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Commentary

TWO items of technical interest were contained in the television development plans for 1955 announced recently by Sir George Barnes, the Director of Television Broadcasting of the BBC.

The first relates to the establishment of a permanent two way television link between London and the Continent, and it was stated that an order had been placed with the Post Office for the provision of this equipment.

The many problems arising from language, economic circumstances and different television standards have all combined to retard the exchange of television programmes between the countries of Western Europe and, while the network which is now gradually spreading across Europe is small compared with the vast coast to coast network of America, it is nonetheless a remarkable technical achievement.

It began in 1950 when the BBC carried out a successful cross-channel broadcast from Calais in connexion with the centenary celebrations of the first Anglo-French telegraph cable. For this occasion a mobile television unit was despatched to France and a microwave radio relay link carried the signals across the Channel from Calais to Dover, from whence they were conveyed to London by further radio links. This experiment was, in fact, no more than an extension of an " outside broadcast " by the BBC, but it demonstrated that the Channel could be crossed and the next step was to arrange, in conjunction with the *Radiodiffusion et Télévision Française*, a series of programmes originating from Paris for transmission through the BBC's network.

The difficulties arising from the different television standards in the two countries were successfully overcome by the BBC who evolved a " standards convertor," and in July, 1952, viewers in Britain received their first programmes from Paris. In April of the following year tests were carried out in the reverse direction over a network across France to Holland and Western Germany and the climax of European exchange was reached with the relaying of the Coronation ceremonies in June.

Since then the network has spread across Europe to Italy, Switzerland and Denmark, and schemes are afoot for extensions to the Scandinavian countries and elsewhere.

The temporary link between London and the Continent is now to be replaced in two stages by a permanent installation. The first stage will consist of a coaxial cable between London and St. Margaret's Bay, and it is anticipated that this will be in operation by the end of this year, while the second section will comprise a two-way cross-channel microwave link to be operated jointly by the Post Office and the French PTT. The surprisingly long time of three years will, it is stated, be necessary before this stage is completed, but in the meantime the permanent coaxial cable will be extended to Swingate near Dover where the BBC and the RTF will provide and operate a temporary cross-channel relay link.

On the second item, namely colour television, Sir George Barnes had, wisely, less to say, and he did no more than underline what has already been stated.

Experience in America has shown that colour television is still a long way off and an enormous number of problems have to be solved before colour television is as universal as the present monochrome system. A system of colour television has yet to be adopted for this country and a further period of some two years may be required before a decision can be reached. The end is by no means in sight when a suitable standard has been found for there immediately arises a host of other problems related to the manufacture and operation of colour television equipment.

It seems to us that the television receiver of the future, compared with the relatively simple fixed programme monochrome receiver of today, is likely to be a most complicated piece of apparatus not only to make but to maintain. And nobody has yet stated what the price of such a receiver is likely to be.

We hesitate to suggest that television design both here and in America is developing along the wrong lines, but it is apparent that an entirely new approach to the whole problem is required before colour television can be placed on a sound engineering basis. On the transmission side alone, it does seem, particularly in view of the difficulty in finding sufficient space in the appropriate wavebands, that there might be something to be gained if the responsibility were transferred to the Post Office to transmit and distribute the television service into our homes by means of cable.

The advantages at first sight are attractive. Such a method of rediffusion might bring about a considerable simplification in receiver design with consequent reduction in both maintenance and cost and it would, at the same time, provide an interference free reception.

Another advantage which should not be overlooked is that the multi-band aerial array would no longer be required and anyone who has seen, for example, the veritable forest of arrays in the Haarlem district of New York as seen from the East River, would immediately agree that this is more than a step forward.

Not the least among the advantages as far as the revenue collecting side is concerned is that the service can be disconnected if the licence fee is not paid.

The cost is bound to be high, even taking into account the savings brought about by the elimination of the chain of television transmitting stations. It may, unfortunately, be prohibitive.

A Sensitive Continuously-Evacuated Cathode-Ray Oscillograph

and its Use in Stress-Wave Measurements

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As a rule, continuously evacuated, high-speed cathode-ray oscillographs are used to record surge potentials of the order of kilovolts. In stress-wave experiments, using capacitor techniques, the durations of the transient p.d. are of the order of a fraction of a millisecond and their peak values never exceed 100mV. Using the conventional design as a basis, it is possible to develop an oscillograph which, in conjunction with suitable electronic equipment, gives ample sensitivity for stress-wave work and which gives better oscillograms than those obtained with sealed-off tubes. The apparatus has been used to investigate stress-wave phenomena in bars of rectangular cross-section and a parallel-plate capacitor unit, suitable for use with such bars, is described.

IN experiments on stress-waves in solids using the Hopkinson[1] pressure bar as modified by Davies[2], it is necessary to record small, non-recurrent transient potential differences of the order of a millivolt whose duration is 100μsec or less. The accurate recording of such p.d's. with a cathode-ray oscillograph presents a number of difficulties, mainly because the trace tends to become blurred and weak at high writing speeds. The normal technique is to use a sealed-off c.r.t. in conjunction with a video amplifier and a single-sweep time-base triggered by the transient to be recorded. During the past fifteen years or so, cathode-ray tubes of this type have been developed for recording at writing speeds of the order 25cm/μsec, but at the higher speeds, the quality of the trace tends to become poor. For permanent records, it is necessary to photograph the trace and, to avoid distortion, it is essential to use a tube with a flat screen and a camera fitted with a large-aperture lens of high quality.

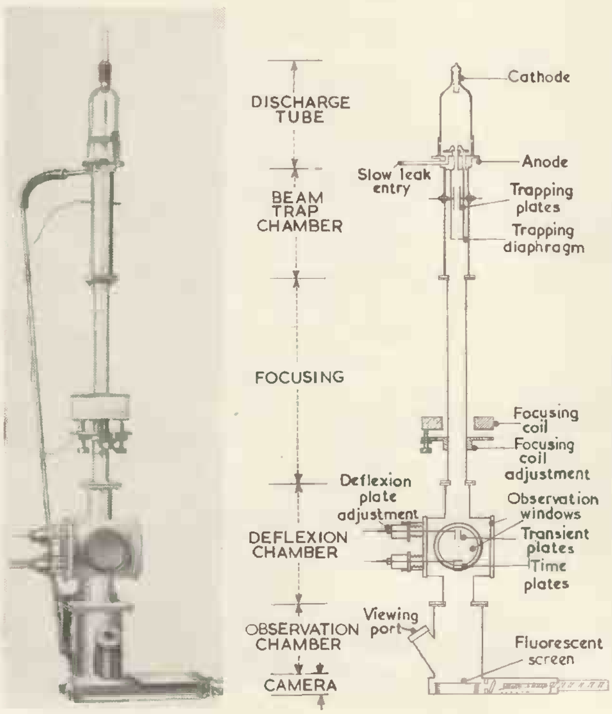

Fig. 1. The oscillograph

The forerunner of the sealed-off tube was the continously-evacuated c.r.t. which became available in usable form about 30 years ago; excellent accounts of the development and design of the instrument are given by Wood[3,4], MacGregor-Morris and Mines[5] and Miller and Robinson[6,7]. Compared with sealed-off c.r.t's., the main disadvantages of the continuously-evacuated c.r.t. are its bulk, its cost and the technical difficulties encountered in maintaining and operating it. On the other hand, the continuously-evacuated tube does possess certain advantages over the sealed-off type and these may be summarized as follows:

(a) The record is produced by the direct action of a beam of electrons on a photographic emulsion, giving greater photographic sensitivity than the normal method of photographing a trace on a fluorescent screen with a camera. Moreover, it eliminates the distortion introduced by photographing at short distances with large aperture lenses.

(b) The high accelerating p.d. normally used on continuously-evacuated c.r.t's. gives increased recording sensitivity since the photographic effect of electrons increases with their speed. It is true that the high accelerating p.d. will also reduce the deflexion sensitivity, but this effect can be counteracted by paying attention to the geometry of the system, for example, by having a large distance between the deflecting plates and the graphic plate.

(c) Since the oscillographs can be constructed almost entirely of metal and built up in demountable sections, they can be made very flexible as far as internal configuration is concerned. For example, the size, shape and separation of the deflecting plates can be changed without difficulty and the separation can, if necessary, be adjusted while the oscillograph is in operation.

In its original form, the continuously-evacuated c.r.t. was designed almost exclusively for recording high-speed transient p.d's. of the order of kilovolts and even megavolts and it was largely used for studying surge pheno-

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mena in overhead transmission lines. In stress-wave experiments, on the other hand, the transient p.d's. are only of the order of millivolts, but it was thought that by paying attention to the geometry of the oscillograph and by utilizing modern high-gain, video frequency amplifiers, it would be possible to design an apparatus which would be extremely useful for this type of work, particularly in investigating the fine-structure of dispersion effects.

In this article, an account is given of the construction and operation of a continuously-evacuated tube and of the electronic apparatus associated with it: the system gives sharp, dense traces at sweep speeds ranging from 0·05 to 1cm/μsec and it was used to study stress-wave phenomena, using the capacitor technique described by Davies[2].

The Construction of the Oscillograph

The oscillograph is built of demountable sections constructed mainly of rolled or drawn brass, the joints in the sections being hard or soft soldered. The sections are joined by bolting suitable end-flanges and the joints are made vacuum-tight by means of Apiezon wax.

The essential features of the instrument are shown in the photograph and the drawing of Fig. 1; the overall length of the oscillograph is 4ft 6in and its axis is vertical.

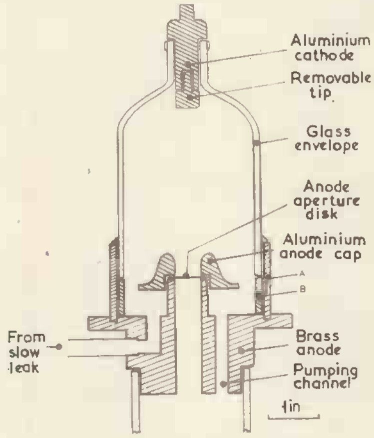

Fig. 2. The discharge tube

The electron beam is produced in the cold-cathode discharge tube shown in Fig. 2; the design of the tube is similar in many respects to the tube described by Finch and Quarrel[8,9]. The cathode is made of aluminium and it has a removable aluminium tip which may be removed for polishing when necessary. The anode consists of a massive brass block in which is set a nickel disk in which a small hole of diameter 0·15in is drilled to serve as the aperture through which the electron beam passes on its way to the fluorescent screen. The discharge tube is operated at voltages ranging from 8 to 25kV at a pressure of approximately 10^{-2}mm of mercury. It is normally run with a discharge current of 0·1 to 0·5mA, and it gives a steady and monochromatic beam of electrons from a small emitting area. The high voltage is supplied from a transformer and half-wave rectifier working into a smoothing capacitor of 2μF. A resistor of 1MΩ is connected in series with the discharge tube.

The main body of the oscillograph is kept at a pressure of the order of 10^{-5}mm of mercury by means of an oil-diffusion pump backed by a rotary pump. The higher pressure which is required for the correct operation of the discharge tube is obtained by allowing air to leak at a constant rate from a reservoir at a pressure of a few millimetres of mercury through a needle valve into the discharge chamber.

After emerging from the discharge tube, the electron beam passes through the beam trap chamber (see Fig. 1) whose function is to trap the beam when necessary and so avoid fogging the photographic plate used for recording. The beam is trapped by maintaining a high uni-directional p.d. across a pair of deflecting plates situated above a small aperture. When a recording is to be made, a pulse from the time sweep unit, initiated by the transient to be recorded, is applied to the plates of the beam trap, bringing them to a suitable potential and releasing the beam.

In order to prevent fogging the photographic plate by charged atomic nuclei ("retrograde" rays) produced in the discharge, the discharge tube is inclined slightly to the vertical so that its axis does not pass through the aperture in the beam trap chamber. When the electrostatic field is applied between the plates of the beam trap chamber to release the beam it is possible to adjust matters so as to constrain the electron beam to travel along the axis of the oscillograph and emerge through the aperture of the beam trap. On the other hand, the deflexion of the retrograde rays, because of their larger mass, is very much smaller and they cannot pass beyond the beam trap chamber.

The electron beam is brought to a sharp focus on the fluorescent screen or photographic plate by means of a magnetic focusing coil situated approximately midway between the cathode and the camera. The position and orientation of the coil as well as the magnetic flux can be varied; about 1 000 ampere-turns are required for focusing.

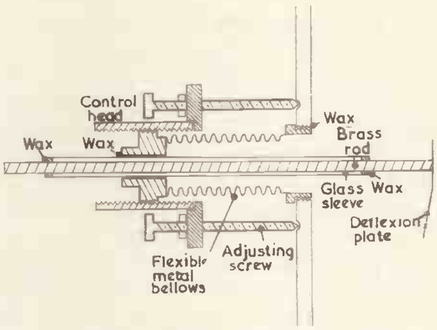

Fig. 3. Deflexion plate adjustment

The deflexion chamber of the oscillograph is designed so that the factors controlling the sensitivity can be varied. The separation of the four deflecting plates can be varied from outside the vacuum by means of a mechanism incorporating a metal bellows, shown in Fig. 3, which gives each deflecting plate three degrees of freedom. Typical values of the separation of the plates, their axial length and the distance from the centre of the plates to the photographic plate are 0·5, 4 and 30cm respectively. Two plate glass windows, set at right-angles in the deflexion chamber, enable the exact position and separation of the plates to be observed. A very thin deposit of zinc sulphide, dusted on the deflecting plates, enabled the plates to be aligned symmetrically with respect to the electron beam and also allows the width of the beam to be observed.

A viewing port is provided above the camera to enable the trace of the electron beam to be observed on the fluorescent screen before recording. The camera has already been described (Griffiths[10]) and it incorporates an arrangement whereby the screen can be replaced by the photographic plate before recording, and also an air-lock system to enable the photographic plate to be replaced without letting down the main vacuum.

Photographic Recording

The oscillogram is recorded by the direct action of electrons on the photographic emulsion and a series of tests were carried out with a number of different types of emulsion in order to find which were the most suitable. At low electron accelerating voltages (up to 10kV), the intensity of the trace was greatest when Q plates, originally developed for spectrographic work in the ultra-violet, were used. At the higher accelerating voltages at which the oscillograph is normally operated, Ilford Special Gaslight Plates were found to be the best and they were used throughout the experiments. By treating these plates in a solution of a yellow desensitizing dye (e.g., phenosafranine), they retained their sensitivity to electrons and became relatively insensitive to light and the camera could be loaded and unloaded in daylight.

The Amplifier

The peak value of the transient p.d. from a capacitor unit used in stress-wave experiments is usually of the order of 50mV and its duration is between 0·1 and 1msec. In order to record such a signal on the c.r.t. described above, it is necessary to use an amplifier with a gain of about 2 000, and to avoid distortion, the rise-time of the amplifier should be a fraction of a microsecond and the droop should be negligible for times of the order of 1msec. The circuit of a suitable four-stage resistance-capacitance coupled video amplifier is shown in Fig. 4; the design is based on a circuit given in volume 22 of the Radiation Laboratory Series[11], the main difference being in the output stage which has been modified so as to give an output swing of 150V without distortion. The gain may be varied between 400 and 2 000 by means of the variable resistor in the cathode circuit of the first valve. When the amplifier is adjusted for maximum gain, the (gain, frequency) curve is substantially flat between 200c/s and 1Mc/s; at minimum gain, the flat region of this curve extends from 100c/s to 4Mc/s. The rise-time is about 0·1μsec and the droop is about 14 per cent in 250μsec.

The Time-Base Unit

The function of this unit is to provide the p.d's. necessary to release the electron beam and to sweep it across the photographic plate when a transient is to be recorded. The circuit of the unit is shown in Fig. 5 and it provides:

(a) A single sweep of the electron beam, triggered by the transient to be recorded. The magnitude of the sweep voltage is about 1·2kV and it is symmetrical with respect to earth in order to avoid defocusing effects (in the case of the amplifier, the deflexion of the electron beam at the deflecting plates is so small that a push-pull output is unnecessary); its duration can be varied between 1 and 500μsec. (b) Shift potentials to enable the initial position of the beam to be adjusted. (c) A pulse applied to the beam trap plates (Fig. 1), which releases the electron beam just before the sweep voltage begins to operate and which retraps the beam immediately after the end of the sweep.

The various pulses are obtained from the discharge of the capacitors C through the resistors R and the mercury thyratron V which is initially in the non-conducting state and which is triggered into the conducting state by applying a suitable pulse to the terminal Y; in normal use Z and Y are disconnected, while Z and X are connected. The sweep voltage and the shift potentials are taken from the terminals X_1 and X_2 which are connected to the "time plates" shown in Fig. 1; the beam release pulse is taken from the terminal T which is connected to the appropriate trapping plate of Fig. 1, the second trapping plate being earthed. Two separate full-wave rectifier circuits are used with the time-base unit; the first provides a smoothed d.c.

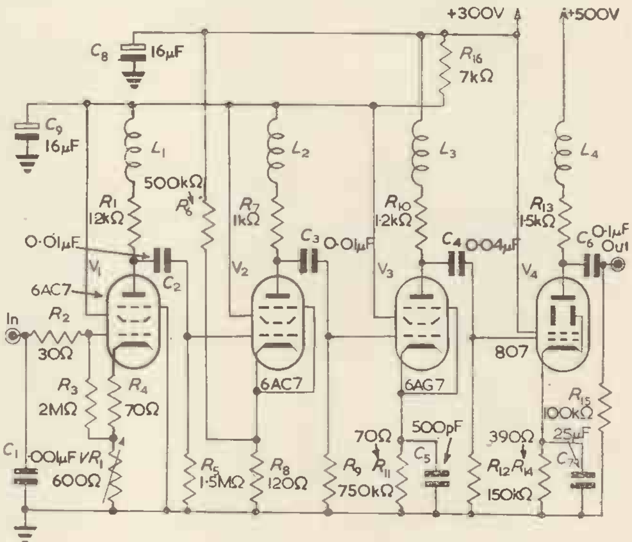

Fig. 4. The circuit of the video-amplifier

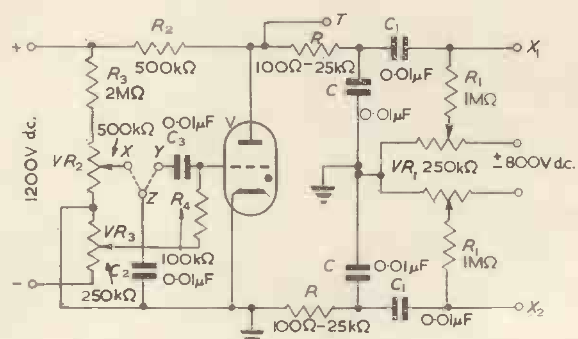

Fig. 5. The time-base circuit
V = CV12

supply of 1·2kV for the thyratron circuit and the second a similar supply of ±0·8kV for the shift potentiometer VR_1.

The pulses obtained from this unit are simple exponential pulses; the sweep on the photographic plate is calibrated by shifting the electron beam through a small distance in the Y-direction and recording a signal of known frequency immediately after the transient.

In stress-wave experiments, the initial triggering pulse, applied at Y, is taken from a simple inertia switch mounted on the pressure bar (see Davies[2]); by altering the position of this switch, it is possible to vary the time of initiating the time sweep relative to the signal from the capacitor unit.

Performance

A typical oscillogram is shown in Fig. 6.

It is seen that the traces are narrow and dense and that the deflexion sensitivity is ample; the original plates can be measured accurately with a travelling microscope.

When the oscillograph was used for experiments in which the spot was traversed across the plate at sweep speeds of the order of 0·05cm/μsec, the diameter of the anode aperture was 0·04cm and the accelerating voltage was 20kV with a discharge current of 0·5 to 1mA. These conditions gave clear records and with the transient deflecting plates at their minimum separation of 0·5cm, the deflexion sensitivity of the oscillograph was about 0·01cm/V; allowing for the amplifier with its gain of 2 000, the overall deflexion sensitivity, reckoned from the amplifier input terminals, was 0·02cm/mV. A useful criterion of the quality of the trace is obtained if the diameter of the focused spot on the photographic plate is taken as the unit of length for expressing the deflexion sensitivity, thus expressing the sensitivity in terms of trace-diameters per volt. The magnification of the electron-lens system of the oscillograph does not differ greatly from unity and the diameters of the anode aperture

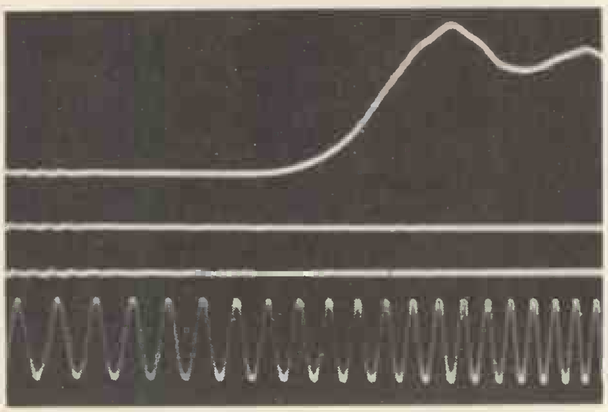

Fig. 6. Oscillogram of a pulse due to the impact of a bullet

Pressure bar : steel ; length 7ft, rectangular cross-section 4 × ⅝in.
Capacitor unit : parallel plate, area of insulated plate = one-third cross-sectional area of bar.
Upper trace : amplified p.d. from capacitor unit.
Middle traces : datum lines.
Lower trace : timing wave, period = 10μsec.

and the trace are approximately equal; the overall sensitivity of amplifier and oscillograph was thus about 0·5 trace-diameter/mV.

For higher writing speeds of the order of 1cm/μsec, deflexion sensitivity has to be sacrificed to some extent in the interest of trace density. The diameter of the anode aperture is increased to 0·1cm, the accelerating voltage to 25 to 30kV and the discharge current to about 1·5mA. Under these conditions, the minimum separation of the transient deflecting plates is 0·75cm and good oscillograms are obtained with a sensitivity of approximately 0·007cm/V at the deflecting plates, corresponding to overall values of 0·003cm/mV or 0·5 trace-diameter/mV at the amplifier input terminals.

Operation

In the initial stages of the work, some trouble was caused by the instability of the cold-cathode discharge. This was traced to the effect of the brass which was, at that time, used for the anode cap of the discharge tube (see Fig. 2); when this cap was replaced by one made of aluminium and when an anode aperture disk made of nickel was used, the trouble disappeared, the oscillograph operated satisfactorily for long periods and the discharge was stable, giving an intense beam of electrons. It was not found necessary to water-cool the anode. The only attention which was found necessary was to polish the aluminium tip of the cathode periodically; after running for a period of about 10 hours, the tip became discoloured and the discharge erratic. It is possible that a hot cathode source of electrons would be more satisfactory in this respect.

The Propagation of Stress-Waves in Bars or Rectangular Cross-Section

The main use to which the oscillograph has been put is a preliminary investigation of the propagation of elastic waves in a steel bar of rectangular cross-section, 4in by ⅝in, and 7ft long. The capacitor technique described by Davies[2] was used in the experiments and, in addition to the changes in the electronic circuits which have already been described, it became necessary to use a modified capacitor unit which is shown in Fig. 7. In this diagram *C* represents a brass plate which forms the insulated plate of the unit; *C* is mounted in a perspex block *G* which is screwed

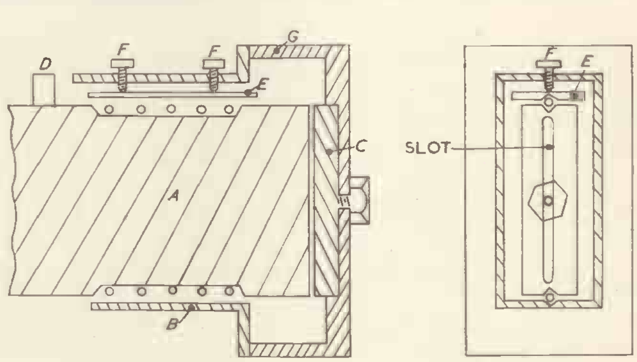

Fig. 7. Capacitor unit for use with a bar of rectangular cross-section

to the brass sleeve *B* which fits over the pressure bar *A* which is earthed. Attempts to make *B* a good sliding fit on the bar were unsuccessful and the difficulty was overcome by using steel balls, ⅛in diameter, between the horizontal surfaces of the sleeve and the bar, forming two linear ball-races as shown in the diagram. In order to retain the balls, short groves were milled in the two horizontal surfaces of *A* and in the upper horizontal surfaces of *B*; a small grooved plate *E* was fitted between the balls and the inner top surface of *B* and by manipulating the position of *E* by means of the screws *F*, the unit could be adjusted so that it would move freely, but without side-play, in the direction of the axis of the bar.

When the apparatus is used in the usual way to measure the variation of pressure with time, the change in the capacitance between *C* and the end of the pressure bar, *A*, is a measure of the average displacement of the free end of the bar. For some purposes, it is useful to be able to measure the variation of this displacement over the end and this can be done by using an insulated plate of suitable dimensions. In the present experiments, the plate *C* shown in Fig. 7 could be replaced by a square plate with the lengths of the edges equal to the width of the pressure bar; the slot in the perspex block made it possible to move this plate in the direction of the depth of the pressure bar so as to measure the longitudinal displacement of the free end, averaged over the area of the square, at different points on the cross-section.

Since the use of the apparatus and the calculation of the results have already been discussed in detail (Davies[2]), it is unnecessary to describe them here. The experimental results obtained with bars of square and rectangular cross-sections will be discussed in detail elsewhere.

Acknowledgments

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Wool Carding Control Equipment

An equipment, which measures the density of the wool web on a carding machine and controls the machine to provide uniform slubbings, has recently been developed by Lancashire Dynamo Electronic Products Ltd, in association with Mr. C. Liversidge, of James Watkinson & Sons Ltd, and the Wool Industries Research Association. A prototype equipment was subjected to lengthy tests on a carding machine in the laboratories of W.I.R.A. at Torridon and also at the Washpit Mills of James Watkinson & Sons Ltd, and the equipment as a whole has received the approval of the Association as providing accurate control of slubbings produced on a Woollen Carding Engine.

The complete control equipment is now being produced by Lancashire Dynamo Electronic Products Ltd, under licence from the Wool Industries Research Association, being covered by provisional patent 21598/51.

The principle of controlling the carding machine is based on the following facts.

(a) The change of intensity of light after passing through the wool web is closely proportional to the change in weight per unit area of the web.

(b) The weight per unit length of slubbings from the whole width of the web is approximately proportional to that of a few ends of slubbings sampled from the centre of the web.

(c) Variation in condenser speed in relation to the remainder of the machine will alter the thickness of the web, i.e. if the speed of the condenser and final doffer is increased in relation to the remainder of the machine, a thinner web will be produced, conversely a thicker web will be produced for a reduction in condenser and doffer speed. Furthermore, the slubbing count in skeins can be considered as directly proportional to the doffer speed.

In the equipment a photo-electric cell is used to measure the degree of attenuation of a beam of light passing through the web, the output of the photo-electric cell being amplified and ultimately used to control an electric servo-motor which varies the ratio of an adjustable ratio transmission unit inserted in the drive between the swift and the doffer and condenser. The speed of the latter section of the machine is thus varied with respect to the speed of the swift in order to provide a product of approximately constant weight at all times.

The complete system is divided into three sections, the measuring section, the recording section and the controlling section.

The installation can be provided in two forms, one being complete and incorporating all three sections, i.e., measuring, recording and controlling and the second form for those cases where fully automatic control is not required, incorporating only the measuring and recording sections.

The latter form of the equipment is of great assistance in setting up the card for minimum variations, even though the fully automatic control system is not used. The incorporation of the recorder in this arrangement is of major importance, however, since it allows a quick check to be made on the effect of making adjustments to the various parts of the card during setting up for any blend.

Physically the equipment comprises three units; a floor mounting cubicle which houses the measuring section, recording section and controlling section as required for the particular type installation; a head unit and reflecting mirror unit for mounting on the machine and servo controlled variable ratio transmission unit which provides the speed adjustment between the appropriate sections of the machine.

A common head unit for mounting on the machine houses the measuring photocell and the stabilized light source, the light being directed through the wool web to a reflecting mirror beneath the web, and back through the web again to the photocell. The wool web attenuates the light reaching the cell, the degree of attenuation providing an indication of the density of the wool, i.e. weight per unit area. Pre-set controls are included to enable the equipment to be adjusted for stable operation on white, black or coloured wools. A further control governs the weight of wool produced, this adjustment being made at the photo-electric head unit.

In order to ensure that variations in the intensity of the light source and changes in the sensitivity of the photocell do not affect the operation of the system, a self checking arrangement has been introduced which regulates the lamp intensity to compensate for errors which would otherwise be introduced.

The system is arranged so that a rotating shutter in the head unit causes the photocell to alternately observe first the light source directly and then the light which passes through the web and is reflected back by the mirror unit.

During the period when the light falls directly on the photocell the control circuits regulate the light source to maintain constant illumination at the photocell and during the period when the web is observed, the control circuits operate, as will be outlined below, to adjust the web density to again maintain a constant light level at the photocell. In this way, the density of the web is held constant.

In order to provide an adjustment of web density, a variable density optical element is introduced into the direct path from the light source to the photocell. If the density of this element is increased, the circuits automatically controlling the lamp will increase its brilliance to return the light intensity at the photocell to the original level. As a consequence, in order to maintain the intensity of illumination at the photocell constant when the light passing through the web is observed, the control circuits will increase the web density until balance is again achieved.

During the period before correction, when the illumination at the photocell has deviated from the normal value, an "error" signal is produced indicating that the web density is incorrect and it is this "error" signal which operates the correction circuits.

A Precision Dynamic Balancer

(For Small Gyroscopes)

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The problem of dynamic balancing is briefly discussed and a comparison is made between resonant and non-resonant types of balancers. An account is given of the development of a new balancer of the non-resonant type. A prototype model made for use on miniature electrical gyros is capable of indicating the position and magnitude of out of balance forces of less than 0·1mg.cm, and is extremely simple and rapid to operate.

In a gyroscope the rotor is driven about its axis of rotation, the axis determined by the position of its bearings. There is also another axis through the rotor, the axis of gravity, which passes through the average of the centres of gravity of successive thin sections of the rotor. When the axes of rotation and gravity do not coincide the rotor is said to have dynamic out of balance and will generate undesirable vibrations when spinning. By the addition or removal of masses at suitable points on the rotor it is possible to modify the axis of gravity until it coincides with the axis of rotation. The function of a dynamic balancer is to indicate the position and magnitude of the correcting masses needed to effect this.

It can be shown that any desired shift in the axis of gravity can be achieved by applying suitable correcting forces to any two points along the axis, preferably spaced as far apart as possible. In a gyroscope the two side faces of the rotor are normally chosen as the correction faces, the usual procedure being to drill holes in them at the correct angular position and of the desired depth. To effect this a dynamic balancer has to perform the following operations:

(1) To resolve the out of balance distributed along the axis into two equivalent out of balance couples located on the correcting faces and to separate their effects so that each can be measured independently of the other.

