

Line Standards in 1946

IN recent weeks we have observed the growth of a myth which we feel should be dispersed before it becomes permanently entangled in the present gyratory arguments about television line standards. Its wide acceptance is understandable, for, if it is believed, it removes responsibility for the present line-standards dilemma (real or imagined) from the present generation and attributes it to the folly of our administrators in re-starting television too soon in 1946, and in any case on 405 lines!

What, then, should we have done? Waited for complete international agreement? We should still be waiting now. Tagged along, viewless and clueless, behind the rest of the field until a majority movement became apparent? Sweden began technical experiments with a 625-line system in 1947 and was followed by Italy in 1949, but the first regular 625 television broadcasts (in Federal Germany) did not start until the end of 1950. Prior to that (in July 1950) a meeting of the Television Study Group of the International Radio Consultative Committee (C.C.I.R.) in Geneva, attended by delegates from Belgium, Denmark, Italy, the Netherlands, Sweden, Switzerland, France, the U.S.A. and the U.K., established standards which were recommended for those countries wishing to adopt a 625-line system. These were endorsed together with three other systems on 405, 525 and 819 lines at the VIth Plenary Meeting of the C.C.I.R. in Geneva in the following year, but, and this point was made clear in our issue of August 1952, none of these systems was adopted as an international standard; nor has any been agreed upon to this day.

By the end of 1953 eleven countries in West Europe had either started broadcasting or were sending test transmissions on 625 lines, and Argentina, Turkey and Venezuela had also declared for this system. So we should have been pretty safe in starting a 625-line service in that year or even in 1950 without much risk, but we should have lost four valuable years. Years in which television engineers and technicians, whose skill and knowledge had been extended by radar and communications work during the war would have been disbanded, and years in which this country would have lagged instead of leading in the post-war development of television.

All these factors were seen clearly by the Tele-

vision Committee appointed in 1943 under the chairmanship of Lord Hankey to prepare plans for the reinstatement and development of the television service after the war. This report emphasizes the need for an international standard, and because no one had yet thought of the magic number 625 the established 525 American standard was considered. They gave two reasons for rejecting it: that the improvement in picture quality over the 405 was not significant, and the differences in mains and field frequency would involve more serious problems than a mere change in the number of lines. Wisely they decided not to defer the reopening of the television service "for the uncertain period required to give an opportunity of incorporating some fundamental improvement in the system" but to restart broadcasting with 405 lines "which had achieved a high degree of reliability and afforded consistently good entertainment value in the home." The inherent limitations of the 405-line system were squarely faced, and intensive research into a radically improved system with a line standard of the order of 1000 and with colour and stereoscopic effects was strongly urged to keep this country in the forefront of the television field. While we are awaiting this or a comparable radical improvement we enjoy what is in practice the world's best television service.

Belated Acknowledgment

WE apologize to our readers for what may have seemed a discourteous delay in thanking them for their congratulations and good wishes on the occasion of our Jubilee. It had been our intention to publish their letters, or at least some extracts from them in our June issue, but as they were still coming in from distant parts we delayed doing so. The file is now so voluminous that there is just not room in the journal to do justice to them all, and selection would, we feel, be invidious.

Our historical survey has evoked much reminiscence among our readers and the word nostalgia has been on everyone's lips (excepting "Free Grid's" who tells us that we have forgotten the original derivation and meaning of the word!). We claim his indulgence for the duration of these celebrations. They have been particularly pleasant for us, and we again thank our many friends for making them so.

Having, so to speak, crossed the line, we can now square away on our course with renewed confidence in the future.

Television Standards Conversion

REMOVING THE 10c/s FLICKER IN 50c/s-60c/s FIELD CONVERSIONS

CONVERSION of television pictures from one standard to another has been common practice for a number of years, and has made possible the Eurovision link. However, conversion of European standards, which all employ a 50c/s field frequency, to the 525-line 60c/s system in use in North America, and *vice versa*, has set a new problem. In addition to the relatively easily removed moiré pattern, caused by the interaction of closely related line-structures, a new type of picture deformation becomes apparent. The different field frequencies interact one with the other to produce a 10c/s amplitude modulation of the video signal, which appears as a flicker at this frequency, and which renders the converted picture intolerable to the viewer.

Equipment designed to overcome this problem has been developed by the B.B.C. Engineering Division and has already been used to handle recordings, for translation to the American standard, of the Paris Summit Conference and the wedding of H.R.H. Princess Margaret.

The principle of a standards converter is shown in diagrammatic form in Fig. 1. The incoming video signal is amplified and displayed on a high-quality cathode-ray tube which has an afterglow time constant of 7msec. A lens focuses the displayed picture on to the storage mosaic of a camera tube scanned at the rate corresponding to the new standard, the output of which is processed in a sync-pulse insertion and blanking unit. The signal emerging from this unit is the converted signal.

As has been mentioned, when the number of lines per field of the two standards under consideration are closely related the picture on the new standard is subject to moiré interference caused by the fact that the lines of the two systems will be at very slightly different angles to the horizontal. In practice this effect is removed by the addition of "spot wobble" to the displayed incoming picture of such an amplitude as to camouflage the line structure of each field.

The mechanism producing the 10c/s flicker is indicated in Fig. 2. The top curve is a graph of the brightness of a single displayed picture element plotted against time and it is assumed that the signal at this point is peak white. It will be seen that the

brightness increases to peak white as the element is scanned, once every 16.6msec, and that it then dies away exponentially. The time constant of this decay is, with the cathode-ray tube used, 7msec. The middle curve is the charge on the C.P.S. Emitron camera tube target, which in this case is being scanned at a 50c/s field frequency. The charge would increase linearly with time if display brightness were constant, but as the brightness of the display tube decays exponentially the charging curve of the target is also exponential.

The target charge increases in this way until the display tube element is rescanned. The camera tube element has not yet been neutralized by its scanning beam and continues to increase for a further 3.4msec, when it is discharged. It now commences to charge again, but at a lower rate, as the display tube element brightness has decayed from its peak level. The action continues in this manner until the fifth camera tube scan, when the two scans are once more coincident. If the peaks of the target charging curve are joined, a sawtooth type of waveform is obtained at a frequency of 10c/s, and this is proportional to the output of the camera tube. The signal is thereby amplitude modulated at 10c/s.

Removal of this flicker is effected by a pulse-sampling, manually adjusted amplitude compensator, followed by an automatic compensator which removes any flicker remaining after the signal has been subjected to the effect of the manually set circuit. The system, which is the subject of British Patent 801140 (T. C. Macnamara and A. M. Spooner), operates in the manner indicated in Fig. 3. The incoming video signal is passed through a low-pass filter which is switch-selected to pass the band of frequencies used by the incoming standard (3Mc/s for 405-line 50c/s standard). The next process is the insertion at the end of each line of the picture of a reference pulse which has a width of about 2% of the line period, and an amplitude of about 85% peak white. The pulse slightly overlaps the right-hand edge of a line of video signal and is apparent as a bright vertical stripe on the picture. The video signal with the reference pulse added is now amplified and displayed on the cathode-ray tube. The conversion process referred to earlier

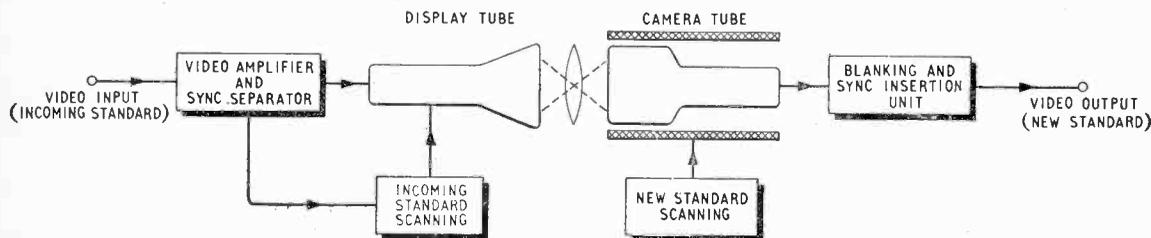


Fig. 1. The basic principle of a standards converter.

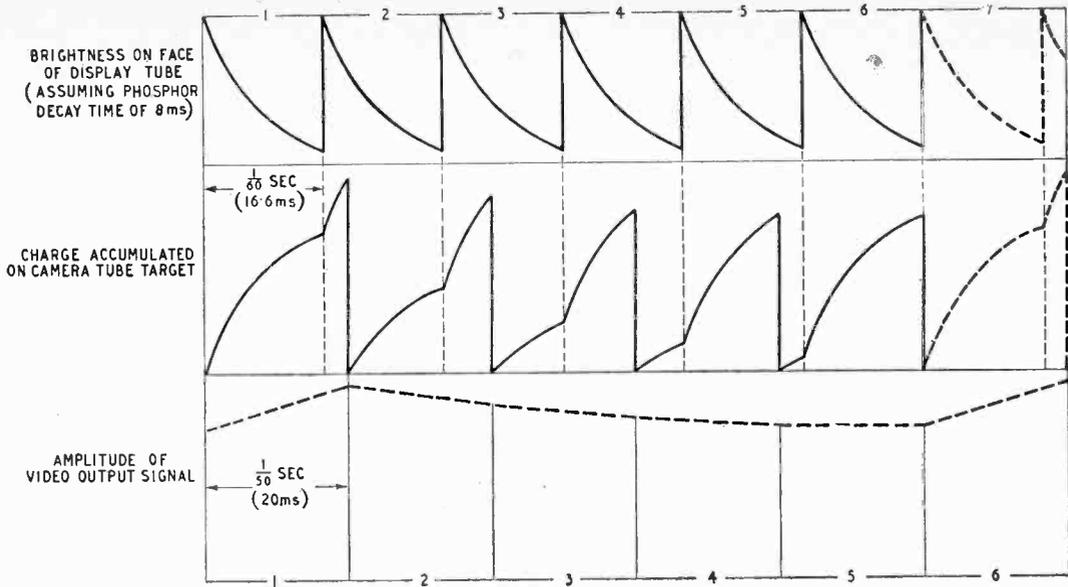
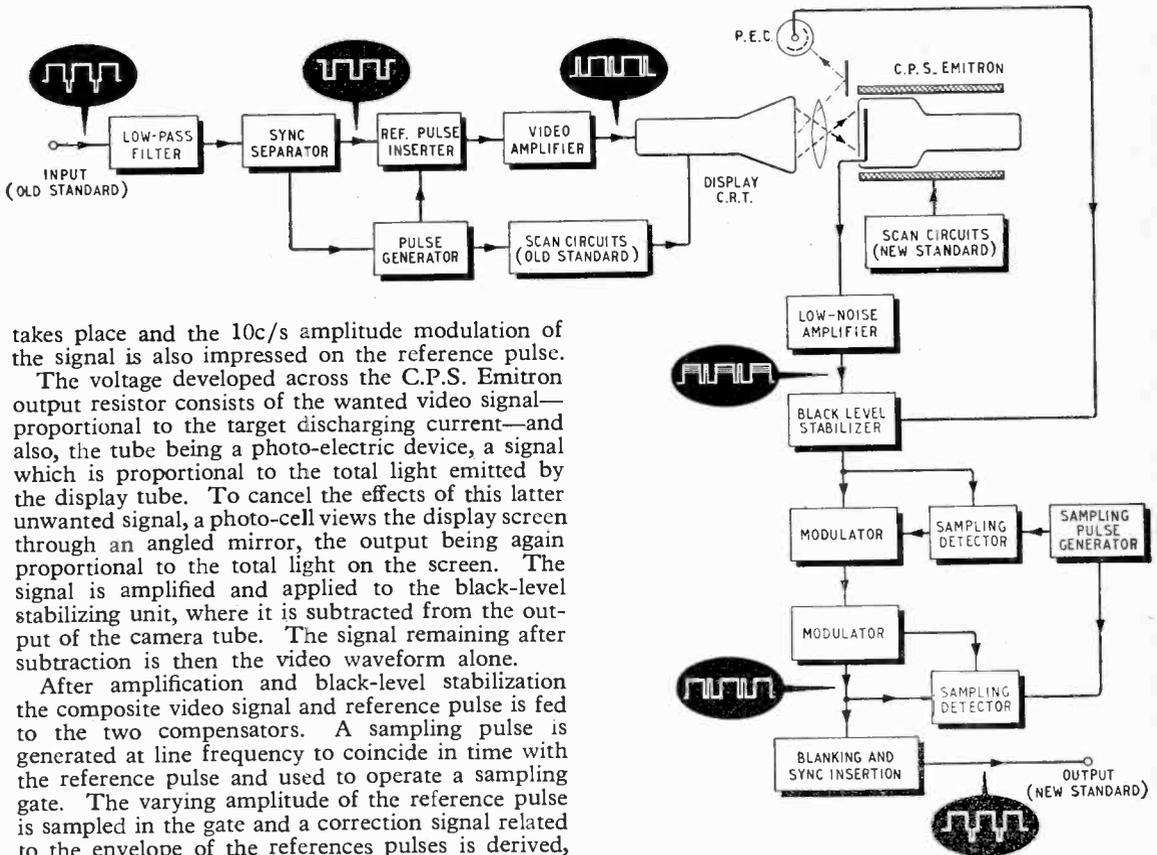


Fig. 2. The mechanism producing the 10c/s amplitude modulation of the video signal, in a conversion from 525 lines 60 fields/sec to 405 lines 50 fields/sec.

Fig. 3. Block diagram of B.B.C. 50c/s-60c/s converter, showing units concerned with 10c/s flicker removal. Waveforms shown are of peak white lines.



takes place and the 10c/s amplitude modulation of the signal is also impressed on the reference pulse.

The voltage developed across the C.P.S. Emitron output resistor consists of the wanted video signal—proportional to the target discharging current—and also, the tube being a photo-electric device, a signal which is proportional to the total light emitted by the display tube. To cancel the effects of this latter unwanted signal, a photo-cell views the display screen through an angled mirror, the output being again proportional to the total light on the screen. The signal is amplified and applied to the black-level stabilizing unit, where it is subtracted from the output of the camera tube. The signal remaining after subtraction is then the video waveform alone.

After amplification and black-level stabilization the composite video signal and reference pulse is fed to the two compensators. A sampling pulse is generated at line frequency to coincide in time with the reference pulse and used to operate a sampling gate. The varying amplitude of the reference pulse is sampled in the gate and a correction signal related to the envelope of the references pulses is derived,



The B.B.C. standards converter. From left to right: the flicker correction bay, the camera and display control unit with monitor, and the display pedestal including the camera and display tube.

this being used to drive a modulator which is in series with the signal path. The manual gain control adjusts the amplitude of the correction signal until the flicker is at minimum level. After this compensator the signal passes through a similar circuit which functions as an a.g.c. After passing through a modulator the signal feeds the sampling gate, which then applies the derived correction signal to the series modulator. The whole circuit is a feedback loop and is capable of reducing amplitude variations at

10c/s from 30% to less than 1%. The signal, then, first passes through a manually adjusted compensator, which reduces the level of modulation to a value which is within the range of control of the automatic circuit.

On leaving the two compensating circuits the signal is processed in a unit which inserts sync pulses and blanking intervals, and in which the reference pulses are removed. The signal is now converted to the new standard and ready for use.

BOOKS RECEIVED

A Textbook of Electricity, by H. G. Mitchell. A school textbook suitable for use up to advanced level G.C.E., and by University Scholarship candidates. A complete account of electric and magnetic phenomena is given, and the rationalized m.k.s. system of units is used throughout. A short description of technological applications is included, and the final chapters include discussions of atomic and nuclear physics, the quantum theory and a physical picture of wave-mechanics. Some 300 questions, taken from recent examination papers are set. Pp. 598; Illustrated. Methuen & Co., Ltd., 36, Essex Street, London, W.C.2. Price 25s.

V.H.F. Line Techniques, by C. S. Gledhill. Designed for both undergraduate and practising engineer, the book seeks to impress the advantages of the circle-diagram over the more traditional, analytical methods of transmission-line problem solution. Worked examples of typical problems are given, which enable the work to be used as a reference book. Pp. 60; Figs. 51. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 12s 6d.

How To Use Meters, by John F. Rider and Sol D. Prensky. The second edition of a practical handbook on the principles and operation of all types of meters.

The basic types of movement are described, and their use as voltage and current meters, with descriptions of more sophisticated instruments such as chopper electrometers and valve-voltmeters. Information is given on measurement of quantities in receivers and transmitters and a chapter is included on more sophisticated electronic measurements. Pp. 210; Figs. 181. John F. Rider Publisher, Inc., 116, West 14th Street, New York 11, N.Y. Price \$3.90.

Hi-Fi Amplifier Circuits, by E. Rodenhuis, translated by G. Du Cloux. For all who are interested in the design and construction of high-quality audio amplifiers. A chapter on general design considerations is followed by descriptions of several power amplifiers and pre-amplifiers, including a four-channel mixer. Pp. 105; Figs. 64. Philips' Technical Library. Obtainable from Cleaver Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 15s.

Boolean Algebra and its Applications, by J. E. Whitesitt. Introduction to algebra of logical deductions with particular reference to computer and switching circuit applications. Pp. 182; Figs. 100. Addison-Wesley Publishing Co., Inc., 10-15, Chitty Street, London, W.1. Price 51s.

TRANSISTOR PARAMETERS

By G. de VISME*, B.Sc.

DEFINITIONS AND INTER-RELATIONSHIPS

ANYONE who has glanced at the manufacturer's figures for transistor characteristics must have been bewildered, as I was, by their profusion. Figures are quoted for some or all of about thirty different quantities, with careful stipulations as to which of the three configurations (grounded base, grounded emitter or grounded collector) these figures relate to.

How easy-going seem those far-off days of thermionic valves, when only three figures appeared, namely g_m , R_a , and μ —and anyone who pursued a course at a Technical College would have learned at a very early stage that μ equals $g_m \times R_a$, so only two parameters were really needed!

It is the purpose of this article to sort out and relate the transistor parameters, beginning with a description of the transistor in terms of its static characteristics, and including one or two digressions which may be of interest.

Transistor Behaviour.—The simple transistor is basically a three-terminal active network. Very briefly its action is as follows: for suitable voltages between the electrodes, the current flowing into the emitter divides between the collector and base, with about 97% of it flowing to the collector and about 3% flowing to the base.

Variations of the voltages produce corresponding variations of these currents, and whilst the overall

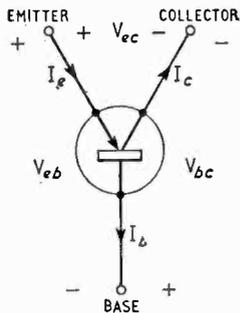


Fig. 1. Three voltage and three current variables for the transistor.

currents remain roughly in the above proportion, the incremental changes of each current depend on the incremental changes of voltage.

It is true to say, however, that a change of emitter current produces a roughly comparable change of collector current, whilst a change of base current is accompanied by a much larger change in collector current. For this reason, the base current is treated as an independent variable.

We may compare the above behaviour with that of a triode in which the anode current is slightly affected by the anode voltage, but very much more affected by the grid voltage, and so the grid voltage is usually treated as an independent variable.

We have six variables—three voltages and three currents—as shown in Fig. 1. Two suffixes are used for each voltage, their order defining which electrode is positive with respect to the other.

Two fundamental equations hold:—

$$V_{ec} = V_{eb} + V_{bc} \text{ and} \\ I_e = I_b + I_c$$

so in fact there are only four variables, which four being entirely a matter of choice.

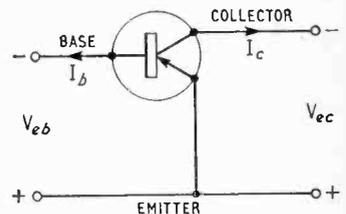


Fig. 2. Grounded-emitter configuration for the transistor.

If, out of these four, any two are fixed externally, the transistor fixes the other two. Thus if a certain voltage is applied between emitter and base, and another voltage between base and collector, the emitter-collector voltage is determined by the first equation above, and the three currents I_e , I_b and I_c are determined by the transistor and the second equation.

It is equally true to say, if a given emitter-collector voltage is applied, in order that a given base current shall flow, a unique value of emitter-base voltage will be needed, and so unique values of collector current and emitter current will flow. Once again, therefore, two variables, in this case V_{ec} and I_b , effectively determine the other four.

It is important to realize that, whilst the voltages are in a sense the "prime movers" and cause the currents to flow, this does not mean that we cannot regard a current as an independent variable—in fact, as we saw above, the base current is usually so considered.

Static Characteristics of a Transistor.—Since we have four separate variables, two of which are independent and two dependent, the characteristics of a transistor cannot be expressed by means of one set of curves, as can those of a valve. Two sets are needed, each incorporating either one voltage and two currents or two voltages and one current, the two sets together covering two currents and two voltages. Evidently a set incorporating the three voltages or the three currents is useless, as these are related by the fundamental equations anyway.

Which variables to plot against which is once

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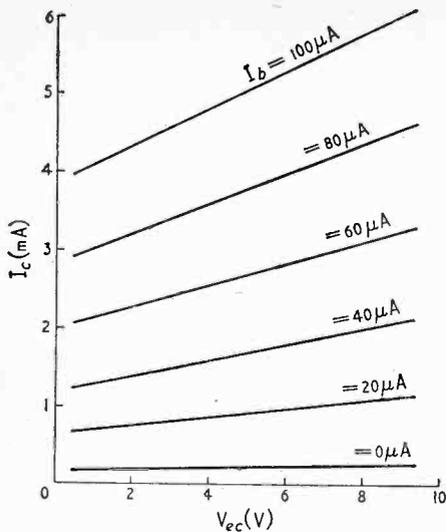


Fig. 3. Typical output curves for a transistor in the grounded-emitter configuration.

again a matter of convenience. The following table gives a few of the possibilities:—

X axis (first independent variable)	V_{ec}	V_{ec}	I_b	I_b	V_{bc}	V_{bc}	...
Parameter (second independent variable)	I_b	I_b	V_{ec}	V_{ec}	I_b	I_b	...
Y axis (dependent variable)	I_c	V_{eb}	I_c	V_{eb}	I_e	V_{eb}	...

There are 108 permissible sets in all. In those given here, I_b has been chosen as an independent variable for the reason given above. A bracketed pair supplies the whole information about the transistor's behaviour and consequently, given one such pair, it is possible to plot from it any of the remaining 106 sets of curves.

It is possible to choose the variables in such a way that both the sets needed may be plotted on one sheet of graph paper, for example:—

X axis	I_c	I_c
Parameter	I_b	I_b
Y axis	V_{ec}	V_{eb}

but although the first of these is a re-arrangement of the "output characteristic" in the grounded-emitter configuration, the second set is of little practical value.

Four sets of curves are usually supplied though only two are necessary. Since the transistor is usually used in the grounded-emitter configuration as in Fig. 2, the four sets are plotted for this configuration. For the reason set out above, I_b is treated as an independent variable in each set. Also, to enable the location of a working point, one of the sets relates the output current (y axis) with the output voltage (x axis). The four sets are called "output", "voltage feedback", "current transfer" and "input" characteristics, and are

the first four sets of curves respectively in the above table.

Typical output curves are shown in Fig. 3. They closely resemble those of a pentode valve, except that the parameter I_b takes the place of the corresponding parameter V_g .

By what has been said above, analogous characteristics for either of the other two configurations (grounded base and grounded collector—see Figs. 4a and b) may be derived from these.

Transistor Parameters.—Three quite separate sets of parameters are defined expressing the behaviour of a transistor for small signal amplification. These are: (i) The Hybrid, or "h", parameters; (ii) The T-network parameters; and (iii) The Mullard parameters.

Each of these sets is in turn subdivided into three sets—undashed, dashed and double-dashed—respectively expressing the small-signal behaviour of the transistor in the grounded-base, grounded-emitter and grounded-collector configuration.

Three other quantities a , a' , and a'' are further defined, rather loosely called "current amplification" (dI_{out}/dI_{in}), for the three configurations.

Hybrid Parameters.—To define the h-parameters, the transistor is regarded as an active four-terminal

network, the lower pair of terminals being connected together and joined to the "common" electrode, i.e., base, emitter or collector (see Fig. 5). In this diagram I_1 signifies the input current, I_2 the output current, V_1 the input voltage and V_2 the output voltage.

Fixing any two of these quantities automatically

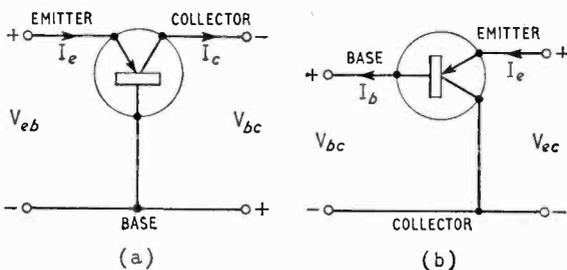


Fig. 4. (a) Grounded-base and (b) grounded-collector configuration for the transistor.

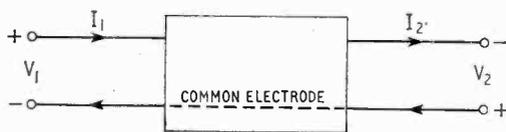


Fig. 5. Four-terminal network treatment of a transistor.

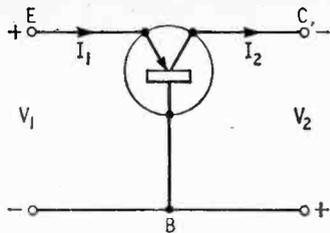


Fig. 6. Four-terminal network treatment of a transistor in the grounded-base configuration.

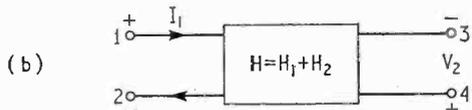
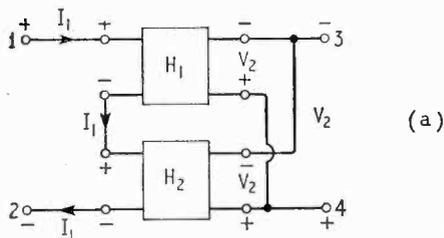


Fig. 7. Two four-terminal networks connected as in (a) can be reduced to a single four-terminal network as in (b) whose hybrid parameters are each the sum of the two corresponding hybrid parameters of the two four-terminal networks of (a).

fixes the other two, as was explained above. Thus if we take I_1 and V_2 as independent variables, we may express the dependent variables V_1 and I_2 in terms of these as follows:—

$$dV_1 = \left(\frac{\delta V_1}{\delta I_1} \right)_{V_2} dI_1 + \left(\frac{\delta V_1}{\delta V_2} \right)_{I_1} dV_2 \text{ and}$$

$$dI_2 = \left(\frac{\delta I_2}{\delta I_1} \right)_{V_2} dI_1 + \left(\frac{\delta I_2}{\delta V_2} \right)_{I_1} dV_2$$

For small increments, the partial differential coefficients may be considered constant, so the equations may be re-written.—

$$dV_1 = h_{11}dI_1 - h_{12}dV_2 \text{ and}$$

$$dI_2 = -h_{21}dI_1 + h_{22}dV_2$$

where h_{11} , h_{12} , h_{21} and h_{22} are the "hybrid parameters". The name arises from the fact that h_{11} has dimensions of resistance, h_{22} has dimensions of conductance, while h_{12} and h_{21} are pure numbers. The negative signs are conventional.

