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The R.C.M.F. Exhibition

ORGANISED by the Radio Component Manufacturers' Federation, the sixth exhibition of components, valves and test gear was held at Grosvenor House, London, from March 1 to March 3, with the object, to quote the Radio Industry Council, of "acquainting the radio and electronic manufacturers and engineers with the most recent advance in the design and development of British radio, television and electronic components, valves, accessories, radio and television test gear and instruments, and materials used in their manufacture."

For the first time the exhibition included valves and cathode-ray tubes and welcome new exhibitors were the Board of Trade to provide information on the export market and the Ministry of Supply whose display of apparatus developed in its research establishments was most interesting.

While the British manufacturers of radio receivers for export are making small demands on the component industry, the market for the export of components is encouraging. As Sir Robert Renwick stated in his opening speech, the present export trade has increased no less than eight-fold in the space of the last three years. Before the war the imports of radio components was greater than our exports, although both, of course, were on a comparatively small scale. In the three years since 1945 exports of radio components had risen from about £450,000 to over £3,500,000, while in the same period valve exports had risen from £750,000 to £2,000,000.

There can be no doubt therefore that the component industry is in a healthy position and it needs no more than a casual inspection of the exhibition to confirm this.

From the technical point of view there was much of interest. The design of the components was everywhere good, and on a sound engineering basis. Particular mention might be made here of the very excellent design of the potentiometers developed initially for radar purposes and now finding considerable application in electrical computer circuits.

The trend towards "miniaturisation" of components and valves continues with the consequent saving of materials and space, and a new aspect of "miniaturisation" is the appearance of multiple components—assemblies of resistors and capacitors into a single unit—of small bulk and high stability.

Altogether, therefore, an encouraging exhibition—our only comment is that with components and instruments finding application in so many new non-radio fields from watch rate recorders to vibration analysers, the term radio as applied to components seems a misnomer.

Cathode-Ray Tube Applications

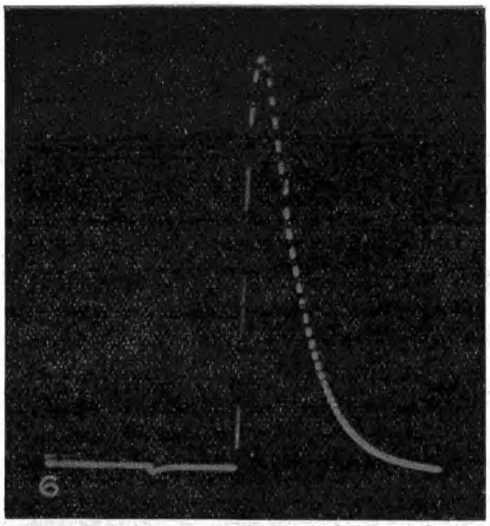


Fig. 1. Typical shutter opening v. time characteristics. Shutter speed 1/100th of a second. Time markings one millisecond apart

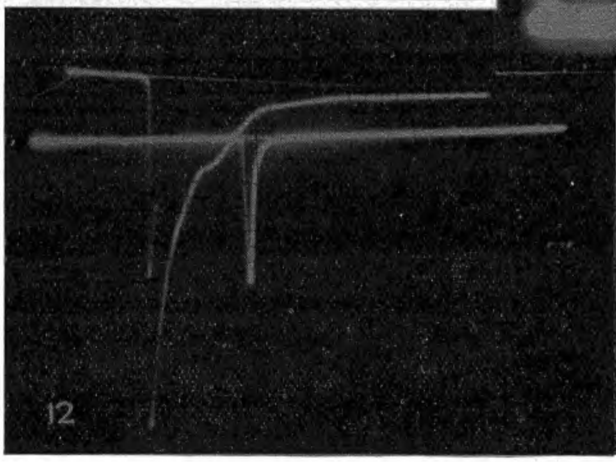
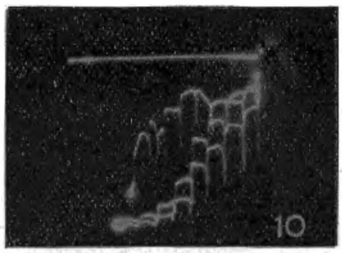


Fig. 10. Three triple-exposed H and D curves. The bottom curve shows the start of development and the top curve the final appearance of the strip



Above

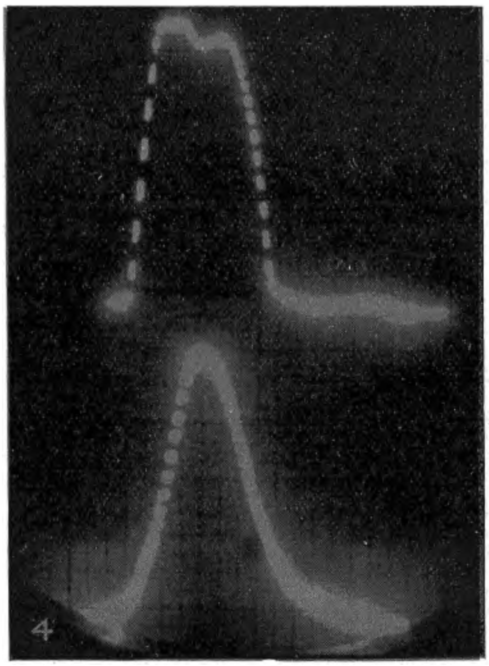
Fig. 6. Electronic gas-filled flashlamp characteristics with high-speed sweep and 40 Kc/s (25 microseconds) time markings. The small negative pip is due to the synchroniser operation

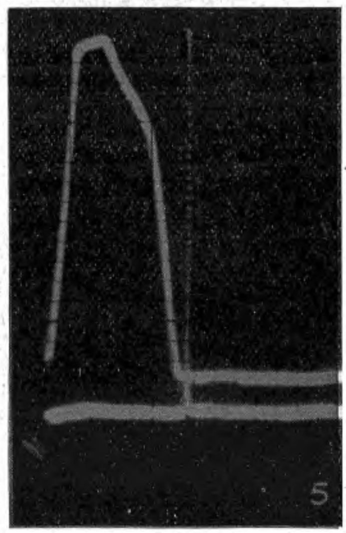
Fig. 12. Double exposures comparing light from stroboscope lamp with light from cathode ray tube light source

Right

Fig. 4. Dual beam recording of 1/100th of a second shutter opening (top trace) and No. 5 flashbulb (bottom trace). Time markings 2 Kc/s

Fig. 5. Dual beam recording of 1/100th of a second shutter opening, plus electronic flashlight output. The time marking is given by a 40 Kc/s oscillator





in Photography and Optics†—Part 1

By CARL BERKLEY* and RUDOLF FELDT*

CATHODE-RAY tubes and oscilloscopes are ideal tools for the solution of many technical problems in the related arts of Photography and Optics. The methods described represent typical examples of the application of electronic measurement techniques in such fields.

Applications considered and illustrated include:—

1. Gloss measurement on photographic papers.
2. Goniophotometry of light sources.
3. Shutter, flashbulb and synchroniser testing.
4. Cathode-ray tube light sources for facsimile and stroboscopic work.
5. Scanning technique for television film recording.
6. The combination of optical and electronic magnification for the study of gear and sprocket imperfections.
7. Automatic "H and D" curve plotting during film development.
8. Cathode-ray tube sound on film recording systems.
9. The measurement of ripple in light sources.
10. Colour studies in natural colour reproduction and chromatic aberration in lenses.
11. Vibration studies of motion picture equipment.

The techniques and cathode-ray oscilloscope accessories described will find wide application in other fields as well.

Due mainly to its rapid response and graphic presentation of results, the cathode-ray oscilloscope has found wide application in the solution of many technical problems in diverse fields. In the course of their work the authors and the members of the Applications Engineering Section of DuMont Laboratories have gained considerable experience in the application of the basic oscillographic techniques used in the solution of these problems. Since photographic and optical methods have become increasingly important in oscillography, a surprising proportion of the applications studied at the laboratories have been in these fields. The techniques here described for photography and optics are basic and applicable to a much wider range of problems. To better illustrate this point, it will be shown later that many of the methods herein described will find direct application in the motor car industry. It is therefore felt that their description will be of interest and help to anyone concerned with a precise electronic approach to a measurement problem.

One of the basic problems in photography as in many other industries is that of accurate short-interval timing. Photographic shutters are called upon to operate reliably and reproducibly over a wide range of speeds. Synchronisers and flashbulbs must be timed to operate within milliseconds of one another. This problem of proper adjustment is becoming more important with the increasing use of colour films whose latitude does not tolerate the careless operation to which photographers using monochrome emulsions have become accustomed.

Shutter Testing

The obvious way to study and make these adjustments is by picking up the opening of the shutter by means of a photocell and light and displaying its output on an oscilloscope. This procedure was in fact, tried many years ago using a string or mirror oscilloscope with fairly satisfactory results.[1]

There are a number of advantages to be gained by the use of a cathode-ray oscilloscope:

(1) There is no practical limit on the shortest time that can be measured so that high-speed mechanical shutters or electro-optical shutters can be readily studied.

(2) The image of the shutter characteristic appears instantaneously on the face of the cathode-ray tube, so that no waiting is necessary to view the record.

(3) The shutter may be rapidly operated any number of times in succession, synchronised with the single sweep on the oscilloscope, and any erratic operation easily observed by comparing each pattern with the previous one by means of a long-persistence cathode-ray tube screen; by operating the shutter a few times and then observing the persistent image, an average value for the shutter speed may be obtained. This is of value in the case of simple shutters whose reproducibility is not such that a single reading suffices for calibration. Fig. 1 shows a typical opening *vs.* time curve.

(4) Various other electronic methods of testing camera shutters have been devised. These generally involve integrating the total light transmitted during the operation of the shutter, and expressing the result as a single reading on a meter. Such a reading fails to show any erratic operation of the shutter such as bouncing or slow opening and closing which, while it may give rise to the same integrated value of light, represents improper operation of the shutter. Such improper operation is readily displayed on the cathode-ray tube.

Realising all these advantages, many photographers to-day have devised elaborate oscillographic equipment to enable production testing of shutters.[2] Such equipments are now being used by most camera manufacturers to check their shutter operation.

The previous remarks have all referred to the testing of between-the-lens leaf-type shutters. The cathode-ray oscilloscope has also been applied successfully to the testing of focal plane shutters by a technique described by T. H. Bullock in "American Photography."[3] This technique involves the photographing of a vertical oscillator trace on the cathode-ray tube and the sweep of this trace horizontally across the cathode-ray tube for a time somewhat longer

† Based on a paper presented at the National Electronics Conference, November 5th, 1948.

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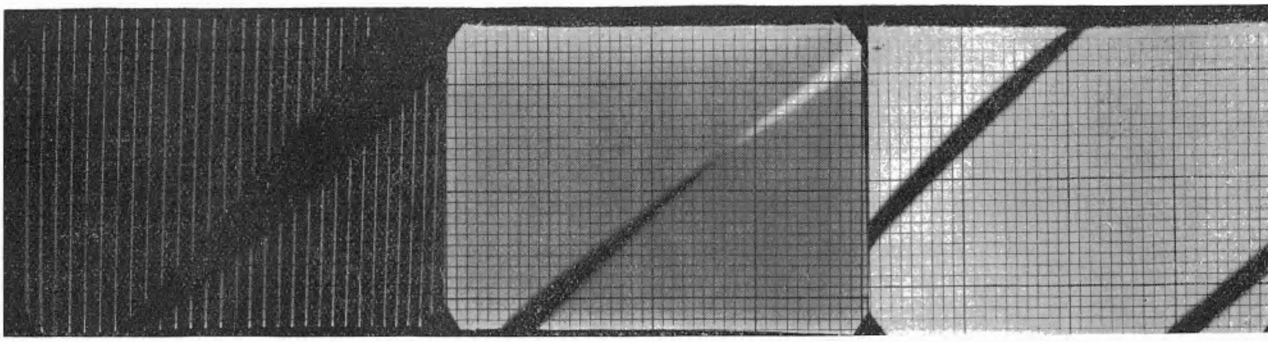


Fig. 2. Focal plane shutter characteristics. Shutter speed 1/20th of a second on Graflex shutter. Horizontal sweep approximately 1/20th of a second

(*a*) With low frequency vertical sweep approximately 600 cycles to show principle.

(*b*) Same shutter with higher speed vertical sweep, showing change in speed of slit from top to bottom of focal plane.

(c) Same shutter properly adjusted for uniform slit travel.

than the operation time of the shutter. This pattern is then imaged in the focal plane. The sum of the cathode-ray tube spot and focal plane slit motions gives rise to diagonal areas from whose appearance the shutter opening characteristics may be evaluated. Figs. 2(a), (b) and (c) show some typical examples of such operation on a Graflex shutter. Fig. 2(a) was made with a rather low vertical-oscillator frequency in order to illustrate the principle. The horizontal distance represents the time during which a particular portion of the slit traversed the film. This time can be seen to vary from one end of the focal plane to the other, indicating that the shutter did not move at constant speed. The next figure shows another example of this defect with a higher sweep frequency. Fig. 2(c) shows a properly-adjusted shutter which moves at almost constant speed from one end of the image plane to the other.

Flash Bulb Testing

Using almost exactly the same equipment, for example, an oscilloscope and a photocell pickup, many other applications present themselves in photography. For example, the testing of photographic flash bulbs and their light output *vs.* time characteristics, may readily be accomplished. Fig. 3 shows the setup for such tests. A method, using the same basic technique which was prescribed for shutters is now used as a standard ASA method for testing photographic flash lamps.[illegible] Fig. 4 shows a typical recording of the light output of a Mazda No. 5 lamp, produced on a Type 279 dual beam cathode-ray oscilloscope so that it may be compared for synchronisation directly with the shutter operation. The time markings have been produced by intensity modulating the cathode-ray tube grid from an external oscillator. The frequency is 2,000 cycles/sec. It is also possible to make recordings of the characteristics of a combustion type of flash lamp with a high-speed recording galvanometer. This equipment, however, fails when an attempt is made to measure the new gaseous-discharge micro-flash lamps, whose duration of light output may be of the order of a few microseconds; only a cathode-ray oscilloscope can measure times of such order conveniently. Fig. 5 compares relative duration of shutter and flash. The circuit for studying these phenomena can be a very simple one. The gas tubes usually have an ignition coil as an ancillary operating from a trigger circuit, consisting of a small, cold-cathode gas tube. The same pulse which fires the cold-cathode tube can be used to start the sweep of the oscilloscope. There is sufficient delay in the initiating tube so that the sweep starts before the ionisation in the flash tube becomes appreciable. The light output *vs.* time curve is shown in Fig. 6. The markers here are 25 microseconds apart instead of 1 millisecond. Fig. 7 shows dual beam oscillograms of such a photoflash tube in which a much higher shutter speed has been used, displaying the opening of the shutter and the flashing of the lamp unsynchronised and synchronised. These are made with a shutter that shows considerable rebouncing which, as mentioned previously, would not be indicated on an integrating type of shutter opening meter.

Gloss Measurement

One of the basic problems in optics is the proper description of the visual or optical character of a surface—the gloss of the surface. For this reason, in many industries, so-called " standards " of various degrees of gloss or surface finish are maintained. This problem is of importance in photography in con-

Fig. 3. Typical set-up for flashbulb testing

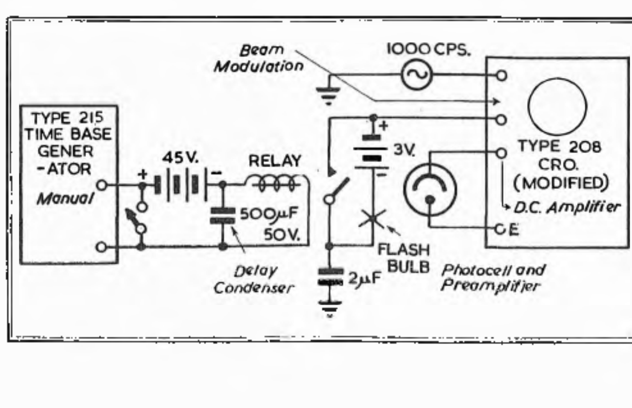
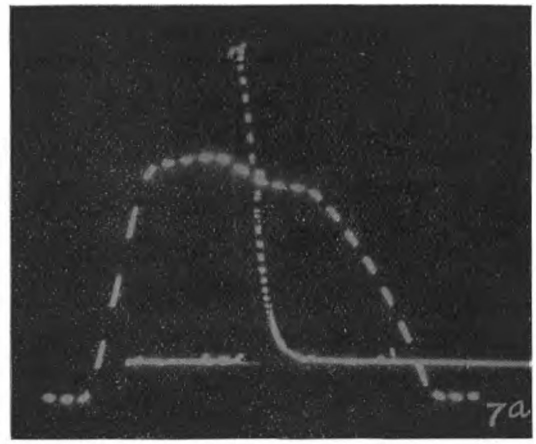


Fig. 7. **Dual beam recordings of high-speed shutter and electronic flashlamp**
(*a*) synchronised. (*b*) unsynchronised.



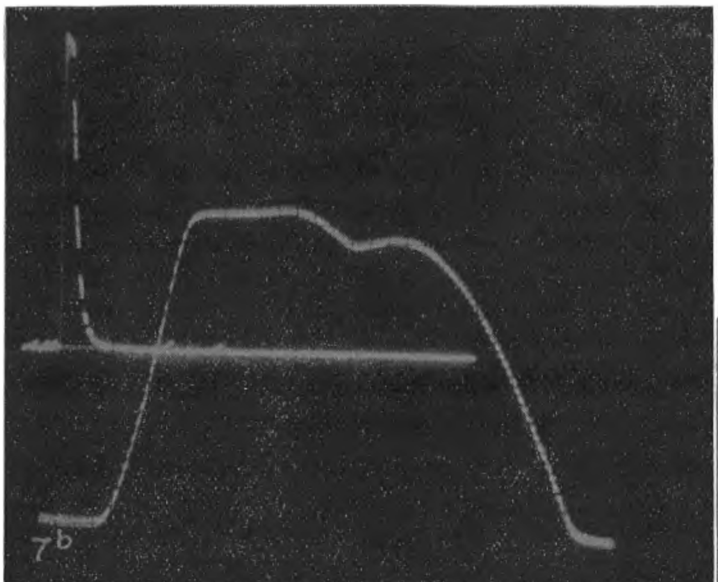
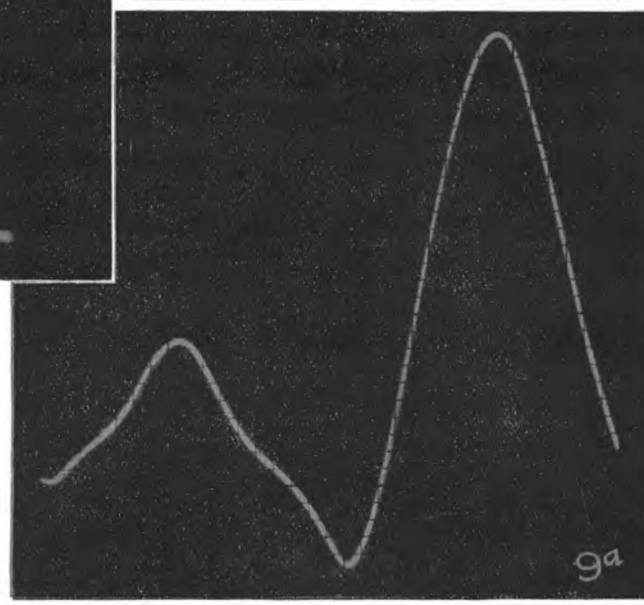
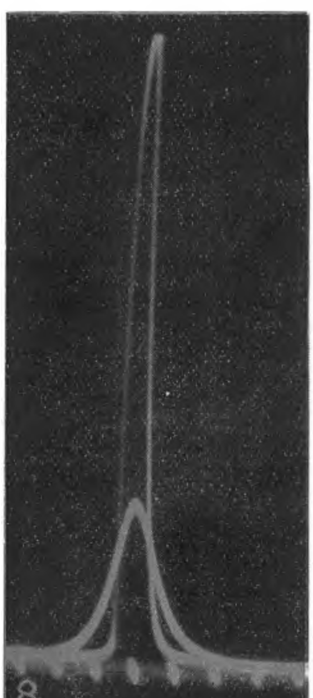


Fig. 8. **Relative reflexion v. angle for clear glass (tall spike) and matte-coated glass. Angle markers on base line are 3.6° apart**





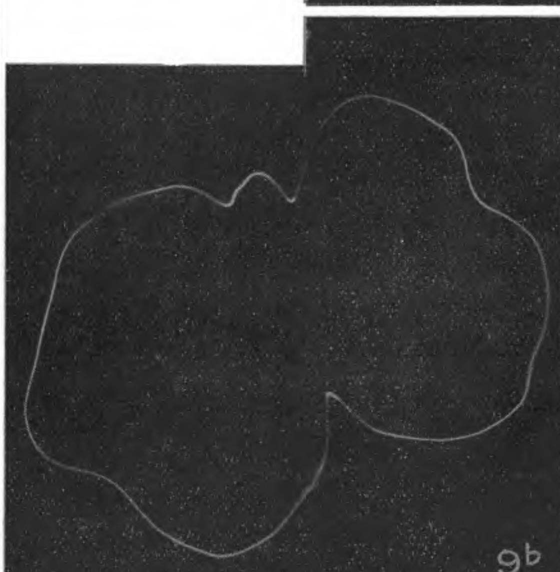


Fig. 9. **Light distribution from small flashlight bulb**
(*a*) In cartesian co-ordinates.
(*b*) In polar co-ordinates.

nexion with the proper specification of the surfaces on photographic papers. The so-called "feel" of the surface, being a subjective matter, is of extreme importance in the final effect that a photograph produces upon the viewer. However, no good method for specifying these surfaces which assures uniform quality and reproducibility yet exists. For this reason, in every photographic supply store there will be found so-called standard samples of these various surfaces which serve as no specification whatsoever. The only satisfactory way, to date, to specify the gloss of a surface is by drawing its complete reflectance curve as a function of the angle of view of the surface under certain standardised lighting conditions. This graph should preferably be plotted as a family of curves in order to express the effect throughout a solid angle. For cases where the reflexion is rotationally symmetrical about some point, a two-dimensional curve such as the curve on a cathode-ray oscilloscope is sufficient and offers a very convenient means for obtaining these curves quickly. This can be done by many simple means. For example, this graph may be obtained in cartesian co-ordinates merely by rotating the photocell around the sample illuminated in a standard fashion and expressing the output of the photocell on the vertical plates, and by expressing its position by means of a potentiometer geared to the photocell on the horizontal axis. This type of presentation has been duplicated by slower methods such as pen recorders. In some cases, however, it is desirable to do this very rapidly. For example, if there are a large number of samples, it is necessary, continually, to draw these distribution curves. This may be done readily by means of the following system, which also enables the use of a standard sample for comparison: Two samples, one the standard and the other under test, are mounted back to back and spun by means of a synchronous motor about the axis of the motor. At some angle arbitrarily chosen, or at 90°, a photocell and light source are placed. As the samples are rotated by the motor, the angle, at which the photocell alternately views the standard and the sample, changes continuously. The photocell output displayed with a synchronous sweep on a cathode-ray tube is then a graph of light reflexion as a function of the angle of view. Since the samples are presented alternately, the curves appear simultaneous and superposed to the observer.

Fig. 8 is a typical example of such a recording in which the reflexion from a clear sheet of glass is compared with that of a sample treated with glare-reducing material. By means of intensity modulation, using a synchronised multivibrator, 3° angle markers have been put on the baseline which was recorded by double exposure. This technique, as mentioned previously, should find wide application in any industry where surface specification is desired. With this type of presentation, changes of reflectance characteristic during a drying process can be seen. This method may also be reversed by moving the photocell rapidly around the sample and drawing a great many curves as the sample dries.

Polar Presentations

It is more conventional in optics to express these light-distribution patterns in the form of polar rather than cartesian co-ordinates. These patterns are generally used to describe the light distribution from lighting equipment such as photographic flood lamps. These patterns may be readily produced on cathode-ray oscilloscopes, such as the Type 275 polar co-ordinate indicator. This instrument produces polar diagrams which are synchronised with the motion of any rotating object merely by attaching the small lightweight, two-phase generator to the rotating part.[5] If a photocell is placed on the rotating shaft its output can serve as a measure of the amount of light reaching a certain point from all angles by applying the output of the photocell to the radial-input terminal on this indicator. Similarly, the light source may be rotated and the photocell remain stationary. Fig. 9(a) shows a cartesian light distribution obtained from a small flashlight bulb. Fig. 9(b) shows a similar light-distribution pattern in polar co-ordinates on the Type 275A indicator. Photocells and cathode-ray oscilloscopes have also been used to scan the illumination of scenes being photographed to depict graphically the variation between highlight and shadow brightness so that, for example, the contrast range of the recording film is not exceeded.[6]

Automatic "H and D" Curve Plotting

One of the best specifications for the behaviour of a photographic emulsion is its "H and D" curve which relates the photographic density to the logarithm of the exposure. These curves are generally produced by exposing either a stepped or continuously graded logarithmic variation of exposure along a strip of film, which is then processed in the usual manner. The dry film is examined by means of a densitometer and the results plotted on graph paper. This procedure is quite laborious and time-consuming. The shape of the "H and D" curve and its slope (the gamma) is affected widely by the conditions of development.

In cases such as in motion-picture processing where it is desirable to develop to constant gamma in the face of increasing exhaustion of the developer, sensitometric strips are frequently included every few hundred feet so that the development may constantly be checked, at least visually. This check would be much more useful if the actual curves were drawn as each strip passed through the developer so that the development could be shortened or prolonged as required.

Such an "H and D" curve can easily be plotted by having the strips pass through an infra-red light beam to a photocell while in the developer. The resultant variation in density is displayed on a cathode-ray tube.