(2) To indicate the amount of metal to be removed by measuring the magnitudes of the vibrations caused by each couple.

(3) To indicate the angular positions of the points from which metal is to be removed by measuring the phases of the vibrations relative to that of a known angular position on the rotor.

Types of Balancer

Dynamic balancers may be broadly divided into two categories—resonant types, where the rotor is mounted in a suitable resonant fixture and tested while being driven at a speed equal to the resonant frequency of the system, and non-resonant types, where the operating speed is remote from and generally higher than the frequency of the main mechanical resonances.

Resonant balancers have the following advantages and disadvantages, as compared with non-resonant types.

ADVANTAGES

(1) Higher sensitivity, as mechanical amplification of the vibration to be measured is obtained at resonance.

(2) Easier separation of the effects of the two correction faces as this can be achieved by utilizing a system which oscillates about a fixed axis, and mounting the rotor so that one of the correction faces lies in a plane containing this axis.

DISADVANTAGES

(1) Position indication is more difficult as there is a rapid change of phase-angle when passing through resonance.

(2) Accurate speed control is needed to maintain a constant testing speed.

(3) Extraneous vibrations and internal vibrations of a transient nature, e.g. bearing noise, generate oscillations of resonant frequency for all rotor speeds, thus introducing a masking effect which presents a practical limit to the sensitivity of which the system is capable.

(4) The magnitude of the vibration and hence the calibration of the balancer depends on the damping of the system, which can often be a rather variable quantity.

When developing a dynamic balancer for use on small electrical gyroscopes it was decided to concentrate on a non-resonant type as being fundamentally more accurate and easier to operate. Development of a suitable balancer raised the problems firstly of devising a mechanical system which allowed accurate separation of the effects of the two correcting faces, and secondly of evolving a method of measuring accurately, in both magnitude and phase, the minute vibrations of fundamental frequency (i.e. once per revolution of the rotor) when masked by the much larger vibrations due to bearing noise, etc. An idea of what the latter involves may be given by the fact that a typical signal-to-noise ratio for an out of balance of 1mg.cm, measured on a moving coil pick-up, is of the order of 1 : 100.

In an electronic balancer there are usually two main units: the mechanical unit, which comprises a suitable resilient fixture in which the rotor is mounted and driven, together with the transducers necessary to detect the vibrations and convert them into electrical quantities, and the electrical unit, in which the transducer outputs are measured.

The Mechanical Unit

THE MOUNTING SYSTEM

Early attempts to produce a balancer were based on methods used in some commercial resonant balancers, where the gyro is mounted in a cradle which is clamped in a resonant fixture having only one degree of angular freedom, the mounting being such that the axis of oscillation lies in the plane of one of the correction faces. While such a system worked well at resonance, at other

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frequencies it gave very erratic results, depending on the tightness of the clamping of the gyro in the fixture, etc., and did not separate the effects of the two correction faces properly.

The method finally used[1] was that of free suspension, where the gyro is mounted in a fixture which allows vibrations in all directions. With a system of this nature it is possible to obtain accurate separation of the effects of the two faces by correct positioning of the vibration pick-ups, or by suitably mixing their outputs.

The Dynamics of a Freely Suspended Gyroscope

Consider a system as shown in Fig. 1 in which a perfectly balanced symmetrical gyroscope runs in spring restrained bearings, the springs being of the same stiffness in all directions in a plane at right-angles to the gyro axis of rotation, and having negligible damping. To this system is applied an out of balance mass m rotating at a radius r, and at a distance b from the centre of gravity G of the vibrating system.

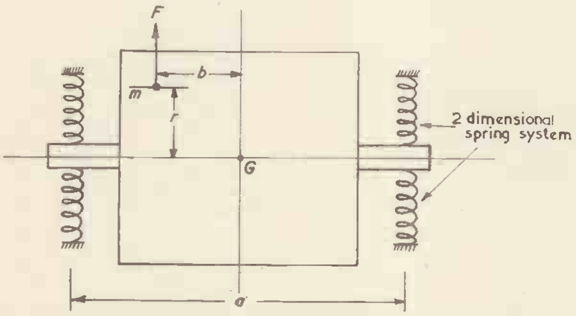

Fig. 1. Gyroscope running in spring-restrained bearings

Let M = the total mass of the system, including clamps, etc.

I = the moment of inertia of the whole system about an axis at right-angles to the shaft axis, and passing through G.

J = moment of inertia of gyro rotor about its axis of rotation.

S = stiffness of support at the end of the shaft in any direction in a plane at right-angles to the shaft axis.

a = distance between supports.

F = the centrifugal force generated by the unbalanced mass m

$= mr\omega^2$.

ω = angular speed of the rotor.

The effect of the force F on the system is the same as a parallel force F acting at G plus a couple $F.b$ acting about G. If the system is linear their effects may be calculated separately and added.

Analysis along these lines yields the following results:

1. Due to the force F at G, G is displaced by an amount x which has a value in any plane, say the vertical plane, of:

$$x = \frac{mr \cos \omega t}{2S/\omega^2 - M} \qquad (1)$$

and which has a resonant frequency when:

$$\omega^2 \; (= \omega_T^2) = 2S/M \qquad (2)$$

This is the lower, or transverse resonant frequency.

2. The precessional forces developed by the gyroscope have to be taken into account when considering the couple Fb, the effect of which is to rotate the axis, in any plane, through an angle:

$$\theta = -\frac{mrb \cos \omega t}{Sa^2/2\omega^2 - (I - J)} \qquad (3)$$

This has a resonant frequency, the upper or rotational resonance, when:

$$\omega^2 \, (= \omega_R^2) = \frac{Sa^2}{2(I - J)} \qquad (4)$$

When $\omega \gg \omega_R$ and $\omega \gg \omega_T$ the stiffness term may be neglected. Then, considering, say, the vertical plane, the centre G is displaced by a maximum amount:

$$x = mr/M \qquad (5)$$

when the axis is tilted through a maximum angle:

$$\theta = \frac{mrb}{I - J} \qquad (6)$$

From this (see Fig. 2) it can be seen that the system will oscillate in the vertical plane about the point O, where the distance:

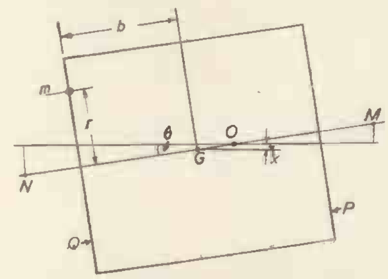

Fig. 2. Analysis of displacement

$$GO = x/\theta = \frac{I - J}{M.b} \qquad (7)$$

the point G moving along the circumference of a circle of radius mr/M.

The above results show that the position of the point O is a function only of the constants of the gyroscope and of the distance b, i.e. it is independent of the amount of out of balance. An out of balance mass located on the correction face of the rotor, when the distance b is a constant, will, in any one plane, oscillate the axis about a fixed centre O through a maximum angle proportional to the out of balance mass.

An experimental mounting system utilizing these properties was built up and proved very successful. The general arrangement is shown in Fig. 3. The gyro was clamped in blocks (2) which were bonded to soft rubber suspensions (3), in turn bonded to a rigid framework (4, 5). The gyro was run up to a speed well beyond the upper resonant frequency, and the vibrations due to the out of balance were transmitted to the electrical pick-up (8) via a rigid arm (6) and a thin wire connecting rod (7). This flexible coupling ensured that only movements in the vertical plane were transmitted to the pick-up, horizontal movements merely causing flexing of the wire.

The point of attachment of the wire (7) to the arm (8) was made in line with the point O, discussed above, the position of which could be calculated from the constants of the system. For the gyroscope under consideration it was about one-quarter of the length of the rotor from the centre point. Out of balance on the face (11) should then have no effect on the pick-up. In setting up the system an out of balance mass was applied to the face (11) of an otherwise balanced gyroscope, and the pick-up and point of attachment of (7) to (6) were moved slightly in an axial direction until the position for minimum pick-up output was found. No great difficulty was experienced in obtaining a rejection ratio of 20 : 1, the rejection ratio being the ratio between the pick-up output caused by an out of balance mass on face (12), and that from an equal mass on face (11).

This method of balancing gyros was quite successful, the gyros being tested by first measuring the out of balance on one face, and then reversing the gyro in its cradle and testing the other face.

To avoid the need for stopping the rotor and reversing it in its mounting, and also to make the system more flexible as regards use with other sizes of gyro, a rather different system was used in the final version. This used two pick-ups, and achieved the same results by electrical mixing of their outputs[2].

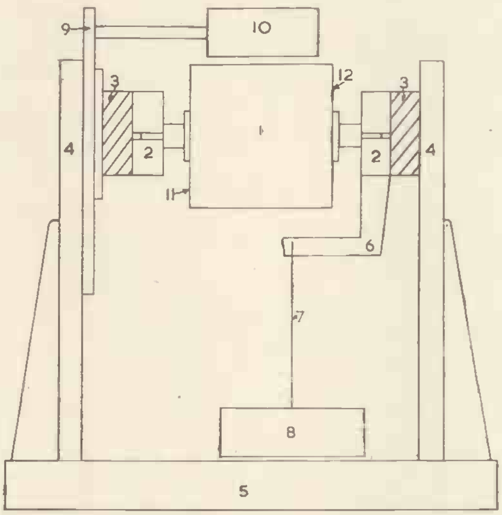

Fig. 3. Simplified mechanical arrangement of dynamic balancer

(1) Gyroscope under test, (2) clamping blocks, (3) rubber mounting, (4) supporting brackets, (5) base, (6) rigid arm, (7) piano wire connecting rod, (8) moving-coil pick-up, (9) rotating disk, (10) position pick-up (lamp and photocell), (11 and 12) gyro correction faces

Referring again to Fig. 2, suppose there are two pick-ups to measure the displacement of the axis, located at the points M and N, equal distances from the centre G. For the case shown of an out of balance mass on the face Q of an otherwise balanced rotor, the output E_N of the pick-up at N will be proportional to the distance ON, say $K \, . \, ON$, and that of pick-up M, E_M, to the distance OM, but of opposite polarity, i.e. will equal $-K \, . \, OM$. If the outputs from the pick-ups are mixed so that $E_N + \alpha E_M$ is fed into one channel, and $E_M + \alpha E_N$ into the other, and the ratio α is made equal to OM/ON, then the total voltage in channel 1 will be:

$$K \, . \, ON - K \, . \, OM \; OM/ON = K\frac{(ON^2 - OM^2)}{ON} \quad . \quad (8)$$

while that in channel 2 will be:

$$K \, . \, ON \, . \, OM/ON \; - \; K \, . \, OM \; = \; 0 \; \ldots\ldots \; (9)$$

From this it is seen that any out of balance on face Q has no component of output in channel 2, while out of balance on face P has none in channel 1 for a symmetrical system. Thus by correct setting of the ratio α it is possible to separate the effects of the two correction faces, selecting either at will by means of a simple changeover switch, without the need for reversing the gyro in its mountings.

Once determined, the ratio remains fixed for that size of gyro. For other types it will most likely be necessary to use a different attenuation ratio. In practice this can be easily arranged by switching or by using a calibrated attenuator.

The final version of the balancer is similar in general arrangement to that of Fig. 3 except that, as stated, two vibration pick-ups are used. These are connected, via flexible connecting rods, directly to the gyro clamping blocks. By mounting them in the horizontal plane instead of the vertical, it was possible to use a suspension which was stiffer in the latter direction, where it has to support the weight of the gyro, than in the former, in which the desired vibrations are measured. This allows a lower resonant frequency without too much sagging of the mounts due to the weight of the gyro, a minor defect of the earlier model. A simple but effective mounting was obtained by cementing vertical strips of hard rubber to the edges of a block of sponge rubber, and bonding these composite suspensions to the clamping blocks and the frame.

Other features of the final version are that one of the clamping brackets can be moved axially to accommodate different lengths of gyro, quick release clamping blocks are used to facilitate testing, and the whole unit is resiliently mounted to reduce the effects of external vibrations.

The Electrical Pick-ups

To reduce the effects of bearing noise, which are mainly of a higher frequency than the operating speed, and to make the system more independent of speed variations, a displacement type pick-up is to be preferred, i.e. one in which the voltage generated is proportional to the amount by which the pick-up is displaced. Possible types are electro-magnetic and capacitance with a.c. polarization. piezo crystal, carbon and strain gauge. The first two had been tried in earlier attempts to make a balancer but, though sensitivity can be high, they suffer from the disadvantages of the need to extract the modulating frequency from the carrier, and are critical as regards relative position between fixed and moving parts. Carbon pick-ups are sensitive but not very consistent, and in the form tried introduced too much stiffness to the system. Piezo crystals have not been tried, but probably have similar disadvantages.

The main types of velocity pick-up are moving-iron and moving-coil. The moving-iron is normally more sensitive, but it is more critical as regards relative armature position and usually introduces more mechanical stiffness and is more prone to electro-magnetic pick-up than the moving-coil.

The type of pick-up used in the final balancer was a moving-coil, in the form of an insert taken from moving-coil headphones. In this form it is dustproof and reasonably robust, has low mechanical stiffness, gives a signal of low distortion which should be quite consistent as it is not greatly affected by small changes in the position of the coil, and will handle large vibrations without overloading. While its output is not very high compared with some types, it is high enough to allow easy amplification by step up input transformer and amplifier. Moreover, by adding a suitable stage of integration, a velocity pick-up can be easily converted into the equivalent of a displacement type.

Position Pick-up

For the electronic system developed it is necessary to generate a voltage reference pip once per revolution of the rotor, triggered by some known point on the rotor, which can be varied in phase relative to that of the out of balance vibrations. This is done by painting a non-reflecting line on a known position on the outer periphery of the rotor. Light from a small lamp is directed on to the surface of the gyro, from which it is reflected on to a small layer type photocell. Thus every time the line on the gyro passes under the photocell a voltage pip is generated. The lamp and photocell assembly (10) is carried by a disk (9) which can be turned by hand coaxially with the gyroscope so that the phase of the reference pip can be varied relatively to that of the vibration pick-up output. (See Fig. 3).

An earlier method which was quite satisfactory though not quite as flexible, was to replace one of the non-magnetic screws of the gyroscope by a steel one, and detect the presence of the steel one when it passes a suitable electromagnetic pick-up.

The Electrical Unit

The function of this unit is to extract the fundamental component due to the out of balance from the various frequencies generated by the vibration pick-up, to measure its magnitude, and, from its phase-angle, to determine the angular position of the out of balance. Earlier attempts at a dynamic balancer made use of sharply tuned filters, tuned to the testing speed of the rotor. This method, however, suffers from the disadvantage that the speed needs to be very accurately controlled, as slight variations in speed not only affect the apparent magnitude of the out of balance, but, more important still, they cause large phase shifts, with consequent position errors, i.e. electrical tuning introduces many of the disadvantages of mechanical tuning.

The method which has been used in the present equipment is to detect the fundamental by means of a phase sensitive detector. When the vibration signal is applied to the detector, which is polarized by a square wave locked in frequency to the speed of the rotor, the mean d.c. output, indicated on the out of balance meter, is a function only of the out of balance signal and the relative phase between polarizing voltage and out of balance. With the exception of odd harmonics of the fundamental no other frequency applied to the detector will give a mean d.c. output. Odd harmonics give an output reduced by a factor equal to their order by comparison with the fundamental.

The system used can be explained more fully with reference to the block diagram Fig. 4. The gyro is clamped in the test fixture and run up to the chosen operating speed. The position pick-up (1), in the present case a photoelectric cell, generates a voltage pulse once per revolution of the rotor, when the dark line on it interrupts the light beam. In addition there are other spurious voltages of lesser magnitude due to lack of uniformity of the reflecting face of the gyro, and to a.c. pick-up. This signal is amplified by transformer (2) and electronic amplifier (3), and then fed to a second stage of amplification (4) which is biased beyond cut-off so that the unwanted lower magnitude signals are suppressed, the output being in the form of a pulse once per revolution of the gyroscope.

This voltage pulse is used to trigger an asymmetrical multivibrator (5). In its free running state the multivibrator passes alternate approximately flat topped pulses of current through one or other of its valves, in one valve for a predetermined fixed period of time equal to half the period of the chosen operating frequency, and in the other for a much longer time. As the gyro is run up to speed, the trigger pulse progressively reduces the period during which the second valve is conducting until, at the correct operating speed, it is equal to the fixed period of the first valve. The multivibrator output is then of the form of an alternating voltage with flat-topped symmetrical waveform, locked in phase and frequency to the reference line on the rotor.

The output from the multivibrator is used to polarize a suitable phase sensitive rectifier circuit. In addition, the difference between the outputs of the two valves is applied to a centre zero d.c. measuring instrument (7). At the correct gyro speed, the mean output has no d.c. component and the meter reads zero. At speeds respectively above and below the chosen speed there is a positive or negative d.c. component which is shown on the meter, so that the meter may be calibrated in terms of rotor speed.

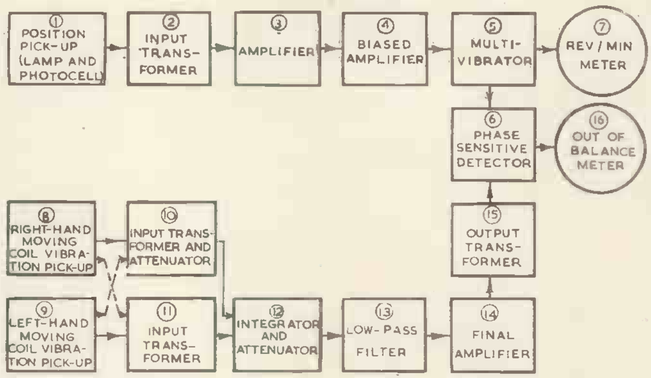

Fig. 4. Arrangement of electrical equipment of dynamic balancer

The outputs from the vibration pick-ups (8) and (9), after transformer amplification, are mixed in the right proportion to eliminate the effect of the side not being tested, and applied to a simple electronic integrator. This converts the signal into one equivalent to what would have been generated by a displacement type pick-up, i.e. of magnitude independent of speed.

The low-pass filter (13) is designed to cut-off sharply just higher than the operating frequency; so that any harmonics of the fundamental, most of the bearing noise, and any 400c/s pick-up from the gyro energizing supply are heavily attenuated. This prevents them from overloading the phase sensitive rectifier on the more sensitive ranges. After filtering the signal is passed via a final amplifying stage (14) and transformer (15) to the phase sensitive detector (6).

The practical details of the circuit are shown in Fig. 5. The first half of V_1 is a straightforward amplifying stage, while the second half is biased beyond cut-off to suppress the unwanted signals from the photocell. V_2 is the multivibrator stage, triggered via the small coupling capacitor C_5. The output from the multivibrator is taken from the cathodes, and polarizes the half-wave phase sensitive rectifier arrangement of $R_{13,14,15,16}$, VR_4, MR_1 and MR_2.

In the signal channel a preset portion of the output from the pick-up on the side not being tested is added to the output from the other pick-up via the mixing network $R_{21}R_{22}$, and applied to the integrator stage V_{3a}. Six ranges of sensitivity are provided by switching in any of six feedback capacitors, each step changing the sensitivity by a factor of 3.

Heavy attenuation of all frequencies above about 300c/s is provided by the next stage, a single stage modified parallel-*T* network feedback amplifier. The signal is then amplified in the output stage V_4, and applied via output transformer T_4 to the phase sensitive rectifier, the mean d.c. output of which is indicated by M_2.

A simple power supply using a small metal rectifier for reliability provides the h.t. current, which is only about 15mA total. It was found desirable to energize the lamp with d.c. as the ripple generated in the photocell when a.c. energized tended to swamp the position " pip ". This d.c. is provided via a second metal rectifier, the degree of smoothing provided by the simple *RC* filter proving adequate.

designed. Choice of operating speed is dictated by the conflicting requirements of a speed low enough to allow rapid run up to speed to reduce balancing time and to enable any 400c/s pick-up from the gyro energizing supply to be eliminated by the top cut filter, and a speed high enough to be well above the top resonant frequency of the system.

With the rotor cruising at the chosen operating speed, the multivibrator potentiometer VR_2 is adjusted till the periods of each half of V_2 are equal. VR_3 is then adjusted until the polarizing voltage to the phase sensitive rectifier has no mean d.c. component, i.e. until M_1 reads zero. M_1 may then be calibrated for other speeds on either side of the operating speed. For balance calibration a known out of balance is applied in line with the line on the

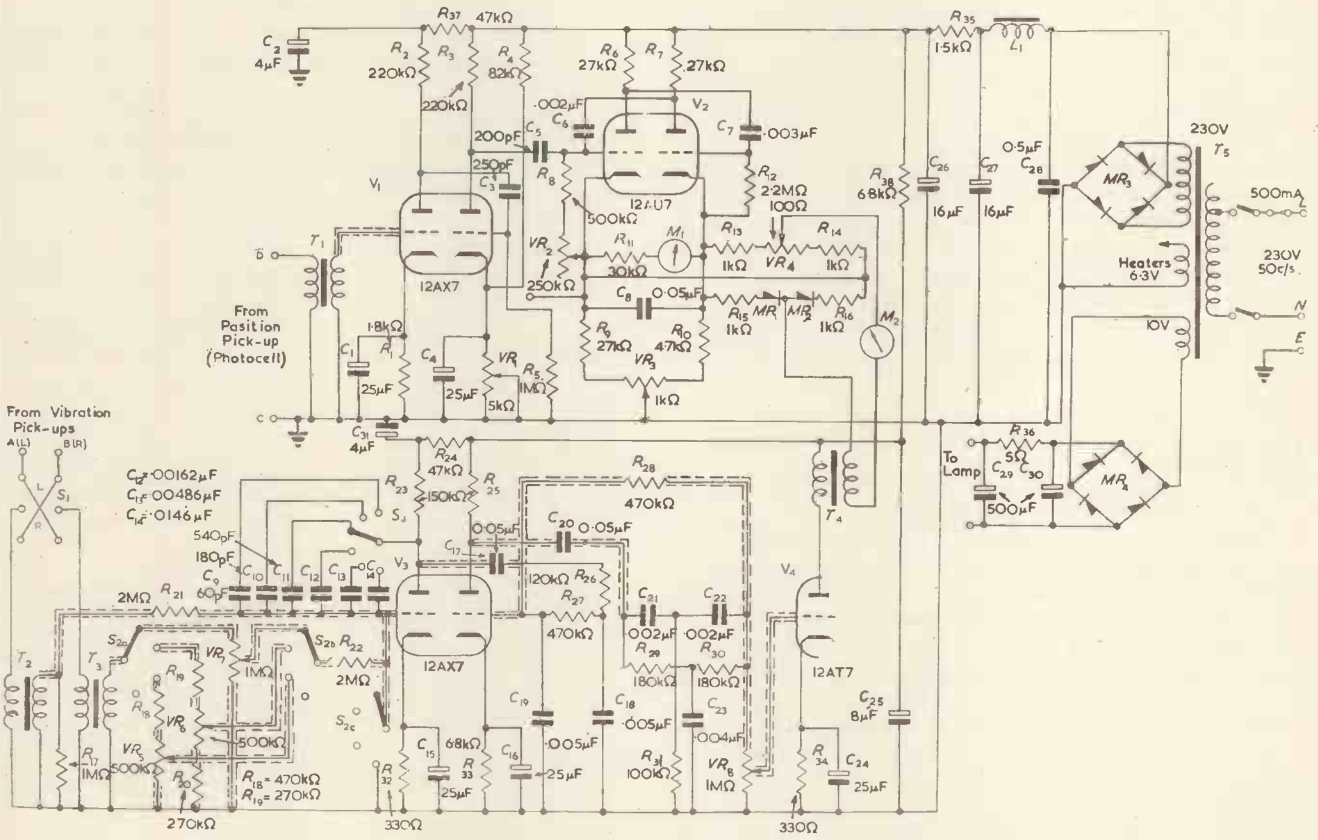

Fig. 5. Circuit of dynamic balancer

Beyond the screening of the low signal level leads, no special precautions were taken with wiring and layout, as the system is insensitive to any but an excessive amount of mains hum. The complete unit is mounted in a case 14in by 10in by 9in.

Calibration

A non-reflecting line about $\frac{1}{8}$in wide is painted or applied by rubber stamp to the periphery of the rotor. If the line has to be removed after balancing, its weight should be as little as possible. The gyro is run up to speed and the bias potentiometer VR_1 adjusted if necessary to obtain perfect synchronization of the multivibrator throughout the speed range.

An operating speed of 16 000rev/min was chosen for the small gyro's types A and B, weighing approximately 400 and 200g respectively, for which the equipment was

periphery to, say, the right-hand face of an otherwise balanced gyro, which is then run up to speed. With the changeover switch to "left" the potentiometer VR_5 (for gyro A) is adjusted until a minimum out of balance is indicated. VR_5 can then be locked. With the changeover switch to "right" the balance meter, coupled with the appropriate setting of attenuator S_3, may then be calibrated for a wide range of balance weights, the disk (9) (Fig. 3) carrying the position pick-up being turned by hand until a maximum out of balance is indicated. For position calibration the disk is then turned in the same direction as the gyro is rotating until the balance meter reads zero. The disk is provided with a degree scale, with a fixed pointer mounted on the frame of the balancer. Their relative positions should be such that at this point the pointer should be in line with the zero on the scale.

It will be appreciated that, as the position pick-up is turned through 360° (in practice, stops limit the travel to about 350°) two null positions will be obtained. Hence, to avoid ambiguity it is necessary to specify the direction of rotation of the pick-up and also the change in the balance meter reading from positive to negative. The position for maximum out of balance reading could alternatively have been used to calibrate for position without risk of ambiguity, but the null position is much more accurately defined than the maximum.

Balancing Procedure

When testing a new gyro a line is first marked on the periphery and the gyro is then clamped in the fixture and run up to 16 000rev/min, when the supply voltage is reduced sufficiently to let it coast at this speed. With the selector switch at "left" the position pick-up disk is turned until a maximum positive reading is obtained, which is noted together with sensitivity range. The disk is then turned to the correct null, and the angular reading on the degree scale noted. The changeover switch is set to "right" and the procedure repeated. When the gyro is at rest the drilling position may be marked on it, at the same angle from the calibration line as given by the scale reading. Alternatively, the drilling position could be selected automatically by placing the gyro in a suitable drilling jig with degree calibration. The out of balance reading is converted directly into depth of hole to be drilled by a calibration chart. A standard drill accurately ground to a 90° angle is used for drilling. This procedure is repeated until the desired accuracy of balance is obtained.

Performance

Accuracy

Very satisfactory results have been obtained with the balancer. At its present setting the out of balance ranges for the larger gyro type B are from approximately 450mg f.s.d. (Range F) to 2mg f.s.d. (Range A) for weights at a radius of 1·5cm. Greater sensitivity could be easily obtained (the attenuator VR_8 is at approximately mid position), but is not considered necessary with the present gyros, as vibration due to bearing noise is much greater than that caused by 2mg out of balance. Gyros have, however, been balanced to 0·2mg.cm, and a quite well defined out of balance reading could still be obtained, showing that the balancer is capable of still greater accuracy. In practice this is not possible as the gyro will not maintain an accuracy of balance much less than ½mg.cm, which is not really surprising when it is realized that this is equivalent to a shift in the axis of rotation of only 1 millionth of an inch. With the smaller type A gyro the sensitivity is approximately twice as high.

The operating speed is not critical as there are no large frequency dependent phase shifts developed in any part of the signal channel. Moreover, the small phase shift introduced by the combined effects of the mechanical system, transformers, filters, etc., is largely cancelled out by an effective phase shift in the opposite direction of 0·9° per 1 per cent change of speed brought about by the use of an asymmetrical multivibrator for polarizing the phase sensitive rectifier. Errors in speed setting of 1 000rev/min cause an error in apparent position of the out of balance of only 2°. With the aid of the speed meter, which is calibrated for the range 10 000 to 22 000rev/min, no difficulty whatsoever is experienced in holding the gyro speed to ±200rev/min.

Position indication is very accurate and with a moderate out of balance, results can usually be repeated to within 2°.

Consistency

Criticisms have been made of the use of rubber for the suspension, on the grounds of long term stability. It should be realized, however, that provided the operating speed is at least 50 per cent higher than the upper resonant frequency, the calibration of the system depends almost entirely on the inertia of the moving system, and is almost independent of the stiffness and damping of the mounting. In the course of development, a wide range of different types of rubber mountings have been used, but change of rubber has never had more than 5° effect on the zero calibration, and has had little effect on the magnitude.

In the form used the rubber mounting has the advantage of compactness, while the rubber to metal bonding ensures there are none of the inconsistencies due to end effects experienced with some types of spring mounting. By providing inherent damping the vibrations at mechanical resonance are much less than with an undamped spring system, making the system much less sensitive to external vibrations.

In the signal channel of the electrical unit the first two stages have heavy negative feedback and their gain should not change, though there might be slight change of gain in the output stage due to valve ageing etc. However, it will be a simple matter to make periodic tests on the equipment with a known out of balance, and re-set the gain attenuator VR_8 if necessary.

Being a null indicator, the speed meter is inherently accurate at the testing speed. Accuracy at other speeds is not required. Nevertheless, occasional checks since calibration have indicated that it is reliable to about 2 per cent.

Separation of Out of Balance

With optimum setting the rejection ratio between the side being tested and the side not being tested is about 20:1. Particularly in the case of the larger gyro this optimum setting, which involves the subtraction of two nearly equal quantities, is rather speed sensitive, so, from this point of view it is desirable to maintain the speed to within ±200 rev/min for the best results, particularly when the side being tested has a much smaller out of balance than the opposite side.

External Vibrations

Despite the electronic integrator which amplifies the lower frequencies relative to the high, the use of the phase sensitive detector together with the damping provided by the rubber suspension make the system practically immune to external vibrations. The only effect of a heavy blow on the bench on which the balancer is stood is a slight kick on the balance meter when on the most sensitive range.

Operating Time

A gyro can be clamped in the fixture, electrically connected, run up to speed, tested on both faces, stopped and removed in some 2 to 3 minutes. Assuming an average of three drillings to reduce the out of balance from an initial, say, 200mg.cm to 2mg.cm, one machine should be capable of balancing about 50 gyros per day.

Other Applications

The balancer was developed specifically for two sizes of gyro. At the same time, however, the fixture was designed to accommodate gyros of up to 3in total length and 3in diameter, although in many cases it might be desirable to modify the stiffness of the rubber mounting system and/or the operating speed. The design allows easy interchange of different mounting and clamping systems.

Difficulties might be experienced with those types of gyroscope which have a large diameter compared with their axial length, as this results in a high rotational moment of inertia, J, compared with the transverse moment of inertia I. This has the disadvantages that, as J approaches I, the upper mechanical resonant frequency is raised (see equation (4)), also that the distance GO (Fig. 2) becomes smaller (see equation 7)), resulting in a higher mixing factor α, which makes accurate separation of the effects of the two faces more difficult. The upper resonant frequency may be lowered by reducing the stiffness of the mountings. A better method, however, is to increase I by adding mass to the balancer clamps. This not only lowers the resonant frequency, but at the same time reduces the mixing factor.

