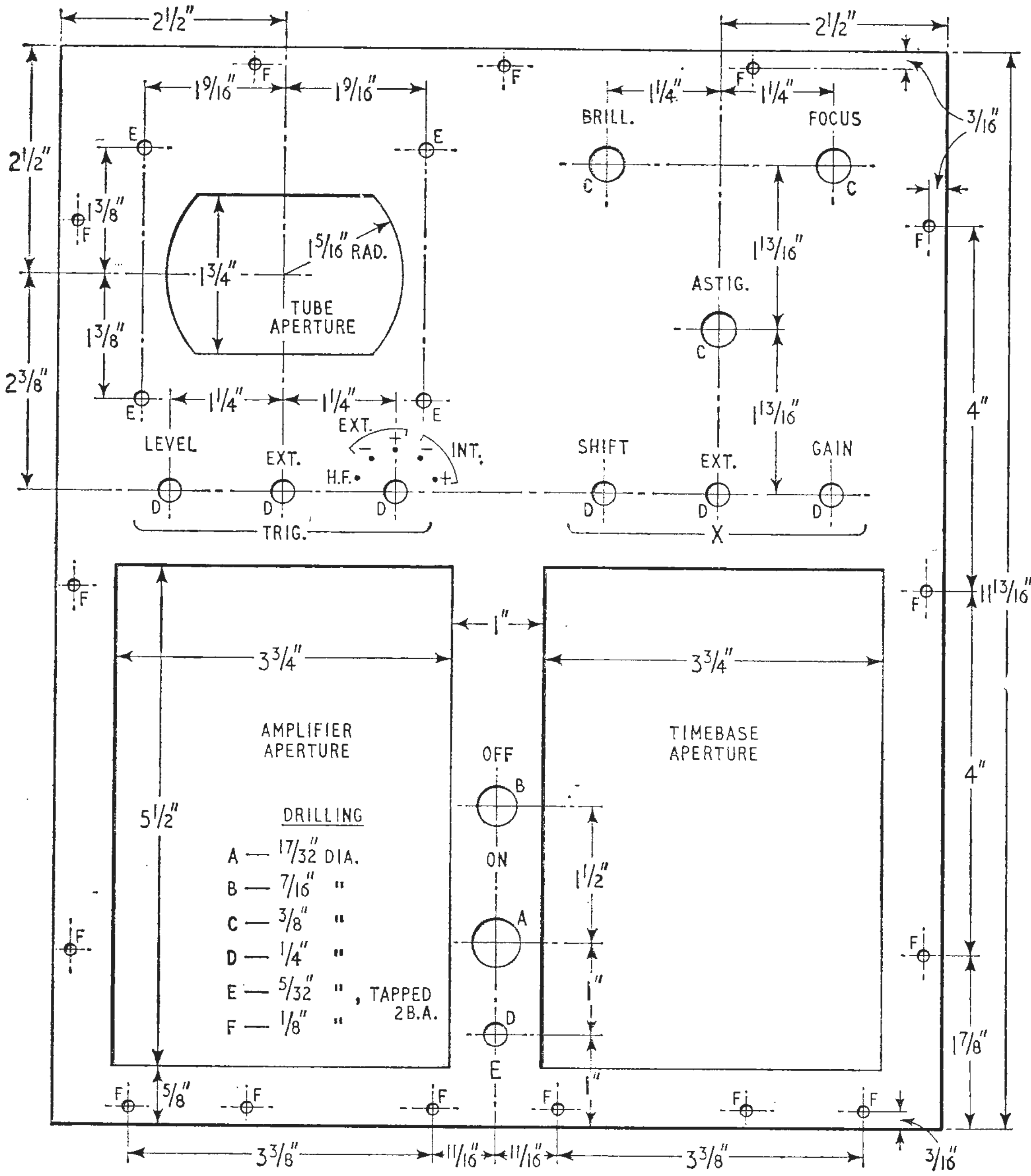
If the timebase is run at a much lower speed in relation to the signal frequency than is normal, it may be found that sync pulses, which appear on the Miller valve screen grid, due to inter-electrode capacitance, show up as a darkish horizontal band. This can be cured, if necessary, by the insertion of an OA81 between pin 8 of V_1 and pin 7 of V_2 From this latter point, the cathode-follower grid, a 470kΩ resistor should be taken to h.t. and a 150kΩ resistor to chassis. This has the effect of further clipping the top of the screen waveform, and with it, the superfluous sync pulses. The diode "cathode" is connected to V_1, pin 8.

In order to accommodate a wider tolerance in sensitivities of c.r.t.s and to cater for ageing valves, the anode loads of the *x* amplifier valves have been increased by 2.2kΩ to 12kΩ. This will always give at least 10% overscan between the overload points of the amplifier. This may not be needed by the majority of constructors, but it will avoid any cramping that may be visible at the end of the time-base.

After using the expanded trace facility of the instrument, we decided that the amount of expansion given erred a little on the generous side, and was not particularly useful. If the reader feels the same way about this, the amplitude can be cut down by adjustment of the cathode circuit. A 470Ω resistor should be placed in series with VR_1, the gain control of the *x* amplifier.

As the trigger stage was drawn in the June issue, it was responsible for an odd effect. Any sudden adjustment of the *y* shift control caused the brightness to vary slightly. This was due to the fact that the amplifier V_{3b} was drawing heavy current because of the long time-constant C_5 R_{15}, and loading the unstabilized h.t. supply. This upset the "floating" output of the e.h.t. oscillator on the tube grid. The easiest way out of this is to drop the supply to V_{3b} by the insertion of an 18kΩ resistor at the h.t. end of R_{17}, with an 8μF, 350V electrolytic to earth from the junction. Removal of the capacitor C_6 prevents distortion of the signal fed to the trigger stage V_4 at high signal levels, and the effect is further improved by increasing R_{16} to 680Ω.

There is very little space in the instrument for air circulation, and we have found that heat from the transformer is a problem. In order, therefore, to



Front panel consists of 18 s.w.g. aluminium faced with decorative plastic sheet.

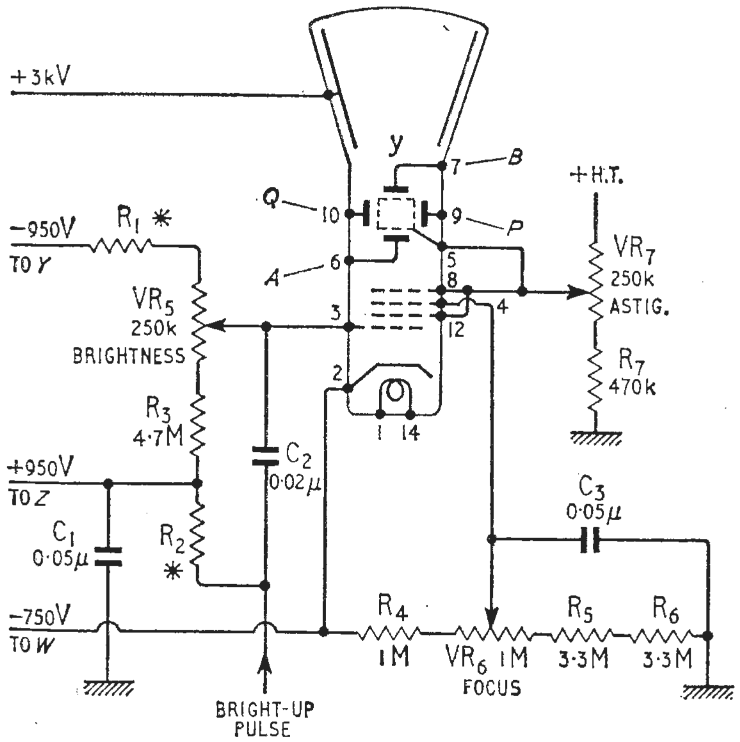
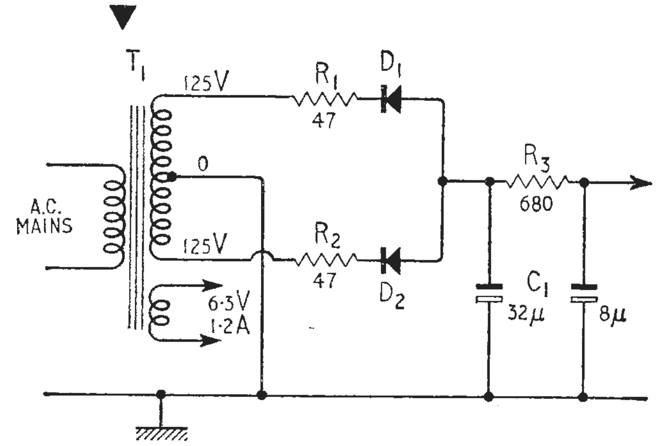
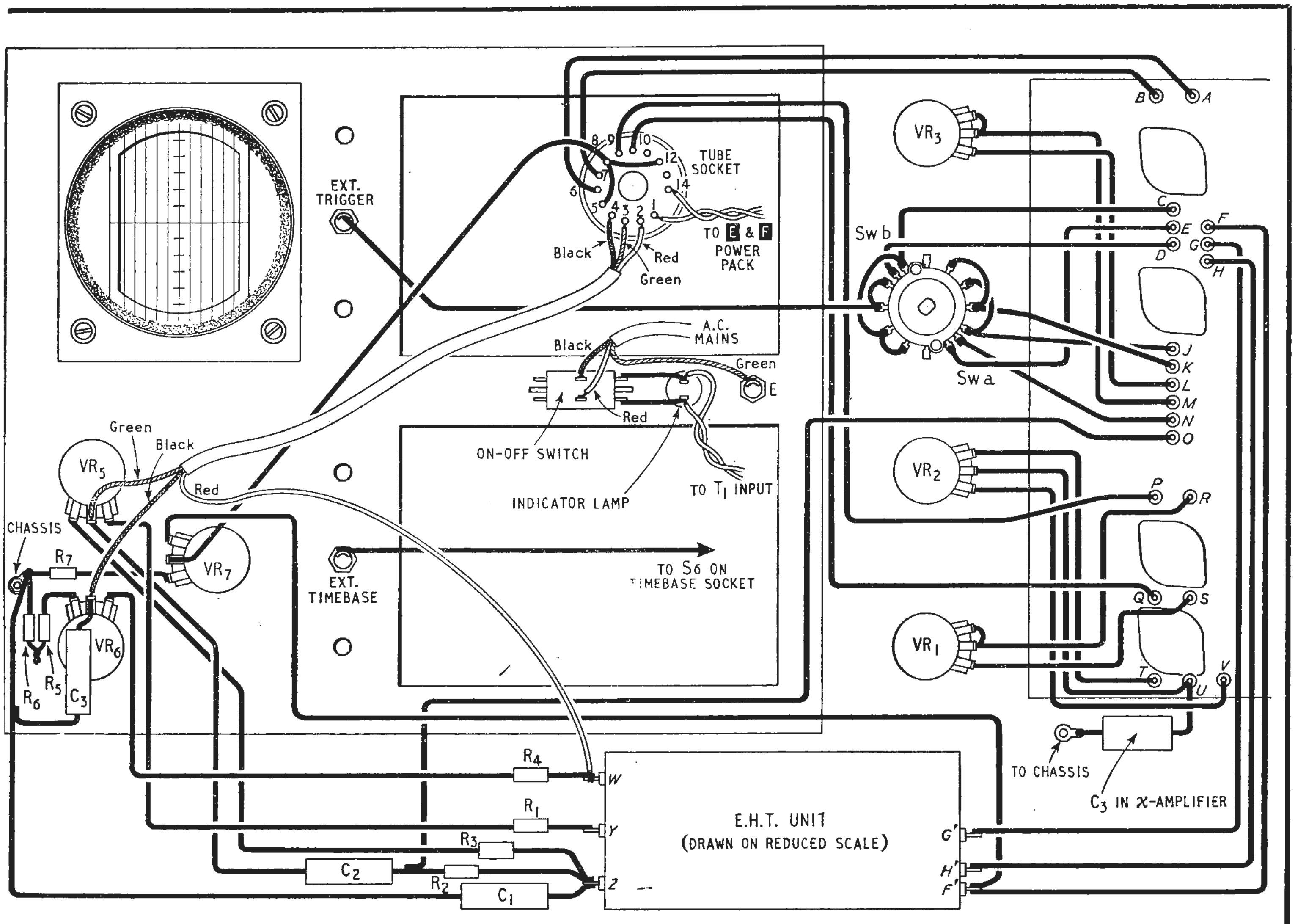


Fig. 1. Tube circuit.

Fig. 2. Modification to power unit.





Completion of wiring.

reduce heat generation, we have altered the circuit a little.

The main source of heat is the negative supply. This draws extra current from one half of the main transformer and also, as it provides many more volts than are required, heat is developed in the dropper resistors R_{32}, R_{33}. The best solution to the heat problem is the use of a separate transformer to supply the negative line, and we chose the Radiospares miniature mains type. This possesses a 125-0-125V secondary and the new circuit is as shown in Fig. 2. It also helps to reduce loading if the heater windings AB and EF are changed over. The transformer can be mounted on the side wall of the main chassis between C_1 and $C_{12, 13}$, which should be moved slightly rearwards.

Calibration of home-built instruments is always a difficult problem. This could be done, rather inaccurately, by the use of the 50c/s mains waveform, but we propose to describe a more accurate system later, and also some applications of the instrument.

COMPONENTS LIST

*R_1	680kΩ	± 10%	½W
*R_2	27kΩ	± 10%	½W
R_3	4.7MΩ	± 10%	½W
R_4	1MΩ	± 10%	½W
R_5	3.3MΩ	± 10%	½W
R_6	3.3MΩ	± 10%	½W
R_7	470kΩ	± 10%	½W
VR_5	250kΩ	±	linear
VR_6	1MΩ	±	linear
VR_7	250kΩ	±	linear
C_1	0.05μF		250V
C_2	0.02μF		1kV ceramic
C_3	0.05μF		350V

DN7-78 cathode-ray tube (Mullard)
Mu-metal screen for DN7-78 (Telcon)
Double-pole on/off switch
4×5-in length of ¼-in polystyrene rod
4× spindle couplings (Radiospares)
Three-core mains cable
7× Miniature Instrument knobs (Radiospares)
2× Red Single sockets, insulated (Radiospares)
1 Black Single sockets, insulated (Radiospares)
* See text

COMPONENTS LIST FOR MODIFICATIONS

Timebase
OA81 diode
470kΩ ± 10% ½W resistor
150kΩ ± 10% ½W resistor

Power Unit (Fig. 20)
R_1 47Ω ± 10% ½W
R_2 47Ω ± 10% ½W
R_3 680Ω ± 10% 3W
D_1 D_2—rectifiers already used
C_1 32 μF 250V
T_1 Midget mains transformer (Radiospares)

Trigger Stage
18 kΩ ± 10% ½W resistor
680Ω ± 10% ½W resistor
47kΩ ± 10% ½W resistor (R_{18})
8μF 350V

X Amplifier
2×2.2k ± 10% ½W resistors

The BC-221 Frequency Meter

HINTS ON ADJUSTMENT AND USE OF A POPULAR DISPOSALS INSTRUMENT

By R. L. CONHAIM

ONE of the most versatile pieces of surplus electronic gear is the BC-221 Frequency Meter. Oddly enough, based upon the amount of advertising one sees for this instrument, there are more of them available in Great Britain than in the United States. In the U.S., it has been popular among amateurs, small manufacturers, Citizens Band users, service technicians and communications users.