Actually these symbols represent the parameters for the transistor in the grounded-base configuration (see Fig. 6), and it is easily seen, by considering the action of a transistor, that h_{11} is positive, h_{12} is also

positive since $\left(\frac{\delta V_1}{\delta V_2} \right)_{I_1}$ is negative, h_{21} is negative

since $\left(\frac{\delta I_2}{\delta I_1} \right)_{V_2}$ is positive, and h_{22} is positive.

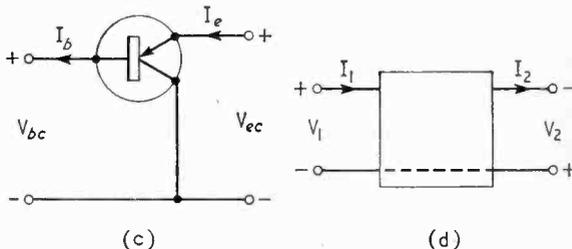
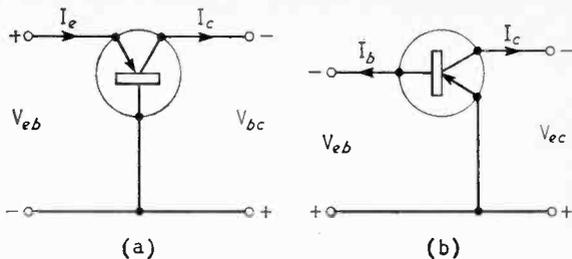


Fig. 8. (a), (b) and (c) Three configurations of a transistor and (d) four-terminal network treatment of a transistor.

Corresponding h -parameters for the grounded-emitter and grounded-collector configurations are defined by exactly the same equations, but the "h"s are dashed and double-dashed respectively, and have correspondingly different values.

An interesting property of hybrid parameters follows from their definition. If two four-terminal networks, having sets of parameters H_1 and H_2 , are connected as shown in Fig. 7(a), they can be reduced to a single four-terminal network whose four parameters, forming a set H , are the sum of the corresponding parameters of sets H_1 and H_2 , as shown in Fig. 7(b).

Sinusoidal Voltages and Currents.—The equations may be re-written:—

$$V_1 = h_{11}I_1 - h_{12}V_2 \text{ and}$$

$$I_2 = -h_{21}I_1 + h_{22}V_2$$

where V_1 , I_1 , V_2 and I_2 are complex numbers ("rotating vectors") representing sinusoids of small amplitude.

For low frequencies, the coefficients h_{11} , etc., are real numbers. For higher frequencies, it is necessary to regard them as complex functions of frequency.

Relation Between h -Parameters for Different Configurations.—Figs. 8(a), (b) and (c) show the transistor connected in its three possible configurations, along with applied voltages and currents, while Fig. 8(d) shows the transistor treated as a four-terminal network with its input and output voltages and currents.

Comparing the diagrams 8(a), (b) and (c) in turn with (d), we have, for the grounded-base configuration:—

$$V_{eb} = V_1, I_e = I_1, I_c = I_2 \text{ and } V_{bc} = V_2$$

$$\text{and therefore}$$

$$dV_{eb} = h_{11}dI_e - h_{12}dV_{bc} \text{ and}$$

$$dI_c = -h_{21}dI_e + h_{22}dV_{bc}$$

For the grounded-emitter configuration we have:—

$V_{eb} = -V_1$, $I_b = -I_1$, $I_c = I_2$, and $V_{ec} = V_2$ and therefore

$$-dV_{eb} = -h'_{11}dI_b - h'_{12}dV_{ec} \text{ and}$$

$$dI_c = h'_{21}dI_b + h'_{22}dV_{ec}$$

For the grounded-collector configuration we have:—

$V_{bc} = V_1$, $I_b = -I_1$, $I_e = -I_2$, and $V_{ec} = -V_2$ and therefore

$$dV_{bc} = -h''_{11}dI_b + h''_{12}dV_{ec} \text{ and}$$

$$-dI_e = h''_{21}dI_b - h''_{22}dV_{ec}$$

We also have the two Kirchhoff equations

$$V_{ec} = V_{eb} + V_{bc} \text{ and}$$

$$I_e = I_b + I_c$$

and we can therefore find all the members of any one set of parameters in terms of those of any other set.

We will derive, as a demonstration, h'_{21} and h'_{22} in terms of h -parameters, merely quoting the remainder.

$$dV_{eb} = h_{11}dI_e - h_{12}dV_{bc}$$

$$= h_{11}dI_b + h_{11}dI_c - h_{12}dV_{ec} + h_{12}dV_{eb}$$

$$= h_{11}dI_b/(1 - h_{12}) + h_{11}dI_c/(1 - h_{12}) - h_{12}dV_{ec}/(1 - h_{12})$$

$$dI_c = -h_{21}dI_e + h_{22}dV_{bc}$$

$$= -h_{21}dI_b - h_{21}dI_c + h_{22}dV_{ec}$$

$$= -h_{21}dI_b/(1 + h_{21}) + h_{22}dV_{ec}/(1 + h_{21}) - h_{22}dV_{eb}/(1 + h_{21})$$

Therefore

$$dI_c = -h_{21}dI_b - h_{21}dI_c + h_{22}dV_{ec} - h_{11}h_{22}dI_b/(1 - h_{12}) - h_{11}h_{22}dI_c/(1 - h_{12}) + h_{12}h_{22}dV_{ec}/(1 - h_{12})$$

$$= \left[\frac{-h_{21} - h_{11}h_{22}/(1 - h_{12})}{1 + h_{21} + h_{11}h_{22}/(1 - h_{12})} \right] dI_b$$

$$+ \left[\frac{h_{22} + h_{12}h_{22}/(1 - h_{12})}{1 + h_{21} + h_{11}h_{22}/(1 - h_{12})} \right] dV_{ec}$$

Comparing this with

$$dI_c = h'_{21}dI_b + h'_{22}dV_{ec}$$

we see that

$$h'_{21} = (h_{12}h_{21} - h_{11}h_{22} - h_{21})/D \text{ and } h'_{22} = h_{22}/D$$

where $D = (1 + h_{21})(1 - h_{12}) + h_{11}h_{22}$

Summarizing the results, we have:—

$$h'_{11} = h_{11}/D, h'_{22} = h_{22}/D, h'_{12} = 1 - (1 + h_{21})/D$$

and $h'_{21} = (1 - h_{12})/D - 1$

$$h''_{11} = h_{11}/D, h''_{22} = h_{22}/D, h''_{12} = (1 + h_{21})/D$$

and $h''_{21} = -(1 - h_{12})/D$

We can write down certain simple relations, for example:—

$$h'_{11} = h''_{11}, h'_{22} = h''_{22}, h'_{12} + h''_{12} = 1,$$

$$h'_{21} + h''_{21} = -1 \text{ and } (h'_{11}h'_{22} - h'_{12}h'_{21}) =$$

$$(h_{11}h_{22} - h_{12}h_{21}) (h''_{11}h''_{22} - h''_{12}h''_{21})$$

Measurement of h -Parameters.—From the equations

$$dV_{eb} = h'_{11}dI_b + h'_{12}dV_{ec} \text{ and}$$

$$dI_c = h'_{21}dI_b + h'_{22}dV_{ec}$$

we have

$$h'_{11} = \left(\frac{\delta V_{eb}}{\delta I_b} \right)_{V_{ec}}$$

characteristic,

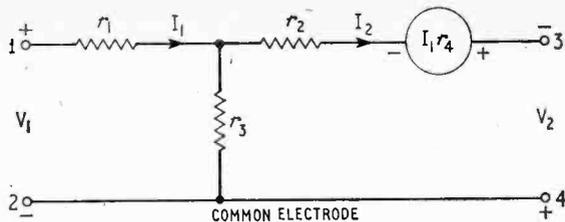


Fig. 9. T-network representation of a transistor.

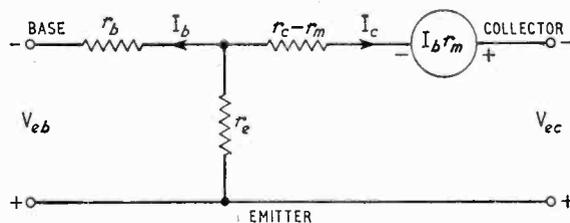


Fig. 10. T-network representation of a transistor in the grounded-emitter configuration.

$h'_{12} = \left(\frac{\delta V_{eb}}{\delta V_{ec}} \right)_{I_b}$, which is the slope of the voltage feedback characteristic,

$h'_{21} = \left(\frac{\delta I_c}{\delta I_b} \right)_{V_{ec}}$, which is the slope of the current transfer characteristic, and

$h'_{22} = \left(\frac{\delta I_c}{\delta V_{ec}} \right)_{I_b}$, which is the slope of the output characteristic.

All of these are in fact positive, as can be seen by considering the transistor action.

We have to calculate the values of the grounded-base and grounded-collector parameters from these slopes, using the relations quoted above.

One very important point must be noted: the relations calculated above hold only for increments about the same working point in the three configurations. Thus, if the values of h and h' are quoted for $V_{ec} = -2V$ and $I_c = 1mA$, we must remember that " $V_{ec} = -2V$ " in the grounded-base configuration means " $V_{bc} = 2V$ ", whilst " $V_{ec} = -2V$ " in the grounded-emitter configuration means " $V_{ec} = 2V$ ", so in fact the values of h and h' are quoted for slightly different working points since V_{ec} usually exceeds V_{bc} by about 0.2V.

Hybrid parameters must be regarded as the fundamental parameters describing the behaviour of any four-terminal network (active or passive, linear or non-linear, frequency sensitive or otherwise). They are somewhat too academic, however, for an electronic engineer seeking to analyze transistor circuits.

T-Network Parameters.—When considering the behaviour of a transistor in circuit, it is convenient to represent it as a T-network consisting of three resistances and one active element, as shown in Fig. 9.

The four parameters (clearly four, and only four,

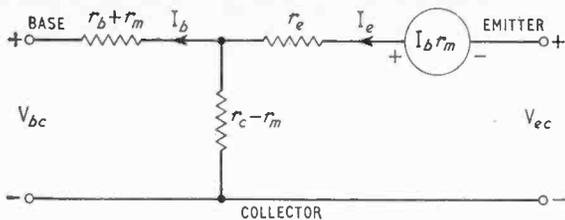


Fig. 11. T-network representation of a transistor in the grounded-collector configuration.

For the grounded-collector configuration, the coefficients of I_1 and V_2 in the equations are double-dashed, and so

$$r_1 = (h''_{11}h''_{22} - h''_{12}h''_{21} - h''_{12})/h''_{22}, \dots \text{ and}$$

$$r_4 = -(h''_{12} + h''_{21})/h''_{22}$$

Again, substituting h -parameters for h'' ones and using the relations above for r_b, r_e, r_c and r_m , we get:—

$$r_1 = r_b + r_m, r_2 = r_e, r_3 = r_c - r_m \text{ and } r_4 = r_m$$

so the equivalent T-network becomes as shown in Fig. 11.

One advantage of the T-network representation is immediately apparent—the elements of the equivalent circuits for the grounded-emitter and grounded-collector configurations are extremely simply related to those for the grounded-base configuration.

Other Equivalent Circuits.—The representation above included three passive and one active element. Four separate constants are required; one therefore asks oneself if a representation such as Fig. 12, containing four separate passive elements, will do. If however one forms equations for this network in the form $V_1 = h_{11}I_1 - h_{12}V_2$ and $I_2 = -h_{21}I_1 + h_{22}V_2$, where the h coefficients are functions of the four resistances, one finds that $h_{21} = h_{12}$. This representation therefore only provides us with three separate h -parameters and cannot therefore represent a transistor. We could have predicted this from the theorem of reciprocity, a theorem which applies in the case of passive, but not active, networks.

However, other representations are possible. All that is required of a representation is that we should be able to form two equations of the form shown above in which all four h -parameters are different. One such alternative representation containing two passive and two active elements is shown in Fig. 13. The constants of this circuit can, of course, readily be worked out in terms of h or any other set of parameters. In particular, the factor “ b ” for the grounded-base configuration is very nearly equal to 1.

“ a ” and “ a dashed”.—As was mentioned at start, a and a' are two additional parameters loosely termed “current gain” in grounded-base and grounded-emitter configurations, respectively.

Current gain under what conditions?

With the output short-circuited to a.c., i.e., with $dV_2 = 0$, $a = (dI_c/dI_e)$ in the grounded-base configuration

$$= -h_{21} = (r_b + r_m)/(r_b + r_e)$$

while $a' = (dI_c/dI_b)$ in the grounded-emitter configuration

$$= h'_{21} = (r_m - r_e)/(r_e + r_c - r_m)$$

and there is no relation whatever between them.

On the other hand, if the input is short-circuited

separate constants will be required whatever system of parameters is adopted) in this case are r_1, r_2, r_3 and r_4 .

The equations relating V_1 with I_1 and V_2 , and I_2 with I_1 and V_2 , are respectively:—

$$V_1 = (r_1r_2 + r_1r_3 + r_2r_3 - r_3r_4)I_1/(r_2 + r_3) - r_3V_2/(r_2 + r_3)$$

$$I_2 = (r_3 + r_4)I_1/(r_2 + r_3) + V_2/(r_2 + r_3)$$

By comparing these equations with those relating the same quantities in terms of h -parameters, we obtain the following relations between the resistances in this representation and the h -parameters:—

$$h_{11} = r_1 + r_3(r_2 - r_4)/(r_2 + r_3), h_{12} = r_3/(r_2 + r_3), h_{21} = -(r_3 + r_4)/(r_2 + r_3) \text{ and } h_{22} = 1/(r_2 + r_3)$$

For the grounded-base configuration, terminal 1 is the emitter and r_1 is called the emitter resistance r_e ; terminal 2 is the collector and r_2 is called the collector resistance r_c , and terminals 3 and 4 are the base and r_3 is called the base resistance r_b . Resistance r_4 is usually denoted r_m . So, in this configuration the above relations yield:—

$$r_b = r_3 = h_{12}/h_{22}, r_c = r_2 = (1 - h_{12})/h_{22}, r_e = r_1 = (h_{11}h_{22} - h_{12}h_{21} - h_{12})/h_{22}, \text{ and } r_m = r_4 = -(h_{12} + h_{21})/h_{22}$$

For the grounded-emitter configuration similar equations apply, except that the coefficients of I_1 and V_2 are dashed, yielding therefore:—

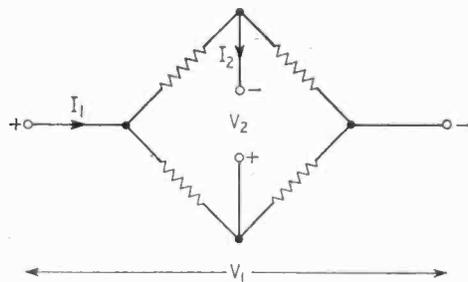
$$r_1 = (h'_{11}h'_{22} - h'_{12}h'_{21} - h'_{12})/h'_{22}, \dots \text{ and}$$

$$r_4 = -(h'_{12} + h'_{21})/h'_{22}$$

Substituting h -parameters for h' ones and using the relations derived for r_b, r_c, r_e and r_m , we obtain:

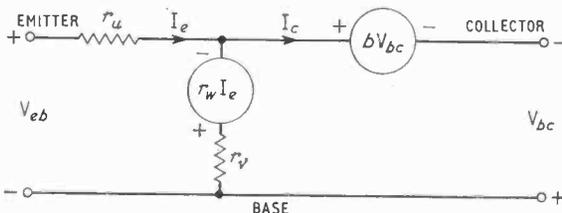
$$r_1 = r_b, r_2 = r_c - r_m, r_3 = r_e \text{ and } r_4 = -r_m$$

giving the T-network representation as shown in Fig. 10.



Above: Fig. 12. Four passive elements as shown cannot fully represent a transistor.

Right: Fig. 13. Possible transistor representation containing two passive and two active elements.



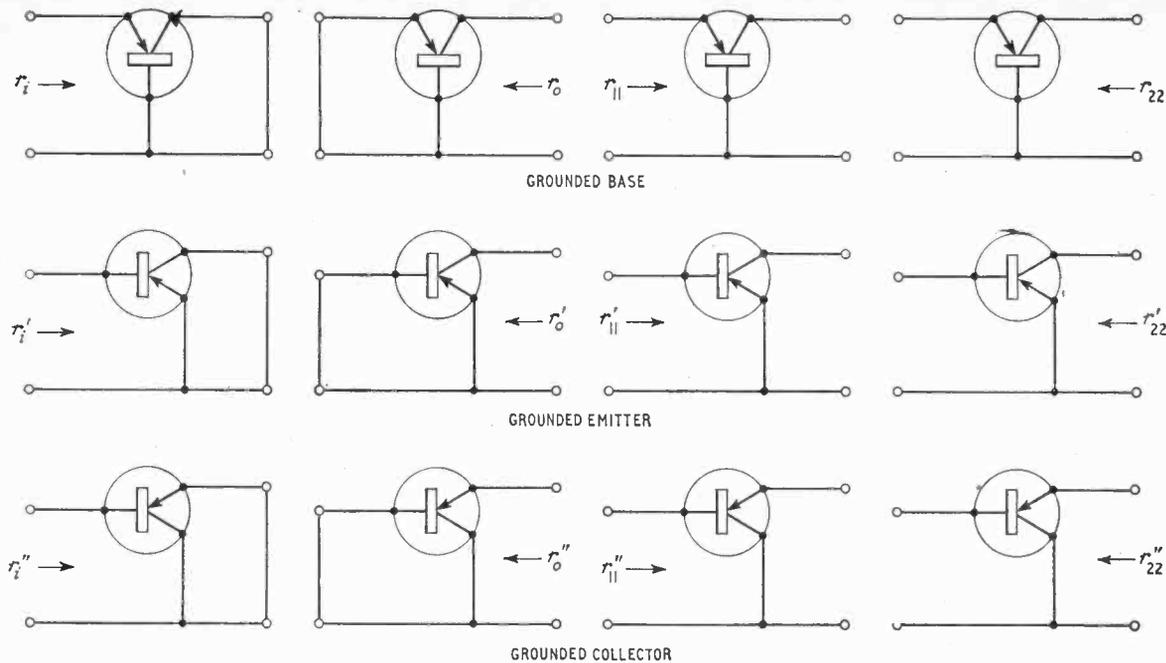


Fig. 14. Definition of the Mullard transistor parameters.

to a.c., i.e., $dV_1 = 0$ and the currents are varied by varying the output voltage, $a = (dI_c/dI_e)$ in the grounded-base configuration

$$= (h_{11}h_{22} - h_{12}h_{21})/h_{12} = (r_b + r_e)/r_b$$

and $a' = (dI_c/dI_b)$ in the grounded-emitter configuration

$$= -(h'_{11}h'_{22} - h'_{12}h'_{21})/h'_{12} = -(r_b + r_e)/r_e$$

$$= a/(1 - a)$$

We note that a in this case is greater than 1, and so a' is negative. This latter case is *not* equivalent to using the transistor the reverse way round.

When treating a transistor as a T-network, we find a quoted as r_m/r_c and a' given as $r_m/(r_c - r_m) = a/(1 - a)$. In fact, in order that the current gain may be r_m/r_c in the grounded-base configuration, it is necessary to measure it with a collector load of $r_b(1 - r_e/r_m)$ in circuit (about -17Ω !), whilst to get a current gain of $r_m/(r_c - r_m)$ in the grounded-emitter configuration, you would need a collector load of $(r_c r_e/r_m)$, that is, about 18Ω .

In view of the constants of a normal transistor, this ambiguity is perhaps rather academic. Taking r_b as 700Ω , r_c as $1\text{ M}\Omega$, r_e as 18Ω and r_m as $976\text{ k}\Omega$, the short-circuit current gain in the grounded-base configuration $= (r_b + r_m)/(r_b + r_e) = 976.7/1000.7$, whilst the usual expression, r_m/r_c , for current gain in this configuration comes to 0.976 .

Likewise, the short-circuit current gain in the grounded emitter configuration $= (r_m - r_e)/(r_e + r_c - r_m) = 975.982/24.018$, whilst the usual expression, $r_m/(r_c - r_m)$, for current gain in this configuration comes to $976/24$.

However, it is as well to be on one's guard when discussing current gain.

Mullard Parameters.—Mullard parameters are the input and output resistances of a transistor with output and input respectively open-circuited and short-circuited to a.c.

The symbols for the grounded-base parameters are r_i , r_o , r_{11} and r_{22} . Corresponding dashed and double-dashed symbols are defined for the other two configurations. The parameters are defined in Fig. 14.

Mullard parameters perhaps betray the influence of the electrical engineer, who tends to define the properties of all his machinery in terms of its open and short circuit impedances or their equivalent, but they have the great advantage of being *directly measurable*. A large inductance is used to provide an open circuit to a.c. if a d.c. path is required, and a large condenser is used to provide a short circuit to a.c. where a d.c. open circuit is required.

Mullard parameters, however, suffer from one vital limitation. Unlike the other two sets of parameters, they fail in themselves to give all the properties of the transistor.

The reason is very simple. Consider for example the grounded-base configuration:—

r_i = input resistance with output short-circuit to a.c., i.e. with $dV_2 = 0$,

$$= h_{11}$$

r_o = output resistance with input short-circuit to a.c., i.e. with $dV_1 = 0$,

$$= h_{11}/(h_{11}h_{22} - h_{12}h_{21})$$

r_{11} = input resistance with output open-circuit to a.c., i.e. with $dI_2 = 0$,

$$= (h_{11}h_{22} - h_{12}h_{21})/h_{22}$$

r_{22} = output resistance with input open-circuit to a.c., i.e. with $dI_1 = 0$,

$$= 1/h_{22}$$

It is seen at once that $r_i r_{22} = r_o r_{11}$.

In the same way, similar relations may be obtained for the other two configurations.

Thus, although you can measure *four* constants of the transistor, you only obtain three separate

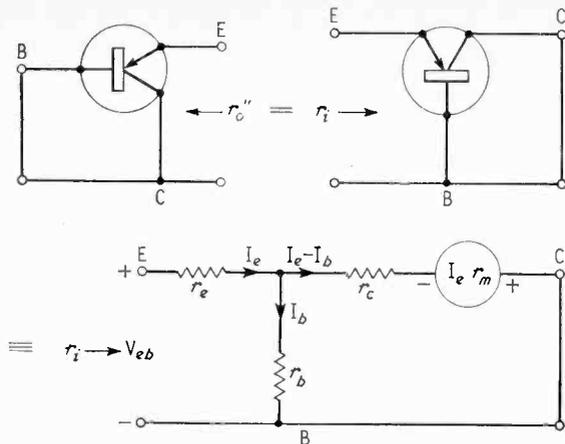


Fig. 15. Equivalent circuits of a transistor using Mullard and T-network parameters.

pieces of information about it; it is therefore necessary to measure one *other* property of the transistor, for instance the short-circuit current gain in the grounded-emitter configuration, h'_{21} .

Be that as it may, Mullard parameters are defined, and can be very easily related to the other sets of parameters. We limit ourselves to a derivation of only one of these relations to show the method:— r'_{o} in terms of the T-network parameters.

Fig. 15 gives the equivalent circuits, from which we have:—

$$V_{eb} = r_e I_e + r_b I_b = r_e I_e + r_c (I_e - I_b) - r_m I_e$$

Therefore

$$I_b = I_e (r_c - r_m) / (r_b + r_c)$$

Therefore

$$V_{eb} = I_e (r_e + r_b (r_c - r_m) / (r_b + r_c))$$

and so

$$V_{eb} / I_e = r_i = r_o'' = r_e + r_b (r_c - r_m) / (r_b + r_c)$$

We give a table of various parameters in terms of h'_{21} and the Mullard parameters for the grounded-emitter configuration, since the latter are those most easily measured:—

T-network Parameters

$$r_b = [(1 + h'_{21}) r'_{11} - r'_i] / h'_{21}, r_c = (1 + h'_{21}) r'_{22}, r_e = (r'_i - r'_{11}) / h'_{21} \text{ and } r_m = h'_{21} r'_{22} - (r'_i - r'_{11}) / h'_{21}$$

Grounded-Base Mullard Parameters

$$1/r_i = (1 + h'_{21}) / h'_{21} r'_o + (1 + h'_{21}) / r'_i - 1/h'_{21} r'_{22}, r_o = r'_{o} r'_{11} = r'_{11} \text{ and } r_{22} = r'_{o} r'_{11} (1/r'_i) \text{ (q.v.)}$$

Grounded-Collector Mullard Parameters

$$r''_{11} = r'_i, r''_{o} = r_i \text{ (q.v.)}, r''_{11} = r_{22} \text{ (q.v.) and } r''_{22} = r'_{22}$$

Grounded-Base h-parameters

$$h_{11} = r'_i (r'_{22} / r_{22}) \text{ (q.v.)}, h_{12} = 1 - (1 + h'_{21}) (r'_{22} / r_{22}) \text{ (q.v.)}, h_{21} = -(h'_{21} + (r'_i / r'_o)) (r'_{22} / r_{22}) \text{ (q.v.) and } h_{22} = 1 / r_{22} \text{ (q.v.)}$$

Grounded-Emitter h-parameters

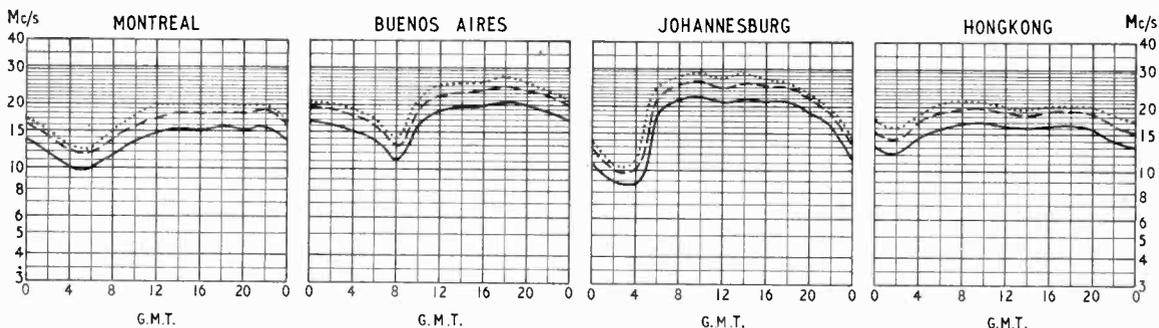
$$h'_{11} = r'_i, h'_{12} = (r'_i - r'_{11}) / h'_{21} r'_{22} \text{ and } h'_{22} = 1 / r'_{22}$$

Grounded-Collector h-parameters

$$h''_{11} = r'_i, h''_{12} = 1 - h'_{12} \text{ (q.v.)}, h''_{21} = -(1 + h'_{21}) \text{ and } h''_{22} = 1 / r'_{22}$$

Conclusion.—The whole of this article has been written around the transistor and a number of approximations may therefore be made by reason of its nature. The treatment, however, has been quite general and is therefore equally applicable to any quasi-linear active four-terminal network.