The electrical unit is not restricted to the balancing of gyroscopes, and, with a suitable mechanical unit could be used to balance rotors, shafts, etc. One application for which it has been used successfully has been the dynamic balancing of a radar aerial.

Future Developments

While being considered quite satisfactory for its purpose it would no doubt be possible to make further improvements to the equipment. For instance, the last stage of signal amplification V_4 could be replaced by a higher gain amplifier with negative feedback to stabilize the gain.

Other improvements to the electrical system would depend on whether the balancer is to be of the present specialized type, operating at one chosen speed, or whether it is wished to make the equipment more universal. In the former case sensitivity might be improved by replacing the top cut filter by a band-pass filter, so arranged as to reduce any interference effects from lower frequency bearing noise emanating from the bearing cage or from vibrations at the resonant frequency. In the latter case the "set operating frequency" control VR_2 could be provided with a scale calibrated in speed, and made to cover a wider range, while the speed meter would be calibrated only in percentage departure from selected speed. This arrangement would allow some choice of operating speed to suit the gyro being tested.

The expedient of artificially increasing the inertia I might be further developed to produce a balancer in which the point(s) O coincided with the point of attachment of the pick-up(s) M (and N). In this case no electronic mixing would be required, as each pick-up would respond only to the out of balance from its own side. Fine adjustment of I, to ensure accurate selection, could be readily achieved by arranging that the position of the added mass, or of part of it, could be adjusted in an axial direction. The limit to the amount by which the inertia I can be increased will be brought about by the fact that the rotor out of balance will have to vibrate this added mass via the gyro clamping, so with large inertias there is a risk of inconsistent results unless the gyro is clamped very tightly. In the present equipment simple finger tight clamping of a knurled nut is all that is needed for consistent results.

Conclusion

Despite its present semi-experimental form the balancer is proving both accurate and extremely simple to operate. So far as is known it is capable of an accuracy as high as that of any other type, yet it is simpler in construction and less critical as regards operating speed and external vibrations than other balancers of comparable accuracy.

Acknowledgments

The author would like to thank his colleague Mr. G. M. Russell for his valuable contributions on the theory of unbalanced gyroscopes. Permission to publish the results of work carried out in their Development Laboratories was kindly given by the management of Messrs. Ferranti Ltd.

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"EMP" (Electronic Multiplying Punch)

THE London Midland Region of British Railways have recently installed an electronic computor in the Works Accountants Office at Crewe.

This machine, manufactured by Powers-Samas, is known as the "Emp" (electronic multiplying punch) and is capable of multiplying up to £999 19s. 11·999d. by 99 999·99. Both input and output is by means of punched cards.

An important feature of the machine is its self checking ability. All calculations are performed twice simultaneously, using entirely different methods, the two products are then compared and only if they are identical is the answer punched into the card. The machine will work at a speed of 7 200 calculations per hour.

One of the major problems is the documentation and control of an average daily movement of approximately 7 000 receipts and issues ranging over 60 000 different items, and this has for many years been accomplished on Powers-Samas punch card equipment of conventional design. The following is a brief description of the slightly amended system to be used incorporating the electronic multiplying punch.

For every item held in stores, there is a Powers-Samas punched card file showing its catalogue number, rate, class, unit and balance in value and quantity.

At the commencement of the daily routine an average of 7 000 receipts and issues documents for the previous day arrive in the machine room, and for each of these a 65-column card is punched and verified. These cards are then sorted on the high speed sorter at a speed of 600 cards a minute into catalogue number order, and then tabulated on the Powers-Samas tabulator to provide control figures and a list of items moved, which is used to hand pull the appropriate ledger sheets.

While the ledger sheets are being hand pulled from the files the punched cards are interpolated against the balance card file mentioned above in order that the movement cards (receipts or issues) may be merged with their corresponding balance card. This operation is carried out on the Powers-Samas interpolator, which automatically brings together the movement card(s) with its appropriate balance card.

The movement cards with their corresponding balance cards are then fed into the electronic multiplying punch which, at a constant speed of two calculations a second, senses the rate from the balance card, multiplies it by the quantity in the following movement card or cards, checks its own calculation and punches the product into the movement card(s). The 7 000 or so daily calculations of rate by quantity which hitherto have taken many man hours are now completed in little more than an hour on the "Emp."

After passing through the "Emp" the cards are fed into the Powers-Samas tabulator for posting the ledger sheets. The tabulator senses the opening balance of each item in value and quantity, prints the details of each movement on the appropriate ledger sheet, adds or subtracts values and quantities and produces a new closing balance card.

Integrated Microwave Circuits

By E. Jamieson*, B.Sc.

The assembly of microwave structures is discussed, and a simplified form of construction is described, which has both electrical and mechanical advantages over the more orthodox forms.

THE term "circuit" as applied to an arrangement of microwave elements is hardly comparable to what is known as a circuit at the longer wavelengths. At these frequencies, capacitance, inductance, and resistance, are usually uniquely associated with capacitors, coils and resistors, but at microwave frequencies this uniqueness is no longer apparent. It is almost impossible to apply simple values of capacitance and inductance to such microwave components as resonant cavities, hybrid waveguide structures, etc., and in consequence it is probably more useful to designate a microwave circuit as an arrangement of microwave components, e.g. crystal mixers, attenuators, hybrid structures, etc., rather than to describe a single microwave component as a circuit merely because, following low frequency convention, it has in itself the elements of capacitance, inductance and resistance.

Using the above definition, microwave circuits, either for use as test benches or r.f. heads, generally consist of a larger or smaller number of matched components, suitably connected by lengths of waveguide, each component having input and/or output couplings. The various types of coupling will be considered in detail later, but here it will suffice to say, that the introduction of a relatively large number of such couplings in any circuit, must cause a deterioration in overall performance both technically and operationally.

The object in the integrated microwave circuits as described in this article, is to eliminate the use of such couplings, using a technique which is in some ways similar to the lower frequency technique of printed wiring.

As stated above microwave circuits are usually employed in a test bench arrangement or in an r.f. head. In the first case, it is required that certain characteristics of electromagnetic waves, materials, and waveguide assemblies, e.g. frequency, dielectric constant, impedance, etc., be measured to a specified accuracy. In the second, that the functions of duplexing, superheterodyne mixing, r.f. switching, monitoring of frequency power, etc., be carried out efficiently. In both cases to achieve the required electrical excellence, attention must be paid to the mechanical assembly. Robustness, reproducibility, vibration resistance and easy replacement of expendable components, e.g. crystals, thermistors, etc., are now design factors at least as important as those controlling the electrical design.

Before considering the construction of such circuits the problems involved in the manufacture of the individual components will be discussed, as a basis of comparison for the integrated form of construction to be described later.

Microwave Component Construction

A complete list of all microwave components would be difficult to compile, but a few representative items will be considered.

V.S.W.R. Indicator

In the 3 000 to 24 000Mc/s range, v.s.w.r. indicators usually consist of a length of rectangular waveguide sustaining the H_{01} mode, with a narrow slot cut along the centre of one of the broad faces of the guide ; into which a travelling probe is introduced. The most important factor in the design of a v.s.w.r. indicator is that the depth of probe penetration should remain constant as it traverses the length of the instrument, consequently the manufacture of the waveguide section and the mounting of the probe carriage guide rods, with respect to the inside wall of the waveguide, must be kept to very close tolerances. There are various ways of making the waveguide section, then indexing the position of the guide rods with respect to its inside face, and the following methods will be considered.

(a) A short hand-picked length of precision drawn waveguide is incorporated into an accurately machined holder, into which the guide rods are mounted.

(b) The two halves of the waveguide (split along the centre of broad face) are machined separately from solid material, then dowel mounted together, fixtures for the guide rods being machined into the same blocks as the half-waveguide ducts.

(c) The waveguide section is electroformed on a steel mandrel, the fixtures for the guide rods being indexed from the face of the mandrel whilst still in position.

(d) The waveguide section and guide rod fixtures are fabricated from sheet in a jig assembly.

(e) The waveguide section is formed by hot pressing, the guide rod fixture being thereafter fabricated into position.

Methods (b) and (c) although expensive for small quantities, do lead to appreciably greater accuracy than the others.

Crystal, Thermistor Mounts, etc.

Such waveguide mounts are usually manufactured from a short length of precision drawn waveguide with suitable details brazed into position. The alternative method of electroforming is not usually recommended because of the complex inner structure, but the technique of milling halves from solid, although slightly bulky for an individual component, allows very simple assembly. (See Table 1.)

Hybrid Rings, T-Junctions, Bends, etc.

There are a large number of alternative methods of manufacturing such waveguide parts, especially when the matching arrangements are limited to changes in the "b" dimension. They can be listed as follows :—fabrication from precision drawn tube, fabrication from sheet, milling from solid in two halves, electroforming on a solid or fusible mandrel, hot pressing, pressing the two halves of the waveguide from thin sheet, and the various casting processes, including lost wax and die-casting. (See Table 2.)

Resonant Cavities, Wavemeters, etc.

For these components, the most important design feature

* *Ferranti Ltd, Edinburgh.*

is a smooth and lossless internal surface. Consequently the manufacturing processes of electroforming, hot pressing and machining from solid are normally employed.

The internal finish of all waveguide components is a very debatable subject. It is often stated that silver plating, polished and rhodium flashed is necessary, but for the short lengths of waveguide normally encountered in such components, except in the case of resonant cavities, excessive attention to micro-finishes is hardly justifiable.

Microwave Circuit Construction

As already noted, a circuit usually consists of a number of components inter-connected by means of waveguide couplings. These couplings can be of various types and manufactured in different ways.

(a) Plain flanges, where the mating faces are smooth machined, and lapped for accurate finish. These are fitted to the waveguide by brazing or as an insert during electroforming.

(b) As (a) but with the addition of thin shims.

(c) Choke couplings, where an electrical short-circuit is placed at the mating edges by means of an $\lambda/4$ ditch in one of the mating faces. These may be machined completely or machined from a rough casting and fitted as (a) above.

TABLE 1

Manufacturing Methods suitable for Crystal, Thermistor Mounts, etc.

(Order of preference—*****, ****, ***, **, *.)

METHOD	DESIGN DRAWING-OFFICE WORK	ACCURACY	COST FOR SMALL QUANTITIES INCLUDING TOOL COSTS	COST FOR LARGE QUANTITIES INCLUDING TOOL COSTS	ROBUSTNESS	EASE OF INSPECTION	SPECIAL NOTES
FABRICATION FROM PRECISION DRAWN GUIDE	****	****	*****	***	****	****	—
ELECTROFORMING WITH INSERTS AND FABRICATION	***	*****	—	***	***	***	—
FABRICATED FROM TWO HALF WAVEGUIDE BLOCKS	*****	*****	****	***	*****	*****	—
DIE-CASTING	***	***** (See Note)	—	*****	*****	***	Draw allowances may prohibit standard waveguide aperture dimensions to be held

TABLE 2

Manufacturing Methods for Hybrid Structures, T-junctions, Bends, Corners, etc.

METHOD	DESIGN DRAWING-OFFICE WORK	ACCURACY	COST FOR SMALL QUANTITIES INCLUDING TOOL COSTS	COST FOR LARGE QUANTITIES INCLUDING TOOL COSTS	ROBUSTNESS	EASE OF INSPECTION	SPECIAL NOTES
FABRICATION FROM PRECISION DRAWN GUIDE	****	***	*****	***	****	***	—
FABRICATION FROM SHEET	***	**	****	**	****	***	—
FABRICATED FROM TWO HALF WAVEGUIDE BLOCKS	*****	****	*****	****	*****	*****	—
ELECTROFORMING	**	*****	***	*****	***	***	—
HOT-PRESSING	**	*****	***	***	*****	****	—
LOST WAX CASTING	**	*	***	****	*****	**	—
DIE-CASTING	**	****	—	*****	*****	****	—

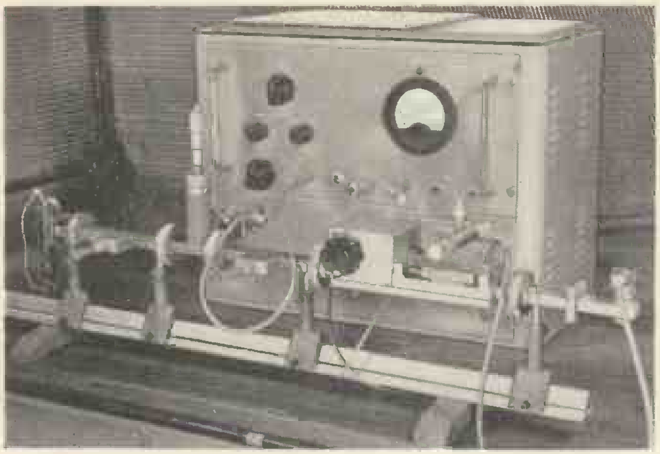


Fig. 1. A representative X-band test bench, including one klystron, variable attenuator, wavemeter, v.s.w.r. indicator and crystal detector

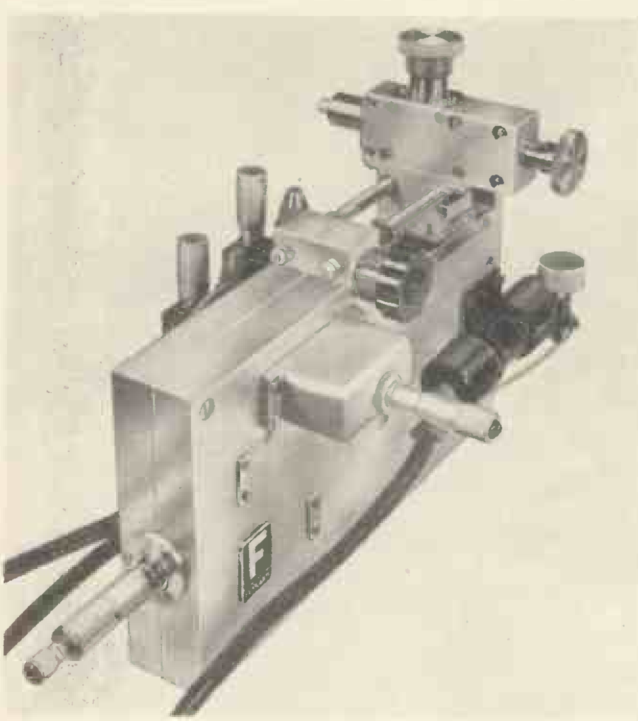
The introduction of a relatively large number of such couplings, must of necessity materially impair the overall performance of the circuits, both as regards impedance mismatch and loss. The use of the integrated waveguide circuit technique reduces the number of couplings required to an absolute minimum. This is illustrated in Figs. 1 and 2—a comparison of two X-band test benches, one in orthodox waveguide "plumbing" and the other using the integrated method. Also Figs. 3 and 4, which compare two 50kW r.f. heads based on the different methods of construction.

This technique while achieving its object of eliminating couplings, has also many other advantages.

A Single Manufacturing Technique

A glance at Tables 1 and 2 shows that the best method of manufacturing one component, is not necessarily the best

Fig. 2. Integrated microwave test bench, at X-band, including three klystrons, wavemeter, variable attenuator and v.s.w.r. indicator



method of manufacturing another, and consequently the production of a circuit requires a relatively large number of different manufacturing techniques. This is uneconomical. Although it is also apparent from Table 1 that milling from solid is not the best method of making certain individual components ; it has been found that the introduction of such a component into a milled block circuit, usually materially simplifies the design, and the close packaging that is possible counterbalances the objection of bulkiness in the individual components.

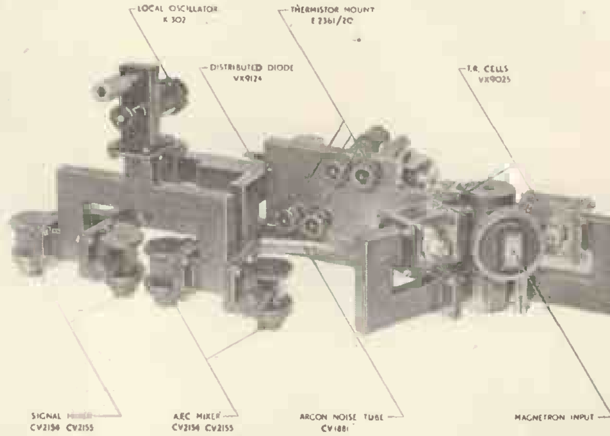


Fig. 3. A representative r.f. head in orthodox waveguide "plumbing"

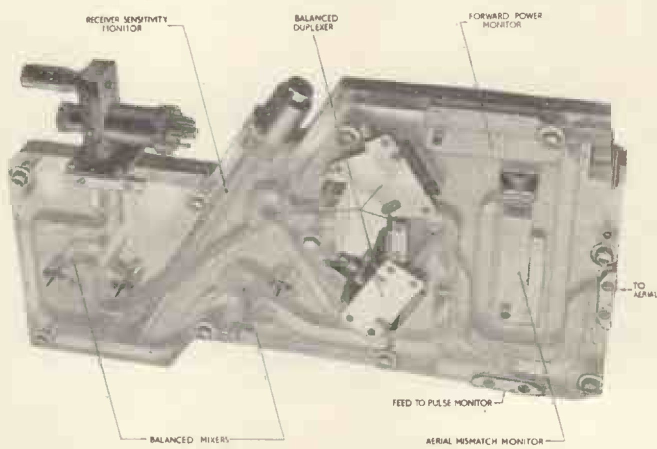


Fig. 4. An "integrated" version of the r.f. head in Fig. 3
(Demonstration block with Perspex replacing the top half.)

Less Drawing Office Work

For complex circuits, the requirement of compactness often leads to a three-dimensional arrangement of waveguide "plumbing." This in turn involves exceptionally accurate tolerances to enable the various components to mate properly, because of the rigid nature of the couplings. A large number of short flexible couplings, is not, of course, a solution. Such arrangements are often difficult to visualize, and drawing office time tends to increase. The milled block arrangement being essentially a plane device, allows all parts to be dimensioned from two edges at right-angles, with the consequence that tolerances are very seldom additive. Final checking of the drawing, too, is relatively speedy.

Compactness and Accessibility

If one considers the usual test bench arrangement (Fig. 1) where the various components are strung out along a 3 to

5ft stand, easy adjustment of the various controls, e.g., klystron, wavemeter, variable attenuator, etc., is not always possible. In the 3 klystron arrangement shown in Fig. 2, these controls are all located in a space of less than 12in. square. Adjustments to the item under test can also be conveniently carried out.

The requirements of compactness and accessibility of replaceable components, e.g., crystals, thermistors, t.r. cells, etc., are, of course, much more stringent in r.f. head design. A comparison of Fig. 3 and 4 will show the advantages of the milled block constructions. In Fig. 3 which shows a relatively compact arrangement, access is required from six faces to replace all the components, while the comparable milled block arrangement requires access only from one face and one edge. It also has the advantage that sub-units, e.g., head amplifier, i.f. strip and a.f.c. unit can be "plugged in," directly to the block, thereby eliminating the need for flying coaxial leads.

Robustness

Milled block circuits being simple shapes are much more robust than their "plumbed" counterparts. Deformation of the waveguide section is almost impossible, and there are relatively few projections capable of being damaged. It is particularly suitable for production testing as shown in Fig. 5.

Simplification of Component Construction

There are certain components which are greatly simplified by incorporation into the milled block. One example is the directional coupler. Generally, a directional coupler, comprising two waveguides with coupling via holes in a mutual wall, demands "blind fitting." Fig. 4 shows how directional couplers need only be slots cut in the mutual wall. Thermistor and crystal mounts are much simpler items. Bends and corners can also be produced without any deformation of the cross-section of the waveguide.

Restricted Components

There are microwave components in current use, which cannot be included into such an arrangement. Any component which cannot be divided in such a way that no current lines are broken by the division, is incapable of being incorporated into such a circuit. The hybrid-*T* is an example of this, but it can, however, be replaced by the hybrid ring, or 3dB coupler. H bends and certain types of directional couplers are also prohibited. This apparent limitation has,

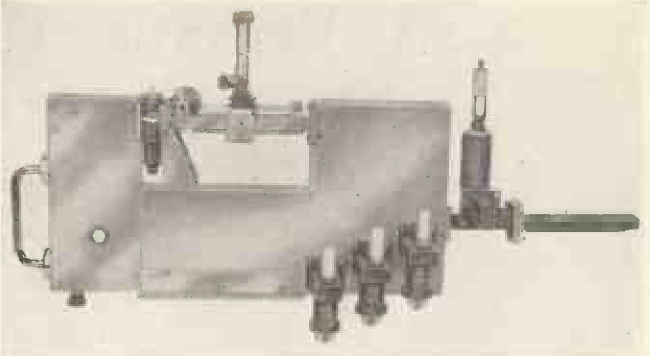


Fig. 5. An "integrated" r.f. production test bench for X-band t.r. cells, including 3 klystron feed, variable attenuator, dummy load and power monitor

however, little practical significance, as alternate designs are usually possible.

Quantity Production

When only one model is required of any particular circuit the most convenient method of manufacture is to mill each half from solid material. If larger quantities are required, e.g., 6 to 12, then the original blocks can be used as masters for copy milled replicas. For still larger quantities it is convenient to prepare a double-sided template in tool steel as the master. Alternative methods of quantity production will suggest themselves to engineers, for example, electroforming of the two halves. This is a possibility but there are major difficulties with respect to acid traps in certain of the narrow interstices, and in the removal of the matrix. Die-casting, too, has been considered, but with present technique requires a prohibitive "draw" allowance, resulting in a waveguide duct with the walls as much as 10° from parallel for a circuit as complex as that in Fig. 4.

Conclusion

It would appear that the milled block construction has a worthwhile advantage, both electrically and mechanically over the traditional waveguide "plumbing" of microwave circuits. Most of the examples quoted in the text refer to the 10 000Mc/s band, but the technique has still advantages at both 30 000Mc/s and 3 000Mc/s.

V.H.F. Radio for the Forestry Commission

In order to facilitate fire-fighting operations, the Forestry Commission has installed a v.h.f. radio system to cover the Thetford Chase area on the borders of Norfolk and Suffolk. The Commission's first v.h.f. radio scheme, it utilizes throughout equipment supplied by the General Electric Co. Ltd. Results have been so good that several other areas with similar communication problems are to be equipped with v.h.f. radio shortly.

Thetford Chase, which comprises 50 000 acres of continuous plantation, is the largest forestry area in England in full production, the total estimated value of its timber being about £6 000 000. Its large size makes it particularly vulnerable to fires. In addition, the exceptionally dry climate which prevails in East Anglia greatly increases the fire hazard there in comparison with the rest of the country. In conditions such as these it is particularly important that incipient fires should be put out with the least possible delay, for they can become uncontrollable within a matter of minutes. V.H.F. radio is especially useful in this work, since it provides continuous two-way direct communication between the District headquarters and the mobile fire-fighting team. The control is, therefore, extremely flexible; reinforcements can be despatched at once to the points where they are most required; and the fire-fighting team can, if necessary, be redirected at a moment's notice even when they are actually on the road.

The installation comprises a fixed station, two mobile transmitter-receivers and four portable packsets. The fixed station is located adjacent to the telephone switchboard in Santon Downham District Office, the Administrative Headquarters for the Thetford Chase area. In order to obtain maximum coverage, the aerial has been set up on the top of a watertower situated on a piece of high ground some four hundred yards from the office.

The mobile transmitter-receivers are mounted in two Land Rovers, one of which forms part of the fire-fighting transport, while the other is used for general administrative purposes. The four packsets are for use by fire-fighting teams in the field and by fire patrollers.

A Versatile Transistor Tester

By R. Bailey*, B.Sc.

The equipment provides a convenient method of measuring the characteristics of experimental transistors of either pnp or npn type, at voltages up to 150V, and currents up to 60mA. To enable a rapid assessment to be made, the characteristics can be displayed as families of curves on the screen of a cathode-ray tube. The sensitivity of the displays is known and measurements with an accuracy of about 10 per cent are possible. If greater accuracy is required, the equipment contains built-in power supplies and meters to facilitate point by point plotting to an accuracy of 1 to 2 per cent.

THE operating characteristics of a transistor are specified by families of curves relating the emitter current (I_e), the emitter voltage (V_e), the collector current (I_c), and the collector voltage (V_c). When a number of experimental transistors are being prepared, a quick inspection of one or more of these families enables the faulty transistors to be rejected and, from a more careful examination, all the required data can be obtained. To plot even one family by the point by point method is fairly tedious, and, if many transistors have to be examined, the work becomes excessive. The equipment to be described displays any family of curves on the screen of a cathode-ray tube so that a rapid inspection is possible. The accuracy of the display is limited to about 10 per cent, which is not sufficient for some purposes, and so a convenient arrangement of power supplies and meters is also provided to enable the curves to be plotted with an accuracy of about 2 per cent by the point by point method.

General Arrangements

To plot a family of curves one parameter is varied in steps and the other is swept continuously over the required range. Suitable waveforms are shown in Fig. 1. Since the variables may be either voltages or currents, the waveforms shown in Fig. 1 must be applied to power amplifiers, which have either very low or very high output impedances, so that the voltages or currents applied are independent of the properties of the transistor. The dependent variables will be affected by the transistor and must be measured and displayed. For measurements by the point by point method, the input can come from a manually adjusted potentiometer instead of the waveform generator. The equipment was originally designed for use with the transistor base earthed but, later, it was required to monitor the base current and provision has been made for this.

Transistors may be of the pnp or npn type, and the equipment was designed to deal with either sort but, to avoid ambiguity, the circuit will be described as if a pnp transistor were being tested. If an npn type is being considered, for " emitter " read " collector ", and vice versa.

The range of voltages and currents available for test should be as wide as possible to cover existing and future transistors. This equipment has been designed with multiple ranges, so that voltages from 1·5V to 150V, and currents from 600μA to 60mA, will give full-scale deflexion on the screen.

A block diagram is shown in Fig. 2. The emitter current and voltage amplifiers are not separate entities but are different arrangements of the same circuit, as will be seen later. The switching A, B and C selects the input to the amplifiers, and ensures that they act as voltage or current amplifiers as required; switching D enables the voltage or current at any electrode to be applied to either the X or Y plates. For example, suppose one wanted to

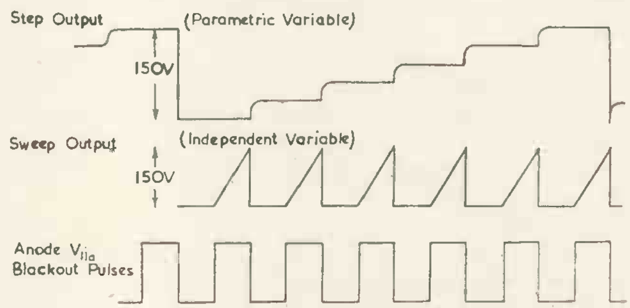


Fig. 1. Waveforms

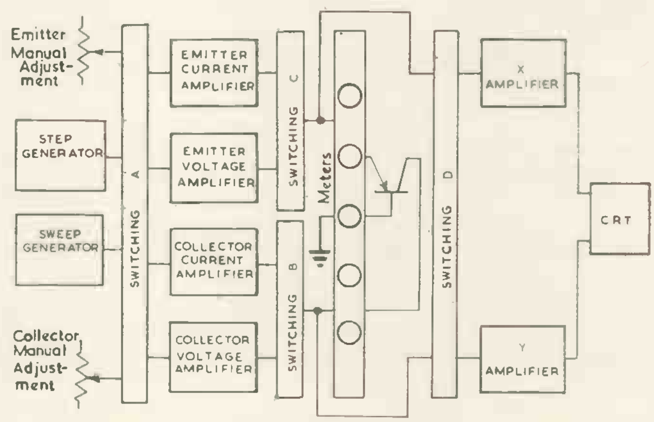


Fig. 2. Arrangement of the tester

view the output characteristics, i.e. to plot V_c against I_c for various values of I_e. The emitter selector would be turned to step current, the collector selector to sweep voltage, the X-amplifier to collector current, and the Y-amplifier to collector voltage. In a similar manner, any set of characteristics can be plotted. The circuits of the individual blocks will now be considered in more detail.

Circuit Details

Waveform Generator

The waveform generator, shown in Fig. 3, produces the waveforms shown in Fig. 1. V_{11} is a free-running symmetrical multivibrator operating at a frequency of about 300c/s. One square wave output passes through a cathode-follower V_{12a}, and has its amplitude limited to 150V by diode V_{13a}, and then passes to a diode storage counter having negative feedback from V_{12b}. When the voltage on

* *Research Laboratory, Associated Electrical Industries Ltd.*

the cathode of V_{12b} exceeds the bias on diode V_{16}, the thyratron V_{15} fires and discharges the storage capacitor C_2. The size of the steps is determined by the ratio $C_1 : C_2$, and the number of steps by the setting of V_{16} bias (VR_1). The step waveform is referred to earth potential by diode V_{1a}, and passes to the switching circuits by the cathode-follower V_{2a}.

The sweep waveform is generated by a Miller integrator V_{17}. During the positive half portion of the square wave, V_{17} draws grid current through diode V_{13b} and the anode bottoms. During the negative half-cycle, the Miller action produces a positive going sawtooth, which is referred to earth by diode V_{1b} and passed to the switch circuits by cathode-follower V_{2b}. Since the sweep does not take place until the second half of the step, any curvature of the leading edge is of no great importance.