We have produced such an "H and D" curve experimentally by examining the reflexion from a sheet of paper exposed from an Eastman circular step wedge. The resultant "H and D" curves obtained at three different times during development are shown in Fig. 10. The experimental setup used appears in Fig. 11. The exposed strip was mounted co-axially with a potentiometer, which produced horizontal positioning as the exposed sheet was rotated in a tray of developer. The wedge was illuminated by

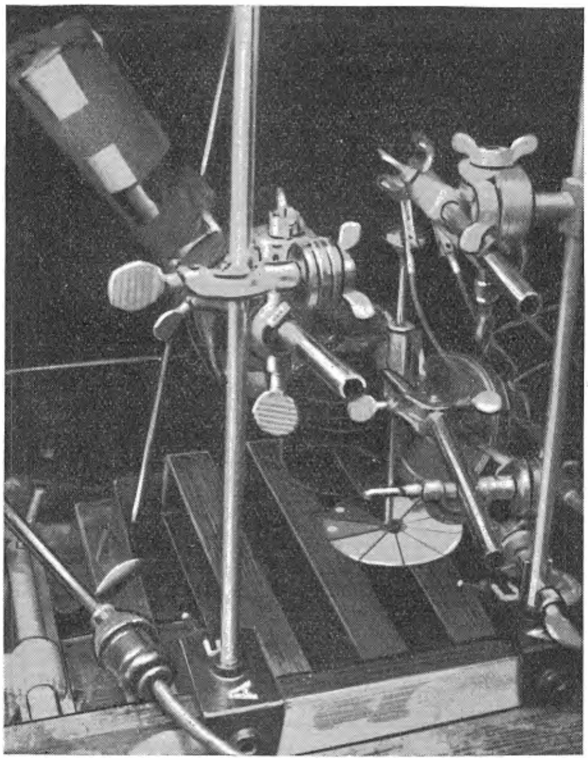


Fig. 11 (*left*). **Experimental setup in darkroom sink**

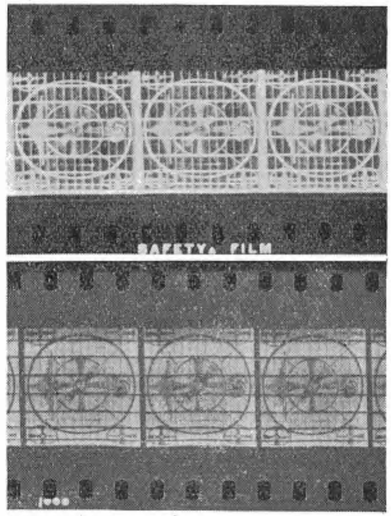


Fig. 14 (*right*). **Negative and positive television film recording made with a continuous motion camera**

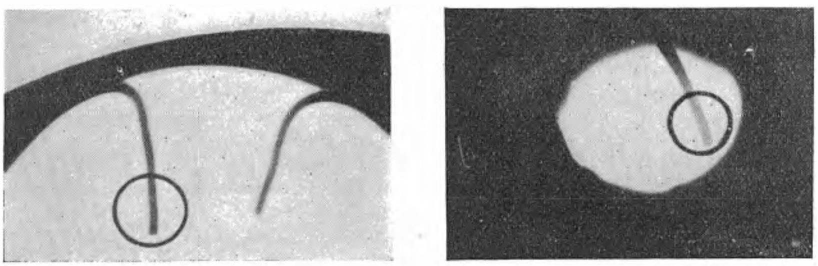


Fig. 13 (*below*). **Photographs of a wire rotating at high speed, made with: (a)** (*left*) **a stroboscope lamp and (b)** (*right*) **a cathode-ray tube light source. The circle encloses the same wire in both cases**

means of the vertical lamp which produced a small spot of non-actinic light on the paper. The reflexion was plotted as a negative vertical deflection. The sharp peaks in the pattern are due to the black lines separating the various steps in the wedge.

Cathode-Ray Tube Light Sources

Present photographic flashlamps are gas-filled tubes and therefore limited with respect to the shortest flash that they can produce, mostly because of the finite velocity of the gas particles. Since cathode-ray tubes are vacuum tubes, they are not subject to these limitations. By the use of phosphors having extremely short build-up and decay times, such as zinc oxide, it is possible to produce very short light pulses. Several experimental cathode-ray tubes for use in producing these short light pulses have been built in connexion with the relaying of video information over light beams.[7] In order to demonstrate the capabilities and advantages of such cathode-ray tubes over conventional lamps for stroboscopy at high speeds, the light output *vs.* time characteristics of such a cathode-ray tube have been compared oscillographically with that of the light from a gas stroboscope lamp. The results are shown in Figs. 12 and 13. Fig. 12 shows on the same time base the oscillogram of a 2-microsecond flash from a cathode-ray tube (a small spike) and the comparatively long light output from a stroboscope. Not only is the stroboscope flash much longer in duration, but it also rises and falls much less steeply and tends to oscillate. The effect of these light sources on a photograph is shown in Fig. 13. These two photographs are pictures of a wire being rotated at high speed by means of a synchronous motor. The picture taken by means of the stroboscope is seen to correspond roughly to the oscillogram and to have both leading and trailing edges blurred while the photograph made with the cathode-ray tube light source is acceptably sharp. Such cathode-ray tubes, capable of being modulated with high frequencies, also have been used successfully to replace the gas crater glow modulator tube which is capable of modulation up to only about 15 Kc/s. These tubes have been successfully modulated at frequencies up to 10 Mc/s.

An oscilloscope with a single sweep beam blanking circuit can be converted into a stroboscope of somewhat limited usefulness by the use of a short-persistence cathode-ray tube. The length of each light pulse may be controlled by setting the sweep speed. For studying electrical or other machinery, it is frequently possible to obtain a synchronising signal, connect it to the synchronising signal input on the oscilloscope and have a workable stroboscope for illuminating small areas. A further advantage is the possibility of using the cathode-ray tube, both as a stroboscopic light source and as a viewing tube to study simultaneously the electrical and mechanical characteristics of some machine or circuit. A further refinement lies in the use of a double beam tube in which one beam acts as a stroboscopic light source, the other beam as a conventional cathode-ray oscillograph. The advantage here is that very much higher speed phenomena may be studied than is presently possible with gas tube stroboscopes.

By the use of such short decay and build-up phosphors, it is also possible to make continuous recordings of television programmes from a cathode-ray monitor tube, for example, by merely using the film motion as the vertical sweep and allowing it to spread a complete record of each frame of the television picture along the length of the film. Fig. 14 shows two recordings made in this manner with a Type 314 oscillograph-record camera. There are here no complications due to the differences in frame frequency and shutter frequency since no shutter is used on the camera. The same method is used in the present "Ultrafax" facsimile recording system.

(*To be continued*)

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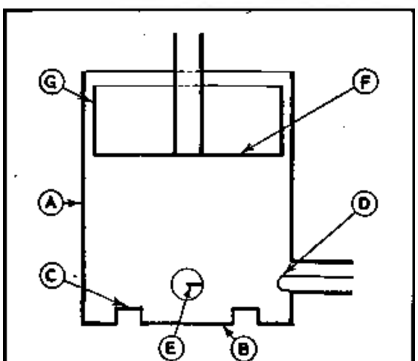
Microwave Discriminator Circuit

A COMMON form of frequency discriminating device is the arrangement employing stagger tuned circuits. In this device two circuits are tuned so as to resonate respectively at two more or less closely adjacent frequencies and the circuits feed associated rectifiers whose outputs are combined in opposition.

When such a circuit is required for operation at centimetre wavelengths it is natural to use resonators of the cavity type rather than tuned circuits of lumped form. The use of cavity resonators, however, enables the arrangement to be simplified to a striking degree insofar as it becomes possible to replace the two separate cavities by a single cavity. In this single cavity the source of excitation is so coupled as to set up two component oscillations of the cavity of differing mode. These modes take the place of the simple vibrations of the separate circuits in the normal arrangement, and the natural frequencies of the modes are thus selected accordingly. Furthermore the cavity is arranged so that each component oscillation separately excites a rectifier. The remainder of the circuit is normal and the outputs of the rectifiers are combined in opposition in standard fashion.



The diagram shows the general form of the arrangement. *A* is a cylindrical conducting cavity conductingly closed at either end so far as operating frequencies are concerned. In the cavity the two modes of vibration are established, one as a transverse electric type, and the other as a transverse magnetic type. These may be those known conventionally by the notation $TE_{0,1}$ and $TM_{1,1}$ respectively. If the cavity were of the form of a perfect right circular cylinder the natural frequencies of such modes would be identical. The frequencies, however, are made somewhat different by arranging on the end wall *B* a raised conducting annulus *C* coaxial with the axis of the cavity. This annulus has the effect of slightly reducing the length of the cavity so far as the transverse electric wave is concerned, but does not significantly modify it in relation to the transverse magnetic wave. The two modes are excited by a single exciting loop not shown in the diagram, but which is inclined to the axis of the cavity. Output loops *D*, *E*, feeding separate rectifiers are arranged so that each couples to its respective mode and not to the other. In the instance of the transverse magnetic mode the plane of the coupling loop lies parallel to the axis of the cavity and in the transverse electric mode the plane of the loop is disposed perpendicularly to the axis of the cavity.

As will be seen in the drawing, the end of the cavity opposite to the annulus *C* is closed by a piston *F* which can be moved along the axis of the cavity for the purpose of tuning the cavity as a whole. The piston does not touch the walls of the cavity, but has a skirt *G* which is spaced a small distance from the cavity wall and extends for a quarter of a wavelength parallel to the axis of the cavity, so that in effect the edge of the piston face is short circuited to the wall of the cavity.

Obvious uses of the device are in the normal stabilisation and control of frequency of oscillators. The discriminator may, however, be adapted as a self-tuning cavity whose mean frequency locks automatically to an injected signal. In this manner it may be developed as a self-tuning "echo box" for the monitoring of radar equipment when real targets are not available, as may happen at sea. Another use for the circuit is in the frequency modulation of microwave oscillators. When arranged for this purpose an oscillator may be controlled by the discriminator and its frequency will then follow any small change in the length of the cavity.

—*Communication from E.M.I.*

Signal Noise and Optical Relations in Television Cameras

By G. LIEBMANN, D.Phil., F.Inst.P*

EARLY television broadcasts were all made from the studio. This was not only due to the absence of such facilities as radio-links and outdoor broadcasting vans, but just as much to the lack of sensitivity of the early types of television pick-up tubes. The position has changed meanwhile, and the earlier discussion of the optical relations in television cameras, due to De Vore and Iams,[1] will be extended in this article to the problem of outdoor broadcasting and long-range television work.

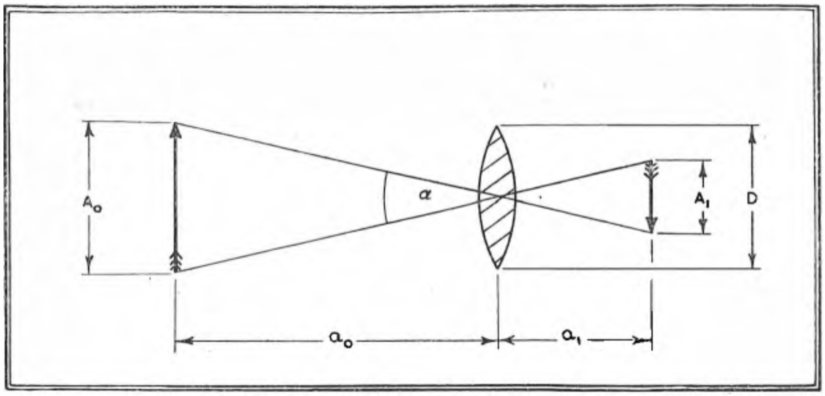


Fig. 1. Geometrical relations in camera

"Noise" Considerations

The signal strength of the received television image must be high enough to make the background noise negligible by comparison. The signal/noise ratio e_s/e_N may be called satisfactory if it has a value of 40 db., although a value of 50 db. is desirable in half-tone pictures. As we are here only interested in the problem of the television *camera*, we can disregard the additional sources of "noise" noticed in the received picture. The following considerations will be based on a signal-to-noise ratio of 40 db. at the television camera output.

The noise associated with the pick-up tube is due to three main components, *viz.*, the random fluctuations ($\bar{i_1^2}$) of the pick-up tube current i_s, the noise voltage appearing at the load resistor R_a of the pick-up tube (e_2^2), and the noise originating in the circuits of the first amplifier stage (e_3^2), expressed by its "equivalent noise resistance" R_{eq}. The other sources of noise in the amplifier can usually be neglected.

These well-known relations apply:

$$i_1^2 = 2ei_sdf, \text{ and}$$
$$e_1^2 = i_1^2R_a^2, \text{ or}$$
$$e_1^2 = 3.2 \times 10^{-19}\ R_a^2i_sdf \quad \ldots\ldots (1)$$
$$e_2^2 = 1.6 \times 10^{-14}\ R_adf \quad \ldots\ldots (2)$$
$$e_3^2 = 1.6 \times 10^{-14}\ R_{eq}df \quad \ldots\ldots (3)$$

i_s in μA, df in Mc/s.,
R_a, R_{eq} in ohms.

Symbols Used

a_0 = average distance of scene from camera (ft.)
A_0 = width of scene (ft.)
α = viewing angle ($\tan\alpha/2 = A_0/2a_0$)
A_1 = width of photocathode or mosaic (inches)
f = focal length of lens (inches)
D = diameter of lens diaphragm (inches)
F = f-number of lens (F = f/D)
Δ = depth of focus (ft.)
H = hyperfocal distance (ft.)
t = transmission factor of lens
B = surface brightness of televised objects (candles/ft².)
L = light flux falling on photocathode or mosaic (lumens)
σ = "overall" pick-up tube sensitivity (μa/lumen)
N = number of scanning lines in television picture
df = bandwidth of pick-up tube amplifier (megacycles/s)

i_s = signal current delivered by pick-up tube (μA)
e_s = signal voltage
e_N = noise voltage
Ra = load resistor in pick-up tube output circuit (ohms)

The total noise voltage is then $e_N = (e_1^2 + e_2^2 + e_3^2)^{\frac{1}{2}}$, and the signal/noise ratio e_s/e_N becomes:

$$e_s/e_N = 10\ i_sR_a\ [3.2 \times 10^{-5}R_a^2i_s + 1.6\ (R_a + R_{eq})]^{-\frac{1}{2}}\ (df)^{-\frac{1}{2}} \quad \ldots\ldots (4)$$

The signal/noise ratio is given in Table I for a few representative values of i_s and R_a, for a standard bandwidth of 1 Mc/s. and R_{eq} = 500 ohms.*

This table demonstrates that for small signal currents (less than 0.1 μA) the noise is mainly due to the load resistor R_a. In this noise calculation, no account is taken of any noise introduced by the electron multiplying stages of pick-up tubes incorporating secondary electron multiplication of the primary photo-electric current. The signal/noise ratios given in the two last lines of Table I, which apply at present only to secondary multiplier pick-up tubes, are therefore higher than can be expected in practice. Further, it is not yet known how far Equation (1) applies in the case of a mosaic electrode.

A graph of the signal/noise ratio following from Equation (4) is given in Fig. 2 for several values of load resistor R_a, for 1 Mc/s. bandwidth. If the amplifier bandwidth is greater than 1 Mc/s. the corresponding values, in db., listed in Table II have to be subtracted from those shown in the graph, Fig. 2, for the values of i_s and R_a selected.

The greatest resistance value R_a which can be used is approximately given by the relation R_adf = constant[2]. The value of this constant depends on the type of amplifier circuit used, on the shunt capacitances of pick-up tube output and amplifier input, and on the required degree of "flatness" of the frequency response of the amplifier. For a compensated wide-band amplifier of 1 Mc/s. bandwidth a value of $R_a = 10^5$ ohms would seem to be already fairly

* In a more accurate treatment of the signal noise problem, the shunting effect of the input capacitance Ci of the amplifier would have to be included, leading to the replacement of Req by $\mathrm{Req}\left(1 + \frac{4\pi^2}{3}\ \mathrm{Ra^2Ci^2df^2}\right)$ The influence this correction term is negligible, with the values of Ci and df used in modern practice, except when Ra has a very high value, of the order of 10^5 to 10^6 ohms. Even in this case the signal/noise ratio will be within 1 or 2 db. of the values listed in Table I, which is based on eqn. (4).

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TABLE 1

i_s (μa)	$R_a = 10^3$ ohms		$R_a = 10^4$ ohms		$R_a = 10^5$ ohms		$R_a = 10^6$ ohms	
	e_S/e_N	db	e_S/e_N	db	e_S/e_N	db	e_S/e_N	db
0.001	0.2	−14	0.8	−2	2.5	−8	7.8	+18
0.01	2	+6	8	+18	25	28	72	37
0.1	20	26	79	38	23×10^1	47	46×10^1	53
1	20×10^1	46	71×10^1	57	14×10^2	63	17×10^2	65
10	19×10^2	65	45×10^2	73	55×10^2	75	56×10^2	75

TABLE 2

df (Mc/s.) ...	1	1.5	2	2.5	3	4	5	10	
db	0	1.8	3	4	4.8	6	7	10	Ra=const.
db	0	3.5	6	8	9.5	12	14	20	Radf=const.

TABLE 3

Type of Tube	(μA/lumen)	Reference
Iconoscope, Emitron	0.3	3)
Super-emitron	4	4)
Orthicon	4	5)
Image-orthicon	400	6)

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high, and R_a = .25 Megohms about the maximum practicable value, if the need for excessive compensation be avoided.

For a 405-line 50-frames interlaced picture with an aspect ratio of 5:4, the amplifier bandwidth would have to be about 2.5 Mc/s. From the graph, Fig. 2, and Table II, row 3, we see that we would then require a signal current of i_s = 0.08 μA for a "satisfactory" picture (e_s/e_N = 40 db.), the maximum value of the load resistor being $R_a = 10^5$ ohms.

Pick-up Tube Sensitivity and Choice of Lens System

We have now to consider how we have to choose the optical system of the television camera to obtain the required signal current of 0.08 μA with modern pick-up tubes.

The total light flux reaching the photo-cathode or mosaic is

$$L = \frac{\pi B\ t\ A_1^2}{4 \times 144 \times F^2} \text{ lumens}$$

The transmission coefficient t of the lens depends on the number of glass-air interfaces in the lens, and may be anything between .3 and .8, being mostly near .5 in high speed lenses. For sake of simplicity, we assume t = .46, as this makes the numerical factor $\pi t/144 = 1/100$.

Hence

$$L \approx \frac{B\ A_1^2}{400\ F^2} \text{ lumens} \quad \ldots\ldots\ldots\ (5)$$

In using this formula, the angle subtended by the scene can be calculated from the used width of the photo-cathode A_1, the focal length f and the speed F of the lens, with the help of the relation

$$\tan \alpha/2 = \frac{A_1}{2f} = \frac{A_0}{2a_0} \quad \ldots\ldots\ (6)$$

The effective lens diameter (diaphragm) of the lens is given by

$$D = f/F. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

Equation (5) can therefore be written in these alternative forms which are often more convenient to use:

$$L \approx \frac{B\ A_1^2 D^2}{400 f^2} \text{ lumens,} \quad \ldots\ldots\ (8)$$

or

$$L \approx \frac{B}{100} \cdot D^2 \tan^2 \alpha/2 \text{ lumens.} \quad \ldots\ldots\ldots\ldots\ (9)$$

The signal current i_s is then:

$$i_s = \sigma L\ \mu A \quad \ldots\ldots\ldots\ldots\ldots\ (10)$$

where σ is the "overall sensitivity" of the pick-up tube in μA/lumens.

The "overall sensitivity" σ is the product of these three factors: (i) primary photo-sensitivity of photo-cathode or mosaic, (ii) internal efficiency factor, and (iii) secondary electron multiplication factor (if applicable).

The internal efficiency factor of the iconoscope type of pick-up tube is of the order of 1 per cent to 3 per cent, whereas it is near 50 per cent in the orthicon type of tube.

The overall sensitivity σ varies from tube to tube, and depends also on the operating conditions of the pick-up tube and on the level of illumination reaching the tube, falling off with increased illumination. For low illumination levels, these *average* values of σ can be assumed for the different types of present-day pick-up tubes (Table III):

To obtain a satisfactory output signal (e_s/e_N = 40 db.) in a 405 line television system ($df \approx 2.5$ Mc/s., $R_a = 10^5$ ohms) these quantitative relations must then be fulfilled:

$B\ D^2 \tan^2 \alpha/2 \geqq$

27 iconoscope, emitron

2 super-emitron, orthicon

0.02 image-orthicon .... (11)

In this equation, B is measured in candles/ft² and D in inches.

In studios, a surface brightness of about 100 candles/ft² is usually

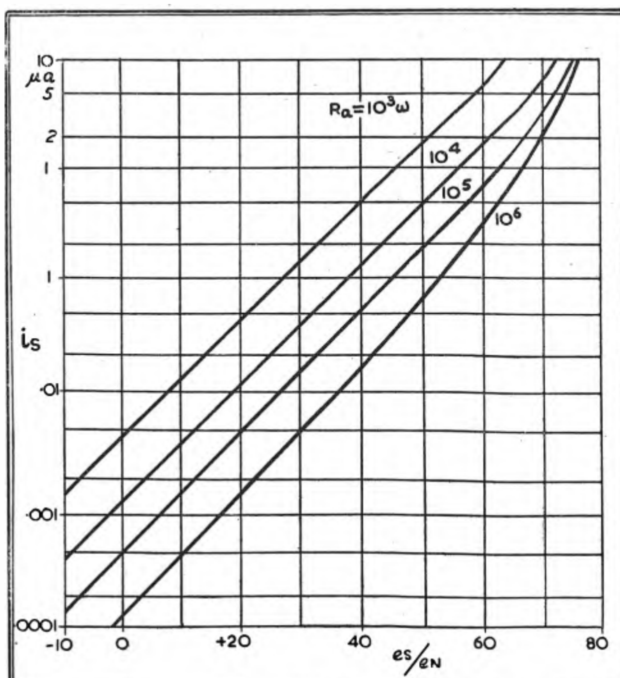

Fig. 2 Signal/noise ratio (db) as function of pick up tube current for several values of load resistance Ra (equivalent noise resistance of first valve Req = 500 ohms)

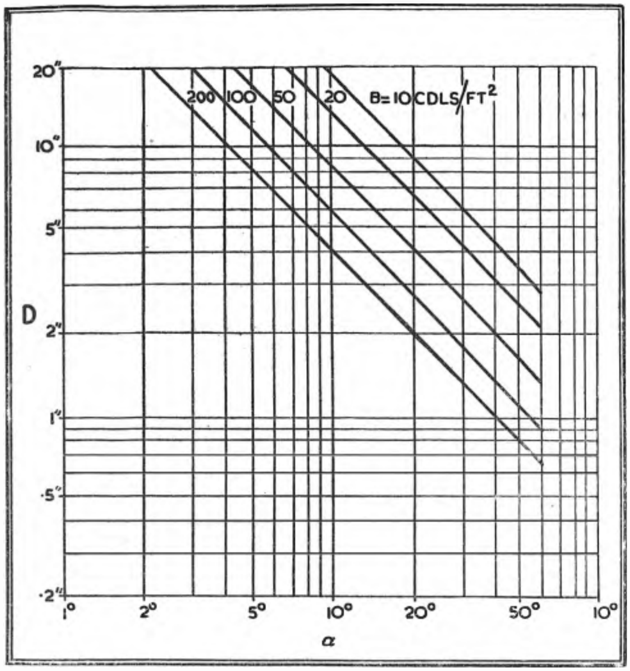

Fig. 3. Minimum diameter D of lens diaphragm as function of viewing angle α of iconoscope camera for several values of object brightness B. df=2.5 Mc/s. $R_a=10^5$ ohms

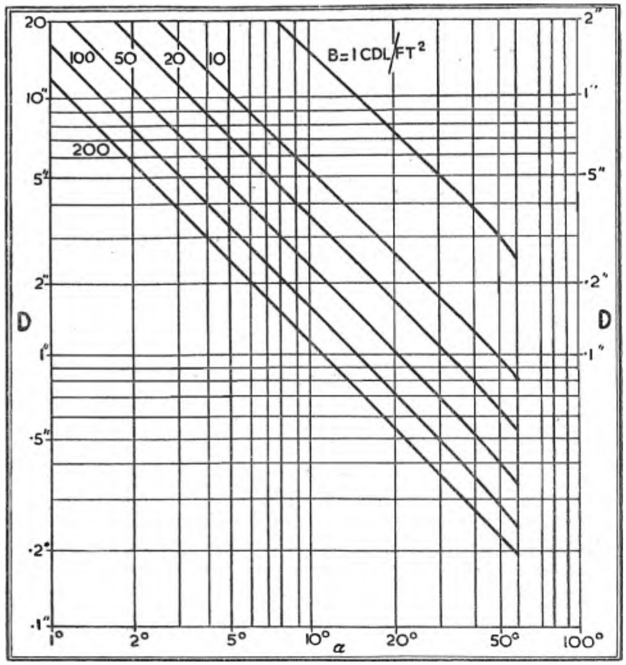

Fig. 4. Minimum diameter D of lens diaphragm as function of viewing angle α for several values of object brightness B. Left-hand scale D—super-emitron. Right-hand scale—image orthicon df=2.5 Mc/s. $R_a=10^5$ ohms

obtained in the high levels. In outdoor broadcasts, the surface brightness level varies considerably, between 1 candle/ft² and 1,000 candles/ft².[7] Under "normal" daylight conditions, B will be between 10 and 200 candles/ft² in the open.[8]

Diagrams of lens sizes required for different levels of surface brightness and different sizes of the angular field covered by the television camera, based on Equation (11), are given in Figs. 3 and 4. Fig. 3 refers to iconoscope or emitron cameras and Fig. 4 to super-emitron or orthicon cameras (left-hand scale) or to image-orthicon cameras (right-hand scale).