The BC-221 is a heterodyne frequency meter consisting of a dual-range, variable frequency oscillator and a crystal-controlled fixed oscillator operating at 1 Mc/s. The variable frequency oscillator operates in the ranges 125 to 250 kc/s and 2,000 to 4,000 kc/s on fundamentals. The outputs of both oscillators are rich in harmonics so that the instrument can be used well into the v.h.f. range. It is calibrated on harmonics to 20,000 kc/s. Each instrument has been individually calibrated, and each is furnished with a calibration book, marked with the serial number of the instrument. Some of the instruments were furnished with wooden cases, while others were contained in aluminium alloy cases. The instrument, when supplied complete with headset and batteries, was known as the SCR-211. Few surplus meters are so furnished, but practically any headset can be used and either battery or a.c. power (using a separate power pack) will operate the BC-221 satisfactorily.*

TABLE I

BC-221 Letter Suffix	Valve Complement, Commercial	Military Valve Designation**	Modulation	Warm-up
A,C,D	77 6A7 76	VT-77 None VT-76	No	No
E	7G7 7B8LM 7A4	VT-193 VT-208 VT-192	No	No
B,N,Q, AA, AE, AG	2 of 6SJ7 6K8	VT-116 VT-167	No	No
F,J,K,L	6SJ7Y* 6A7 76	VT-116B None VT-76	No	No
R, AC, P, T, AF AH, M, O	6SJ7Y* 6K8 6SJ7	VT-116B VT-167 VT-116	No	No
AK, AN	2 of 6SJ7 6K8	VT-116 VT-167	Yes	Yes
AJ, AL	6SJ7Y* 6K8 6SJ7	VT-116B VT-167 VT-116	Yes	Yes

**Military valve designations are no longer used, but some surplus valve from World War II are marked with these designations.
*6SJ7Y has a special low-loss base. In an emergency, it can be replaced by standard 6SJ7 with some loss of accuracy. However, the 6SJ7Y is still being manufactured.

Valve complements vary from model to model and are shown in Table 1 which also indicates special features. Those meters with modulation provide for modulating the v.f.o. This feature is used mainly for receiver calibration. The model BC-221-AN has provision for modulating either the crystal or variable oscillators. Modulation frequency is 375 or 400 c/s.

The warm-up feature refers to a special switch position in which all current is off except the heater current for the variable oscillator. This feature permits somewhat more stable operation without excessive warm-up period. When such equipped instruments are not in use, they can be left in the warm-up position with very little current consumption, but time must be allowed for the crystal oscillator to stabilize.

The BC-221 can be used to check transmitter frequencies, receiver dial setting accuracy, signal generator accuracies, amateur radio band edges and other similar applications. In normal use, the variable frequency oscillator is calibrated against the internal crystal oscillator at various check points. These points are listed on each page of the calibration book. The fundamental or some harmonic of the v.f.o. is calibrated against the fundamental or some harmonic of the crystal oscillator. The "Corrector" control is tuned for a zero beat indication in the headphones. The function switch is then set to the "Operate" or "Het. Osc." position and the main tuning dial set at the desired frequency as determined from the calibration book. Crystal oscillator output is available in the "Crystal" or "Xtal" positions.

In addition to the crystal check points shown in the calibration book, there are many others. Those shown in the book will provide the loudest heterodyne beat in the headphones. The intermediate ones which can be heard, should not be used since the instrument was calibrated against those shown in the book. It should also be noted that the instrument will not operate unless headphones are plugged in to one of the "Phones" jacks. These are switching types which turn off the valve heaters unless a plug is inserted.

Accuracy of the BC-221:—There has always been a question about the accuracy of this instrument, and lively discussions have taken place in U.S. journals. Some users claim an accuracy of 0.01%, while others insist the BC-221 cannot achieve such accuracies. If we consult the original technical manual covering

* The headphones are isolated by a single capacitor (see Fig. 4) and for mains operation an additional double-wound output transformer should be used to conform to British Standard 415:1957. —ED.

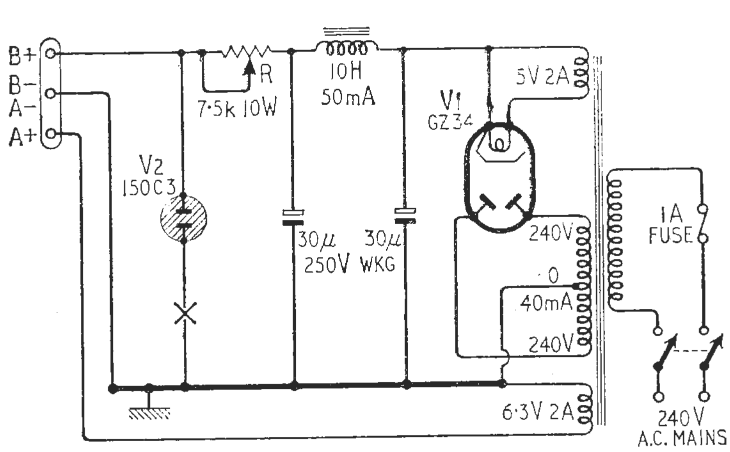


Fig. 1. Voltage-regulated power supply suitable for use with BC-221 frequency meter. R is adjusted to give 15 mA in a milliammeter inserted at X.

this instrument, we find that the maximum errors at 4,000 kc/s are as follows:

Small shocks, caused by handling	100 c/s, maximum.
Locking the dial	30 c/s, maximum.
Warming up	100 c/s, maximum.
Changing of load on antenna post†	50 c/s, maximum.
A drop of 10% in battery voltage or a change of 5°C. in ambient temperature	325 c/s, maximum.
Error in calibration	500 c/s, maximum.
Error in crystal frequency	250 c/s, maximum.
Total maximum error	1,355 c/s or 0.034% at 4,000 kc/s

Maximum possible errors at other frequencies are: 985 cycles at 2,000 kc/s, 180 cycles at 250 kc/s and 180 cycles at 125 kc/s. These are theoretical maximum errors under field conditions. However, these errors are not necessarily additive, so that from a practical standpoint, the errors under such usage amount to about 50% of those shown. This would mean an accuracy of about 0.017% at 4,000 kc/s. But the interesting point is that most of these errors can be considerably reduced or even eliminated. For example, we need not lock the dial; the instrument can be left on at all times for maximum stability; the load on the antenna post need not be changed during use; a voltage-regulated a.c. power supply can be substituted for the battery supply and the crystal can be calibrated against MSF at 5 or 10 Mc/s.

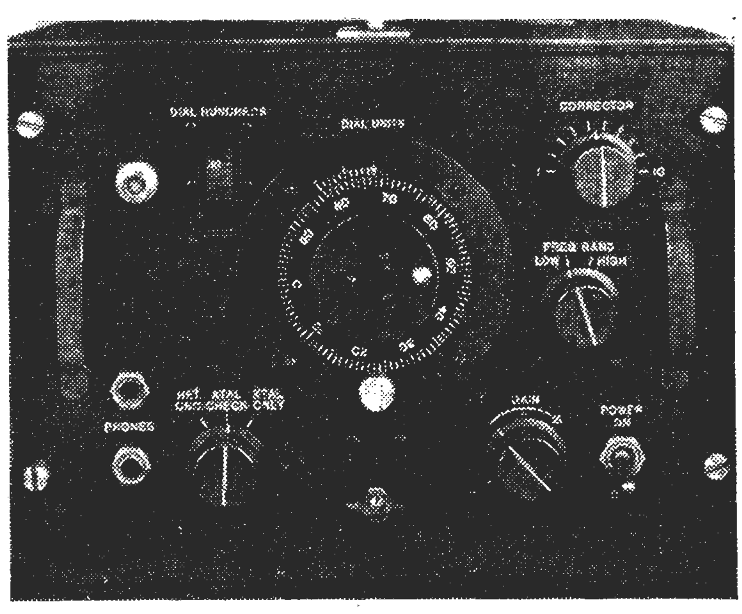
To determine how such measures would affect accuracy, the author tested six BC-221 models with an electronic counter. In each case, sufficient warm-up time was allowed, and the crystal was calibrated against the internal crystal of the counter. Checking in the 27 Mc/s range, accuracies better than 0.01% were consistently achieved, and using the additive method, which we will discuss below, accuracies greater than 0.0025% resulted with all six samples.

The Voltage-regulated Power Supply:—A simple voltage-regulated power supply is shown in Fig. 1. This supply is easy to build, parts should be readily available, and layout is not critical. Although the battery voltage originally was 135V d.c., we found that a 150V d.c. supply worked admirably, and without sacrifice in accuracy. The worst feature of using an a.c. supply is the possibility of hum in the headset. This can be eliminated by using d.c. on the heaters of the valves, but in most cases, this is unnecessary because hum is not that objectionable. Some models of the BC-221 will present worse hum conditions than others. The power supply is located several feet from the BC-221 to avoid the possibility of heat affecting the frequency meter.

† The aerial terminal stamped "ANT" in the standard model. It may be convenient to replace this by a coaxial input socket.

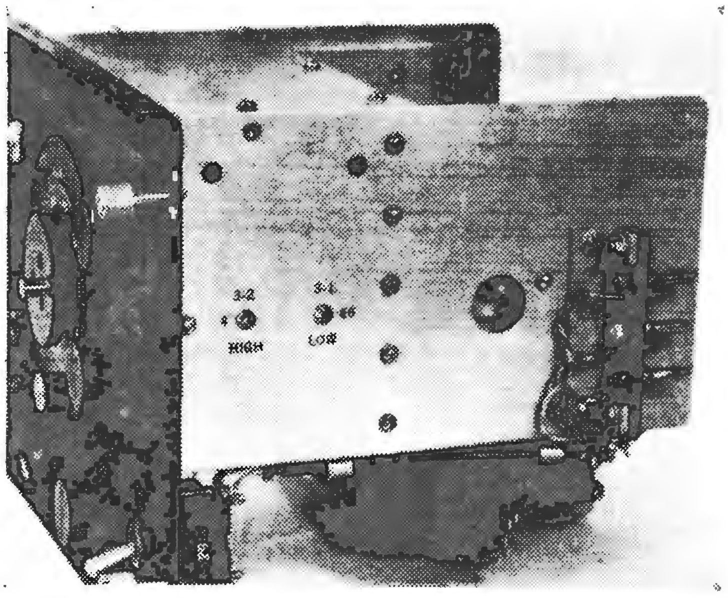
Setting the Crystal Frequency:—Most models of the BC-221 contain within the crystal oscillator circuit, a trimmer capacitor which allows zero-beating the 1 Mc/s crystal with an external standard. This trimmer capacitor location varies from model to model. In many models, the capacitor is located behind the nameplate, as shown in Fig. 2. In other models, the trimmer cannot be made accessible without removing the instrument from its case. This means either making a wiring harness so the instrument can be operated out of its case, or drilling a hole in the case at the trimmer location. The author has used the latter technique with complete success. A plug is placed in the hole to keep air currents out of the instrument.

To set the crystal frequency, use a receiver capable of receiving MSF at either 5 or 10 Mc/s. A receiver with an "S" meter will be most satisfactory, since it will provide a visual, and consequently more precise, indication of zero-beat. An oscilloscope connected across the receiver output may also be used as a visual indicator. Tune to MSF and loosely couple a short length of wire from the aerial terminal of the BC-221 to the input connection of the receiver. Some adjustment in the closeness of coupling may be required. While observing the "S" meter, adjust the crystal trimmer capacitor of the BC-221 very slowly. As the crystal oscillator is brought close to 1 Mc/s, you will notice the "S" meter needle begin to vibrate. These vibrations become slower and slower as you approach the correct 1 Mc/s adjustment, and the needle excursions become greater. With this technique, you can achieve a short term crystal accuracy of 1 part in 10^6, or better. In practice, the author leaves the BC-221 on at all times, and checks the crystal each time the meter is to be used. For this



(Photo courtesy "Electronics World".)

Fig. 2. BC-221-0 with nameplate removed to show trimmer capacitor for adjusting crystal oscillator frequency.



(*Photo courtesy "Electronics World"*).

Fig. 3. BC-221 removed from case showing location of adjustment capacitors and power supply plugs.

purpose, the nameplate is removed from the BC-221-O and left off at all times for quick access to the crystal trimmer capacitor.

Internal Adjustments:—While most instruments advertised are tested and guaranteed before sale, it is possible that the suggested use of a 150V d.c. supply, or the subsequent disuse of the instrument for long periods of time may cause internal changes in circuit capacity. This will be evidenced by the impossibility of finding zero-beat "Corrector" settings for all the indicated calibration points in the calibration book. However, internal adjustments can be made to bring the instrument within range of the "Corrector" capacitor at all calibration points. The physical location of these adjustments is shown in Fig. 3. The location may vary from model to model and those shown are for the BC-221-O. Make a three-wire cable harness with plugs and jacks to fit the appropriate connectors in your BC-221. These are usually the "banana" type. After the unit has warmed up outside the case, check each crystal check point on the "Low" band. If some points cannot be made to reach zero-beat with the "Corrector" capacitor, make the correct setting for the lowest crystal check point in the book and centre the "Corrector" knob on its scale. Now adjust the "Low" internal capacitor for zero-beat in the headphones. If possible, check with a calibrated low-frequency receiver to be sure the meter is emitting a 125 kc/s signal. Check the highest checkpoint in the "Low" band to see if zero-beat can be reached by the use of the "Corrector" control. By varying the initial setting of the control, either a little to the left or right of its centre position and adjusting the internal capacitor, some point will be found which will allow the "Corrector" capacitor to be adjusted for zero-beat on all check points in the "Low" range. The procedure should then be repeated using the "High" internal capacitor for "Corrector" settings in the "High" range. After long periods of disuse, you may find it necessary to repeat these procedures, but they will not affect the accuracy of the instrument.

The Additive Method:—The most accurate (but most difficult) way of using the BC-221 is known as the additive technique. In this procedure, the crystal oscillator is left on at all times and the output is the sum or difference of some crystal harmonic plus the v.f.o. fundamental or harmonic. Suppose, for example, you wanted to check the frequency of a transmiter at 28.240 Mc/s. In the additive method, you would use the 28th harmonic of the crystal oscillator plus the fundamental of the v.f.o. at 240 kc/s in the "Low" range of the instrument. To do this, you first make the correct calibration setting indicated in the calibration book on the page containing the setting for 240 kc/s. Then you set the frequency dial to the indicated setting for 240 kc/s. Leave the function switch in the "Check" or "Xtal Check" mode. Now, loosely couple the antenna wire from the BC-221 to a dummy load connected to the transmitter output. Key the transmitter and listen in the headset for a heterodyne tone. Adjust the coupling as required. Turn the frequency dial of the BC-221 until zero-beat is heard. Then read the dial and by direct reading or interpolation between settings shown in the calibration

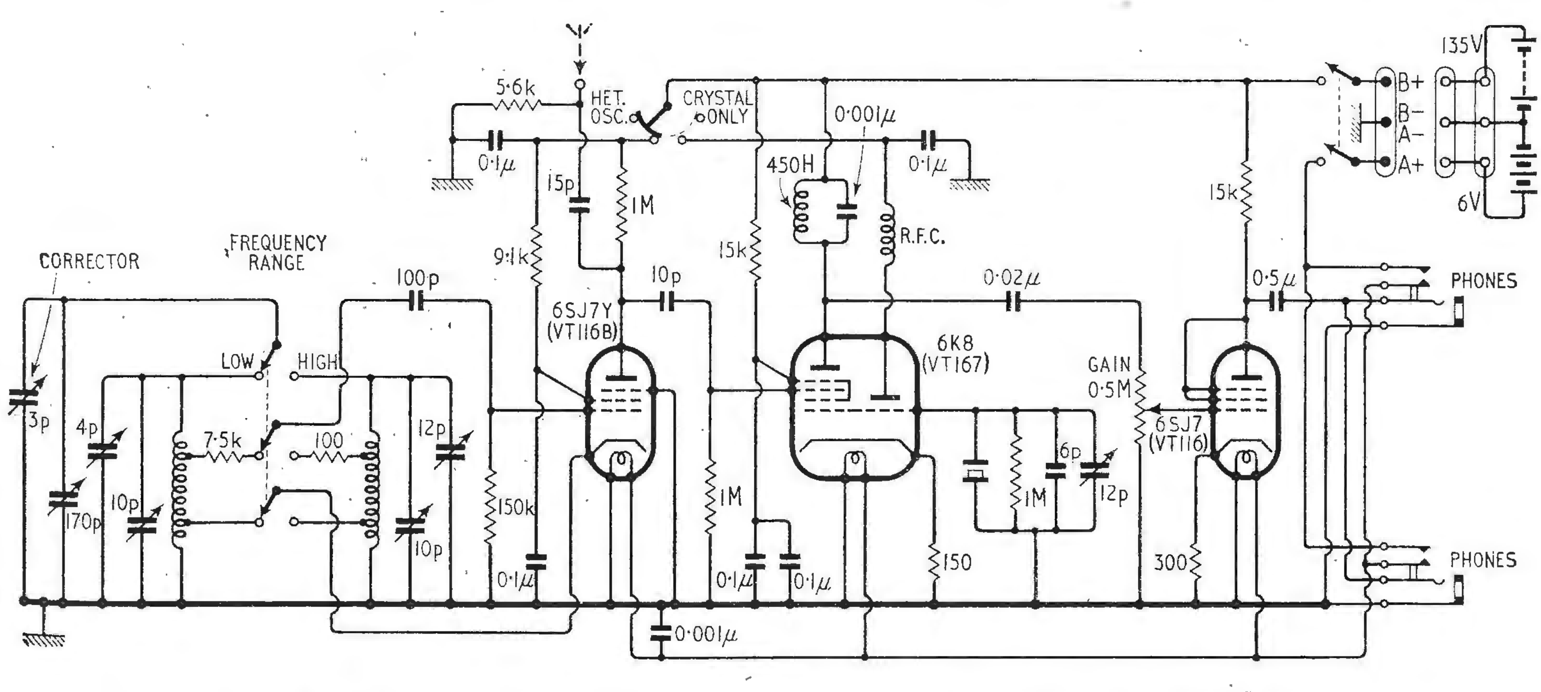


Fig. 4. Circuit diagram and components list of BC-221-O. This is typical of most models.

book, determine the frequency. This is the frequency at which the transmitter is operating.