Emitter Voltage Amplifier

Fig. 4 (page 66) shows the complete circuit of the amplifiers, including the switches, while Figs. 5, 6, 7 and 8 show Fig. 4 broken down into its component parts. Consider now the emitter voltage amplifier, Fig. 5. The input to the amplifier, which may be either the sweep or step waveforms or a direct voltage determined by the manual setting of VR_3, is applied via an attenuator to the grid of V_{3a}. V_3, V_5 and V_{7a} form a feedback amplifier rather similar to the conventional "ring of 3", except that there are two cathode-followers in cascade at the output, with the load in series with the first. The reason for this is that it is essential for the current through the transistor to go through zero. With the usual connexion this would require that both V_{3a} and V_5 were biased to cut-off which would break the feedback loop in two places. With this circuit, V_5 is biased critically to cut-off by

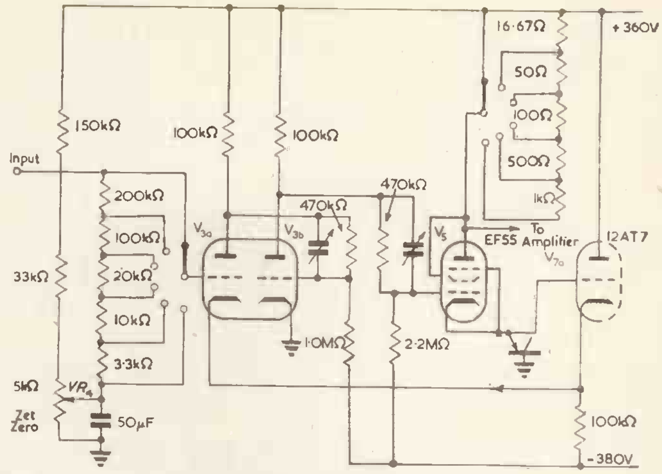
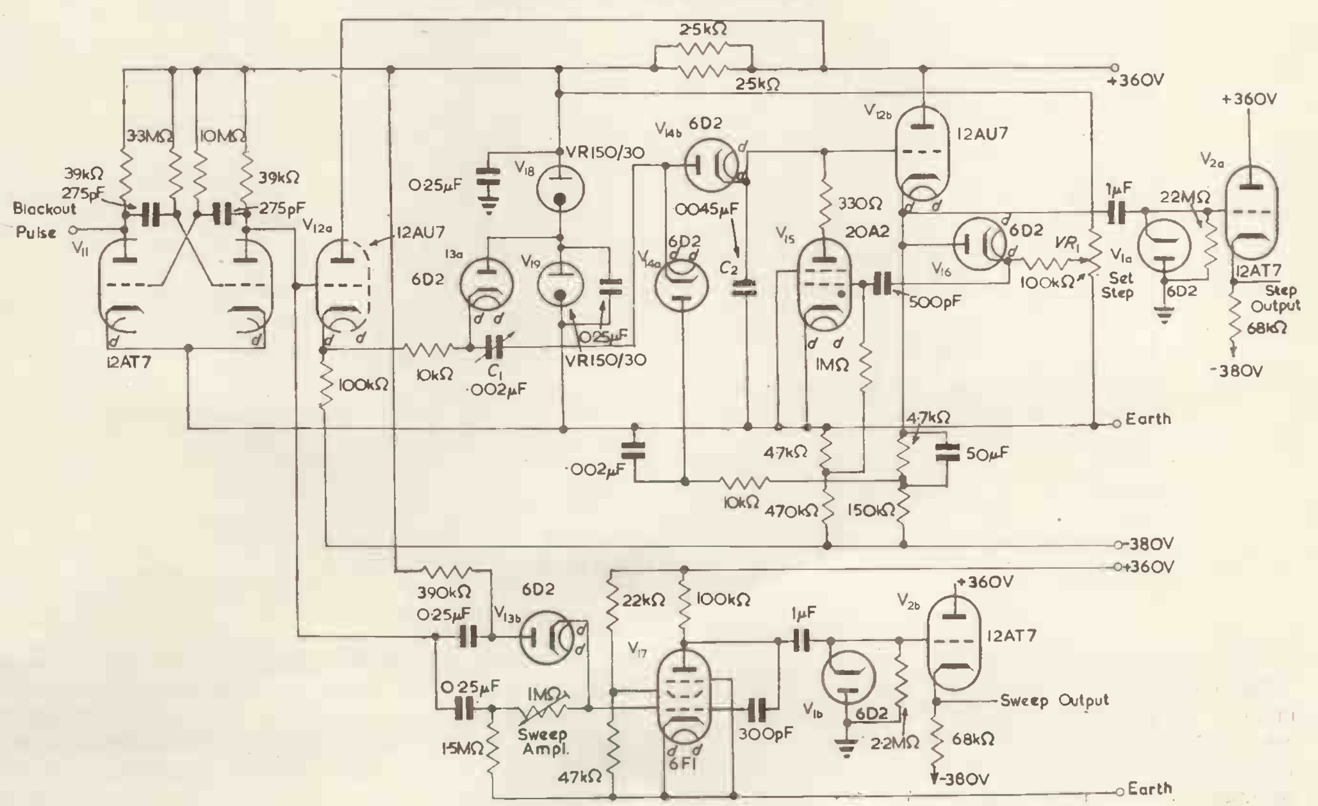


Fig. 5. Emitter voltage amplifier

the voltage developed across VR_4, and the loop will be completed as soon as it draws any current at all. Moreover, most of the loop gain is obtained in V_{3a} and V_{3b}, so that a low output impedance is obtained even with V_5 almost cut off. The current through V_5 and the emitter is measured by a resistor in the anode circuit. It is permissible to have a resistance as large as 1·66kΩ, and to drop as much as 1V, since this is within the feedback loop and does not add significantly to the output impedance. This resistance is placed in series with the anode, rather than the cathode, since, with large voltage outputs, the design of a balanced amplifier, to measure accurately an anti-phase signal of 1V in the presence of an in-phase signal of 150V, would be very difficult.

Fig. 3. The waveform generator



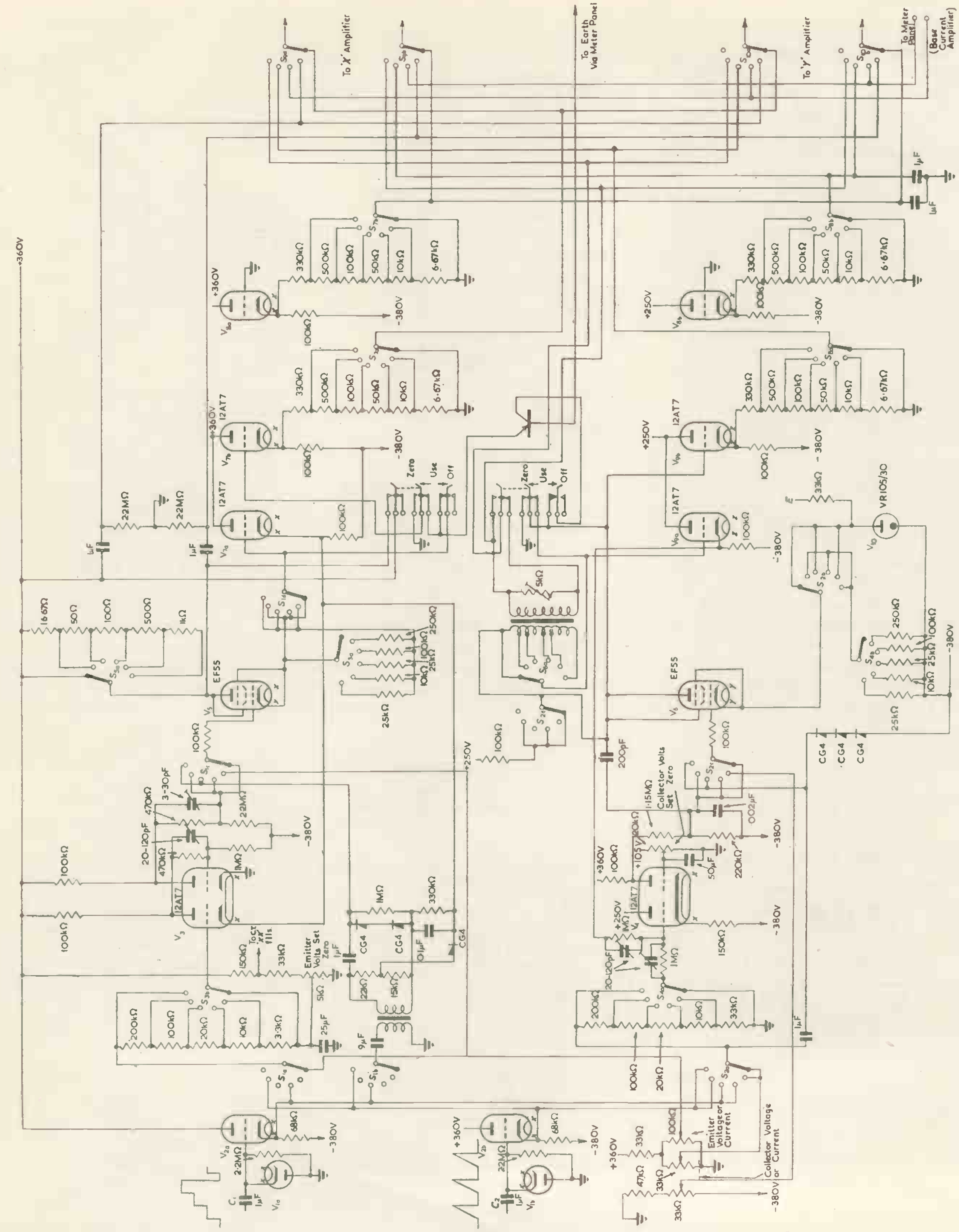


Fig. 4. The complete tester

EMITTER CURRENT AMPLIFIER

The circuit in this case differs, depending whether the input is direct voltage from the potentiometer or a voltage waveform from the waveform generator. The circuit for direct voltage is shown in Fig. 6. It is not, strictly speaking, a constant current circuit if the impedance of the emitter is significant compared with the cathode resistor but, since this connexion is usually used for point by point plotting, it is not usually troublesome. A simple method of improving the circuit would be to gang a second potentiometer to VR_3 and to return its lower end to the cathode of V_{7a}, as is done for the step and sweep circuits.

(Fig. 4) SWITCH POSITIONS

S_1. Emitter selector	S_3. Emitter range	S_5. Emitter current display	S_7. Emitter voltage display	S_9. X amplifier selector
1. Direct voltage	1. Off Off	1. Set zero	1. Off	1. Emitter voltage
2. Direct current	2. 0–1.5V 0–0.6mA	2. 10mA/cm	2. 25V/cm	2. Emitter current
3. Step voltage	3. 0–6.0V 0–1.5mA	3. 2.5mA/cm	3. 10V/cm	3. Base current
4. Step current	4. 0–15V 0–6mA	4. 1.0mA/cm	4. 2.5V/cm	4. Collector voltage
5. Sweep voltage	5. 0–60V 0–15mA	5. 0.25mA/cm	5. 1.0V/cm	5. Collector current
6. Sweep current	6. 0–150V 0–60mA	6. 0.1mA/cm	6. 0.25V/cm	6.
S_2. Collector selector	S_4. Collector range	S_6. Collector current display	S_8. Collector voltage display	S_{10}. Y amplifier selector
As S_1 above	As S_3 above	As S_5 above	As S_7 above	As S_9 above

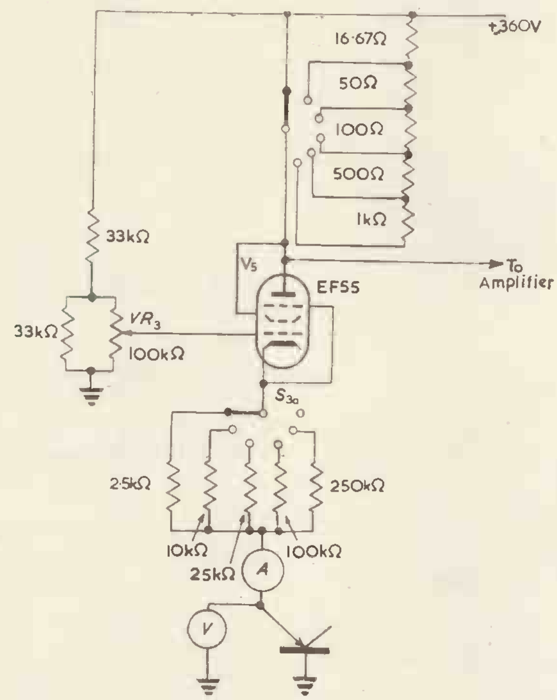


Fig. 6. Emitter current amplifier (*direct voltage input*)

The circuit for step and sweep currents is shown in Fig. 7. The input voltage is transformer coupled, rendered positive going by germanium diodes, and applied between the grid of V_5 and the cathode of V_{7a}. The reason for connecting to the cathode of V_{7a} rather than to the emitter terminal is that interwinding capacitance causes spurious pulses in the emitter circuit. A small portion of the 150V peak waveform is rectified and used to bias V_5 to cut-off.

Collector Voltage Amplifier

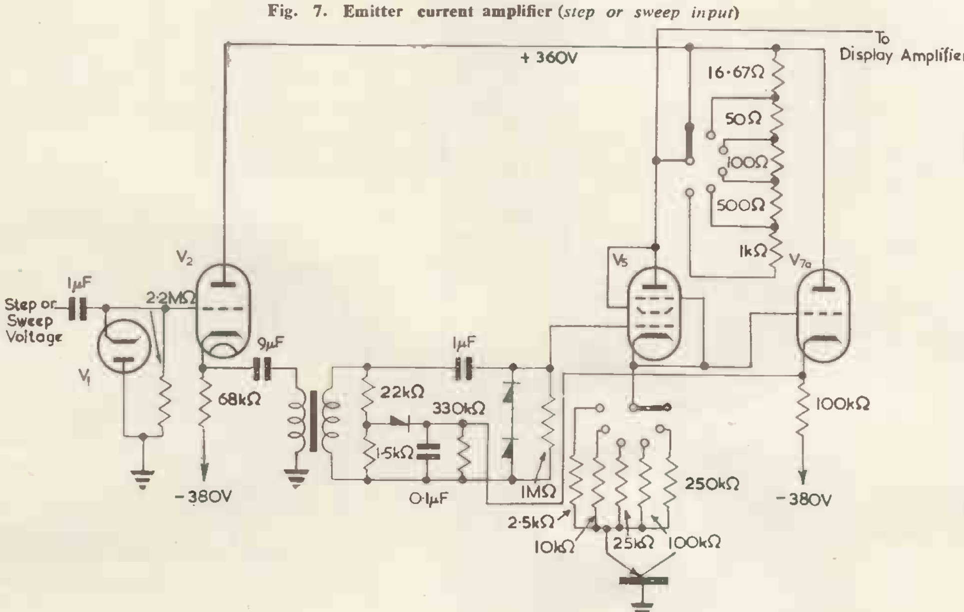
The circuit of this is shown in Fig. 8.

It is essentially an anode-follower feedback circuit with an additional non-reversing amplifier stage and a cathode-follower. The overall gain is unity. V_6 is adjusted to cut-off by potentiometer VR_5 connected to the spare grid of V_4. The stability of the feedback loop depends, to some extent, on the load impedance but, by careful adjustment of the various preset capacitors, stability has been attained for all the transistors tested so far. The currents are measured by means of a tapped current transformer in the anode circuit of V_6. This is inside the feedback loop so that a voltage drop of 1V is permissible. At the expense of some loss of loop gain, the transformer could be replaced by resistors connected between the cathode of V_6 and the anode of V_{10}. This would facilitate direct coupling as suggested later.

Collector Current Amplifier

This resembles the circuit used for direct emitter current, and calls for no special comment except to remark that the input is positive going with respect to the negative line. (See Fig. 9.)

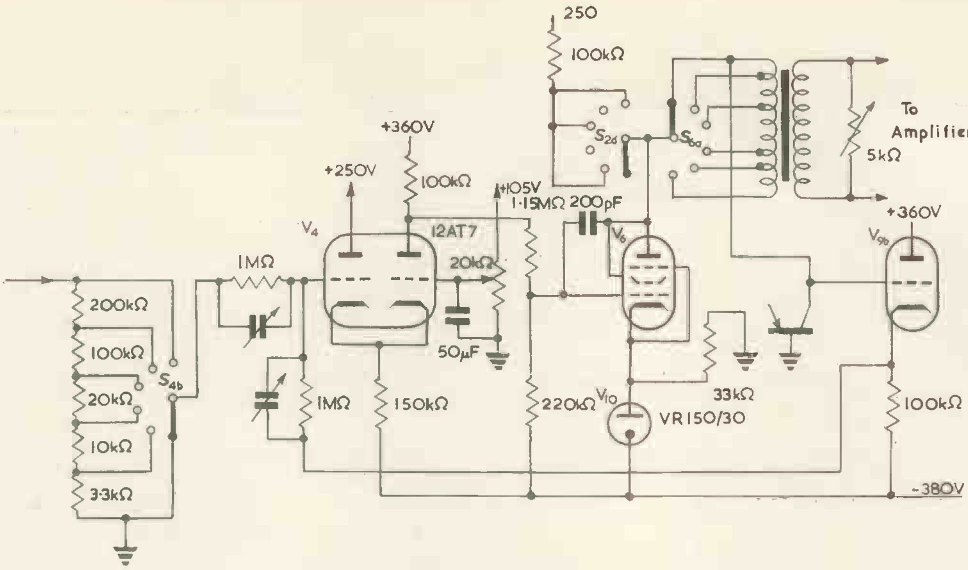
Fig. 7. Emitter current amplifier (*step or sweep input*)



Metering Circuits

The metering circuits are shown in Fig. 10. There is a multi-range voltmeter and milliammeter for both emitter and collector. The voltmeters consume 50μA f.s.d. so that, at low currents, a correction should be made. The meters are controlled by two-position key switches which enable them to be reversed at will. The range switch includes a blank position in which the meters are disconnected.

The metering of the base current requires more careful consideration. If the transistor has a current gain



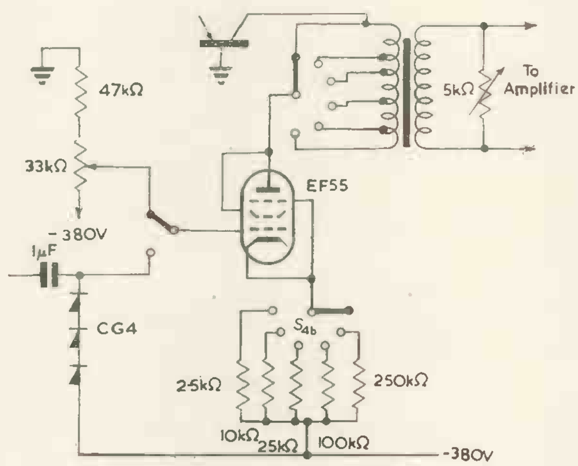
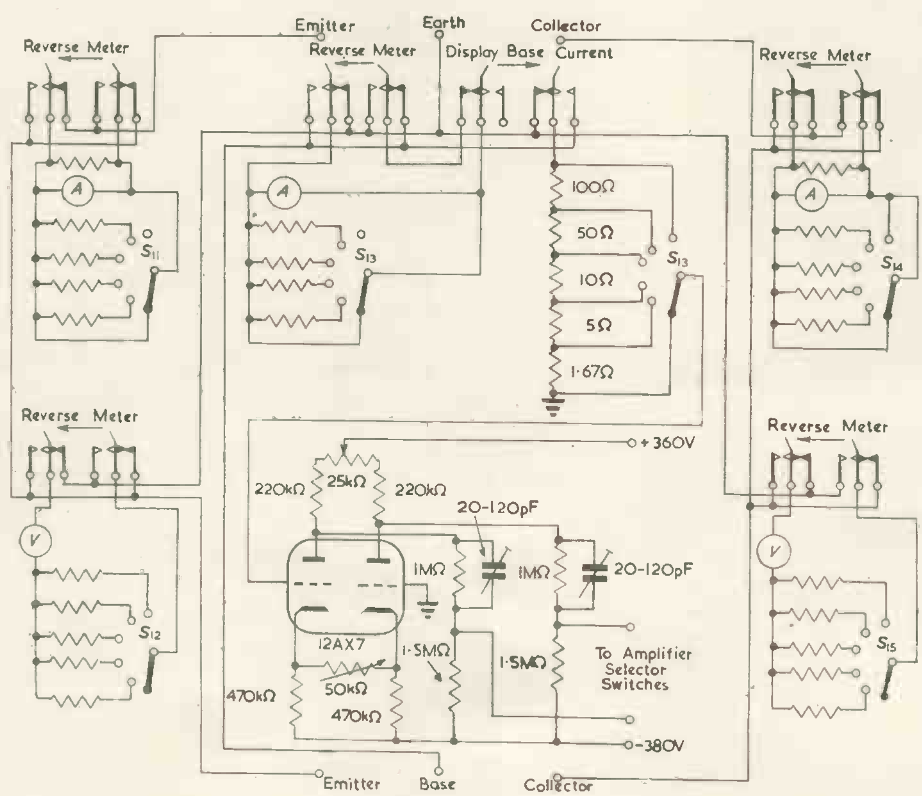


Fig. 8. (above) Collector voltage amplifier.

Fig. 9. (left). Collector current amplifier

Fig. 10 (bottom). Metering circuits



greater than unity, resistance in the base circuit causes positive feedback and perhaps oscillation; this must be carefully watched.

To display the base current, it is also necessary to insert an impedance in series with the base and the same objection pertains. In addition, a resistor large enough to drop 1V, as used in the emitter and collector circuits, would produce intolerable errors. The resistors are therefore reduced by × 10, and a single-valve d.c. amplifier is used to make good the deficiency. In any subsequent model, the base current might perhaps be measured as the difference between emitter and collector current.

Display Amplifiers

Two similar direct-coupled amplifiers precede the X and Y deflector plates (Fig. 11). Only the input circuits call for comment. When displaying voltages, inputs up to 150V are possible. To keep the input impedance high, a cathode-follower precedes the attenuator, and a similar cathode-follower with its grid earthed is used to maintain symmetry and freedom from drift.

When measuring emitter current, the voltage drop across the current-measuring resistors is capacitance coupled to the grids of the amplifiers. This results in the loss of zero level but, provided V_5 is initially cut off, the end of the trace corresponds to zero current. In any subsequent model, direct coupling will be used, and the voltage-dropping resistors adjusted to compensate for the attenuation in the coupling chain. Similar considerations apply to the transformer-coupled collector circuit.

Power Supplies and Cathode-ray Tube

The c.r.t is a VCR97, and the power supplies are stabilized and quite standard.

Switching and Checking

The operation of the equipment is controlled by 15 wafer switches. S_1 (emitter selector) enables voltage or current, and direct, sweep or step waveforms, to be applied to the emitter; S_2 (collector selector) does the same for the collector; S_3 and S_4 (emitter and collector range) determine the magnitude of the voltage or current applied to the electrodes; S_5 and S_6 (emitter and collector current display) control the sensitivity of the current displays; S_7 and S_8 do the same for the voltage display; S_9 and S_{10} (X and Y amplifier selectors) connect the inputs of the amplifier to any electrodes or the current-measuring resistors; S_{11} to S_{15} control the sensitivities of the meters.

By intelligent use of the switches, it is possible to make the equipment almost completely self-checking. For example: the sensitivity of the display amplifiers can be checked by comparing the deflexion on the c.r.t., produced by a direct voltage applied to, say, the collector, and the corresponding reading of the collector voltmeter. Similarly, if the step waveform is applied to one plate and the sweep to the other, the result should be a series of equally spaced parallel lines. If the sweep is applied to both X and Y amplifiers, on the same sensitivity, the result should be a line at 45°. Many of these tests can be carried out with the transistor under working conditions, so that the effect of loading can be checked.

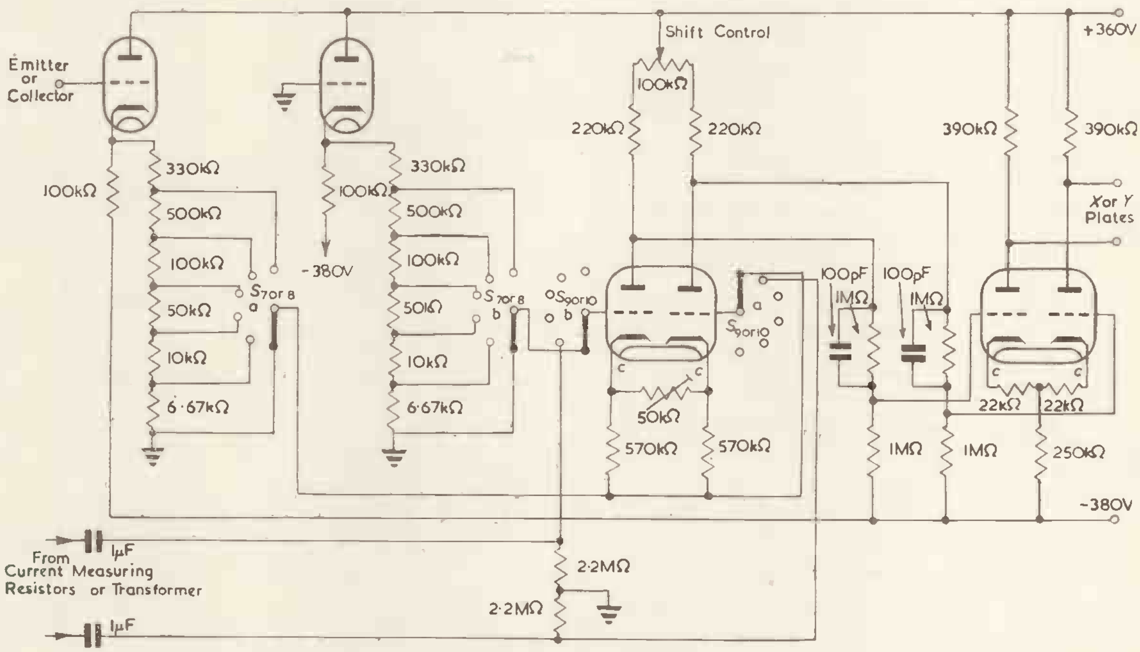


Fig. 11. Display amplifiers

Mechanical Construction

The equipment consists of three panels in a bench mounting rack. The top one contains the power supplies, the middle one the waveform generators, amplifiers and cathode-ray tube, and the lower one the meters and the auxiliary amplifier to display the base current.

Conclusion

The equipment is a very convenient and versatile method of investigating the circuit properties of transistors at voltages up to 150V, and currents up to 60mA. Apart from an extension of voltage and current ranges, the worthwhile improvements would be direct coupling in the current ranges, and an increase in the output impedance on the direct emitter current position, as suggested in the text.

A Frame Synchronizing Separator

By J. E. Attew*

The interlace filter described is a pulse duration discriminator. Due to its fast recovery time it produces, from the composite synchronizing waveform, the eight frame pulses as separate pulses identically on odd and even flames, which ensures an excellent interlace. Good clipping action of both line and frame pulses gives improved noise immunity.

THE problems and methods of ensuring a correctly interlaced television picture have been admirably stated by Keen[1] and Patchett[2]. Both authors mention the frame synchronizing separator used in some television receivers manufactured by Pye Ltd. The circuit is shown in Fig. 1.

This circuit produces pulses which are identical on odd and even frames, effecting a correct interlace. The negative going mixed synchronizing pulses at the anode of valve V_1, which is a conventional synchronizing separator, cut off diode V_{2a}, allowing the capacitor C_k to discharge through

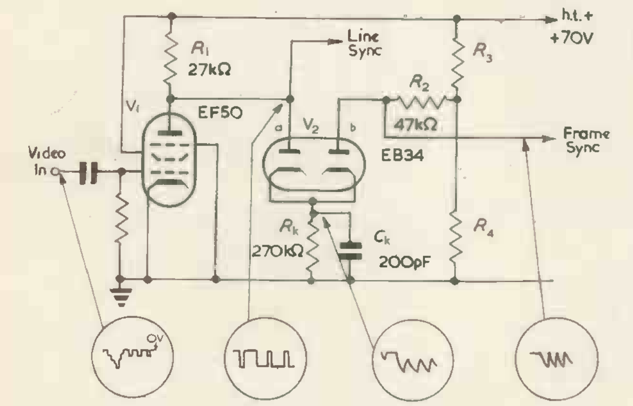


Fig. 1. Pye synchronizing separator

resistor R_k from a potential approximately equal to

$$\frac{(\text{h.t.}+) \,.\, R_k}{R_1 + R_k}$$

During the line synchronizing pulses C_k discharges only a small amount, so that the diode V_{2b} does not conduct, but during the longer frame pulses the cathode of V_{2b} falls below its anode potential, allowing it to conduct, producing pulses as shown in the drawing.

An improved version of this circuit, which has many advantages over the original, has been developed by the writer. The circuit is shown in Fig. 2. It can be seen that the original double diode has been replaced by a double triode, with the subsequent advantages as listed below.

(1) The use of a separate anode circuit V_{2a} (Fig. 2) to obtain line synchronizing pulses prevents feedback of pulses from the line time-base affecting the frame separator action. This anode is also a convenient point to place a pulse transformer used in some flywheel synchronizing circuits.

(2) Due to the clipping action of V_{2a} the line synchronizing waveform has fast rise times, and the effect of noise is very much reduced.

(3) The grid of triode V_{2b} acts as an electrostatic screen between cathode and anode, reducing capacitive breakthrough of the line pulse.

(4) The frame synchronizing pulses at the anode of V_{2b} can be of much greater amplitude than those from the original circuit. This is advantageous when synchronizing

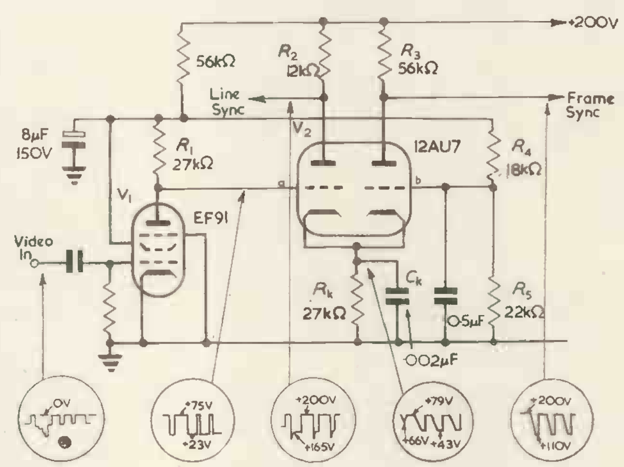


Fig. 2. Improved synchronizing separator

blocking oscillators. This set of pulses, as shown in Fig. 2, can be differentiated to provide negative leading edge and positive trailing edge pulses, enabling any type of time-base to be synchronized (thyratrons, blocking oscillators, multivibrators, etc.).

(5) The recovery time of the circuit of Fig. 2 is very short, due to V_{2a} acting as a cathode-follower to recharge capacitor C_k at the end of every pulse. This fast recovery time may be necessary in some applications.

Design Data

VALVE V_1

EF91 h.t. $\approx +75$V. From manufacturers' curves cut-off bias $\approx -1{\cdot}5$V.

I_a at zero bias = 1·9mA with 27kΩ anode load.

$\therefore I_a$ (average) $\approx$ 0·2mA.

V_a (anode swing) = 52V.

VALVE V_2 (12AU7)

During negative pulse on grid of V_{2a} voltage drops from +75V to +23V (from above), therefore capacitor C_k is initially charged to a potential $V = +79$V.

* *Pye Ltd.*

Thus I_a (V_{2a}) = $V/R_k \simeq 2{\cdot}9$mA. With anode load of 12kΩ this current swing produces line synchronizing pulses at anode of 35V amplitude.

The cut-off bias of V_{2a} under these conditions is −9V, and with the grid (V_{2a}) input voltage swing of 52V a very effective clipping action is possible.

CAPACITOR C_k DISCHARGE (405 line system).

Time-constant $C_k . R_k = 54\mu$sec. V = 79V.

During the 10μsec line pulse, $v = V \exp(-t/C_kR_k) = 66$V where v is the voltage to which the cathodes of V_2 have fallen and t is the time taken. During a 40μsec frame pulse v = 38V. Therefore a voltage on V_{2b} grid between + 66V and + 38V, but nearer the latter, will provide the correct operating point. With V_{2b} grid at a potential of +40V, $V_a \simeq 150$V then, the cut-off bias is −12V.