The diagrams, Figs. 3 and 4, are based on a pick-up tube amplifier bandwidth of 2.5 Mc/s., and a load resistor of $R_a = 10^5$ ohms. The lens sizes or viewing angles possible with television systems employing a different bandwidth can be easily obtained from these diagrams with the help of the relations:

$$D \tan\alpha/2 = k_1(df)^{-\frac{1}{4}} \ldots\ldots \quad (12)$$
for R_a = constant

$$D \tan\alpha/2 = k_2(R_a)^{-\frac{1}{4}}, \ldots \quad (13)$$
for df = constant

* The surface brightness B in candles/ft² of a flat object is connected with the numerical value, in foot-candles, of the incident illumination I by the formula $B = RI/\pi$, where R is the reflexion coefficient of the object surface; as a rough guide, B will therefore have a numerical value which is about 1/10 of the numerical value of the incident illumination in foot-candles.

following from the condition of keeping the signal/noise ratio constant. For a given viewing angle, the lens diameter D will therefore have to go up, in high definition systems, in proportion to the number of scanning lines employed.

In using the diagrams, Figs. 3 and 4, the required width A_1 of the photocathode can be determined from the viewing angle α and the effective lens diameter D, once the focal length f or the lens speed F has been chosen, or the required focal length f and lens speed F can be obtained from the given size of the photocathode or mosaic. Alternatively, the minimum viewing angle which can be obtained for a given brightness and given dimensions of lens and photocathode may be worked out.

If the overall sensitivity σ of the pick-up tube should be materially different from that listed for this type in Table III, the graphs, Figs. 3 and 4, can still be used if corrected with the help of the formula

$$\sigma D^2 \tan^2\alpha/2 = \sigma_0 D_0^2 \tan^2\alpha_0/2, \ldots \quad (14)$$

where σ, D and α are the corrected values, σ_0 the value of σ listed in Table III and D_0 and α_0 the values of D and α taken from the graphs.

With the help of Equation (11) we can also answer the question of how the optical system of the television camera must be adjusted to give the same resolving power as the human eye. This resolving power is approximately 1.5 minutes. The viewing angle of a 405 lines television picture giving the same resolution, *i.e.*, 1.5 minutes per picture element, is then - 10°, about one-fifth of the viewing angle of the human eye. As $\tan\alpha/2 = .087$ in this case, we have

$$B D^2 = \begin{cases} 3600, \text{ iconoscope, emitron} \\ 260, \text{ super-emitron, orthicon} \\ 2.6, \text{ image-orthicon} \ldots\ldots\ldots \end{cases} \quad (15)$$

Equation (15) indicates that the iconoscope type of tube would require a lens of 6 in. diameter to transmit satisfactorily objects of the relatively high surface brightness of 100 candles/ft², and impracticably large lenses for objects of lower brightness. The super-emitron camera and the orthicon tube could give the required resolution with reasonably sized lenses even under fairly bad lighting conditions.

The problem becomes rather more difficult if the television camera is used as a *telescope*, giving a "close-up" view of a distant object. If we require the television camera to reveal as much detail as a good pair of field glasses, magnifying 10×, our relation would be

$$B \cdot D^2 = \begin{cases} 2.6 \times 10^4, \text{ super-emitron, orthicon} \\ 260, \text{ image-orthicon} \end{cases} \quad \ldots\ldots\ldots\ldots (16)$$

We see that tubes of the high sensitivity of the super-emitron or orthicon cannot transmit such a telescopic picture satisfactorily under the best lighting conditions, even if a large diameter mirror optical system (Schmidt camera) were used. However, if we reduce our requirements to an "acceptable" signal-to-noise level of 20 db., a telescopic picture (10× enlarged) could be transmitted at the highest levels of outdoor illumination with ordinary lenses of large diameter (4 in. to 6 in.), whereas a Schmidt camera with a 12 in. mirror would allow "acceptable" transmission of objects of a surface brightness of about 20 candles/ft². The best answer yet to the problem of telescopic television cameras is therefore the use of pick-up tubes of the image-orthicon type.

The small viewing angles needed in telescopic television cameras would require the development of special pick-up tubes which can give high resolution with small photocathode areas, to obviate the use of quite impracticable optical systems. Tubes of the super-emitron type and the image-orthicon type would lend themselves particularly well to this purpose, as the "image converter" section can be designed to enlarge a small section of the photocathode electronically, eliminating the loss of resolution inherent in small sized mosaics. To give a practical example, the telescopic television camera giving a magnification of 10× would require a viewing angle of $\alpha = 1°$. If the photocathode had a diameter of 1 in., as found in some recent pick-up tubes, the focal length of the camera lens would have to be 58 in. By making the used width of the photocathode only .2 in., increasing at the same time the electronic magnification of the image converter section by a factor of 5, the focal length of the camera lens could be reduced to (58/5)in. = 11.6 in. If the effective lens diameter D is kept as great as for the 58 in. lens, the same light flux would be collected, and the same signal level obtained as with the larger cathode and longer focus lens.

The graph, Fig. 2, taken together with Tables II and III, or graphs, Figs. 3 and 4, and Equations (5) to (13) allow the working out of all optical questions arising in television camera work, except those where the limited depth of focus near the camera must be taken into consideration, *i.e.*, in studio scenes and in foreground scenes outdoors.

For completeness, we note therefore these formulæ for the hyperfocal distance H (distance from which all objects are in focus if the camera is focused on infinity) and the depth of focus Δ (range over which the image is sharply focused), under the assumption that the largest tolerable disk of confusion has the size of one picture element ($\delta = A_1/N$):

$$H = \frac{f\,D\,N}{12\,A_1} = \frac{D\,N}{24 \tan \alpha/2}, \quad \ldots (17)$$

and

$$\Delta \approx \frac{2a_0^2}{H}$$ for scenes near the camera ($a_0^2 << H^2$). .... (18)

The near focus limit is

$$a_0' = \frac{H\,a_0}{H + a_0}, \quad \ldots\ldots\ldots\ldots (19)$$

and the far focus limit

$$a_0'' = \frac{H\,a_0}{H - a_0}. \quad \ldots\ldots\ldots\ldots (20)$$

In these formulæ, f, D and A_1 are measured in inches, the distances in feet.

Our discussion of the optical relations in television cameras has demonstrated that the photo-electric sensitivity of the pick-up tube plays an all-important part in television. The recent introduction by the B.B.C. of the new C.P.S. Emitron camera tubes has brought the practical proof through the greatly increased range and quality of outdoor television broadcasts, as witnessed by the very successful transmission of the Olympic Games events.

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Compensation for Wear in a Magnetophone Recorder Head

SOUND recorders of the magnetophone type make use of two oscillatory currents in the recording head. One of these currents is the audio frequency modulating current that effects the magnetisation of the recording tape. The other is the high frequency current whose function it is to overcome the effect of magnetic hysteresis in the tape. It is found in practice, however, that the continual passage of the tape between the pole pieces of the head wears the pole pieces, so modifying the flux between them and reducing the effectiveness of the high frequency current. To surmount this difficulty it has been customary to increase the high frequency current fed to the head as the pole pieces wear.

In order to avoid the necessity of such periodic adjustment a simple scheme has been derived by which the adjustment is achieved automatically and, moreover, in a continuous manner so that the action of the high frequency current on the tape is maintained always the highest possible.

The scheme depends on the use of a compensating capacitor whose capacitance operates to tune out the inductance of the high frequency windings of the head. This use in itself is standard practice and is necessary to obtain a large current in the windings. However, what has now been effected is to tune the high frequency windings not to resonance but to some frequency slightly below resonance by employing a slightly larger tuning capacitor. This being so, as the pole pieces wear and the inductance of the windings is in consequence gradually reduced, the windings by a continual process come more into resonance and the current in them is steadily increased as desired.

The scheme is equally effective as applied to the erasing head where a similar high frequency current is used for removing existing magnetisation of the tape.

—*Communication from E.M.I., Ltd.*

The Practice of Printed Circuits

By P. P. HOPF*

RECENTLY expressed opinion on the printed circuit technique and its uses in the electronic industry has shown that there is considerable and widespread misunderstanding not only of possibilities, but mainly of its use as an aid to the electronic constructor.

A number of publications, particularly on techniques developed in the U.S.A., have tended to create the impression that the printed circuit itself is a "throw-away" unit. Such a unit is obviously not fitted for the European market, and while mass production at a cheap rate of "throw-away" units might enter the American market, developments in Britain have not been on these lines. The printed circuit technique, as developed here, is a new technique requiring new ancillary operations of a circuit layout or sub-assembly in which parts are replaceable and which can be mended or repaired.

The object of this article is not to give instances where this technique can be used in design and construction of circuits, but to inform the electronic engineer on the nature of the tool that has been offered to him, and on the way it should be handled and treated.

The orthodox technique of constructional assembly may be regarded for the purpose of this argument to consist of metal or plastic chassis on which pre-manufactured components such as valves, coils and resistors and capacitors are connected and fixed by means of wires, screws and rivets, using the soldering iron or the screwdriver. Indeed, a large industry has developed in the pre-manufacture of such components, and each component is regarded as being manufactured within certain tolerances to give a certain life, after which most of them will be discarded. In other words each component is in itself a "throw-away" unit which has been accepted by the constructor as part and parcel of his technique.

The printed circuit method has been regarded as something that ill fits this technique, and yet something that cannot be entirely ignored. It is not surprising, therefore, that there is considerable opposition among constructors to printed circuits, and to introduce what appears to be just another "throw-away" unit to replace the wiring which so far has not given great trouble, and is comparatively inexpensive. The tendency in this country has been to regard printed circuits as something that is useful in miniaturisation and yet a retrograde step for large scale construction, especially in view of the fact that neither the soldering iron nor the screwdriver find much use in connexion with this technique. There is also a natural reluctance to discard long-tried components available on a large scale, and at reasonable prices, in favour of new ones. This impression which prevails is entirely erroneous, and if allowed to persist will hold up development of a new and promising production technique for years. It is only natural that in order to test the value of the technique it should be first adapted to existing methods of circuitry, and that the constructor should try to find a place for printed circuits in his present assembly. While this is undoubtedly a natural point of view it must not be forgotten that the printed circuit is a revolutionary technique, and when

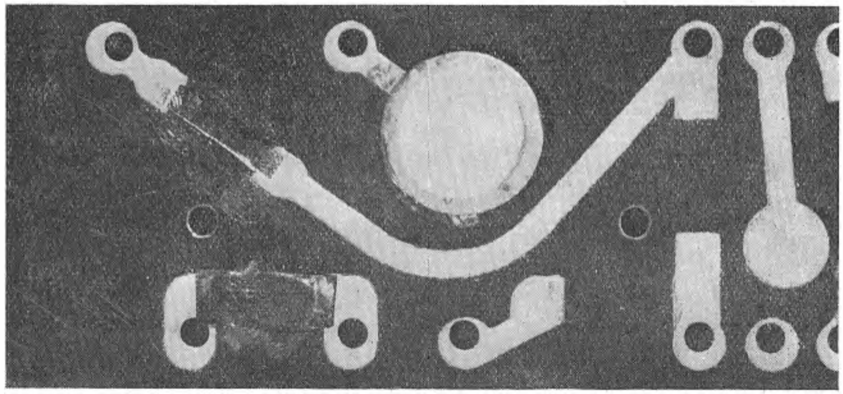

Fig. 1 (above). Sub-assembly showing wiring with one capacitor and two resistances in place

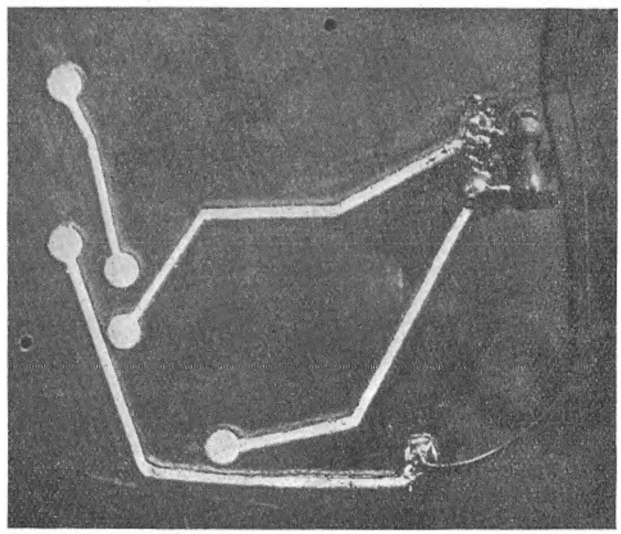

Fig. 2. Printed circuit showing miniature resistor and wire soldered directly into the circuit

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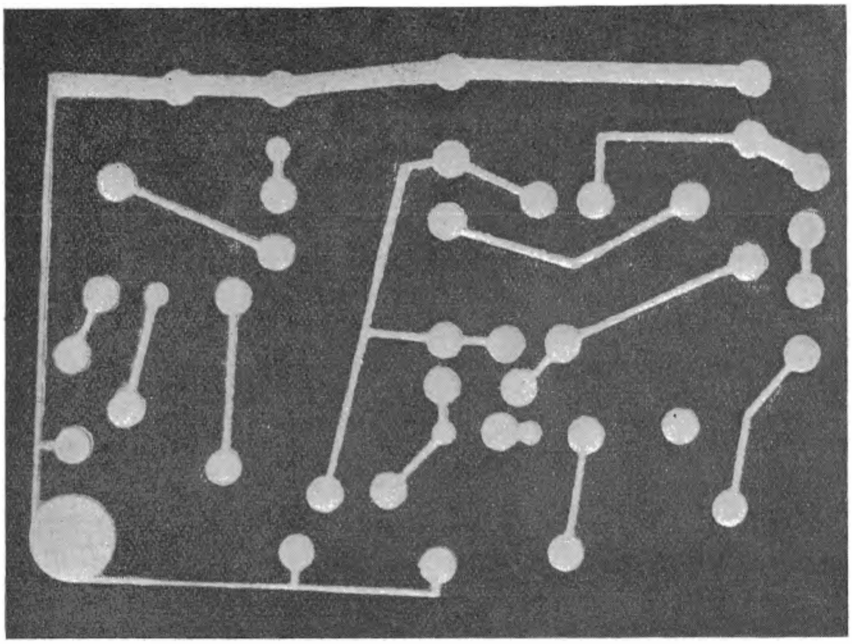


Fig. 3. Circuit printed on bakelite showing line terminals and space for capacitor

fully introduced and fully developed, aims at increasing production and putting the assembly line on an entirely different basis; thus it is likely that the soldering iron may eventually be replaced by chemical solutions, and the screwdriver by plastic presses. This aspect may sound frightening at first, yet, as will be shown, difficulties introduced are not great and the technique may offer considerable advantages from the point of view of increased production at lower cost. It would be premature to say that the technique has been developed in the laboratory to its fullest possibilities, and that all problems in connexion with printed circuit technique have been solved. Problems arising in the construction of various receivers are not identical and will have to be tackled individually, yet the technique has now reached a state where it must enter the industry and the assembly line. Development has reached a stage where the advantages are apparent and can be translated into money-saving and improved performance.

Wiring

The first step in the application of the technique is the wiring, and unlike the orthodox method of assembly, the printed wiring is to be regarded as part of the chassis.

In the "Elargol" technique to which the author has confined himself, this wiring is printed in metallic silver by an offset press. The chassis may be in any plastic material including low temperature thermo-plastic materials, and high temperature ones such as polytetrafluoroethylene, and all types of thermo-setting materials, principally the electrical bakelites. The chassis may or may not be preformed or pre-drilled and may be flexible or rigid. It may consist of 0005" polystyrene film or of silicone plates of ½ in. thickness.

The circuit is laid out in much the same manner as a wiring diagram in which only the wires themselves are drawn to scale. This is then printed by the photo-offset method described in a previous article.* The width and thickness of silver deposit can be specified to close limits and naturally governs the performance.

If the printed line is overloaded this will lead to heating which may be detrimental to the plastic, and before laying out the circuit it is necessary to know what currents have to be carried, in order to specify the width and thickness of the deposit. Normal deposits are one thousandth of an inch thick and a line of 1/16th of an inch in width can carry 1 amp. safely for an indefinite period, while a line of double that width can carry 2.5 amp. indefinitely without appreciable heat. There is, however, no limit to the width or thickness of line that can be printed. In laying out the circuit it is important that the designer should divorce himself as much as possible from the ideas of orthodox construction. It is often possible to place components in much closer proximity, and to include in the wiring items not normally included; thus, for instance, a loop aerial may be placed as a frame around the circuitry.

Crossing of wires is effected by drilling through the chassis, when it is easy to silver the inside of the drilled hole for conducting purposes. Rivets or screws may be placed through the circuit, but although this method of contact may seem attractive to the designer used to orthodox wiring, much of the value gained by printed circuits is lost by the introduction of unnecessary components of this nature. The print may be soldered directly, giving joints of serviceable strength. (50 lb. pull on an average joint can easily be obtained). There may, of course, be joints where greater mechanical strength is required, and here rivets have to be used. When selecting a suitable solder it must be at least as flexible as the plastic. Bismuth-tin solders which are attractive for their low melting point and small affinity for silver are unsuitable because they are too brittle. Best results are obtained with a resin-cored lead solder previously saturated with silver, and ordinary silver solders using non-corrosive fluxes, all of which are commercially available. With these materials even unskilled operators can make soldered joints quickly and efficiently. While the present state of the art does not permit the complete elimination of soldered joints, the designer should reduce these to a minimum, as they must only be regarded as links of the printed circuit to the parts that can, up to date, not be printed, and to outside connexions such as loud speaker leads, etc. Other points that should be remembered are that for the sake of servicing it is an advantage to arrange the chassis so that the tap-off holes or joints lie near the edge of the panel, so that the panel can be regarded as a unit which is connected to the rest of the components by eliminating leads from a minimum number of points. This gives an easier access

* *Electronic Engineering*, June 1947, p. 198.

to the printed panels and allows for quick and efficient repairs.

One of the important points to the electronic engineer is the question of repair. It cannot be too strongly emphasised that any repair to the circuit can easily be done without complete replacement of the printed unit. A colloidal silver solution like "Elargol" W.8 may be applied by brush with subsequent stoving for a short time at a low temperature, say 20 minutes at 85° C. or five minutes at 120° C. Taking for example an extreme case of a bakelite chassis having broken right through, thereby breaking several printed lines on both sides of the chassis. First the plastic is gummed together with a suitable adhesive, preferably a bakelite or any other resinous adhesive. With a suitable brush the gaps in the silver line are bridged with "Elargol" solution and the chassis put into an oven for 10 minutes at 100° C. (a temperature which is quite safe for all bakelites and most other plastics, but due regard must be paid to components of the capacitors). It is then removed and the gaps are bridged on the other side, and the process repeated. If these repairs are to be done on a large scale, both sides can be bridged at the same time, and the plastic stoved in a jig. The repair is a permanent job which will not affect the performance of the circuit. It is also often possible to return the print to the makers to be overprinted without affecting any other components on the chassis. This, however, in most cases would prove too expensive.

Resistors

The usual printed resistance is a film of graphite or carbon suspended in a suitable resin and applied between the two terminals. This is then adjusted to a given value by scraping away some of the material while measuring on a bridge. It is often difficult to adjust this value while the resistance is part of a circuit, and may be connected to other components.

The "Elargol" resistor developed in these laboratories does not use this method, which although acceptable for many purposes, flavours of the "throw-away" unit. The "Elargol" resistor consists of a fine grid system printed in a resistance material on to thin plastic film to definite values. The small plastic lamina has silver terminals printed on it, and is inserted into the circuit by means of an adhesive and under slight heat and pressure to ensure perfect contact of the terminals, also complete adhesion to the plastic chassis. This resistor when inserted is part of the printed circuitry, but is in itself a prefabricated unit, *i.e.*, all measurements are done before it is inserted. These flat laminæ can be made to specifications within 5 per cent, as far as ohmic resistance is concerned for a definite length or width, ranging from 250 ohms to 5 megohms. Their rating can be specified as from $\frac{1}{8}$ watt to 1 watt. For high resistance values it is not recommended to use these resistances at a rating of more than $\frac{1}{2}$ watt. The lamina is placed with the resistor face downwards on the chassis so that the plastic film backing acts as a protective layer. For further protection it may be painted over with a suitable varnish, say a urea formaldehyde non-tracking varnish. This pre-formed printed resistor, apart from great advantage in cost, particularly where testing is concerned, allows quick and easy repairs to be carried out.

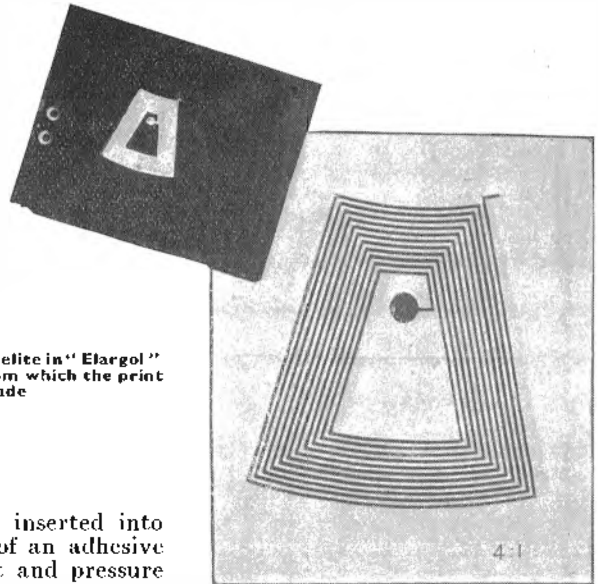


Fig. 4. 1.5 μH coil on bakelite in "Elargol" showing the drawing from which the print was made

To replace an "Elargol" resistor the existing resistor is dissolved out with a suitable solvent such as carbon tetrachloride, trichlorethylene or petrol. This dissolving out process for a faulty resistor is easily carried out with a wad of cotton wool soaked in the solvent, or by painting the solvent over the resistor and allowing it to stand for a minute and then wiping off with a soft cloth. The resistor can then be replaced by another pre-printed unit, by just pressing it in, preferably but not necessarily with a warm iron (80° C.) and then painting over with a non-tracking varnish. It is, however, often an advantage to the designer to insert a standard resistor rather than have a printed one. The best method available at present for this is soldering a miniature resistor directly with the shortest possible leads to the printed wiring. This may arise in cases where no space is available on the chassis but sufficient space above it, or where the resistor is intended to bridge large gaps on the circuit. It may also be advantageous where ratings or values are desired which cannot be conveniently printed.

Coils

Coils may be printed as part of the wiring either on the chassis or on a cylindrical plastic core, and the remarks made on wiring apply to these coils. Again it will have to be taken in consideration whether more space is available above or below the panel. If space is available above, it is an economical advantage to print it as part of the circuit, as this will in no way increase the cost of the print which is independent of circuit intricacy. The choice of coil, as far as shape and number of turns are concerned, is a question of electronic design. It is sufficient to state that coils can be printed like wires and the lines may be of any desired width down to .005 in., but it must be considered that as the width decreases the thickness of line that can conveniently be printed also decreases, and hence the resistance increases, which would have an obvious detrimental effect on Q for a very few lines.

Capacitors

Capacitors, like resistors, will have to be pre-formed and inserted afterwards as part of the print. The most convenient form known at present is the flat ceramic disk which is being developed by various capacitor manufacturers at the present time, and can already be made of materials with high values for K. These ceramic disks are silvered on both sides, the face being connected to the printed wire either with a conductive adhesive such as "Elargol W.8" or by melting solder at the interface. The top may be connected either by soldering a small piece of foil between its silver and the silver of the conductive line, or where possible by painting a bridge down the side of the capacitor in the manner described for the mending of wiring. Similarly, a conventional unit may be soldered into the circut. These disks may be of rutile or high permittivity steatites, their faces being ground to give a flat disk. To replace such a unit either the adhesive is dissolved, or the solder melted by local heating. It may then be replaced by a new unit. This capacitor cannot, of course, be described as a printed unit. At present it is the type of unit that fits the printed circuit technique most closely and is known to give satisfactory performance for most purposes. On the same lines a piled mica capacitor may be inserted, the principal difficulty in either case being that this type of capacitor has not the same flexibility as the plastic chassis and being of a brittle nature, may be more likely to break.

For low value capacitors it is often advantageous to use the chassis itself as a dielectric, in which case the plastic chosen will have to be of a suitable permittivity, and a pre-determined area of silver is printed on either side of the chassis, and suitably connected within the printed wiring. This is the only type which can be truly described as a printed capacitor and sufficient precision may be obtained in this way for smaller values. This type, when faulty, is repaired in the same way as the wiring, as indeed it is part of the wiring, and may be adjusted by scratching out the silver with a suitable tool. This type has so far not been widely used.

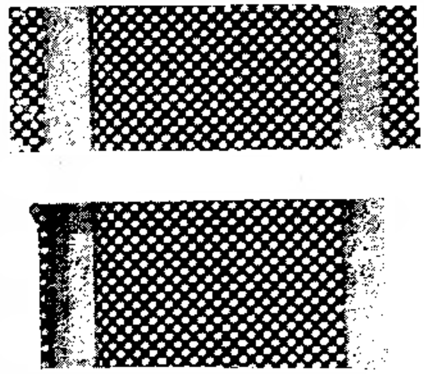


Fig. 5. 10,000 and 100,000 ohm resistances, showing resistor grid and silver terminals

Other Components

Sub-miniature valves may be soldered directly into the circuit, or suitable holders may be soldered in.