The one disadvantage of the additive method is that a number of beats may be present, and it may be difficult to determine which is the correct beat. The simplest technique is to key the transmitter on and off while listening in the BC-221 headphones. The correct beat note will only be heard when the transmitter is keyed on. All the other beats should be ignored. With this technique, you can achieve outstanding accuracies for an instrument of this type. The author has used it consistently on U.S. Citizens Band transmitters operating in the frequency range of 26.965 Mc/s to 27.255 Mc/s. Checks with an electronic counter show accuracies in the range of 0.0001% to 0.0025%.

Leaving the instrument on at all times does consume current, but assures greater stability. Valves have been replaced as required without change in accuracy. Experience of the author has shown that the 6K8 requires changing more often than the other valves.

Considering its price, the BC-221 is a very good buy and with careful use, it is able to achieve accuracies that rival those of much more costly laboratory standards. It is an instrument of great versatility. Generally, you will find accuracies greater on the "Low" range, since its total frequency spread is only 125 kc/s as compared to 2,000 kc/s on the high band for the same dial spread.

The calibration book will provide 1,251 dial frequency settings spaced 100 cycles apart for the "Low" range, and 2,001 settings spaced 1000 cycles apart for the "High" band. Several harmonic readings are also given for each of these discrete settings.

No attempt has been made in this article to provide complete operating instructions. Brief instructions are provided in the calibration book accompanying the instrument including methods for interpolating between listed settings. While technical manuals are no longer in print, if you are able to find technical manual, TM-11-300, you will have complete instructions for all models. A change to the manual, TM-11-300 C1, gives further information on setting the internal capacitors.

Maximum accuracy is achieved by operating the BC-221 in a room free from draughts and in which the temperature is reasonably constant. Leaving the instrument on at all times contributes to stability, but if you find this impossible, turn the instrument on about two hours before use. Before making any frequency readings, under these conditions, first calibrate the crystal oscillator against MSF. Repairs can be made to the crystal oscillator or the audio section of the instrument, but any changes in the variable oscillator, such as changing parts or even moving any of the wires, will require recalibration of the instrument against laboratory standards.

BOOKS RECEIVED

Transistor Television Receivers, by T. D. Towers, M.B.E., M.A., B.Sc., A.M.I.E.E., Grad. Brit. I.R.E., is an up-to-the-minute survey of circuits used in the U.S.A., Great Britain, France, Germany, Italy, Russia and Japan. This is not a catalogue of current models but a comparative analysis, stage-by-stage through the receiver, of the design methods adopted and should be of value not only to students of design but also to servicemen in gaining advance information of this growing class of receiver. Pp. 194, Figs. 188. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 55s.

The Application of Transistors to Sound Broadcasting, by S. D. Berry, Assoc. I.E.E. (B.B.C. Engineering Division Monograph, Number 46: February 1963) describes a number of transistor audio amplifiers and associated apparatus designed for general use in the sound broadcasting services of the Corporation. The characteristics of some frequently used circuit configurations are considered and a treatment is given of some of the properties of the input circuits of transistor microphone amplifiers with regard to noise. Pp. 20. British Broadcasting Corporation (Publications), 35 Marylebone High Street, London, W.1. Price 5s.

Proceedings of the International Conference on The Ionosphere (held at Imperial College, London, July 1962). Papers from this conference appear under four main sections: ionospheric constitution and ionizing radiations, geomagnetism and the ionosphere irregularities and drifts in the ionosphere and the mathematics of wave propagation through the ionosphere. Each section is introduced and summarized by an invited contributor. Also included are three papers giving preliminary results from the UK1, "Ariel" satellite. Pp. 528. Published by The Institute of Physics and the Physical Society and distributed by Chapman and Hall Ltd., 37 Essex Street, London, W.C.2. Price £5 5s.

Radio and Line Transmission. Volume 2 by G. L. Danielson, M.Sc. (Tech.), B.Sc., A.M.I.E.E., and R. S. Walker, Grad. I.E.E., Grad. Brit. I.R.E., covers the syllabus of the City and Guilds of London Technicians Certificate examination in Radio and Line Transmission B. and forms part of the Telecommunication Technical Series. Pp. 295, Figs. 226. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 21s.

Wireless Servicing Manual, by W. T. Cocking, M.I.E.E. This standard reference book now appears in its tenth edition to which a chapter on transistors has been added as an extension of the principles discussed earlier in connection with valve equipment. Pp. 286, Figs. 135. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 25s.

Radio Research 1962. The report of the Radio Research Board and the Director of Radio Research in D.S.I.R. gives outlines of the principal activities centred on the Ditton Park, Slough, station. These include the calculation of ionospheric structure at heights up to 100km to fit the field strengths observed by three mutually perpendicular aerials in an exploratory rocket; preliminary results of observation from the Canadian "topside sounder" satellite made at Slough; and the phenomenon of "resonance rectification" which results in a sharp increase of flow of a direct current from a probe electrode in the ionosphere when an alternating voltage is applied at a specific frequency. Pp. 26. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 3s (3s 2½d by post).

Marconi and the Discovery of Wireless, by Leslie Reade. A popular, non-technical account (in the "Men and Events" series) of Marconi's life and worth. Pp. 166, Faber and Faber Ltd., 24, Russell Sq., London, W.C.1.

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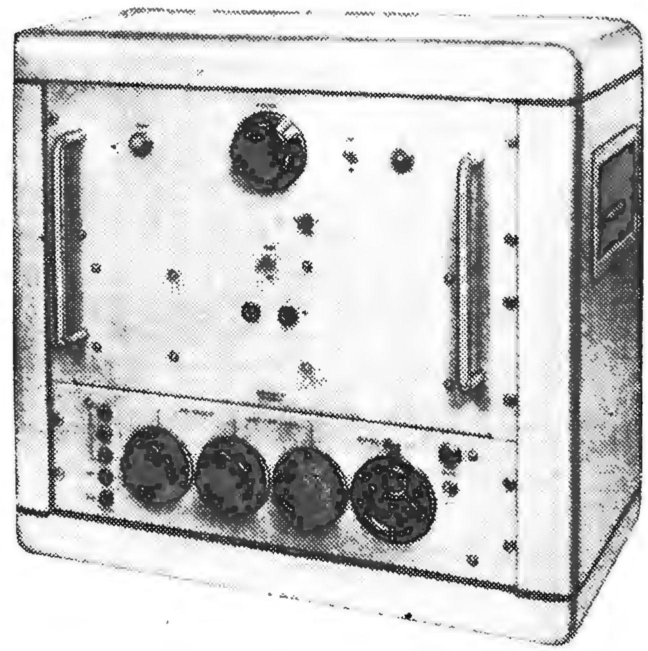

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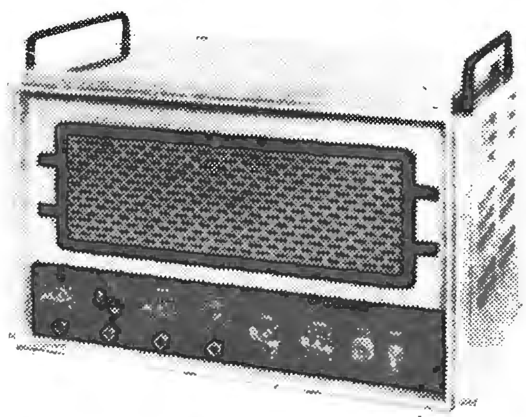

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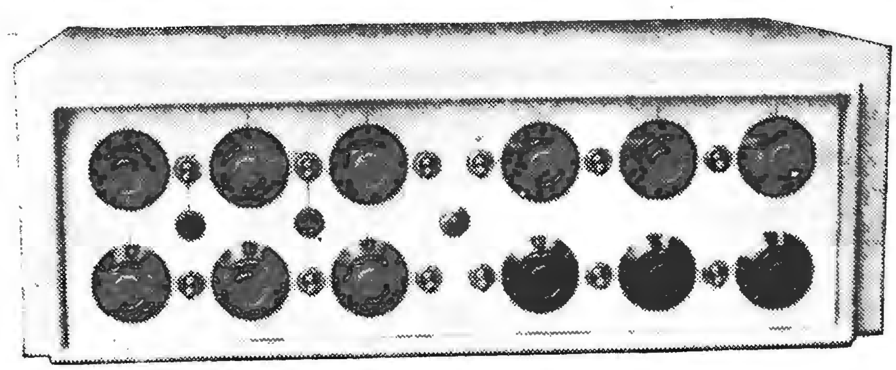

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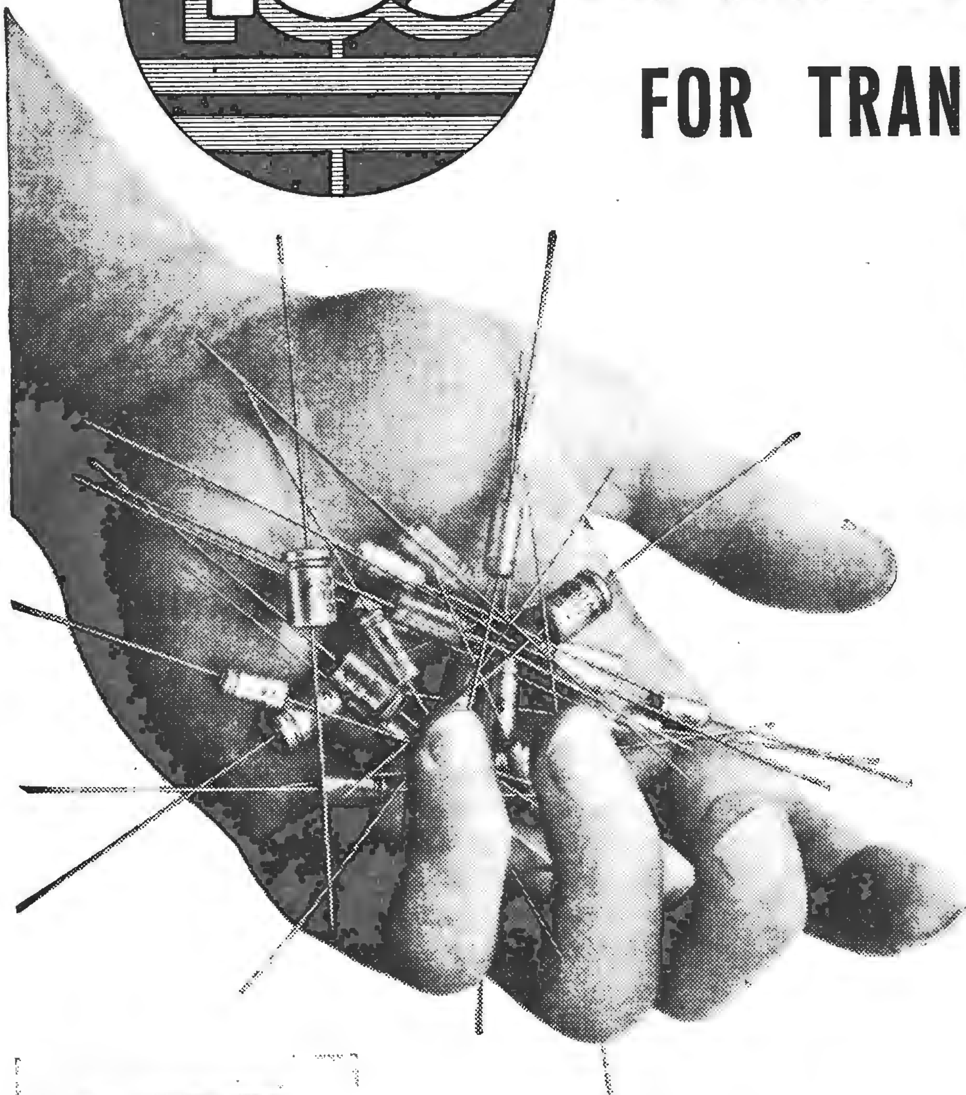

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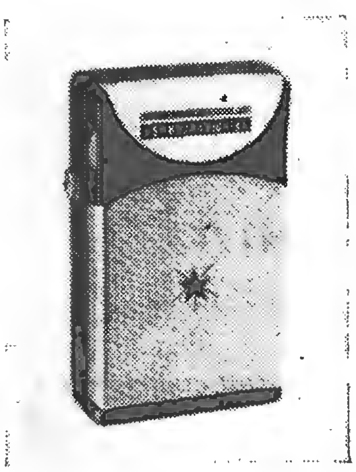

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LETTERS TO THE EDITOR

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Interference from Vacuum Lamps

THE attention of one of the authors was drawn to a particularly bad case of v.h.f. (f.m.) interference which was found on investigation to come from an old "hairpin-filament" vacuum lamp. This phenomenon was fully discussed with reference to television interference, in the correspondence columns of *Wireless World* in 1953 and 1954, culminating in an explanation by "Cathode Ray"[1], who showed that the oscillations were basically of the Barkhausen-Kurz type. At any given instant the negative end of the long filament would emit electrons, and the positive end behave as the positive grid. The negative anode, which provides the decelerating field necessary to produce these oscillations, was assumed to correspond to a tungsten coating on the inside of the bulb, evaporated from the filament.