SHORT-WAVE CONDITIONS Prediction for June



THE full-line curves indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during June.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

- FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME
- PREDICTED MEDIAN STANDARD MAXIMUM USABLE FREQUENCY
- FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

WORLD OF WIRELESS

Stereo Broadcasting

ON April 20th the U.S. Federal Communications Commission authorized the introduction of f.m. multiplex stereo broadcasting from June 1st. The technical standards approved are a combination of proposals put forward by the Zenith Radio Corp. and General Electric. Other systems investigated by the American Electronic Industries Association at the request of the F.C.C. included those of Crosby Teletronics Corp., Multiplex Development Corp., Calbest Electronics Co. and also the E.M.I. Percival system (see *W.W.* November, 1958).

The approved system, which is fully compatible with single-channel f.m. broadcasting, is f.m./a.m. with the sub-carrier amplitude modulated.

New F.M. Stations

WORK is well advanced on the first two of the ten additional v.h.f. sound broadcasting stations announced by the B.B.C. in 1959. They both share sites with existing television stations—at Londonderry, Northern Ireland, and Les Platons, Jersey—and their directional aerials will be erected on the stations' television masts.

Both stations are planned to be brought into operation during this summer. The Londonderry station, which will have a mean e.r.p. of 5.6 kW, will radiate on 88.3 Mc/s (Light), 90.5 Mc/s (Third), and 92.7 Mc/s (Home). Les Platons, which will have a mean e.r.p. of 3.1 kW, will transmit on 91.1 Mc/s (Light), 94.45 Mc/s (Third), and 97.1 Mc/s (Home). At Les Platons the programmes will be received by radio from either the North Hessary Tor or Rowridge v.h.f. stations.

Technical Writing Scheme

MODIFICATIONS have been made to the Technical Writing Award Scheme which is now jointly sponsored by the Radio Industry Council, the Electronic Engineering Association and the Electronic Valve and Semi-Conductor Manufacturers' Association. In future the number of annual awards will be increased from six to eight and their value increased from 25 to 30 guineas each. Also some of them will be awarded for purely technical articles in addition to those made for articles of "commercial or interpretative merit."

The judges for 1961 will be H. E. F. Taylor (E.E.A.), who is chairman, B. C. Brookes (University College, London), A. H. Cooper (E.M.I.), F. Jeffery (Murphy), Professor C. W. Oatley (Cambridge University), G. Reeves (A.E.I.), and Dr. R. C. G. Williams (Philips).

Band V Colour

COLOUR transmissions on 625 lines are to be radiated experimentally in Band V by the B.B.C. from the Crystal Palace station. E.M.I. Electronics

are carrying out the necessary modifications to the 10-kW transmitter which was used for the 405- and 625-line monochrome test transmissions in Band V during 1957 and 1958. No date has yet been announced for these transmissions nor has it been stated whether the sense of vision modulation will be positive or negative or if a.m. or f.m. will be used for sound. It is understood that an 8 Mc/s bandwidth will be employed.

The P.M.G., in reply to a question in the House on May 10th, reiterated his decision not to accede to the request of the B.B.C. for a limited service of colour television on 405 lines.

U.H.F. Television in Germany

WEST GERMANY'S first regular u.h.f. television service was inaugurated by Hesse Radio, Frankfurt, on May 1st. Other West German broadcasting organizations are planning to start u.h.f. services in June. Hesse Radio is using some of the 30 u.h.f. stations set up by the Government in preparation for the start of the "Adenauer" network, which, it will be remembered, was finally banned by a decision of the Federal Court earlier in the year.

A second programme is being introduced by each of the broadcasting organizations on u.h.f., but it is planned to combine their operations from June 1962 into a network with a proportion of local programmes.

Italy's second TV service is scheduled to come into operation at the beginning of November. It will be operated by the national broadcasting organization—Radiotelevisione Italiana (RAI)—whose present TV network totals nearly 400 stations, the majority of which are low-power relay transmitters. About 20% of last year's income of RAI was from advertising which is carried on by both the sound and television services.

Dual TV Standards.—France, which has used the 819-line standard for its television service since 1950, is introducing the 625-line standard for its second service scheduled to start in June next year in the Paris region. Stations will operate in Band IV (470-582 Mc/s).

Plastics Exhibition.—Over 350 U.K. and overseas manufacturers of plastics materials, finished products and machinery will be exhibiting at the biennial International Plastics Exhibition which opens at Olympia, London, on June 21st for 10 days. A three-day convention (June 26th-28th) is being held in conjunction with the Exhibition and admission to both is by ticket obtainable free from *British Plastics* (Dorset House, Stamford Street, London, S.E.1), which, with the co-operation of the British Plastics Federation, is organizing the show.

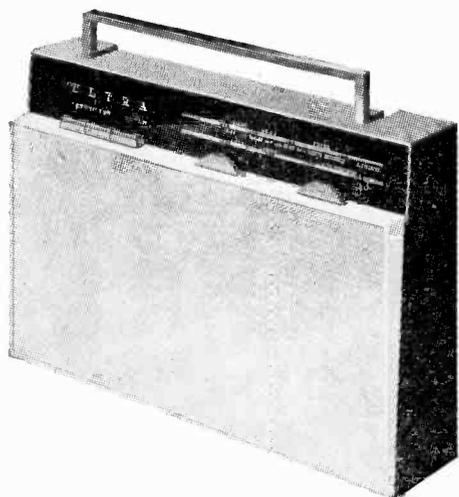
Berlin Radio Show.—The German national radio and television show is to be held for the first time for 22 years in Berlin from August 25th to September 3rd. There will be 150 exhibitors in the 13 halls in the exhibition grounds at the Funkturm in West Berlin. The Federal Post Office is issuing a special 20-pfennig stamp to mark the occasion.

B.R.E.M.A. Council.—The new council of the British Radio Equipment Manufacturers' Association consists of the following firms, whose representatives' names are in parentheses:—A. J. Balcombe (E. K. Balcombe), British Radio Corporation (F. W. Perks), Bush Radio (G. Darnley-Smith), Ferguson Radio Corporation (S. T. Holmes), General Electric Co. (M. M. Macqueen), Kolster-Brandes (E. P. Wethey), Murphy Radio (A. P. Power), Perdio (Viscount Suidale), Philips Electrical (A. L. Sutherland), Radio and Allied Industries (R. H. Pengelly), Rediffusion Vision Service (M. Exwood), and Ultra Radio and Television (E. E. Rosen). A. L. Sutherland is again chairman of the association.

British Wireless Dinner Club.—At the 38th annual dinner of the Club on April 14th Air Marshal Sir Leslie Dalton-Morris, was elected president in succession to Admiral Sir Alan Scott-Moncrieff. Sir Leslie was Air Officer C.-in-C., Signals Command R.A.F. until his appointment earlier this year to the Maintenance Command. The new vice-president of the Club is Major-General L. de M. Thuillier, who headed the U.K. team which towards the end of last year visited the U.S.A. for discussions on the use of earth satellites for communications systems. The joint honorary secretaries of the Club are Capt. F. J. Wylie, director of the Marine Radio Advisory Service, and L. T. Hinton, of Standard Telephones and Cables.

B.E.A.M.A.—An Industrial Electronic Equipment Section has been formed by the British Electrical and Allied Manufacturers' Association. In addition to the day-to-day work relating to technical matters, standardization, exports, and statistics, the section is intended also to "provide a means of closer discussions with other associations and help towards the wider examination of general policy questions affecting the industrial electronics industry as a whole." W. Gregson, of Ferranti, has been elected chairman, and R. J. F. Howard, of Metal Industries, is vice-chairman. A. Newton has been appointed secretary.

Society of Relay Engineers.—R. I. Kinross, managing director of Rediffusion Research, Ltd., has been re-elected president of the Society of Relay Engineers, and R. P. Gabriel, chief engineer of Rediffusion, Ltd., re-elected vice-president. The secretary of the society is T. H. Hall, Obelisk House, Finedon, Northants.



ELEGANCE.—The Ultra TR70 transistor portable which was selected by the Council of Industrial Design for the Duke of Edinburgh's Award for Elegant Design. It employs seven transistors and two crystal diodes (one of which provides additional a.g.c.) and covers both m.w. and l.w. bands. The dimensions are 12 x 8½ x 3 in.

Television Society Council.—At the annual general meeting of the Television Society on April 27th the following were elected to fill the vacancies on the council:—B. Eastwood (A.E.I.), I. J. P. James (E.M.I.), C. A. Marshall (*British Communications and Electronics*) and Dr. R. D. A. Maurice (B.B.C.). Three new vice-presidents were elected. They are Sir Willis Jackson, Dr. R. L. Smith-Rose and P. H. Spagnoletti.

R.E.C.M.F.—John Clark (Plessey Company) has been elected vice-chairman of the Radio and Electronic Component Manufacturers' Federation, in succession to Dr. G. A. V. Sowler (Telcon Metals) who, as announced last month, is now chairman.

Stockholm R.E.C.M.F. Show.—The date of the fourth British Components Show to be held in Stockholm should be added to the list of exhibitions on page 337. Organized by the Radio and Electronic Component Manufacturers' Federation it will be held from October 9th to 13th.

Milan.—Another addition should be made to the list of exhibitions on page 337. It is the date of the Milan Radio Show which will be held from September 10th to 17th.

Baird Memorial Lecture.—Professor Martin Ryle, Professor of Radio-Astronomy at Cambridge University, is to deliver the second Baird Memorial Lecture at the Royal College of Science and Technology, Glasgow, on June 7th. His lecture is entitled "Exploring the Universe with Radio Waves."

Industrial Electronics.—C. Metcalfe, of E.M.I., who is chairman of the Electronic Forum for Industry, will be one of the speakers at the Industrial Electronics Symposium in Boston on September 20th and 21st.

CLUB NEWS

Barnet.—At the May 30th meeting of the Barnet and District Radio Club V. A. Frisbee (G3KVF) will talk about mobile equipment. On June 27th T. H. A. Withers (G3HGE) will deal with v.h.f. equipment. Meetings are held at 8.0 at the Red Lion Hotel, Barnet.

Bexleyheath.—The North Kent Radio Society will be operating the club transmitter (G3ENT/A) at the Careers Exhibition being held in the Crayford Town Hall in connection with the Commonwealth Technical Training Week (May 29th-June 3rd). It will be using telephony on all bands but mainly on 1.8 and 7 Mc/s.

Birmingham.—"Transistors" is the title of the talk to be given by N. B. Simmonds to the Slade Radio Society on June 16th at 7.45 at Church House, High Street, Erdington.

East London.—Short-wave listeners in the London districts of East Ham, Manor Park, Ilford and Barking are invited to join the East Ham Group of the Radio Society of Great Britain. Details of activities are obtainable from J. Brown (G3DBO), 19, Compton Avenue, London, E.6.

Halifax.—The Halifax and District Amateur Radio Society now meets at the Beehive and Crosskeys Inn at 7.45 on alternate Tuesdays. The June meetings are on the 6th and 20th. The town's second radio club has recently been formed and is known as the Northern Heights Amateur Radio Society. It meets on alternate Wednesdays at 7.45 at the Sportsman Inn, Ogdon.

Harlow.—A mobile rally is being organized by the Harlow and District Radio Society for June 11th. It will be held at Magdalen Laver, near Harlow, Essex. There will be two "talk-in" stations—G3ERN on 160 m and G3JMA on 2 m.

Sheffield Amateur Radio Club meets on the 2nd and 4th Wednesday of each month at 7.45 at the Dog and Partridge, Trippett Lane. Details of forthcoming meetings are available from D. R. A. Hill, 16 Tynley Road, Sheffield, 2.

Warminster.—On June 25th the City and County of Bristol Group of the R.S.G.B. is holding a mobile rally at Longleat House, near Warminster, Wiltshire. The control stations will operate on 1.9 Mc/s (G3CHW/A) and 144.15 Mc/s (G3GYQ/A). Particulars from C. N. Chapman (G2HDR), "Yeovil," Stoke Hill, Stoke Bishop, Bristol, 9.

Personalities

Sir Harold Roxbee Cox, D.Sc., Ph.D., D.I.C., who is 58, has been appointed chairman of the Council for Scientific and Industrial Research for five years from October 1st. He will succeed **Sir Harry Jephcott**, who has been chairman of the Council since its formation in 1956. Sir Harold has been a member of the Council since 1957. He spent over twenty years in the Government service prior to 1954 when he became associated with a number of industrial companies. He is chairman of the National Council for Technological Awards, and vice-chairman of the Governors of the College of Aeronautics.

W. J. Richards, C.B., C.B.E., director of the Royal Radar Establishment, Malvern, since 1953, has been appointed director of the proposed new Staff College for Further Education. He will take up his new appointment in July. The aim of the College, premises for which have yet to be found, is to create a "national centre at which principals and other selected staff from colleges of technology and commerce can exchange ideas and experience with senior staff from industry, local and central government, the universities and overseas and where they can jointly study the aims, ideas and the growth of education in the light of the rapid advances in science and technology." Mr. Richards, who is 57, graduated in engineering with first-class honours from Manchester University. After spending some years in research and development work at the R.A.E., Farnborough, he became deputy director of scientific research at the Ministry of Aircraft Production in 1942. During his tenure of office at R.R.E. he has established the College of Electronics.



W. J. Richards



Dr. R. A. Bones

Roger A. Bones, B.Sc., Ph.D., A.Inst.P., has joined Wayne Kerr Laboratories as head of the company's contracts division. After graduating at London University in 1949 with first-class honours in physics and mathematics, Dr. Bones studied X-ray crystallography at University College, London. After a period with the Foreign Office, where he was concerned with electronics and telecommunications research, he lectured at Hong Kong University for three years, later becoming an industrial adviser to the Federal Ministry of Commerce and Industries in Nigeria. Immediately prior to joining Wayne Kerr, Dr. Bones was with the de Havilland Aircraft Company.

D. J. Cole, B.A., LL.B., son of the founder and present chairman of E. K. Cole, Ltd., has been appointed to the board of directors. He joined the company in 1954.

R. Wrathall, formerly radio and television sales manager of E. K. Cole Ltd., has been appointed director and general manager of Ekco Radio and Television Ltd., which has been formed to control the marketing of all Ekco television and radio receivers, car radio and allied



R. Wrathall



R. A. Drummond

products. **W. M. York** is chairman of the board of directors. Three additional directors have been appointed to the board of the associated company Ferranti Radio & Television Ltd. **R. A. Drummond**, who has been with the Ekco Group for nearly 30 years and has been sales manager of Ferranti Radio and Television Ltd. since its formation four years ago, has become director and general manager. The other new directors are **N. T. Atkinson** and **A. C. Segger**, who have also joined the board of Ekco Radio & Television.

J. W. Soulsby has been re-elected chairman of the Radio Officers' Union for his seventh consecutive term of office. Born in 1900, he joined Marconi's in 1918, and is at present Chief Radio Officer in the British India Steam Navigation Company's *Uganda*. The new vice-chairman of the Union is **J. G. Salvesson**, who is a radio officer with British European Airways, which he joined soon after demobilization from the R.A.F. in 1946. He is 41.

K. J. H. Adams, recently appointed production manager of the semiconductor division of Brush Crystal Company, Hythe, Southampton, was formerly senior production engineer at Semiconductors Ltd. After graduating with honours in physics at London University in 1951, he joined Mullard Radio Valve Company as a development engineer working on problems associated with repeater valves. In 1953 he left the company but returned the following year to head the department handling its guided missile valve project. He joined Semiconductors in 1959.

J. W. C. Robinson, M.B.E., managing director of Relay Exchanges Ltd., has been appointed chairman of the company in succession to the late **Sir Walter J. Womersley, Bart.** Mr. Robinson is also joint managing director of Goodmans Industries, which was acquired by Relay Exchanges in 1958.

E. G. Westray has retired after 49 years' service with Ericsson where, since 1946, he has been export sales manager. Mr. Westray, who was for many years in the company's laboratories, was throughout the last war Ericsson's liaison officer to the Ministries.

F. A. Vick, O.B.E., Ph.D., who was appointed director of the Atomic Energy Research Establishment at Harwell last September, has also been appointed director of the Research Group of the U.K. Atomic Energy Authority. Dr. Vick, who is 49, was Professor of Physics in the University of North Staffordshire from 1950 until 1959 when he joined the A.E.R.E. as deputy director. Prior to that he was for five years on the staff of Manchester University and throughout the war was Assistant Director of Scientific Research in the Ministry of Supply.

Air Commodore John C. Millar, D.S.O., the new commandant of the R.A.F. Central Signals Establishment, was formerly Director of Flight Safety at the Air Ministry. Air Commodore Millar, who is 47 and was educated at Trinity College, Cambridge, was Chief Signals Officer at R.A.F. Bomber Command in 1954.

Colin H. Gardner, manager of the Mullard Films and Lectures Organization for the past eight years, has retired after thirty-two years' service with the company. He will continue to act in an advisory capacity to the organization. He has been succeeded by **P. I. Nicholson, M.Brit.I.R.E.**, who joined the company in 1950 and for the past two years has been deputy manager of the Films and Lectures Organization.

Arthur L. Budlong (W1BUD), secretary and general manager of the American Radio Relay League, and editor of *QST*, has retired and is succeeded by **John Huntoon (W1LVQ)**. "Bud," as he is affectionately known in amateur circles, is also secretary to the International Amateur Radio Union. He has been on the staff of the A.R.R.L. for 37 years.

Peter Rushen, who writes in this issue on leakage in printed circuits, has been with Bush Radio since 1946, except for a two-year break when he was with English Electric. Whilst at English Electric he worked on the Thunderbird ground-to-air missile. He is at present engaged in the development of export television receivers.

Graham Miller, B.Sc., has been appointed home sales manager of Wayne Kerr Laboratories, which he joined two years ago. He studied electronics at Manchester College of Technology and was a graduate in physics at Swansea University. He subsequently became a circuit design engineer and spent two years as head of the Ferranti Standards Laboratory at Wythenshawe.



G. Miller

H. G. Hinckley

H. G. Hinckley has been appointed manager of the Machine Tool Control Department of Ferranti, Ltd., Edinburgh, in place of **D. T. N. Williamson**, manager of the department since its inception in 1952. Mr. Hinckley, who is 40, served with T.R.E. and British European Airways before joining Ferranti in 1948. Mr. Williamson, who has joined Molins Machine Co., as director of research and development, will be remembered as the designer of the amplifier bearing his name which he described in *Wireless World* in 1947.

Brian M. Lee, who a few months ago was appointed manager of the Industrial Division of Belling & Lee Ltd., has become a member of the board of executive directors.

News from Industry

British Space Development Company, which, as announced in our March issue, has been formed by a consortium of companies, has appointed Sir Robert Renwick as chairman and the following have been elected to the board: J. R. Brinkley (Pye), Grp. Capt. E. Fennessy (Decca Radar), G. C. I. Gardiner (Hawker Siddeley Aviation), A. A. Rubbra (Rolls-Royce) and Grp. Capt. D. Saward (Rank Organization). The following companies, together with those already mentioned, are founder members: A.E.I., Associated Television, B.I. Callender's Cables and Plessey. A technical committee has been set up "to examine and prepare plans designed to achieve British participation" in the future utilization of "space." The members of the Technical Committee, of which G. K. C. Pardoe is chairman, are: D. E. Burchett (A.E.I.), A. V. Cleaver (Rolls-Royce), J. M. C. Dukes (Plessey), Dr. W. F. Hilton (Hawker Siddeley), W. M. Lloyd (Rank), L. F. Mathews (A.T.V.), Dr. K. Milne (Decca Radar), T. P. Blott (Pye) and G. A. Dodd (B.I.C.C.).

Vactic.—The News of the World Organisation Ltd., has purchased the whole of the issued share capital of Vactic (Control Equipment) Ltd., and Vactic (Precision Tools) Ltd., from the receiver of Vactic Ltd. (in liquidation). New boards will be formed with Sir William Carr as chairman, and the present managing director, T. W. Roberts, continuing in that capacity.

G.E.C.-Sobell-McMichael.—The merger between the General Electric Company and Radio & Allied (Holdings) has now been completed and M. Sobell, chairman of R. & A., and A. Weinstock, the managing director, have joined the board of G.E.C. Lord Coleraine has also joined the board and Sir Toby Low has been elected vice-chairman. The object of the merger is to "strengthen the operations of the two companies in the radio and television field and in domestic appliances." Each company will continue to market its own range of receivers and to this end a new G.E.C. company, G.E.C. (Radio & Television) Ltd., has been formed. The headquarters are at Langley Park, Slough (Tel.: Slough 22201). The service department is at Lena Gardens, London, W.6 (Tel.: Riverside 4671).

Relay Exchanges Ltd. announce a group trading profit for 1960 of £3,949,892 which is almost £600,000 above the 1959 figure. After deducting £2,747,397 for depreciation and further sums for taxation, the net group profit was £1,024,825.

Elliott-Automation.—Preliminary figures for 1960 issued by Elliott-Automation Ltd., show a group profit before taxation of £1,776,510 compared with £1,015,630 the year before. The recently acquired Rheostat Company Group contributed £520,648 towards the 1960 total.

Ultra have entered into two agreements with companies in the western hemisphere. Ultra Electronics has signed an agreement with Electronics Investment Management Corp., of the U.S.A., for the interchange of information on research, development, marketing and production of electronic equipment. The corporation is associated with a number of companies both in the U.S.A. and outside to which it renders advisory and consulting services. The parent company Ultra Electric (Holdings) has entered into an agreement with Electronics International Capital Ltd., of Bermuda, whereby E.I.C. has purchased 40% of the shares of Ultra Electronics Ltd. for a sum of £800,000. Electronics International Capital Ltd. has, in addition, agreed to make available five-year loan facilities up to a total of £950,000.

B.S.R. announce record production and sales of all their products in 1960 resulting in a group net profit of £860,452 after deducting £666,124 for tax. The net profit was some £73,000 up on 1959. The group recently purchased for cash majority shareholdings in two companies, Tape Heads Ltd. (formerly Bradmatic Productions Ltd.), of Birmingham, and P. A. Marriott & Company Ltd., of Wembley, Middlesex. The managing directors of these two companies—G. Littlewood and P. A. Marriott, respectively—will continue in office.

Southern Areas Electric Corp., of which Ross, Courtney & Co. is a subsidiary, record a profit for 1960 of £47,782 (after taxation) which was £4,000 above the 1959 figure.

Plessey-Mallory.—Under an agreement with P. R. Mallory and Company Inc., the Plessey Company is now manufacturing a range of solid electrolyte tantalum capacitors. Chief features of the new capacitors are stability of capacitance with changes of temperature, and the ability to operate at extremely low temperatures down to -80°C without loss of performance. The range of capacitance values available is 0.33 to 330 microfarad at d.c. working voltages of 35 to 6.

Bach-Simpson Company, instrument manufacturers of London, Ontario, have appointed Aveley Electric Ltd., of South Ockendon, Essex, as their sole U.K. agents.

Marconi's W.T. Company has acquired the Wembley factory of E.M.I. Electronics Ltd. as a staffed and equipped working entity. The factory is approximately 85,000 sq ft and at present employs between 400-500 people.

Cossor Radar & Electronics.—As a result of severe damage by fire to its Servicing Department at West Norwood, Cossor Radar and Electronics have transferred the department to Edinburgh Place, Temple Fields, Harlow, Essex (Tel.: Harlow 25537).

Western Electric Company, manufacturing and supply unit of the Bell Telephone System, of the United States, has charged Transatron Electronic Corp., of Wakefield, Mass., with infringement of five separate Bell System U.S. Patents relating to semiconductor devices such as transistors and silicon diodes.

Aveley.—The recently formed Components Division of Aveley Electric Ltd. is holding an exhibition of its products in the Grill Foyer of the Kensington Palace Hotel, London, W.8, from May 30th to June 2nd.

Perth Radios Manufacturing Ltd., which was formed in 1953 by Mohamed Hussain Ismail, has gone into liquidation. Since 1957 the company has been operating from Marten House, 39-47 East Road, London, N.1. The liquidator is A. J. Cooke, 9 Basinghall Street, London, E.C.2.

CQ Audio, formerly R.G.A. Sound Services, of 111 Cecil Road, Enfield, Middx., have gone into liquidation.

C.R.T. Servicing.—Facilities for the servicing of Ediswan Mazda cathode-ray tubes, formerly available at A.E.I. Radio and Electronic Components Division's service department at Brimsdown, Middx., have been moved to the division's factory at Ducklees Lane, Ponders End, Middx. Bulbs for salvage under A.E.I.'s reclamation scheme should be returned to the same address.

EXPORTS

B.E.A.M.A. will hold a two-day export conference on October 5th and 6th. The opening speaker will be the Rt. Hon. Reginald Maudling, President of the Board of Trade.

Marconi Instruments' mobile demonstration unit is now on a 3,000-mile tour of Germany and Scandinavia. The vehicle houses over 30 electronic measuring instruments.

New Zealand.—Le Quesne Electronics Ltd., of 3, Faraday Street, Napier, New Zealand, wish to represent British radio and electronic equipment and component manufacturers.

Swedish Agents.—Telequipment have appointed their Swedish agents Magnetic AB, Stora Ny Gatan, Stockholm 3.

New Zealand Agents.—Telemechanics Ltd., of Southampton, have appointed Electronic Development and Applications Ltd., P.O. Box 1905, Auckland, C.1, as their agents in New Zealand.

Portuguese Agents.—Telemechanics have appointed Rualdo Lda., Rua S. Jose 15-1, Lisbon 2, Portugal, as their agents.

BRITISH TRADE FAIR MOSCOW

THE radio and electronics industry is well represented among the 600 or more companies participating in the first British Trade Fair to be held in Moscow which opened on May 19th for a fortnight. The following companies and research establishments are among the exhibitors in the fourteen sections, one of which is devoted to electrical equipment (which includes radio and television consumer and capital goods and electronic equipment) and another to scientific instruments.

This fair will be followed in July by a reciprocal Soviet Trade and Industrial Exhibition to be held at Earls Court, London. Both exhibitions are sponsored jointly by the Association of British Chambers of Commerce and the All-Union Chamber of Commerce of the U.S.S.R.