The same applies to miniature valves where the pins may be bent over and envelope strapped horizontally to the chassis. The conventional valve holder, however, will have to be mounted in the orthodox fashion and connected in this way. There is no reason why a suitable new valve holder should not be designed to be part of the printed circuit. It is sometimes beneficial to the designer to separate printable units, *i.e.*, that can form parts of the printed circuit from the unprintable ones, such as valves, variable capacitors, etc., and to mount these in the orthodox fashion and to connect to them the printable components on a separate chassis. Thus the printed circuit may be regarded as a composite unit of the orthodox complete circuit. A complete assembly can be envisaged to contain several such composite units mounted in various fashions.

General

It is often convenient to coat the whole printed assembly or sub-assembly by dipping in a solution of rubber or non-tracking varnish for tropicalisation. This step is neither costly or complicated, but care should be taken that the varnish is of such a nature that it does not attack the plastic chassis or any of the components.

It is felt that this new technique opens new fields for the designer and the electronic engineer, leading to increased production at lower costs.

New Electrical Engineering Building at Illinois

THE new $2,000,000 electrical engineering building of the University of Illinois at Urbana, Illinois, will be formally dedicated at ceremonies extending from May 19 to May 21. The planning of this building was under the direction of Dr. W. L. Everitt, head of the electrical engineering department and recently appointed as Dean of the College of Engineering.

An important feature of the dedication ceremonies will be a symposium whose main theme is "Expanding Frontiers in Electrical Engineering."

In addition to the technical symposium, a general sessions programme will be devoted to the "Development of an Electrical Engineer" both in college and in industry.

The new building is of modified Georgian design. It has ample classrooms and laboratories for experimental work in communications, illumination, measurements, servomechanisms, and electrical machines. The machines laboratory, for example, covers an area of 12,400 sq. ft. and is equipped with fluorescent lighting, sound proofing, and forced-air ventilation. Electric transfer cables are provided to class and conference rooms throughout the building to facilitate lecture demonstrations.

The former electrical engineering building has been renamed the Electrical Engineering Research Laboratory and has been reconditioned to make room for a rapidly expanding research programme. At present it houses an electron tube research laboratory which is completely equipped for the design and development of experimental tubes. Space has also been provided for the accommodation of an electronic computer which is to be constructed in the near future.

Guided tours will be conducted through both the electrical engineering building and the electrical engineering research laboratory to allow visitors to inspect the available facilities. Most of the laboratories will be in operation—with students conducting typical experiments and performing electrical demonstrations.

Leakage Inductance

By N. H. CROWHURST

THE principle of leakage inductance or reactance will be quite familiar to transformer designers, but due to a possible ambiguity as to definition we here define the quantity as it will be determined from the data sheet on page 133. Due to current in each of two windings there will be a quantity of magnetic flux which will link with the winding causing it, but not with the other winding, and due to each of these groups of flux there will be an E.M.F. induced when the current and flux change. The total leakage flux could be regarded as due to combined effect of the current in both windings, and the E.M.F. induced in each winding treated separately, or the flux due to the current in each winding could be treated separately and the E.M.F.'s in each winding derived and integrated. For the purpose of the calculations made from this data sheet, the leakage inductance from one winding to another can be defined as the inductive component of the impedance of one winding, the other winding being short-circuited.

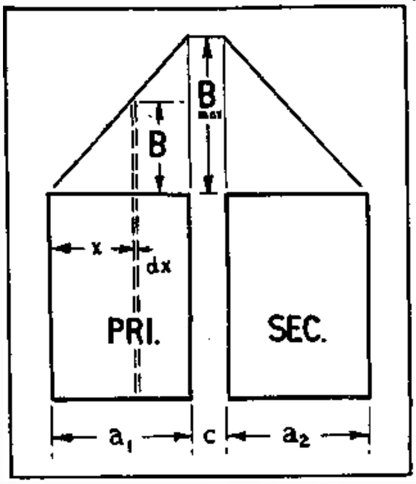


Fig. 1. Derivation of leakage inductance formula

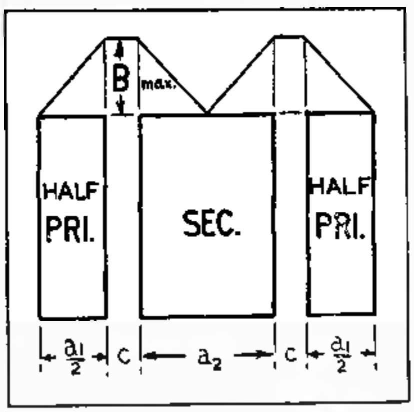


Fig. 2. Effect of elementary mixing

Derivation of Formula

If we consider an element of one of the windings of a simple double wound transformer in cross section, the element being taken parallel to the division between the two windings so that the leakage flux throughout the length of the element is constant, then the leakage flux density, B (Fig. 1) will be proportional to the distance from the outside of the winding, the maximum occuring in the space between the windings, where the leakage ampere-turns are maximum. The E.M.F. induced in the whole winding due to the element of flux will be proportional to the number of turns which the flux couples, and the value of the flux. Thus, if x measures the distance from the outside of the winding, the E.M.F. induced in the winding due to the flux passing through the element will be proportional to x^2dx. The total E.M.F. throughout the winding will be proportional to $\int_0^{a_1} x^2dx$, or $a_1^3/3$.

Thus, the leakage inductance due to the winding space will be proportional to one-third of the thickness as compared with the leakage inductance due to the maximum flux in the space between the windings. If a_1 and a_2 are the thicknesses of the windings, and c is the space between the windings, the leakage inductance will be proportional to

$$\frac{a_1 + a_2}{3} + c.$$

If one of the windings is divided in two, each half being disposed on opposite sides of the other winding, then the maximum leakage flux ampere-turns at the spaces between the windings, responsible for producing B_{max}, will be half that of the simple winding case, see Fig. 2. The leakage inductance due to each half winding will, according to the integration above, be one-eighth of the previous value for that winding. The leakage inductance for the whole winding will be reduced to one-quarter, or by a factor of four, ignoring the space between the windings. To simplify the conception as windings are further subdivided, it will be noted that there are two points of maximum flux in this second case, so we coin the term "leakage flux area" to express the integration for each pair of winding

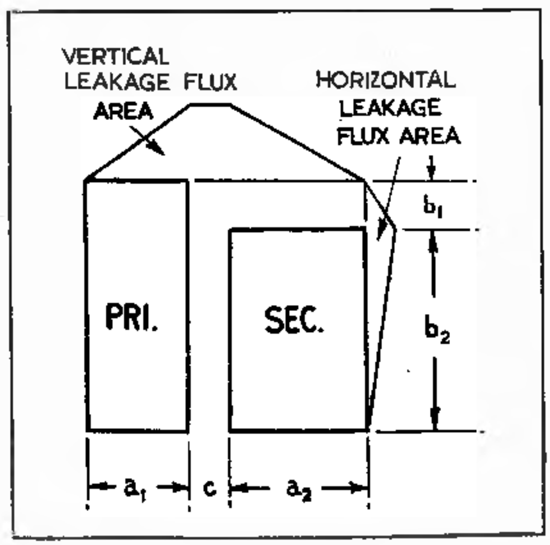


Fig. 3. Components of leakage flux in two directions

sections. This leakage flux area is represented graphically by each rhomboid at the top of Figs. 1 and 2. The leakage flux in each space between windings has half its original value, but there are now two such spaces, so the total component of leakage inductance due to the spaces will be the same, if each space is equal to the single space in the original case.

Thus the leakage inductance can be written as proportional to $a/3N^2 + c$, where a is the total thickness of all winding sections, N represents the number of leakage flux areas, and c is the thickness of each insulation section.

Considering the leakage flux now on the basis of the reluctance of its magnetic circuit: the reluctance of the whole of the circuit outside of the windings may be ignored; the reluctance within the windings will be proportional to the length of the flux paths, or dimension " b " of the winding (*see* Fig. 8) and inversely proportional to the area of flux. The area of flux will be proportional to dimension " a " of the windings, as already considered, and also to the length of the mean turn of the windings, which we will denote by d. Thus, the whole expression for leakage inductance, if T is the number of turns in the winding at which it is measured, can be written:

$$L \propto \frac{d}{b}\left(\frac{a}{3N^2} + c\right) T^2 \qquad (1)$$

Windings without Common Dimension in one direction

In the foregoing consideration the assumption has been made that both windings are of equal dimension in direction " b ". Where this is not true, the simplest method of predicting leakage inductance will be to resolve the leakage flux into two components at right angles. In the simple case where the windings have equal dimensions in the one direction there is zero component of leakage flux at right angles to the main direction.

As the E.M.F. produced by a rate of change of current in a winding is proportional to the square of the component of flux being considered (as shown by the term N^2 in Equation 1) the total E.M.F. due to two fluxes at right angles will be equal to the sum of the E.M.F's due to the component fluxes. Therefore the total leakage inductance will be equal to the sum of the values given due to each component of flux. Where the windings are not of equal length, or having non-coincident ends, the leakage flux in the second direction will be proportional to the unbalance of ampere turns. Fig. 8 illustrates this for a simple case The leakage inductance due to the flux in a vertical direction will be calculated directly from the formula given above, while the leakage inductance due to the flux in a horizontal direction can be calculated from the same formula using a modified value of turns, T_x, given by $T_x = T\left(\frac{b_1}{b_1 + b_2}\right)$. For this component of flux, the positions of b and a will be reversed and there will be no c (Fig. 8).

Various degrees of mixing

By increasing the number of equivalent leakage flux areas, N, the leakage inductance can be reduced for a given number of turns and winding cross section, until the limit is reached where $a/3N^2$ is less than c, when c becomes the limiting factor. Thus, where a high degree of mixing is used, the thickness of insulation between windings becomes important, and it may be necessary to use the absolute minimum permissible. The table of winding arrangements shows values of N^2 for various ways of dividing up primary and secondary. It will be noticed that the best arrangement, *i.e.*, that giving the highest value of N^2 for a given number of sections, is always that having a half area section at each end of the arrangement. This is sometimes two half area primary sections and sometimes one half area primary section and one half area secondary section.

In the same table the winding sections are shown connected in series for convenience. This is not essential, and parallel or series parallel connexions can equally well be used. Where series connexion is used a half area section should have half the number of turns in each unit area section, and the whole number of turns in the winding will, of course, be the sum of the turns in the individual sections. Where parallel connexion is used, the turns in all parallel groups of winding must be equal, and if a half area section is parallel with full sections, then the wire gauge of the half section should be such that the winding occupies half the area and has twice the resistance.

Use of the information given here will show that for a push-pull transformer design the best coupling will be obtained by increasing the number of layer sections in the winding rather than by using a complicated cross connected winding using a divided bobbin. It is quite possible to produce an arrangement which will give identical resistance and leakage inductance for each half of a centre tapped push-pull winding, for example, the seventh arrangement in the left-hand column in the table, using the centre primary section for one half and the two outside half area sections for the other half. These will each have identical D.C. resistance and identical leakage inductance to the whole of the secondary, whether the secondary be series or parallel connected. The only possibility of lack of balance with this arrangement occurs in the winding capacity and inter-winding capacity, which will be considered in a later data sheet.

In general, the best shaped winding cross section from the viewpoint of achieving a low leakage inductance will be one having a long layer length corresponding to dimension, b, and a small winding depth (dimension a). The standard " *wastefree* " type laminations give a winding area which is practically ideal from the viewpoint of combining a high primary, or shunt, inductance with a low leakage inductance. The thicker stacks of laminations give increased ratio of primary inductance to leakage inductance, because the primary inductance is proportional to the cross sectional area of the iron circuit, while the leakage inductance is proportional to the length mean turn, and increasing the stack of laminations increases the cross sectional area by a greater ratio than it does the length mean turn. The limit in this direction will usually be a practical one imposed by the difficulty of producing a winding with long, flat sides.

Putting leakage inductance to use

The author has produced several is put to practical use by making it an inductive element in a filter. Use of leakage inductance for this purpose has the great advantage that the associated capacitive elements can be transformed by the turns ratio of the winding, so that conveniently small values of capacitance may be used where the theoretical circuit values may be many times larger. A typical bobbin used to produce two of the inductance elements in a low pass m-derived filter is shown at Fig. 4. The winding located in the slot lettered a_3 will have a slightly higher leakage inductance to that in a_2 than will the one located in slot a_1, due to the fact that b_2 is greater than b_1. It should be realised that the leakage inductance can only be varied by adjusting the number of turns in the input winding or by rearranging the spacing and dimensions, although the inductance referred to any winding can be adjusted by variation of the turns of that individual winding. The input and output of the filter may be designed for 600 ohms or any other convenient impedance and the turns of the various windings adjusted so that all the capacitors used may be of a standard value, say, 0.01 µF. Fig. 5 shows another arrangement used for producing two absorption dips in a response curve by simply shunting windings 3 and 4 by a standard value capacitor. The actual size of a complete transformer with its associated condensers can be made very much smaller than such an absorption filter designed to operate at the line impedance of the network.

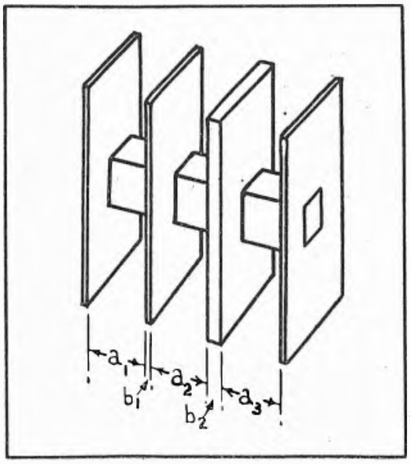


Fig. 4. Bobbin for m-derived low pass filter using leakage inductance.

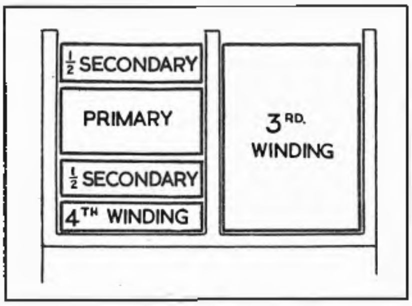


Fig. 5. Bobbin for microphone matching transformer incorporating two absorption circuits

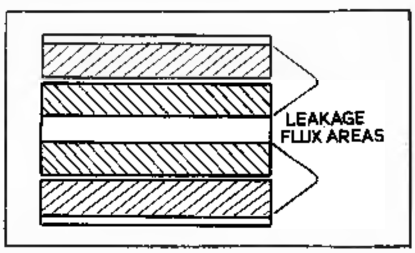


Fig. 6. Mixing arrangements for multi-ratio transformers

Multi-Ratio Transformers

In designing a transformer where parts of the winding will not always be used, the winding layout should be so arranged that portions of winding not in use at any time occupy a space where leakage flux is not induced by the active windings, or is at a minimum, in order to obtain a minimum leakage inductance. With the simple type of winding having only one section each for the primary and secondary, the inactive portion of winding can be arranged so that it is on the side of its own winding remote from the other winding. If sectioning is used, more careful consideration is necessary, but it will always be possible to arrange the winding so that the inactive portion is in a space between leakage flux areas. Fig. 6 shows how this can be achieved in the simplest form of mixing, having a primary in two sections and the secondary in one section. If a portion of the secondary is to be inactive, it should be at the centre of the winding, both electrically and physically, which means that tappings will have to be made at the ends of the active portions, and the inactive portion must be left open circuit. If part of the primary is inactive, then it should be the part remote from the secondary winding. In Fig. 6 the shaded areas of winding represent active portions, while the unshaded areas are inactive.

Auto Transformers

In calculating the leakage inductance for an auto transformer, the series and shunt sections of the winding can be treated in the same way as separate windings. The leakage inductance referred to the input or output terminals can then be calculated in the same way as winding resistance loss is calculated for an auto transformer.

Use of Chart

An appropriate value of N^2 for the winding arrangement being used can be found on the left of the Table overleaf. Referring to the chart on page 132, this value of N^2 is intercepted with the dimension "a" of the winding cross-section at A (*see* Fig. 7). This is then referred vertically to the small space in the chart. Here add dimension "c", the space between sections of winding. Where multisectioning is used this will be the spacing between each primary and secondary section. Refer this sum value vertically to intercept with the length mean turn at B and follow the diagonal scale to intercept with the dimension "b" of the coil at C. From here refer again vertically to intercept with the turns scale at D. The value of leakage inductance is then read off at E. If the number of turns in the winding, the value of dimension "b", or length mean turn, is not accommodated within the range shown, the appropriate value on the chart should be multiplied by a power of ten to bring it to the actual value, and the value of leakage inductance obtained from the chart multiplied by the power of ten obtained from the table below.

Example I: Winding space on bobbin, ⅝ in. long by 3/16 in. deep; mean turn length, 2½ in. Primary turns, 600; secondary turns, 8,000; simple single-section windings in layer arrangement; insulation between windings, 0.020 in.

From this information dimension "a" can be taken as about 0.15 in., allowing for insulation and clearance. The intercept of the 0.15 in. (interpolating between 0.14 in. and 0.16 in.) on the "a" scale with $N^2 = 1$ gives 0.05 in. on the vertical scale. Add to this the 0.020 in. for

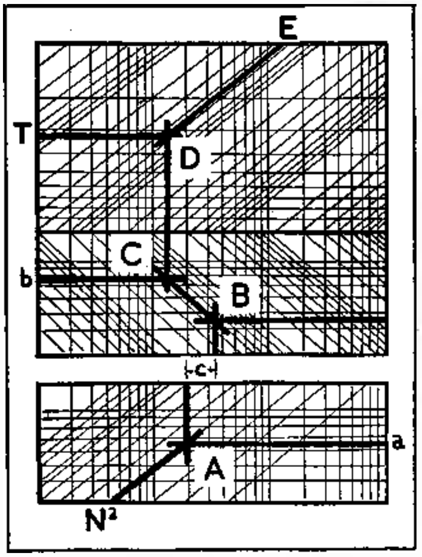


Fig. 7. Showing use of chart

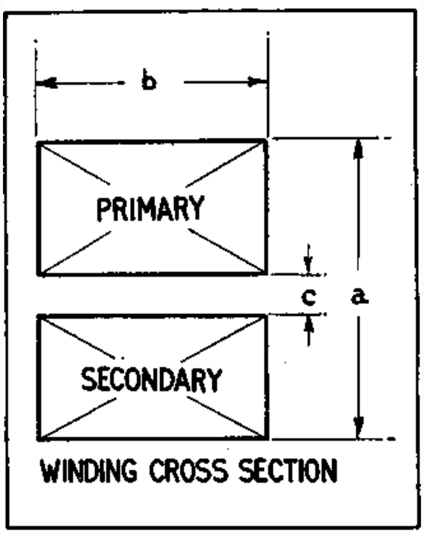


Fig. 8 Dimensions used in chart

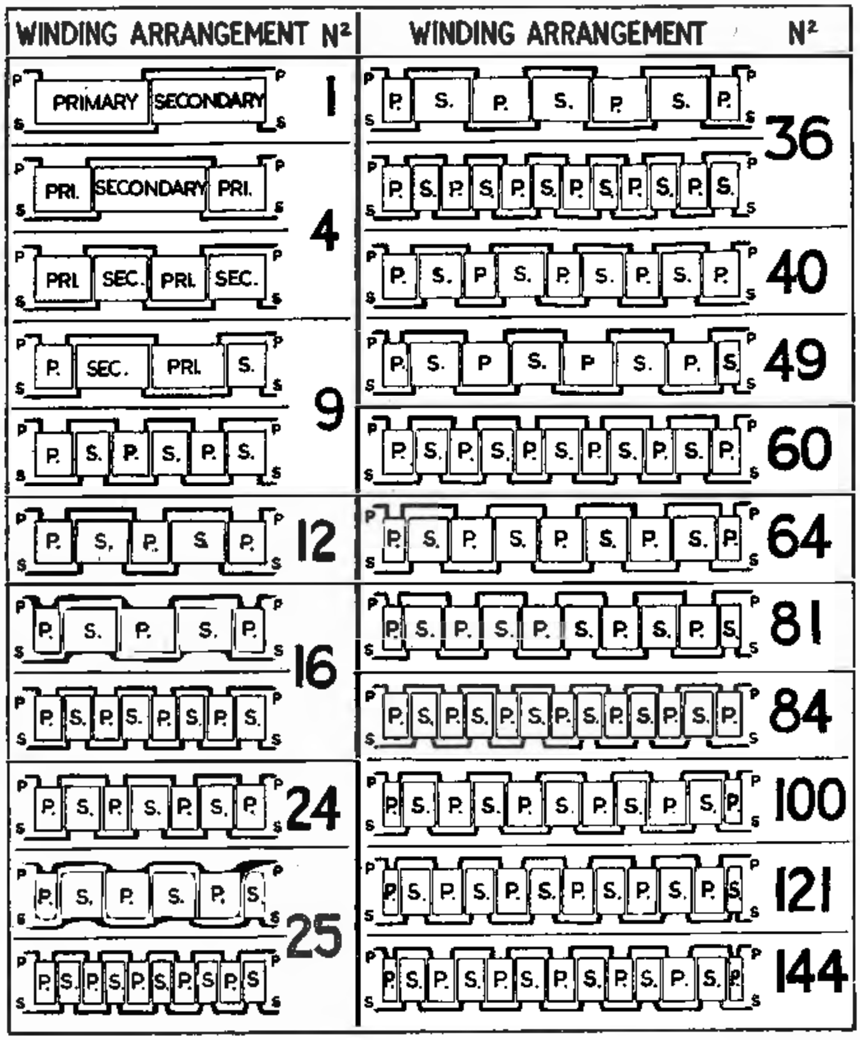


Table of Winding arrangements

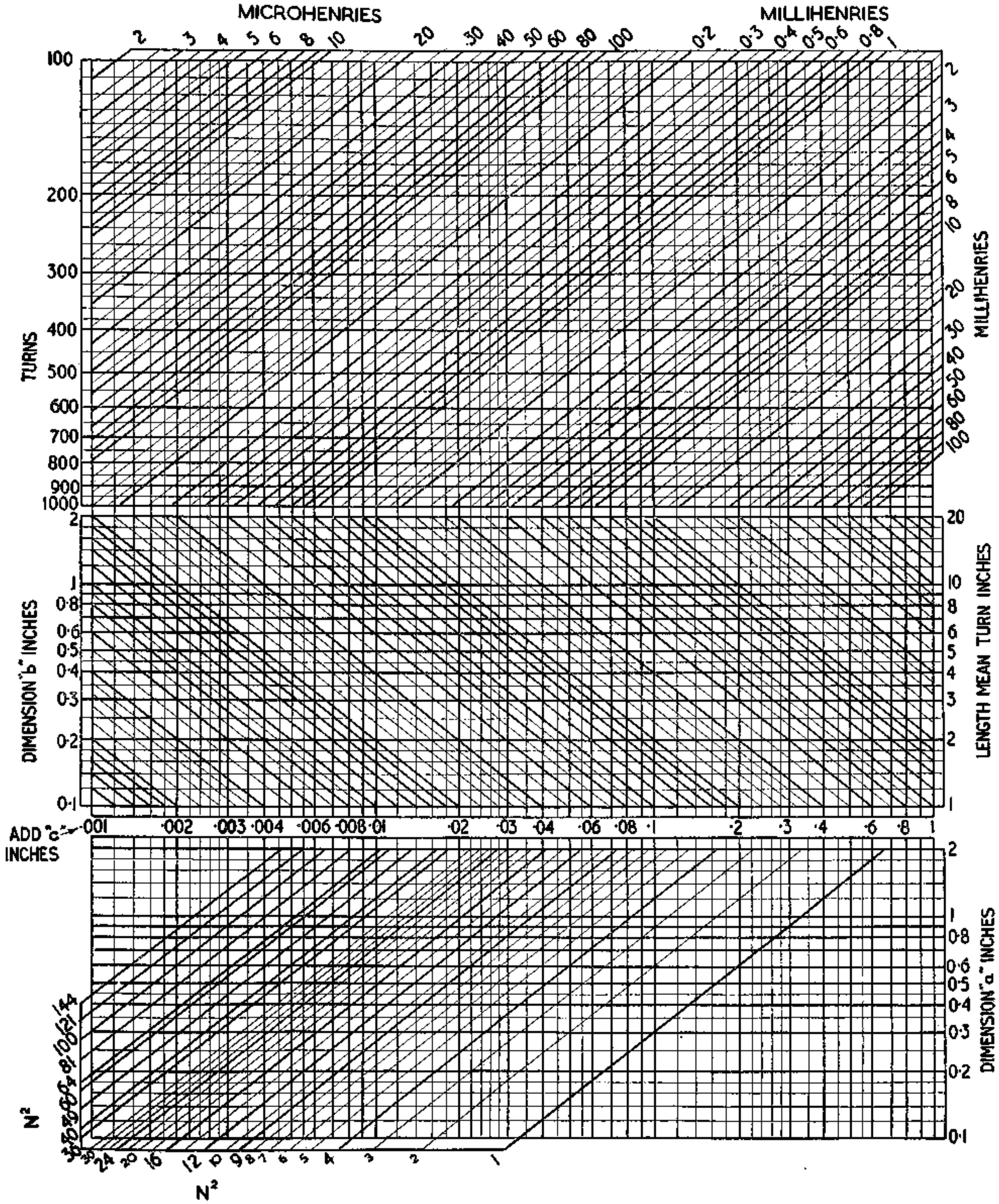
insulation, we have 0.07 in. Following the diagonal from the intercept with 2.5 in. length mean turn to the intercept with the 0.625 in. dimension "b", gives about 0.028 on the vertical scale. Following this vertically to intercept with 600 turns, gives leakage inductance referred to the primary as about 1.75 mH. Taking the intercept with 800 turns gives about 2.9 mH. Therefore leakage inductance referred to the secondary of 8,000 turns will be about 290 mH., or 0.29 H.

Example II: Using the same bobbin as above, but with a partition vertically, 0.025 in. thick, the primary and secondary are to be wound either side of the partition.