A total of five lamps of this type were found and tested for oscillation, using an f.m. receiver. Four of these, which had been in normal service for many years, gave rise to oscillations at differing power levels, but the remaining lamp showed no inclination to do so. This lamp had been employed exclusively for photometric work, and had been used only very infrequently. It was decided to investigate the reason for its refusal to produce interference, especially as it was of similar construction and size to the (40-watt) lamp first found to exhibit this phenomenon so strongly. The glass of the original offender was, however, slightly discoloured and it was obvious that its bulb had an internal coating due to evaporation. It was decided to test for the existence of this coating, by the method of Reynolds and Rogers[2], and three parallel silver rings ($\frac{1}{4}$in wide and $\frac{1}{8}$in apart) were painted around the outside of the bulb, each in a plane perpendicular to the bulb axis. The centre ring was earthed and the admittance between the outer rings measured using a transformer bridge of the type described by Calvert.[3] This bridge has the advantage of separate independent adjustments for capacitance and conductance, and is also particularly adapted to 3-terminal measurements. As shown by Reynolds and Rogers, the existence of an internal coating causes an increase in the capacitance from which the resistivity of the coating may be calculated. Since the glass thickness was not known, a quantitative estimation of film resistivity was not possible. However, typical results of measurement at 1000 c/s are given below, for three of the lamps:—

	Capacitance (pF)	*Conductance* (mμ mho)	
Test jig alone ..	0.55	0.6	
Test jig + lamp A	39.4	96.5	(40-watt lamp—strong oscillation)
Test jig + lamp B	2.5	5.0	(25-watt lamp—weakest oscillation)
Test jig + lamp C	2.2	0.6	(40-watt lamp—no oscillation)

These figures show that the bridge used has detected the change of capacitance due to the internal coating, also that the equivalent conductance of the system is a more sensitive measure of the presence of the coating than capacitance at this frequency. Lamp A has a considerable coating, and this is present to a much smaller extent on lamp B. With lamp C, however, the conductance measured is the same as for the test jig alone, demonstrating that there is no detectable coating on the inside of the bulb.

Thus it appears that an internal coating on the glass bulb is a necessary requirement for oscillation to occur, as "Cathode Ray" correctly deduced.

B. C. BRODRIBB
K. W. E. GRAVETT
Electrical Engineering Department,
Brighton College of Technology.

1. "Cathode Ray," "Vacuum Lamp Interference"—*Wireless World*, Vol. 60, May 1954, p. 245.
2. Reynolds, F. H., and Rogers, M. W., "A New Method for the Detection of Thin Conducting Films in Thermionic Valves," *Proc. I.E.E.*, Vol. 104B, May 1957, p. 337.
3. Calvert, R., "The Transformer Ratio-Arm Bridge"—*Wayne Kerr Monograph No.* 1.

"R.M.S.' and 'Effective' Values

IN his article on "Non-linear Inductance" (July issue, page 361) "Cathode Ray" comments that "the whole idea of r.m.s. values is founded on linearity." I have far too much respect for "Cathode Ray" to believe that his thinking is faulty, but perhaps the expression could be improved.

It seems to me that when the waveform of current is known, the r.m.s. value can always be found; it is the result of a mathematical operation on the waveform. It does not depend on the linear or non-linear nature of the resistance through which the current flows. Whether the r.m.s. value, when found, is useful or not is another topic, but at any rate the r.m.s. value can be expected to be shown on a moving-iron or thermo-couple meter.

If we think of the effective value of current (that value of direct current which, flowing through a given resistance for a given time, dissipates the same energy as does the varying current) then, when resistance is not constant throughout the cycle, the effective value is not defined: what we would like to do would be to divide the mean power by the resistance, to give I^2, when I is the effective value of the current. If resistance is not constant, we cannot perform this division.

I may be quibbling but rather than say that r.m.s. values are based on linearity, I would prefer to say that the effective value can only be found when there is linearity; and when there is linearity, the effective value is numerically equal to the r.m.s. value.

Unfortunately this does not agree with the British Standards Institution Glossary of Electrical Terms. For them, "r.m.s." and "effective" are synonymous (and they tell me that when they say "effective" they have in mind energy as the basis of comparison).

Surely whenever there is a repetitive time-function, and the waveform is known, the r.m.s. value can be evaluated whether we are interested in energy or not. If the people who walk across London Bridge each day have regular habits, it would be possible to find the r.m.s. value expressed in people per minute. And whether there is linearity or not in their motion is of no more importance than the linearity of the electrical circuit (unless of course someone's non-linearity is so marked that he falls off the bridge).

All this may seem very trivial; but the confusion between "effective" and "r.m.s." can mislead students in problems dealing with non-linear resistance.

Kew, Surrey. T. PALMER.

The author replies:

It is quite true, as Mr. Palmer points out, that the r.m.s. value of any periodic quantity can be calculated, given its waveform, without reference to any other quantity. But surely this would be a rather pointless mathematical exercise. The r.m.s. idea only makes practical sense when applied to a quantity which appears to the second power in a formula with at least one other factor which is invariable with respect to the first.

The r.m.s. quantities that come first to mind are current and voltage, with resistance as the other factor in the formula for power; but of course the same principle applies to such things as magnetic flux. If the resistance, etc., varies with the r.m.s. quantity, then the purposes for which r.m.s. values are normally used cannot be fulfilled. That is what I meant when I said that the whole idea of r.m.s. values was based on linearity. I am still to be convinced that r.m.s. values apart from linearity, or a distinction between r.m.s. values and effective values, serve any useful purpose.

"CATHODE RAY."

Technician Engineers

IN your issue for June 1963 you referred to the recently published I.E.E. Report of the Joint Committee on Practical Training in the Electrical Engineering Industry, a report which, as you said, is intended to serve as a guide to those who are concerned with the education and training of electrical technician engineers.

At the end of your editorial comment (p. 262) you said, and I quote:

> "At present there is no organization which caters specifically for the increasingly large number of men in this category, and while the I.E.E. itself cannot take them under its wing it is apparently prepared to foster their recognition as engineers provided that the term is appropriately qualified."

The Association of Supervising Electrical Engineers, founded in 1914, concerns itself closely with the education and training of electrical technician engineers, and is recognized by the I.E.E. as being an eminently suitable body to do so. This point was brought out by Professor Sir Willis Jackson, F.R.S., Chairman of the Joint Committee on Practical Training in the Electrical Engineering Industry, in his remarks from the Chair at the meeting at the I.E.E. in May, when the Report was introduced to the Press and others.

The Association, with its rapidly growing membership, does in fact "cater specifically for the increasingly large number of men in this category," and in doing so is encouraged, and aided in very many ways, by the Institution of Electrical Engineers.

London, W.C.1. E. A. BROOMFIELD,
General Secretary,
Association of Supervising Electrical Engineers.

Tape Recorder Flutter Distortion

A KNOWN source of "flutter" distortion is the felt pressure pad used extensively in many machines. Some manufacturers have eliminated this method of getting the tape into close contact with the heads with a consequent marked reduction of flutter distortion. The felt pads give rise to flutter due to the high, but non-constant, coefficient of friction possessed by the felt.

Polytetrafluoroethylene (p.t.f.e.) is a plastic with a very low coefficient of friction. I have found that if a very thin film of this material (0.003 in) be placed between the felt pad and the tape there is a marked reduction of flutter distortion. The advantages of the soft "bedding" characteristics of the felt are retained, while the undesirable friction characteristic of the felt is eliminated.

Unsintered p.t.f.e. should be used and the grade made for pipe thread sealing as supplied by Messrs. Turner Brothers Asbestos Co. Ltd., of Rochdale, is very suitable.

Croydon. W. P. SKINNER.

Flag Day

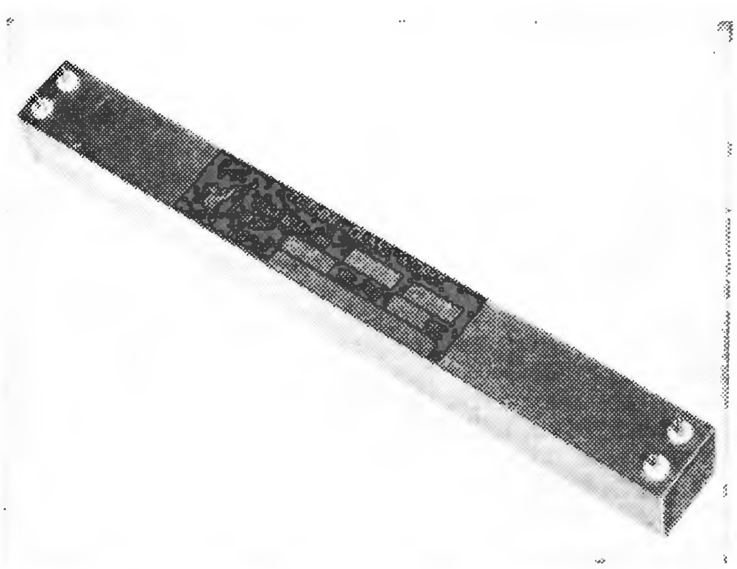
IN response to "Free Grid's" request (May issue) for suggestions about a suitable heraldic device for the patron saint of radio, St. Gabriel, here is mine.

I think nothing could be more "simple or striking" than, say, a herculean figure destroying a pocket transistor radio with a very large sledgehammer.

London, N.13. GEORGE STRATTON.

DELAY LINES FOR SECAM

ONE of the factors which will influence the decision to be made by the European Broadcasting Union on colour television standards is the cost of receivers. The comparative simplicity of SECAM, which at first sight would make a cheaper receiver, is to some extent offset by the need to use a delay line. "SECAM," it will be recalled, is short for "Séquentiel à mémoire," which means that the two transmitted sets of colour information, red and blue, come one after the other. The "mémoire" part of the name means that each line of colour is stored in a memory for the duration of a line so that the colours are brought into step and are applied to the tube simultaneously. (Green is transmitted with the luminance signal and does not enter into the discussion.) Each line scan occupies about 64μsec, and all the frequencies contained in the colour signal must be passed by the delay line.



Glass delay line for SECAM colour television by Corning Glass International.

A lumped-constant line or delay cable to give this order of delay and bandwidth would be difficult and costly to make, and to overcome this difficulty, Corning Glass International have developed a simple glass delay line working on the ultrasonic principle. The signal is launched into and extracted from the glass by ceramic transducers, and the glass used will give a variation in delay time of less than 0.1μsec from $-10°$C to 55°C. Corning say that, in the numbers needed by an internationally-agreed system, the lines could be produced for $5 each. A small quantity of these lines is held by Electrosil Limited, Colnbrook By Pass, Slough, Bucks.

Overload Protection of Transistor Regulated Power Supplies

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

A GOOD deal of information is available on the design of transistor regulated power supplies but little appears to have been published about current limiters or overload trips to give short-circuit protection. This feature is built into some commercial units and it may be of interest to describe three simple systems which can be incorporated in new units or added to existing power supplies to safeguard them from accident or abuse. In certain cases it may also be possible to protect the connected equipment from the effects of a sustained overload. It can be said at once that ordinary fuses are quite useless for this purpose since they are far too slow in action and this is also true of many types of electromagnetic circuit breaker. Catastrophic damage can be done to transistors in a matter of microseconds and, to be of any value, protective gear must act almost instantaneously.

Three basic circuits will be described. In one of them the maximum possible output current is limited to a preset value. This protects the power supply unit from damage but does not necessarily safeguard the equipment which constitutes the load. In the other two a silicon controlled rectifier, capable of switching in a few microseconds, is used to cut off the power. Under favourable conditions this may clear the fault so rapidly that there is not much, if any, consequential damage. High-speed protection must be applied intelligently; for example it is useless to cut off the supply current if a high-energy reservoir capacitor remains connected across the load.

Series-transistor Voltage Regulators

One of the simplest and best-known regulator circuits is that shown in Fig. 1. The transistor Q1 acts like a variable resistance between the input voltage and the load. The voltage drop across Q1 is determined primarily by its base bias which is varied in such a way as to compensate for supply voltage or load current changes. The base bias is taken from the junction of R_1 and Q2. The collector current drawn by Q2 is in turn a function of its own base bias. The latter is determined in part by the potential divider R_3, R_4 connected across the regulated output. The Zener diode Z in the emitter lead of Q2 is fed through R_2 and develops a constant voltage which is applied as negative bias to the emitter of Q2. The effective base bias on Q2 is thus the difference between the Zener voltage and the potential at the junction of R_3 and R_4. The former is fixed while the latter varies with any change in the output voltage. Such a change constitutes an error signal which causes Q2 to draw a changing collector current. In turn, this alters the base bias of Q1 in such a sense as to tend to correct the initial error. The system is in effect a negative feedback amplifier, operative down to d.c., and to exercise strong control high gain is required. One simple way of achieving this is to use compound-connected transistors instead of the single transistor Q1. Alternatively, a 2-stage amplifier may be used instead of Q2 but it must be so arranged as to retain the negative feedback characteristic. The system is not only effective in correcting slow changes in supply voltage or load current but serves also to reduce supply voltage ripple. Because Q1 acts like an emitter follower, its output impedance is low and the good regulation in respect of load changes may be regarded as a consequence of the emitter follower characteristic.

With a fixed bias and emitter load resistance the collector-voltage/collector-current characteristic of a transistor is almost flat, corresponding to a high slope resistance. This effect is partly responsible for reducing the effect of supply voltage changes, including ripple components. However, for maximum ripple suppression the base bias of Q1 should be filtered by RC or LC circuits. Unfortunately this results in a sluggish response to sudden load or supply voltage changes and the technique is not often used in practical regulator circuits. An example of such a scheme will be given later in which some filtering is used without serious time-constant difficulties or penalties.

The problem of voltage control is somewhat simplified if the associated power supply unit has inherently good voltage regulation. In this respect, types which have a capacitor-input filter are notoriously bad. Choke-input filters have a much lower percentage regulation and they make the most of power transformer and rectifier ratings. To reduce ripple to an acceptable level normally requires a second LC filter stage and this puts up the cost so much that the cheaper system is often preferred,

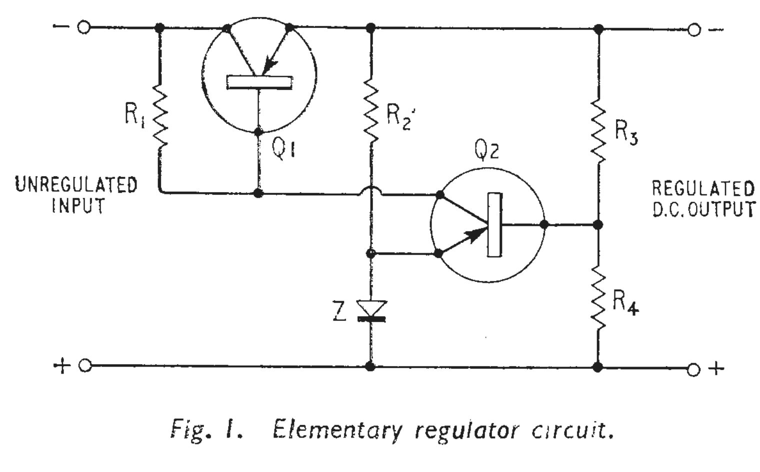


Fig. 1. Elementary regulator circuit.

particularly as the output voltage is a good deal higher. The use of a series-transistor regulator will cut down choke-input filter ripple to a low level without requiring a second stage of smoothing. The regulator circuits and overload protection systems to be described are intended for use with power supplies of the type shown in Fig. 2. Even with this type of circuit there is a sharp rise of output voltage under no-load or very light load conditions and to avoid this it is usual to connect a permanent ballast resistance across the filter capacitor or across the regulator output. It need draw no more than five per cent of the full load current.