Advance Components	Kelvin & Hughes
Associated Electrical Industries	Labgear
Automatic Telephone & Electric Co.	Lancashire Dynamo Holdings
Avo	Langham Thompson, J.
Blackburn Electronics	Marconi Instruments
Board of Trade	Marconi International Marine
British Ferrograph Recorder Co.	Marconi's Wireless Telegraph Co.
Brush Electrical Engineering Co.	Mullard Equipment
Cambridge Instrument Co.	Napier, D., & Son
Casella (Electronics)	Pye
Cossor Instruments	Pye T.V.T.
Crompton Parkinson	Pye Telecommunications
Dawe Instruments	Pye, W. G., & Co.
E.M.I. Electronics	Rank Cintel
Electronic Instruments	Savage, Bryan
Elliott Automation Group	Scientific Instrument Manufacturers Assoc.
Endecotts (Filters)	Solartron Electronic Group
English Electric	Standard Telephones & Cables
English Electric Valve Co.	Taylor, Taylor & Hobson
Faraday	Telequipment
Fleming Radio (Developments)	Thermionic Products (Electronics)
G. B. Kalee	Ultra Electronics
Goodmans Industries	Wayne Kerr Laboratories
Griffin & George	

Reliable Circuit Designs

REDUCTION OF DEPENDENCE ON VALVE CHARACTERISTICS

By B. PRIESTLEY

THE object of this article is to suggest some general pointers to good design procedures which can be used to produce a required standard of performance in most circuits. Electronic circuit design is not a black art, giving unpredictable results, but a logical science capable of producing reliable and stable performance. By reliability is meant stability in the face of variations both in circuit components, due to tolerances, ageing and temperature, and in external supplies.

The extent to which good design can help reliability does not always seem to be realized. This may be due to many textbooks giving explanations of how a particular circuit works, once constructed, but no explicit design information.

Circuits which depend on ill-defined parameters should be avoided. Thus, for example, one can design a blocking oscillator for a specific pulse width, but with no great accuracy. If an accurate pulse width is required it is preferable to define it with a delay line.

The effects of supply voltage variations and component tolerances are calculable and should be evaluated in all cases where high reliability is required. This, of course, does not reduce the effects of variations, but calls attention to the variation in performance to be expected and may spotlight defects such as working with unequal safety margins for under- and over-voltage, or decide between two apparently equally suitable circuits.

Some components, particularly valves and transistors, have parameters which are subject to wide tolerances, made wider by variations due to age and temperature respectively. While more information on the form of variation to be expected would be welcome, much can be done by the application of negative feed-back and similar techniques to make the operating conditions largely independent of valve and transistor parameters.

In order to illustrate the above points, two similar cathode-coupled monostable multivibrator circuits are discussed in detail. Both are practical circuits but one is much more dependent on valve parameters.

The anode voltage/anode current curves used in the designs have 130% and 50% of nominal anode current curves added at each relevant value of grid potential, Fig. 1. These are dotted and broken lines, respectively, and are intended to take account of initial high emission and deterioration with life.

Consider first in Fig. 2 the reliability of the multivibrator's stable state (V_2 conducting V_1 off). In circuit (1) V_2 anode current is controlled by the flow of grid current through R. Thus, without positive-grid data, accurate design is impossible. However, experience indicates that with R in the region of $1M\Omega$ the grid/cathode potential will be about 0V.

Referring to the load line of slope $(R_{L2} + R_k)$, the anode current is a nominal 12.8 mA with limits of 14 and 9.5 mA.

Now examine the circuit in Fig. 3. The grid is clamped at $-40V$, and since R_k is much greater than $1/g_m$ the cathode will "follow" the grid fairly closely; hence the anode current will be about

$$40 \text{ volts} \div 4700 \text{ ohms} = 8.5 \text{ mA.}$$

Note that this can be calculated with only a very rough idea of the valve characteristics, thus variations in these characteristics are not going to affect the result greatly. More accurate design using the same characteristics gives a nominal 8.85 mA with limits of 8.95 and 8.65 mA. The method of calcu-

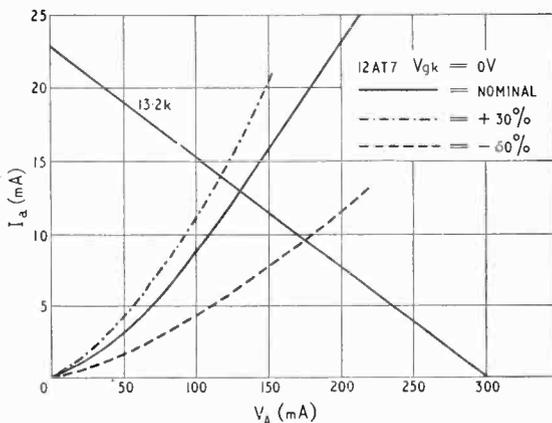


Fig. 1. In the absence of grid-clamping, anode current is seen to vary between 14mA and 9.5mA.

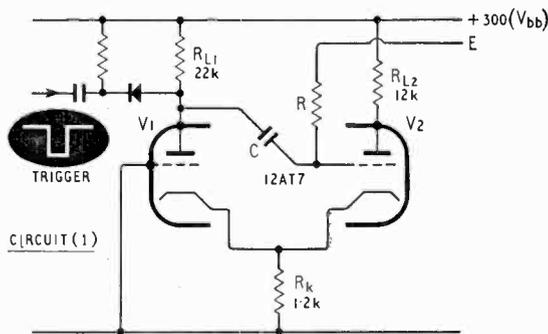


Fig. 2. In this cathode-coupled multivibrator, V_2 anode-current is controlled by an unspecified grid-current in R. Accurate design is, therefore, impossible.

lation is given in appendix (1). This considerable improvement illustrates the extent to which tolerances can be designed out by letting the external circuit define the current.

Unfortunately, a price must be paid for this gain. It will be seen that the current in circuit (2) is less but it would appear that by clamping the grid to a higher potential, more current could be passed. However, this is not so. In the low-emission case considered the anode current was 8.6 mA, implying a cathode potential of $8.655 \times 4.7 = 40.5V$. Thus the grid/cathode potential would be $-0.5V$, already at the edge of grid current, so that any increase in grid potential would result in grid current, reducing the accuracy with which the cathode "follows" the grid. If more current is required either more h.t. is needed or the user must accept a shorter valve life.

This reduction in performance is the normal consequence of negative feedback, but in most cases is not too high a price to pay for the simplification in design which has been almost reduced to a problem in Ohms Law. It may be objected that another variable—the clamping-potential tolerance—has been introduced, but the effects of this variable are more easily calculated, and its magnitude more easily controlled than valve tolerances.

Stabilization of the clamping potential may seem attractive, but if this is done, then any variations in the h.t. supply are reflected in full at V_2 anode, since this valve passes a constant current. Also considerable dependence of pulse width upon h.t. is introduced by stabilization. Consideration of the expression for pulse width:—

$$\tau \approx CR \log_e \left(\frac{E + V - V_{k_2}}{E + V_{co} - V_{k_1}} \right) \dots \dots (1)$$

shows that if all the terms in the bracket are allowed to vary together there is no change in τ , but obviously this is not so if V_{k_1} and V_{k_2} are fixed. Thus the best procedure is to derive all potentials from the same h.t. rail which may be stabilized if necessary.

Also in the second circuit the current in the quasi-stable state is fixed at approximately $20V \div 4.7k\Omega = 4.3$ mA in the same way as in the stable state. Consequently, the value of V is given by $10k\Omega \times 4.3$ mA within similar limits. In circuit (2) the magnitude of V has deliberately been kept low so that for a given pulse width the logarithmic term of expression (1) is less than in circuit (1), and C may be increased to compensate giving less dependence on stray capacities. These two points give

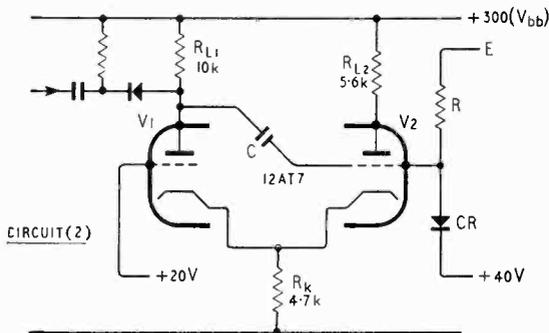


Fig. 3. This is a similar circuit to that in Fig. 2, but in this case, grid-current does not flow, and V_2 anode current can be accurately determined.

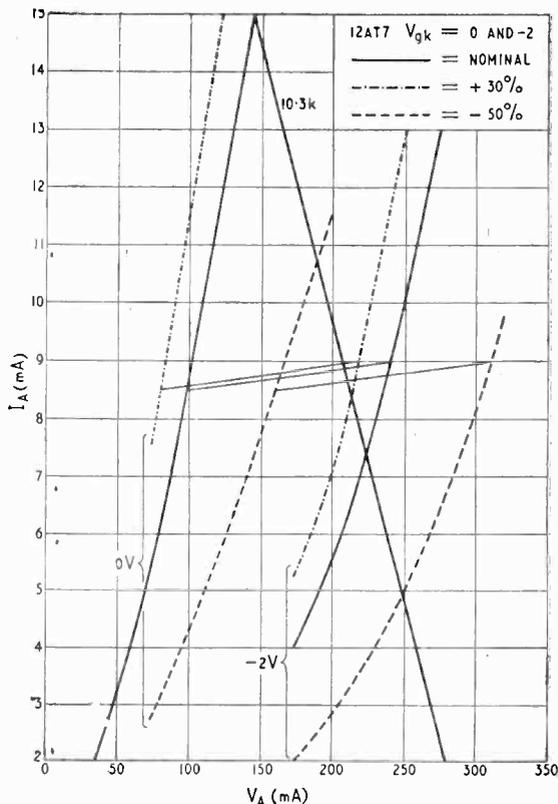


Fig. 4. Negative-feedback and grid-clamping greatly reduce anode current variations. Only a small portion of the curves are shown, in order to show the three "bias lines."

greater control of the pulse width in the second circuit.

It will also be clear that in circuit (1), R must be high to prevent excessive grid dissipation, without being so large as to give trouble due to negative grid current. In circuit (2), however, the limitations are solely the rating of $CR1$ and the internal impedance of the clamping voltage. Thus in circuit (2) it is possible to vary the pulse width by variation in R , giving a linear relation, but in circuit (1) E must be varied, giving a non-linear relation.

Enough should have been said to demonstrate that these two circuits, though identical in operation, differ considerably in "designability." Circuit (1) will always show wide variation in performance even when close tolerance components are used. Circuit (2), however, will repay the use of such components, as the variations in performance will be corresponding and simply-calculable. In fact it can be designed on paper with a high degree of accuracy. If the effects of all valve, component and voltage tolerances are calculated the procedure, though simple, becomes a little tedious, even when common sense is used to pick the extreme combinations, but this does save having to "frig" a design at the production stage.

APPENDIX I

Calculation of D.C. level in circuit (2)

If $V_{gk} = 0V$ then $V_k = 40V$ as V_{g_2} is clamped at $+40$. Thus $I_a = V_k/R_k = 40/4.7 = 8.5$ mA and this point is plotted on the $V_{gk} = 0$ curve, in Fig. 4.

Similarly if $V_{gk} = -2V$ then $V_k = 42V$ and so $I_a = 42/4.7 = 8.9 \text{ mA}$ and this point is plotted on the $-2V$ curve.

The "bias line" defined by these points cuts the load line at the actual working point. In theory several points are needed to define the bias line as this is not exactly straight, but the error is very small.

By repeating this procedure on the $+30\%$ and -50% sets of curves, the consequential variation in D.C. level can be calculated.

APPENDIX II

Calculation of Pulse Width.

V_{k_2} — Cathode potential in stable state.

V_{k_1} — Cathode potential in quasi-stable state.

V — drop in potential at V_1 anode.

$V_{c/o}$ — cut off bias of V_2

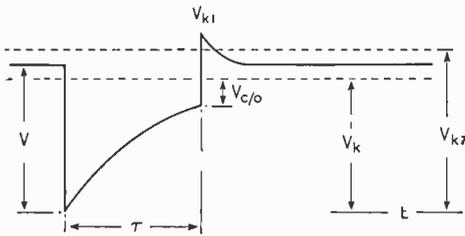
E — aiming potential of V_2 grid.

R' — $R + [R_{L1} R_{D1} \div (R_{L1} + R_{D1})]$

R_{D1} — D.C. resistance of V_1 .

— $(V_{bb} - V) \cdot R_k$

V_{k_1}



Grid 2 potential rises from $(V_{k_2} - V)$ toward E with a time constant CR' . Changeover occurs terminating the pulse when the grid rises to $V_{k_1} - V_{c/o}$.

$$\text{i.e. } e_g = E - (E + V - V_{k_2}) e^{-\frac{t}{CR'}}$$

at $t = \tau$

$$e_g = V_{k_1} - V_{c/o}$$

$$\therefore \frac{E + V_{c/o} - V_{k_1}}{E + V - V_{k_2}} = e^{-\frac{\tau}{CR'}}$$

$$\therefore \log_e \left\{ \frac{E + V_{c/o} - V_{k_1}}{E + V - V_{k_2}} \right\} = -\frac{\tau}{CR'}$$

$$\therefore \tau = CR' \log_e \left\{ \frac{E + V - V_{k_2}}{E + V_{c/o} - V_{k_1}} \right\}$$

X-ray Image Amplifier

MUCH effort has been directed, in recent years, towards the improvement in sensitivity of X-ray fluoroscopy equipment. Reduction of the X-ray dose incurred by the patient and greater flexibility of operation have been two of the chief aims. By the introduction of the Marconi Instruments 12-inch Image Amplifier, many former obstacles to the wider adoption of fluoroscopy in diagnosis and treatment have been removed.

Formerly, the light from the fluorescent screen was viewed at the output of an optical system. The disadvantages were that the image was of very low density and that the radiologist, who must be dark-adapted, was obliged to devote a large proportion of his attention to the purely mechanical business of operating the equipment.

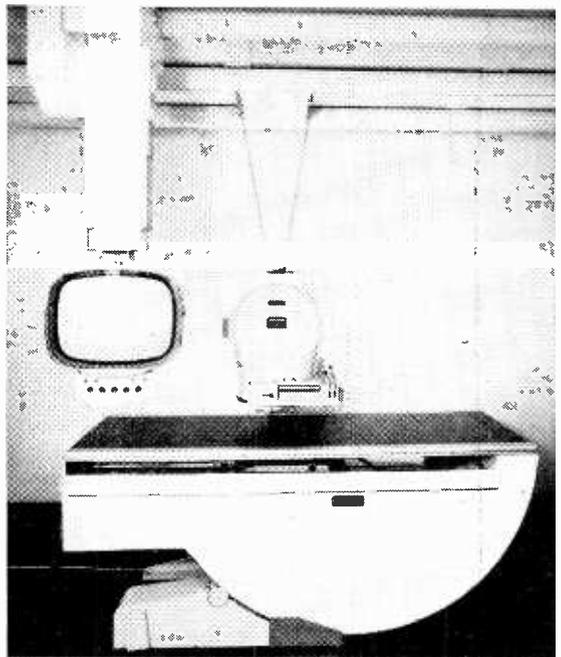
In the Marconi system, amplification of the image produced on the fluorescent screen is accomplished elec-

tronically and the image is viewed on a high-definition television-style monitor. The X-ray shadow image is produced on a 12-inch diameter fluorescent screen and focused by a Schmidt optical system on to the photocathode of a specially developed $4\frac{1}{2}$ -inch image orthicon camera tube. The output is fed, via a low-noise head amplifier situated near the camera tube, to a high-gain video amplifier of 10Mc/s bandwidth. It is possible to vary the proportion of the image which is focused on to the target of the camera tube, thereby enabling the operator to control the magnification, while giving greater definition, as the number of lines per unit area of the original image is effectively increased.

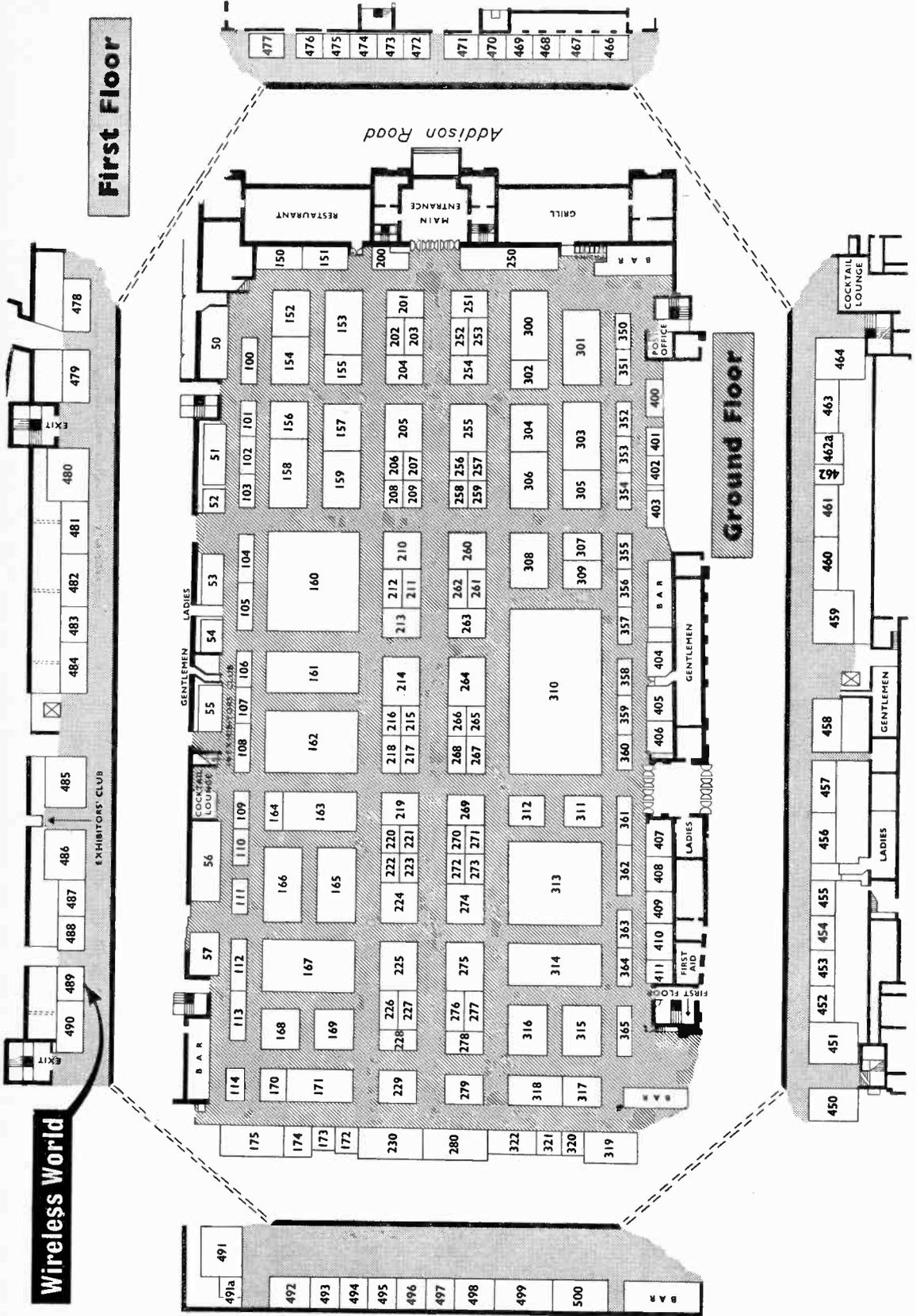
The picture on the 17-inch monitor tube is of 1024-line, triple-interlace standard with a horizontal resolution of 10Mc/s. Cine-recording is provided for and a system known as target-pulsing is employed. With this in operation, alternate fields are stored on the orthicon target, which results in the scan producing twice the normal signal amplitude at half the frequency. The pull-down time of the cine film is thereby not wasted, and during film exposure the picture is twice the normal brightness, which permits the use of fine-grain, slow-speed film. The full potentialities of 1000-line working are realized, with no trouble from faulty or critical interlace; time-base synchronizing pulses are not mixed with the video signal, as in a television system, but are fed separately.

The video signal polarity may be inverted when copies are required, eliminating the necessity for photographic reversal. It is also possible to reverse the scanning direction, a procedure which is of advantage when the radiologist finds it convenient to reverse the patient on the table.

The most important features of this equipment are the brilliance and convenience of the display, allowing the radiologist to work with no distraction and necessitating no dark-adaptation. The X-ray dose to the patient and, indeed, to the radiologist, is greatly reduced, and several people may view the monitor simultaneously, remotely if necessary.



The 12-in Image Amplifier. The unit containing the optical system and orthicon camera tube is over the centre of the table. The X-ray tube is situated underneath.



RADIO AND ELECTRONIC COMPONENTS SHOW

Olympia, London, 30th May - 2nd June

ON May 30th the Component Show, sponsored by the Radio and Electronic Component Manufacturers' Federation, opens for four days. This show, which for 16 consecutive years was held at Grosvenor House, is for the first time to be in the Grand Hall at Olympia. This change of venue has enabled considerably more space to be devoted to each of the 220 stands and also a much greater freedom of access. With the aid of the following list of exhibitors and the plan opposite it is hoped visitors will readily be able to find individual stands. For the convenience of readers unable to visit Olympia we plan to include a report on the show in our next issue.

The Exhibition will be open daily from 10 to 6. Admission is no longer by invitation card, except for overseas visitors, but will cost 5s.

A.B. Metal Products	210	Bulgin	315	Enthoven, H. J., & Sons	268	Lucas, Joseph	456	Salter, George	170
A.E.I.	162	Burndept	52	Equipment & Services	411	Lustraphone	272	Sanders, W. H. (Electronics)	498
A.K. Fans	353	C.C.L.	457	Erg Industrial Corp.	256	M.C.P. Electronics	468	Scott, Geo. L.	50
Air Control Installations	358	Carr Fastener	202	Ever Ready	51	M-O Valve Co.	163	Semiconductors	310
Aircraft-Marine Products	491	Cathodeon Crystals	362	Fane Acoustics	401	M.S.S. Recording	477	Service Electric	356
Alma Components	726	Chapman Ultrasonics	228	Ferranti	364	McMurdo Instrument	400	Sheffield Steel Products	483
Amphion	426	Ciba (A.R.L.)	152	Fine Wires	300	Magnetic Devices	279	Simmonds Aeroproseries	278
Amplifier Developments	455	Clarke, H., & Co.	157	Floform Parts	270	Magnetic & Electrical Alloys	306	Sims, F. D.	484
Anderson Springs	351	Colvern	154	Formica	251	Mallory Batteries	222	Smith & Nephew	355
Antiference	354	Connollys (Blackley)	171	Fortiphone	316	Mansel (Great Britain)	104	South London Elec. Equipment	487
Ardenre Acoustic Labs.	100	Continental Connector	402	Fox, P. X.	352	Marconi Instruments	314	Spear Engineering	215
Arielle Pressings	407	Cosmocord	213	G.E.C.	350	Marrison & Cathairl	466	Standard Insulator	54
Arrell Electrical	207	D.S.I.R.	462	Gardners Radio	163	Mec-Test	55	Steatite & Porcelain Products	307
Arrow Electric Switches	500	Dagnall & Kendall	102	Garrard Engineering	475	Microcell Electronics	476	Stevenson Relays	498
Arrow	498	Darwins	102	Gayler & Hall	475	Microelectron	481	Stocko (Metal Works)	101
Ashburton Resistance	473	Datum Metal Products	409	General Controls	275	Midland Silicones	224	Stratton	201
Aucup Laundry	458	Dawe Instruments	212	Goodmans Industries	465	Miniature Electronic Components	459	Suffex	302
Avesley Electric	350	Day, J., & Co.	110	Gramophone Company	208	Ministry of Aviation	486	Swift, Levick & Sons	258
Avo	225	Delecto H. Switches	254	Greencoat Transformers	264	Morganite Resistors	305	Sylvania Thorn Colour TV Labs.	274
B.I.C.C. Bundy	156	Direct T/V Replacements	152	Guest, Keen & Nettlefields	251	Mullard Equipment	491a	Symonds, H. D.	277
B.I. Callender's Cables	186	Doran Instrument	214	Haddon Transformers	224	Multicore Solders	308	Taylor Electrical	211
Biden Machinery	434	Dubilier	214	Hallam, Sligh & Cheston	276	Murex	206	Technograph	463
Bakelite	491	Duratube & Wire	252	Harwin Engineers	492	Mycalex & T.I.M.	253	Tektronix Inc.	451
Balkman Instruments	471	E.M.I. Sales & Service	105	Hellermann	408	N.S.F.	219	Telcon Metals	306
Belling & Lee	313	Egen Electric	265	Henry & Thomas	269	Neill, James, & Company	227	Telephone Condenser Co.	205
Berect International	401	Electro Acoustic Industries	259	Herbert Publishing Co.	357	Newmar-Ket Transistor	361	Telegaph Manufacturing	304
Betal Electronics	152	Electrolube	474	Heywood & Co.	114	Oliver Pell Control	483	Telegaph	497
Bird, Sydney S.	109	Electronic Components	488	Hughes International	499	Painton & Company	155	Thermo-Plastics	106
Birmingham Sound Reproducers	161	Electronic Technology	489	Hunt (Capacitors)	166	Parmeko	168	Thorn Electrical Industries	480
Bradley, G. & E.	108	Electroacoustic Industries	204	I.C.I. Plastics Division	309	Parnahoid	207	Thorn Electrical	480
Brayhead Electronics	319	Electroacoustic Industries	474	Imhof, Alfred	489	Plesimar	53	Ticker Eyelet Co.	452
Brimond	274	Electroacoustic Industries	474	Inaluting Components & Materials	159	Plesimar	53	Turner, Ernest	261
British Electric Resistance	479	English Electric Valve	165	International Rectifier Co.	281	Plesimar	53	United Trade Press	467
British Physical Labs.	405	English Electric Valve	165	Ionic Plating	231	Plesimar	53	Vacette Wire	365
Brush	317	English Electric Valve	165	Irish Cables	229	Plesimar	53	Vidor	52
				Jackson Brothers	263	Redcliffe Industries	483	Wayneside Cable Works	229
				Jobling, James A.	220	Reliance Cords & Cables	359	Wayne Kerr Laboratories	485
				K.L.G. Sparking Plugs	458	Reliance Manufacturing Co.	372	Wegow Condenser	203
				L.S.B. Components	152	Resound	152	Wegwyn Electrical Labs.	260
				Labgear	362	Richard Allan Radio	402	Westinghouse	153
				Langley London	464	Rivlin Instruments	255	Westinghouse	153
				Lewis Spring	130	Rola Celestion	493	Whitely Electrical Mfg.	218
				Linton & Hirst	113	Ross, Courtney	493	Whitely Manufacturing Co.	224
				Linvar	469	S.T.C.	167	Wingrove & Rogers	217
				Livingston Laboratories	451	Salford Electrical Instruments	216	Wire Products & Machine Design	490
				London Electric Wire Co.	262			Wireless & Electrical Trader	489
				London Electric Mfg.	311			Wireless World	310
								Woodsen Transformer	489
								Wolsey Electronics	405
								Zenith Electric	257

Elements of Electronic Circuits

26.—Pulse Modulation (1)

By J. M. PETERS, B.Sc. (Eng.), A.M.I.E.E., A.M.Brit.I.R.E.