Dimension "a" will now be 0.6 in., "b" approximately 0.17 in. (allowing 0.0175 in. clearance at the top), and "c" 0.025 in. Intercept with "a" = 0.6 in. and $N^2 = 1$ gives a vertical of 0.2 in. Adding "c" this becomes 0.225 in. Intercept with length mean turn of 2.5 in. and "b" of 0.17 in. (in opposite direction along the diagonal line this time) brings us to the vertical reference at about 0.35. Following this up to intercept with 600 turns gives leakage inductance referred to the primary of about 20 mH. The 800 intercept gives 36 mH, so the leakage inductance referred to the secondary will be about 3.6 H.

Example III: A push pull output transformer is to be wound on a bobbin of length $1\frac{1}{2}$ in. and depth, allowing for top clearance, of $\frac{3}{8}$ in. The length mean turn is 6 in. Primary turns 4,000; secondary turns 75. First consider completely layer mixing arrangement using the 7th arrangement in the left hand column. Insulation between sections can be as low as 0.015 in. Required leakage inductance between each primary and secondary and between whole primary and secondary. Each primary half-winding to occupy 30 per cent of the available space, and the secondary 40 per cent.

LEAKAGE INDUCTANCE



Four thicknesses of 0.015 in. take 0.060 in., leaving just over 0.3 in. actual winding depth. Each primary should occupy a total of 0.09 in. and the secondary 0.12 in.

Leakage inductance between each primary and secondary: "a" = 0.21 in., $N^2 = 4$. This intercept gives vertical of about 0.017 in. Adding 0.015 in. for "c" gives 0.032 in., which intercepted with length mean turn 6 in. and "b" of 1.5 in. brings us to about .013. For 2,000 turns, read off for 200 and multiply by 100. This gives leakage inductance from each primary to secondary of about 8.5 mH.

Between whole primary and secondary: "a" = 0.3 in., $N^2 = 16$. This intercept gives vertical, 0.0063 in. Adding "c", 0.0213. (There would be considerable advantage here if winding insulation thickness could be reduced.) Intercepts with length mean turn and "b" of 6 in. and 1.5 in. respectively give vertical of about .0085, and intercept with 400 turns gives inductance of 0.22 mH, or 22 mH for 4,000 turns.

Example IV: For the same transformer as the previous example, the bobbin is divided in the centre by a partition 0.1 in. thick, and each side is wound with two primary sections and one secondary section. Required, leakage inductance between each primary and secondary and between whole primary and secondary, when the primary sections making up each half are (a) both in the same side of the bobbin, and (b) when they are cross-connected.

Between each primary and whole secondary: (a) both primary sections same side: first due to axial flux, "a" = 0.3 in., $N^2 = 4$; "b" for primary 0.7 in., for secondary 1.4 in. As primary occupies 60 per cent of depth and secondary 40 per cent, mean can be taken as 1.12 in. Thus inductance due to axial flux is given at 13.5 mH. Due to radial flux, ampere turns are 50 per cent of total, thus this portion can be referred to 1,000 turns; "a" = 1.4 in., "b" = 0.25 in. (computed as above for axial flux), $N^2 = 1$, "c" = 0.1 in. Thus inductance due to radial flux in given as about 180 mH. Total leakage inductance from each primary to whole secondary is thus nearly 200 mH. (Given above as 193.5 mH.)

Between each primary and whole secondary (b) cross-connected arrangement: this can practically be regarded as two leakage flux areas only, both having only axial flux, each having a physical area of cross-section "a" = 0.21 in. and "b" = 0.7 in. Treating the two together as a composite winding such that "a" = 0.42 in., $N^2 = 4$, "b" = 0.7 in., the inductance is now found to be about 28 mH, about one-seventh of the value given by the other method of connexion.

Between whole and primary and secondary:—This value is not affected by the method of connexion, since the whole area is used in each case; "a" = 0.3 in., $N^2 = 4$, "b" = 1.4 in., c = 0.015 in. (as before). Inductance thus given is 44 mH referred to 4,000 turns.

In examples III and IV any of the values of leakage inductance can be referred to the secondary by taking the appropriate intercept with 750 turns and dividing by 100 to obtain the inductance referred to 75 turns.

The Use of the Decca Navigator System for Under-Water Oil Exploration

THE world's consumption of mineral oil has been rapidly rising over the past 10 years, and the existing land resources are inadequate to meet this growing demand. Oil experts have, for a number of years, been studying the possibility of recovering oil from the ocean bed. It is known that the sea areas of the Caribbean Sea and the Persian Gulf are probably rich in oil resources, and where the water is not unduly deep, present-day techniques permit drilling to be carried out.

An essential feature of oil recovery is the preliminary exploration and survey. When this work is carried out on land, normal survey techniques can be employed, but when the same problem is to be tackled at sea, the surveyor finds himself faced with entirely new problems. The work must often be done out of sight of land and it is quite unsatisfactory to rely on astronomical observations. Fortunately, recent developments in radio position fixing provide an entirely new method. The Decca Navigator System, developed primarily as a radio aid to marine navigation, has been found by many survey authorities, including the Hydrographer of the Royal Navy, to possess an accuracy unequalled by any other radio device. It can provide, over thousands of square miles of sea, a fix of position with an accuracy adequate for purposes of hydrographic survey and oil exploration.

A chain of Decca navigator stations, consisting of a master and two slave stations, lays down a pattern of radio position lines which, interpreted by a radio receiver carried in the survey launch, enables the surveyor to plot his position with very great accuracy. Thus, over a featureless area of sea, is provided a grid which marks the position of any point as simply and as accurately as though it were on land.

The Decca Navigator Company, appreciating the value of the System in this new field, have developed a transportable Decca transmitting station which can be rapidly erected in any part of the world.

The decision of the Bahrein Petroleum Company to employ the Decca System in their oil exploration work was taken after a careful study of all existing electronic aids, including several American systems, and it may therefore be assumed that British progress in this field is in advance of American.

The application of Decca to underwater oil exploration is arousing very considerable interest among oil surveyors throughout the world, and it may be expected that a number of other systems will shortly be employed for similar work in various parts of the world.

Ferro-Resonance

By BERNARD DRAKE, B.Sc., A.M.I.E.E.*

An investigation of the oscillations at sub-harmonic frequencies by semi-graphical analysis

WHILE many networks in the field of electronics contain non-linear elements that do not obey the strict current *versus* voltage proportionality of Ohm's Law, those containing resonating, saturating iron-cored inductances[1] have remained the most inscrutable. Although the development of these circuits has inevitably proceeded empirically, a rational theory that lifts them out of the realm of the mysterious should lead to wider applications, if not to better performance. However, the fact that previous attempts to explain the functioning of such circuits have presented almost insuperable difficulties suggests that it is incorrect to approach the problem by purely mathematical means, and that what is required is a combination of theory and practice—in this case simple mathematics wedded to an exact graphical representation of measurements. In what follows, two concrete examples—first the simplest case of ferro-resonance, next an actual frequency converter of more complex design — are attacked, and in both of them the semi-graphical analysis leads to a logical, satisfying explanation.

Ferro-resonance

Ferro-resonance, which occurs under certain conditions in a resonant circuit containing one or more saturating iron-cored inductors, can be defined as a state of heavy, non-sinusoidal oscillation that may even have a repetition frequency below that of its sinusoidal exciting source. Now, while an iron core has a permeable state, which is used in normal transformers and chokes, where some only of the magnetic "domains" have turned round into the direction of the field, in the current waveform during ferro-resonance there are always characteristic heavy pulses that alternately drive the core beyond the normal state into the abnormal saturated states where the domains are all aligned either in one direction or the other. Between these various states are non-linear transitions which are represented by the "knees" of the magnetisation curves (MM in Fig. 2(a)), and are the cause of the peculiarities of ferro-resonance.

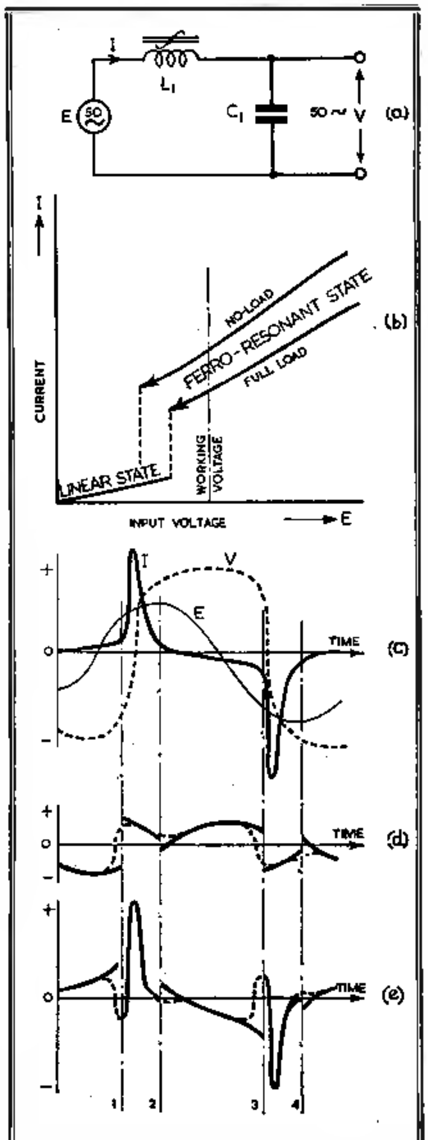


Fig. 1. Ferro-resonance at fundamental frequency (self-starting oscillations):—(a) Circuit diagram; (b) R.M.S. current/voltage characteristics showing transitions to linear state at low voltages; (c) Waveforms of input voltage E, output voltage V and current I; (d) Forced component of current I; (e) Semi-free component of current I.

The necessity for maintenance of the heavy current pulses makes ferro-resonance differ markedly from ordinary resonance. For instance, while the input voltage of a given circuit must exceed a certain minimum, ferro-resonance can, as there is no definite inductance value, subsist over a range of driving frequencies. There is thus for each case a voltage/frequency zone—graphically an area—in which ferro-resonance can occur.[2]

Ferro-resonance at Fundamental Frequency

Ferro-resonance is most simply illustrated, as shown at (a) in Fig. 1, by a series circuit which, while driven from a supply **E** of low impedance such as the 50 c/s. mains, has merely a capacitor C_1 in addition to the inductor L_1, the core symbol of which has a long S drawn across it to indicate that it is being driven into saturation. The curves at (b) in Fig. 1 of the R.M.S. value of the current *I* plotted against the input voltage *E* demonstrate how the ferro-resonant state of oscillation exists only with higher voltages. As the input is reduced (see arrows on curves) a critical value, depending on the intensity of the load connected across the condenser, is finally reached when ferro-resonance can no longer be maintained, and oscillation then continues at a very low level in a linear mode. The critical voltages corresponding to no-load and rated full-load are illustrated by the vertical, dashed portions of the curves. The working voltage, however (chain dotted line), has been chosen at a higher value in order to prevent the stopping of ferro-resonance except on excessive overload. The waveforms at (c) in Fig. 1 show, besides the input voltage *E* with its sinusoidal form, also the output voltage *V* with a squarish shape and the current *I* with alternate pulses, the peak values of which drop on reduction of input or on application of load. Although the heavy pulses

* Telephone Manufacturing Co., Ltd.

of the saturating inductor occur also in a parallel-circuit driven from a constant current supply such as a pentode valve, the input current, which in this case is sinusoidal, is very much lower in amplitude. Apart from this difference, however, the functioning and analysis of a parallel circuit is very similar to the series circuit described here.

Our new approach to the explanation of the series circuit begins with the reduction of the results of measurement to graphical form. The first step is to prepare on graph paper a B/H loop ((a) in Fig. 2) exactly tracing under working conditions the magnetisation of the inductor L_1. For this purpose a cathode-ray oscillograph of the loop may readily be obtained by feeding the horizontal plates from a small series resistor and the vertical plates from an integrating capacitor of about 2 μF paralleled to the inductor through a 1 megohm resistor. Although the general shape of the loop is then given by the oscillograph, the scale to which it must be drawn is obtained from a normal D.C. magnetisation curve which will also give a more accurate rendering of the slopes, particularly in the region of saturation where the loop is least affected by speed of cyclic magnetisation.

The loop as drawn will be a curve, but it is then necessary to approximate it by a series of straight lines so that the equations of linear network theory may be applied to it. Although a large number of lines would give most accurate results, saving of labour calls for the minimum number that will represent the main features of the loop. All that is necessary to approximate the loop at (a) of Fig. 2, and incidentally to account for the hysteresis as well, are two pairs* as at (b)—one pair almost horizontal for the positive and negative saturated states, the other pair almost vertical for the permeable states. The approximation is reasonably close except in the neighbourhood of the "knees" where judicious interpolation at a later stage will suffice to bridge these transition sections.

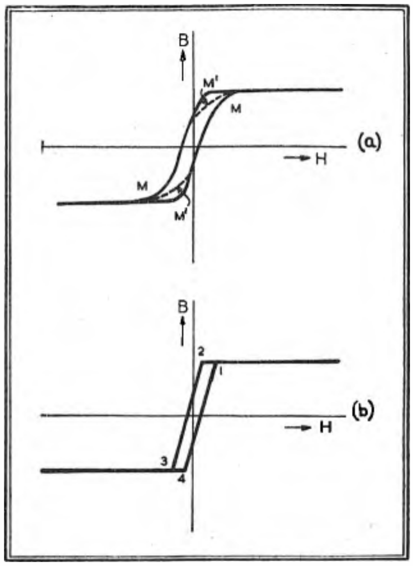


Fig. 2. Actual B/H loop (a) is, for mathematical analysis, approximated at (b) by straight lines representing main features

The instants corresponding to transitions 1,2,3,4 between the straight lines of the approximate B/H loop must now be determined. Since the magnetising force H is proportional to the current, a calibrated oscillograph of the latter is used to draw an accurate waveform I Fig. 1(c)) on graph paper on which the transition instants are then marked as indicated by the vertical chain-dotted lines 1,2,3,4 of Fig. 1. Observe that it is only in the comparatively short intervals 1-2 and 3-4 that the inductor is in the abnormal saturated state.

Leaving now the practical for the analytical stage of our investigation we find that before we can proceed we must split the actual currents and voltages into two sets of components which may be termed "forced" and "semi-free." The term "forced component" signifies that at any instant it is the value that the electromotive force would produce in a circuit having a fixed inductance equal to the instantaneous value of the incremental inductance. The "forced" components, which correspond to the familiar steady-state values of linear networks, are by definition of supply frequency. The term "semi-free component," on the other hand, signifies that it is an additional component which, during the time the iron core is passing through a substantially linear part of its B/H loop, is force-free, and oscillates with decaying amplitude at its natural frequency. But it is only semi-free because it receives impulses at the non-linear transitions or "knees" in the B/H loop between permeable and saturated states that, provided input conditions are suitable, continuously maintain it in a repeating cyclic manner. The "semi-free" components, which correspond to those "free" components occurring in linear networks as decaying oscillations superimposed during the transient period following switching or impulsing, are always different in frequency from the supply.

The forced component of current I is readily obtained once the slopes of the approximate B/H loop are measured, for these measured incremental permeabilities give corresponding inductance values from which any forced component can be computed for various phase angles by means of the ordinary equations of linear theory.[4] When plotted, as shown by the full-line curves at (d) in Fig. 1, the component will be seen to consist of sections of sine-waves of supply frequency except at the transition points where there are abrupt changes. These jerks, although partly a result of a change of amplitude, are mainly the reflexion of change of phase which is lagging in the permeable section and leading in the saturated.

Having obtained a graph of the forced component as at (d) in Fig. 1, we can, by subtracting it from the actual current I as at (c), immediately plot the semi-free component as at (e). The abrupt breaks which result from the approximation of the B/H loop by straight lines can be modified, as indicated by the smooth dotted transition sections in (d) and (e), to correspond with the curved nature of the actual "knees." These jerks in the semi-free component are the features that, as previously explained, cyclically maintain it in existence against the decay that occurs during the remainder of the cycle when it is force-free and consequently subject to linear theory equations for free components or, as they are more familiarly called, transients. For the permeable sections 2-3 and 4-1 of the B/H loop, calculations made with these equations on a typical ferro-resonant series-circuit show that the semi-free oscillation is lightly damped with a period

* The semi-graphical work described here was inspired by the purely mathematical analysis (limited to 2-element networks) of Boyajian (see reference 3). For the saturating inductance he substituted two hypothetical linear ones of high and low values imaginarily switched alternately into circuit in such a way that the D.C. magnetization curve of the actual component was replaced by two straight lines.

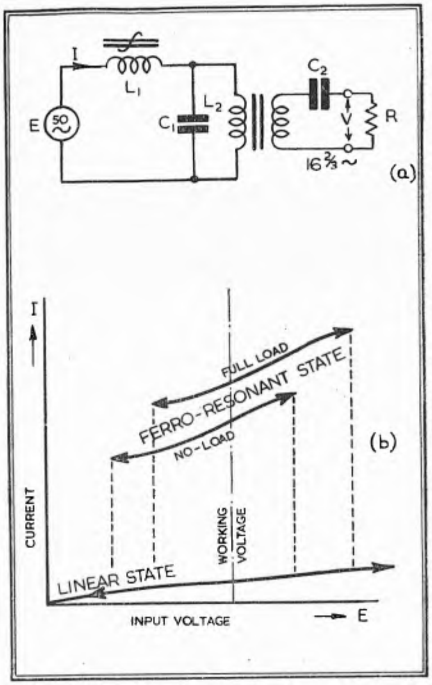


Fig. 3 (*Left*). **Ferro-resonance at sub-harmonic frequency (impulse started oscillations): (a) Circuit diagram; (b) R.M.S. current/voltage characteristics, showing transitions to linear state at both low and high voltages**

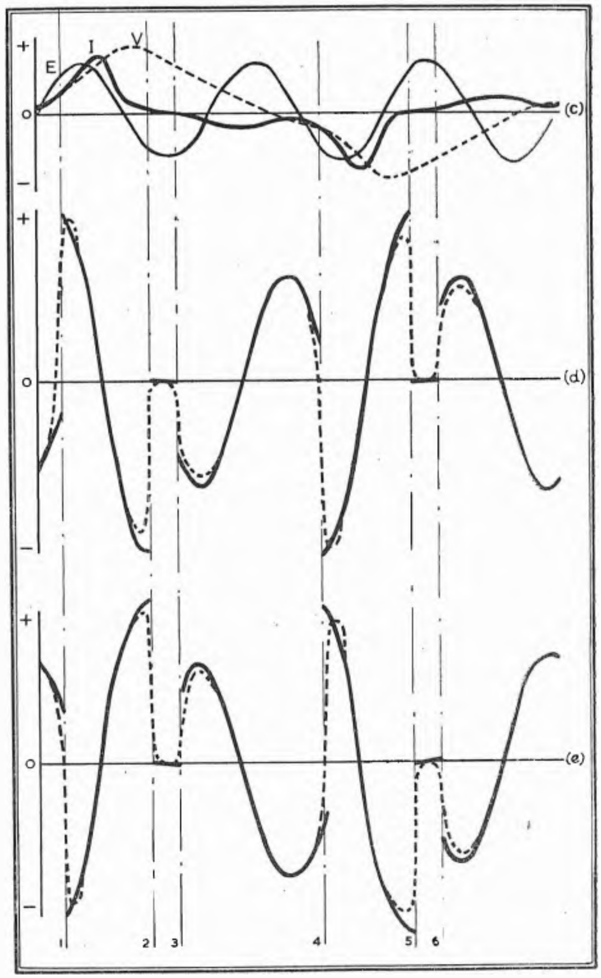


Fig. 3 (*Right*). **(c) Waveforms of input voltage E, output voltage V and current I; (d) Forced component of current I; (e) Semi-free component of current I. (Note that in (c) and (d) of both Figs. 1 and 3 the dotted portions graphically correct for the discontinuities arising out of the approximations made in the mathematical analysis)**

slightly exceeding that of the supply; and, as the current as shown at (e) in Fig. 1 is in amplitude roughly equal and opposite to the forced component at (d), the combination results in the almost horizontal parts of the actual wave of I at (c). For the saturated sections 1-2 and 3-4, similar calculations show that the semi-free oscillation is so near to critical damping and of such short period that, when the curvature of the "knee" is taken into account, it dies out after a short unidirectional pulse; and, as the current as shown at (e) in Fig. 1 preponderates in amplitude over the forced component at (d), the combination of both components also comprises a short unidirectional pulse.

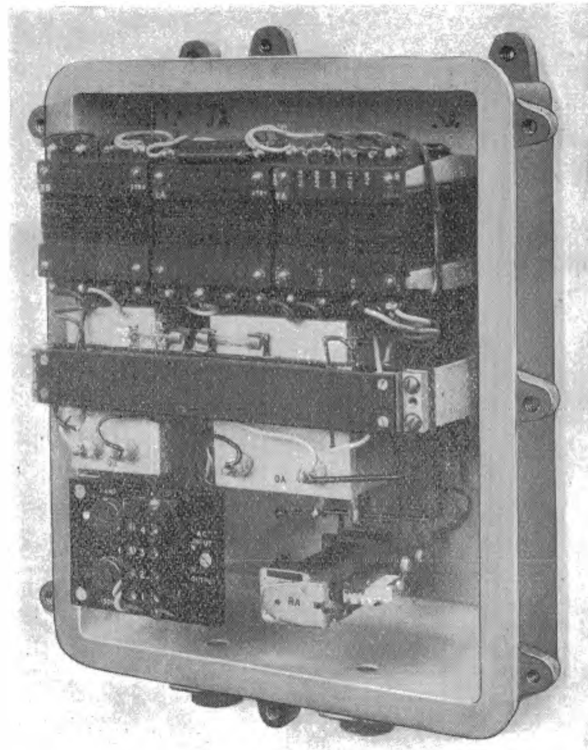
The foregoing analysis leads us to the explanation of the functioning of ferro-resonance at fundamental frequency as follows. The inductor current, which controls the magnetisation, passes alternately through a long phase of a small magnitude oscillation having a natural period slightly longer than that of the supply, and then through a short phase of a heavy oscillation of single pulse type, having a much shorter natural period. With increase of input voltage, while the long phase will remain little altered, the short phase will become heavier in magnitude and shorter in period on account of the decreased incremental inductance, and the corresponding output voltage waveform V (at (c) in Fig. 1), although little larger, will approach nearer to a square shape. To prevent oscillations, once excited, from dying out, the jerks of the semi-free component must be not only correctly timed, but also sufficiently great: the input must consequently be of appropriate frequency and of correspondingly sufficient voltage. But, as correct timing depends on the natural period in the normal permeable state of the iron-core being but slightly longer than that of the supply, conditions are normally so near to resonance that ferro-resonance will be *self-starting* for input voltages exceeding the critical minimum by a small amount.

Ferro-resonance at Sub-harmonic Frequency

If, on the other hand, a resonant network containing a saturable iron-cored inductor has a natural period in the normal state so much longer than the supply period that ferro-resonance will not build up on application of even a very high voltage, similar heavy pulses of inductor current *I* initiated from an outside source, while no longer able to keep pace with successive alternations of the input E as at (c) in Fig. 1, may nevertheless be able to synchronise as at (c) in Fig. 3 with one in every three, or higher odd number, of alternations. Whether such ferro-resonance can be maintained or not will depend on whether the induced long-period oscillation can so adjust itself as to repeat cyclically. Should it do so, the repetition frequency, which is the reciprocal of the period, will be an odd-numbered sub-harmonic of the input frequency. If now the voltage and frequency applied to such an *impulse-started* circuit are varied, zones—graphically areas—in which ferro-resonance is maintained will be found to exist for each order of sub-harmonic in addition to the zone previously described for the fundamental mode. While the generation of even-numbered sub-harmonics without the aid of polarising current is somewhat fortuitous, and while their corresponding zones are very narrow, the zones of odd-numbered sub-harmonics, especially those of low order, are broad.[2] Therefore, in utilising a non-polarised ferro-resonant circuit as a frequency dividing power converter, the third, out of all possible sub-harmonics, will give not only the highest stability but also the greatest output efficiency.

The photograph shows 5 watt ferro-resonant converter (hermetically sealed version), which reduces the 50 c/s mains frequency to $16^2/_3$ c/s.

(Photo by courtesy of the Telephone Manufacturing Co. Ltd.)



The second example taken for analysis is the converter circuit of Fig. 3, which is ferro-resonant at the third sub-harmonic of the 50 c/s. input frequency. The complete unit, shown in the accompanying photograph, delivers power at $16\frac{2}{3}$ c/s. from the mains for ringing telephone bells from private or branch exchanges in offices, factories, hotels, hospitals and similar situations where upkeep is restricted to the occasional visits of a maintenance engineer.[5,6] The network, besides the main inductance L_1 and capacitor C_1, has an output transformer L_2 which has, on account of its air gap, been considered linear enough for its inductance, at working flux density, to be used in the calculations. The additional capacitor C_2, although of sufficient capacitance to transmit the rated power of 5 watts at 75 volts to load resistance R, is incorporated to prevent ferro-resonance being stopped by the heaviest of resistance loads.

As in the previous example, the first step preparatory to analysis is to trace out the B/H loop of L_1 from an oscillogram. But careful examination under various conditions of ferro-resonance shows that accompanying the main loop there are, corresponding to the minor peaks in the current waveform I (Fig. 3c), always a pair of minor re-entrant loops M-M′ (Fig. 2a) located just above the "knees," although for clarity in reproduction they are shown below them as dotted lines. These minor loops, which only die out at the critical minimum input voltages represented for different load conditions by the left-hand dotted lines at (b) in **Fig. 3**, apparently correspond to an intermediate semi-saturated state of the inductor core. They behave perfectly regularly except when the input is raised somewhat above the working voltage, which is indicated by the chain-dotted line, when their increased irregularity eventually sets an upper voltage limit represented by the right-hand dotted lines. Growing in size with increase of input voltage, the minor loops appear to struggle for supremacy of peak current with the saturated parts of the main loop, and at voltages exceeding the limit the strife leads to such violent fluctuations that oscillation soon dies down to the low level linear mode.