Protection by Current Limiting

Examination of Fig. 1 will show that, for a given input voltage, the output could be reduced by connecting a resistance between the base of Q1 and the positive d.c. line. This would reduce the forward bias on Q1 and increase the collector-emitter voltage drop. A variable resistance serves to produce a variable output voltage. Similar effects would be observed if a transistor were used instead of this resistance and in this case the output voltage could be controlled by variation of the base bias on the third transistor. In particular, it would be possible to supply so much forward bias that this transistor would saturate and so reduce the forward

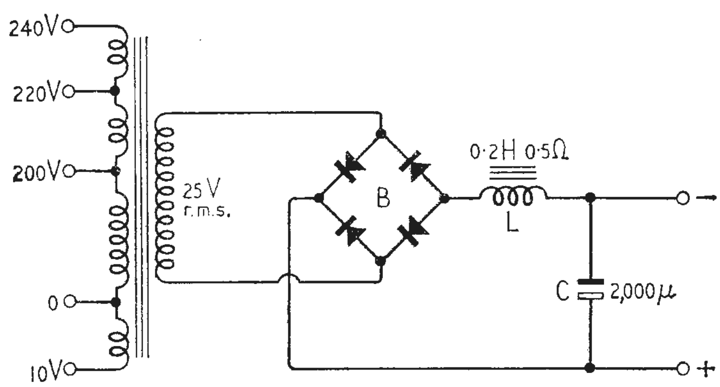


Fig. 2. Power supply unit with choke-input filter.

bias on Q1 that the load current could not exceed a safe maximum value, even if the output terminals were short-circuited.

This principle is embodied in the practical circuit shown in Fig. 3. Here the compound-connected transistors, Q3, Q4 and Q5, mounted on a common heat sink, together constitute the series regulator element. Because of the compound connection, only a minute change in the base current of Q3 is required to cause large changes of collector current in Q5. The transistor Q6 and its associated components form the error-signal amplifier. The remaining units Q1 and Q2 provide the current-limiting feature.

Q2 is normally cut off and does not affect the regulator operation while in this state. It can be turned on by base current derived from the collector circuit of the low-power n-p-n transistor Q1. This, too, is normally cut off by taking its emitter to the junction of R_1 and R_2 which form a potential divider across the unregulated d.c. input. Some forward bias is applied to Q1 in consequence of the voltage drop across the low resistance R caused by the presence of load current. At some critical value of load current the voltage drop across R will be sufficient to bias Q1 into conduction. The resulting collector current puts forward bias on Q2 and initiates the sequence of events described above. By selecting the value of R so that, with full load current through it, Q1 remains cut off, it can be seen that any further rise of load current can be checked. In practice the regulation characteristic can be made quite flat up to some preset maximum. A short circuit on the output will not cause more than a 20 per cent increase in this figure.

To set up the system it is best to remove Q1 and Q2 from the circuit and first get the regulator working properly. Q3 and Q6 are low-power transistors with a collector voltage rating well in excess of the unregulated d.c. input voltage. Q4 is an intermediate power transistor while Q5 is rated to carry the full load current. Its power dissipation rating can be estimated by taking, as an extreme case, the unregulated input voltage and multiplying this by the full load current. Q5 must be fitted on a well-designed heat sink with free air circulation. The resistors R_4 and R_5 give some protection against thermal runaway, though this is an unlikely contingency. Ignoring R_7 for the moment, the output voltage is dictated by the values of R_3, R_8 and R_9. Reducing R_3 or R_9 will have the effect of increasing the load voltage, while an increase in R_8 also increases the output. By making any of these resistances semi-variable the output voltage can be set at any value between wide limits. The resistance R_7 may be chosen to give a slight rise of load voltage in response to an increased load current. Initial settings of the regulator are best made at about half load. Minor variations in component values can then be made to secure good regulation over a wide range of load current.

Once proper operation of the main regulator has been achieved, attention can be turned to the protective circuit. Q1 and Q2 should be connected in position and either R or R_1 adjusted so that Q1 and Q2 remain cut off until full load current is being drawn at the rated output voltage. Any increase in load current should then bias Q1 and Q2 into conduction and cause a marked fall in the voltage developed across the load.

This simple circuit gives adequate protection against all but sustained short circuits. Under these conditions the power dissipation in Q5 is a maximum since the full unregulated voltage is applied to it and it is carrying a current slightly in excess of the rated full-load current. Ample time is available to disconnect the load before the temperature rise becomes excessive.

By adjusting R (continuously or in steps), the protective circuit can be brought into operation at any selected value of load current. This feature is useful, particularly when a wide variety of loads are likely to be operated from the supply unit.

Overload Trip Using a Silicon Controlled Rectifier

A controlled rectifier is a solid state device analogous to a thyratron. It has anode, cathode and gate electrodes. It blocks current in the direction which makes the anode negative but will conduct current in the other direction (anode-to-cathode), provided that the gate electrode is positively biased. Without positive gate bias, the device blocks current in both directions. Once triggered into conduction by for-

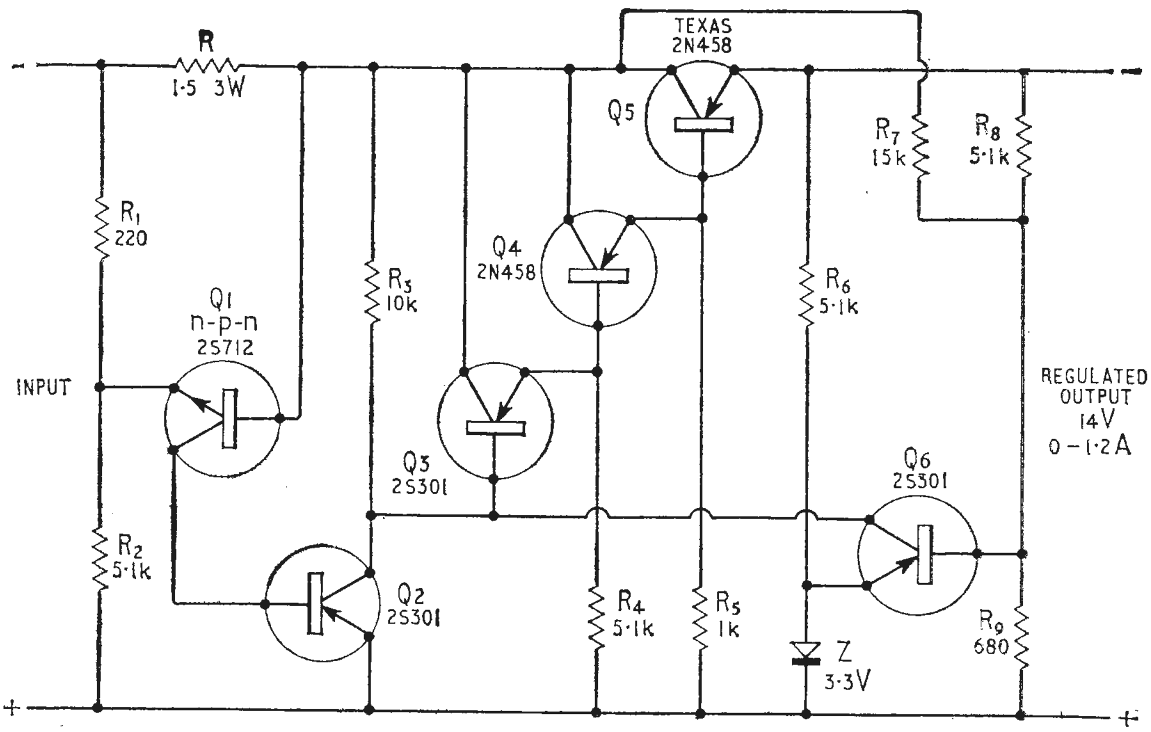


Fig. 3. Transistor regulator with current-limited output.

ward gate bias, the gate electrode exercises no further control and current can only be interrupted by switching, reversing the applied voltage or introducing a very large resistance into the anode circuit.

The circuit of Fig. 4 shows one way of using an SCR to cut off the load current at any preset value. Transistors Q1-Q5 correspond to Q2-Q6 in Fig. 3 and the actual regulator circuits are identical. The choke L and capacitor C act as a filter circuit for the base bias supply by Q2. They are not essential but they do result in a substantial reduction in the ripple voltage developed across the load. The SCR is connected in series with a reset button (normally closed), and the two resistors R_1 and R_2. The resistance R carries the main load current and the voltage developed across it is applied through R_1 to the gate electrode of the SCR. With normal full-load current in R the resulting gate current of the SCR is insufficient to trigger it into conduction. Any increase in load current beyond the preset value fires the SCR and it passes a current which is determined by the unregulated input voltage and the components R_1 and R_2. Actually there is a small voltage drop across the SCR in its conducting state but its effect is negligible. The voltage drop across R_2 is applied as forward bias to the transistor Q1. This is normally cut off and in this state has no effect on the regulator action. When Q1 is forward biased to saturation the series regulator stage Q5 is practically cut off and the load current drops to an insignificant fraction of its normal value.

The SCR remains conducting even when the load current in R is small and the gate bias is far below the level required to initiate conduction. To restore operation to normal after the circuit has been tripped it is necessary to press the reset button. This momentarily opens the SCR anode circuit and interrupts the current. It cannot start again until sufficient forward bias is again applied to the gate electrode. If the circuit has been tripped because of a load short circuit it is obviously necessary to clear the fault before pressing the reset button. While this is open the circuit is unprotected.

By suitable choice of the value of R the circuit can be arranged to trip with any desired value of load current. The switching action is virtually instantaneous and is certainly fast enough to protect an ammeter in series with the load even when the output terminals are short circuited. This instantaneous protection is not given if a capacitor is used in parallel with the load. This point should be borne in mind if one wishes to make full use of the high speed switching characteristics of SCRs.

Protection by Silicon Controlled Switch

The silicon controlled switch is another semiconductor device which is ideally suited for short-

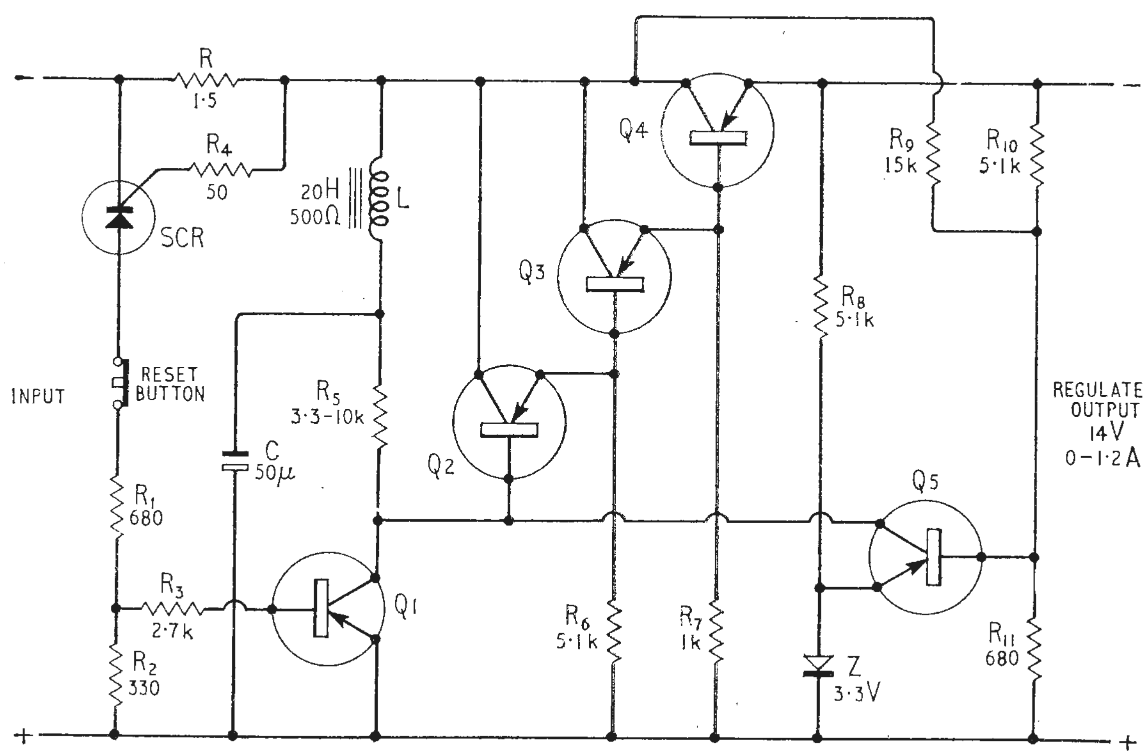


Fig. 4. Overload trip action is provided by this circuit, using a silicon controlled rectifier.

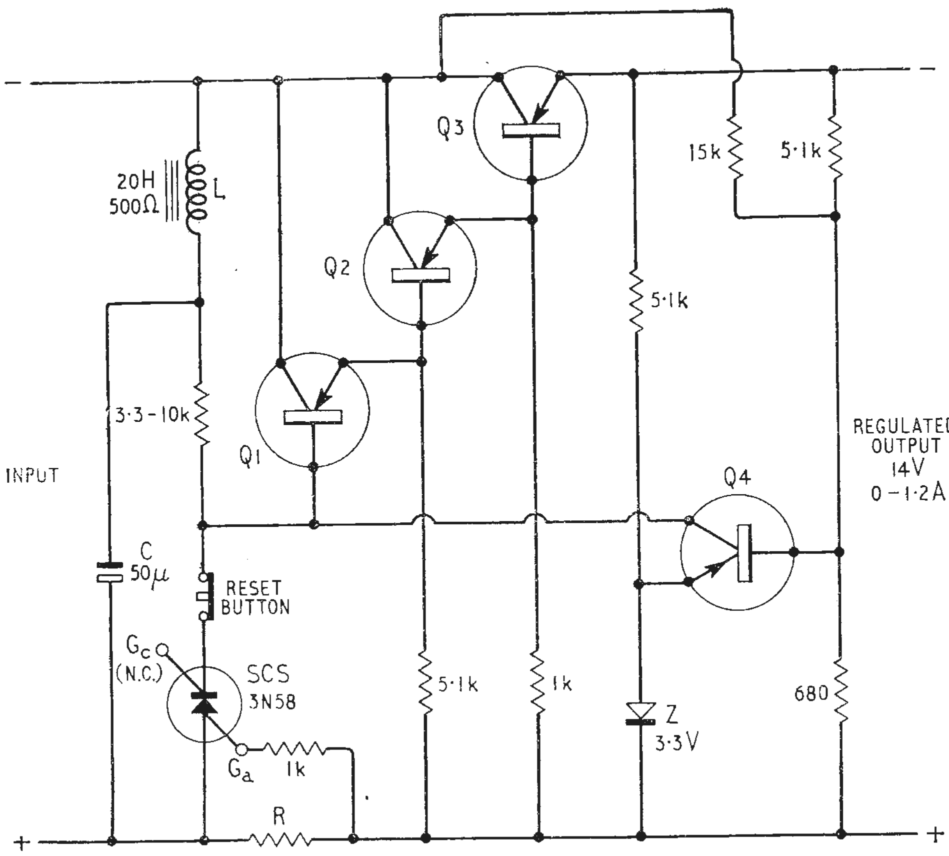


Fig. 5. Overload trip using silicon controlled switch.

circuit protection. One form of this device, developed by the General Electric Company (U.S.A.) and described in their "Transistor Manual," is a low-power SCS which is provided with two gate electrodes, Ga adjacent to the anode and Gc next to the cathode. Either gate may be used to trigger the SCS into conduction. If Gc is used it requires a positive drive signal while, if Ga is employed, the gate signal must be negative. In either case an extremely small trigger current is effective from a low voltage source. The existence of two gate electrodes makes the SCS more versatile than the normal SCR. The cost is also lower than even the smallest controlled rectifier. The G.E. Type 3N58 is priced at about 25 shillings in small lots and its switching capability is more than adequate for the protection of most regulated power supplies.

Fig. 5 is the complete circuit diagram of a voltage regulated supply incorporating this form of overload protection. The action is essentially the same as in Fig. 4. The SCS is normally non-conducting except for a very small leakage current. The resistance R is so chosen that with full load current the gate bias on Ga is insufficient to trigger the switch. Any increase in load current is sufficient to fire the SCS and bring the base potential of Q1 down to earth or H.T.+.