∴ V_{2a} starts to conduct when C_k has discharged to +52V, which is half-way between 66V and 38V.

With an anode load of 56kΩ, the cathode voltage falls to a minimum value of + 43V, and an anode current of 1·6mA giving a frame synchronizing pulse amplitude of 90V.

RECOVERY TIME

The recovery time-constant of Fig. 1 can be shown to be:

$$t_r = \frac{(R_1 + R_D) . R_k}{R_1 + D_D + R_k} . C_k \simeq 5\mu\text{sec}$$

where R_1, R_k and C_k are as in circuit, and R_D = diode forward resistance.

In Fig. 2 the recovery time-constant at the cathode of V_2 is now:

$$t_r = 1/g_m . C_k \simeq 0{\cdot}8\mu\text{sec}$$

where g_m is the mutual conductance of V_{2a}. In this circuit C_k has been increased by ten times, but the recovery time is still six times shorter than the original circuit.

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2. PATCHETT, G. N. Faulty Interlacing. *Wireless World 58*, 250 & 315 (1952).

A Combined Frequency Sub-Standard and Beat Frequency Oscillator

By J. H. Haskell and P. T. Haskell*, B.Sc., A.R.C.S.

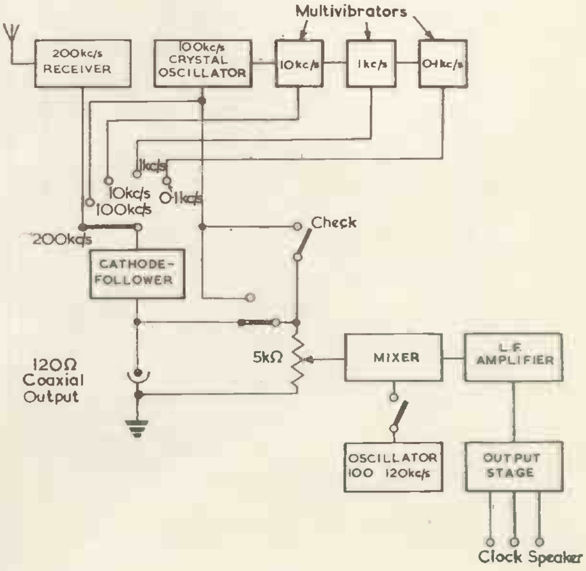
This article gives brief details of the design and construction of an inexpensive apparatus for use in electrophysiological work. The frequency sub-standard, controlled by a 100kc/s quartz crystal oscillator gives multivibrator outputs of 0·1, 1, 10 and 100kc/s at a low impedance (120Ω) suitable for time marking on an oscilloscope. Simultaneously but independently a b.f.o. output is available with a frequency range of 0 to 20kc/s. A check circuit is built in which enables the 100kc/s crystal oscillator to be set accurately against the 200kc/s BBC long wave transmitter. The output stage is arranged to allow audible check on the multivibrator output by loudspeaker, and the driving of a synchronous clock mechanism, as well as providing b.f.o. output.

ONE of the authors (P.T.H.), engaged in electrophysiological research, required a time marker for oscilloscope analysis work, and also a beat frequency oscillator for use as a source of sound stimuli and for general laboratory use. No commercial apparatus was then available (1952) combining these features, and the cost of separate commercial units was extremely high. It was therefore decided to build an apparatus combining the two requirements, using normal components easily obtainable.

The block circuit diagram of the apparatus is shown in Fig. 1. A 200kc/s h.f. amplifier can be switched to receive the BBC long-wave transmission and with it the frequency of the 100kc/s crystal oscillator can be accurately set. Beating of the h.f. envelopes can be seen on an oscilloscope by feeding into it the output from the cathode-follower; this method allows zero beat to be obtained with great accuracy. The 100kc/s crystal oscillator controls the frequency of the multivibrator divider chain, the outputs of which can be obtained through the cathode-follower by means of a selection switch.

The mixer grid circuit potentiometer can be switched either to the cathode-follower output, or to the crystal oscillator output. In the first case the mixer acts as an amplifier and the multivibrator pulses can be heard in the speaker, a useful monitoring check. If in this case the l.f. amplifier is driven by the 100c/s multivibrator a

Fig. 1. Arrangement of apparatus



* Department of Zoology and Applied Entomology, Imperial College Field Station.

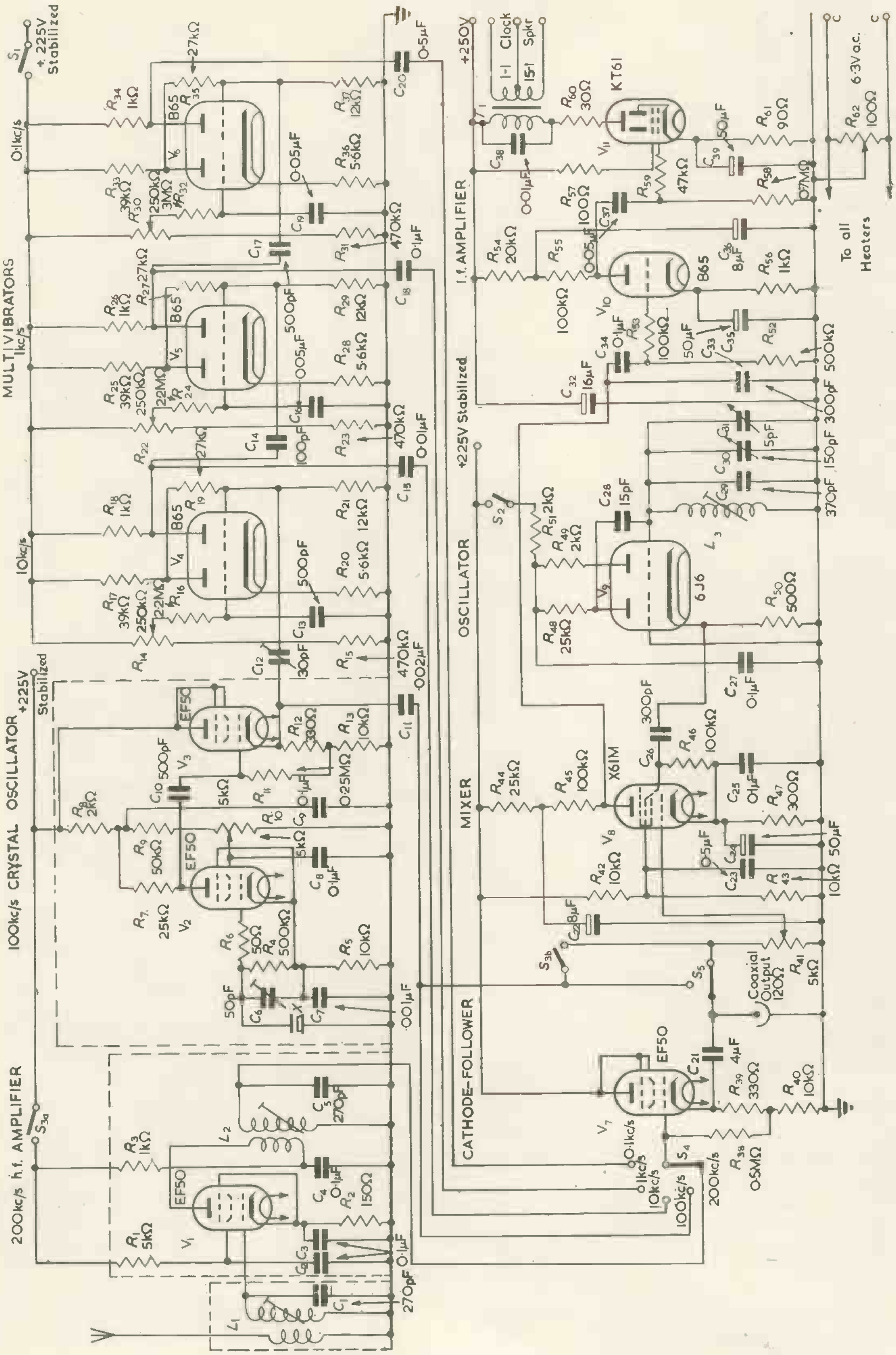


Fig. 2. Circuit of frequency standard and b.f.o.

synchronous clock mechanism can be operated. In the second case referred to above, both the 100kc/s crystal frequency and the variable oscillator frequency are fed into the mixer, and the difference frequency passed on to the l.f. amplifier and output stage. It will be seen that both the multivibrator output and the b.f.o. output can be used simultaneously but independently.

The circuit diagram for the frequency sub-standard and b.f.o. is shown in Fig. 2. The crystal oscillator circuit used is that recommended by the makers of the crystal, and has the advantage that the variable screen feed controls the amplitude of oscillation. Various grades of thermal stability for crystals can be obtained, but the unit used, the Q7/100, was found adequate in ambient temperatures of 10-20°C. The output from the crystal oscillator is obtained via the cathode-follower V_3, which acts as a buffer stage. The multivibrator circuits are based on those of Attew[1].

This circuit is stable and does not suffer from frequency division jumping; indeed, the h.t. can be switched on and off without affecting the division ratio. The variable oscillator in the b.f.o. uses a shunt-fed cathode coupled circuit; the use of shunt feed enables the tuned circuit to be earthed. C_{28} controls the feedback. Inductance L_3 consists of two long wave broadcast coils in series, thus avoiding construction of a special coil. C_{31} is a zero corrector, panel mounted, which produces a capacitance change of about ±5pF around an arbitrary zero. Thermal drift is minimized by placing the coil L_3 outside the front panel, as mentioned later; drift may be further corrected in the finished apparatus by experimenting with trimmers of different temperature characteristic. The b.f.o. in this particular apparatus was to be used mainly as a source of interpolating frequencies for time marking and also for provision of sound stimuli, and so no great attempt has been made to produce the usual attributes of b.f.o. output as regards waveform or constancy of amplitude, but these could be introduced by slight modification of the basic design. There is scarcely any "pulling" even at low frequencies between the two oscillators since both are protected from interaction by their cathode-follower output stages provided that the input to the control grid of V_8 is not made too high. The h.f. filter is of the simplest form, but if necessary a low-pass filter can easily be added.

The power supply circuit is shown in Fig. 3. Although it is essential to use a stabilized power supply for the multivibrator and oscillator stages, the l.f. amplifier and output stage only need an ordinary smoothed supply. This is obtained from the non-regulated side of the power pack through an appropriate decoupling circuit. One KT66 valve will pass 80mA as a series valve, which is ample for the multivibrator and oscillator circuits. It may now be possible to substitute a more stable control valve for the type 7475 used, but this gave adequate control apart from occasional flicker effects.

The physical basis of the equipment consists of the power pack and amplifier panels of a 25 watt R.A.F. Ground Control P.A. Equipment; this equipment, including the standard rack is still available. The main components of the power pack such as chokes and capacitors are all used in the new power supply. The b.f.o. tuning dial must be robust and capable of high accuracy of resetting. The radio receiver, crystal oscillator, multivibrator stages and variable oscillator for the b.f.o. are built into Eddystone cast screening boxes, which enables these units to be placed comparatively close together with consequent saving of space. The coil L_3 of the variable frequency oscillator of the b.f.o. is mounted on the front panel facing outwards and is protected and screened by a thick brass case; this arrangement lessens thermal drift. There are no other special physical features and, as long as normal care is taken in respect of wiring carrying oscillatory and pulse currents, no instability should be found.

To cut down the number of valve types used to a minimum, a B65 is used at V_{10} in the l.f. amplifier; half this valve is thus unused, but as the present apparatus is still experimental this was looked upon as an advantage, since it could provide an additional cathode-follower output or similar stage if required, without further work.

The setting-up and operation is very simple and should be done with an oscilloscope. The crystal oscillator is first

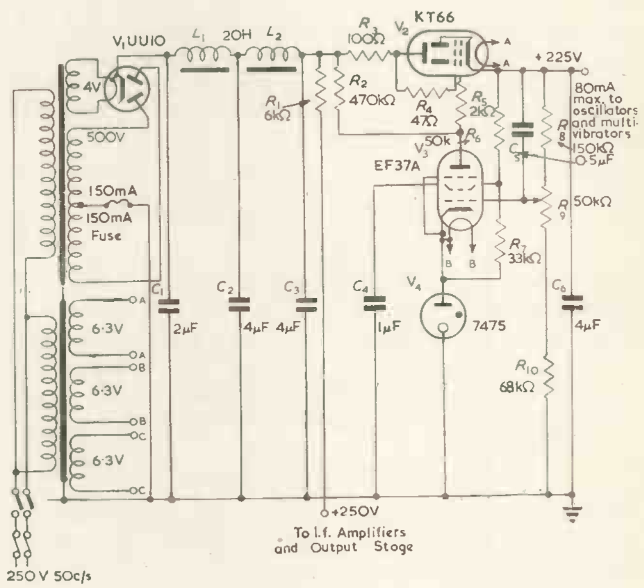


Fig. 3. The power supply circuit

set accurately against the BBC 200kc/s signal using the crystal frequency control C_6. The frequency division of the multivibrators can now be checked on the oscilloscope, alteration being effected by the grid potentiometers R_{14}, R_{22} and R_{30}. If a double-beam oscilloscope is available, the b.f.o. dial can now be calibrated by direct frequency counts of the output waveform against the appropriate multivibrator scale. By this means, a calibration graph of b.f.o. dial reading against frequency can be constructed. In use, the ambient temperature should be kept if possible between 10 to 20°C. The frequency characteristic of the crystal is quite flat in this region, but breaks away outside this range. To cure these variations a thermostatically controlled oven, or a crystal of GT cut, could be used, but these are not justified for the order of accuracy required. With the particular components used in the variable frequency oscillator the temperature characteristic is negative, but it can be taken up by the zero corrector. After about an hour warm-up period, drift is not serious.

REFERENCE

1. Attew, J. E. Decade Multivibrator Design. *Wireless World* 58, 114 (1952).

A Scaler for the Measurement of Half-Lives

in the Range Three Seconds to Thirty Minutes

By J. L. W. Churchill* and W. W. Evans*

New determinations have been made of the half-lives of the positron emitters aluminium-25, aluminium-26 and nitrogen-13, and the results of these have been reported previously[1]. *The equipment used to make these measurements is novel in that it employs the comparatively new cold cathode decade counting tubes known as "Dekatrons"*[2]. *The method employed is to count the number of disintegrations of the sample occurring in successive equal intervals of time and the Dekatron tubes offer a simple and economical method of providing a number of scaling units and a timing device.*

IT can be shown that for a sample of radioactive material the arithmetic mean of the individual times at which particles have been observed after an arbitrary time origin is equal to the decay time τ of that material, where τ is the exponent in the equation relating N the number of particles remaining after a time t to N_0 the number existing at the time origin:—

$$N = N_0 \exp - (t/\tau) \quad \ldots \ldots \ldots \ldots \quad (1)$$

The half-life μ is then related to τ by the equation

$$\mu = \tau \ln 2 \quad \ldots \ldots \ldots \ldots \quad (2)$$

This is the basis of Peierls' rigorous method[3] and is the one adopted in the present measurements.

In practice not all the disintegrations are observed since this would entail counting for infinite time. Consequently the counting is terminated after a period of about 3τ and τ is computed from an equation given by Peierls[3]:—

$$1 - s/P = \frac{P/\tau}{(\exp\ (P/\tau)) - 1} \quad \ldots \ldots \ldots \ldots \quad (3)$$

Where s is the arithmetic mean of the individual times of counting, P is the total counting period and τ is the required disintegration constant.

Experimental Procedure

The aluminium-25, aluminium-26 and nitrogen-13 isotopes were produced by resonant capture of protons by magnesium-24, magnesium-25, carbon-12 using proton energies of 418keV, 392keV and 457keV respectively. Separated magnesium targets were employed and further it was established that the yields from magnesium-24 for 392keV protons and from magnesium-25 for 418keV protons were each negligible. The targets were bombarded until near equilibrium activity had been built up and were then placed in front of a Geiger Müller counter. The counts obtained in successive equal intervals of time were then recorded by the instrument to be described. If insufficient counts for good statistical accuracy were obtained in one irradiation then the target was re-irradiated and the experiment repeated several times to give the required total counts.

The Instrument

A block diagram of the instrument is shown in Fig. 1. It consists of nine scalers, each of two Dekatron counting tubes, a timer, switching circuits and a triggered pulse generator producing the two pulses necessary to drive the scalers. The timer is a further Dekatron scaler the input to which is a 50c/s sine wave derived from the mains supply. The last decade of this timer is a Dekatron which has all ten cathodes brought out to separate load resistors. This acts as a ten-way selector and operates the switching

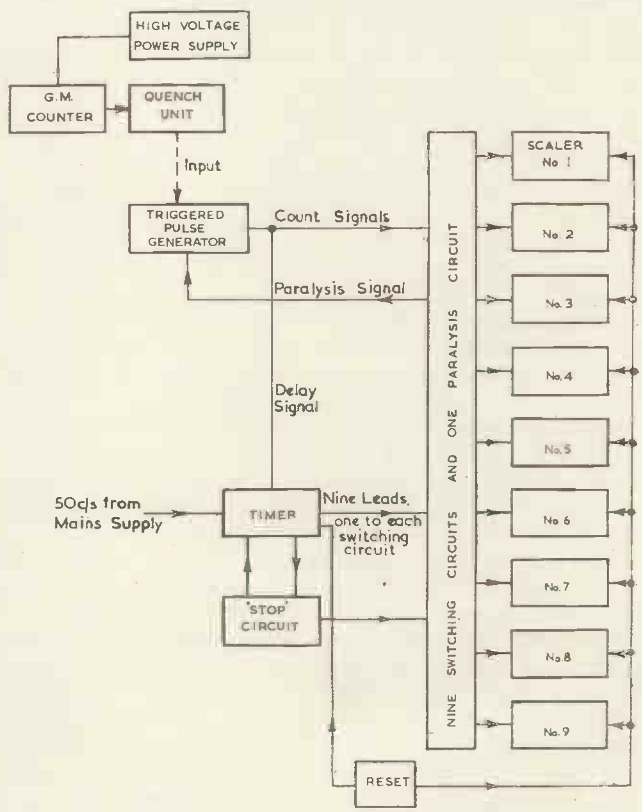


Fig. 1. Equipment for the determination of mean lives

circuits such that the input pulses are counted for equal intervals of time on each scaler in turn. This interval can be varied by changing the radix of the timer. The tenth position of the selector tube operates a circuit which stops the timer and switches off the scalers.

Circuit Details

TIMING UNIT

The detailed circuit is shown in Fig. 2. Valves V_{31} to

* *Associated Electrical Industries Ltd.*

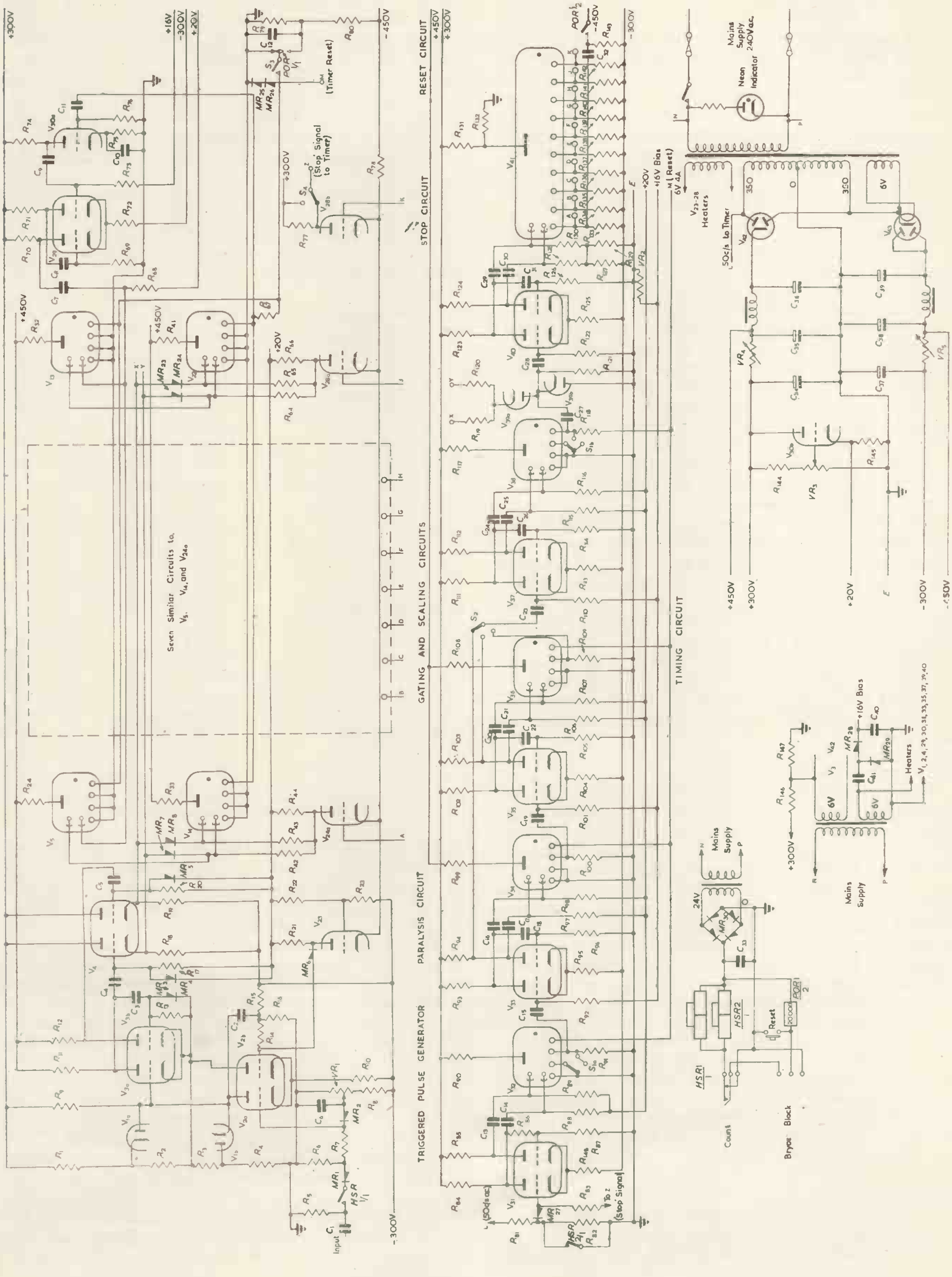


Fig. 2. Detailed circuit diagram

V_{41} form the timing circuit. V_{31} is a Schmitt trigger circuit which is fed with 50c/s a.c. on the input grid and delivers positive going square pulses from one anode and negative from the other. The negative going pulses are coupled to the guide-1 electrode of Dekatron V_{32} and the positive ones are differentiated and fed on to guide-2. Output pulses are derived from cathode 9, or from both cathodes 4 and 9 as determined by switch S_{1a}, and are differentiated and the negative going part of the waveform used to trigger the flip-flop V_{33} which drives the next Dekatron in a similar manner. This arrangement leaves the zero cathode free for the reset operation.

Two more similar decades follow. The output pulses from V_{38} are derived as positive going ones from cathodes 5 and 0 and the reason for this is connected with the circuit of V_{39} which is described below. The final decade V_{41} in the timer is a Dekatron which has all ten cathodes brought out to separate load resistors. Each cathode is connected to the grid of one of ten cathode-coupled triodes V_{24} to V_{28}. Hence the triode which conducts is determined by the count registered by V_{41}. A further triode V_{23} is cathode coupled to these ten and has its grid returned to a fixed potential such that this valve conducts when the current through V_{41} is flowing to a guide electrode and not to one of the cathodes. The periods between transfers in V_{41} can be varied by switches S_1 and S_2, between 0·5sec and 200sec.

The triodes V_{24} to V_{28a} operate the switching circuits formed by the germanium rectifiers MR_7 to MR_{24}. Consider the case of V_{24a}. When this valve is cut off its anode will assume the potential of the +20V line which supplies the guide bias for the Dekatrons. Hence the guides of Dekatron V_{14} will be held at +20V and negative going pulses generated by V_4 will not be fed on to them. When V_{24a} conducts its anode potential falls and the guides of V_{14} will then follow the potentials of the cathodes of V_4.

A count of ten in V_{41} causes V_{28b} to conduct. The drop in its anode potential cuts off V_{31a} and thus arrests the timer.

The Scaling Circuits

The input pulses received from the Geiger counter are fed into the circuit of V_2 and V_3. This circuit, when triggered, generates two output pulses, such that the trailing edge of the first coincides in time with the leading edge of the second. These pulses appear at the anodes of V_3 and are fed via the cathode-followers V_4 to the switching circuits. The waveforms of this circuit are shown in Fig. 3. V_2 is a cathode-coupled flip-flop circuit in which V_{2a} is normally conducting with its anode potential caught by the diode V_{1b}. When a negative going pulse appears on the grid, V_{2a} is cut off and its anode potential makes a positive jump followed by an exponential rise towards the h.t. potential. The initial jump is used to turn on V_{2b} and thus provide the trigger action, and the following exponential rise is used to time the change over between V_{3a} and V_{3b}. Initially the anode current of V_{2b} flows through V_{3b} but when the grid of V_{3a} has risen sufficiently to cause V_{3a} to conduct, a rapid change-over occurs and the current is diverted through V_{3a}. The whole circuit returns to its quiescent condition when the grid of V_{2b} has fallen sufficiently for the flip-flop V_2 to trigger back, and V_{1a} helps to determine the period.

The Dekatrons V_{14} to V_{22}, which form the first decades of the nine scalers, are coupled to their respective second decades by means of a single flip-flop V_{29}. The guide-2 electrodes of the first decades are each connected to the guide-1 electrodes of the respective second decade tubes. Further the Dekatrons V_{14} to V_{22} have a common output cathode load resistor R_{67}. Hence a positive going pulse is generated across this resistor when any one of the first decade tubes conducts to its output cathode. These pulses are differentiated and amplified by V_{30a} and used to trigger the flip-flop V_{29}. The negative going output pulse from this circuit is fed on to all the guide-2 electrodes of the second decades V_5 to V_{13}.

Hence the following two conditions apply. Firstly, whenever a count is registered in one of the first decade tubes a guide-1 pulse is fed into the corresponding second decade tube, and secondly whenever the count in any first decade tube changes from 9 to 0 a pulse is fed on to the guide-2 electrodes of all the second decade tubes. Hence for a count to be registered in a second decade tube these two conditions must be fulfilled simultaneously and it will be seen that this gives the required operation of the scalers. Any tube for which only one condition applies does not register a count.

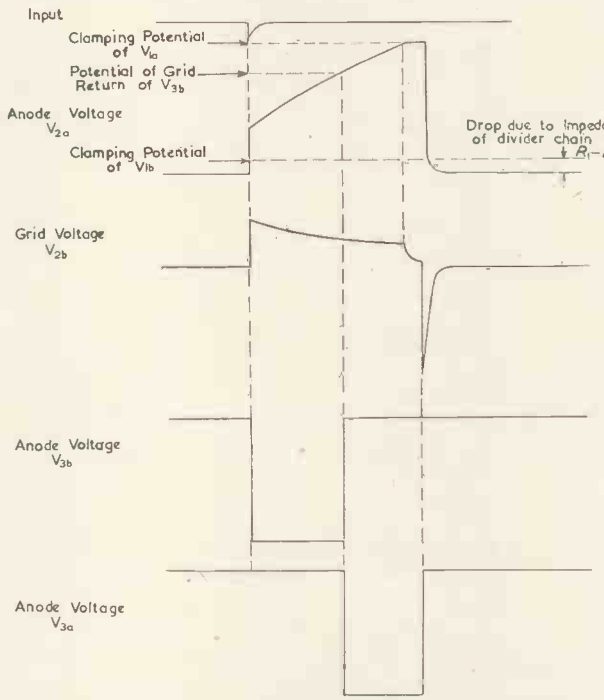


Fig. 3. Scaling circuit waveforms

Circuits are incorporated to reject input pulses during the process of transferring the glow from one cathode to the next in the selector tube V_{41} and also to delay this transfer if the trigger circuit $V_{2,3}$ is in operation when it becomes due. If these precautions are omitted incorrect operation of the second decades can arise. The probability of errors would be very small, but the result of an error could be ten counts in one channel.

As pointed out above V_{23} conducts during the transfer time of V_{41}. Hence during this time the grid of V_{2b} is driven negative and the operation of the trigger circuit $V_{2,3}$ inhibited. The delaying of the transfer of V_{41} is accomplished by the circuit associated with V_{39}. The relevant waveforms are shown in Fig. 4. Fig. 4(a) is the positive going step generated across R_{118} while Fig. 4(b) is the waveform which appears across R_{121} in the absence of input pulses. The latter waveform is modified by feeding in the sum of the outputs of the cathode-followers V_4 through the diodes V_{39}. The result is that during pulses from V_4 the waveform across R_{121} is depressed to slightly below earth potential as determined by V_{39b}. Figs. 4(c) and (d) show two possible conditions. In (c) an input pulse has been received just before the glow of V_{41} transferred to its output cathode. The result is that the leading edge of the pulse across R_{121} and therefore the triggering of V_{40} has been delayed until the operation of the paired pulse generator is complete, i.e. until the time t_1. Fig. 4(d) shows the effect when an input pulse is received during the decay of the waveform across R_{121}. Due to the operation of V_{23} there is a definite period during which an input pulse is not accepted. t_2 in the figure represents the earliest time after the initial rise at t_0 at which an input pulse can be accepted and by suitable choice of C_{27}, R_{121} and t_2 it can be assured that the rise at t_3 is not large enough to trigger V_{40}.

All the Dekatrons are reset by forcing the glow to strike to the output cathode. This is achieved by momentarily driving the appropriate cathode about 200 volts negative.

The power supplies are conventional and are not stabilized.

The time measurements in the instrument are referred to the frequency of the mains supply so that if this frequency changes errors will arise in the time measurements. During the course of all experiments a close check was kept on the mains frequency and it was found that for 95 per cent of the time it was within 0·3 per cent of the mean with occasional variations up to twice this. However, for most of the experiments these variations were negligible compared with the statistical errors involved in the counting of the disintegrations.