Leaving aside the instabilities for the moment, and concentrating on the regular mode of oscillation at the working voltage, we draw a graph of the **B/H** loop, and approximate it as in **Fig. 2** but with the addition of a pair of straight lines (not shown) to represent the minor loops. Then on the current waveform of **Fig. 3c**, we mark, corresponding to those instants when the magnetising force **H** reaches the corners of this approximate loop, vertical broken lines 1,2,3,4,5,6, from which it will be observed that the semi-saturated sections (3-4, 6-1) usurp the predominant role previously played by the permeable sections which here (2-3, 5-6) act for less than 10 per cent of the time.

Continuing as in the previous example we calculate and plot for each section the forced component of current as shown at (d) in **Fig. 3.** The curves are again portions of sine-waves of supply frequency with discontinuous jumps which are also reflected in the semi-free component (**Fig. 3e**) obtained by subtraction. As before, the jumps are rounded by the dotted transition sections to take into account the curved nature of the actual B/H loop. The calculations that were made brought to light the important fact that the oscillations pass through resonance at the beginnings and ends of the saturated sections, and, whereas the jumps at transitions 3 and 6 to the semi-saturated sections are due mainly to an increase in amplitude, those at 4 and 1 to the saturated sections are due primarily to the consequent change of phase from lagging to leading. The jumps at 5 and 2 at the ends of the saturated sections finally restore both amplitude and phase so that the cycle is repeated.

On commencing analysis by network theory[1] the semi-free component was shown to consist of three sub-components, first an oscillatory one and then two non-oscillatory ones corresponding to the additions of transformer L_2 and output capacitor C_2. Unlike the high decrement existing during the saturated section in ferro-resonance at fundamental frequency when the semi-free component becomes damped out, the calculated decrement for all sub-components in each section is here so low that the semi-free oscillation is fully maintained throughout the cycle. The natural frequency of the oscillatory sub-component, which, it will be remembered, is excited by a 50 c/s. supply, was computed for the permeable, semi-saturated and saturated sections respectively, as 9, 40 and 58 c/s. Before the sub-components may be plotted, however, it is necessary to know the amplitudes of each, as well as the phase of the oscillatory one. These values depend on the initial conditions for which in this case four parameters measured from graphs like Fig. 3e are required. From curves of the sub-components, which were in this way calculated and plotted for the semi-saturated section, it was found that the non-oscillatory sub-components, which are opposite in sign to one another, were roughly equal although about one-third of the amplitude of the oscillatory sub-component which in its turn was roughly equal and opposite to the forced component.

This balancing, which the analysis brought to light, of the various components during the semi-saturated section, not only accounts for the actual current in this section remaining for such a comparatively long time with little variation, but is the key to the explanation we are seeking. Ferro-resonance at sub-harmonic frequency, it appears, is an alternation between a long oscillation of slightly lower natural frequency than the supply during a semi-saturated condition, and a shorter oscillation of slightly higher natural frequency during a saturated condition, while, as the current changes direction after the latter, there intervenes a very short commutating period corresponding to the normal permeable condition.

It will now be seen that ferro-resonance at either fundamental or sub-harmonic frequency demands, for regular timing of the saturating current pulses, an intervening oscillation, not just of a comparatively low current value, but having a period slightly longer than that of the supply. Any inability of the oscillations, therefore, after leaving a saturated state, to tide over the necessary time—about one complete period of the supply in the case of the third sub-harmonic—before entering the opposite saturated state, will upset the orderly type of oscillations which have just been analysed. It is this disability, when over-driving the sub-harmonic circuit by excessive input voltages, that explains the disorderly oscillations described previously, as well as their tendency to die out. If, on the other hand, the voltage is so low that not enough energy is absorbed from the supply to maintain oscillations in a semi-saturated condition, it will again be seen that ferro-resonance must cease.

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[6] B. Drake: "Frequency Converters." *Brit. Eng. Export Jour.* p. 1589. June, 1947.

Television For All

"HIS Master's Voice" announce that they have gone into quantity production with a first-class "Popular" television receiver at only 36 guineas (excluding purchase tax £8 12s.).

The new H.M.V. receiver model 1807 is a 14-valve television table model for D.C./A.C. mains and has a 10-in. Emiscope tube of the latest aluminised type giving a picture size of 9 in. by 7 in. approximately, with a brilliancy of twice that of the normal tube. A brief circuit description of the new receiver is as follows:—

T.R.F. circuits of high efficiency are employed for both sound and vision channels. Provision is made for the connexion of a suitable pre-amplifier in order to increase the range of the receiver if necessary. Focusing is achieved by means of a special permanent magnet assembly. The E.H.T. is obtained by utilisation of the line generator fly-back voltage and H.T. rectification is provided by a metal rectifier.

A Modern Home-Built

TELEVISOR

ANNOUNCEMENT

Components

Components additional to those given in the December, 1948, issue as having been approved for use in the *Electronic Engineering* Televisor have now been tested. The full list of such components approved, to date, now reads:—

Scanning Coils
(i) Haynes Radio Ltd.
(ii) Scanco Ltd.

Focus Coil
(i) Albert Mnfg. Co.
(ii) Haynes Radio, Ltd.
(iii) Porthminster Engineering, Ltd.
(iv) Scanco, Ltd.
(v) Walpole Norman Engg. Co., Ltd.

Line Output Transformer
(i) Haynes Radio, Ltd.
(ii) Scanco, Ltd.
(iii) Walpole Norman Engg. Co., Ltd.

E.H.T. Transformers
(i) Haynes Radio, Ltd.
(ii) Partridge Transformers, Ltd.
(iii) Varley (Oliver Pell Control), Ltd.
(iv) Vortexion, Ltd.
(v) Woden Transformer Co., Ltd.

H.T. Transformer
(i) Gardners' Radio, Ltd.
(ii) Partridge Transformers, Ltd.
(iii) Varley (Oliver Pell Control, Ltd.).
(iv) Vortexion, Ltd.
(v) Woden Transformer Co., Ltd.

250mA and 80mA Chokes
(i) Gardners' Radio, Ltd.
(ii) Partridge Transformers, Ltd.
(iii) Varley (Oliver Pell Control, Ltd.).
(iv) Vortexion, Ltd.
(v) Woden Transformer Co., Ltd.

Albert Manufacturing Co. have also submitted a satisfactory chassis complete with valve holders and coil formers.

Variable Frequency R-C Oscillators

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

WIDE range audio-frequency generators are commonly of the heterodyne type. To avoid waveform distortion at low audio frequencies the beating oscillators must be entirely free from mutual coupling, and careful control of the two input levels to the detector is normally required. Frequency stability is poor, especially at low output frequencies, unless particular care is taken to ensure that the beating oscillators are physically and electrically similar. To offset these disadvantages, the beat frequency oscillator has two features of great practical convenience. A wide range of frequency can be covered in a single range, and the frequency scale can be made to conform with any desired law of variation.

In recent years, various forms of phase-shift oscillator have been developed and models have been designed to cover the full range of audio and video frequencies. The basis of all these is a frequency-selective network associated with a suitable amplifier. The conditions necessary for the production of sustained oscillations in a system of this kind are that the attenuation in the network must be balanced by a corresponding amplifier gain, and that the phase-shift round the loop, including the amplifier and the network, should be zero or a multiple of 360 degrees.

The electrical networks applicable to oscillators of this kind are of three general types:

(a) Lattice or bridge circuits in which certain elements are reactive.

(b) Bridged-T or twin-T arrangements, electrically equivalent to their corresponding lattice structures.

These circuits have the advantage that one terminal is common to both input and output.

(c) Recurrent ladder networks in which the series and shunt elements are, respectively, resistances or reactances.

Networks of types (a) and (b) are employed in most wide-range oscillators at present on the market.

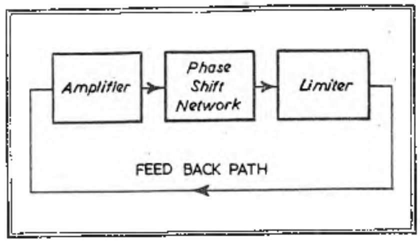


Fig. 1. Fundamental circuit for phase shift oscillator

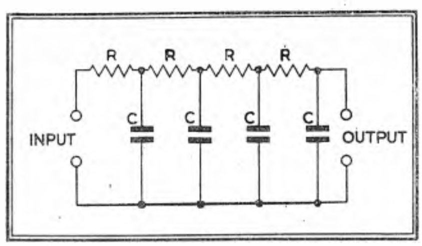


Fig. 2. R-C ladder network

Recurrent networks of type (c) are more usually applied to oscillators built in as an integral part of more complex equipment.

At a given frequency the output of any of the above networks is strictly proportional to the amplitude of the input voltage, on the assumption that linear circuit elements are employed. Minor departures from linearity, negligible in this connexion, are exhibited by certain types of resistances and capacitors. The response of the network is in marked contrast with the non-linear characteristics of the associated amplifier. To secure an output with a good waveform, it is essential to include some form of limiter which will restrict the amplitude of the amplifier output voltage. When such a limiter is included, it is possible to devise an extremely simple oscillator giving a satisfactory performance in respect of waveform.

Choice of Phase-Shift Network

Referring to Fig. 1, there is a wide choice of suitable phase-shift circuits. The preferred choice is settled by considerations of attenuation, harmonic rejection, ease of adjustment of operating frequency and circuit simplicity. On these grounds the ladder network shown in Fig. 2 has been selected.

For convenience, four R-C sections are shown, but an oscillator can be made to work satisfactorily with three or more. The network is associated with a single resistance-coupled amplifier valve. At one particular frequency the phase change in the network is 180 degrees so that when the output is back-coupled to the amplifier input, conditions are favourable for the production of sustained oscillations, provided only that the amplifier gain exceeds the network attenuation.

The frequency at which a given R-C network produces a phase shift of 180 degrees, *i.e.*, the operating frequency, is tabulated below for three-, four-, five- and six-stage circuits, together with the corresponding voltage attenuation. The attenuation decreases with an increase in the total number of stages, and there is a much greater attenuation of the higher harmonics in the more complex networks.

It will be seen that any increase, above four, in the number of stages results only in a small decrease in attenuation, and it is not economically justifiable to provide for a much greater number, though there are advantages from the point of view of harmonic filtering.

Number of Stages	Attenuation Ratio	Operating Frequency
3	29	$f = \frac{0.8}{CR}$
4	18.4	$\frac{0.38}{CR}$
5	16.15	$\frac{0.23}{CR}$
6	13.72	$\frac{0.16}{CR}$

The frequency will be given in cycles per second with C in microfarads and R in megohms. In the particular case of a 4-gang variable capacitor

(0.0005 μF per section) associated with 1 MΩ resistances, the lowest attainable frequency is 760 c/s. The use of 5 MΩ resistors brings this down to 152 c/s.

In R-C oscillators of this type, variable capacitors are employed as the frequency-controlling elements, in preference to ganged potentiometers, because of their higher stability and greater re-set accuracy. It is then necessary to accept the use of extremely high resistances in order to generate very low audio-frequencies, and this limitation is often responsible for poor performance at this end of the range, although, by good design, the worst effects may be avoided.

With a given selection of resistors, the maximum frequency of operation is settled by the minimum capacitance of the sections. When care is taken in the circuit wiring to keep this figure low, and to equalise the minimum capacitances of all the sections, it is possible to make the maximum frequency at least 20 times the minimum, though, under these conditions, frequency stability will not be high. At the expense of reduced range, the stability may be raised by using padding capacitors in parallel with the gang sections.

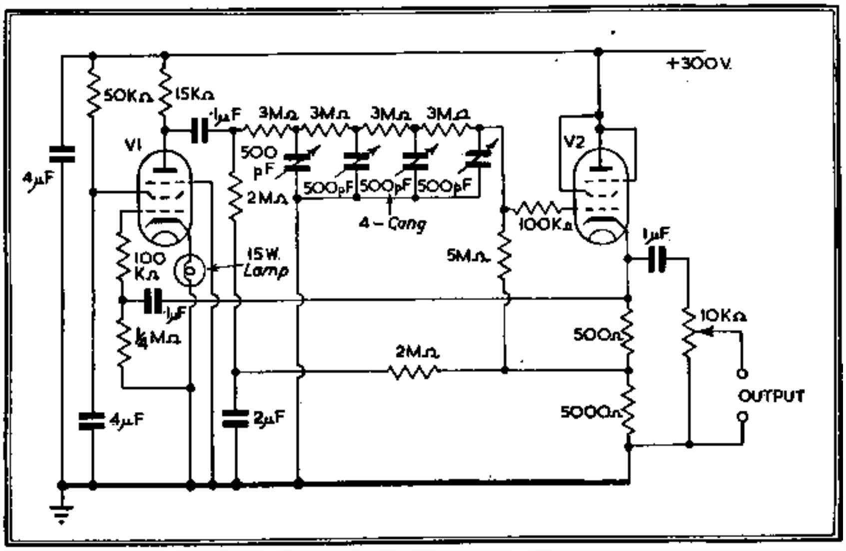


Fig. 3. Simple phase shift oscillator with fixed range of 250-5,000 c/s

Practical Oscillator Circuit

Fig. 3 gives the circuit diagram of an oscillator which in one range will cover frequencies between 250 and 5,000 c/s., using the component values shown.

The output from the network is taken to a cathode follower V_2 which provides the desired output and which also supplies the driving voltage to V_1. The main object in using a cathode follower is to ensure that the output from the phase shift network is applied to a stage with an exceedingly high input impedance. A valve with a top-cap control grid connexion is desirable. The Mazda SP 41, or its 6-volt equivalent, is suitable for use in both positions.

A few additional circuit details call for comment. A species of limiting is provided by the 15 W metal filament lamp used as the bias resistance of V_1. Table 1 shows the measured resistance of such a lamp with different applied voltages.

Any increase in the r.m.s. value of the anode current of V_1 is accompanied by an increase in the lamp resistance, and hence in the effective cathode bias. The amplifier gain is reduced, and its output partially stabilised.

The 100 kΩ resistance in series with the grid of V_1 limits the amount of possible grid current and thus restricts the drive to V_1. A network consisting of two high resistances and a shunt capacitor links the output side of the amplifier coupling capacitor to the junction of the cathode follower bias and load resistors. The purpose of this network is to minimise the effect of D.C. leakage through the coupling capacitor, which, if allowed to flow through the 5 MΩ grid leak of the cathode follower, would set up a positive bias voltage across it. The 2 μF capacitor, connected between earth and the junction of the two 2 MΩ resistors serves to filter out all audio signals. With this network connected there would seem to be no purpose in providing an additional grid leak for the cathode follower. The reason for including the 5 MΩ resistor is to reduce the grid-cathode resistance to a moderate value. Omitting the 5 MΩ leak, the grid-cathode resistance would be 16 MΩ. When it is included, the figure falls below 4 MΩ. Neglect of this precaution requires the special selection of gas-free valves, and is the cause of potential trouble when very low output frequencies are required. Ceramic insulation is desirable in the gang capacitor, and all wiring associated with the phase-shift network should be highly insulated.

TABLE 1

CHARACTERISTICS OF 15W VACUUM LAMP

Applied Voltage	Current (mA.)	Resistance	Power Consumption
1	2.4	396	2.4 mW
2	3.8	525	7.6 ,,
3	4.8	630	14.4 ,,
4	5.7	700	22.8 ,,
5	6.6	760	33.0 ,,
10	10.0	1,000	100 ,,
15	12.9	1,160	194 ,,
20	15.1	1,320	302 ,,
25	17.8	1,400	445 ,,
30	20.0	1,500	600 ,,
40	22.9	1,740	916 ,,
50	27.0	1,850	1.35 W
75	34.7	2,160	2.16 ,,
100	41,7	2,390	4.17 ,,
150	52.5	2,860	7.9 ,,
200	63.1	3,170	12.62 ,,
230	69.2	3,280	15.9 ,,
250	72,4	3,460	18.1 ,,

The circuit shown in Fig. 3 is extremely simple and reliable. The frequency coverage is adequate for many purposes, and though the output is a few volts only, the level can be raised by the use of one additional output stage. If a wider range is required, then switching of the phase-shift components will be necessary. This operation calls for considerable care in design, because of the very large values of resistance and reactance in the phase-shift network. To preserve the simplicity of Fig. 3 and still give a wide frequency coverage in a number of separate ranges, it is possible to mount the four-phase shift resistances on an insulating strip fitted with plug contacts engaging corresponding sockets on the gang capacitor stators. Range-changing is achieved by plugging in different resistance groups. Once the resis-

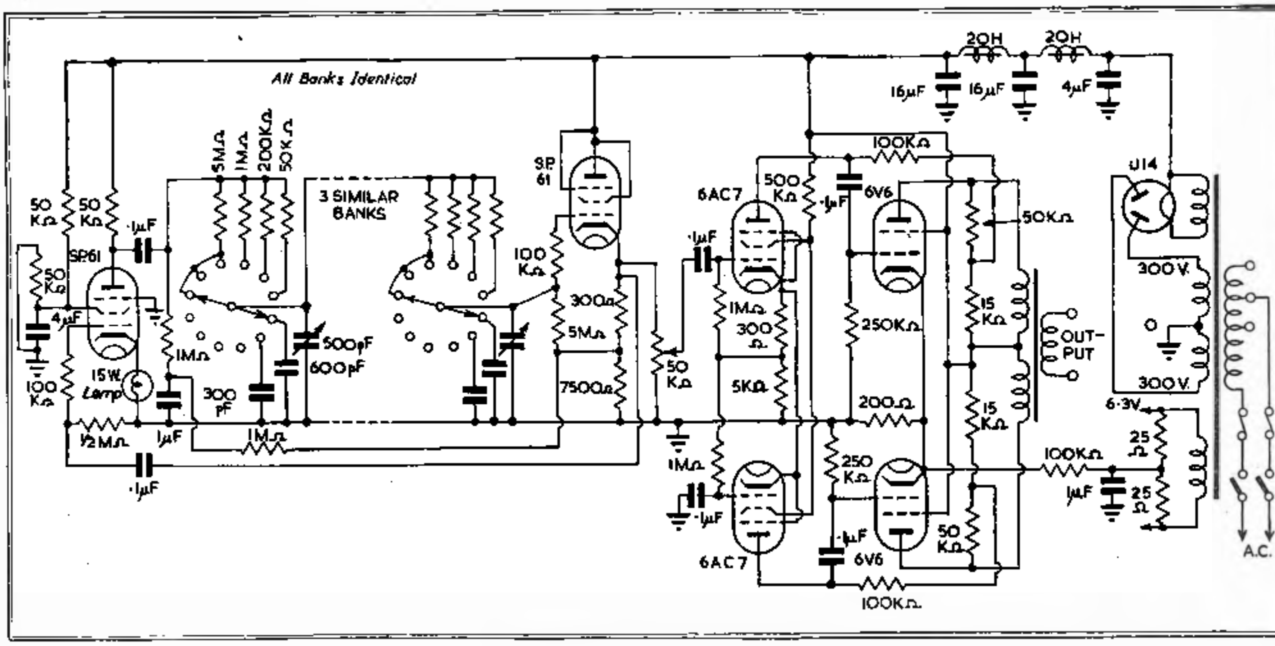


Fig. 4. Complete circuit diagram of switched phase shift oscillator and amplifier covering range 25-17,000 c/s in six steps

tance values are settled to cover a particular range, other ranges can be calculated, bearing in mind that in circuits of this kind, the operating frequency is inversely proportional to the resistance. Thus, to halve the frequency corresponding to a particular setting of the gang capacitor, the associated resistance is doubled.

If the range-switching facility is essential, then two requirements must be met. First, the switch wafer insulation must be extremely good, and ceramic construction is desirable. In the second place, the switch banks must be screened electrostatically from each other, and the resistors connecting adjacent banks must be mounted in such a way that they have their ends in separate compartments, the body of each resistor being passed through a bushed hole in the inter-switch screen. If these precautions are observed, a satisfactory performance can be attained, but the mechanical construction of the oscillator becomes far more complex.

Fig. 4 gives the circuit diagram of a switched oscillator, covering 25 c/s. to 17,000 c/s. in six ranges. It is basically similar to that of Fig. 3, but includes an audio-frequency amplifier covering the above range. The optimum anode-to-anode load of the output stage is 10,000 ohms, and an output of 1 watt is available with low distortion. Precise measurements of harmonic content have not been made, but a simple check at 1,000 c/s., using a twin-T null network to suppress the fundamental frequency, shows that the r.m.s. value of the residual harmonics is not greater than 5 per cent of the fundamental amplitude. In common with other apparatus of this class, the performance deteriorates at frequencies below 100 c/s., although, even at 25 c/s. there is no visible distortion on the oscillograph trace of the output waveform. The effect of power supply hum is just perceptible at near multiples of 50 c/s., and shows up as a very shallow beating or modulation on the output. The visual indication of this naturally disappears when the oscillator frequency is an exact multiple or sub-multiple of the power supply frequency.

The amplifier employs a cathode-coupled phase inverter and negative feedback is applied to the penultimate stage from the 6V6 anodes.

With the component values shown in Fig. 4, the frequency coverage is as shown in the Table:

Range 1	...	25	—	34 c/s.
2	...	32	—	60 c/s.
3	...	50	—	250 c/s.
4	...	200	—	1,100 c/s.
5	...	1,000	—	5,000 c/s.
6	...	3,500	—	17,000 c/s.

The layout of the oscillator and amplifier components should conform to normal audio-frequency practice, and the only difficulty likely to be experienced is in the effective shielding of the high impedance phase shift network from extraneous electrostatic fields. Provided that care is taken over this single point, there is no difficulty in constructing the entire equipment to give a very satisfactory performance.

The simplest method of calibrating the various range scales is by the use of an auxiliary oscillator in conjunction with a cathode-ray tube, using the Lissajous' figure method of frequency comparison.

References

Terman, Buss, Hewlett and Cahill, "Some Applications of Negative Feedback." *Proc. I.R.E.* Vol. 10, p. 649. October, 1939.

H. H. Scott, "A New Type of Selective Circuit," *Proc. I.R.E.*, Vol. 26, p. 226. February, 1938.

Ginzton and Hollingsworth, "Phase Shift Oscillators," *Proc. I.R.E.*, Vol. 29, p. 43. February, 1941.

W. N. Tuttle, "Bridged-T and Parallel-T Circuits," *Proc. I.R.E.*, Vol. 28, p. 23. January, 1940.

F. W. Dawe, "Wide Range Audio Oscillator," *Electronic Engineering*, p. 246. August, 1947.

NOTES FROM THE INDUSTRY

R.G.D. and Mersey Harbour Control

The Port of Liverpool is to be equipped with radio-telecommunication equipment. This is to enable the fullest use to be made of the port's radar installations and to save valuable time in the turnround of shipping.

Portable radio-telephone transmitter receivers and shore station equipment are being specially designed and made for this work by R.G.D. of Bridgnorth.

The installation, it is claimed, will be the first of its kind in the world and has already attracted considerable attention among American shipping authorities.

Royal Netherlands Fair

The Royal Netherlands Industries Fair held twice a year at Utrecht, Holland, is one of the most important business events on the Continent.

The first Fair in 1949 will be from March 29 until April 7.

ELECTRONIC ENGINEERING together with the other publications of Morgan Bros., Ltd., will be shown on Stand No. 5201, General Section, Main Building, Vreeburg.

The Stand will be under the management of Mr. S. H. Hartog, our Subscription Representative for the Netherlands, who will be pleased to assist and advise all visitors.

Those unable to visit the Fair can communicate with Mr. Hartog c/o Hotel Kasteelvan, Antwerpen, Utrecht.

Plessey Engineering Apprenticeship Scheme

The Plessey Company, Ltd., Ilford, Essex, have revised their apprenticeship scheme which is open to juveniles between the ages of 16 and 17 years without payment of a premium.

Although intended primarily as a trade training course apprentices who, by their progress, demonstrate their aptitude for technical occupations, will when their indentures are endorsed at the age of 18, have courses of training laid out to qualify them as draughtsmen or technical assistants.

Since only a limited number of apprentices can be absorbed each year, selection will be made purely on merit and applicants will be required to pass an entrance examination as determined by the Apprenticeship Committee. Courses will normally commence in March and September of each year, the appropriate application forms having to be completed and returned by January 1 and July 1 respectively.

Government Department Electrical Specifications

The Committee on the Standardisation of Electrical Cables and Wires for Government Services (Secretary, Ministry of Supply I.E.M.E. "Walsingham," Chislehurst, Kent) have recently issued a revised version of G.D.E.S. 22-1948 for Equipment Wires. Some types and sizes have been deleted from the previous issue and a number of other minor modifications made. Copies can be obtained from H.M.S.O. price 3d.

Changes of Address

Messrs. A. B. Metal Products, Ltd., have opened a London office at Ludgate House, 107 Fleet Street, London, E.C.4. The telephone number is Central 5667.

The address of the Sheffield office of Wild-Barfield Electric Furnaces, Ltd., and their associates, Messrs. G. W. B. Electric Furnaces, Ltd., is 4 Paradise Square, Sheffield 1. The telephone number remains unaltered as Sheffield 22776.

Raymond Electric Ltd., announce that they have taken over a larger factory at Brent Crescent. The new address and telephone number is: Brent Crescent, North Circular Road, London. N.W.10. Telephone No. ELGar 6687.

Agents for Birmingham Sound Reproducers, Ltd.

Messrs. N. Miers and Co., Ltd., of 115 Gower Street. London, W.C.1 (telephone number Euston 7515) have been appointed agents in London and the South for the special products division. This covers the new range of scientific instruments, including beat frequency oscillators, valve voltmeters, harmonic analysers and vibration analysing equipment. Messrs. N. Miers and Co., Ltd., are also in a position to give direct assistance to those concerned with the normal range of products such as sound amplification and recording equipment.