IN the preceding article (May, 1961) we saw how an open-ended delay line could be used as a pulse-forming network in a simple pulse modulator. Other types of pulse modulator are used, however, and some of the various ways of producing a pulse-modulated signal will be dealt with in this and the next instalments. It is usual to divide pulse modulators into two main categories, grid modulators and anode modulators.

Grid modulation, as the name implies, can only be used when the transmitting valve has a control grid, and consequently its use is restricted to frequencies below about 500 Mc/s. At centimetric wavelengths, where the transmitting valve is usually a magnetron, anode modulation must be used.

Grid Modulation

Fig. 1 illustrates a tuned-anode tuned-grid r.f. oscillator V2 which is prevented from oscillating

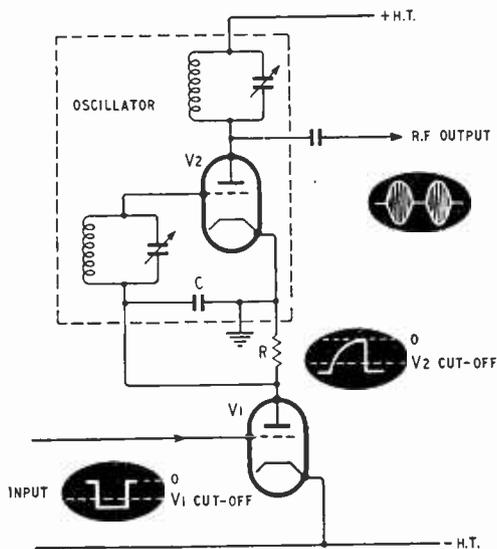


Fig. 1

by the bias caused by a heavy current flowing through its grid resistor R. This grid resistor forms the anode load of a triode pulse amplifier stage which in the absence of an input is conducting heavily. A negative pulse applied to the pulse amplifier grid cuts off the anode current of V1, produces a positive voltage at V1 anode (i.e., V2 grid) and consequently allows V2 to oscillate for the duration of the pulse. Unfortunately the combination of R, the r.f. bypass capacitor C and the inter-electrode anode/grid capacitance of V1 tends

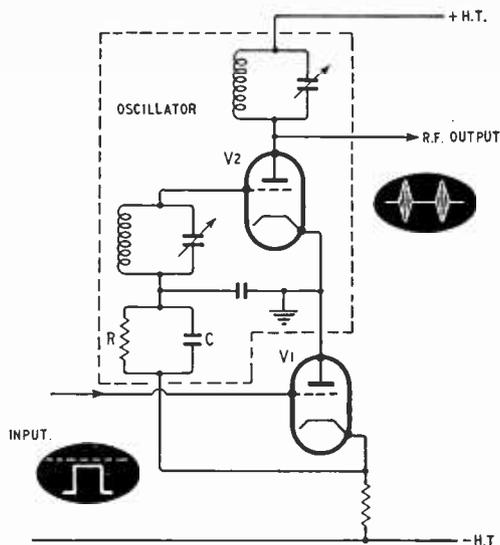


Fig. 2

to cause a slow rate-of-rise of oscillator grid voltage to zero. This in turn produces a slow build-up of r.f. oscillations and the leading edge of the r.f. pulse is of poor shape. This can be improved by making the value of R small, thus the time constant represented by the total shunt capacitance multiplied by

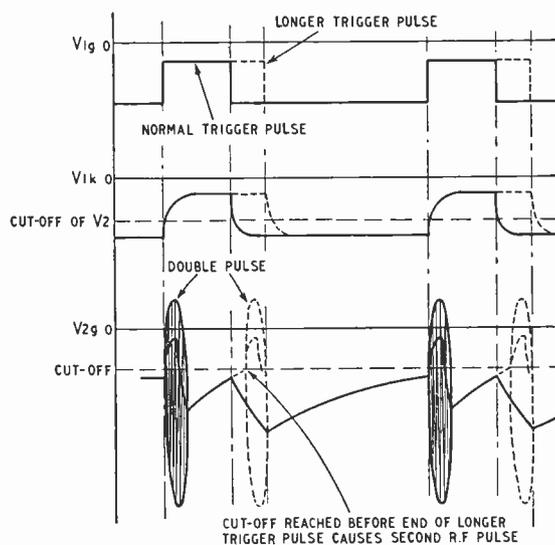


Fig. 3

R is smaller and the build-up of r.f. oscillations is quicker.

Squegging Oscillator.—Another type of grid modulator is the squegging oscillator which is often triggered by a cathode-follower stage (Fig. 2). First let us consider the action of a squegging oscillator: If the auto-bias CR time constant of the oscillator is too long, a charge is built up on C (by grid current) and the bias voltage becomes greater than the value at which oscillations can be maintained; r.f. oscillations then die away. The charge on C leaks away through R until the bias voltage rises through cut-off when r.f. oscillation recommences. This again causes grid current and an increase in bias so that the cycle repeats. The repetition frequency of these free-running bursts of r.f. oscillation is largely dependent on the time constant CR. If we now trigger the grid circuit of the oscillator, as shown in Fig. 2, the recurrence frequency of the

bursts of r.f. oscillation may be locked to the input (from the sub-modulator). The action of the oscillator is initiated by the triggering pulse which is made longer than the required duration of the r.f. pulse. The duration of the r.f. oscillation is thus still dependent on the rate at which C is charged by grid current flow but, due to the trigger circuit, an r.f. pulse cannot be generated unless a trigger pulse is present. If the duration of the trigger pulse is made longer still, or if the rate-of-rise of mean grid potential after the end of the r.f. pulse is such that cut-off is reached before the end of the trigger pulse, then it is possible for a second r.f. pulse to be produced. This results in the production of double pulses or "doublets" (see Fig. 3). So that the valve is ready for operation by the time each trigger pulse is applied, the free-running repetition frequency is chosen to be greater than the p.r.f. of the trigger pulse.

LETTERS TO THE EDITOR

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

Negative Feedback and Non-linearity

ONE must admire the way in which "Cathode Ray" in the April issue handles this very tricky subject, the care and hard work that has obviously gone into the article, and the guarding against snipers at every point, for example "apparent reduction of distortion" in the caption of Fig. 2, and the checking up on what he said in 1946.

Added to all this is his ingenious method of proving that feedback improves the signal-to-distortion ratio, so that it will surely be called mud slinging if I venture to ask if "Cathode Ray" would have trusted this method if he had not checked it experimentally?

I suggest this because hum (or noise) is another important factor in amplifier design, and by substituting "hum" for "distortion" and h for p the method seems to apply practically word for word to hum, in fact even slightly better as in this case the amplifier gain can be assumed constant.

We "prove" that negative feedback increases the signal-to-hum ratio by the feedback factor, but "Cathode Ray" states at the beginning of the article that feedback may or may not increase this ratio, and even may decrease it. The writer believes that it does not change it.

We reluctantly conclude therefore that even this method does not always work, and so, as often happens with the corresponding explanations in text books, we do not know when to be trusting.

Another point arises in Fig. 6(a) where it is assumed that -40, -48 should read -32, -40 respectively.

The maximum negative output possible in Fig. 5 is -24V, which is assumed equal to a fundamental of -32V + 8V second harmonic. This seems fair enough. But it is difficult to understand why it is considered fair to apply an 8V bias here to make these figures -32V and -40V and not to apply any bias in the Fig. 7 case.

Binley, nr. Coventry

D. L. CLAY

"CATHODE RAY" in his article on the above topic has raised several interesting points but has, I feel, missed an important one. In discussing the output power available with feedback he has assumed that it is necessary to maintain an input signal centred about the same zero as that without feedback. Since, in theory, the zero value of any signal can be adjusted at

will, it would perhaps be better to consider his amplifier curve with feedback when driven from a ± 4 volt swing centred about the 1.5 volt value of V_1 . The fundamental output voltage available is then ± 40 volts and is produced with negligible distortion.

If such an arrangement is permissible, and there seems no practicable objection, then some of the conclusions reached in the article would need reconsidering since under the proposed alternative the output power with feedback is certainly no less than that obtainable without feedback.

I do not agree with conclusion 6: large power-handling capacity in "hi-fi" systems is to enable the occasional peak levels to be handled without distortion.

Finally his remark about feedback that is not precisely negative is open to doubt since the magnitude of AB and not its phase is important in the reduction of non-linear distortion.

Since the harmonic distortion in a feedback amplifier is reduced in value by the factor $|1+AB|$ evaluated at the harmonic frequency in a region or frequency range where a reasonable amount of feedback has been applied and the approximation $|1+AB|=|AB|$ holds, the harmonic distortion will depend on the magnitude of AB and not the phase of AB.

Dartford, Kent

J. F. TILLY

The author replies:

I am grateful to Mr. Clay for his appreciative remarks and for pointing out the error in the scale of Fig 6(a). Meanwhile I have observed that the same or another gremlin added noughts to the last two figures in column (2) of the table on the same page.

My statement that negative feedback may either reduce or increase hum was proved both theoretically and experimentally in your issue of May 1946, but as that may be rather far back for even Mr. Clay to recall (though it was reprinted in "Second Thoughts on Radio Theory," Chap. 19) I hope to return to the subject before long, with particular reference to present-day circuit practice.

The question of fairness does not really arise with regard to the 8V "bias." It represents the d.c. component, which is removed before the signal reaches its ultimate destination.

The comparison made in the article, on which the

conclusions were based, was between Fig. 5 and Fig. 8, the latter representing the same working conditions as the former except for the ten-fold increase of input to make up for the ten-fold reduction of gain due to feedback. It is quite true, as Mr. Tilly points out, that a better result could be obtained—at least on paper—with feedback if the working point were altered. The same means would also achieve a better result without feedback. But it was tacitly assumed that the output stage (which is normally responsible for nearly all the non-linearity) was already being worked at its limit of power dissipation, so that in practice such adjustment would be inadmissible.

It might well be, in any particular practical case, that some slight readjustment of working conditions would be desirable when feedback is adopted, but this does not, I think, substantially affect the main conclusions. The object of my exercise was to bring out what happens when non-linearity at some part of the signal cycle is large—a condition that is inevitable when the input amplitude is excessive.

I am at a loss to understand Mr. Tilly's disagreement with my conclusion 6; his alternative statement is in perfect agreement with it.

There is surely no doubt at all that the phase of the fed-back voltage is important, for it is what decides whether the feedback is negative or positive. In his final paragraph Mr. Tilly commits the logical fallacy of assuming what he is attempting to prove, by putting "magnitude" signs around the feedback impressions he has used.

With regard to the last two words of his penultimate paragraph I would refer Mr. Tilly to the top right-hand corner of p. 173 of the April issue.

"CATHODE RAY"

Further Thoughts on Inductance

THE abstract and intangible quantities involved in the understanding of the behaviour of magnetic circuits seldom fails to present real difficulties to students. It is for this reason that authors must write with great care on such matters.

It is to be regretted that Thomas Roddam writing on Inductance in the April issue has confused

- (a) magnetizing and magnetomotive force
- (b) flux and flux density

throughout the whole of his article.

His appreciation of engineers being unwilling to "put back the clock" is very sound. One wonders why the older and more cumbersome magnetic expressions were employed in preference to those of the m.k.s. system.

Finally, no useful purpose whatsoever is served by assigning a proper noun to cover the product or quotient of electrical quantities. On the contrary, a very serious barrier to learning is set up, as the identity of the expression is lost.

For example, the pedant gives Roddam about half marks for stating the energy stored in a magnetic circuit as $\frac{1}{2}LI^2$. "Joules" have been overlooked even as the pedagogue may well have overlooked the fact that his pupils are not very happy about this particular unit and its derivation.

Malvern.

F. K. WEBB.

AFTER I had tried, in your March issue, to clarify magnetic units and relationships for the beginner, it was a little naughty, was it not, of Thomas Roddam to confuse them again in the April issue by referring to H as magnetomotive force and B as flux? A lot of readers will be sure enough of their ground not to be tripped up by this loose language, but ought we not to remember that there are others who are liable to be so confused by such a contradictory usage right at the start of the article as to fall out at that point and thereby fail to benefit from Mr. Roddam's interesting thoughts on non-linear inductance.

312

Encouraged by your historical reference, in the same issue, to my efforts to make logic and order prevail in our terminology, I will also lodge a protest against "HENRYS" in the sub-title. I know this is in accordance with B.S.560:1934 (Amendment 1), but (owing to my objections?) it was dropped in B.S.1991:Part 1:1954 which has superseded it. Clearly the names of units are common nouns, as indicated by their lower-case initial letters, and therefore the plural of "henry," like other English common nouns ending in -ry, is "henries." Only the Welsh could take any pleasure in "rys."

"CATHODE RAY".

The author replies:

Mr. Webb and Mr. Ray are quite correct in reprimanding me for using loose language. Last July, however, and the reference to rain rather than snow indicates that my holiday was in summer, I had not had an opportunity of reading Mr. Ray's clarification.

Why do I get confused over these magnetic terms and why do I not use m.k.s. units? The answer to the second question is easy: our makers of magnetic materials express all their information in oersteds and lines per square centimetre. The answer to the first question is also, I am afraid, an engineer's answer, too. Most of my transformer designing life was associated with a well-defined set of standard sizes of core with a range of standard air-gaps. I think of maximum flux as so many ampere-turns because once a size is chosen that NI term is the only one which is free. Like Mr. Ray (page 145, March issue) I sweep all the dirt under the carpet but I have chosen a different corner.

I must disagree with Mr. Webb's blanket damnation of proper nouns for products and quotients. Does he really want to use volts per amp for his resistors and kilovolt-amperes for his electric fire?

Finally, sir, should I be taken to task? When I was a student I was assured that it was my stupidity which led me into those difficulties. Surely either the students of today or other pedagogues of yesterday are to blame. The manufacturers of magnetic materials could, however, make it easier for us to fall into righteousness.

THOMAS RODDAM.

Graphical Solutions

MAY I suggest that the graphical solution proposed in the Appendix to Foss and Sizmur's article in "Multi-vibrator Design" (p. 224, April issue) would be made even simpler by the use of linear/log scales?

To provide a graphical solution which really replaces the use of (low-accuracy) tables, $E_1/E_0 = e^{-t/T}$ should be drawn on linear X/logarithmic Y paper, whereby it becomes a straight line, a property which this function shares with all functions of the form a^x . It is then only necessary to know one point on this graph in addition to the point (0 - 1).

As an example a straight line was ruled from (0 - 1) to (4.60 - 0.01) on paper with two log decades along the Y-axis and a linear X-axis scale. The accurate figure for Y at this point, taken from "Tafels van e^x " H. W. Holtappel (Groningen, 1938), is 0.0100518357.

These tables show that the point (4.605 - 0.010) is closer to the correct figure, but the easily memorized co-ordinates (4.60 - 0.01) give ample accuracy for the purpose at hand.

The above assumes that linear-log graph paper is available, but in an emergency the two decades of the vertical scale can be transferred from the upper scale of a slide rule. If an ordinary log table can be assumed to be available, the ordinates can be marked off in proportion to the logarithms of 1, 2, 3, etc., the units being centimetres, inches or multiples thereof.

Finally, when required, it is easy to draw the curved graph on ordinary linear-X/linear-Y paper, taking individual points from the straight line graph first prepared.

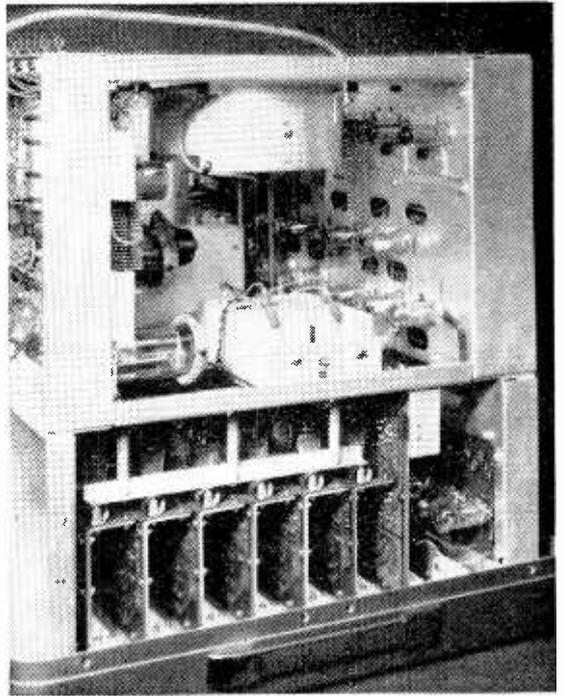
Ramstad, Norway.

KAYE WEEDON.

The Marconi Instruments TF1345 10Mc/s Counter, showing the plug-in, printed-circuit decade units.

SOME APPLICATIONS OF COUNTING TECHNIQUES

By P. R. DARRINGTON



DIGITAL MEASUREMENTS

IMPROVEMENTS in the stability of oscillators have brought in their train a demand for more and more accurate methods of frequency measurement. Accuracies of a few parts in a hundred or even a thousand million are becoming commonplace, and the most easily operated instruments for measurements of this order are the digital frequency-meters now being produced in many parts of the world.

Digital measurements of time and the counting

of random events have been adopted by the industries concerned with nuclear energy, and many types of input transducer have extended the advantages of digital measurement to the engineering industry in general.

The advantages of this type of measurement may be summed up as extremely high accuracy, simplicity and freedom from operator fatigue, the latter being influenced to some extent by the type of read-out presentation adopted.

Counters generally available are divisible broadly into two groups. The lower-speed instruments tend to rely on the counting tubes, as instanced by the Dekatron. This is a gas-filled device consisting of a central anode surrounded by ten cathodes (K0 to K9 in Fig. 1). Between each pair of cathodes are two electrodes known as switching-grids. On first switching on, an ionization path is formed between the positive anode and one of the cathodes which are returned to earth: from this time, the path will be formed to whichever is the most negative electrode in the tube. If a negative-going pulse is applied to all the grids connected to S1, the path will move to the S1 grid nearest the original cathode; it cannot move backwards to S2, as S1 is more negative. A second negative-going pulse, delayed slightly to overlap the first, is now applied to S2. When the S1 pulse ends, S2 is more negative and the path is formed here. At the expiry of this second pulse, the path moves on to K1, as all cathodes are maintained at a more negative d.c. potential than the grids. The two pulses are obtained from a mono-

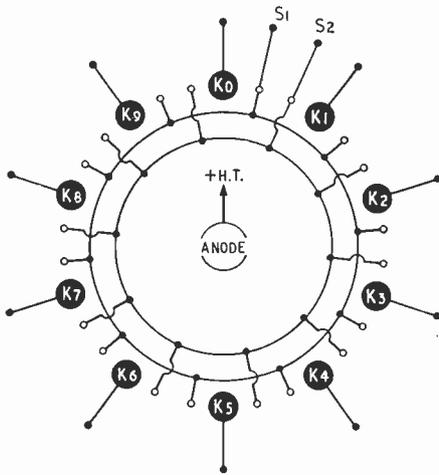


Fig. 1. Dekatron.

stable multivibrator triggered by the input signal, a delay network providing the overlap. Ten pulses at the input to the multivibrator result in the ionized path performing a complete circuit of the tube. A resistor in K0 will develop a voltage when the path is formed between K0 and the anode, which results in division by ten. Reset is effected by the momentary application of a negative voltage to K0. The position of the path is identified by the formation of a glow on the cathode in use, which corresponds to a numbered surround on the instrument front-panel. This type of presentation can be fatiguing to the operator, and the principal disadvantage is that the maximum switching frequency is limited to about 20kc/s. Counting tubes are used widely in comparatively low-speed industrial applications.

A device belonging to the family of counting tubes, but working on a different principle is the beam-switching tube. This is a vacuum tube, the electron stream being directed from a central cathode to one of ten anodes, or "targets," by the combined influence of a magnetic field and the voltage applied to a grid or "spade." The maximum switching speed of later developments of the beam-switching tube is in the region of 10Mc/s, and the tube will drive read-out devices, such as neon tubes and printers directly.

Most of the higher-speed counters—10Mc/s and above—employ as their basic counting element the bi-stable flip-flop or toggle. Circuits using tran-

sistors are capable of switching at speeds in excess of 50Mc/s, although in commercial instruments the present-day limit is about 20Mc/s.

Principle of Operation

The basic requirement of an electronic counter, when used other than purely as a batch counter, is that it should have an accurate and stable source of frequency. When built into the instrument, this almost invariably takes the form of a temperature-controlled crystal oscillator, usually working at a frequency of 100kc/s, 1Mc/s or 5Mc/s. The 5Mc/s crystal is being widely adopted because of its low long-term ageing drift. The temperature of the crystal, and sometimes of the complete oscillator is held constant by enclosing it in an oven, controlled by a bimetallic thermostat, or an electronic circuit using a temperature-sensitive element in a bridge circuit. The more sophisticated control circuits are capable of working with differentials of a few milli-degrees; divergence from nominal frequency is normally limited to not more than a few parts in 10^7 per week, or even an order better. Oven temperature control employing the latent heat of fusion has also been described.*

The output of the crystal oscillator is used as a reference frequency in the gating and timing cir-

*Wireless World, Dec. 1960, p. 613, "Technical Notebook".

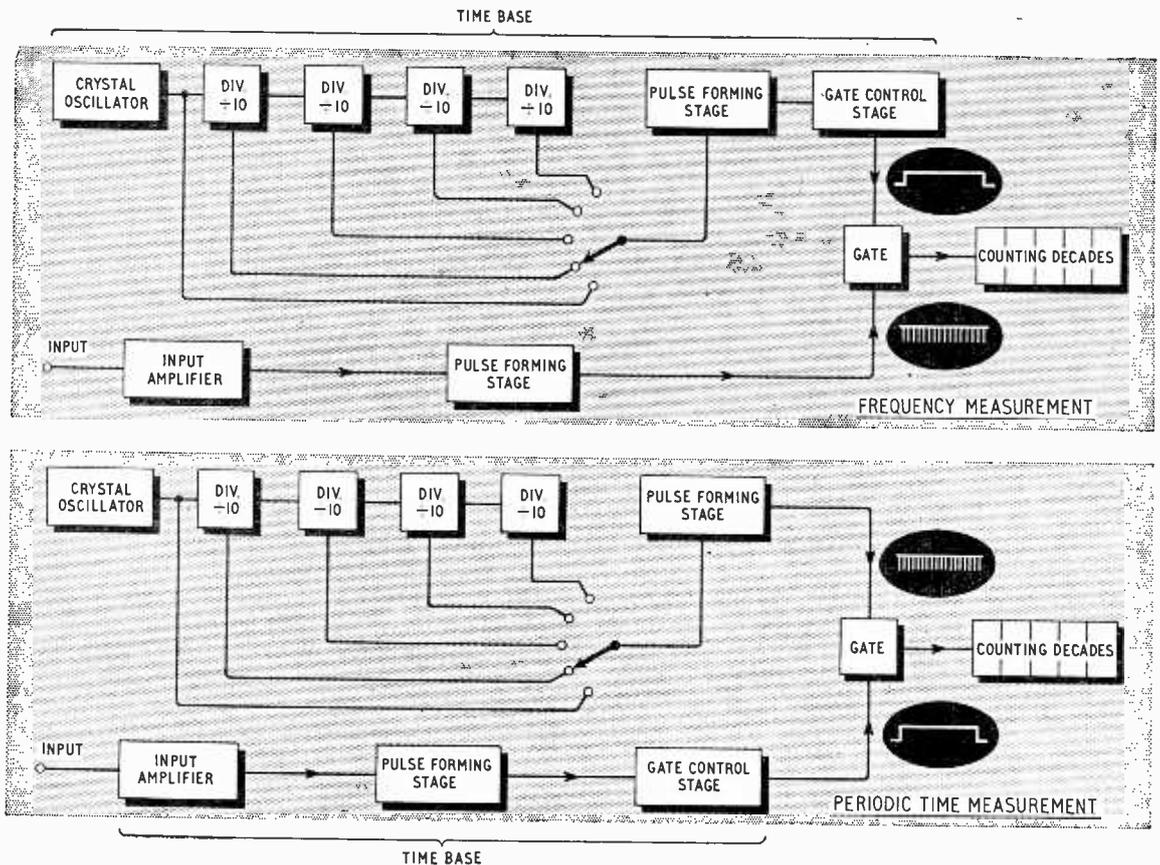


Fig. 2. Circuit configurations for frequency and time measurements.

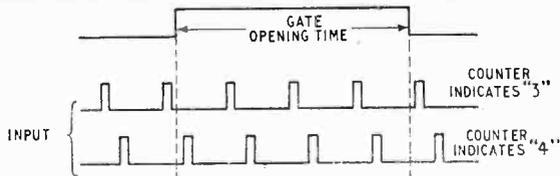


Fig. 3. The ± 1 digit error inherent in the system of gating is due to the lack of phase relationship between the crystal oscillator and the unknown frequency.

counts of the counter. Two main configurations of the internal circuits are required, providing the two functions of frequency and time measurement. Block diagrams are shown in Fig. 2.

The obvious method of frequency measurement is to allow the input to pass through an electronic gate which is open for one second precisely. The output of the gate is fed to a chain of counting decades of one of the types described earlier; the result showing on the display when the gate closes is the frequency in cycles per second. The accuracy of the result is governed by the stability of the crystal oscillator which indirectly determines the opening time of the gate, and also by an inherent error of \pm one digit, caused by the lack of a phase relationship between the frequency being measured and the output of the crystal oscillator (Fig. 3).

At very low frequencies, say 10c/s, the accuracy is determined by the gating error (1c/s) which is, in this case, $\pm 10\%$. The method of measurement is therefore inverted. In order to obtain a larger number of significant figures on the display, the unknown frequency itself is made to determine the gate opening time, during which a high frequency derived from the crystal oscillator is counted. In this way, the gating error is reduced, the major inaccuracy being due to crystal frequency tolerance, which is controllable. The result displayed is now the time of one cycle of the unknown frequency in units of the standard frequency being counted, and the frequency is obtained by a reference to a set of reciprocal tables.

Measurement of time is made in exactly the same way; the input determines the opening time of the gate, this being defined precisely by the standard frequency derived from the crystal oscillator. In some counters it is possible to vary, by means of a calibrated front-panel control, the standing bias on the trigger circuit which controls the gate opening time. The points on a waveform at which the gate opens and closes are therefore variable. This is a useful facility for the measurement of pulse widths at different amplitudes, the time taken for a slowly-varying voltage to cross predetermined levels, etc.; but it must be borne in mind that the accuracy of measurement has a limit set by the maximum frequency employed as a standard. For instance, if the standard frequency used is 10Mc/s, the accuracy cannot be better than $\pm 0.1\mu\text{sec}$. In many counters, automatic positioning of a decimal-point gives the result in kc/s, or, if time is being measured, in the appropriate timing-units.