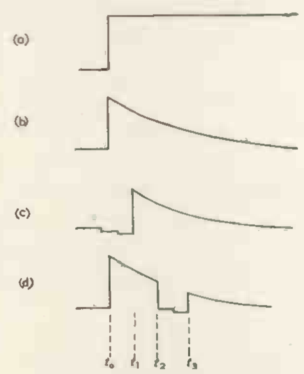


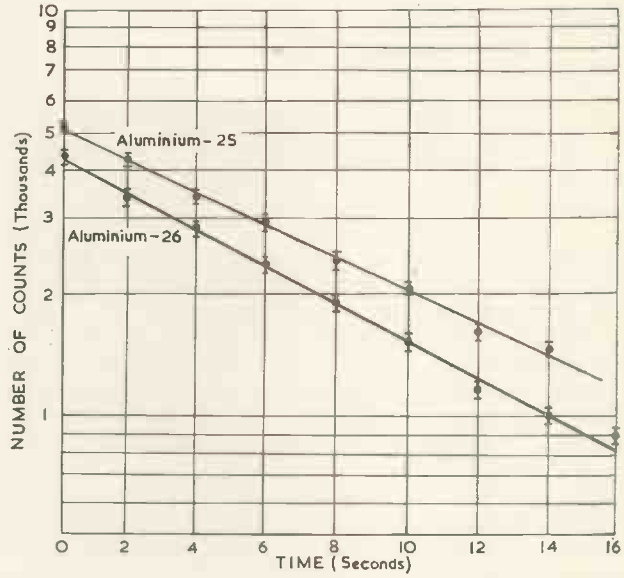
Fig. 4. Circuit waveforms

Results

Measurements have been made on the positron-emitters aluminium-25, aluminium-26 and nitrogen-13 and the results of these which have been reported previously[1] are shown plotted in logarithmic form in Figs. 5(a) and (b). Due to the exponential nature of the decay the mean counting rate in any channel does not occur half way through the period but at a time nearer to the start of the period. In the case of the two aluminium isotopes for which time periods of 2sec were employed for each counting channel this correction was approximately 0·03sec while for nitrogen-13 the corresponding figures were 200sec and 3·8sec.

One hundred and eight irradiations were performed on the magnesium-24 targets and three hundred on magnesium-25 giving a total number of counts in each case of approximately twenty thousand. Due to the very much higher yield obtained from the carbon target it proved to be necessary to insert an electronic scale of one hundred between the Geiger quench unit and the nine channel scaler in order to make use of the higher counting rate. In this case a correction had to be applied for the counting loss due to the 300μsec dead time of the quench circuit.

Computations according to Peierls' method, yield the following results for the half value periods: aluminium-25, 7·62 ±0·13sec; aluminium-26, 6·68 ±0·11sec, and nitrogen-13, 603 ±2sec.



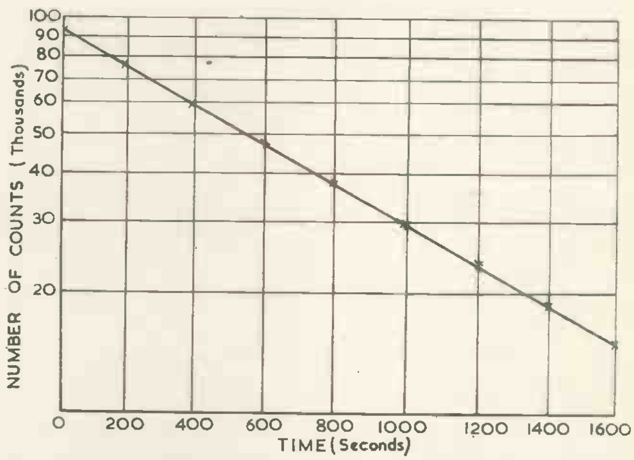


Fig. 5(a) (top). Results for the decay of aluminium-25 and 26, and (b) (below) nitrogen-13

Acknowledgments

These measurements formed part of a programme of research being pursued by Dr. S. E. Hunt and Mr. W. M. Jones of this laboratory and the authors wish to acknowledge their collaboration in conducting the experiments. The authors also wish to thank Mr. B. Millar for helpful discussions and in particular for suggesting the circuit of V_2 and V_3. The Van de Graaff generator used to produce the radioactive isotopes was maintained and operated by Mr. D. Hancock. Thanks are also due to Mr. D. R. Chick for his interest and encouragement and to Dr. T. E. Allibone, F.R.S., for permission to publish this article.

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A Versatile Pulse Shaper

By G. E. Kaufer*, M.S.

In this article a circuit is described which is capable of reshaping pulses of various amplitudes and widths, such as are encountered in computors, radar, etc. The circuit, which is very simple, is of the triggered thyratron type and is designed to feed into a 100Ω line. A table is given showing the output waveshape for various circuit elements.

IN computors and other pulse circuits, it is often desirable to be able to reform pulses so that the resultant waveform will meet with certain required specifications. This is particularly important where a train of high amplitude, sharp pulses are to be distributed centrally to remote parts of an installation via low impedance coaxial lines. Assuming a series of variable amplitude, variable width pulses are originally available, these pulses must be reshaped before distribution. The object of this article is to describe a circuit which may be used to accomplish this purpose. It must be borne in mind that simplicity, reliability, compactness and economy are of prime importance in this design, and that these factors will govern the resultant final choice of circuit.

The statement of the problem is then:

Given a set of incoming pulses conforming to the following specifications:

1. Amplitude—between 25 and 100V.
2. Polarity—positive.
3. Rise Time—less than 0·5μsec (10 to 90 per cent).
4. Width—between 1 and 50μsec between points which are 50 per cent of peak amplitude on the initial rise.
5. Backswing—less than 25 per cent of maximum amplitude.
6. Source Impedance—between 500 and 5 000Ω.
7. Minimum Pulse Spacing—2 000μsec between pulses.

Find a simple one valve circuit to accept these pulses and provide as an output a train of constant amplitude and width pulses conforming to the following specifications:

1. Amplitude—greater than 75V.
2. Polarity—negative.
3. Rise Time—better than 0·1μsec.
4. Width—greater than 0·2μsec between points which are 50 per cent of peak amplitude on the initial rise.
5. Backswing—less than 1V.
6. Output Impedance—must drive a 100 ohm line.

The terminology used in the preceding specifications is indicated on Fig. 1 which shows a typical pulse waveform.

In the text that follows, a circuit will be described which will not only fulfil the above specifications, but which is versatile enough to be easily modified to yield a variety of output pulse amplitudes and widths. Circuit constants will be listed together with resultant output waveshapes.

Background

A majority of the currently employed pulse reshaping circuits which are to drive low impedance lines are centred about blocking oscillators. The low output impedance requirement presents a severe limitation on the choice of adequate circuits.

After considerable thought, a blocking oscillator type generator was rejected because of the following drawbacks:

(a) A blocking oscillator transformer would have to be designed and compactly constructed.

(b) To eliminate backswing in the negative output; the line must be capacitively coupled, necessitating the use of a physically large capacitor (approximately 0·1μF).

(c) Eight components and a high power dual triode (such as a 5687) are necessary, yielding only a scant maximum of approximately 75 volts output without paralleling valves.

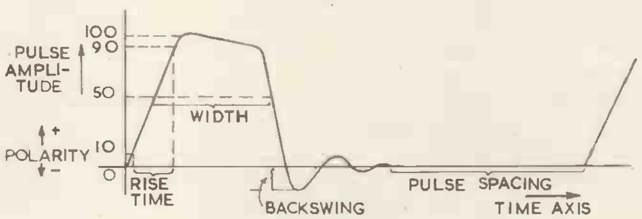

Fig. 1. Pulse waveform

(d) Fairly high voltage bias supplies must be constructed, requiring additional large components as well as special transformers. There are no negative supplies ordinarily present from which to derive these voltages.

Gas Valves

Thyratrons offer the advantage of being capable of supplying high peak anode currents (as long as the duty cycle is short) and utilizing a minimum of associated circuit components. Bias requirements are not severe, this voltage being derivable from the filament supply as explained toward the end of this article.

Circuit operation is straightforward. Referring to Fig. 2, the thyratron is quiescently biased at cut-off so that no anode current is flowing. The capacitor in the anode circuit (in this case the delay line) charges to the power supply potential through the 680kΩ anode resistor and the load. When a positive trigger of sufficient amplitude to raise the grid potential above the critical voltage (approximately −3 volts for an anode supply of +300V—type 2D21 valve) is applied, an arc is initiated and the valve fires. When current flows, it is limited only by the ability of the cathode to supply electrons and by the resistance in the external circuit. Once conduction has begun, there is only

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one way to stop it—that is to remove the anode voltage. After a time interval which varies from valve to valve (in the order of 10 to 1 000μsec), the grid regains control and prevents the flow of current. Similarly, a brief time is required for ionization to occur.

The conducting resistance of the valve is low, the voltage across it dropping from the anode supply V_b to the maintaining voltage V_m of approximately eight volts. At this time, the anode capacitor (or pulse forming network) discharges through the valve, cathode resistor and load in such a fashion that a positive pulse is formed at the cathode and a negative pulse across the load resistor situated between capacitor and ground. The pulse duration is determined by the length of time it takes for the capacitor to discharge through its associated circuit elements. If a pulse forming network is used, the duration is slightly greater than the delay of the line. If no inductance is present, the pulse would have a duration determined by the *RC* discharge time-constant, where *R* includes all the resistors in the discharge path.

With a high tension supply of 300V and a single load resistor, for a 0·2μsec output pulse one would expect to

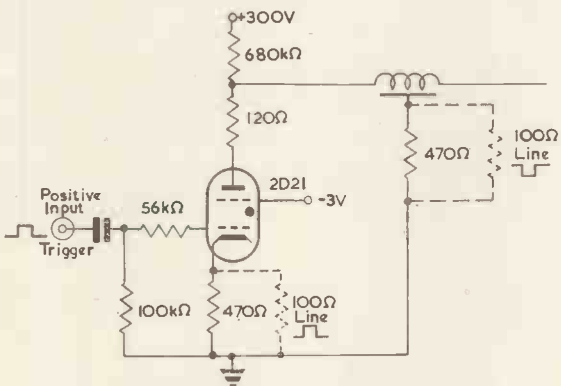

Fig. 2. First model of thyratron oscillator

get a 292V ($V_b - V_m$) amplitude. Under actual conditions, however, the output pulse has only half the anticipated height due to the phenomena of ionization characteristic of gas tubes operating under high speed conditions (fractional microsecond discharge times).

Once started, the anode capacitor will continue to discharge through the valve until the anode current falls below the minimum maintaining current (approximately 1mA). The 680kΩ anode resistor insures that the anode supply will not be able to furnish the required 1mA and hence the arc will extinguish when the capacitor discharge current plus the small amount of anode supply current falls below the minimum value. The valve is then cut off and remains in such a state until the next trigger appears, at which time the sequence of events is repeated. The large series anode resistor also serves to effectively decouple the high tension supply from the pulse sharpener.

A desirable feature of thyratron oscillators is that the output amplitude is only slightly affected by changes in load resistance. The minimum series resistance is, naturally, dependent on the maximum peak anode current permissible for the particular thyratron chosen and is approximately equal to the anode supply voltage divided by the peak anode current. The output impedance is quite low if the load itself is used as the current limiting resistor.

If triggers are injected at too fast a rate, the anode capacitor will not have time to charge to the full supply voltage. As an example, for an anode resistor of 680kΩ and a capacitor of 0·001μF, triggers should be spaced at least 2 000μsec (three time-constants) apart to allow adequate time for a charge to be built up. Otherwise the output voltage will decrease materially as can be seen by referring to the graph of Fig. 3 which is a plot of the output amplitude versus input trigger spacing for a fixed load and a 680μsec anode time-constant.

As is stated above, once the valve fires, the grid loses control. A varying potential applied to this grid would serve only to vary the thickness of the positive ion sheath surrounding this electrode. Advantage may be taken of this fact in the design of a bias supply since, even though the supply regulation is poor and the potential drops when the grid draws current, the grid circuit plays no part in the discharge circuit at this time and hence bias variations are of no consequence. The only time a negative cut-off voltage

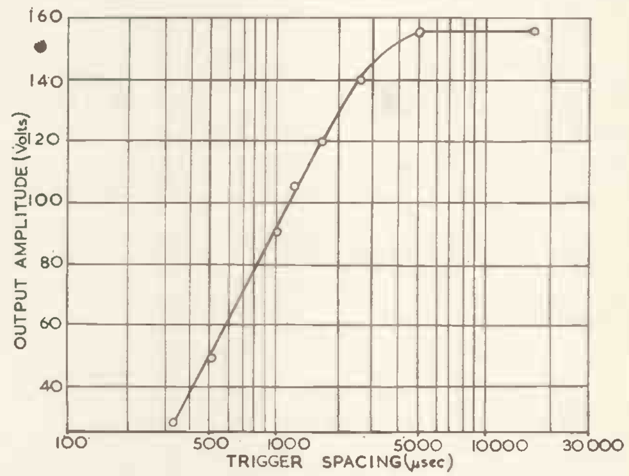

Fig. 3. Output amplitude/input trigger spacing for a fixed load and a 680μsec anode time-constant

must be maintained is when the valve is not conducting (when the drain on the bias supply is least).

It should be noted that either triode or tetrode thyratrons may be employed in this application. Under the same conditions, the shield-grid valve will pass much less grid current than the three-element valve. Furthermore, the shield-grid construction tends to prevent transient conditions in the anode circuit from affecting the grid circuit and the operating conditions of the circuit. The non-conducting grid current of a triode thyratron is a few tenths of a microampere. If an extremely high grid impedance is desired, addition of a fourth electrode serves to accomplish this result, reducing pre-ignition grid current to approximately $10^{-3}\mu$A and cutting down the grid to cathode electrostatic capacitance because of the new physical structure. The critical grid starting characteristics are a function of the shield grid voltage, adding to the versatility of the valve. If the shield grid is connected to the cathode, the tetrode is converted into a very sensitive thyratron.

Development of a Triggered Thyratron Pulse Shaper

A unit which would reliably trigger from the given pulses and which would deliver sharp negative output pulses greater than 75V in amplitude into a 100Ω line was first designed around a 2D21 miniature thyratron and a type D6-5Z10 pulse forming network (Fig. 2). Bias was applied

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to the suppressor grid as indicated. Equal positive and negative outputs would be obtained across the 470Ω resistors loaded by the 100Ω lines. When positive output only is desired, a dummy load consisting of a 100Ω carbon resistor must be permanently wired across the negative output and vice versa to maintain the output at the correct voltage level. It was found that this additional feature of making available both positive and negative pulses introduced the disadvantage of raising the heater-cathode potential so as to exceed the valve rating during the intervals when the valve conducts. Tying the filament to the cathode will remedy this, but doing so necessitates the inclusion of separate filament transformers, one for each thyratron in the system. In subsequent models, the cathode was grounded directly, resulting in a single high amplitude negative pulse output. If necessary, either output polarity may be obtained by replacing the remaining load resistor with a pulse transformer and taking the output from one or the other terminal, but many disadvantages inherent in blocking oscillator units result.

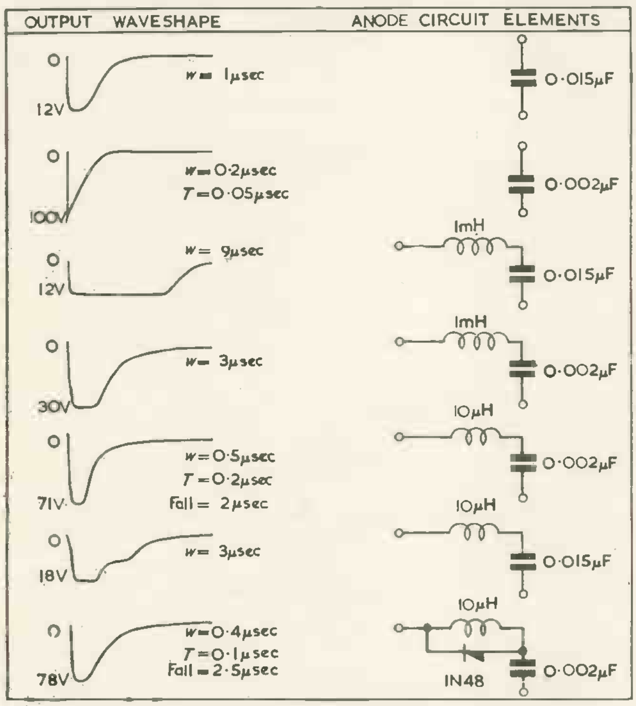

Fig. 4. Anode circuit networks and relative waveshapes

w = width at 50 per cent amplitude
T = rise time (10-90 per cent)
All above waveforms measured with Browning model ON5 oscilloscope and indicate relative magnitudes
Circuit of Fig. 7 used for all measurements

The correct load for the particular pulse forming network chosen is 470Ω. Experimental tests verified that for loads much less than rated, the network behaves as a pure capacitor and differentiates the pulse. Since the effective capacitance is small the output is of very short duration (less than 0·1μsec) and hence is of low amplitude due to the inability of the thyratron to ionize completely in this short period of time. After investigation, it was found that the effect of mismatching the delay line is to introduce a series of steps into the transient discharge which, for a decrease in load resistance, alternate in sign. Since the thyratron was required to work into a 100Ω line, the delay line was discarded in favour of a simple *LC* timing network.

A variety of two terminal pulse networks was tried, ranging from a single 0·015μF capacitor to a 10μH inductor shunted by a 1N48 diode all in series with a 0·002μF capacitor. A tabulation of networks and relative resultant waveshapes is formulated in Fig. 4 for purposes of comparison. It was found that a small series inductance considerably lengthened the discharge time of the capacitor, permitting one to obtain a wide range of output pulse shapes and widths. Although the opposition to changes in current afforded by the inductance appreciably lengthens the output pulse, this phenomenon is accompanied by a corresponding decrease in pulse amplitude. This due to the fact that the total area under the curve represents energy, and the source energy stored in the anode capacitor is fixed according to the relation, $W = \frac{1}{2}CV^2$.

The next problem was that of triggering with short pulses. The mechanism of initiating conduction consists of injecting on the grid a positive pulse large enough in amplitude to cause the gas between grid and cathode to

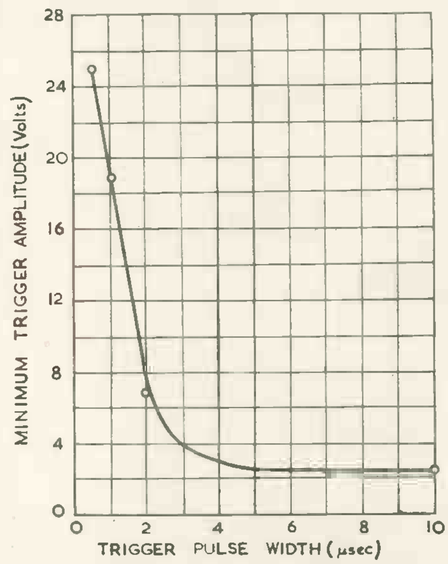

Fig. 5. Trigger amplitude/pulse width for fixed bias (−4V)

ionize. If the pulse amplitude at the grid is maintained, the arc is transferred to the anode and the valve breaks down. On the other hand, if the pulse amplitude decreases appreciably, the grid-cathode arc will extinguish before it has transferred to the anode, and the valve remains in the non-conducting state. In view of this, it would be anticipated that as the trigger pulse width is decreased, the minimum trigger amplitude required would increase. Unfortunately, when the grid-cathode circuit ionizes, the network consisting of the series grid limiting resistor and the thyratron grid resistance acts to attenuate the input trigger. This is especially serious for triggers of short duration, since the area under the pulse directly at the grid is low and hence the initial amplitude must be correspondingly high. Since the quiescent bias voltage on the thyratron is somewhat greater than that required to prevent the valve firing, and since for proper operation the firing of a thyratron must be positive, it is usual to drive the grid well beyond the critical point when firing. This practice creates the need for a finite amount of grid power and any circuit feeding the grid must be capable of delivering this power. This grid current produces a loading on circuits which tends to reduce the actual voltage appearing at the grid. In very high impedance circuits, the trend of this effect is to make the operation of the valve independent of the intended actuating voltage. In addition, this effect may vary; for example, as the valve warms up its characteristics change. This is the underlying reason for reducing the grid resistor to a minimum value if reliable triggering from fractional microsecond pulses is to be obtained. In the final circuit, 10kΩ was found to be a good compromise value. This is verified experimentally; the graph of Fig. 5 obviously illustrating the aforementioned statements. This curve was plotted for a fixed grid bias of −4V, a value which was found to produce the best results. A larger negative bias would require an even greater trigger amplitude as well as introducing power

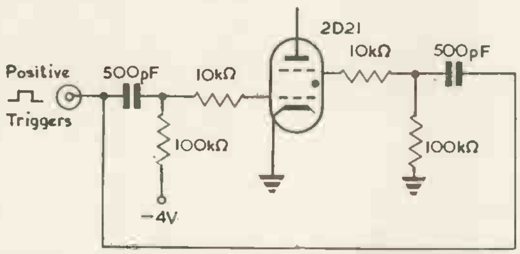

Fig. 6. Triggering circuit in which both grids are pulsed simultaneously

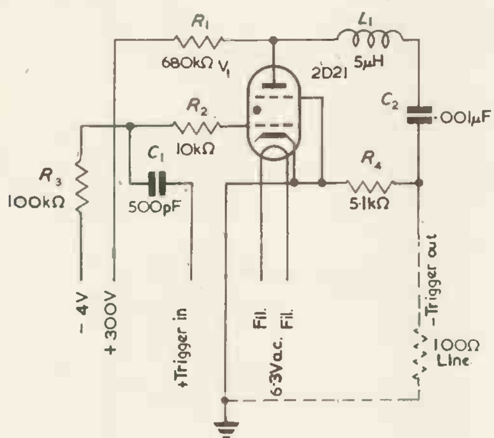

Fig. 7. The final circuit

C_1—500V mica
C_2—500V ceramicon
L_1—100 turns of 32 enamelled wire close-wound on 100kΩ—¼W carbon resistor (three layers). Inductance: approx. 5μH
P_1—9-pin "octal style" plug mounted on vector can

supply design problems, whereas a more positive bias would result in the thyratron oscillator becoming astable.

In an effort to speed up the ionization time, pulsing and biasing of alternate grids was tried as well as tying both grids together and triggering them simultaneously. The latter connexion yielded the worst condition, it requiring 48V with 0·5μsec triggers instead of 25V if only one grid is pulsed. This is due to the fact that with this mode of operation we now have two grids biased negatively under quiescent conditions, a much larger surface area. Even a triggering circuit such as illustrated in Fig. 6 does not improve the firing time above that of the simple method eventually resorted to.

Conclusion

The final unit is shown schematically in Fig. 7. The previous 120Ω anode resistor is omitted since adequate peak current limiting is provided by the 100Ω load itself. The compromise in anode pulse forming network finally resorted to consists of the series combination of a 5μH coil and a 0·001μF capacitor. At a pulse repetition frequency of 400p/s the peak output is 140V negative (see graph of Fig. 3) into a 100Ω line with a pulse width (50 per cent down) of 0·28μsec. The rise time (0·1 to 0·9) is 0·08μsec and there are no oscillations. No output coupling capacitor is required.

The thyratron sharpener meets all physical and electrical specifications. Heat dissipation of components is negligible and ½W resistors are used throughout. The 5μH coil is constructed by closely winding 100 turns of No. 32 enamelled wire in three layers using a 100kΩ half watt carbon resistor as a coil form. Inductance is not critical as the output pulse amplitude is well above the required 75V.

In both the experimental set-up and the final system, bias was derived from the same transformer that supplies filament current to the valve as illustrated in Fig. 8. The 50μF

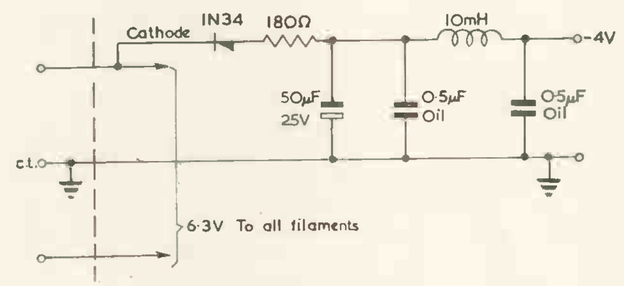

Fig. 8. Compact bias supply

capacitor provides adequate filtering, while the 180Ω resistor limits the peak current to a safe value for the 1N34 germanium diode. If the full 6·3V a.c. winding is used as the input, the open circuit voltage is 10V. For this case a 680Ω load insures good regulation and drops the output to the required 4V.

Communications System for Ethiopia

An important contract has recently been signed between the Imperial Board of Telecommunications of Ethiopia and the two British firms, Standard Telephones and Cables Ltd and Marconi's Wireless Telegraph Company Ltd for a new International Radio Communications system working from Addis Ababa.

The system will provide radio telephone and telegraph communication with London, Nairobi, and important centres in the Middle East. Additional services may be inaugurated later to other European centres.

M.W.T.C. are equipping the complete receiving station and will be responsible for engineering, supplying and installing the complete aerial systems for both the transmitting and receiving stations and also for supplying all the independent sideband drive equipment.

S.T.C.'s share of the contract includes two 4kW transmitters type DS 12 together with high stability oscillator; telephone terminal equipments providing two simultaneous telephone channels; voice frequency telegraph equipment providing two telegraph channels, and special screened underground cable for linking the radio station sites to the city of Addis Ababa.

In addition both companies are supplying a considerable quantity of ancillary equipment.

A team of British engineers will be installing the equipment during the coming months and training Ethiopian personnel to operate the new stations, which will then be among the most modern and well equipped in the world.

Use of a Rubber Sheet Model

for Investigation of Electron Trajectories

By K. R. Allen*, B.Sc., A.Inst.P. and K. Phillips*, M.Sc., A.M.I.E.E.

This article describes the investigation of electron trajectories for a simple type of electron gun by means of a rubber sheet model. The purpose of the work was to attempt to assess the possibilities and accuracy of the rubber sheet as a method of plotting electron trajectories. Kleynen's original article describes the technique but does not attempt to assess its usefulness, particularly in the design of electron guns. Walker has more recently considered the factors influencing the design of a rubber sheet model on a more theoretical basis. There has been a tendency in recent years to believe that the results given by the model are rather misleading. An example is given which shows that this state of affairs may exist when due attention is not paid to the exact shape of the emitting surface. Good correlation, however, between the model predictions and experimental results has been found provided certain conditions are satisfied. The electron gun chosen is a particularly good example for the purpose of this article as it indicates certain pitfalls which should be avoided. A novel method of obtaining equipotentials is also described.

NUMERICAL and graphical methods of electron ray tracing generally depend upon an accurate plot of the field existing between the electrodes. It is usual owing to the tedious mathematical analysis which is involved, to resort to the use of an electrolytic tank method of field plotting. Another method of obtaining electron trajectories which does not require a direct knowledge of the field map was suggested by Moon and Oliphant[1] and Kleynen[2], and has been used in the design of electron photo-multipliers[3]. It has been shown that the motion of an electron in a two-dimensional electrostatic field could be compared with the motion of a small ball on a stretched rubber membrane.

For the case (see Fig. 1) of a rolling ball of radius r and mass m, travelling with velocity u on a rough surface, the forces acting on the ball can be resolved along and at right angles to the surface (assuming point contact) giving the following expressions:

$$m\dot{u} = mg \sin\theta - F$$
$$O = mg \cos\theta - R$$

where θ is the angle of slope of the rubber sheet at the point of contact.

Taking moments about O:

$$mk^2\dot{\omega} = Fr \quad \text{also} \quad u = r\omega$$

where ω is the angular velocity and k is the moment of inertia.

Hence the friction $F = mk^2\dot{u}/r^2$ and the equation of motion in the x direction is:

$$\frac{md^2x}{dt^2} = mg \sin\theta \cos\theta - \frac{mk^2}{r^2 + k^2} g \sin\theta \cos\theta$$

putting $k^2 = 2/5\ r^2$

$$d^2x/dt^2 = 5/7\ g\ d\phi/dx$$

where ϕ is the height of the membrane.

This is similar to the equation of motion of an electron which may be written as:

$$d^2x/dt^2 = -e/m\ dV/dx$$

The condition that the ball does not slide is $F/R < \mu$ (μ = the coefficient of sliding friction), i.e. $2/7 \tan\theta < \mu$.

* *Metropolitan-Vickers Electrical Co. Ltd.*

If, however, the ball slides then the equation of motion is:

$$d^2x/dt^2 = -g(d\phi/dx - \mu)$$

and the coefficient of friction will reduce the effective potential of the electrodes. Hence even though the ideal case of a sliding ball gives the correct results, discrepancies will arise when both sliding and rolling occur.

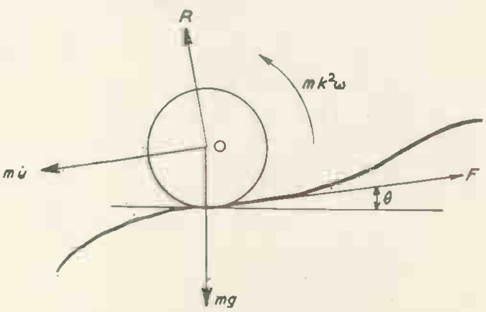

Fig. 1. Forces acting on a sphere moving on a sloping surface

So far only the upper limit of membrane slope has been considered, but there is also a lower limit. This is of particular import when the ball is commencing its trajectory, i.e. when its momentum is small. This lower limit excludes the obvious trivial case of no slope when the ball will not roll. It is rather difficult to treat the problem analytically as it depends to a large extent on the individual case in question. It is obvious that no matter how tight the membrane is stretched, the ball will form a small indentation. The deformation of the contours may reduce the slope and prevent the ball from rolling. Furthermore, when the ball is travelling very slowly it is easily scattered by small particles of dust and surface irregularities in the rubber sheet (see Fig. 4(a)). On substituting the experimental values of the parameters into the results obtained by Walker[4] the error due to energy loss by friction is found to be about 5 per cent.

Apparatus

The membrane was made of 0·040in thick pure rubber sheet clamped between two brass frames 48in long by 24in wide. Considerable care was taken in finding the best and simplest method of clamping the sheet so that it could be uniformly stretched. The final method arrived at is shown in Fig. 2. The rubber sheet, trapped between the two angle pieces, was secured by means of 30 "G" clamps placed around the frame at equal intervals. Uniform stretching of the sheet was achieved by marking a grid of equally spaced lines on the underside of the unstretched rubber, and so tensioning the sheet that all segments of the grid maintained their original shape. The frame was supported on two tubular-steel-framed laboratory tables with adjustable legs, thus enabling the model to be accurately levelled.

A model of the electron gun was constructed of bakelite strips mounted on ¼in diameter brass pillars of various heights. All the electrode dimensions were enlarged by a factor of a hundred. Steel ball bearings 3/16in diameter were used to represent the electrons. At first the balls were hand released, but the initial velocity given to them was found to give inconsistent results, so an electromagnetic release was finally adopted. A series of tests was performed and it was found that the paths were reproducible to within

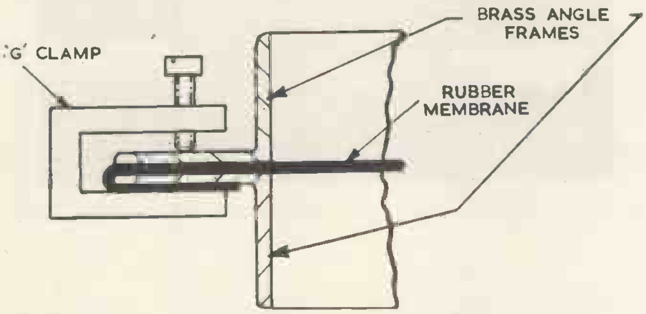

Fig. 2. Method of clamping rubber sheet

5 per cent of the final beam width. The trajectories of the balls were photographed using low angle oblique lighting from a 600 watt Photoflood lamp. The camera was a Retina I mounted directly above the model. It was found that by using 35mm Super XX film developed in fine grain developer good resolution and contrast of the tracks could be achieved.