New Maintenance Depot at Croydon

New developments in the organisation of their air radio department, including the extension of repair, maintenance and instructional facilities at Croydon Airport, are announced by Marconi's Wireless Telegraph Co., Ltd., Chelmsford. This is a revival of facilities available before the war when the Marconi's main air service depot at Croydon, provided a valuable service to the commercial air lines operating from that airport.

In order to bring about even closer co-operation with the company's development and production sections engaged on air radio projects, Marconi's aeronautical division has now been centralised at Chelmsford, Essex, under the Manager of the Aeronautical Division, Mr. L. A. Sweny. The staff of the air radio department dealing with sales and contract matters who, until recently, were at Hackbridge, have accordingly been transferred to head office at Chelmsford.

The telephone number of the Croydon establishment is Croydon 7744.

Publications Received

"Low Temperature Brazing Tungsten Carbide Tool Tips" (Publication No. 2128). An informative booklet well illustrated with clear photographs and simple diagrams, published by: *Johnson Matthey & Co., Ltd., 73-83 Hatton Garden, London, E.C.1.*

"The Triple Diode A.V.C. Circuit." Another of the excellent Mullard Technical Reports (No. 9/1948) issued, primarily for the benefit of equipment designers, by *Mullard Electronic Products Ltd., Century House, Shaftesbury Avenue, London, W.C.2.* Copies are not available for general circulation.

Oscillograph Equipment and *M731 Universal Reading Camera.* Two highly informative and delightfully produced booklets on some of the equipment manufactured by *Southern Instruments, Ltd., Fernhill, Hawley, Camberley, Surrey.*

Trix Quality Sound Equipment. Folder containing illustrated lists of their full range of loudspeakers, amplifiers and allied equipment issued by *The Trix Electrical Co., Ltd., 1 5 Maple Place, Tottenham Court Road, London, W.1.*

"Eddystone Short Wave Components" (Publication No. WL56811 Price 6d.) and "The Eddystone 145 Mc/s. Guide" (Price 1s. 6d.) received from *Stratton & Co., Ltd., Birmingham, 31.*

"Ediswan Mazda B8A Valves—and others in the A.C. range." (Publication No. R1339) giving ratings, operating and capping data. Issued by *The Edison Swan Electric Co., Ltd., 155 Charing Cross Road. London, W.C.2.*

"Corrugated Perspex"

Three booklets (1) 453/53/1247, (2) R1/396/14/648, (3) R1/2Ed/454/24/748 giving technical notes and applications of this product have been received from *Imperial Chemical Industries, Ltd.*

"Wiggin Nickel Alloys." Periodical notes on the properties of nickel and nickel alloy products (formerly called "Monel Notes") obtainable on application from *Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16*

Telcon Metals.

Publication No. M44 relating to Transformer and Choke Laminations in MUMETAL, RADIOMETAL and RHOMETAL.

The Telegraph Construction and Maintenance Co., Ltd., 22 Old Broad Street, London, E.C.2.

APRIL MEETINGS

The Institution of Electrical Engineers

All meetings, unless otherwise specified, are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Ordinary Meeting

Date: April 21. Time: 5.30 p.m.
The 40th Kelvin Lecture—"Semi-Conductors and Rectifiers."
By: Professor N. F. Mott, M.A., F.R.S.

Radio Section

Date: April 6. Time: 5.30 p.m.
Lecture: "Hot-Cathode Thyratrons: Practical Studies of Characteristics."
By: H. de B. Knight, M.Sc.

Date: April 12. Time: 5.30 p.m.
Informal Lecture: "Radio-Frequency Heating."
By: R. H. Barfield, D.Sc.

The Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Cambridge Radio Group

Date: April 26. Time: 8.15 p.m.
Held at: The Cavendish Laboratory.
Lecture: "Meteors."
By: A. C. B. Lovell, O.B.E., Ph.D.

Hon. Secretary: G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

South Midland Radio Group

Date: April 28. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: "Some Aspects of Gramophone Reproduction."
By: K. N. Hawke, B.Sc.

Secretary: E. May, Birmingham Electric Furnaces, Ltd., Tyburn Road, Birmingham, 24.

North-Western Radio Group

Date: April 27. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Discussion: "Audio-Reproduction."
Opened by: G. J. Scoles, B.Sc.(Eng.), A. G. F. Smith, and G. I. Thomas, B.Sc.

Secretary: A. L. Green, 244 Brantingham Road, Chorlton-cum-Hardy, Manchester, 21.

North Staffordshire Sub-Centre

Date: April 22.
Held at: The English Electric Company's Hall, Stafford.
Annual General Meeting and Lecture: "Television Developments."
By: K. R. Sturley, Ph.D.

Secretary: D. Smith, 82 Beatty Hall, Stone, Staffs.

Institute of Physics

Electronics Group

Date: April 12. Time: 5.30 p.m.
Held at: 47 Belgrave Square, London, S.W.1.
Lecture: "The use of Electronic Devices for Measurement of Life-times in Nuclear Physics.
By: Dr. J. Rotblat.

Hon. Secretary: G. W. Warren, Research Laboratory, The General Electric Co., Ltd., Wembley, Middx.

Midland Branch

Date: April 7. Time: 6.30 p.m.
Held at: The Imperial Hotel, Birmingham.
Lecture: "Physics in Steel Manufacture."
By: Dr. C. Sykes, F.R.S.

Hon. Secretary: Dr. J. H. Nelson, Messrs. Joseph Lucas, Ltd., Gt. King Street, Birmingham.

The Television Society

Date: April 1. Time: 6 p.m.
Held at: The Waldorf Hotel, Aldwych, London, W.C.2.

Annual General Meeting followed by the Annual Dinner at 7.30 p.m. Full details may be obtained from Mr. T. M. C. Lance, 35 Albemarle Road, Beckenham, Kent.

Midlands Centre

Date: April 8. Time: 7 p.m.
Held at: Room 6, The Chamber of Commerce, New Street, Birmingham.
Lecture: "Electronic Testing Instruments."
By: A. E. Crawford.

Lecture Secretary: Dr. W. Summer, 31 Beech Road, Bournville, Birmingham.

Constructors' Group

A Constructors Group in connexion with the Midlands Centre has now been started. Regular meetings are held at the Church Hall, Beaumont Road, Bournville, on Monday evenings at monthly intervals. Further details may be obtained from Mr. R. Baxendale, 50 Alcester Road, Birmingham, 13.

British Sound Recording Association

Date: April 6. Time: 7.15 p.m.
Held at: The Gaumont British Theatre, Film House, Wardour Street, London, W.1.
Lecture: "Developments in Magnetic Sound-on-Film."
By: Dr. O. K. Kolb.

Note—This is a joint meeting with the British Kinematograph Society.
Hon. Secretary: R. W. Lowden, "Wayford," Napoleon Avenue, Farnborough, Hants.

Institution of Electronics

Midlands Branch

Date: April 20. Time: 7 p.m.
Held at: Room 7, The Chamber of Commerce, New Street, Birmingham.
Lecture: "Servo Mechanisms."
By: Professor A. Tustin, M.Sc.

Lecture Secretary: Dr. W. Summer, 31 Beech Road, Bournville, Birmingham, 30.

R.S.G.B.

Date: April 29. Time: 6.30 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Lecture: "Some Aspects of High Quality Sound Recording and Reproduction."
By: R. W. Lowden.

The Secretary: New Ruskin House, Little Russell Street, London, W.C.1.

Society of Instrument Technology

Date: April 27. Time: 7 p.m.
Held at: The Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, W.1.
Lecture: "The Telerecording of Thickness, Pressure, Flow and other Physical quantities using a simple electro-magnetic circuit."
By: Dr. W. J. Clark.

Hon. Secretary: L. B. Lambert, 56 Tudor Gardens, London, W.3.

Brit. I.R.E.

London Section

Date: April 21. Time: 6 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Discussion: "Frequency Modulation and Amplitude Modulation."

The Secretary: The British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1.

South Midlands Section

Date: April 28. Time: 7 p.m.
Held at: The Technical College (Room A5), The Butts, Coventry.
Lecture: "Electronic Voltmeters."
By: R. A. Lampitt.

Secretary: C. Stokes, 6 Esterton Close, Coventry.

Radar Association

London Branch

The above branch holds its meetings on the first Tuesday of each month at the Albert Tavern, Victoria Street, London, at 7 p.m. Further details may be obtained from The Honorary Secretary, Radar Association, 70 High Holborn, London, W.C.2.

ABSTRACTS OF ELECTRONIC LITERATURE

CIRCUITS

Pentriode Amplifiers

(H. M. Zeidler and J. D. Noe)

Conventional video amplifier design is complicated by low-frequency phase shift and degenerative decrease in gain caused by inefficient screen-grid and cathode by-pass circuits. This paper describes two amplifier circuits in which phase shift and degeneration in those by-pass circuits may be eliminated throughout the entire range to zero frequency. Small paper or mica capacitors may be substituted for bulky electrolytic units, with consequent improvement in electrical and physical amplifier characteristics.

These circuits are applicable to amplifiers with stage gains less than the control-grid to screen-grid amplification factor of the tube. Inasmuch as common tubes have factors ranging from approximately 10 to 50, the circuits described are primarily applicable to video amplifiers. In practice, the interstage circuits are designed in accordance with conventional methods involving either two-terminal or four-terminal networks. The by-pass circuits described may then be incorporated into the design to provide the advantages outlined above with no loss in stage gain.

—*Proc. I.R.E.*, November, 1948, p.1,332.

Shunted-Amplifier Input Admittance

(A. Shadowitz)

A method is presented for finding the input admittance of an amplifier having a shunt impedance between its output and input. The shunted-amplifier gain is the sum of two terms that have simple physical significance. Several cases are worked out for a shunting capacitance, and include a single stage with both resistive and tuned loads and a double stage with resistance-capacitance coupling. Application to a frequency modulator is given in detail. Extensions are indicated to the theory of the tuned-plate tuned-grid oscillator, multivibrator, and negative-impedance devices.

—*Elect. Comm.* December, 1947, p.468.

F-M Receiver Design Problems

(E. C. Freeland)

A survey of design and production techniques, including an evaluation of limiter-discriminator, ratio, and synchronised-oscillator detectors. Hum reduction and the tracing and elimination or regenerative effects in I.F. and R.F. stages, particularly for A.C./D.C. receivers, are described.

—*Electronics*, January, 1949, p.104.

THERMIONIC DEVICES

Microphonism in a Subminiature Triode

(V. W. Cohen and A. Bloom)

The simple theory of the symmetrical plane triode has been applied to the calculation of the change in plate current as a function of motion of the grid and cathode. For perfect symmetry, the first-order approximation gives zero change in current. The second-order expressions are evaluated and show that an output signal may be expected having twice the vibration frequency. A description is given of equipment for vibrating a tube for test, measuring the amplitude of vibration, detecting very small resonance of tube parts, and studying the wave form of the electrical output.

Experimental studies have been made on tubes to determine the mechanical origin of several different forms of electrical output. In some cases, individual tubes which exhibited particular forms of microphonism have been opened up, the structure altered, and the tube operated under vibration in an evacuated bell jar. In this way, the mechanical origin of particular forms of microphonism were determined quite definitely. A few general comments are given regarding tests for microphonism, and the design of tubes.

—*Proc. I.R.E.*, August, 1948, p.1,039.

Duplex Tetrode UHF Power Tubes

(P. T. Smith and H. R. Hegbar)

The major factors affecting the design and development of wide-band UHF power tubes are considered and emphasis is given to the television application. A qualitative discussion of methods for obtaining the required performance is presented, and a 5 KW 300 Mc liquid-cooled, internally neutralised duplex tetrode is described.

—*Proc. I.R.E.*, November, 1948, p.1,348.

Geiger Müller Counters

This symposium on Geiger Müller counters comprises the following three articles: (1) "Some Geiger-Müller and proportional counters of spherical shape." by G. Salvini, (2) "A new quenching circuit for Geiger counters," by H. Maier-Leibnitz, and (3) "Circuits for testing efficiency of Geiger counters," by G. E. Hagen and D. H. Loughbridge.

—*Rev. Sci. Inst.*, August, 1948, p.494.*

* Abstract supplied by courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester

INDUSTRY

A Digital Computer for Scientific Applications

(C. F. West and J. E. deTurk)

During the past two years development has been initiated on several large-scale automatic digital computing machines, both in this country and abroad. The present paper is concerned with the over-all organisation of one such machine. A logical division of the machine into four major components is described, and the machine performance is interpreted in terms of these component functions. The electronic techniques used to accomplish the storage, transmission, and arithmetic manipulation of numbers, together with certain methods used for control of the computer, are briefly discussed. Although the paper is concerned with the design of a particular machine, it is felt that the design problems and engineering techniques are applicable to most large-scale computing machines.

—*Proc. I.R.E.*, December, 1948, p.1,452.

Ultrafax

A new facsimile method uses cathode-ray tubes as light sources at both transmitter and receiver. Ultimately high-speed transmission depends upon 10-megacycle microwave relay chains. Receiving device uses photographic film that can be developed in a few seconds.

—*Electronics*, January, 1949, p.77.

Shutterless Television Film Projector

(L. C. Downes and J. F. Wiggin)

Motion pictures on 16-mm. film are converted from 24 to 30 frames per second. Electron tubes control speed and phase of projector driving motor, pulse and synchronise the light sources and provide the accompanying sound.

—*Electronics*, January, 1949, p.96.

Nickel-Iron Alloy Dust Cores

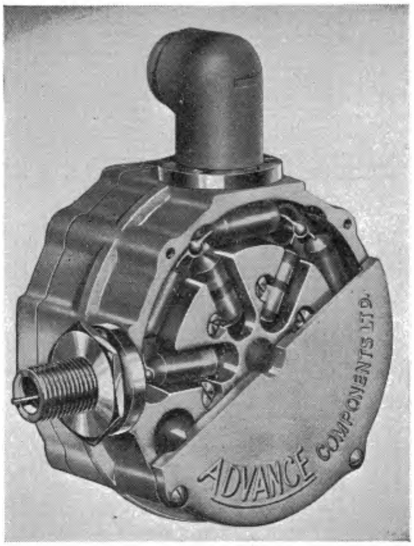
(S. E. Buckley)

The development of dust cores to meet the increasing demand for use in telecommunications equipment is outlined. Requirements for such uses are defined, a high and constant permeability and low losses in the core being the most important. Among the materials used for dust cores described are electrolytic iron, Permalloy (nickel-iron), and molybdenum-Permalloy.

The constancy of permeability and its influence on design, the question of calculating the dust-core permeability from inherent properties of the metal, and core losses are discussed.

The effective resistances at audio-frequencies of dust-cored coils of various materials are compared.

—*Elect. Comm.*, June, 1948, p.126.



Advance Attenuator (type A.38)

(Illustrated above)

THIS attenuator has been designed primarily for use in radio frequency standard signal generators. It can, however, be used in any audio or radio frequency application where attenuated outputs from 1 volt down to a microvolt or less are required even at frequencies greater than 300 Mc/s.

The attenuator consists of an aluminium die casting which houses an unbalanced ladder network and a switching device for selecting any one of six positions. The switch blades and contacts are rhodium-plated in order to eliminate wear and contact troubles.

The various cavities in which are located the resistance network, switches, contacts etc., are so proportioned that optimum performance is obtained at high frequencies when the impedance of the ladder network is 75 ohms.

A four step 75 ohm network is normally fitted having each step adjusted to within 20 db plus/minus 0.2 db. High-stability carbon resistors are used since they are the only type available which are sufficiently nonreactive at high frequencies. Up to 100 Mc/s the accuracy of the attenuator is determined by the accuracy of the resistors. At 300 Mc/s. megacycles the attenuation per step is approximately 20.5 db's.

Specification

Impedance : 75 ohms.
Maximum Attenutation : 80 db.
Attenuation Per Section : 20 db.
Accuracy (at 80 db) : 0-100 Mc/s.± 1 db. 100-300 Mc/s.± 2 db.
Input Connexion : $\frac{3}{4}$ B.S.F. externally threaded bush.
Output Connexion : Standard Pye sockets.
Weight : 9 ozs.

Advance Components Ltd., Back Road, Sherhall Street, Walthamstow, London, E.17.

High Accuracy Precision Potentiometers

(Illustrated below)

A RANGE of cam-corrected high accuracy potentiometers is displayed by Colvern Ltd.,

In the Colvern cam-corrected potentiometer a certain amount of angular motion is transmitted to the rotor contact, in addition to, and independent of, the main spindle, this motion being communicated to it by means of a lever which bears down on a track concentric with the resistance element. The profile of the track is controlled by screws arranged at regular intervals round its circumference and is adjusted so that inherent errors at any point in the winding are compensated for by the automatic retarding or advancing of the rotor contact.

A guaranteed linear accuracy of better than $\pm$ 0.1 per cent is maintained in all standard cam-corrected potentiometers, whilst in the Type CLR9101 6½ in. model the linearity tolerance can be held as low as 0.04 per cent and even lower, dependent on resistance value.

Specification

Rating : 10 watts.
Resistance Values Available : 1,000 to 150,000 ohms.
Overall Resistance Tolerance : $\pm$ 5 per cent.
Linear Accuracy : $\pm$ 0.04 per cent.
Maximum Working Voltage between Spindle and Track : 1,000 volts D.C.
Effective Angle of Resistance : $315° + 0.25° - 0°$
Angle of Spindle Rotation : 360 .

Colvern Limited, Mawneys Road, Romford, Essex.

ELECTRONIC at the R.C.M.F.

THE sixth private Exhibition of the Radio Component Manufacturers Federation was held at Grosvenor House, London, from March 1st to March 3rd, 1949.

B.S.R. High Gain Valve Voltmeter Type V.M. 1000

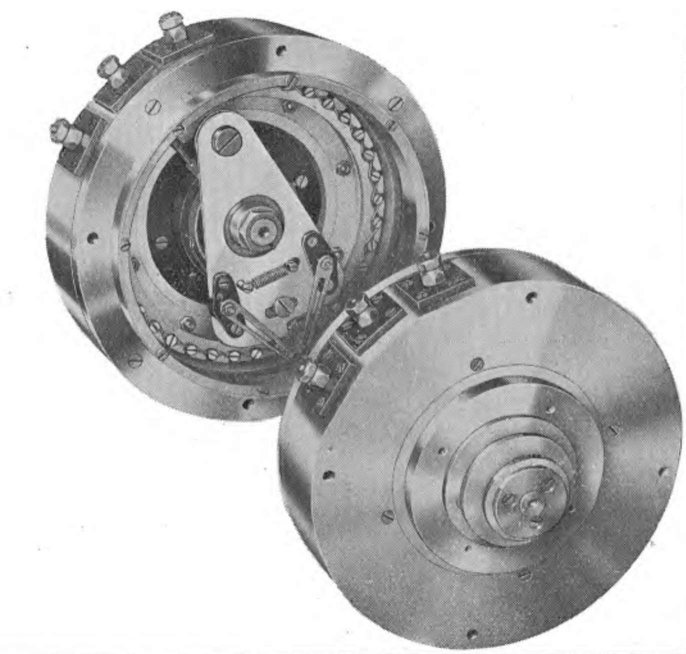
THE V.M. 1000 is a voltage measuring instrument of exceptionally wide frequency range and high sensitivity.

A full scale sensitivity down to 10 mV permitting measurements down to 1 mV and a frequency range of 20 cycles to 200 Kc/s. is, in itself, a unique feature, but by the use of a skilfully designed cathode follower probe, an input impedance of 100 megohms with an effective input of only 7 pF has been achieved.

The V.M. 1000 will be found invaluable on Supersonic work. A companion instrument to this, is the R.C. Oscillator Type R.C. 200.

Specification

Valve Voltmeter Type V.M.1000
Voltage Range (full scale) : 1.0 mV to 30 volts in 8 ranges.
Frequency Range : 20 cycles to 200 Kc/s.
Meter (3 scales) : (1) Decibel scale minus 10 dB. to plus 10 dB. (OdB=1 volt). (2) A.C. volts 0-3. (3) A.C. volts 0-10.
Overall Accuracy : 5 per cent better down to approx. 1/6th f.s.d.
Operation : 200/250 volts, 50/60 cycles



EQUIPMENT EXHIBITION

A selection of the newer and more important exhibits is given on these pages. Further information can be obtained from the firms concerned.

B.S.R. R.C. Oscillator Type R.C. 200

THIS instrument operates from a 6 volt battery source, with an H.T. vibrator unit. Three 2 volt non-spillable accumulators are combined in a portable case, forming a complete power unit. A mains unit is available as an alternative supply.

An internal 600 ohm load is provided which can be selected by a switch. This load is tapped at 0.6 ohms and brought to an output terminal on the front so that very low voltages are available for most exacting requirements, and is fitted with precision.

A nominal 1 volt output is available across 600 ohm output terminals, and a meter is built in which has the following scales : 0-1v., minus 1 dB.-0-plus 1 dB. LT., and H.T. level indications.

Specification

R.C. Oscillator Type R.C. 200

Frequency Ranges :

(1) 20 c/s.- 200 c/s
(2) 200 c/s.-2000 c/s.
(3) 2000 c/s.- 20 Kc/s.
(4) 20 Kc/s.-200 Kc/s.
} plus minus 2 dB.

Output : Nominal 1 volt across 600 ohm unbalanced. Optional internal load with 0.6 ohm tap. Output meter scaled 1 volt and minus 1 dB./plus 1 dB., also with L.T. and H.T. levels.

Attenuators : 60 dB. in 1 dB. steps (or 120 dB. max. on 0.6 ohm tap).

Birmingham Sound Reproducers Limited,
The Claremont Works, Old Hill, Staffs.

Ear Mounting Drilitic Capacitors

(Illustrated on right)

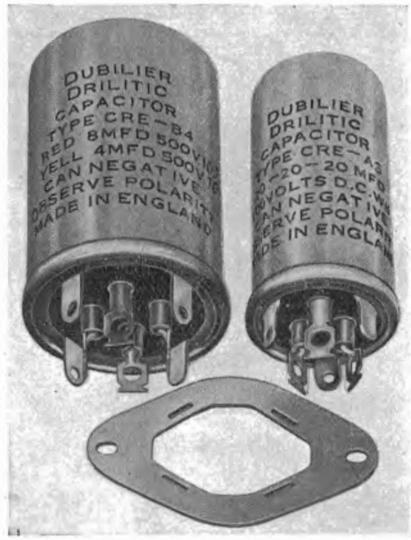
A NEW method of Ear-mounting is now introduced to obtain the maximum advantage of size reductions and to provide a more rapid efficient method of mounting and fixing capacitors.

With the use of direct Ear-mounting the actual diameter of the capacitor represents the maximum chassis space required, thus saving the space previously occupied by the usual fixing feet on the clamp bands.

No loose parts in the form of clamp bands, fixing screws and nuts or rivets are required ; a slight twist of the mounting ears, when inserted through the chassis rigidly fixes the capacitor. They are available in a full range of the usual capacitance and voltage values in single, dual and triple capacitance forms.

For the time being, these capacitors are only available to manufacturers of radio and electronic equipment.

Dubilier Condenser Co. (1925), Ltd.,
Ducon Works, Victoria Road,
North Acton, London, W.3.



Microphones for Hearing-aid Component

(Illustrated below)

TWO crystal microphones manufactured by Cosmocord Ltd., are claimed to be the smallest ever produced. A round type, the Acos MIC 15 has a case diameter of 0.8 in. (21 mm.) and square type, the Acos MIC 17 has a square case of 0.8 in. Both types are illustrated.

Another microphone, the Acos MIC 18 has been developed which has exactly the same response as the Company's standard hearing-aid microphone but is housed in a shallow case, a reduction in size without loss of performance which is a considerable improvement.

Other equipment exhibited included the Acos G.P.15 Microcell cartridge, which is the first British gramophone pick-up cartridge to play both the new microgroove records and standard 78 r.p.m. records.

Cosmocord Ltd.
Enfield, Middlesex.

Miniature Metallised Paper Capacitors

(Illustrated below)

THE W99 capacitor has been developed to meet a demand for a small, inexpensive component for applications where the new range of miniature valves renders orthodox types difficult in assembly. They are particularly useful for decoupling at frequencies up to and exceeding 100 Mc/s., their effective inductance equalling that of a straight wire of equal length of $\frac{1}{8}$ in. dia. (approx.).

Dimensions : Length $\frac{7}{16}$ in. (11.11 mm.). Diameter $\frac{3}{16}$ in. (4.75 mm.).

Capacitance Range : 150 v. D.C. Wkg. 0.004 μF to 0.01 μF. 350 v. D.C. Wkg. 50 pF to 0.003 μF.

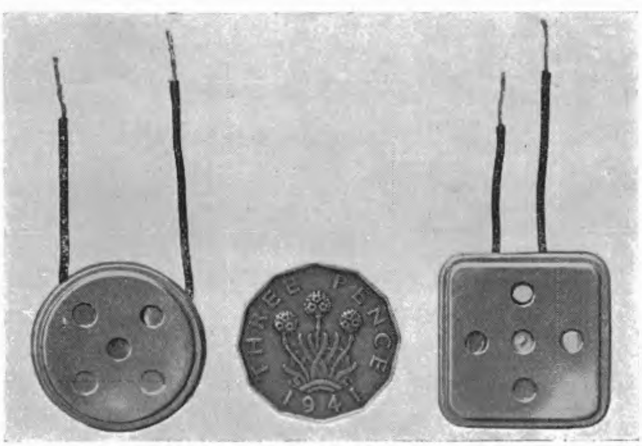
Capacitance Tolerance : Standard $\pm$ 20 per cent. Closer tolerances are available.