The measurement of frequencies outside the range of the basic counter is made possible by recourse to heterodyne techniques. The method is to beat the unknown frequency against a multiple of the crystal frequency, selected by a front-panel control, and obtained by harmonic generation or locked-oscillator

techniques, the difference frequency being measured on the counter. The presentation is then the selected multiple added to the counter indication. For instance, if the frequency to be measured is 185.734Mc/s, the harmonic selection control is set to 180Mc/s. The difference frequency is fed to the counter and is displayed as 5734kc/s. The problem of which harmonic to select is usually resolved by means of a wavemeter. This method is applicable up to about 200-300Mc/s, above which it is general practice to employ a transfer-oscillator. This consists of an oscillator operating within the range of the counter, with or without heterodyne facilities, harmonics of which beat with the unknown frequency. Provided that the harmonic is known, the result is obtained by measuring the frequency of the transfer-oscillator and multiplying by the harmonic number.

It has been mentioned that the crystal oscillator determines the opening time of the gate. To achieve this, the crystal oscillator output must be divided in frequency to give pulses spaced in time by an

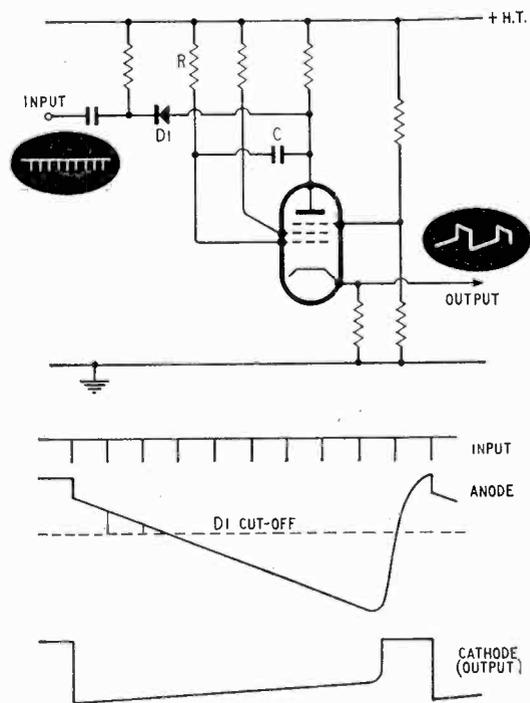


Fig. 4. A typical phantatron divider. The division ratio is set by the value of C and R.

amount equal to the gate time required. In practice, several frequencies are produced to give a selection of gate times depending on the frequency being measured and the accuracy required.

Circuits employed as dividers are well-established, among them being blocking oscillators¹, phantatrons¹, multivibrators¹ and the diode-pump integrator with transistor linearization and flyback². Fig. 4 shows a typical phantatron divider. Characteristics required are stability with temperature and supply voltage changes and ease of setting-up. The divider should not free-run in the absence of input pulses.

All these circuits depend on a time-constant, which, at frequencies below about 10c/s, becomes

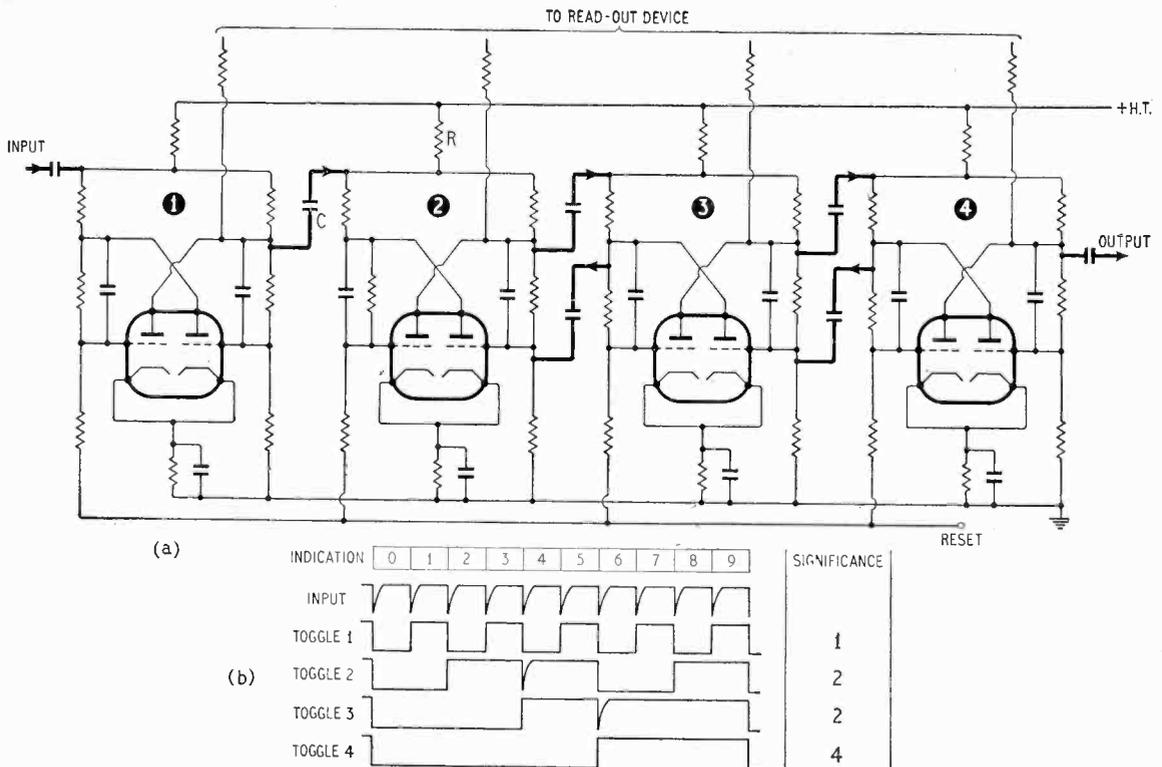


Fig. 5 (a). A counting decade, showing the signal and feedback paths in heavy lines. (b) Waveforms appearing at the anodes of valves whose grids have the reset pulse applied.

unmanageably large, and insulation resistance of circuit components tends to cause trouble. To overcome this, aperiodic circuits, such as toggle decades are used, there being no lower limit to their frequency of operation. Many transistor circuits use decades throughout the dividing chain.

A self-checking facility is incorporated in most counters which tests for correct working of all division, gating and counting circuits. The gating circuitry is set to function as in the case of frequency-measurement, while the output of the crystal oscillator and the stages in the division chain are counted.

The result should be exactly correct, although accumulated phase-shifts in the division chain, and the finite opening and closing times of the gate circuit may result in a ± 1 digit error.

This check does not give an indication of crystal accuracy, as a low crystal frequency gives rise to a longer gate time, and the two effects cancel out.

Decade Operation

Referring to Fig. 5a it is seen that the decade is composed of four bi-stable toggles, the output of each triggering the succeeding stage: the last toggle provides the input to the next decade.

The line marked RESET may be considered, for the moment, as being returned to earth. Assume an initial state where all left-hand valves are conducting.

The grid of a toggle in the conducting condition is returned to a positive voltage with respect to

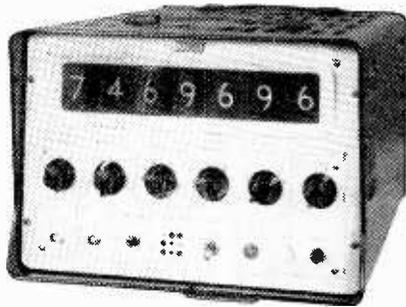
cathode, but is held at very nearly cathode voltage by grid current limiting. When cut off, the grid may be up to 50V negative. Obviously, then, a positive-going pulse applied to a toggle will not affect the conducting valve, and will need to exceed 50V to trigger the stage. On the other hand, a small negative-going pulse will be amplified by the conducting valve, and will "flip" the toggle into the reverse condition. All trigger pulses, therefore, are negative-going.

The first input pulse triggers toggle 1 into the condition where the output anode (left-hand) has performed a positive-going step-function. The step is differentiated by C R, but this has no effect on toggle 2 for the reason explained above.

The second pulse compels toggle 1 to revert to its original state, the negative-going step-function on its anode being differentiated to form a negative-going pulse suitable for triggering toggle 2. Toggle 1 continues in this manner; a negative-going output pulse is delivered for two pulses at the input.

At the onset of the fourth pulse, the output of the second toggle is of the correct polarity to trigger toggle 3, which is duly reversed. However, at the opposite anode of toggle 3, a negative-going step-function is performed which is differentiated by C R and used to re-trigger the second stage. In the absence of feedback this state of affairs would not be achieved until the sixth input pulse. The count has therefore been advanced by two.

Operation proceeds normally until the sixth pulse, when feedback occurs between toggle 4 and toggle 3. The "natural" count of 2^4 —sixteen—has been



The Racal Type SA505 10Mc/s Digital Frequency Meter. Transistor decades are used in both the counting and dividing chains.

reduced to ten by feedback, and the tenth pulse restores all toggles to the initial condition.

The system of feedback is typical of operation at frequencies up to about 100kc/s. At higher frequencies, although the principle remains, accumulated delay in successive stages of the decade enforces refinements such as gated feedback, whereby the first toggle triggers the fourth directly, via a gate. Heavy clamping of anode and grid excursions is required to reduce recovery times and valve ageing effects.

Reset is effected by applying a large-amplitude positive-going pulse to all the left-hand grids. The source impedance of the circuit producing the pulse is low, to avoid grid impedance unbalance between the toggle halves.

The information stored in the decades is indicated by the condition of each of the toggles when the gate closes, and is readable by several different methods. The most often used are meters, graduated 0-9, vertical decades of neon lamps numbered 0-9, and several kinds of in-line read-out, consisting of a horizontal row of numerals, one per decade.

A meter display is probably the simplest to provide, as it consists of only four resistors and a meter. Each toggle has connected to one of its anodes a resistor, the four resistors being taken to a common output which feeds the meter, as in Fig. 6. The problem is to assign to the four resistors values which will give a current output proportional to the significance of each toggle. In a "decade" without feedback, these four currents would increase in powers of two, i.e., the first toggle would signify 1, the second 2, the third 4 and the last one 8. This

is known as pure binary code and is often referred to as 8421 code. However, with the addition of feedback necessary to make the four toggles work as a decade, the significance of each toggle is altered; the decade shown in Fig. 5a produces a 4221 code. If each resistor is given a value calculated to provide the required current, the result will be a ten-step staircase. The system described is used in several commercial counters, but suffers from the disadvantages common to analogue devices presenting digital information. The meter movements are comparatively slow in operation, and in low-speed decades, where anode travel is not clamped, varying valve characteristics necessitate setting-up of limits, by means of variable resistors. Considerable effort is required to make a long series of readings; the result is not immediately apparent.

Read-out employing vertical decades of neon lamps is used widely and is probably the ideal form of display. Each neon lamp is fed via resistors from the anodes of three toggles, the connections being arranged so that one cut off and two conducting valves are connected across the appropriate neon for each indication. This avoids any tendency for more than one neon to fire at any one time. This form of display is instantaneous in operation and has the advantage that it is, in effect, a positional-analogue indicator, in addition to being digital in form. The point is of some importance on many counters, as the display and reset time can be so short as to give a virtually continuous reading. Variations of the input parameter are apparent as a slow rise or fall of the decade indications, and the direction of drift of frequency or time is obvious.

One method of in-line read-out is an extension of the method described above. In front of each neon lamp of the vertical decade is mounted a photo-electric cell. As the neon lights, a voltage is applied to the appropriate electrode of a gas-filled indicator tube. Each electrode consists of a wire formed to represent a numeral 0-9; as the decade neon lights, a glow forms on the indicator tube electrode.

Another common method of obtaining an in-line read-out is to decode the four outputs of a counting decade by means of either semiconductors or relays, Fig. 7. A conducting path is formed from the common input of the decoding matrix to one of ten outputs by the relay-controlling valves or transistors, which are controlled by the four decade outputs. Current is fed via this path to one of a series of ten lamps in a projection display unit.

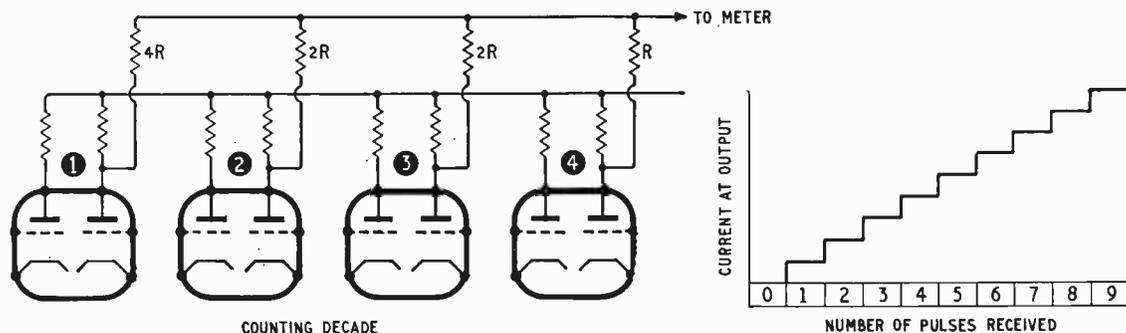


Fig. 6. Circuit giving meter readout. The anode resistors are graded to accommodate the differing "significance" of each toggle.

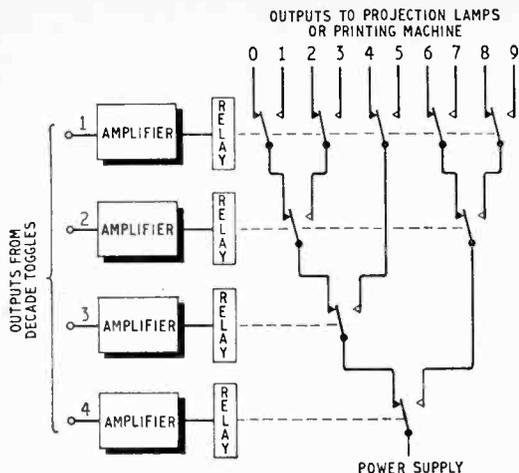


Fig. 7. A relay decoding matrix to convert a 4221 code to a decimal output.

Each lamp has a focusing-lens and a number mask, the number being projected on to a ground-glass screen.

The meter read-out referred to previously is capable of modification to provide an in-line display. The movement carries, in place of the needle, a transparency, consisting of the numerals 0-9 and moving in an optical system. The appropriate numeral is thereby projected on to a screen. The system is especially useful as an indicator for use with transistor decades, where voltages of a magnitude suitable for the operation of neons do not exist.

In-line displays are most useful for a measurement in which the reading is either used once only, or stays sensibly constant during a series of readings. If the input is varying, the display becomes a mere jumble of numbers and cannot be read if the cycling time of the counter is short. The analogue feature of the vertical display is then lost.

Both the vertical display and the in-line read-out may be read from a distance; the vertical display by virtue of the fact that the numbers do not have to be read, as the position gives the result, and the in-line system because the numbers can be made large.

The type of equipment so far described is used, as has been said, for the measurement of frequency and time. An extension of the principle is that of voltage measurement. The direct voltage to be determined must first be converted into either a frequency or a time-delay. A common method is to trigger a time-delay circuit, e.g., a phantastron, by means of the pulse that also opens the gate. As the phantastron anode "runs down," a comparator compares the anode voltage with the amplified input voltage. When the two are in coincidence, a pulse is formed which closes the gate. During the gate opening time, pulses from a crystal oscillator have been counted by a series of counting decades, and the displayed result can be arranged to indicate voltage numerically.

Errors in this method of measurement stem from non-linearity of the time-delay circuit, drift in the direct-coupled input amplifier and possibly frequency error in the circuit providing the standard frequency pulses.

An alternative method is to control, with the amplified input, the frequency of a pulse generator, the output of which is then measured as in the case of a normal frequency measurement. In this case, the inaccuracy is due to a non-linear relationship between voltage and frequency in the pulse generator and drift in the d.c. amplifier.

To obtain a more linear voltage-frequency conversion, especially at the extreme lower end of the range, a common method is to employ a b.f.o. system, in which one oscillator is made voltage-variable. In this way, the transfer characteristic may be made linear down to zero frequency.

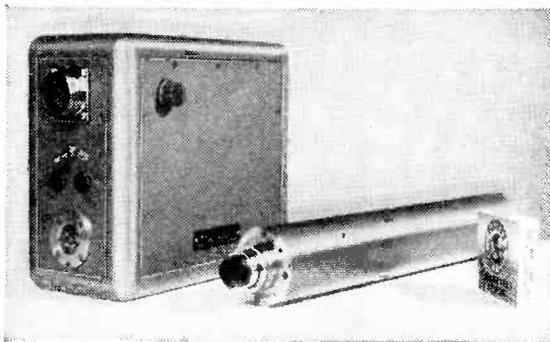
It frequently becomes desirable to preserve the results of a series of measurements in the form of a numerical printed record. To achieve this, some form of decoding is necessary between the binary-form of the decade four-wire outputs and the required decimal presentation. This may be achieved either electrically or electromechanically. The most common method is to employ a relay matrix, shown in Fig. 7, controlled by valves which have on their grids the outputs from each toggle of a decade. The relay contacts are arranged to provide, for each decade indication, a path from the input of the matrix to one of ten outputs, which feed a printing machine.

An analogue output which may be used to drive a pen recorder is easily obtained from a resistive network on the four outputs as in the meter display circuit. If several decades are in use, the analogue outputs from each decade may be combined in a further network to provide, for instance, units, tens and hundreds.

It can be seen that digital techniques afford, in general, a convenient and rapid method of frequency and time measurement with a high potential accuracy. With the advent of v.h.f. transistors and tunnel diodes, it is inevitable that counting-speeds will rise and that the simplicity of operation and compactness of the counter will bring measurement at an accuracy of 1 part in 10^7 down to the level of the production line.

REFERENCES

- ¹ A. H. Frederick, *et al.* "Waveforms." M.I.T. series, Chap. 16.
- ² P. R. Darrington. "Marconi Instrumentation." Vol. 7, No. 3. Sept., 1959. Page 82.



This closed-circuit television camera, made by Marconi's W.T. Co. Ltd., is only $2\frac{3}{8}$ in diameter by 15 in long. It can thus be employed conveniently for the internal inspection of pipes and bore holes. The control unit is also shown.

Leakage in Printed Circuits

PROS AND CONS OF WAX COATING

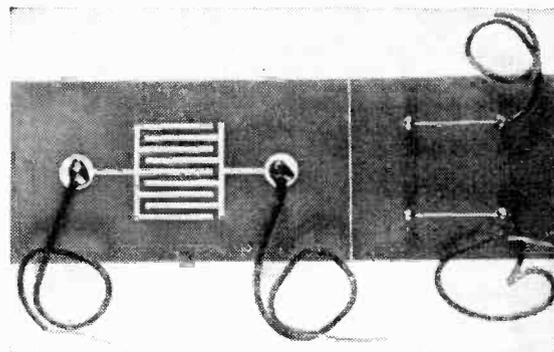
AS A CURE

By P. RUSHEN*

THIS article is based on some original work done on printed wiring and its use in conditions of high humidity and temperature. Cost of materials and ease of production were two of the factors considered throughout, whilst the successful use of printed wiring in exported radio receivers was the main object.

Effects of Leakage

Consider some aspects of a conventional valve circuit using printed wiring—in general, every valve-base tag will be in intimate contact with the base material and in some cases anode and grid tags are adjacent to each other. An a.g.c. line may have as



Test piece, showing arrangements used by author for determining surface leakage on material (left) and (right) insulation resistance of "body" of board. In latter case pins are driven through board: consequently surface contact is negligible.

radio or television receiver can cause malfunction and, possibly, complete failure. A 100-M Ω leakage resistance from a 6.3-V filament line to the control grid of an amplifier could result in an audio power output of 100mW or more. No less depressing may be the prospect of a similar value of resistance from the h.t. line to an a.g.c. point.

Base Materials

If one were able to consider the use of only the more expensive base materials, the foil-to-foil leakage resistance on the surface would be the main factor. For practical purposes, however, one is obliged to look to the less expensive and more common synthetic-resin-bonded paper (s.r.b.p.) materials and those considered here are in general use and conform to British Standard Specifications 1137 Type 1, 2572 Type P1 and Type P3. When used as a base material for printed wiring, the insulation resistance of these materials becomes as important as the surface leakage resistance.

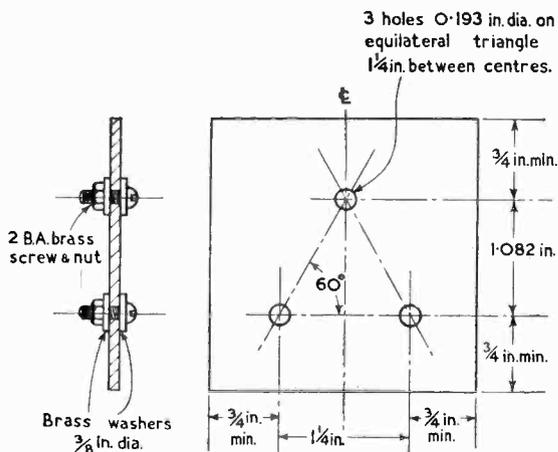
With these base materials one could therefore anticipate:—

1. Leakage through the base material.
2. Foil-to-foil leakage through any surface material whether intentionally added or otherwise acquired.

Base-material Leakage

Insulation resistance can be related fairly well to the quality of the material and thus, inevitably, to the cost, for which 25% of the total cost of a board, printed, etched, punched and finished appears to be acceptable. Although the quality of the material undoubtedly has some effect on the punching operation, it seems unlikely that the cost of the complete process would be very much affected. For example, an increase in the cost of base material of, say, 20% would probably result in an increase of 5% in the cost of the finished article.

The British Standard Specification for the three materials considered above calls for a 24-hour period of water immersion prior to measurements of insulation resistance. We might be inclined to regard water immersion as rather a hard test and the re-



This drawing, extracted from B.S. 1137:1949,† shows the recommended arrangement of specimen and electrodes for test of insulation resistance. The specimen is immersed in water for 24 hours at 20°C (Type I material) or subjected to relative humidity 75% at 20°C for 48 hours (Type III material) before electrical test is applied.

many as four or five contacting points. The h.t. line, the filament supply and, possibly, near-mains voltages all make close contact with the base material at various points on a typical panel.

The effect of any leakage resistance will of course depend on the type of equipment concerned: an unrequired component at a significant point in a

* Bush Radio Ltd.

† Full title: Synthetic-resin Bonded-paper Sheets for use at Power Frequencies. Copies of British Standards may be obtained from British Standards House, 2 Park Street, London, W.1.

sults as a little unrealistic; but after subjecting samples of each material to exposure at 35°C and 95% relative humidity, leakages far worse than those specified for insulation resistance can be obtained over similar distances in the material. Deterioration in insulation resistance is gradual and continuous with hours of exposure; recovery is also a slow process. The insulation resistance of the base material is mainly dependent on the average conditions of humidity. Tests on the three materials considered led to the conclusion that only the best quality (B.S.S. 1137/1) would be free of serious leakage resistance after only 48 hours of tropical exposure.

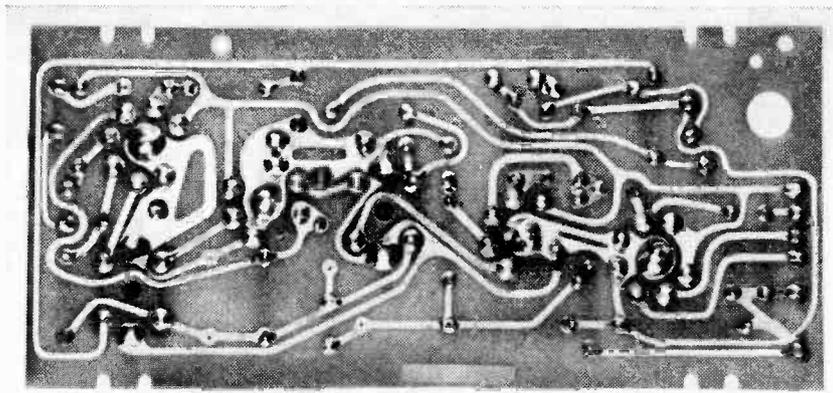
Surface Leakage

Evidence suggests that the surface leakage is not affected seriously by the quality of the base material but is dependent far more on the nature and quality of surface accretions. These may be of any substance which covers the board surface and may include chemicals left by the etching process or subsequently acquired, any fluxes, waxes or preservatives which are added to or allowed to remain on the surface of the board. The volume of surface material will in all cases be small compared to the volume of base material and this gives the surface leakage a rather different character. The insulation resistance of the base material is "solid" and semi-permanent, the surface leakage is variable by comparison. The variability of the surface leakage is usually due to the absorption and evaporation of moisture from the surface material. If the volume of surface material is small, it can be expected to dry out very rapidly with any increase in temperature or any improvement in local conditions of humidity. Power dissipation in the surface material due to leakage current, although very small, assists the evaporation of moisture. In mains-operated or heated equipments, leakage resistance in the surface material may well disappear before its effects become apparent. Unfortunately in practice we cannot separate the two forms of leakage resistance, neither can we, being aware of the effects of time and environment, be very sure of the quality or quantity of the surface material.

Improvement of Existing Materials

We are obliged to consider whether we can improve the conventional materials. The possibility of adding slots in the board was first considered; but this exposes more of the inner material and thus leads to a greater absorption of moisture and worsened leakage.

The most successful results were obtained with a wax treatment of the material. Samples of base materials were immersed in a wax bath at a temperature of 130-150°C for 3 to 5 minutes and a



Foil side of assembled wax-treated board.

considerable improvement in insulation resistance was obtained. Sample boards, etched and pierced but without components or fixtures, were treated in a similar fashion and the results were equally successful. Even the lowest grade of material gave surprisingly good results when treated and maintained its improved qualities after 200 hours of exposure.

The semi-absorbent nature of the inner material, assisted by some de-lamination which occurs as a result of the punching operation, permits absorption of wax at every hole or edge on the board. The thickness of wax deposited on the board is about .001". Unfortunately one cannot achieve the same degree of success with wax treatment applied after assembly, because the holes which would provide access to the inner material will be sealed with solder. Some success may be achieved by having open and unoccupied holes or slots at known vulnerable points but an immersion time of at least three minutes may well be impractical with a complete assembly. A "flash" dip of assembled board has very limited value by itself.

Pre-assembly Waxing

The pre-assembly waxing process, though adequately fulfilling requirements for insulation, has a number of disadvantages. Whether these are acceptable will depend on individual considerations of quantity, production facilities and various other factors, not the least important of which will be the standard of quality acceptable for the product. Many manufacturers are using hand soldering processes on printed wiring in quantity production and reduced reject rates and greater reliability are achieved in most cases. The wax treatment of panels to be hand soldered has little effect on the soldering process but the "people who do the work" are sensitive to changes of any sort and some difference will be apparent to them.

The wax treatment may render difficult the utilization of automatic soldering processes. Individual evaluation would probably be necessary for a specific assembly and process.