As in Fig. 4 the value of R may be chosen to trigger the SCS at any desired value of load current. Complete cut-off takes place in about 1 microsecond and to restore normal action after tripping it is necessary to remove the overload and press the reset button or momentarily switch off the main power supply and then switch on again. In one sense the SCS as employed in Fig. 5 may be regarded as a complementary SCR. If Q1-Q4 were all replaced by n-p-n transistors the regulator could be used to give an output with reversed polarity. In this case a standard SCR could be used in place of the SCS. Its cathode would be connected to H.T.– and in this case the voltage drop across R would be used to put positive bias on the gate electrode. Such an arrangement would be simpler than that shown in Fig. 4 but it would be more expensive because of the requirement for n-p-n transistors, probably silicon instead of germanium. The reversal of polarity would, of course, call for a reversal of the connections of the Zener diode as well as a change in transistor types.

When the highest possible trigger sensitivity is required in the SCS it is recommended that the unused gate electrode should be left open and unconnected.

Choice of Protective Measures

Each of the methods described has its own particular field of application. Fig. 3 is ideally suited for use with d.c. motors. These can be switched direct-on-line and the starting current will only just exceed the normal maximum load current. The motor will quickly accelerate to full speed. By contrast, switching a motor load on to the circuits of Figs. 4 or 5 will cause them to trip every time before the motor has begun to move.

All three circuits are equally reliable and give complete protection without interfering in any way with the normal regulator action. A small voltage drop across R and a trivial power loss in it are the only penalties incurred.

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NOTES ON $(1 + x)$

By THOMAS RODDAM

A MULTI-PURPOSE FUNCTON WHICH IS ALWAYS TURNING UP

EINS within a space and a wearywide space it wast I promulgated in these columns some ipsofacts and sadcontras about some of the design problems of feedback amplifiers. Much of what I had to say, reduced to instant form, lies enshrined in the Radio Designer's Handbook (Iliffe Books Ltd.). The increasing weight of this and my own growing weakness make it likely that I shall never see the results again. Even before then, and very much since then, we have seen the coupling and decoupling networks of amplifiers analysed. Just to remind you of the process, let us choose the simplest form of all, the LR network shown in Fig. 1, and write down the equation

$$V_1/V_2 = 1 + j\omega L/R$$

In this we write $\omega_0 = R/L$ and we can jump directly to the result

$$|V_1/V_2|^2 = 1 + (\omega/\omega_0)^2$$

From this we get the frequency response

$$20\log|V_1/V_2| = 10\log[1 + (\omega/\omega_0)^2]$$

Now we write $(\omega/\omega_0)^2 = x$ and we are dealing with the function $\log(1 + x)$. When we are roughing out amplifier designs we use a very simple approximation for this function. So long as ω is less than ω_0, so that $x<1$, we take $(1 + x)\approx 1$. When ω is greater than ω_0, so that $x>1$, we take $(1 + x)\approx x$. The frequency response of the network in Fig. 1 is then represented by two straight lines, a zero loss line up to the frequency ω_0 at which $\omega L = R$, and a 6dB per octave slope above this frequency. We may go on to note that at $\omega = \omega_0$ the loss is in fact 3dB, and sketch a curve through this point with the straight lines as asymptotes. When we have a number of factors of this kind the errors may leave us with too much uncertainty, but we can easily produce an exact response of an amplifier with decoupling and step circuits by using a template for the function $\log(1 + x)$.

I have frequently preached the doctrine that an engineer should be a lazy man. The modern engineer confronted with the task of building the Pyramids would not have begun by hiring personnel officers. In the great days of T.R.E. he would probably have devoted all his energies to showing that Pyramids were unwanted, unnecessary and incompetent. Convinced that the return in foreign exchange justified the capital expenditure (just think what the Duke of X— could have made out of the Sphinx) the engineer would design a Pyramid building machine. The only trouble would be that in no time at all he would be transferred to making a smaller model to produce pyramids, anti-tank.

Anyway, we have our template of $\log(1 + x)$. We do not need to regard this simply as a device for drawing amplifier responses: it has a number of other uses and, since we have the template, we might just as well apply it. Just how often this approach is really valuable is a matter upon which I will express no opinion because I feel that it could only be a reflection of my own personal attitude. You will find that some engineers choose to plot out every curve for itself, as it were; that others will try to normalize all their sets of graphs into one, and, given the chance, will choose the scales so that they have just a straight line; while yet a third class never draw graphs at all. What one member of one class considers useful, another man may regard as totally unnecessary. I think you may find some use in this technique but anyway, you do not have to use it.

To begin let us take the rather simple case of a resistance bridging a line. The connection of such a resistance introduces what is called a bridging loss and we often have to design systems in which a

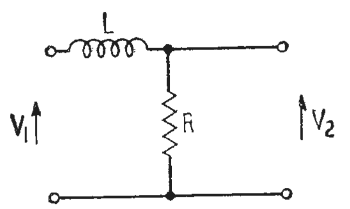


Fig. 1. Simple LR network.

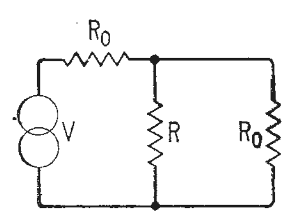


Fig. 2. Resistance bridging a line.

minimum value is prescribed. The resistance may be an amplifier or a monitoring loudspeaker; indeed this is a recurrent problem whenever a signal is carried on a common busbar which can be reached by a number of loads. The standard form is that shown in Fig. 2, where we have a generator of impedance R_0 with a matching load of R_0 and an optional tap along the line at which a second load R can be connected. The voltage across the load R_0 is easily seen to be $V/2(1 + R_0/2R)^{-1}$, which when R is infinite reduces to V/2 as we should expect. The bridging loss, the factor which controls the effect of R is simply $20\log(1 + R_0/2R)$dB. In this we must write $R_0/2R = x$, so that we have for the bridging loss the result $20\log(1 + x)$dB. There are two points to note here. In our previous use of this template we have been dealing with $10\log(1 + x)$ and we must modify the scale accordingly. We have also been *thinking* in terms of ω although the plot is based on ω^2/ω_0^2. As we are using a logarithmic scale there is a second factor of two which must be taken into account. Between them these two factors give us the result that the bridging loss is 6dB when $R = R_0/2$ and the bridging loss increases by 20dB per decade of R when R is much less than $R_0/2$. The result is

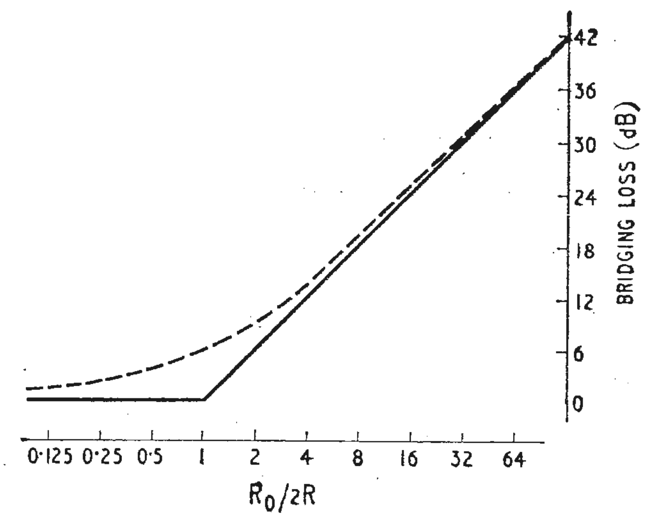


Fig. 3. Bridging loss produced by resistance R across a line, with generator and load impedances Ro.

the graph shown in Fig. 3, which was drawn using a template which I had cut in about 1949.

This example illustrates the only danger in this attempt to use one shape of graph for many jobs; it is very easy to get into trouble with the factors of two. I do not think there is any automatic protection which can be provided here: it is probably always wise to check the $x = 1$ point (3 or 6dB) and the asymptote. I cannot make up my mind whether this whole example is trivial or not. My own inclination would be to stick to the slide rule, but I have seen Fig. 3 plotted out painstakingly both for internal use in a large organization and in one or two books, so obviously the graphical form has its adherents. Indeed, looking back, I recollect using those graphs myself.

The effect of a resistance in series, the series insertion loss, is another $(1 + x)$ form which can be calculated in exactly the same way as the shunt insertion loss and will be left to the reader while we press on in all other directions.

One rather useful form for quick assessments is found in the field of feedback amplifiers. When we are designing amplifiers for instruments, and also, in a more specialized world, when we expect to have a whole string of amplifiers in tandem, we may be more concerned with providing constant gain than with any other aspect of the problem. Some of us may have been at work with scissors and paste to convert Mr. Edwin's calculator* (actually Mr. Felker†, to whom we owe the ability to see an American drinking soda water at the very instant he does so, described this device) into a working model, but what with shrinkage and errors of construction we may find our model is in error by the odd decibel. We can use our template for the following calculation.

Let us write the gain with feedback as

$$\mu_f = \mu/(1 + \mu\beta)$$

where $\mu\beta$ is a positive number with negative feedback. Then rearranging:

$$1/\mu_f = \beta(1 + 1/\mu\beta)$$

This we have seen many times before and we know that $1 + 1/\mu\beta$ is the finite gain correction to the simple form $1/\mu_f = \beta$ or $\mu_f = 1/\beta$. If we call this correction C we can plot 20logC as a function of log $\mu\beta$, or log $1/\mu\beta$, it is the same with reversed scales. I really cannot draw Fig. 3 all over again. When $\mu\beta = 1$ the correction is 6dB: when $\mu\beta = 2$ the value of $1/\mu\beta$ is 0.5 and the correction is 3.55dB by slide rule or 3.6dB from Fig. 3, using the $R_0/2R$ scale as a $1/\mu\beta$ scale. Suppose now we have this system and put in high-gain devices so that μ is doubled, making $1/\mu\beta$ fall to 0.25. The correction factor falls, from Fig. 3, to about 2.2dB so that the change in overall gain will be 1.4dB. Notice that this chart-reading is not tremendously accurate, but it does offer a quick way of getting our ideas into the right region. A very rough calculation is often sufficient to lay down the lines along which a detailed design will develop. Time spent in reconnaissance is seldom wasted.

Moving away from these simple applications let us look at something rather different. The inductance of a coil of n turns wound on a core of area A and permeability μ_0, with an average flux path length of l_c in the core and l_g in an air-gap is given by the well-known expression

$$L = \frac{1.25A\,n^2}{l_g + l_c/\mu_0} \times 10^{-8} \text{ henries}$$

We can rearrange this in the form

$$L = \frac{1}{1 + \mu_0 l_g/l_c} \times \frac{1.25n^2A\mu_0}{l_c} \times 10^{-8}\text{ H}$$

in which we have the second term, the inductance with zero air-gap, multiplied by the gap-effect factor $1/(1 + \mu_0 l_g/l_c)$. If we consider the behaviour to be plotted on log-log scales, the only factor we can vary with this particular form is the gap length, and by thinking in asymptotic terms we see how when the gap length l_g is less than l_c/μ_0 it has not very much effect, while if $l_g > l_c/\mu_0$ the gap begins to take complete control.

Let us change our view-point. Instead of doing what comes naturally, putting an air-gap in a core, let us put a core in a coil. Then we write the inductance as

$$L = \frac{1}{1 + l_c/\mu_0 l_g} \times \frac{1.25n^2A}{l_g} \times 10^{-8}\text{ H}$$

The physical interpretation of this is that the inductor is planned as a system using material of infinite permeability and the inductance is then found to be modified by a "finite permeability factor", $1/(1 + l_c/\mu_0 l_g)$. For a system of high stability we shall have $(l_c/\mu_0 l_g)$ on the below-unity side in Fig. 3 and we can use the curve to estimate just how much the inductance will vary as μ_0 changes either from sample to sample of material or as a result of d.c. flowing through the winding. There are some interesting possibilities here which I have been meaning to examine for some time. At the moment there is quite another application for our standard curve to be considered.

If we have a four-terminal network with hybrid parameters, h_{11}, h_{12}, h_{21} and h_{22} and we drive the terminals 1, 1′ from a source of impedance R_g and load the terminals 2, 2′ with R_l we can calculate the impedances presented at the terminals by applying any of the standard methods. Those of us who dislike effort keep a collection of tables of matrix forms so that we can avoid having to work out these expressions over and over again. "Enough is enough", as one politician is reported to have said to another. The mention of the hybrid parameters will have suggested to the reader that the black box of the

*Wireless World, June 1962, p. 281.
†Proc.I.R.E., Oct. 1949, p. 1204.

four-terminal does not contain the answer to the world's ills (that box, I am afraid, is empty) but is a classy way of talking about a transistor complete with its power supplies.

The input resistance, and we shall assume that we are concerned only with low frequencies and can forget any reactances, is given by the equation:

$$R_{in} = (h_{11} + \Delta h\, R_l)/(1 + h_{22}R_l),$$

where Δh is the determinant $h_{11}\, h_{22} - h_{12}\, h_{21}$. Let us consider plotting this, and let us use log-log paper. We shall then be considering

$$\log R_{in} = \log h_{11} + \log (1 + \Delta h\, R_l/h_{11}) - \log (1 + h_{22}R_l)$$

Let us choose some values for a typical transistor. If we take the sort of numbers we might find in a common-emitter connection, say

$$h_{11} = 1{,}000 \text{ ohms}$$
$$h_{22} = 100\mu\text{mhos}$$
$$h_{21} = 100$$
$$h_{12} = 7.5 \times 10^{-4}$$

we have $\Delta h = 0.1 - 0.075 = 0.025$, so that $h_{11}/\Delta h = 40{,}000$ and $1/h_{22} = 10{,}000$. Do not, I pray, try to identify this transistor, because the parameters were chosen to give these last two results. I see, however, that the figures are not very different from those given for the OC75 so that you may accept them as being quite realistic. This is the danger in faking parameters to get round numbers: you may get numbers which are hopelessly out of line with reality.

When we short-circuit the output, the collector, we have the input impedance as simply h_{11}, 1000 ohms. (We need not use the primes on the h's.) As we increase R_l the two other factors operate against each other. Each factor is of the form $(1 + x)$ and so we can look for two "characteristic impedances," $R_{l1} = 1/h_{22}$ and $R_{l2} = h_{11}/\Delta h$. These are

$$R_{l1} = 10{,}000 \text{ ohms}$$
$$R_{l2} = 40{,}000 \text{ ohms}$$

Interpreting the equation for log R_{in} we see that, as we have said, when R_l is small the input impedance is just h_{11}. Working with asymptotes this condition will hold up to the resistance $R_l = R_{l1}$ above which the logarithmic characteristic falls under the control of the term $-\log (1 + R_l/R_{l1}) \approx -\log (R_l/R_{l1})$. When R_l reaches the value R_{l2}, however, the term $+ \log (1 + R_l/R_{l2})$ comes into action, and as this is $\approx +\log(R_l/R_{l2})$ the input impedance becomes constant again. We can thus draw the asymptotic characteristics shown in Fig. 4 very quickly. Using the template construction for this step circuit, we can draw the exact shape for the curve, too.

Suppose, however, that the transistor were being used in the common-collector mode. The hybrid parameters for the same transistor would then be

$$h_{11} = 1{,}000 \text{ ohms}$$
$$h_{22} = 100\mu\text{mhos}$$
$$h_{21} = -101$$
$$h_{12} = 1 - 7.5 \times 10^{-4} \approx 1$$
$$\Delta h \approx 101$$

The input impedance with zero load is still, of course $h_{11} = 1000$ ohms, because it makes no difference whether the short-circuited load is in the collector lead or the emitter lead. Now, however, we have

$$R_{l1} = 10{,}000 \text{ ohms}$$
$$R_{l2} = 10 \text{ ohms}$$

This implies that as soon as the load exceeds 10 ohms the input resistance begins to rise, and it will rise until the load resistance is 10,000 ohms, when it will be 1 megohm. We can add this characteristic to Fig. 4.