Experimental Results

The results given here are the trajectories plotted for a simple three-electrode gun. The electrode structure is similar to the gun originally designed by Kerst[5] for use in a 20MeV betatron. The gun consists of a helical filament which is surrounded by a metal focusing grid, both being at the same potential. These are enclosed in an earthed anode and under normal conditions a negative pulse of 70kV, is applied to the grid and filament.

The first tests were carried out with a cylindrical cross-section for the gun filament. Fig. 3(a) shows the paths obtained for a spacing of 0·035in between the front of the filament and the front of the grid. It will be seen that the extreme paths cross over outside the anode gap. In Figs. 3(b) and 3(c) the filament to grid spacing was reduced to 0·028in and 0·018in respectively.

In an attempt to verify these results a convenient form of experimental gun was constructed. The complete structure was mounted in a vacuum chamber, one of the inner walls of which was coated with willemite forming a fluorescent screen for observing the size of the electron beam.

A scale was engraved on the screen to measure the width of the beam. The relative positions of the electrodes were varied and the distance between them measured to within ±0·002in with a travelling microscope. Some of the results of varying the position of the filament inside the focusing cup are given in Table 1.

These figures indicate a minimum in the half width of the pattern at the 0·028in spacing. This minimum is also shown with the rubber sheet model tests. One significant

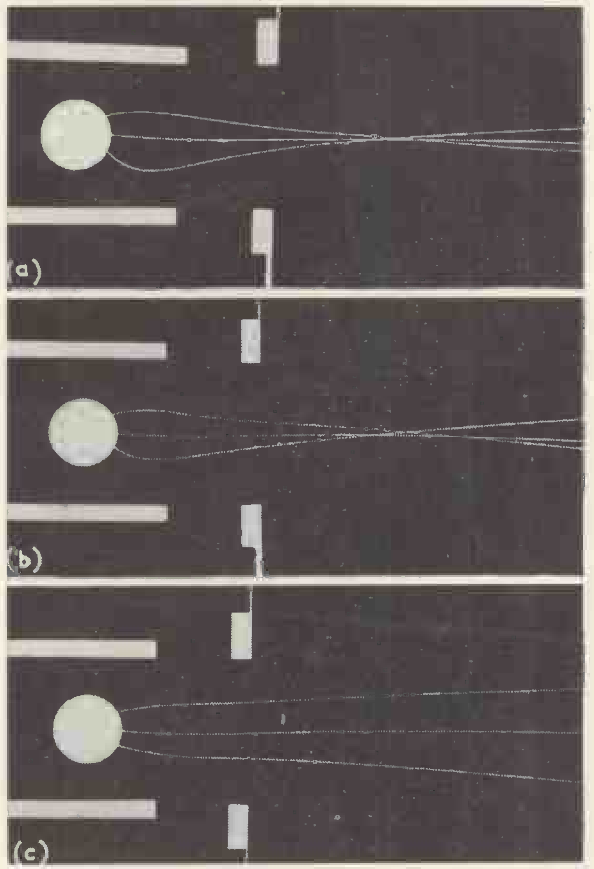

Fig. 3. Electron trajectories for spacings of (a) 0·035in, (b) 0·028in, (c) 0·018in between the front of the filament and the front of the grid using a cylindrical cross-section for the filament

difference between these results and the experimental rubber sheet model values is that in practice the electron beam is much more divergent than was predicted.

Study of Equipotentials

In order to study the focusing properties of the gun, the equipotentials of the system were plotted using the

TABLE 1

DISTANCE OF FRONT OF FILAMENT FROM EDGE OF GRID CUP (INCHES)	HALF WIDTH OF PATTERN ON FLUORESCENT SCREEN (INCHES)	HALF WIDTH OF PATTERN FROM RUBBER SHEET MODEL (INCHES)
0·035	4·75	1·40
0·028	3·25	1·12
0·018	4·75	1·40
Less than 0·018	Very divergent	Very divergent

rubber sheet. The portions of the rubber covering the bakelite model were coated with a thin layer of white poster paint. A screen of clear Perspex, upon which had been drawn a series of equally spaced parallel lines was placed in front of the model. Using low angle illumination the shadows cast by the lines gave the equipotentials of the structure. For a permanent record a photograph was taken using Kodak microfile film. This technique, although perhaps not as accurate as the usual electrolytic tank method of plotting equipotentials, is much simpler and easier for two-dimensional systems. Furthermore, a visual picture is provided immediately. This is a definite advantage when trying to obtain a particular potential distribution by adjusting electrode positions. A typical example of the plots is shown in Fig. 5. It can be seen that inside the grid, the field has a certain amount of focusing action. Extending from the grid to the anode gap there is a defocusing field, which increases as the filament is moved nearer the mouth of the focusing cup. From these plots of equipotentials and by means of a simple graphical construction, it can be shown that the paths of the electrons are approximately the same as predicted by the ball rolling experiments. A further check was made by using relaxation methods to calculate the field configuration and the results are shown in Fig. 6.

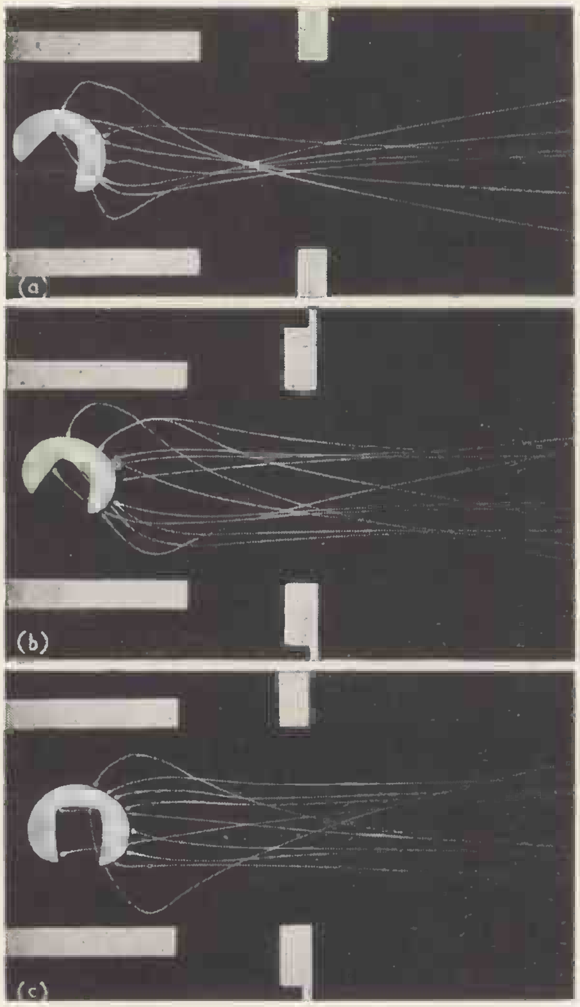

Fig. 4. Electron trajectories obtained by superimposing separate photographs. Spacings of (a) 0·035 in, (b) 0·028in, (c) 0·018in, between the front of the filament and the front of the grid using a segmented cross-section for the filament

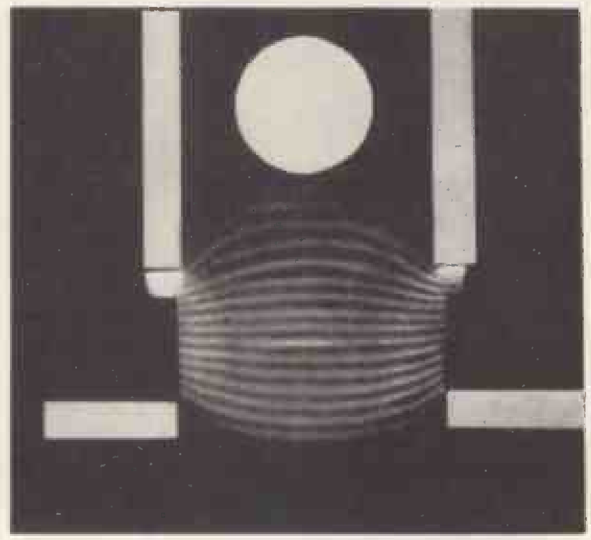

Fig. 5. Equipotential plot of the gun assembly obtained with the rubber sheet model

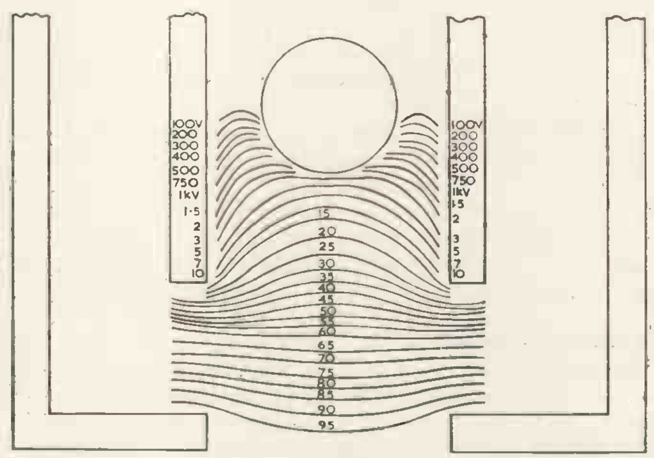

Fig. 6. The calculated field configuration obtained by the relaxation method *(Compare with Fig. 5)*

Discussion

Since the rubber sheet model predictions did not compare favourably with the experimental results on a full size electron gun, it is reasonable to consider how any possible discrepancies may arise. Such errors may be due to the fact that for the case of large electron densities space charge spreading may occur. Attempts were made to detect any space charge defocusing in the gun itself by varying the emission and the relative anode potential, but no such variations were found.

A further source of error could be attributed to the fact that the cross-section of the helical filament in any one plane at right-angles to the filament axis is not a complete circle. In order to test this, a representation of the true cross-section of the filament was used on the model and it was found that the trajectories were much more divergent. Now since the filament may emit from the inside of the spiral it was necessary to examine the electron paths for various angular positions of the segment representing the filament. A good overall picture of the focusing was obtained by superimposing several of the negatives during enlargement (see Fig. 4). A comparison of the final rubber sheet model predictions and the experimental results on an electron gun are given in Table 2.

The rubber sheet model has been used to determine the trajectories of electrons emitted by a simple electron gun. This method has given results which do not agree with measurements of the half width beam pattern on a fluorescent screen unless the shape of the emitting surface on the model is carefully considered.

The results obtained with a circular emitting surface give a less divergent beam than that found in practice as shown in Table 1. When the filament cross-section is modified to conform more closely with the spiral structure of the filament then it is found that the model predicts a more divergent beam, in agreement with practice as shown in Table 2.

One point to note is that the motion of the balls where the slope is small may be erratic if any dust particles are present on the surface of the rubber.

The equipotential lines obtained by the shadow technique agree fairly well with the calculated values and this method can be applied very easily to certain problems.

Acknowledgments

The authors wish to thank Mr. M. M. Lipsicas for his help with the relaxation calculations; also Mr. E. A. Finlay and Mr. F. R. Perry for their constant encouragement and advice, Dr. Willis Jackson, F.R.S., M.I.E.E., Director of Research and Education, and Mr. B. G. Churcher, M.Sc., M.I.E.E., Manager of the Research Department, Metropolitan-Vickers Electrical Co., Ltd., for permission to publish this article.

TABLE 2

DISTANCE OF FRONT OF FILAMENT FROM CUP (INCHES)	HALF WIDTH OF PATTERN FROM FLUORESCENT SCREEN (INCHES)	HALF WIDTH OF PATTERN FROM RUBBER MODEL (INCHES)
0·035	4·75	4·9
0·028	3·25	3·5
0·010	4·75	5·0
Less than 0·018	Very divergent	Very divergent

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A Stabilized Radio-Frequency E.H.T. Supply

By A. E. Lowe*

The apparatus described is an e.h.t. unit to provide a continuously variable d.c. output from about 100 *to* 1 600 *volts at a low current, highly stabilized against variations of components and supplies. It draws its power from an external source, such as the spare power available on a commercial scaler or similar equipment.*

THIS unit was developed to provide stabilized e.h.t. to Geiger counters and photo-multipliers, as used in scintillation counters, and to operate from the h.t. and l.t. power, available externally on electronic equipment associated with radio-isotope work. The power supplies commonly available on such equipment are: 6·3V a.c., plus 315 (nominal) and −105V (nominal). Both the d.c. supplies are stabilized, but the negative line depends on the stabilizing tube voltage and the positive line may be anywhere between 300 and 330V. The power taken from the supplies should be kept to a minimum.

The maximum e.h.t. voltage required for G.M. tubes or multiplier tubes does not exceed 1 600V. The G.M. tube takes only a fraction of a microampere. Most commercial scintillation counters take not more than 20μA from the e.h.t. supply; a few require as much as 100μA.

The unit was therefore designed to produce a maximum output of 1 600V at 20μA; to be independent of load and of h.t. positive line drift to within 0·1 per cent. In addition it was desirable to keep the drain on the external supplies to a minimum and to produce 100μA of e.h.t. with a simple modification. The use of easily available components was also an important consideration.

* *Experimental Radiopathology Research Unit, Hammersmith Hospital.*

The unit consists of two parts:

(1) The r.f. heater supply for the e.h.t. rectifier (EY 51).

(2) The e.h.t. generator and stabilizer.

The circuit of the r.f. heater supply is of very simple design. It uses a Wearite P.O. coil coupled to a home made coil of 11 turns of 20 s.w.g. insulated copper wire. This coal is wound on a 1in diameter former and is held in position by allowing the fixing strip of the Wearite coil to bear on an internal shoulder, as shown in Fig. 1.

A rapid method of checking the r.f. heater power of the EY 51 is to compare its forward resistance when heated by 50c/s (or d.c.) and by r.f.

When the h.t. supply is at maximum (330V) the forward resistance should correspond to not more than 7V at 50c/s, and at minimum h.t. (300V) not less than 5V at 50c/s.

This part of the unit would, of course, demand considerable component value modification if the positive rail voltage was altered much beyond the specified limits.

The E.H.T. Generator and Stabilizer

In principle the generator is a pentode (V_1, CV1116) driving a Hivolt e.h.t. coil, type C150, as shown on the circuit diagram (Fig. 2). The high r.f. voltage is rectified by V_2 and smoothed by C_5, R_3, and C_6. The d.c. so produced is fed to the grid of a single valve d.c. amplifier via the potentiometer R_8, VR_1, R_9, the bottom of which is connected to the highly stable negative line. This line thus acts as a reference potential and its stability is therefore of primary importance. The percentage variation of the e.h.t. voltage cannot be less than that of the negative line.

The output of the d.c. amplifier is fed, via a step-down network to the suppressor of V_1; completing the feedback line and thus controlling the e.h.t. voltage by regulating the oscillator anode current. It will be clear that V_1 must possess high suppressor slope in order to exert proper control. The CV1116 is much the best available valve for the purpose.

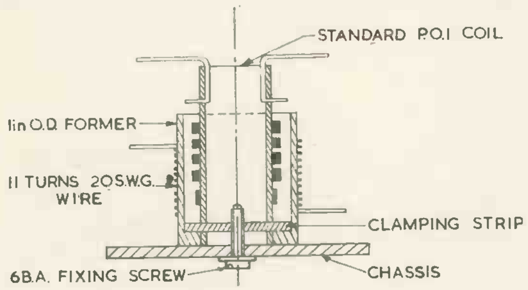


Fig. 1. The r.f. heater supply coil

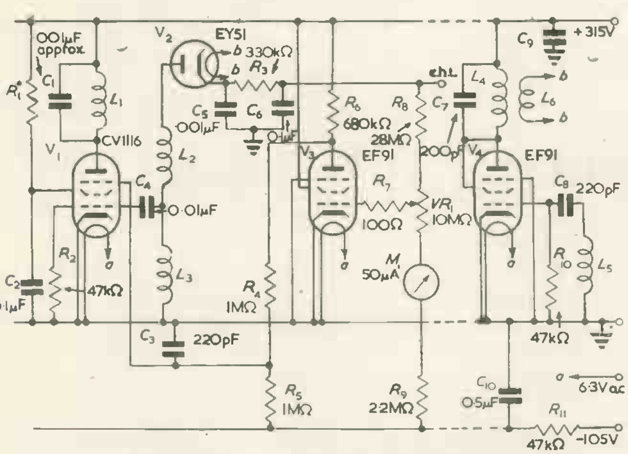


Fig. 2. The e.h.t. generator and stabilizer

R_1 = 180kΩ *for* 30μA *out*; 68kΩ *for* 100μA *out*

L_1, L_2, L_3 = *Hivolt coil C150*

L_4, L_5 = *Wearite coil P.O.1*

L_6 = 11 *turns* 20 *s.w.g. on* 1*in former*

R_1 has the function of limiting the anode current of V_1 and hence the maximum e.h.t. output. However, the action of the suppressor switches current from anode to screen grid and hence if R_1 is reduced the consumption of V_1 will be increased at all outputs, not just at maximum output.

A few words are necessary with regard to the measurement of e.h.t. voltage and the potentiometer formed by R_8, VR_1, R_9.

In order to conserve e.h.t. current and avoid the use of an electrostatic volt meter, it was decided to incorporate the microammeter in the potentiometer chain. This introduces a difficulty as the bottom end of this chain is returned to a potential approximately 100V below earth. The total value of $R_8 + VR_1 + R_9$ is also fixed by this consideration. Having decided on the microammeter current for maximum e.h.t. the value of $R_8 + VR_1 + R_9$ is equal to E_f/I_{mf} (where E_f is the "full scale" e.h.t. voltage and I_{mf} the "full scale" meter current) and the microammeter zero set back, mechanically, by a scale reading equal to

$$\frac{e}{R_8 + VR_1 + R_9 \mu A}$$ (where e is the negative line voltage),

that is by an amount equivalent to the negative line voltage as read on the voltmeter. The scale is then linear. In the circuit under consideration a 50μA instrument was used and it was decided that full scale deflexion should be equal to 2 000V. Therefore $R_8 + VR_1 + R_9 = 40M\Omega$ and the zero was set back 2·5μA. To a close approximation the e.h.t. voltage is given $R_a/R_b - (e - V_g)$ where V_g is the bias voltage (see Fig. 3). Taking $-(e - V_g) = e_1$ the values of maximum and minimum e.h.t. (that is when the slider of VR_1 is at the two extremes of its travel) can be worked out from the following:

$$\frac{E_{max}}{e_1} = \frac{R_8 + VR_1}{R_9} \qquad \frac{E_{min}}{e_1} = \frac{R_8}{VR_1 + R_9}$$

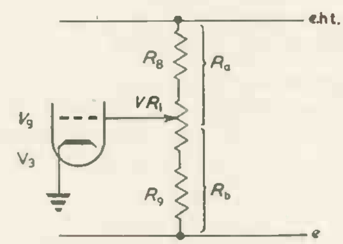


Fig. 3. Calculation of output voltage

As it is usually impossible to obtain multi-megohm potentiometers in any desired value, or to a high tolerance, compromise is necessary in the selection of the voltage range to be covered.

For the circuit described it has already been said that $R_8 + VR_1 + R_9 = 40M\Omega$, e_1 can be considered to be 100V. If E_{max} and E_{min} are 1 600 and 300V respectively, $R_8 = 30M\Omega$, $VR_1 = 7{\cdot}65M\Omega$ and $R_9 = 2{\cdot}35M\Omega$. In fact a convenient value for VR_1 is 10MΩ. This gives R_8 as 28MΩ and R_9 as 2·2MΩ, using as few components as possible. Thus $E_{max} = 100\,(38/2{\cdot}2) = 1\,730$V, and $E_{min} = 100\,(28/12{\cdot}2) = 230$V. In the above calculations the negative line filter is ignored as its effect is negligible.

The lay-out of the circuit is important. All leads carrying r.f., particularly the lead from the anode of V_1 to the coil, must be kept short otherwise power will be lost.

It is necessary that the maximum full load e.h.t. output with the suppressor of V_1 grounded should be at least 15 per cent more than is required under operational conditions, in order to maintain the e.h.t. constant to within 0·1 per cent from full load to no load. This can be done by adjusting the value of R_1.

For the circuit values given and with 1 600V e.h.t. a change in output current from no load to full load (32μA) produced less than 0·1 per cent change in output voltage. For all values of e.h.t. output the change in voltage for a swing of 300 to 330V on the h.t. line is much less than 0·1 per cent.

The ripple voltage on the e.h.t. line is 300mV without, and 80mV with the negative line filter. This filter is not necessary if the negative line ripple is low or e.h.t. ripple is unimportant. Drain of the whole unit from the h.t. rail is 10·5mA at 315V with $R_1 = 180k\Omega$ and 14mA with $R_1 = 68k\Omega$.

Notes from

North America

Research Fellowships

Research fellowships tenable in American institutions under a technical assistance programme sponsored by the U.S. Foreign Operations Administration, have been awarded to five British scientists. The awards were made by the National Academy of Sciences, Washington, on the nomination of the Royal Society.

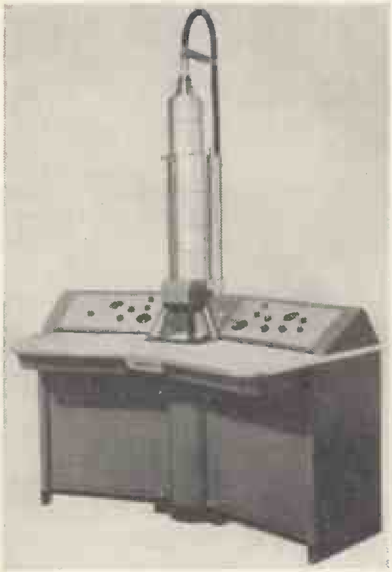
Among the recipients are Mr. G. V. Chester, Scientific Officer, Radar Research Establishment and Dr. G. L. Squires, a Senior Research Fellow at the Atomic Energy Research Establishment, Harwell.

This brings to 16 the number of awards to candidates from the United Kingdom in a programme which was instituted in 1953 and is intended to enable some 150 outstanding scientists from the 14 Western European countries to carry out advanced study for up to two years at American universities and research institutions. The programme has now been extended for Britain by the provision of 35 more fellowships which will be tenable up to June 30, 1957.

The U.S. Government has allocated $1 300 000, plus the equivalent of an additional $210 000 in local currencies, for the programme. A grant at a yearly rate of about $3 300 (approximately £1 180) plus travel expenses will be given each trainee, who must sign a written statement that he promises to return to his country to apply his training. Requirements for a fellowship include the possession of a doctorate in science from a recognized institution of higher education, or equivalent experience.

RCA Electron Microscope

An electron microscope, type EMU-3A, claimed to be the most powerful in the world, has recently been developed and built at Camden, New Jersey, by the Radio Corporation of America. An instrument of this type has been presented to the Karolinska Institute of Stockholm under a grant from the Rockefeller Foundation for research in cell and tissue structure.



The type EMU-3A microscope. The overall dimensions are:—Height 7 ft. 8 in., Width 4 ft. 9 in., Depth 5 ft. 10 in.

The type EMU-3A electron microscope, which is shown in the accompanying photograph, employs unit construction throughout. The desk top and front and rear panel doors are removable for quick inspection and ease of maintenance. The control panels are hinged at the bottom and lift up for easy access.

The principal characteristics of the instruments are as follows:

Resolution 20Å.
Magnification Range 1 400 × to 30 000 ×.
Useful Photographic Enlargement 200 000 ×.
Photographic Facilities Plate—3 or 5 exposures on 2in by 10in plate, or 3 exposures on 3¼in by 4in plates.
Film—30 exposures on 35mm unperforated film.
Exposure—Timing is automatic and a built-in exposure meter is included.
Optical System One set of pole pieces for all magnifications.
Externally alignable objective aperture.
Electrostatic compensation.
Viewing Screen Three 5in by 5in viewing windows.
Binocular viewer.

Forecast for 1955

According to Dr. W. R. G. Baker, vice-president of the General Electric Company and General Manager of the G.E. Electronics Division, Syracuse, it is expected that by the end of 1955 there should be at least 530 television stations in operation in the United States and that more than 50 per cent of them will be able to transmit network colour programmes.

The retail sales of monochrome television receivers is estimated at 5 800 000 which is slightly less than the near record level of 1954. This decline will, however, be offset by an estimated sale of 200 000 colour television receivers.

The anticipated sales of broadcast receivers is in the region of 6½ million, of which one million will make use of printed circuit techniques.

New D.C. Millivoltmeter and Amplifier

The illustration shows the new MV-17 CP millivoltmeter which has just been developed by the Millivac Instrument Corporation of 444 Second Street, Schenectady, New York. This instrument has a range of 100μV to 1kV and contains an accurately tuned 120c/s d.c. modulator which is driven from an internal 60c/s *RC* oscillator.

The new d.c. millivoltmeter can operate as a stable d.c. amplifier with a gain of 1 500 and a d.c. drift of less than 50μV referred to the input circuit over long periods of time. It may be used over a wide power supply frequency range from 40 to 500c/s.

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Very Low Frequency Transformers

(Illustrated above)

A RANGE of hermetically sealed transformers for operation at frequencies as low as 2c/s is now in production and includes both input and output types with balanced windings, internal screens and a heavy mumetal outer case to reduce stray pick-up to a very low level.

Intended for geophysical and similar applications, typical performance figures for an output transformer show a primary inductance of 3 600H measured with an input of 1V at 10c/s in a space of $20in^3$: and a weight of 2lb. All units have Corundite insulators, are vacuum impregnated and completely sealed.

A 1 000H tapped filter choke with a Q of 10 at 50c/s and a weight of 7½oz is also available and a range of miniaturized units for similar and other special applications is under development.

Avis & Baggs Ltd,
11-13 Gosbrook Road,
Caversham,
Berkshire.

Multi-way Connectors

(Illustrated below)

THIS new range of multi-way plugs and sockets provides 20, 30, 40, 60 and 80 way linkages.

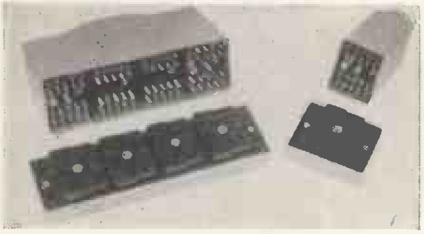
The plugs and sockets of these connectors are very compact, each being contained within a rectangular aluminium case. Units may be packed closely together on a chassis or panel. Comprehensive plug and socket systems can be built up, the following combinations being possible :—

Two 20-way plugs may be mated to one 40-way socket.

Two 30-way plugs may be mated to one 60-way socket.

Four 20-way or two 40-way plugs may be mated to one 80-way socket.

The contacts are silver plated and provide positive connexion when fully



engaged but give a self-ejecting action when being disconnected.

Cable clamps are provided and special attention has been given to the problem of soldering in the small space allowed in these units.

The Plessey Co Ltd,
Ilford, Essex.

Wide Range Oscilloscope

(Illustrated below)

A NEW and very versatile wide range, measuring oscilloscope has recently been introduced by E.M.I. Factories Ltd.

Known as the type WM.5 the basic instrument comprises the display and power units, but provision is made for the incorporation of one or more standard sub-units to meet almost any specialized

requirements. Four types of sub-unit are at present available, but the range will be extended later.

Among the new features of the basic oscilloscope are the following:

Instantaneous a.c.-d.c. voltage measurement by means of a multi-range voltage measuring bridge circuit combined with Y shift and long scale meter, giving by direct reading precise and immediate measurement of the displayed waveform.

Instantaneous time measurements of high accuracy, meter presented, over a time range of 10mμsec to 100msec.

The Y amplifier affords switch selection of two conditions of gain/bandwidth (1) high gain d.c. to 9Mc/s and (2) low gain d.c. to 25Mc/s without overshoot on transients.

Variable control for the c.r.t., e.h.t. and bias giving deflexion sensitivity control ratio of 10:1 with completely stable frequency response.

An eleven-range precision time-base with sensitive phase/frequency selective drive amplifier covering sweep speed range from 33cm/sec to 200cm/μsec.

The horizontal sweep may be delayed with respect to a trigger or synchronizing signal by any interval within the range 1μsec to 1sec.

The pre-sweep period is variable from 1 to 150 times the selected main sweep period. Any long-term signal train can be displayed in compressed form on the linear pre-sweep trace, and from this any small section can be selected and simultaneously displayed in expanded form by the normal sweep.

The WM.5 oscilloscope is available either in console form or rack mounted.

E.M.I. Factories Ltd,
Hayes,
Middlesex.

Gas Jet for Ultrasonic Soldering Iron

(Illustrated below)

WHEN using the Mullard ultrasonic soldering iron to apply solder to large masses of aluminium and similar "difficult" metals, it is necessary to preheat the work to the required temperature. When very large metal parts are to be

soldered, such as large castings to be treated for surface defects, the best way to apply additional heating is by playing a gas jet on the surface of the metal close to the point where the bit of the iron is being applied.

To enable this work to be done and at the same time leave the operator with a free hand, the Equipment Division of Mullard Limited are now making available a gas jet attachment for their ultrasonic soldering iron. The gas jet is automatically played on exactly the right part of the work, and the operator can use his free hand to hold a tool or a stick of solder, etc. The flow of gas is controlled from a small tap on the attachment.

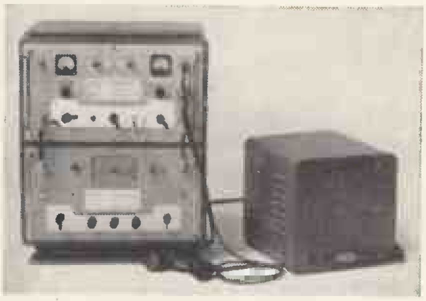
Mullard Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Marine Transmitter-Receiver

(Illustrated above right)

THE Pye Marine "Swordfish" transmitter-receiver is designed to comply with the new Merchant Ship (Radio) Rules for Class III ships (500 to 1 600 tons) and has been granted a G.P.O.-M.O.T. Certificate of Approval.

Both the transmitter and receiver are crystal controlled; the transmitter provides eight spot frequencies between 1·6 and 3·9Mc/s, while the receiver provides nine, eight in the same frequency range



as the transmitter and one on 200kc/s. Services provided are c.w., m.c.w., and r.t. and loudhailer. The output of the transmitter is approximately 50W. The receiver has a built-in vibrator power supply, while the transmitter is fed from a separate rotary transformer unit.

Pye Marine Ltd,
Oulton Works,
Lowestoft,
Suffolk.

Double Pentode Beam Power Amplifier

THE 55A/165M is a loctal based (B8G), indirectly-heated double pentode developed for use as a push-pull power amplifier. Operating at audio frequency it will provide an output power of 22W with an anode voltage of 300V, while with an anode voltage of 500V an output power of 39W can be obtained.