Although it is normal to complete the board production process with an application of fluxing varnish of some sort, the waxing process makes this impractical and unnecessary. It becomes essential, therefore, that the waxing process immediately

follows the post-etching cleaning and drying. It replaces the lacquering process both in time taken and sequence of operations.

It is possible that long periods of storage of un-assembled boards may make a subsequent soldering operation a little difficult but it is to be emphasized here that the protection afforded by a surface preservative is also somewhat limited. Some unlacquered waxed boards were exposed to extreme conditions of humidity and others left outdoors, in both cases for some days, without any apparent deterioration in solderability.

Mounting of Panels

It is possible that some edges of the board may have excess wax deposits due to the drain-off after removal from the bath. If by misfortune these occur

at mounting points, it may be necessary to remove the excess to establish a firm fixing. It is possible of course that arrangements can be made for the board to be drained in such a way that any surplus wax does not build up on the mounting positions.

Conclusion

The pre-assembly waxing should enable use to be made of the lower grades of base material. It may introduce some minor difficulties and inconveniences into a production system but these would appear to be a small price to pay for the degree of success likely to be achieved. The usual care and attention paid to the cleaning and preparation of the surface and the common-sense arranging of foils and holes to isolate vulnerable points in the circuit from high potentials are, of course, still necessary.

TELEVISION AND FILM TECHNIQUES

HIGHLIGHTS AND POINTERS FROM A RECENT CONVENTION

PENNY plain and tuppence coloured" was definitely the tenor of the convention on television and film techniques held at the Institution of Electrical Engineers on 20th and 21st April, sponsored by the British Kinematograph and Television Societies. Of the eight papers, five were primarily concerned with colour: one other paper contained more than a passing mention, and delegates insisted on raising the subject in the discussion following the two others.

Naturally, great general interest centres on the choice of standards for colour television, and those who favoured an adaptation of the N.T.S.C. system (which, it will be remembered, uses phase and amplitude modulation of a subcarrier to transmit colour information and a.m. of the main carrier for luminance or "brightness") might well have had doubts raised in their minds by the paper and demonstration by Polonsky, Sauvenet and Cassagne. The system was the Henri de France* (or as it is now much less euphoniouly known—SECAM) in its latest form. The original system used a.m. of the subcarrier to transmit colour-difference signals, the two signals required being transmitted sequentially on alternate lines of the picture. Changing of the subcarrier modulation to f.m. has resulted, in the main, in a reduction of sensitivity to the effects of noise. Visibility of the f.m. subcarrier has been reduced to the point where, at the moment, it is only 4 to 5dB worse than in the N.T.S.C. system. That the performance of SECAM in the presence of transmission distortions such as phase errors or differential gain effects is vastly superior to N.T.S.C. was demonstrated by the switching-in of such distortions and noise. In the case of a delayed secondary signal (ghost) the amplitude and delay was such that the line synchronizing of one receiver was upset, but no effect on the colour could be seen. It was claimed that the stability of the system was good enough to eliminate the need for either hue or saturation controls; although it was stated by Rodgers (Bush) in discussion that experimental 405-line N.T.S.C. receivers have been made without such extra "colour" controls. A feature of the discussion was the listing, by Maurice (B.B.C.), of points for and against SECAM in comparison with N.T.S.C.: the results were close, being slightly in favour of one system or the other depending on the viewpoint

taken for assessment. It is perhaps appropriate at this point to note the gist of Polonsky's reply to another questioner: over the years thousands have worked on N.T.S.C., SECAM has occupied ten or fifteen people only for a shorter time.

Pictures for the demonstrations were generated by a flying spot scanner at the Hirst Research Centre of G.E.C. and transmitted over radio link and cable.

Colour on Record

The recording on magnetic tape of N.T.S.C. signals was the subject dealt with by Roizen (Ampex International) who reviewed the methods employed and described a new technique, which (as he pointed out) like all good solutions to problems, is extremely simple. The major difficulty is that an inaccuracy in phase greater than 5° is unacceptable, and timing has to be held accurate to 0.002μsec. The scheme that was put into operation some time ago is known as "burst lock." On the American standard, about eighteen lines are recorded in one sweep of one recording head: within one line the errors caused by non-uniform head motion could not, due to the inertia of the head system, exceed the permissible limits. Thus by taking the subcarrier reference burst or pulse which occurs during the back porch of each line-sync pulse and "remembering" its phase with a ringing oscillator correct relative information of colour can be achieved for that line. Then this can be translated back to the stable subcarrier reference required for transmission. This must, as is apparent even from the over-simplification above, lead to much "electronic" complication. The new method, though, is very much simpler and was developed from a device called Amtec (AMPex Time Element Compensator). Amtec was designed to remove the "cogging" effect sometimes apparent on recorded vertical edges when a display employing a flywheel line timebase is used. The device uses a lumped-constant delay line whose capacitors are back-biased junction diodes†. Alteration of the bias, and thus the capacitance, provides a continuously variable delay to which the vision signal is subjected. The sync pulses from the tape replay are compared with a source of local, stable sync: when a timing

* *Wireless World*, p. 287, June 1960

† *Wireless World*, p. 361, July 1960.

error develops, the error voltage is made to change the delay time to compress or stretch out the picture line to its right length, so correcting the "cogging." For colour, the process is carried a step further by comparing, after time correction, the phases of the replayed and local colour burst to develop a "fine" correcting signal.

Another method of registering video signals, in this case by the use of a thermoplastic recording technique† was described by Glenn of the General Electric Research Laboratories (U.S.A.). This technique employs a base material of relatively high melting point coated with a thermoplastic film which is softened by r.f. heating. A "picture" is written in the form of surface charges on to the material by an electron beam: the film is then softened and the electrostatic forces caused by the charges form "ripples" which can be fixed by cooling the film below its melting point. Visual reproduction can be achieved with an interference-type optical system giving a picture which can either be displayed on a screen directly or converted to a television signal for transmission. The demonstration used optical projection: a grating is imaged by a lens on to another grating so that the passage of light is blocked. The ripples of the recording diffract the light allowing it to pass through the grating to be focused on the screen.

Colour recordings can be made too: for this the image itself is registered as very fine diffraction gratings. A photograph of a reproduced thermoplastic recording of one of the "standard" test slides was shown.

Colour Techniques

One source of input to a colour television system is likely to be colour film. Grimshaw (British Kodak) read a paper by Veal and Ritchey of Eastman Kodak, in which they described the measures they had found to be advisable in the production of colour films for television. Measurements of the overall transfer characteristic from a flying spot or three-vidicon teleciné equipment to a display using the shadow-mask tube were made. One test, for contrast range, was accomplished by taking an "average" scene and punching holes in the transparency. The holes were then covered by known densities to discover, against the background of an average picture, the highlight and "black" shadow levels usable. Other tests discovered the definition realizable, colour rendering and noise level corresponding to grain in the film. Broadly the conclusions drawn were that contrast ratio should not exceed 40:1—corresponding to a key light/general light ratio of about 2:1—and that the sharpness and grain acceptable for the U.S. system could be achieved by 16mm film. Colour rendering capabilities of film and TV are slightly different and, in fact, television covers a greater overall area on the colour triangle.

It appeared from the discussion on this paper that the European television engineer would far rather achieve the down-grading of film's full contrast range by electronic means: then as the system was improved the full potential of the film could be employed. The reduction in contrast range necessary would be achieved by a luminance feedback "compression" system: if this were employed with an improved TV system to "restore" a film specially produced for television, it would have to be a type of positive feedback and thus would be difficult to control.

Davies (Kodak) described a compact new machine for the fast processing of black-and-white film for television: the technique makes use of viscous solutions applied to the film.

Stanley and Treays (B.B.C.) gave a thorough account of the experimental programmes broadcast by the B.B.C. since 1954. The purpose of these tests was to assess the 405-line version of the N.T.S.C. system and also to discover its artistic possibilities. Many of the techniques for studio productions turned out, in fact, to be similar to the techniques for using colour film, although, judging from the account, some of the "subjective" effects of

colour (the influence of the appearance of one colour by another) may well prove rather more serious under television conditions. This paper was followed by Stanley and Watson (B.B.C.) reviewing some of the equipment problems and techniques, illustrated by N.T.S.C. colour signals from Lime Grove thrown on a 12×9ft screen by a new Marconi projector.

One objectionable form of distortion is that which results from gain inequalities at different signal levels—in a black-and-white system this distorts the relative contrast between tones but normally is not obvious. The effect on a colour picture of a change of gamma from 0.6 to 0.4 (demonstrated by Stanley and Watson) was to alter a peaches-and-cream complexion to florid, almost fevered appearance! Shading signals, which have to be applied to enable a camera to reproduce an even field of illumination, can result in spurious colours in patches of low luminance. Great care has to be taken here and one solution might be to "common" the red, green and blue signals at low levels. Phase distortion, too, is most important—a shift of 5° in subcarrier phase can produce objectionable colour changes; also the behaviour of a receiver's detector when presented with components in quadrature can, with positive vision modulation, reduce the saturation of colours. However, the fact that it is possible to make a system which produces good results was demonstrated by the switching into the link carrying the demonstration picture of two low-power transmitters and two receivers, all in series. The major effects (and the large picture was being viewed from only thirty feet away) were a slight reduction in saturation and a rise in noise level.

Large-screen Projectors

The slides used in the demonstration were followed by two films which, due to their content, must have placed severe demands on the system and the projector which, incidentally, used three English Electric c.r.t.s with Schmidt optical systems. Beam current was 1mA maximum for each tube (at 50kV e.h.t.) and a screen brightness of about 5 foot lamberts was realized. The definition achieved was a great advance on earlier systems too—the potentialities of the 405-line system were fully realized.

Another large-screen demonstration, again on 405 lines, featured the Eidophor projector. Baumann, of the Institut für Technische Physik der ETH, Switzerland, described how a beam of electrons, modulated by the video signal, builds up a picture upon a raster scanned out on a uniform oil film on a mirror, so causing the oil film to be distorted, by electrostatic effects, in proportion to the modulation. An interference-type optical system, using a Xenon lamp, projects the picture, although in this case the light is reflected from the mirror through "rippled" film. The oil is chosen to have a charge-decay time similar to one field of the picture, and, as it is damaged by the bombardment of the beam it is constantly changed by rotation of the mirror and an oil-circulation system. A recent improvement is the use of focus-modulation of the electron beam by an electrostatic lens: when black is required, the beam is out of focus and has little effect on the oil. However, for high brightness the beam is focused sharply and so exerts a greater effect on the oil film.

Once again, the resolution made full use of the 405-line system and it must be recorded that, after demonstrations of both the Eidophor and Marconi projectors, questioners asked whether the standard used was 625 lines. Field interlace was excellent in both cases.

Finally, to conclude this short report, may we ask why the cobbler should *always* be the worst shod of men? Lecturers were put at a disadvantage by several failures of slide-projection arrangements (it is greatly to their credit that they were not too put out) and the sound reinforcement system behaved, throughout the two days, in a manner that would have disgraced a village fête, let alone the I.E.E.

† *Wireless World*, p. 196, April 1960.

U.K. TELEVISION LINKS

POST OFFICE DISTRIBUTION NETWORK

By W. L. NEWMAN*

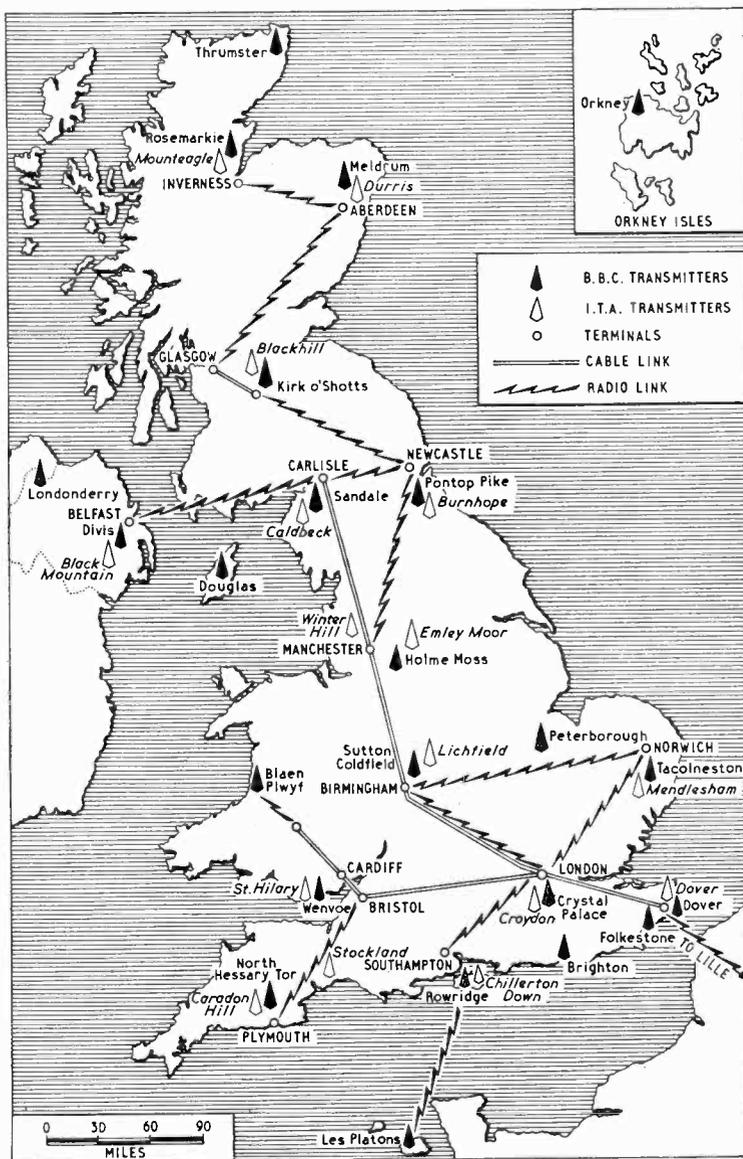
ALTHOUGH the B.B.C. and I.T.A. are individually responsible for providing and operating their television stations, the links between studios and transmitters and between stations in each network are provided by the Post Office which is, of course, also responsible for the links between the B.B.C.'s sound broadcasting stations.

The development of the Post Office television network commenced in 1937, the year after the start of the television service, when a cable of the balanced pair type was laid between various points of interest in London. This ran between Westminster Abbey, Buckingham Palace, Hyde Park, Broadcasting House and the transmitter at Alexandra Palace and was used to televise the Coronation in that year.

The first inter-city television link was provided in 1949 between London and Birmingham. This has now grown to a national network covering the whole of Britain and Northern Ireland, with a connection to Lille in France forming the British Post Office component of the Eurovision chain. It includes 2,500 miles of cable and 2,200 miles of radio circuits used for the distribution of the vision signals. Corresponding networks have been set up for the associated sound and control lines, which are an essential part of the circuits provided for the broadcasting authorities, and these, for the B.B.C. and I.T.A. services combined, account for 10,000 circuit miles. The sound and control circuits are provided over cable links, even when the vision circuits with which they are associated are carried by a radio system.

The main Post Office inter-city circuits are routed between

* Post Office, London Telecommunications Region.



The radio and cable links in the U.K. television network. Where a station relies on the reception of a nearby transmitter for its programmes (in Post Office parlance, R.R.B.—radio re-broadcast) no link is shown. The links between the terminal points and the transmitters are a combination of radio and cable.

Network Switching Centres (N.S.Cs), of which there are about 12 covering the country. Of these, London, Birmingham, Manchester and Carlisle are the largest. Between the N.S.Cs are provided a number of vision and sound channels in each direction; these can be interconnected to provide tandem connections between selected points. The vision channels must have a 3-Mc/s bandwidth to carry a 405-line signal with minimum distortion and the sound channels 10 kc/s. The inter-city channels are rented by either the B.B.C. or the I.T.A. Radiating from each centre are a number of circuits to and from the local studios and broadcast transmitting stations, each link being rented by the appropriate authority. In addition, the B.B.C. and the programme contractors, who provide the I.T.A. programme material, usually have a Programme Switching Centre (P.S.C.) in the main towns. The function of these centres is broadly similar to that of the N.S.C., but deals with a small group of studio connections, and a circuit to the local broadcast transmitter via the N.S.C.

Circuit Routing

The day to day work performed by the Post Office, in setting up and controlling the circuits, varies according to the authority concerned. The B.B.C. television service is essentially a national one, with only a small number of locally produced and transmitted programme items. Therefore, the circuits rented by the B.B.C. are connected from the N.S.C. through to the Corporation's premises; the B.B.C. then retains control of them, unless a fault develops, until the completion of the day's programme. Any inter-connection of circuits is performed by the B.B.C.'s own engineers, as required.

The I.T.A. service is based on regional units, each region being served by a programme contractor, the I.T.A. being responsible only for renting the inter-city and broadcast transmitter circuits. The individual programme contractors rent from the Post Office the circuits to link their studios and P.S.Cs. The I.T.A. programme in any one region is provided by the local programme contractor who is free to sell or buy programme material from any other contractor in the country. To inter-connect the various regions, the I.T.A.-rented circuits are used, and it is the responsibility of the Post Office to link these circuits as required. This is done on a time basis, so that the appropriate programme material is available at the right time and place.

The Post Office also provides circuits for organizations who perform specialized work for the various companies, one such unit provides a video-tape recording service.

The Post Office may be asked to establish a circuit between a studio and a recording unit so that a particular programme may be recorded for use later or for sending abroad for use by other television services. Other companies provide studio facilities which can be hired for use by advertising agents or for closed-circuit television demonstrations, here again the Post Office provides the links.

Another type of circuit requirement is the provision of channels to viewing rooms. These circuits are provided on normal telephone plant using ordinary subscriber's pairs, outside broadcast amplifiers being used to provide the necessary equalization

and gain for a bandwidth of 2.5 Mc/s. These rooms are usually owned or rented by programme contractors whose operational region is not London. They are used to show either broadcast or closed-circuit programmes from their own studios and the Post Office has to provide a circuit from, say, Manchester, to the appropriate viewing room in London.

The main distribution, as explained earlier, is by means of cable and radio system. In general coaxial cables are used for the land line portion of the vision circuits, but there are a few balanced pair cables still in use. The vision signals can readily be carried over coaxial cables at video frequency up to a distance of 15 miles and development work indicates that this will soon be extended.

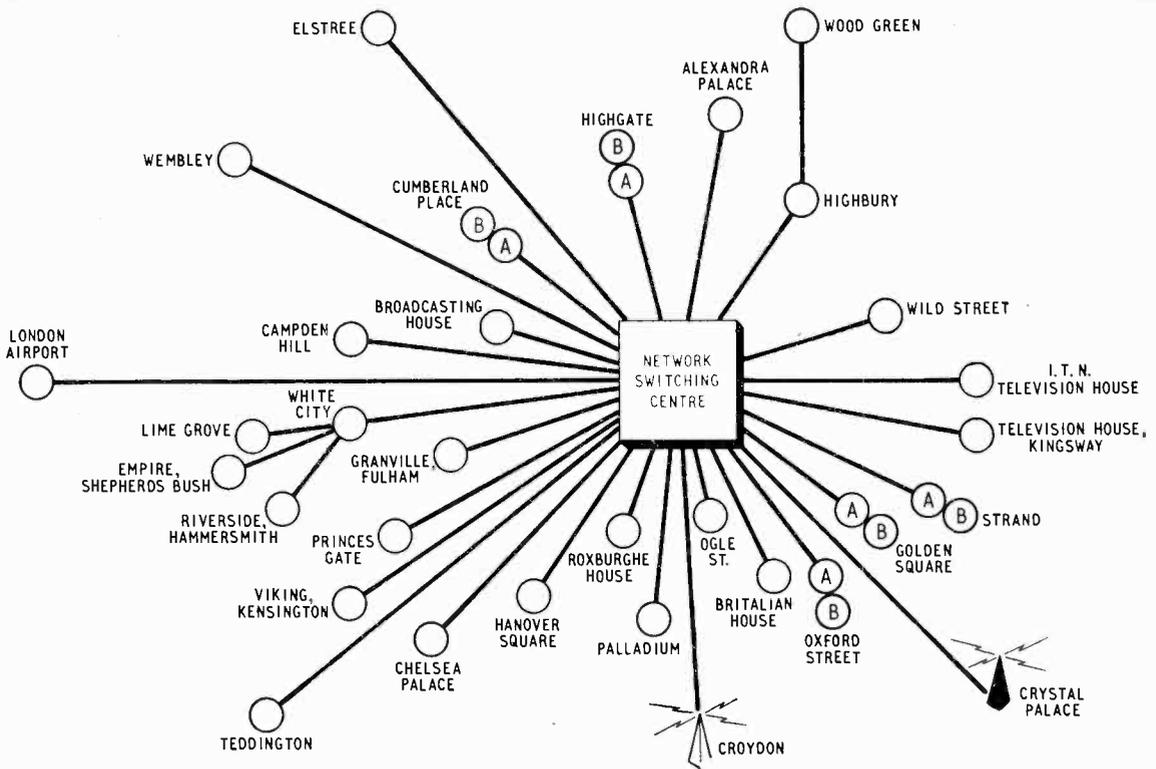
The main connections between the studios, broadcast transmitter and the programme switching centres in one area radiate from the network switching centre using unbalanced transmission on coaxial cables. The size of the cable may be 0.163in, 0.375in or 0.975in in diameter, depending on the installation, the equalization and gain in the amplifiers being adjusted according to the type used. One of the chief disadvantages of this type of transmission was the induced 50 c/s signal from mains cables, but this difficulty has been overcome by the use of large coaxial chokes at each amplifier point which effectively suppress the longitudinal current in the cable sheath. The signals carried on the coaxial cables are amplified at intervals, usually in telephone exchange buildings, if one is conveniently placed, or in repeater stations erected for this purpose.

For longer distance transmission, because of interference to signals below 10 kc/s on coaxial cables, the vision signals are shifted to a higher frequency band using a vestigial sideband transmission system. By a modulation process the video signal is transformed to another range, the limits of which vary with the system employed. Various line frequency standards are employed, the most common being 0.5-4.0 Mc/s with a 1,056 Mc/s carrier frequency, whilst the first system between London and Birmingham has a 3-7 Mc/s band and a 6.12 Mc/s carrier frequency. At the receiving end of a long-distance system a demodulation process restores the video signal. All main line transmission systems have duplicated equipment to guard against failure.

The radio systems vary because of rapid developments in this field, but the main equipments are built to operate in the 2000 and 4000 Mc/s bands, with an intermediate frequency of 70 Mc/s. These systems are frequency modulated using equipment designed in the Post Office Research Station. The original London-Birmingham radio system which was recently replaced by more modern equipment, used carrier frequencies in the 900 Mc/s band and an intermediate frequency of 34 Mc/s.

In the case of the radio equipment some of the earlier systems have complete standby transmitters and receivers, the later systems, however, usually have a complete reserve available from end to end known as a protection channel. This is a separate link working at a different carrier frequency and can be taken into service, either automatically or by manual operation, in the event of a failure.

The London Television Network Switching Centre is situated in part of the Museum Exchange building and comprises a repeater station where the cable systems terminate, a radio station on the roof,



Permanent cable links from the London Network Switching Centre to the television transmitters, studios and centres of entertainment in the London area.

a sound amplifier room, and a control room. The repeater station, besides housing the amplifier and translation equipment, has extensive supervisory apparatus to assist the maintenance engineers in their work. The main cable systems are provided with amplifiers at distances of either three, six or 12 miles, mainly in unattended stations. Any abnormal condition in these stations is signalled over a supervisory circuit to the Centre and remedial action is started. Where there are reserve amplifiers in distant stations they are automatically switched into circuit to cure a fault, or they can be operated remotely from the Centre over other supervisory pairs. Power faults in remote stations are also signalled and standby diesel-powered generators automatically start and supply power if the local mains supply fails. Extensive supervisory equipment is also provided on all the radio systems so that faults can be quickly detected and corrected. On some systems the switching of the protection channel is controlled by detecting the 10.125 kc/s synchronising pulses at both input and output of the system and using these signals to control the switching circuit.

London Focal Point

The Control Room in the London centre is the terminal point of the incoming and outgoing vision links, which now number over 100. In addition there are over 250 sound and 300 control lines. This room is the focal point of the work in the station and the point from which the cable and radio links are operated. Upon the engineers here and their colleagues in other stations, depend the television ser-

vices for the country. Two test consoles in the room are equipped with the apparatus to carry out the routine testing of the circuits.

The engineers have a group of 15 picture monitors in front of them which allow them to keep a constant watch on the signals passing through the station. In addition they have monitors and c.r.o.s built into the consoles so that detailed examination of a signal can be undertaken. From the video distribution rack behind them, the engineers can instantly connect any circuit to their test equipment.

On a number of vision circuits, remotely operated vision test signal generators are provided, so that a maintenance engineer is not required to visit distant stations for routine work. One such circuit provided with this type of equipment is the circuit from London Airport which is rented by the B.B.C. When this is required for service, at any hour of the day or night, operation of the appropriate switches will connect a waveform generator in Queens Building to the outgoing circuit. On completion of the lining-up procedure, the circuit will be connected direct to the camera by restoration of the switches. Between London Airport and the London N.S.C. there are four intermediate amplifier points, each with reserve equipment. These reserve amplifiers can also be switched into circuit from the control room. Tests are applied to all sound and vision circuits at regular intervals, vision circuits being tested daily.

In a side room off the control area is the Automatic Network Distribution Equipment (A.N.D.E.). This is provided to switch the I.T.A.-rented inter-city links to the various programme contractors who wish to send programmes to, or receive programmes from,

the I.T.A. network. Incidentally, "networking" has resulted in the growth of switching operations from 136 in May, 1956, to 4,540 in April, 1961. The equipment is divided into sound and vision components and can cater for changes of routing from any of 15 sources to any one or all of 15 destinations, in any order. Three changes of routing can be set up at the beginning of each day and at any time subsequently two changes are always available in advance. The times at which changes can be made can be set to take place at intervals of ten seconds if necessary. The electronic clock mechanism, which is driven from the 50 c/s mains supply, is automatically synchronized by TIM every ten seconds. To ensure complete reliability, two clocks are provided and the indications of these are continuously compared electronically, any deviation being detected and the faulty clock switched out of service until the fault is corrected, during which time manual switching operations are carried out. Instructions for the operation of the equipment are received from the I.T.A. on a daily schedule; this is amended as required during the day. A news item of major importance can mean the complete rearrangement of an evening's switching schedule; fortunately this is a rare occurrence. Switching operations have to be carried out in a period of three seconds and are usually completed ten seconds before a minute and frequently are required to provide networking conditions for the start of a new programme concurrent with the end of the previous item.

The Automatic Network Distribution Equipment incorporates two vision picture monitors, one of which can be switched by the controlling engineer to any of the signal sources and the other to the destination signals. In addition, a high-quality music amplifier and loudspeaker allows the various sound signals to be monitored. The engineer is able to check both sound and vision before and after a switch operation to ensure that it has been successfully completed.