The third mode is the common-base mode. For this we have, approximately,

$$h_{11} = 10 \text{ ohms}$$
$$h_{12} = 0.25 \times 10^{-3}$$
$$h_{21} = -0.99$$
$$h_{22} = 1\mu\text{mho}$$
$$\Delta h = 0.25 \times 10^{-3}$$

The values of R_{l1} and R_{l2} are obviously

$$R_{l1} = 10^6 \text{ ohms}$$
$$R_{l2} = 40{,}000 \text{ ohms}$$

No more calculations are needed to draw the set of

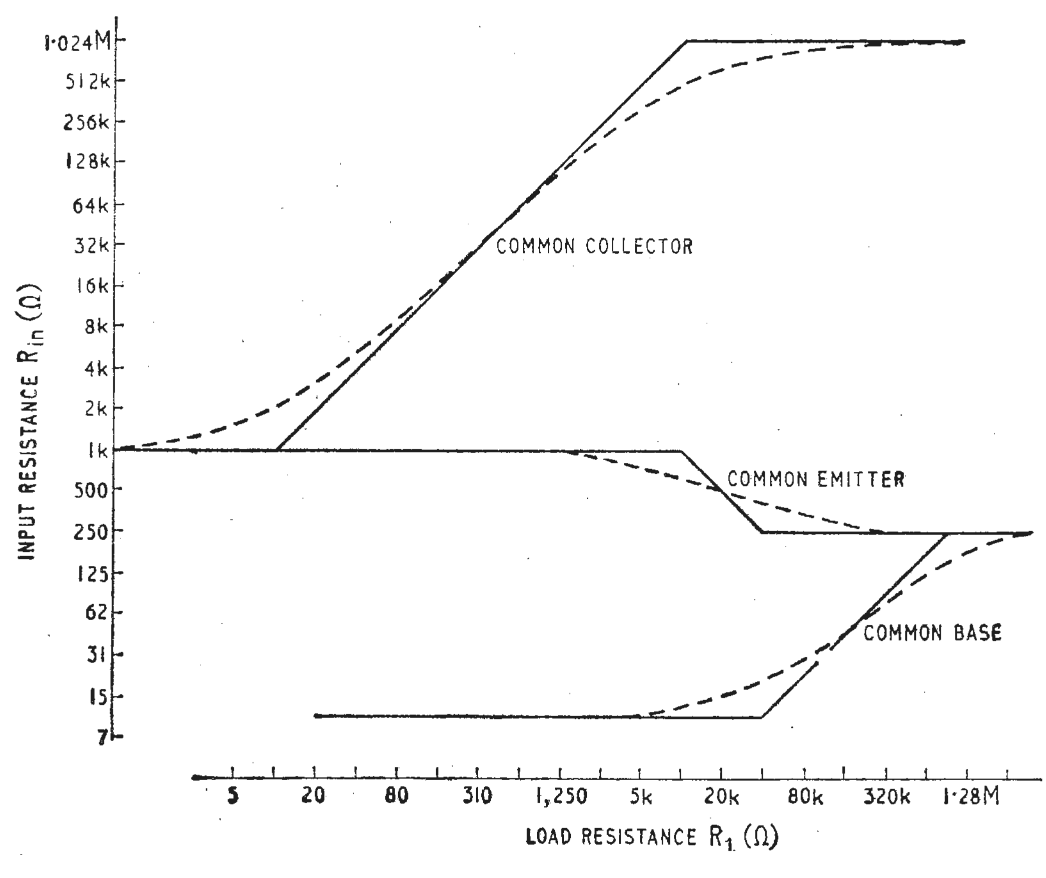


Fig. 4. Input resistance of a transistor as a function of load resistance in the three modes of operation.

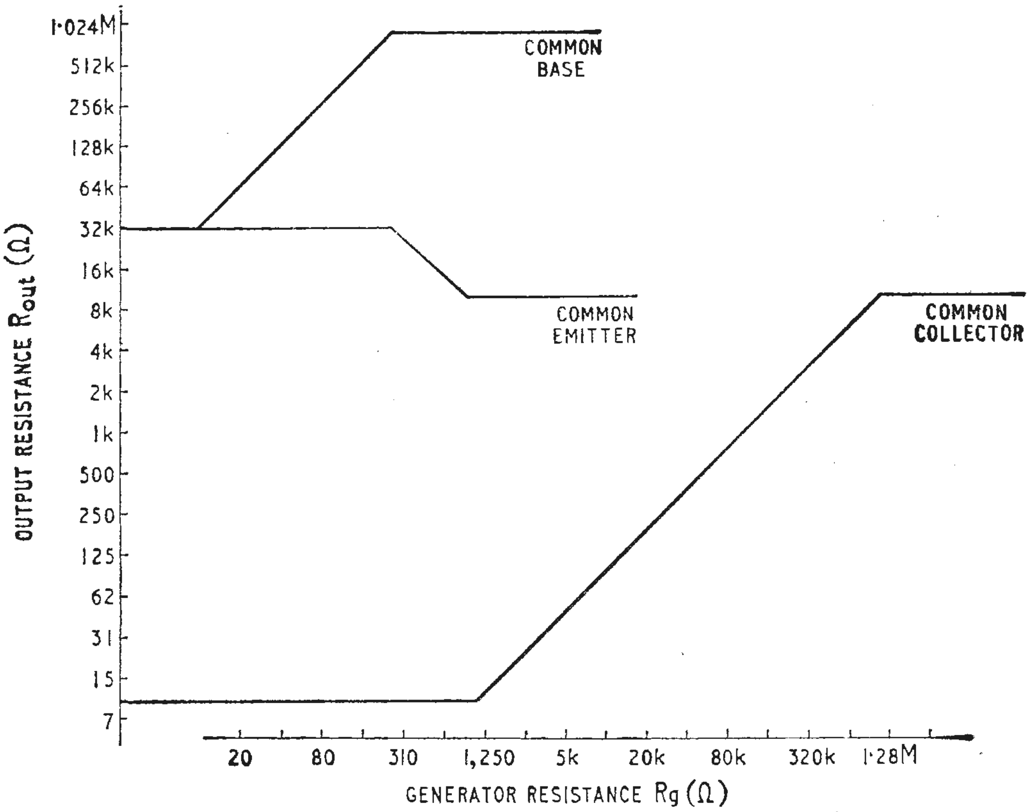


Fig. 5. Asymptotic behaviour of output resistance of a transistor as a function of source resistance.

curves shown in Fig. 4: these show the complete behaviour of the input resistance of a transistor in the three modes of operation as the load resistance is varied. There has been a little dirty work with the scales in order to simplify the drawing and to avoid awkward numbers but this is, I think, fair when the transistor itself has been faked to give illustrative results.

It is possible to produce this diagram with rather fewer calculations, but I prefer to follow the course given above and to note the following check points. The common-emitter mode shares one characteristic resistance with the common-collector mode and the other with the common-base mode. At zero load the common-collector and the common-emitter input impedances are the same, while with an open-circuit load the common-emitter and common-base input impedance are the same. The ramp portion of the common-emitter asymptotic characteristic, when extended, bisects the ramp portions of the other two characteristics.

The output resistance of our transistorized black box has the form:

$$R_{out} = (h_{11} + R_g)/(\Delta h + h_{22} R_g)$$

We write

$$\log R_{out} = \log (h_{11}/\Delta h) + \log(1+R_g/h_{11}) - \log (1+h_{22}R_g/\Delta h)$$

Here we have the same sort of behaviour, with the two characteristic impedancies $R_{g1} = h_{11}$ and $R_{g2} = \Delta h/h_{22}$.

For the common-emitter connection the starting value $h_{11}/\Delta h$ = 40,000 ohms, while R_{g1} = 1,000 ohms and R_{g2} = 250 ohms. For the common-collector mode we have initially R_{out} = 10 ohms, and R_{g1} = 1,000 ohms, $R_{g2} = 10^6$ ohms. For the common-base mode, initially R_{out} = 40,000 ohms, R_{g1} = 10 ohms, R_{g2} = 250 ohms. Notice again how one characteristic resistance is shared by the common-emitter and common-collector modes, and another by the common-emitter and common-base modes. Only the asymptotic characteristics have been drawn in Fig. 5, because of the author's natural laziness and also his belief that these characteristics show the foundations of the behaviour in a way which is hidden by the true smooth characteristics. This seems to be especially true of the common-emitter characteristic.

There is one more transistor equation which fits into this sort of approach and that is the current-gain equation. If the input current is I_1 and the output current is I_2 we have

$$|I_2/I_1| = |h_{21}/(1+h_{22}R_l)|$$

Notice that the signs are left to look after themselves. As always we take logs, and write

$$\log|I_2/I_1| = \log h_{21} - \log (1+h_{22}R_l)$$

Note that the gain asymptote has its corner at $1/h_{22} = R_l$. We know that the values of h_{22} are the same for the common-emitter and common-collector modes, while apart from the minus sign the values of h_{21} are nearly the same: the difference between h_{21} and $1+h_{21}$ is just meaningless in this context. We thus need only consider two curves, the driven base and the grounded base. For the grounded base

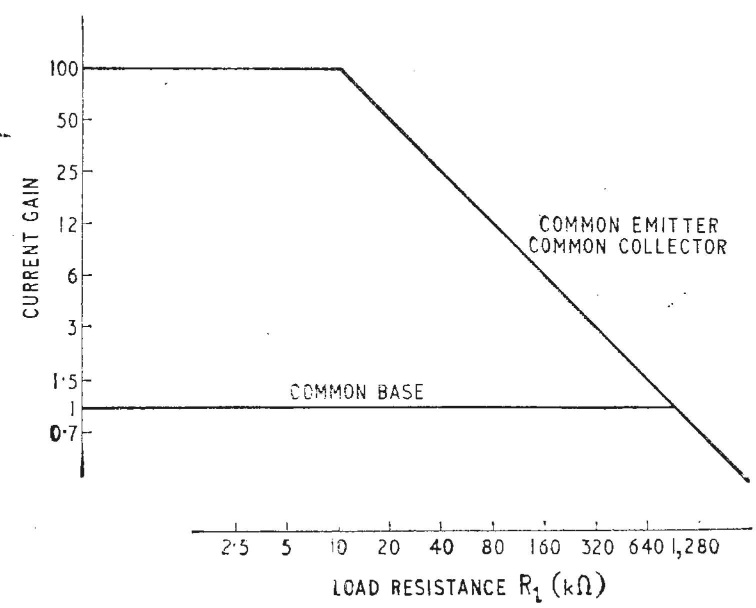


Fig. 6. Asymptotic behaviour of current gain of a transistor as a function of load resistance.

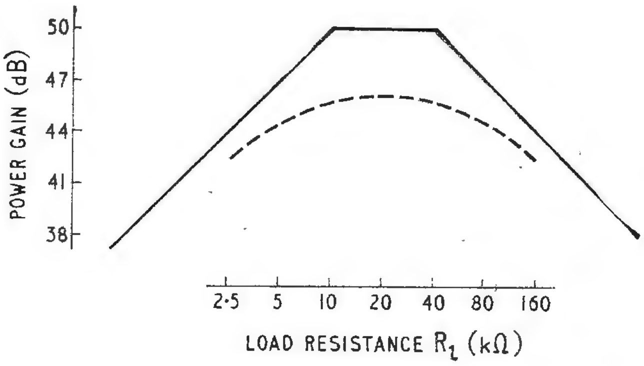


Fig. 7. Power gain of a transistor as a function of load resistance (common-emitter mode).

the gain is, of course, just on unity and the cut-off load resistance (by analogy with cut-off frequency) is β/h_{22e}, where h_{22e} is the common emitter value for h_{22}, and $\beta = 1+h_{21e}$.

The asymptotic ramp where $R_l \rightarrow \infty$, is just the line

$$\log|I_2/I_1| = -\log(h_{22} R_l/h_{21})$$

This is independent of the configuration so long as we accept that β is much greater than unity so that β, $(1+\beta)$ and $(\Delta h_e + \beta)$ are all the same. Looking back to the typical transistor, in the common-emitter mode we have $h_{21} = 100$ and $1/h_{22} = 10{,}000$ ohms. Fig. 6 shows the asymptotic characteristics and enables us to do some simple reasoning. Let us consider only the common-emitter connection. Comparing Fig. 4 and Fig. 6 we see that the input resistance starts its downward run at the same load as the turning point of the current gain. For loads below 10,000 ohms the input voltage needed for a given input current is constant, and the current gain is constant. The voltage gain therefore increases in direct proportion to R_l. Above 10,000 ohms the ratio of volts-out/current-in remains constant, since we are on the sloping part of the $1+x$ characteristic. However, the input resistance is falling, so that the input voltage for a given current is getting smaller and thus the voltage gain continues to rise. When we reach a load of 40,000 ohms the input resistance becomes constant again and so therefore does the voltage gain. From these results it is very easy to generate a power-gain characteristic but it is worth noticing that, as you can see in Fig. 7, the asymptotic characteristic is rather optimistic. It indicates the correct load, but it is about 4dB too high in gain because of the rounding losses. Even so, it is useful to be able to get a quick picture of what is going on. The common-emitter mode is particularly prone to error in this respect because the step is such a short one.

It is not too difficult to hunt out some more examples of the use of this function. Some time ago I analysed the rather queer things which happen when you have a short-circuited turn. The problem, of course, is why a shorted turn is bad on a transformer and yet seems to be harmless if a brass slug is used for an r.f. tuning arrangement. In the analysis, which no doubt will be given a reference** by the Editor, although I have forgotten it, we get two of these factors $(1+x)$ cropping up and one of the typical figures is, I hope, reproduced as Fig. 8.

I find this way of using the function as a guide

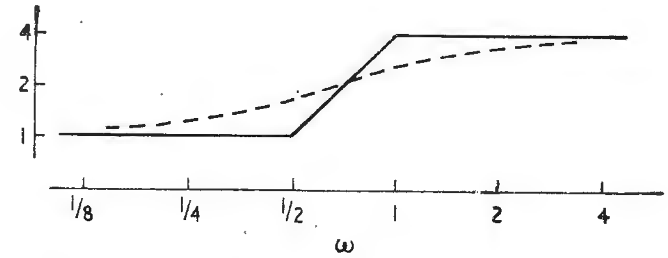
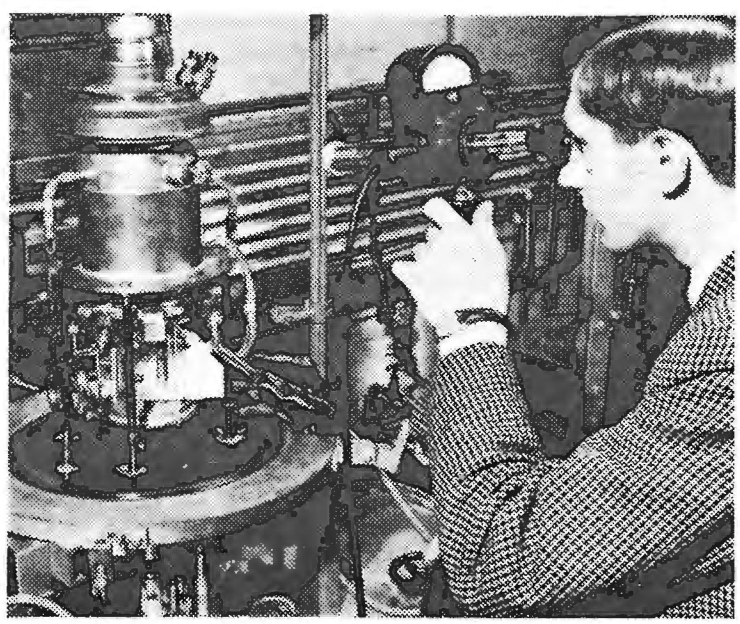


Fig. 8. Typical step figure arising in analysis of short-circuited turn.

very useful because it enables the first rough calculations, estimates might be a better word, to be made very quickly. With just the asymptotic characteristics one can frequently sort out a situation into the possible or impossible class: with the template, or even one's memory of it, many of the doubtful solutions can be assessed. Then you have more time left free for the real plodding work of producing a full solution of the problem. Watch out for that $(1+x)$.