As an unmodulated class-*C* r.f. amplifier an output of 47.5W at 30Mc/s is obtainable with an anode voltage of 500V.

The seated height of the valve is 2⅝in and the diameter is 1 3/16in.

Standard Telephones & Cables Ltd,
Dowlish Ford Mills,
Ilminster,
Somerset.

Miniature Moving-Coil Relay

(Illustrated below)

THE relay consists of a balanced moving-coil in the field of a permanent magnet. The coil has a contact leaf which operates between two adjustable contact springs mounted on the fixed frame. The coil assembly moves to one side or the other and appropriate contact is made according to the direction of the controlling current. The coil has two independent windings which can be wired singly, in series, in parallel or in differential according to the application.

This relay is a magnetically self-shielded unit capable of operating from a power input of $10\mu W$ and being of balanced construction functions efficiently in any position. The overall measurements of the relay are 1⅜in by ¾in by ⅝in.

The contacts are platinum and may be employed to control a non-inductive load providing that the a.c. or d.c. values do not exceed 50V : 100mA : 2W.

Electro Methods Ltd,
Caxton Way,
Stevenage,
Hertfordshire.

Television Test Set

(Illustrated below)

THE Airmec "Televet type 877" provides in one unit all the facilities needed for fault-finding, checking, overhauling and aligning television receivers.

The instrument incorporates a wobbulator, pattern generator, a.m. signal generator, c.w. signal generator, l.f. oscillator, e.h.t. voltmeter and an a.c. and d.c. valve-voltmeter. It operates over a frequency range covering the i.f. bands and television bands 1 and 3.

Airmec Ltd,
High Wycombe,
Buckinghamshire.

Scintillation Counter Head

(Illustrated above right)

THE scintillation counter head type 653 has been designed for exacting research (i.e., gamma-ray spectrometry); to cover measurements when using radioactive isotopes for diagnostic and therapeutic purposes in medicine; and for routine investigations and general monitoring.

Being constructed with simple quickly interchangeable light-tight caps, this scintillation counter head forms a suitable basic unit for adaptation to scintillation counting techniques with liquids or special types of collimator or directional arrangements.

The unit is built in two sections. The upper section (the detector unit) contains the voltage divider chain, photomultiplier tube and phosphor, the whole being covered by an interchangeable light-tight cap. The lower section contains the cathode follower unit.

The upper section containing the photomultiplier tube has a spring-loaded retaining ring to accommodate phosphors up to 44 millimetres in diameter and 25 millimetres in thickness. Light-tight, easily interchangeable caps are available to fit the upper section of the detector

head, to allow for thin end-window counting, lead collimation shielding and the accommodation of various sized phosphors.

Isotope Developments Ltd,
Finsbury Pavement House,
120 Moorgate,
London, E.C.2.

Ribbon Microphone

(Illustrated below)

THE Standard 4038-A ribbon microphone is manufactured by agreement with the BBC who own the patent rights. This microphone has a sensivity comparable with that of the best moving-coil microphones and a constant bi-directional polar response.

The frequency response is substantially uniform from 50c/s to over 10kc/s and throughout this range the shape of the bi-directional polar response curve is well maintained in both the horizontal and vertical planes. The use of correctly damped ribbon of very low mass gives a transient response which is exceptionally good.

Magnetic shielding of the ribbon-to-line toroidal transformer housed in the base of the microphone and the use of hum neutralizing wiring to the ribbon ensure negligible interference from stray electromagnetic fields. In this respect it is 30 to 40dB better than moving coil microphones.

Standard Telephones & Cables Ltd,
Connaught House,
Aldwych,
London, W.C.2.

BOOK REVIEWS

Fundamentals of Transistors

By Leonard Krugman. 135 pp. 102 figs. Demy 8vo. John F. Rider, Inc., New York. 1954. Price $2.70.

ANY well-established technical subject rapidly gathers its own literature, extending from the standard works of reference on the one hand to popular and only semi-technical books on the other.

Before the literature on transistors can adequately cover the whole field, a similar wide range of books will be necessary.

Until quite recently a large proportion of the books and articles on transistors were anthologies or summaries of earlier information on basic physical concepts together with extracts from the already published notes and data of the manufacturers.

The present book is a radical departure from this attitude. It is neither intended to be a standard work of reference nor yet is it a popular book with loose or inaccurate statements. Instead it seeks and achieves a very good balance between the two extremes.

The first two chapters cover the transistor and its basic method of operation—not from the outlook of the physicist but from that of the circuit designer who has to use the device rather than make it. While Chapters I and II contain only outlines of their subject—semi-conductor physics—Chapters III and IV go very extensively into the three major basic circuit configurations used with the transistor, namely, grounded base, ground emitter, and grounded collector, working conditions. Altogether 52 pages are taken up in this task and the reader is given a clear, simple, non-mathematical understanding of why the transistor can be used with each pair of its terminals in turn as the input circuit—the effects obtained—and the reason why it behaves so differently in each case. With this ground work laid, the book turns, in Chapter V, to transistor audio frequency amplifiers. Here again the subject is divided into separate sections. The method of selecting the transistor d.c. working condition is examined, as also is the necessity for some stabilization against d.c. drifts due to the effect of working temperature. This is followed by a survey of the transistor small signal amplifying characteristics, of phase splitting, push-pull operation, and class-B working. Most of the practical pitfalls into which engineers, trained on radio valves, are likely to fall, are noted and explained.

Chapter VI covers transistor oscillators. Chapter VII gives some indication of the factors governing the limits of high frequency performance of the transistor, together with an explanation of the equivalent circuit and miscellaneous matters.

This is one of the very few books that deal mainly with the junction rather than the earlier point contact transistor.

The author is clearly a man of close personal experience with his subject and commendable conviction, which is probably best illustrated by the following quotation.

"On the other hand the junction type (transistor) is generally cheaper to produce, has better reliability, better reproducibility, higher available gain and a lower noise figure than the point contact type. It is safe to predict the gradual displacement of the point contact transistor by the junction transistor in all but a few specialized applications, particularly since the frequency range of the junction type is steadily being increased by new manufacturing techniques.

In view of this the remainder of the book will deal primarily with the junction transistor and unless specified typical junction characteristics will be assumed."

This book is particularly recommended to the circuit engineer faced with junction transistors for the first time. He will find it of considerable help not only in theoretical matters but as a guide to the solution of numerous problems met with in the actual transistor circuit itself.

Not only should a copy be available on library shelves but the book will prove of great assistance at the workbench itself.

To sum up, this book is not a standard work of reference on the transistor art, but fulfils a great need to those engaged in getting actual transistor circuits to work.

G. GRIMSDELL.

Millimicrosecond Pulse Techniques

By I. A. D. Lewis and F. H. Wells. 310 pp. 149 figs. Demy 8vo. Bergaman Press Ltd. 1954. Price 40s.

IT has been possible to generate transients of the millimicrosecond order for many years. This reviewer, while working in the field of nuclear research, realized that the time had come when it would be necessary to shape, count and amplify such pulses. Furthermore the equipment involved should be compact, economical of power and simple to align; for the instruments would find wide use by electronically non-skilled personnel. The authors of "Millimicrosecond Pulse Techniques" show us the considerable extent to which this ideal has been fulfilled. Often, indeed, the instruments they describe, working in the region 10^{-8} to 10^{-9} sec, are as compact and simple as their counterparts for microsecond pulses.

Since the impetus for fast pulse study arose in the nuclear field, it is natural that the application examples should be restricted to this branch of science. However, the reader requires no specialized knowledge to appreciate these designs, nor is the usefulness of the work restricted to this field. That the authors have realized the importance of this infant technique to all branches of electronics is shown by the general form of the book, whose major part is devoted to principles and fundamentals.

Turning the pages of the work we find the subject is introduced by a brief résumé of useful mathematical tools. These analytical methods are then applied in a detailed study of transmission line properties, with especial emphasis on use for narrow pulse transmission, shaping and transformation. The subject of distributed amplifiers follows naturally and leads to the problems of wide band cathode-ray oscillography at high frequencies.

A wide variety of other subjects receives treatment, among which pulse generators and trigger circuits should receive special mention. The final chapters, which illustrate the preceding basic study, are used to introduce further techniques and to show the methods of design integration which are required to form a complete instrument.

With minor omissions the work represents a full review of the millimicrosecond pulse field to date, and an excellent bibliography is included. Since the semiconductor diode plays an important role, it is to be regretted that its pulse properties are scantily treated and its theory is entirely ignored.

All electronics engineers should find the work stimulating, and it can be particularly recommended to researchers who are working in this field.

N. F. Moody.

Amplitude-Frequency Characteristics of Ladder Networks

By E. Green. 155 pp. 88 figs. Demy 8vo. Marconi's Wireless Telegraph Co. Ltd. 1954. Price 25s.

THIS book employs the method of network analysis described by Dishal, "Design of Dissipative Band Pass Filters Producing Desired Exact Amplitude-Frequency Characteristics" (*Proc. I.R.E. 37*, 1050-1069, September 1949), which is really an application of curve fitting. Briefly, the desired frequency response of the filter is expressed as a polynomial of the quantity $(j\omega/\omega_\beta)$ where ω_β is a certain datum frequency and ω is the independent variable. The coefficients of the polynomial are say, U_0, U_1, U_2, . . . U_n. The frequency response of a network configuration, which is known to be of suitable form, is also expressed as a polynomial of $(j\omega/\omega_\beta)$, but here the coefficients are combinations of circuit parameters containing L, C, R and ω_β. It remains to equate each of these coefficients to the corresponding "U" and solve simultaneous equations for the circuit elements.

Such a treatment enables a practical filter, using coils of finite "Q", to be designed to have an amplitude response identical with that of an ideal filter having dissipationless elements.

The method is also extended to show network input-impedances and reflexion coefficients in terms of the frequency response polynomials, to facilitate later discussions on impedance matching, etc. An enormous amount of design information is included which makes the book a valuable and unique work of reference.

However, this review would not be complete without some constructive criticisms, which may be of use if a second edition is ever contemplated. It is appreciated that the subject of network analysis is almost completely mathematical and that it is therefore extremely difficult to write about, but one gets the impression that the text has been written to link together a mass of technical notes and analyses, rather than to develop a logical argument.

The book cannot be "read" in the usual sense but has to be worked through with paper and pencil. The conscientious reader is continually finding it necessary to seek his own explanations and proofs of the statements made and to refer back and forth to a formidable list of symbols which takes up no less than four complete pages in the book. This irritating necessity could be avoided by using suitable introductory remarks in the text (as Dishal does in his paper which is much easier to read).

An example of the inadequacy of the text can be found on page 6 which gives an identity followed by the remark, ". . . so that for consistency we must add a negative sign". Again on page 10, one is invited to change the sign of a whole expression, "...due to the change in type of termination". and it is left to the almost exhausted "reader" to discover that the rigorous reasons for these remarks lie in the definitions of voltage and current reflexion coefficients as derived from constant current sources and constant voltage sources, respectively.

Similarly, a logical derivation of equation (11) from (3) and (10) would have been better than the statement to the effect that a polynomial will now be introduced which is the same as another, except that a certain decrement will be given a negative sign; leaving the reader to discover the reason for doing this.

These examples are typical and it is a great pity that such excellent material, as this book contains, should be made so unnecessarily difficult to extract.

The book is most beautifully printed, the presentation of the mathematics is clear and the diagrams and graphs are of adequate size and well reproduced. In spite of the above criticisms, the book is considered to be excellent value representing, as it does, a monumental collection of design information not only of the passive networks but including their complete performance when interconnected with valves.

W. R. Hinton

BBC Handbook 1955

224 pp. Demy 8vo. The British Broadcasting Corporation 1954. Price 5s.

THE ordinary listener and viewer, as well as all who are professionally interested in broadcasting, will welcome the appearance of this new publication. Its aims are set out in a foreword by the Director-General, Sir Ian Jacob: "to provide a clear and reliable guide to the workings of the BBC, to survey the year's work in British broadcasting, and to bring together as much information about the BBC as can be assembled within the covers of a small book."

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

The Correction of Q Meter Readings

DEAR SIR,—Mr. Newsome (September 1954 issue), shows an elegant method of correction for Q meter readings, given the residual R and L elements in the instrument. He does not, however, indicate how he obtained the values for the residuals quoted by him for a Marconi instrument, and to my mind, this is the more interesting aspect of the question.

His correction factor S should allow for errors due to mutual inductance (as well as l_s) and to skin effect in r_s, but can no doubt be eliminated (or measured) by using the capacitance-variation method instead of the meter reading for Q. But my recollection of tests upon a Boonton Q Meter (about eighteen years ago) suggests that it is by no means a simple matter to evaluate the other corrections near the high frequency end of the range. The residual resistance, r_s', includes series loss in the capacitor and wiring as well as the source resistor r_s; it will increase considerably at the higher frequencies and is not necessarily completely independent of C. The residual inductance l_s could also vary appreciably with C, and the parallel loss G could, in general include a factor of the form G_2f^2 in addition to G_1f G_0. A workable approximate correction formula was eventually obtained, but only on the assumption that the variation in r_s' and l_s with C could be neglected.

The constants which Mr. Newsome quoted would appear to be applicable only to frequencies up to, say, 10Mc/s, and it would be interesting to know whether he has investigated the matter from an experimental angle.

Yours faithfully,

M. V. CALLENDAR

E. K. Cole Ltd.

Southend-on-Sea,
Essex.

The Author replies:

DEAR SIR,—In reply to Mr. Callendar I can say that I am at the moment experimentally investigating the residual impedances of the Q meter measuring circuit.

The form of the residual impedances used in the article is related to the particular circuit analysed. The upper frequency limit of this circuit, when used as a direct reading Q meter, is about 10Mc/s, and is brought about by the inability of the injection circuit to provide a source e.m.f. independent of frequency. It will be observed that the factor Q_A (Fig. 4), which is based on residual impedances is plotted for frequencies $<$10Mc/s. Thus Mr. Callendar's statement that the constants which I have derived are applicable for frequencies $<$10Mc/s is substantially true, because that is the upper frequency limit of the measuring circuit.

It is noteworthy that the manufacturers of the instrument to which the article refers, specify an accuracy of Q indication of ± 5 per cent ± 5 up to 10Mc/s only, although the instrument is provided with an internal oscillator extending to 50Mc/s.

At frequencies greater than 10Mc/s, the residual impedances undoubtedly take on the more complex forms referred to by Mr. Callendar.

Yours faithfully,

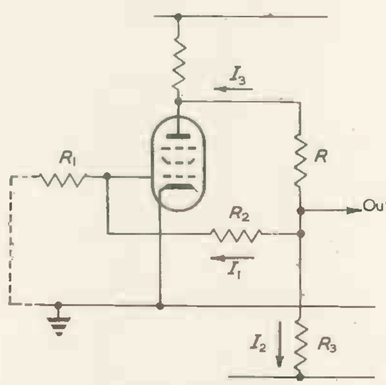
J. P. NEWSOME

Lecturer,

The University of Nottingham.

Output Impedance of Anode-Follower-Type Circuits

DEAR SIR,—Mr. D. McDonnell's useful result given in his letter published in your December issue can be derived by mental algebra without resorting to pen and paper.



Anode-follower circuit

When the output terminal is moved one volt by some external agency a movement of β volts occurs at the grid and $-A\beta$ at the anode. The voltage change across R is, therefore, $A\beta + 1$. In general R will be of the same order as or less than R_2 and R_3, and consequently when $A\beta \gg 1$, I_3 will be much greater than I_1 or I_2, which may therefore be neglected. The output resistance is therefore $1/I_3$ (approx.)

$$= \frac{R}{A\beta + 1} = \frac{R}{A\beta} \text{ (approx.)}$$

As for a cathode-follower, the result does not mean that it is a good idea to work the circuit into a load of this value.

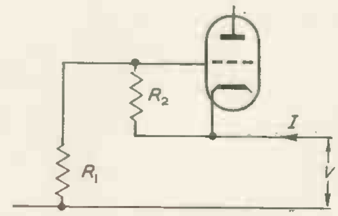
Yours faithfully,

E. F. GOOD

Malvern,
Worcs.

The correspondent replies:

DEAR SIR,—I agree with Mr. Good's comments and find it interesting to apply similar reasoning to the cathode-follower circuit as shown. The output impedance



Cathode-follower circuit

is given by I/V, assuming R_1 and R_2 to be large I is mainly due to the anode current of the valve, i.e.

$$I = \frac{VR_2\,g_m}{R_2 + R_1} \text{ and the output impedance is given by}$$

$$Z_o = \frac{R_1 + R_2}{R_2\,g_m} \text{ and if } R_1 = 0$$

or $R_2 \to \infty$

$Z_o = 1/g_m$ but not otherwise.

Yours faithfully,

D. MCDONNELL,

Weybridge,
Surrey.

Computers and Computors

DEAR SIR,—I find that many people use the word computer to describe both the man who computes and any machine which he may use for the purpose. This can cause unnecessary confusion which is easily avoided, since the language contains two appropriate words, viz. "computer" to describe the man and "computor" for the machine.

Yours faithfully,

O. S. PUCKLE,

Beaconsfield,
Bucks.

Errata. On p. 29 of the January issue, Table 2, the mileage from Montreal to Halifax should read 660, not 2 660. The Radio Laboratory Handbook mentioned on p. 44 of the January issue as being the 5th edition is now superseded by what is virtually a new book, a completely rewritten and much larger edition which is the 6th.

Short News Items

The Radio Show this year is to be held at Earls Court, London, from 24 August to 3 September, with a preview for overseas and other special visitors on 23 August.

The German Radio and Television Exhibition will be held in Dusseldorf from 26 August to 4 September. The German Music Fair will be held during the same period.

Silicones for Industry Exhibition. An exhibition on the history, production, and application of Silicones is to be held in Birmingham, at the Chamber of Commerce, New Street, from 28 February to 5 March. Invitations to this exhibition can be supplied on request to Midland Silicones Ltd, 19 Upper Brook Street, London, W.1, and any visitors to Birmingham during the period of the exhibition will be welcome.

The Harwell Isotope School. There are at present vacancies on Course 27—25 April to 20 May—and Course 28—27 June to 22 July. The courses, which last four weeks, include both lectures and practical work in the laboratory. Students should be graduates of a university. Details of the course fee and further information can be obtained on application to The Isotope School, A.E.R.E., Harwell, Berks.

The Physical Society Spring Meeting will be held at the Atomic Energy Research Establishment, Harwell, on Thursday, Friday and Saturday, 31 March, 1 and 2 April. The subject of the meeting will be "Neutron Physics and Energy Levels". Non-members are welcome to attend this meeting, but owing to limited accommodation in the lecture theatre, applications will be taken in strict order of receipt. Application forms may be obtained from The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

The Council of The Institution of Electrical Engineers at a recent meeting made the thirty-third award of the Faraday Medal to Sir John Cockcroft, Director of the Atomic Energy Research Establishment, Harwell, for the conspicuous services he has rendered to the advancement of electrical science, for his distinguished work in the field of nuclear physics and the development of power from nuclear sources. The Council also elected Mr. James Robert Beard to Honorary Membership of the Institution for his distinguished services to the profession.

Wickman Ltd and Wild-Barfield Electric Furnaces Ltd. Agreement has been reached between these two Companies whereby the induction heating business of Wickman Ltd has been acquired by Wild-Barfield Electric Furnaces Ltd.

The approval by the Postmaster-General of a v.h.f. transmitting station at Wenvoe in South Wales brings the total number of such stations up to ten and the frequency allocations are now as follows:—

STATION	HOME SERVICE	LIGHT PROGRAMME	THIRD PROGRAMME	EFFECTIVE RADIATED POWER KW (EACH TRANSMITTER)
	Mc/s	Mc/s	Mc/s	
Wrotham (Kent)	93·5	89·1	91·3	120
Pontop Pike .. (County Durham)	92·9	88·5	90·7	60
Divis .. .. (Northern Ireland)	94·5	90·1	92·3	60
Meldrum .. (Aberdeenshire)	93·1	88·7	90·9	60
North Hessary Tor (South Devon)	92·5	88·1	90·3	60
Sutton Coldfield	92·7	88·3	90·5	120
Norwich	94·1	89·7	91·9	120
Blaen Plwy .. (West Wales)	93·1	88·7	90·9	60
Holme Moss ..	93·7	89·3	91·5	120
Wenvoe	94·3*	89·9*	92·1*	120

* Frequencies subject to confirmation.

The v.h.f. station at Wenvoe, which will be on the same site as the existing television station, will serve South Wales and a considerable part of Devon and Somerset. It is expected to be in service early in 1956.

Marconi's Wireless Telegraph Co Ltd announce that the initial forty Viscounts ordered by Capital Airlines (U.S.A.) are to be equipped with Marconi Automatic Direction Finders—a dual installation in each.

Marconi v.h.f. radio equipment is being used by the North of Scotland Hydro-Electric Board in connexion with repair and maintenance work on the new 132 000 volt transmission line between Fort Augustus and Speyside, the highest transmission line in Great Britain.

Aveley Electric Ltd is a recently formed company which will act as representatives and agents for Rohde & Schwarz, Munich, manufacturers of communication and laboratory measuring equipment. At a later stage, Aveley Electric will manufacture certain instruments in this range. The agents hitherto have been Dawe Instruments Ltd, whose contract has now expired. The address of Aveley Electric Ltd is 44 Tottenham Court Road, London, W.1.

The Stonebridge Electrical Co Ltd, 6 Queen Anne's Gate, London, S.W.1, have been appointed agents for the Swiss Company, Trub Tauber & Co. of Zurich. This latter Company specialize in oscillographs, electron microscopes, diffractographs, heat meters and a complete range of switchboard indicating and recording instruments.

Mr. Eric H. Underwood, O.B.E., has been appointed Director of Public Relations to the United Kingdom Atomic Energy Authority. He goes to the Authority from the Central Office of Information where he was Director of Photographs Division and, earlier, chief editor of overseas magazines.

At the 28th Annual General Meeting of the Radio Society of Great Britain a presentation was made to Mr. John Clarricoats in recognition of twenty-five years' service to the Society.

Mr. W. A. Turner has been appointed principal of the School of Electronics which Automatic Telephone and Electric Co Ltd has established at Liverpool.

Blick Engineering Ltd announce that their name is now Blickvac Engineering Ltd, and addresses are 96/100 Aldersgate Street, London, E.C.1, and Bedesway, Bede Trading Estate, Jarrow, Co. Durham.

The Oliver Pell Co recently handed over the five millionth Varley coil for assembly in an S.U. petrol pump. The handing-over ceremony was performed at the Savoy Hotel.

The Radio Industry Council announce that British radio exports for 1954 will have set up a new record. Exports for the first eleven months of the year, valued at more than £26 170 000, were higher by nearly £500 000 than those for the whole of 1953.

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 23 February. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London. W.C.1.
Lecture: A Versatile Electronic Engine Indicator.
By: R. K. Vinycomb.

West Midland Section

Date: 9 February. Time: 7.15. p.m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: Electronic Motor Control Systems.
By: J. C. Rankin.

Merseyside Section

Date: 3 February. Time: 7 p.m.
Held at: The College of Technology, Byrom Street, Liverpool, 3.
Lecture: Colour Television, Prospects and Problems in the U.K.
By: D. W. Heightman.

North Western Section

Date: 3 February. Time: 7 p.m.
Held at: Reynolds Hall, College of Technology, Sackville Street. Manchester.
Lecture: Recent Developments in Test Gear in the Radio, Television and Radar Fields.
By: A. G. Wray.

South Wales Section

Date: 23 February. Time: 6.30. p.m.
Held at: Glamorgan Technical College, Treforest.
Lecture: The Training of Radio Engineers.
By: H. W. French.

Scottish Section

Date: 10 February. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders. Elmbank Crescent, Glasgow.
Lecture: Radio Telephone Systems to the Islands.
By: T. Moxon.

BRITISH SOUND RECORDING ASSOCIATION

Date:18 February. Time: 7 p.m.
Held at: The Royal Society of Arts, John Adam Street, London, W.C.2.
Lecture: Electro-acoustics of Microphones.
By: H. A. M. Clark.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London Meetings. unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Informal Meeting

Date: 7 February.
Discussion: The Problem of Radio Interference.
Opened by: C. W. Sowton.

Radio Section

Date: 9 February.
Lectures: A Study of Commercial Time Lost on Transatlantic Radio Circuits due to Disturbed Ionospheric Conditions.
By: J. K. S. Jowett and G. O. Evans.
and: Performance Characteristics of High-Frequency Radio Telegraph Circuits.
By: A. M. Humby, C. M. Minnis and R. J. Hitchcock.
Date: 21 February.
Lecture: The Recent Search for and Salvage of the Comet Aircraft near Elba.
By: Commander C. G. Forsberg and G. G. MacNeice.

Utilization Section

Date: 17 February.
Lectures: An Introduction to the Study of the Servo-Mechanisms.
By: P. J. Bhatt.
The Development of 50c/s Traction in France.
By: E. J. Davies.
Electricity Applied to Oil Production.
By: G. Gascoigne.

Cambridge Radio Group

Date: 15 February. Time: 8.15.p.m.
Held at: The Cavendish Laboratory. Cambridge.
Lecture: Colour Television.
By: L. C. Jesty.

North Eastern Centre

Date: 14 February. Time: 6.15 p.m.
Held at: Neville Hall. Newcastle-upon-Tyne.
Lecture: The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems.
By: D. P. Sayers, M. E. Laborde and F. J. Lane.

North Midland Centre

Date: 1 February. Time: 6.30. p.m.
Held at: The British Electricity Authority. 1 Whitehall Road, Leeds.
Lecture: Modern Developments in Atomic Energy.
By: T. E. Allibone.
Date: 21 February. Time 7 p.m.
Held at: The Town Hall, Leeds.
Faraday Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.

North Scotland Sub-Centre

Date: 9 February. Time: 7.30. p.m.
Held at: The Caledonian Hotel, Aberdeen.
Lecture: The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems.
By: D. P. Sayers, M. B. Larborde and F. J. Lane.
This lecture to be repeated on 10 February at the Electrical Engineering Department, Queen's College, Dundee, at 7 p.m.

South Midland Radio Group

Date: 28 February. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street. Birmingham.
Lectures: Thermionic Valves of Improved Quality for Government and Industrial Purposes.
By: E. G. Rowe, P. Welch and W. W. Wright.
and: A Study of Some of the Properties of Matter affecting Valve Reliability.
By: E. A. O'Donnel Roberts.

Rugby Sub-Centre

Date: 2 February. Time: 6.30. p.m.
Held at: The Rugby College of Technology and Arts.
Lectures: Measurement of the Winding Resistance of a 132kV Power Transformer in Service.
By: K. J. R. Wilkinson and J. D. Harmer.
and: An Examination of High Voltage d.c. Testing Applied to Large Stator Windings.
By: R. T. Rushall and J. S. Simons.

Hatfield District

Date: 7 February. Time: 7 p.m.
Held at: Hatfield Technical College.
Lecture: A Ferrite Frequency Modulator.
By: F. Slater.
Followed by film: The Industrial Applications of Ultrasonics.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: 8 February. Time: 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Lecture: Depreciation and Service Life of Telecommunications Equipment.
By: N. V. Knight.
Date: 23 February. Time: 5 p.m.
Held at: The Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1.
Lecture: Is Our Telephone Equipment too Complex?
By: F. Scowen.

THE RADIO SOCIETY OF GREAT BRITAIN

Date: 25 February. Time 6.30. p.m.
Held at: The Institution of Electrical Engineers.
Lecture: Radio Astronomy and the Radio Amateur.
By: R. C. Jennison.

THE TELEVISION SOCIETY

Date: 11 February. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, London, W.C.2.
Lecture: Television Coverage of Great Britain,
By: R. A. Rowden.
Date: 24 February. (Time and place as above.)
Lecture: Modern Microwave Techniques.
By: R. L. Corke

PUBLICATIONS RECEIVED

RADIOISOTOPE CONFERENCE 1954. The proceedings of the Second Radioisotope Conference organized by the Atomic Energy Research Establishment and held in Oxford in July, 1954, have now been published by Butterworths Scientific Publications. The two volumes of the proceedings give the complete text of the papers read and the ensuing discussions. Volume I, Medical and Physiological Applications, price 65s. Volume II, Physical Sciences and Industrial Applications, price 100s. Butterworths Scientific Publications, 88 Kingsway, London, W.C.2.

PLOTTING WITH THE LOCATORGRAPH is a publication which gives in detail the methods of using this equipment to solve radar plotting problems, together with worked examples. The Marconi International Marine Communication Co Ltd, Marconi House, Chelmsford.

TAILOR-MADE SCIENTIFIC SERVICE FOR INDUSTRY is a brochure describing the full range of services and facilities offered by Nash & Thompson Ltd, Oakcroft Road, Tolworth, Surrey.

BRITISH COUNCIL REPORT 1953-54. The report records that the Council has staff in 60 overseas countries. In the United Kingdom it has 19 offices outside London and five student hostels. The net expenditure for 1953-54, after allowing for receipts of £373 558, was £2 504 008, against £2 463 929 the previous year. The British Council, 65 Davies Street, London, W.1.

ELECTRONIC CONTROLS FOR RESISTANCE WELDERS is a recent catalogue produced by Bates & Bates Ltd, 73 Ashville Avenue, Birmingham, 34.

J. LANGHAM THOMPSON LTD have produced descriptive leaflets relating to various ranges of their products under the following categories: Electronic Measuring Equipment; Electronic Testing Equipment; Transducers; Cameras. This literature is summarized and presented in an easily readable form. J. Langham Thompson Ltd, Springland Laboratories, Bushey Heath, Herts.

VALVE RETAINER DATA booklet has been compiled by the technical staff of Electrothermal Engineering Ltd to fill the need for an accurate reference on the types of valve retainers needed for various valves and it has been laid out in such a way that a valve retainer requirement for most valves in common use can be found in a matter of seconds. There is also a cross index sheet for easy reference. Electrothermal Engineering Ltd, 270 Neville Road, London, E.7.

RADIO AND TELEVISION ENGINEERS' REFERENCE BOOK brings together, within one convenient volume, comprehensive technical data and information on the latest developments in the transmission and reception of radio and television signals, and allied subjects. The book is arranged in 45 main sections, each dealing with a specific branch of the subject, and written by specialists in the particular fields concerned. George Newnes Ltd, Tower House, Southampton Street, Strand, London, W.C.2. Price 70s.

LABORATORY AND WORKSHOP NOTES 1950-1952 compiled and edited by Ruth Lang is the third collection of such notes and has been selected from the Journal of Scientific Instruments for the years 1950, 1951 and 1952. Edward Arnold (Publishers) Ltd, Maddox Street, London, W.1. Price 30s.

MOND CARBONYL IRON POWDERS is a publication issued by the Mond Nickel Co and has been designed to cover all aspects of carbonyl iron powders. It shows by illustrations and tables the properties, methods of manufacture and uses, including recent aspects of television development. Copies are obtainable free of charge from the Mond Nickel Co Ltd, Publicity Department, Thames House, Millbank, London, S.W.1.