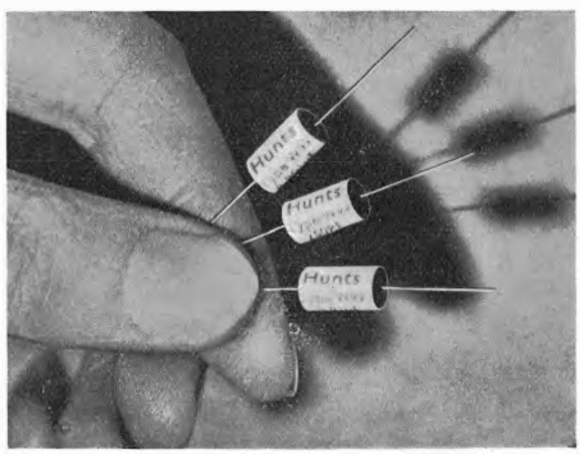
Capacitance Stability : Better than $\pm$ 2 per cent over temperature range.

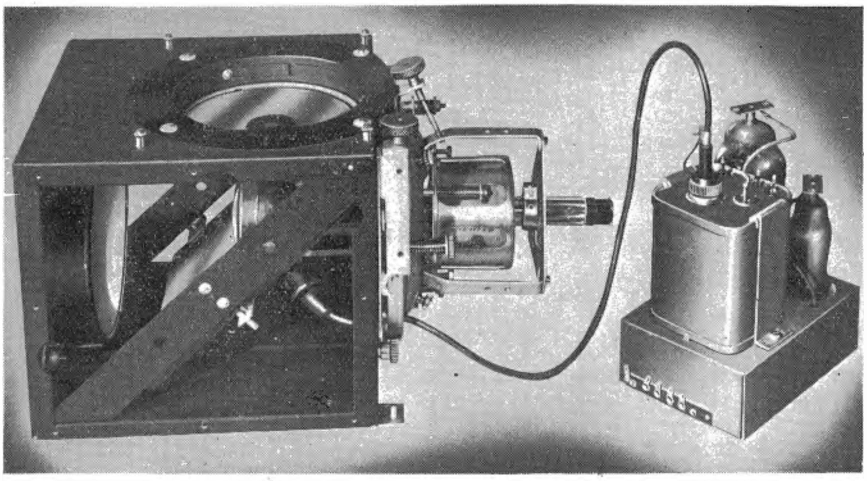
Temperature Range : 150° C. to $-$ 71° C.

Insulation Resistance : Better than 20,000 megohms. All capacitances.

A. H. Hunt Limited,
Bendon Valley, Garratt Lane,
Wandsworth, London, S.W.18.







Projection Television Apparatus

(Illustrated on left)

NEW projection television components have been developed by Mullards and are available only to manufacturers of television equipment.

These components comprise an optical system complete with deflection and focusing coils and a compact EHT unit for the necessary 25 KV supply. These two units, in conjunction with the new Mullard $2\frac{1}{2}$ in. picture tube type MW6-2, enable manufacturers to produce an efficient large screen television receiver using as a basis the chassis of their existing direct viewing set.

Special Features

(1) Large picture 12 in. by 15 in. on a flat screen.
(2) Low tube replacement costs.
(3) Compact optical system is very efficient and makes use of a modified Schmidt principle.
(4) Screen size is suitable for home viewing or for viewing by small groups.
(5) Has high picture brightness and small spot size on the picture tube face.
(6) The system is more than adequate for 405 lines resolution with good contrast and brightness.
(7) Optical unit remains in adjustment with ordinary use.
(8) Mullard television components, together with Mullard picture tube and driver valves, are supplied as a system completely tested and ready for use.

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

Temperature Compensation Capacitors

(Illustrated on right)

THESE capacitors are less than $\frac{5}{8}$ in. long by $\frac{1}{4}$ in. dia. and have been designed specially to offer a large change of capacitance with a relatively small initial capacitance. The tempeature coefficient is strongly negative (-3000 ± 10 per cent $\times 10^{-6}/°C.$) These capacitors are, therefore, suitable for compensation of positive coefficients without inductance in tuned circuits without greatly increasing the minimum of capacitance.

Miniature Pearl and Tubular Capacitors

These now cover all preferred values from 0.47 pF to 10,000 pF. Maximum diameter $\frac{1}{4}$ in., max. length $\frac{5}{8}$ in. In this range, full use has been made of the properties of the new material Unilator K.3000 which combines a high permittivity of 3000 with excellent insulation resistance and high breakdown strength. This range is suitable for coupling capacitors in television, F.M. and radar receivers, and for the I.F filter in normal broadcast receivers.

New Ceramic Transmitter Capacitors

Ceramic "Hi-Load" Capacitors have been extended to cover a variety of dielectric bodies and fittings. Their aerodynamic shape and excellent power factor of the special low loss ceramic bodies, have made it possible to pack heavy R.F. ratings into small dimensions. These new designs ensure greater efficiency in R.F. heaters and transmitters.

New Silvered Mica Twin Capacitors

These capacitors which form one of the end blades of an I.F. transformer assembly have proved extremely popular as their use (patent applied for) affords a considerable saving in the assembly costs. Formerly types were for $\frac{7}{8}$ in. and $1\frac{3}{8}$ in. square cans; the new type will meet requirements of users of 1 in. square cans.

United Insulator Company Limited,
Oakcroft Road, Tolworth,
Surbiton, Surrey.

R.F. Cables

(Illustrated below)

THE wide range of Telcon Radio Frequency and Television Cables were exhibited, together with examples of "GEE" (antimicrophonic) and "WYE" (double-screened) R. F. cables.

Of interest was a new low-loss cable of high uniformity, Telcon type A.S. 84. Al.H, which has been recently developed. It is intended primarily for use as a television antenna feeder. Several advanced features are included in the design in order to achieve the desired characteristics.

A solid copper wire is used as the inner conductor, the insulation is formed by a series of interlocking semi-cylindrical shells accurately moulded in Telcothene: the outer conductor is formed of a seamless extruded tube of high conductivity aluminium. The aluminium tube provides a highly efficient return conductor and serves as a watertight sheath to protect the semi air-spaced insulation. The robustness and light weight permits it to be installed on masts without the use of steel armour. The usual outer servings are applied when the cable is used in external installations.

The Telegraph Construction and Maintenance Co. Ltd.,
Telcon Works,
Greenwich, London, S.E.10.

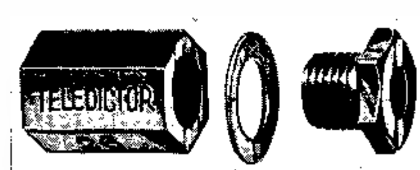
A New Pre-set Mounting Bush

(Illustrated below)

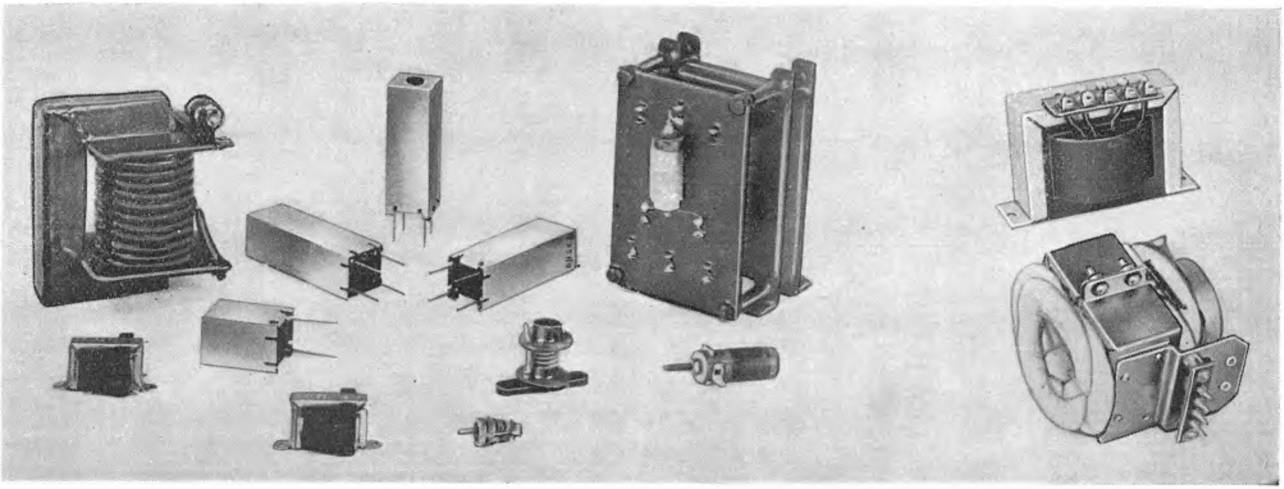
A NEW Teledictor component is a mounting bush in a simple and convenient form for pre-set controls.

The single $\frac{3}{8}$ in. diameter hole fixing makes it possible to dispense with the present method of brackets with all the additional screws and nuts. It provides a positive location for the screw driver, when setting the control. It is suitable for use with all types of instrument panels or chassis up to a $\frac{3}{16}$ in. thickness, and is normally supplied in nickel plated brass but can also be supplied in an insulating material.

Teledictor Limited,
214, Birmingham Road, Dudley, Worcs.



Telcon R.F. Cable



New Range of Plessey Television Components

(Illustrated above)

AS a result of extensive development in the television receiver field, The Plessey Company Limited, Ilford, Essex, has produced a complete range of new components incorporating the latest technical and economic advances. New circuit techniques have been evolved offering substantial simplification and economics. Versions are available for various valve combinations, provision being made for different circuit arrangements according to particular requirements.

Combined E.H.T. and Scan Unit

This is a new combined line scan and E.H.T. unit of high efficiency and economic construction. A new core material is incorporated which has been specially developed by the Company for the purpose, and which offers a number of advantages over contemporary methods. Available for operation from various types of valves e.g. EL 38. Pen 46 and 807, it is also suitable for use in the basic single valve self-oscillating circuit for either hard or soft valves.

Frame Deflection Arrangement

Two types of frame units are available for single valve or drive circuits, but these use different mechanical structures. The single valve construction consists of a yoke type transformer which acts simultaneously as oscillating transformer and deflector.

For driven frame circuits a conventional Output Transformer (T.1441) suitable for operation with valves of the 6L18, 6F13, EF types (triode connexion for maximum current economy) or in an alternative version T.1091 for higher current values, and operated in conventional circuit arrangement.

Scanning Coils

New deflector coil units of simplified design are also provided. The combined line and frame deflector unit is suitable for use in arrangements using a driven frame time-base with output transformers, T.1441 and T.1091 and with the combined E.H.T. and Scan Unit.

Focus Arrangements

Both electro-magnetic and permanent magnet focus units are available. The former is a light coil in three resistance values. This is available separately or on a three point fully adjustable mounting. The permanent magnet arrangement has a ring magnet mounted to give a narrow field gap and is also fully adjustable on a three point mounting. A special feature of this mounting is the facility for movement behind the mounting screen, allowing for easy adjustment when the complete receiver is in its cabinet.

Two magnets are available, flux values giving suitable fields for triode and tetrode C.R. tubes.

The Plessey Co. Ltd.
Ilford Essex.

Miniature Metalmites

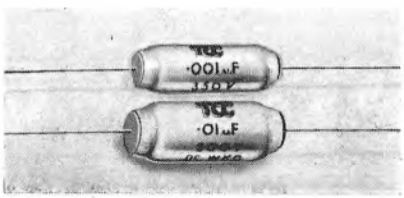
(Illustrated below)

THESE are an extension of the standard Metalmite range of paper tubulars to cover requirements for deaf aid equipment, miniature receivers and transmitters. Their short length makes them very adaptable in small assemblies, whilst their excellent sealing maintains a high insulation resistance and high breakdown voltage under tropical conditions.

Some typical additions are :—

.0002 μF, 500 v D.C. working and .001 μF 350 v D.C. working, at 70° C. and 16 mm. long by 5 mm. diameter.

Telegraph Condenser Co. Ltd.
Wales Farm Road,
North Acton, London, W.3.



Tape Deck Recorder Unit

THE Wearite "Tape-Deck" is the first entirely British made recorder and is, it is claimed, a great step forward in bringing good quality recording within the reach of a wide variety of users.

The outstanding features are :—

(1) Motor-board includes the necessary driving motors, switches, constant speed capstan, brakes and link mechanism, twin-tape reels, heads for recording, erasing, playing back, footage indicator, control knobs and neon indicator.

(2) Controls are limited to stop and start switches, change-speed switch and switch for erasing, recording, winding and play-back.

(3) Speed of playing or recording can be varied at will ; speeds of $3\frac{3}{4}$ in. per second and $7\frac{1}{2}$ in. per second are standard provisions.

(4) Standard $\frac{1}{4}$ in. wide tape is used and reels hold 1,250 feet. Playing time is accordingly 70 minutes at $3\frac{3}{4}$ in. or 35 minutes at $7\frac{1}{2}$ in. per second.

(5) No "threading" of the tape is required. It is simply dropped into the "V"-slot on the right of the motor-board.

(6) The recording and play-back heads are so arranged that two tracks of recording can be stored on the standard tape thus effectively doubling the playing times mentioned in (4) above. Alternatively the two tracks can be recorded or played simultaneously for applications where this is required.

(7) The winding-back time is one minute.

(8) Erasing of the tape is performed at 45Kc/s prior to recording.

At present the "Tape-deck" recorder is available to manufacturers only who will fit the recorder into their own amplifying equipment.

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BOOK

Theory of Servo Mechanisms

By Hubert M. James, Nathaniel B. Nichols and Ralph S. Philips. 375 pp. M.I.T. Radiation Laboratory Series (McGraw-Hill). Price $5.00 net.

THIS book gives a very thorough treatment of the theory of servomechanisms, illustrated by a number of examples, the most important of which is an automatic tracking radar equipment developed during the war. The treatment is almost entirely mathematical based on the methods of Laplace and Fourier transformers, and unless the reader is familiar with these techniques he will find the book difficult to follow. The approach is from filter network theory with which most telephone engineers will be familiar but owing to the lack of simple approach to the theory of the simpler servo systems, those not already familiar with servomechanisms or filter network theory will be well advised to study some simpler approach such as is given in "Servomechanism Fundamentals" by Lauer, Lesnick and Matson, before attempting to use this book. When familiar with the underlying problems and the use of Laplace and Fourier transformers, the reader will find this book of great value and the conclusions reached are of the greatest importance in many applications.

The outstanding contribution is the method developed for determining the optimal values for the velocity-error constant and the time-constants of the various parts of the system to give a minimum value to the mean square error of the output under conditions of random noise appearing either at the input or within the servo loop. The solution will obviously depend on the type of servo system adopted, but the method is applicable in all cases, and so by it the different types can be compared, and taking into account the limits imposed on some of the parameters by design considerations the best system can be designed. This is of the utmost importance in those cases, like the example used, in which the "noise" in the system is of the same order as the accuracy required, but which is not the case in many industrial applications when a simpler approach can be used.

In the cases where the servo system has to work near the limit set by the inherent noise level the stability criterion becomes of importance since the system will also be operating near this limit. The Nyquist criterion is defined and treated in full and a new criterion is developed from the decibel-log-frequency diagram which is approximately in agreement with the usual design practice.

The derivation of weighting functions, transfer function, autocorrelation functions and power frequency spectra and their use is very fully described. This leads directly to the theoretical design of servo systems which is quite straightforward for the usual examples. There follows an excellent chapter on the design of systems when the input data is in the form of pulses instead of the more usual D.C. and A.C. forms. This leads on to the consideration of the effect of noise, as mentioned above, which must be analysed by the use of the autocorrelation function and power frequency spectra.

In the last chapter consideration is given to the effect of introducing a human operator at some point in the system and it is shown how allowance can be made for this somewhat uncertain element

Of necessity, a large number of symbols are used in the course of the book and it is difficult for the reader to carry their meaning to his mind. A list of symbols would therefore be of considerable assistance.

J. F. COALES

Loran (Long Range Navigation)

By Pierce, McKenzie and Woodward. 476 pp. (Vol. 4 of M.I.T. Radiation Laboratory Series. McGraw-Hill. Price 36s. net.)

THIS book is one of the series written at the end of the war, describing the work of the Radiation Laboratory. As such it contains a great deal of practical engineering information on the Loran system and some historical matter. As the name implies, Loran is a Long Range Navigation system which was used extensively by the Allied Naval and Air Forces. The introduction of such a system based upon, at the time, unfamiliar principles, involved not only a study of many branches of radio engineering, but also much investigation into methods of mapping and charting, together with calculations of coverage areas and errors arising from various configurations of ground stations.

The book is divided into two parts, each of which contains a number of sections written by different authors, each an expert on the subject matter of the section concerned. The sections cover the following aspects: history of the system, principles, future trends, propagation, methods of computation and charting, and equipment design.

In the introduction a review is made of alternative methods of radio position fixing and the logical background for the development of Loran is given. The historical section covers

REVIEWS

the early development of ideas, and outlines the rapid development of the system with all its ramifications, until November, 1945, when the night-time service area was about 70 million square miles. Future trends are discussed briefly in a somewhat optimistic manner, and it is probably true to say that none of the schemes described has passed beyond the theoretical stage. In particular, the more refined forms of equipment such as automatic dial reading navigators' sets and automatic plotters have not so far made an appearance.

When Loran development was started, its precise performance could not be predicted, particularly in regard to night-time accuracy, owing to inadequate knowledge of propagation, and a great deal of research was therefore conducted. This is adequately described in the section on Propagation by J. A. Pierce, for both standard Loran on 2.0 Mc/s and for L.F. Loran on 180 Kc/s. Although this work was carried out in such a way as to yield information in a form directly applicable to the Loran system, much of it is of general interest and application.

The section on computation of charts and tables is of general application to other hyperbolic systems, such as Gee and Decca. Several alternative methods of computation are given, including the accurate methods employed for permanent chains and the more approximate ones intended for use by armies in the field.

Part II of the volume is devoted entirely to description of equipments and accounts for about half of the total subject matter. All items of equipment used, ground transmitters and receivers, antenna systems, airborne and naval equipments, are represented here by description of at least one model. The descriptions cover circuit design adequately, although no attempt is made to describe in detail the action of items such as multivibrators, blocking oscillators, etc. As the editors point out, these are adequately covered in other volumes of the series and elsewhere. Nevertheless, an interesting section on antenna design is included, and the difficulties of obtaining an efficient antenna with adequate bandwidths for pulse transmission on 180 Kc/s, together with proposed solutions, are described at some length.

To summarise, this is an interesting book, well produced, but by its nature very practical in regard to its subject matter and of interest to a rather restricted number of readers.

H. R. JOHNSON.

Ultra-High Frequency Transmission and Radiation

By Nathan Marchand. ix and 322 pp. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd. Published 1947, price 27s. net.

THIS book is an elementary introduction to the transmission and radiation of electromagnetic energy. The emphasis of the treatment throughout is analytical; the basic equations are developed in full detail for the fundamental physical elements involved; practical applications of the results are discussed, and in some places, a brief indication is given of the extension of the principles to cover more complex systems.

A chapter on transmission line theory forms the opening. The general equations and their solution are derived, but only the lossless line is treated in detail. The use of resonant lines for impedance measurements is discussed, and the use of circle diagrams is explained (but not derived). Stub matching is also covered. Chapter 3 is devoted to the derivation and discussion of Maxwell's Electromagnetic Equations and their boundary conditions. This is preceded by a very sketchy introduction to Vector Analysis, which appears unsatisfactory to the reviewer. If the student is familiar with the subject, there is no need for the space given to it here; if he is not, he will need a much more detailed and gradual approach. Chapter 4 introduces the concept of electromagnetic waves, and treats the plane wave solution of Maxwell's equations in detail. Poynting's vector is introduced; reflexion and refraction are treated for simple cases. An excellent chapter on radiation follows. It begins with a discussion of the polarised spherical wave, then demonstrates that an oscillating doublet can generate such a wave, extends the treatment to a dipole of finite length, and sorts out the induction field and the radiation field and their respective ranges of influence. Radiation patterns and radiation resistances are evaluated, based on sinusoidal current distributions. In the next chapter, an elementary discussion of aerial arrays and their radiation patterns is carried out, including the effect of a reflecting ground plane. Rectangular and circular wave guides are treated next along conventional lines with the aid of Maxwell's equations. A short but very useful chapter on more complex line problems, such as the effect of breaks in a screen, and balanced-to-unbalanced line transformers, concludes the book.

Taken as a whole, the book provides a readable and clearly presented introduction to the subject, and can be recommended to the engineer for the revision of the fundamentals, as well as to the student.

P. E. TRIER

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BOOK REVIEWS *(continued)*

Elementary Industrial Electronics.

William R. Wellman. 362 pp. 250 figs. (D. van Nostrand.) Price, 22s. net.

THE scope of the book is clearly stated in its title. It is written by an experienced teacher who is an expert in both electronic engineering and pedagogics.

The interesting features of the book are:—

(1) A very thorough, though brief, description of the basic principles, well illustrated by a series of line drawings.

(2) To deepen the understanding of the subject matter, the four experiments which are to be found at the end of each chapter, have been designed to assist the student in digesting the text of the particular chapter. Full directions are given and experimental alterations suggested.

(3) Illustrations with line blocks are well made and are convincing through the clear conception and expression of the "things that matter." Unfortunately, the same cannot be said of the half-tones which are sometimes blurred, sometimes smudged and, with a few exceptions, are not instructive at all.

In some photographic reproductions the electronic gear cannot be seen for all the black background which, one finds out, is the machine for which the electronic equipment in question has been designed.

(4) The author has done very well indeed in including not only the usual list of well-known textbooks and references, but also some of the best technical trade literature (bulletins, catalogues, etc.). Other authors should make a point of perusing—and recommending—the trade literature which, when carefully selected, is an essential adjunct to the student's as well as the engineer's quick-reference-library. A lot of practical information is conveyed in conscientiously written trade literature which will not be found in any textbook and, yet, is an essential part of the expert's knowledge.

(5) A summary at the end of each chapter will make it easy for the student to recapitulate each text, or to brush-up his knowledge.

The few remarks that follow are in no way meant to detract the reader's attention from the merits of the book as a whole.

p. 20 "capacity reactance" should read "capacitive reactance."

p. 21 "capacity" should read "capacitance."

p. 33. When the author says "one or two billion cycles" he means 1.10^9 or 2.10^9 c/s. It must be remembered, when studying books of American vintage, that over there a billion is 10^9, while in most parts of Europe it is 10^{12}. The same applies to a remark on p. 12 where one billion cycles is 1,000 Mc. It would be very much appreciated by the readers in all parts of the globe if such ambiguity could be avoided by simply using non-ambiguous terms as, for instance, 1,000 Mc. or 10^9 c/s.

An obvious omission might be pointed out in Fig. 2-18 where the anode lead has been forgotten.

W. SUMMER.

Frequency Analysis, Modulation and Noise

By Stanford Goldman (McGraw-Hill, 1948). 434 pp. Price 36s. net.

AT first sight the three subjects enumerated in the title of this book appear to constitute a mixed bag. Reflexion shows that they have much in common; and although the author has been at some pains to make the various parts of the text independent, the whole hangs together uncommonly well.

The book sets out to clarify certain fields of radio. Consequently the mathematics, applied throughout with great vigour, is treated no more rigorously than need be for the purpose of imparting a thorough understanding to radio engineers.

The first four chapters deal with the theory and applications of analysis by Fourier series and integrals. Amplitude, phase and frequency modulation is discussed in a sixty-page chapter. The remaining two hundred pages of the text proper are devoted to an exhaustive and penetrating analysis of noise (in the radio sense).

Six short appendices are particularly valuable, having regard to the mathematical flavour of the text. First there is a list of the principal symbols and abbreviations, with notes of the pages where they are defined or first used. Then follow tables of integrals both definite and indefinite, and of trigonometric indentities; these, which could have been strung together so badly, have been compiled with care and evidently from experience as to what is useful in work of this kind. A few examples of Fourier pairs are given in a sample table. The last two appendices contain some miscellaneous information on Bessel functions and values of the function of the first kind, for various integral orders and arguments.

A companion volume concerned with transient analysis and Laplace transforms is in preparation; it is sure to be awaited eagerly by all—and there will be many—who find the volume under notice admirable.

R. G. MANLEY

Report on Progress in Physics Vol. XI (1946-47)

The Physical Society (1948). Price, £2 non-Fellows; £1 5s. Fellows.

THE eighteen reports in this volume are regarded as covering a period of two years; six of the reports deal with meteors, comets and meteoric ionisation, while the remainder are devoted to a variety of physical subjects, including what is virtually a monograph, on Ferromagnetism, by Prof. E. C. Stoner. It is probably unnecessary to state that the reports attain a very high standard indeed; of those which are of particular interest to electronic physicists may be mentioned, "Developments in the Infra-Red region of the Spectrum" by G. B. B. Sutherland and E. Lee, and a lengthy paper on "The Mechanism of Thermionic Emission for oxide coated Cathodes" by H. Friedenstein, S. I. Martin and G. L. Munday. These paper have extensive bibliographies, which makes them of additional value.

There are two reports on "The radio-frequency Spectroscopy of Gases" and "Ultrasonics research and the properties of matter," and the atomic physicists are catered for by several papers. In general these are by specialists, for specialists, or physicists at an advanced level, who will find the reports of inestimable value.

S. RODDA

Electronic Engineering

By E. Molloy (Geo. Newnes Ltd. 5s. 0d.) 106 pp. + figs. in text.

THE title of this book invites the obvious disclaimer that it has no connexion with this journal. It is a collection of short articles on various electronic devices by specialist authors, and by the use of extra small type it has been possible to compress a considerable amount of information into a short book. The subjects dealt with are: C.R. tubes and their applications, the Cyclotron and Betatron, Thyratrons, Photo-cells, and X-rays.

The subject of electronics is now so wide that it is practically impossible for one author to cover it adequately, and the assembly of individual contributions is a more satisfactory way of ensuring that accurate and up-to-date information is available in a convenient form. Such a symposium, however, imposes a task on the editor to maintain balance and, as far as possible, uniformity of style. Mr. Molloy has proved fully equal to the task, and it is only a pity that his efforts were not expended on a book of more dignified appearance.

G. PARR