High Power Pulse Modulator

THE photograph shows the cathode temperature being measured during the exhaust schedule of the M-O Valve Company's E2986 hot-cathode modulator thyratron. This valve has power ratings of 200MW (peak) and 150kW (mean). It is thought to be the largest of its type available in the world at present. A metal envelope construction is used to enable all the the electrodes to be easily watercooled. By eliminating grid emission and gas density changes due to hot electrodes, this also enables a very high power to be achieved in a relatively small envelope. This valve is filled not with hydrogen, but with deuterium, whose greater dielectric strength enables an anode voltage of 40kV to be achieved. While the valve is in use the deuterium gas filling is continuously replenished by means of a titanium deuteride reservoir. The heater of this is controlled by a barretter and thermistor to counteract the effect of changes in the supply voltage or ambient temperature on the gass pressure. An impregnated tungsten cathode is used in association with a secondary emitter to give a maximum peak current of 10,000A with a heater power of 1.8kW.



****** *Wireless World*, March 1957, p. 114.

UNBIASED

By "FREE GRID"

Breach of Security

IN June there was a lot in the newspapers about security, and when I heard that an exhibition was to be held in the New Horticultural Hall, Westminster, called "The International Security, Police & Fire Exhibition" I was determined to visit it.

From what I read in the preliminary publicity it seemed to be easy nowadays to use applied science—and more especially electronics—to turn our homes and offices into well-nigh impregnable fortresses. I gathered that any malefactor seeking entry would not only trigger off local visual and audible warnings, but also send a signal to Scotland Yard or local police H.Q.

It so happened that an early opportunity was vouchsafed to me to test this much-vaunted impregnability, for by pure mischance as I walked along the side of the building, I mistakenly entered by a door which I realized later was really an emergency exit which had been opened because of the excessively humid heat of the afternoon. It was not until I was well inside the building with my 2s entrance money still in my hand that I realized my position.

This incident rather destroyed my confidence in all the very remarkable security arrangements on show as naturally I could not help thinking that if the manufacturers of these ingenious devices could not protect their own exhibition building, what faith could I have in their ability to protect my home or office? However, on reflection I realized it was not their fault but that of the organizers who had failed to make the necessary security arrangements; I wonder how many others made the same mistake as I did?

Actually some of the protective schemes on show, many of which used electronic devices of all kinds, were highly ingenious and first-class in every way, but the thing which chiefly interested me was the new pocket transmitter/receiver for use by individual police officers to enable them to communicate with their stations.

This instrument was very compact and light, and could easily be carried in the pocket. Beyond the fact that its average range is 30 miles, obviously varying according to local screening conditions, I can give no details as I was told that all technical literature was exhausted. I am still wondering if this was the truth or whether the manufacturer's representative withheld information because he thought I looked too much of an anti-social type to be trusted with it. Time will tell, as I asked that full details be sent to the Editor who maybe will receive a visit from the police instead.

Wireless Cribbing

NO doubt some of you noticed in your daily newspapers recently that a report from Lisbon recounted how a schoolboy was caught cheating in an examination by an ingenious but misguided use of wireless.

He had a large surgical dressing over one ear which hid a transistor set by means of which he was able to signal to his brothers outside the examination room who supplied answers to his questions. This method of cribbing by wireless is very old, and I referred to an earlier instance of it in these columns over a quarter of a century ago.

In those primitive days, telegraphy and not telephony was used, and the offender was not successful owing to the difficulty of transmitting by morse a very complicated equation in a mathematical paper. It would, I think, be equally difficult to transmit such an equation by telephony, and so would-be cribbers will have to wait until the days of fully miniaturized TV with a screen the size of a watch face.

Maybe the Editor won't be able to spare the space for me to repeat the equation here, and so those of you who haven't still got the issue of 28th April, 1938, will have to ring him up. If so he may try reading it out to you in order to prove my words about the difficulty of getting it over correctly by telephony.*

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* My line is often busy, so I had better read it now: Jay (bar) equals pi ee squared eff tau over em into integral delta en nought by delta vee into vee cubed dee vee into (square bracket) integral, nought to pi, sine cubed theta dee theta minus integral, nought to pi by two, sine cubed theta dee theta one over tee into integral nought to tee exponential minus zed over lambda nought cos theta dee zed minus integral, pi by two to pi, sine cubed theta dee theta one over tee into integral, nought to tee, exponential tee minus zed over lambda nought cos theta dee zed (close of square bracket).—Ed.

What is a Machine?

SOME more information has been received by the Editor from the managing director of the firm whose troubles of technological terminology I tried to tackle in the June issue.

He has now written to tell the Editor that he has had further correspondence with the British Standards Institution from which he gathers that in the Institution's opinion, a static device such as a transformer is not a machine. But he is rather puzzled by the B.S.I.'s reference in one letter to "rotary machines" as this seems to imply, *in his opinion* that a stationary device can also be a machine.

In my opinion, however, this is not so as the Institution may be using the term "rotary machine" to distinguish it from one having only a reciprocating motion such as the "make & break" mechanism of an induction coil which we used in the old spark transmitter days.

Actually the word "machine" does not imply the possession of any moving parts if we go right back to its basic meaning. Therefore, a static transformer is a machine even though it has no moving parts, or at any rate ought not to have any although in some of them, when under heavy load, one can sometimes detect a faint humming noise, indicative of a certain amount of lamination liveliness.

However, we can discount this, as also we can the suggestion that the electrons shuffling backwards and forwards in the transformer windings constitute moving parts. I realize, of course, that at rock bottom electrons are indeed moving physical objects unless we follow the present tendency to take a sort of metaphysical view of the ultimate nature of electrons by thinking of them as merely a mathematical concept, or as being merely "a strain in the ether," a phrase which I once heard used by an N.P.L. pundit.

Now where are we? We have just decided that a machine does not necessarily have moving parts. The dictionaries—even the heaviest of them—do not help a lot as they refer to a machine as a device or contrivance. They also say the Romans used the word (*machina*) a lot in connection with lifting weights which were too heavy to be dealt with manually. This leads me at once to think of that excellent sort of lever which we usually call a crowbar. It would seem to have no moving parts, and yet when in use, one end of it, as in the case of an oar, does move relative to the other. It is no use trying to dodge the issue by saying a crowbar is a tool; so is an electric drill which is also most certainly a machine.

I think I'm getting rather out of my depth, and must leave to you savants the question in the title of this note. In my opinion it is incumbent upon us to assign our own agreed meaning to all words we employ as we have already done in the case of "atom" which nowadays we all use with an arbitrary meaning quite different to its literal one of "indivisable."

R.F. at Interplas

A FEW weeks ago I paid a visit to "Interplas," or in other words the International Plastics Exhibition, at Olympia. In addition to the use of plastic cases and coverings for domestic receivers plastics also play an important part in the matter of insulation and other things inside the box.

However my real reason for going to the exhibition was to examine the many r.f. heaters used in the plastics industry, which were on view there. The frequencies used seemed to be 35Mc/s or so but I noticed that one firm (Radyne) was urging the superiority of its 80Mc/s machines for certain purposes. I was a little surprised at the use of this frequency as it is, I believe, in one of the bands allocated internationally for radio astronomy.

I therefore approached an expert on the stand for enlightenment. His reply was that the machine was so completely suppressed that it complied with the requirements of authorities not only in this country but even in Germany; these latter requirements, he said, were much more stringent than those over here. In reply to my further questions, he stated that even if his firm's apparatus were to be installed in a laboratory devoted to radio astronomy, the suppression was so perfect that no interference would be caused.

More ψ

AS I mentioned in the issue of June 1959, the symbol ψ (actually the Greek letter which immediately precedes omega) is used to describe telepathy and other kinds of extra-sensory perception about which we know little or nothing.

The only reason I am dragging in ψ again is that I see a report that the Russians are planning to transmit thought waves between Cambridge and Leningrad. Hitherto I had always thought that telepathists had stated that thought waves were *not* radio waves of a certain λ. But since the expression "thought waves" is used they are obviously waves in some medium or other, and if they can indeed be transmitted between Cambridge and Leningrad, it looks as though they may at least be first cousins of radio waves.

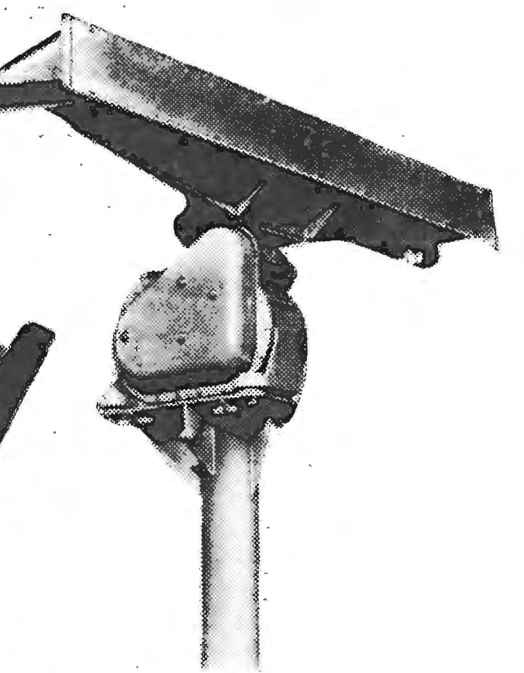
It is all rather disturbing, for obviously if telepathy once got established on a firm basis, it would wreck the radio and industry and make all our apparatus just so much scrap iron.

DECCA D202 RADAR

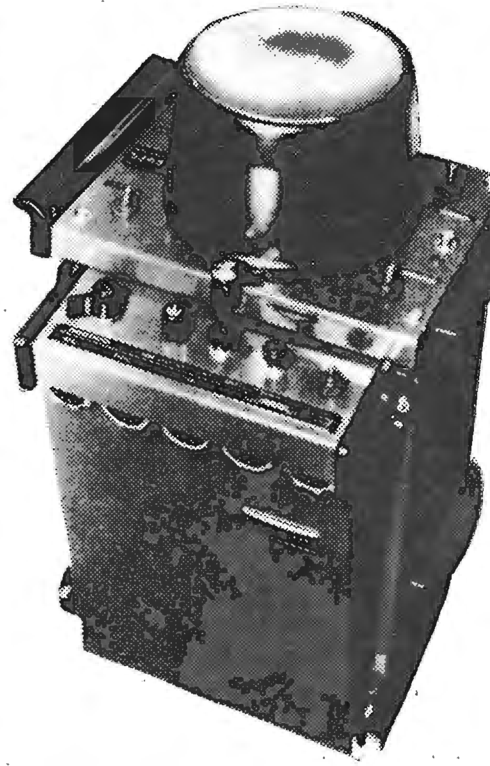
EXTENSIVE use has been made of transistors in the latest marine radar installation designed by Decca Radar Ltd., Albert Embankment, London, S.E.1. Although magnetrons and klystrons have not yet been replaced in the transmitter and receiver most of the other stages have been transistorized with the result that the D202 is much more compact than earlier valve-operated equivalents. It is further expected that reliabilty will be improved, not only because of the long life of the transistors themselves but because other components will be functioning in a lower ambient temperature. The total consumption is only 320 W at 24 V.

Two pulse lengths of 0.1 and 0.5μ sec are provided for good picture quality at short range and better sensitivity at long range. There are six ranges giving maxima from ½ to 24 miles.

The price of the D202 is £950 compared with £1,500 for earlier valve models, but it is in no sense a "cheap" version, indeed, the performance meets the requirements of and has already been given type approval by the British, American and German authorities. One of the first orders was for the new 48ft R.N.L.I. lifeboat and it is expected that there will be considerable interest from coastal shipping lines operating small vessels, as well as from ocean-going vessels requiring a stand-by radar.



Above: The end-fed slotted waveguide aerial of lightweight construction gives a beam width of 1.9° with a 4ft horizontal aperture.



Left: The display unit of the Decca D202 in a welded stainless steel housing is suitable for bulkhead, deckhead or pedestal mounting, at a "safe" distance of anything over 18in from a magnetic compass.

Commercial Literature

A leaflet describing **automatic oscilloscopes**, manufactured by the California Instruments Corporation, is available from A. Dunkley, 14 Wellington Road, Ashford, Middx. The manufacturers claim that a waveform is automatically positioned to provide a "clear meaningful picture, regardless of amplitude, frequency or d.c. offset." This 'scope also displays in digital form vertical sensitivity, horizontal sweep speed and d.c. offset. **(314)**

The 1963 Mullard valve and tube **Equivalents Guide** is now available from the Government and Industrial Valve Division of Mullard Ltd., Mullard House, Torrington Place, London, W.C.1. Its companion publication **abridged data on current types** of valves and tubes for industry, communications and radar is available from the same address. **(315)**

Feroba ceramic permanent magnets are described in a leaflet obtainable from Darwins Ltd., Fitzwilliam Works, Tinsley, Sheffield 9. Details of the physical and magnetic properties of the discs, rings and bars they manufacture are included together with demagnetization curves. **(316)**

A leaflet describing 7,000Mc/s portable outside broadcast **link equipment** for television is available from the Transmission Systems Division of Standard Telephones and Cables Ltd., North Woolwich, London, E.16. **(317)**

A loose-leaf technical catalogue containing information on **Belling-Lee products** is now available to senior designers and engineers on application, from the head of their department, to Belling and Lee Ltd., Great Cambridge Road, Enfield, Middx. **(318)**

A leaflet describing **public address equipment** manufactured by C.T.H. Electronics is obtainable from their Burford Works, Burford Street, Hoddesdon, Herts. **(319)**

A transistor **portable radio telephone** designed for single channel operation in the 50 to 140Mc/s band using amplitude modulation and 25kc/s channel spacing, is described in a leaflet obtainable from the Radio Communications Company, of Crewkerne, Somerset. **(320)**

A.E.I. publication 5887-71, which gives details of a wide range of **components** from anti-corona tags and crystal holders to valve holders and voltage selector panels, is obtainable from the London sales office of Associated Electrical Industries, 51-53 Hatton Garden, E.C.1. **(321)**

Micro-electronic devices and integrated circuits are described in one of the "special series" of catalogues from the Components Group of Standard Telephones and Cables Ltd., Footscray, Sidcup, Kent. This catalogue (No. 8) includes information on integrated tunnel diode circuits and thin film circuits. **(322)**

Keyswitch Relays Ltd., of 120-132 Cricklewood Lane, London, N.W.2, have produced a **reference chart** for use with their 3,000 and 600 type relays. This "calculator" contains all the relevant information required to select the right type of relay for a specific job and also the recommended coil values, in tabular form, for relays with up to 12 contacts working on voltages up to 250V d.c. **(323)**

A leaflet describing the Danish Raaco **industrial storage cabinets**, which have transparent plastic drawers, is now obtainable from Raaco Ltd., Bath House, 57-60 Holborn Viaduct, London, E.C.1. **(324)**

Surge suppressors, for the protection of germanium and silicon rectifiers, are described in the Westinghouse Engineering Publication 19-13. Titled "N Series Selenium Surge Suppressors," it includes electrical and mechanical specifications along with typical circuit configurations and is available from the Westinghouse Brake and Signal Co., 82 York Way, King's Cross, London, N.1. **(325)**

A leaflet describing a new range of **relays** is now available from A.D.S. Relays Ltd., 89-97 St. John Street, London, E.C.1. The relays included in this brochure are approved by A.I.D., A.R.B. and the Admiralty. **(326)**

For the convenience of readers a number has been appended to each of the above items so that when applying for literature all that is necessary is to circle the appropriate number on the Information Service form at the back of this issue.