On coaxial cable systems, to reduce the risk of breakdowns to equipment in remote repeater stations

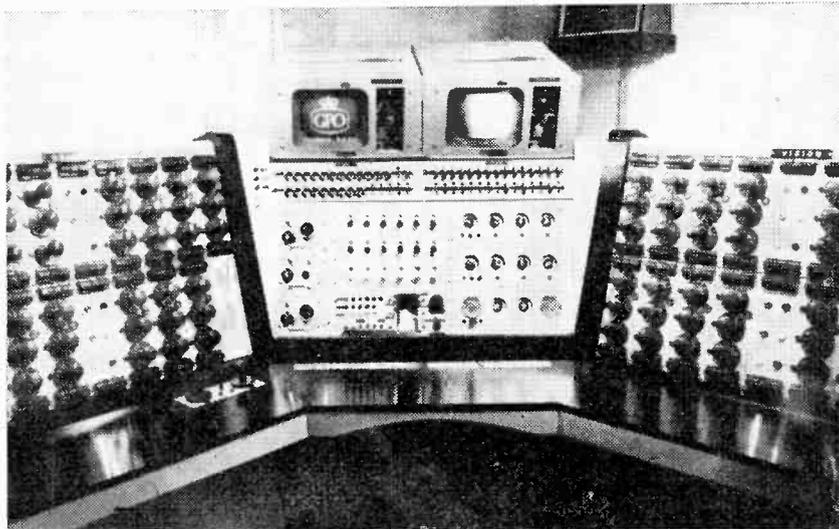
due to mains supply failures, it is only at what are known as power-feeding repeater stations that power is taken from the local supply. These repeaters are usually in towns and from these power is fed at high voltage over the coaxial cable itself to the other repeater stations. At the dependent stations the supply is transformed to a voltage suitable for the local amplifying equipment. At the power-feeding stations, diesel-powered generators are installed and these are automatically switched into service in a period of ten seconds in the event of a mains failure.

Coaxial cables are liable to damage due to road works and by working parties of other public utilities. To give early warning of damage which might interrupt a service, all cables are continually monitored to check their insulation. In addition, on the latest installations, the cables are kept under pressure from a gas reservoir and any damage causes an alarm indication to be given. Also, the escape of the gas limits the amount of damage which can be caused by water, if present. Everything is done to reduce the risk of accidental damage but emergency repair teams are available in all parts of the country to go to the site of any damage. In London the external repair team can keep in touch with the Centre by means of mobile radio equipment in their vans. The fixed station on this system is at Harrow Weald, which is the first intermediate amplifier point on the London-Birmingham radio link system; this is controlled over a land line from the London Network Switching Centre.

Besides the permanent television distribution network, the Post Office also provides a large number of vision and sound circuits on a temporary basis for use from outside broadcast sites. Some of these sites are in regular use and permanent cable facilities are provided, the amplifying equipment being provided only for the duration of the broadcast, however. Other broadcasts need the use of temporary circuits established on ordinary underground telephone wires. Such circuits can be provided using up to three miles of cable, with variable equalization amplifiers at mile intervals. Some O.B.s use a combination of various

types of transmission equipment, perhaps starting from a site using a normal telephone pair to the nearest hilltop, where the signal is injected into a portable microwave radio link, which carries the signal to a receiver positioned near a repeater station on a permanent coaxial cable system, where the signal, in turn, is fed into the main distribution network.

In addition to providing vision circuits for the present standards, a number have been installed to carry 625-line signals. Some of these circuits are used for recording purposes, the tapes being intended for use abroad, others are for closed-circuit work.



Combined vision and sound control position at the London Network Switching Centre which is housed in the Museum Telephone Exchange off Tottenham Court Road.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

High-impedance Voltmeter

THE Electro-sensor voltmeter developed by the American firm of Halex is, in essence, a highly sensitive, unity gain amplifier. The electrometer-valve input stage is followed by three unity gain cathode-followers, the earth of each forming the screen for the succeeding stage. Each screen is connected to one of three guard rings on the coaxial input socket, and as each has impressed on it a voltage very nearly equal to that at the input, the impedance is very considerably increased. This same technique also serves to decrease the input capacitance, and the overall effect is a very high-impedance, short time-constant input.

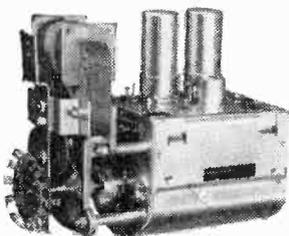
The output of the amplifier is at low-impedance—less than 0.2Ω —and is used to drive a meter, switchable to read from 1V to 250V d.c. full-scale, or 500V p.p. for very low frequency a.c. The input impedance is $10^{11}\Omega$, and the input capacitance less than 0.01 pf. Drift after warm-up is 2mV per hour.

Accessories are available to enable the instrument to function as an ohmmeter, a static charge indicator, a current regulator, etc.

The instrument is marketed in the United Kingdom by Scientific Furnishings, Ltd., West Hampnett Road, Chichester, Sussex.

Motor-driven TV Tuner

RECENTLY introduced by the Plessey Company, this television tuner is driven by a mains-powered induction motor to avoid the interference problems that would be raised by a commutator type. An automatic clutch disconnects the drive when the motor is switched off,



Plessey motor-driven turret tuner.

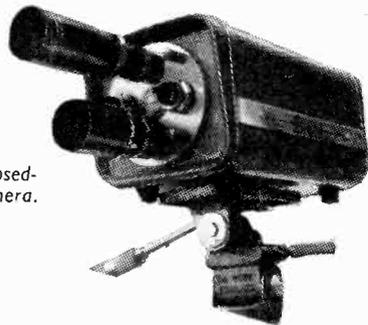
allowing the indexing mechanism in the tuner to exert full control. Remote push buttons or a rotary switch can be used for channel selection and the tuner has the valuable advantage that, as it does not require fine tuning, it can be placed anywhere in the receiver.

The tuner uses frame-grid valves and Band II v.h.f., as well as TV, channels can be incorporated. A complete rotation takes only seven seconds.

The Plessey Co., Ltd., Ilford, Essex.

Closed-circuit Television Camera

THE "Nashton" Mark I industrial closed-circuit television camera provides a signal which can be fed directly into a standard 405- or 625-line domestic receiver (preferably without flywheel sync) covering Band I. Costing £275, this camera is only $13\frac{1}{2} \times 7\frac{1}{4} \times 7\frac{1}{4}$ in and is completely self-contained. A Vidicon-type tube



Nashton Mk I closed-circuit television camera.

is used and the standard lens fitted to the four-position turret has an aperture of $f/1.9$, the lin focal length giving a horizontal field of view of 28° (at 10ft this corresponds to an area 5ft by 3ft 9in). As is common practice, the time bases used are not locked together—the resulting pictures are thus not interlaced. Resolution is about 300 lines overall.

Nash and Thompson, Ltd., Hook Rise, Tolworth, Surrey.

Safe Grease Solvent

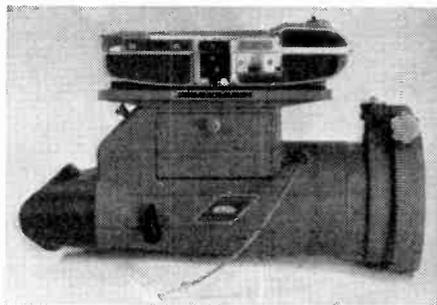
CHLOROTHENE NU, marketed by Penetone-Paripan, is a form of methyl chloroform and has valuable advantages as a solvent for oils, greases and waxes.

The solvent evaporates quickly and is claimed to leave no residue liable to cause tracking. In addition it is far less toxic than the ubiquitous "carbon tet." Comparable maximum allowable atmospheric concentrations are 25 parts in 10^6 for carbon tetrachloride, and 500 parts in 10^6 for methyl chloroform. It is non-flammable.

Penetone-Paripan, Ltd., Egham, Surrey.

Oscilloscope Cameras

AVELEY Electric are to market two oscilloscope cameras manufactured by Du Mont. The type 299, which accepts 120 roll- or cut-film, is for general recording from a 5in tube, while the type 302 incorporates a Polaroid-Land back, and will deliver a finished print

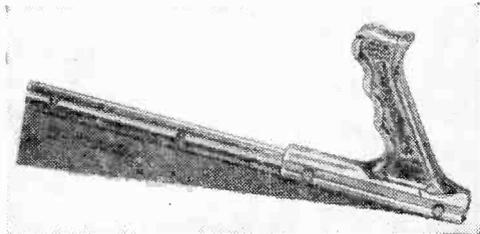


Du Mont type 302 oscilloscope camera. A pointer shows the position of the sliding back in relation to the lens.

on transparent or opaque film within one minute. Both cameras have a sliding back which facilitates the recording of more than one trace on each frame. Either an f/2.8 three-element Wollensak Du Mont or an f/1.9 six-element lens is available, both of 75mm focal length. Adaptors enable the camera to be used with most 5in oscilloscope tubes. Aveley Electric, Ltd., Ayrton Road, Aveley Industrial Estate, South Ockendon, Essex.

Saw for Cutting Sheet Material

THE ordinary hacksaw is inconvenient for the hand cutting of sheet metal or insulating material because the frame gets in the way—this can lead either to the use of blades without a frame or a wood saw, neither of which is the best of tools for the job. Stead's



"Steadfast" sheet saw.

"Steadfast Sheet Saw" employs replaceable 12in-long triangular blades (14 or 24 teeth/in), supported by a "spine"—the edge bearing the teeth is thus presented at the correct angle for cutting without the necessity for the spine to pass through the material being cut. The saw can be used for cutting unlimited length of flat or corrugated sheet as well as being suitable for most of the jobs for which a hacksaw is normally used.

J. Stead and Co., Ltd., Manor Works, Cricket Inn Road, Sheffield, 2.

Pulse Generator

WITH rise- and fall-times of 15 and 20 millimicroseconds respectively, the Wayne-Kerr Short Duration Pulse Generator P131 has many applications in computer development and pulse work generally. The pulse recurrence frequency may be from 50 p.p.s. to 50 k.p.p.s., while the pulse widths available are from 50-1,000 millimicroseconds. The output amplitude is variable in 0.5 dB steps between 0.1V and 10V at an impedance of 75 ohms, while a high level output of up to 40V is available at a source impedance which varies between 50 and 100 ohms. Facilities for pre-pulse, delay and external triggering are provided. Details are obtainable from Wayne-Kerr Laboratories, 44, Coombe Road, New Malden, Surrey.

High-speed Printer

A PRINT-OUT unit capable of operation at a speed of over 10 lines/second has been developed by Solartron. Fourteen columns are printed by continuously-rotating print wheels, which are struck at the required times by hammers. No reset mechanism is employed; as the next available character moves to the correct position on any print wheel, printing begins, no waiting being necessary. The equipment is in two sections—the printing machine proper and the electronic rack in a separate case. Inputs may be either decimal or binary at a voltage of -6V to -12V and the print command signal required is a 6V, 1 msec, negative-going pulse. The equipment is produced by the Solartron Electronic Group, Ltd., Victoria Road, Farnborough, Hants.

Wide Band Oscilloscope

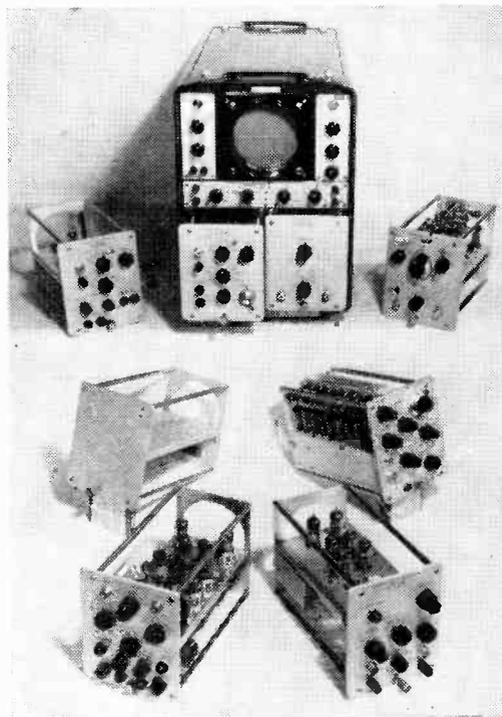
THE Cossor 1076 oscilloscope continues the trend towards a high quality basic instrument with plug-in extension facilities. An extremely wide frequency response (d.c. -60Mc/s at -3dB) is coupled with a sensitivity of 50mV/cm, which it is possible to increase to 5mV/cm while still retaining a bandwidth of d.c. -40Mc/s. Voltage and time are calibrated within $\pm 2\%$ and $\pm 3\%$ respectively, and a useful feature is the provision for Z-modulation at frequencies of 50Mc/s and 500Mc/s.

The 5in-diameter tube is operated at 10kV, the useful area being 6cm \times 10cm. All the usual facilities are provided—illuminated graticule, spot-position indicators, etc., and outputs provided are the amplified Y signal, and the gate and sawtooth waveforms of the timebase. Signal delay, of 150msec, is by a specially designed distributed-constant delay cable.

Extension Y facilities available include a high-gain amplifier, which affords a sensitivity of 1mV/cm from d.c. to 1Mc/s, and which has two input sockets. The inputs may be viewed separately, or combined differentially, in which case the common-mode rejection ratio is of the order of 80dB up to 50kc/s. A dual channel unit is also available which provides for the viewing of two inputs separately, algebraically added, or simultaneously by chopping or beam-switching on alternate sweeps.

A comprehensive range of triggering and delay facilities is provided by three X units. In addition to the normal triggering and windowing modes at a minimum signal level of 2mm deflection, or 0.2V external trigger, two calibrated units provide for sweep delays of from 2 μ sec/cm to 1sec/cm, with the delaying sweep brightened over the portion to be expanded.

The instrument is manufactured by Cossor Instruments, Ltd., Cossor House, Highbury Grove, London, N.5. The oscilloscope with the wide-band preamplifier and general-purpose trigger unit costs £650.



The Cossor 1076 wide band oscilloscope, with its range of plug-in units, which extend the X and Y performance.

Transformer - Ratio - Arm Bridges

USE IN THREE-TERMINAL IMPEDANCE MEASUREMENTS

By J. F. GOLDING*

BRIDGES of the transformer-ratio-arm type are not by any means new. Indeed, the system was the subject of a patent by Blumlein as long ago as 1928. The author first encountered a bridge of this type—an armed-forces instrument designed by E.M.I.—during the early years of the war. It was then known as the *in situ* bridge because its three-terminal-measuring facility permitted measurement of a circuit-component's value without disconnecting it.

The transformer-ratio-arm bridge has a number of other important attributes; but, as the three-terminal facility is probably the most impressive, let us consider the derivation of the bridge from this point of view.

Three-Terminal Measurements.—The requirement for three-terminal measurement arises when the impedance to be measured is in parallel with some unwanted impedance. A typical example is the stray shunt capacitance between test leads or terminals that often makes measurement of low capacitance somewhat uncertain. The effect of this unwanted shunt impedance can be eliminated if it can be divided into two elements in series, with their junction connected to a neutral point in the bridge.

The rudiments of this kind of three-terminal measurements can be illustrated by examination of the circuit arrangement shown in Fig. 1. G is a zero-impedance voltage source generating an e.m.f., E , which causes a current I to flow in the unknown impedance, Z_u . This current is monitored by a zero-impedance meter M . Thus the impedance of the unknown is obviously given by E/I .

But the dotted lines show, in parallel with Z_u , the series combination of two unwanted impedances, Z_1 and Z_2 . The effect of this shunt impedance is, however, obviated by connecting the junction of Z_1 and Z_2 to the neutral line. Z_1 is then connected directly across the source, and Z_2 is across the current

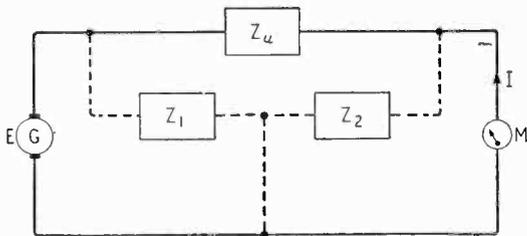


Fig. 1. Basic three-terminal-measurement system.

monitor. It is manifest that, since the source has zero impedance, the p.d. across Z_1 must be equal to E ; and, as no p.d. can be developed across the zero-impedance meter, there is no current flowing in Z_2 . So neither of these unwanted impedances can effect the accuracy of the measurement.

That this idealized arrangement could not be used in practice is too obvious to justify further comment; but the principle demonstrated can be applied to practical bridge systems.

The arrangement of a conventional impedance bridge with resistive ratio arms is shown in Fig. 2(a). This form is very well known, the conditions for balance being $Z_u/Z_s = R_1/R_2$, where Z_u is the unknown, Z_s is the standard impedance, and R_1 and R_2 are the ratio arms.

Applying Thevenin's theorem, the equivalent circuit shown in Fig. 2(b) can be derived. Here the resistive ratio arms are replaced by two e.m.f. generators producing voltages, E_1 and E_2 , equal to those appearing across the respective ratio arms at balance. The equivalent resistance of the ratio arms is represented by R_r between the detector and the junction of the two generators, the value of R_r being that of the two ratio-arm resistors in parallel.

It is conceivable that the values of the ratio-arm resistors could be made so small that R_r became negligible compared with the other impedances in the circuit. The equivalent circuit in Fig. 2(b) could then be redrawn as shown in Fig. 2(c).

In this last diagram the series combination of unwanted stray impedances, Z_1 and Z_2 , is also shown in dotted lines, their junction being taken to the point in the circuit where the detector joins the ratio arms; i.e., point C in Figs. 2(a) and 2(b).

Part of the circuit in Fig. 2(c) is drawn in heavy line; and this part is recognizable as being very similar to the circuit in Fig. 1. The essential difference lies in the fact that, in Fig. 2(c), the current in the unknown impedance is not monitored directly; instead it is balanced by the current in the standard impedance Z_s . But the same arguments regarding the cancellation of the unwanted stray impedance apply to both circuits. Although, in practice, the detector in Fig. 2(c) would not have zero impedance, this would not affect the accuracy of three-terminal measurements because no p.d. is developed across the detector when the bridge is balanced, and thus no current flows in Z_2 .

However, reduction of the ratio-arm resistance to the point where R_r is negligible is not practical in a conventional bridge; for, to obtain a workable

* Marconi Instruments Ltd., St. Albans.

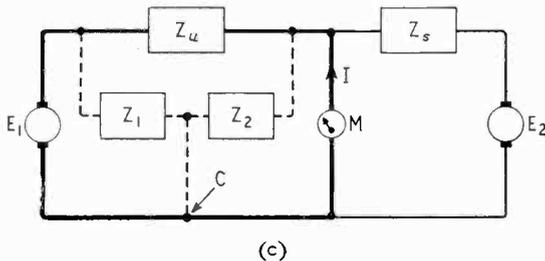
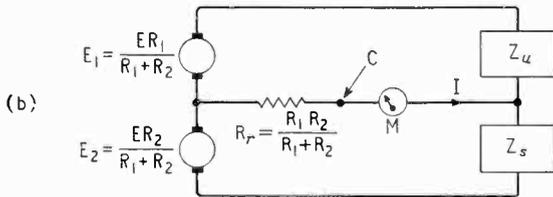
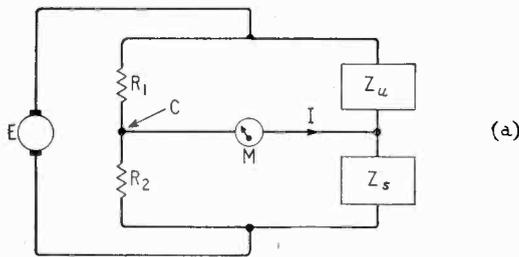


Fig. 2. (a) Conventional Impedance Bridge. (b) Equivalent circuit of conventional bridge of Fig. 2(a). (c) Equivalent circuit of conventional bridge when R_r of Fig. 2(b) is negligible.

sensitivity with such an arrangement, the current in the ratio arms would have to be very high indeed. And, if R_r has an appreciable value, the stray impedance Z_1 appears across the generator E_1 and R_r in series. The current flowing in the unknown and the detector due to E_1 is then reduced by the loading of Z_1 , thus affecting the accuracy of the bridge.

It becomes evident, therefore, that in the practical bridge the impedance of the detector is of secondary importance from the point of view of three-terminal measurements, whereas the impedance of the ratio arms is very important. And the problem resolves into one of producing two voltages, having a constant ratio, from very-low-impedance sources.

This is easily achieved by replacing the resistive ratio arms by a pair of secondary windings of a voltage transformer as shown in Fig. 3. Such a bridge closely approaches the ideal of Fig. 2(c). For, providing the leakage inductance and losses in the voltage transformer are small, the loading of an unwanted impedance, Z_1 , across one ratio-arm winding is distributed proportionally between the windings, and the voltage ratio remains constant.

Circuit Arrangements

Tapped Voltage Transformer.—In the basic circuit of Fig. 3, the standard impedance, Z_s , must be varied to achieve balance. Indeed, the impedance

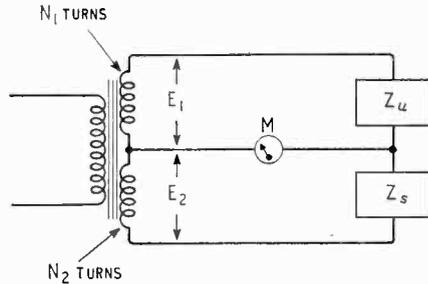


Fig. 3. Basic circuit of transformer-ratio-arm bridge.

range of the bridge is determined by the range over which the standard can be varied.

A variable-impedance standard is costly, complex, and susceptible to errors. Many conventional bridges are therefore built with fixed standards and variable ratio arms; and this system is ideally suited to the transformer-ratio-arm bridge. Fig. 4(a) shows a simple bridge in which a fixed standard is used and the voltage ratio is varied by the use of a tapped winding on the transformer.

The number of turns in the winding feeding the unknown is N_1 , and the winding feeding the standard impedance is tapped at N_2 turns, so that the conditions for balance are:—

$$\frac{N_1}{N_2} = \frac{Z_u}{Z_s} \quad \text{or} \quad Z_u = \frac{N_1 Z_s}{N_2} \dots \dots \dots (1)$$

Thus, the effect of switching the standard impedance through 10 tappings, spaced equally over the winding as shown in Fig. 4(a), is equivalent to changing its value over a range of 10 to 1 in equal steps.

By using a number of standard impedances having decade relationships to each other a multiple-decade bridge can be made. Such an arrangement is shown in Fig. 4(b). This diagram shows three standards Z_{s1} , Z_{s2} , and Z_{s3} , whose values are such that $Z_{s1} = 10Z_{s2} = 100Z_{s3}$. The effective admittances— $N_2/N_1 Z_s$ —of these standards can be added together.

To simplify the expression for balance conditions of such a bridge, let the ratio N_1/N_2 for Z_{s1} be written n_1 , that for Z_{s2} be n_2 and that for Z_{s3} be n_3 . The expression then becomes:

$$\frac{1}{Z_u} = \frac{1}{n_1 Z_{s1}} + \frac{1}{n_2 Z_{s2}} + \frac{1}{n_3 Z_{s3}} \dots \dots \dots (2)$$

Tapped Current Transformer.—If the bridge is intended to cover a wide range of impedances or if more than three significant figures are required, a practical difficulty arises due to the wide divergence of standard-impedance values. This is overcome by feeding the detector via a current transformer with a tapped primary winding as shown in Fig. 4(c).

Here the unknown is connected at N_3 turns, and the standard is connected to a tap at N_4 turns. The voltage across the secondary winding of the current transformer is proportional to the difference between the flux due to the current in Z_u and that due to the current in Z_s . This can be expressed as:—

$$\frac{N_1 N_3}{Z_u} - \frac{N_2 N_4}{Z_s}$$

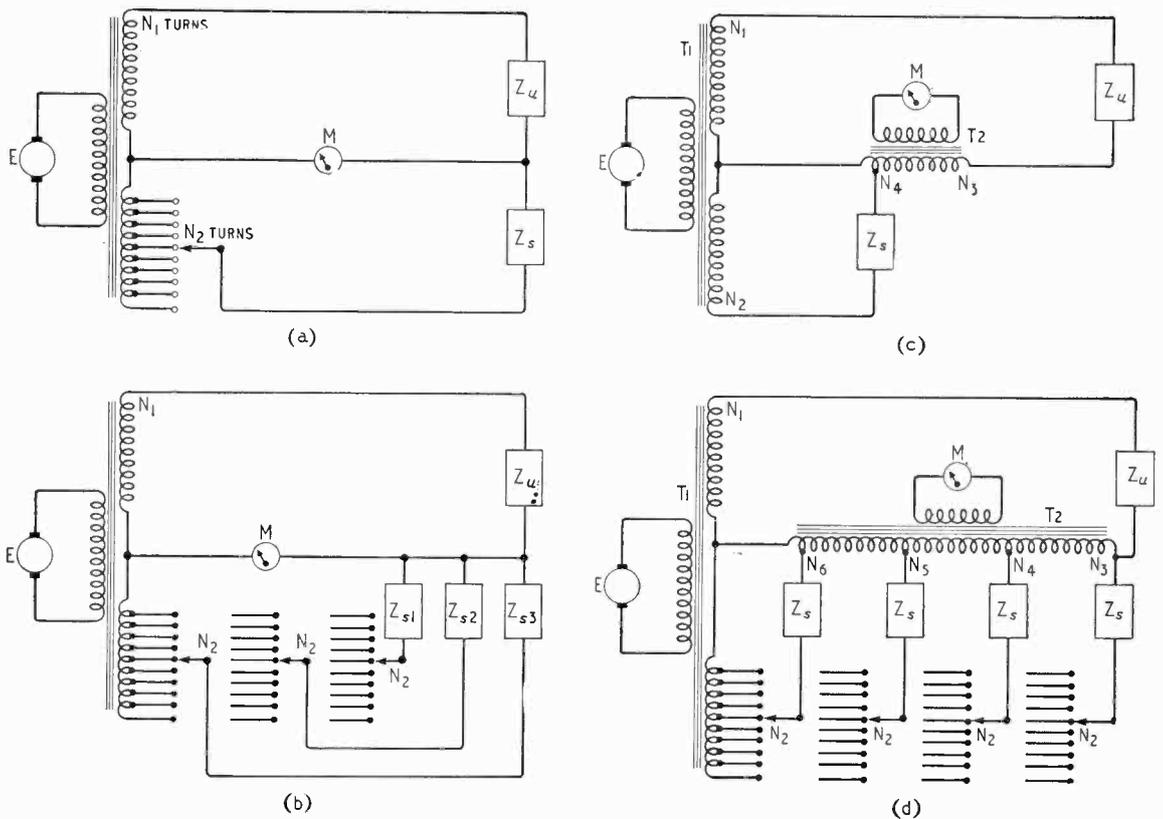


Fig. 4. (a) Use of a tapped-ratio-arm winding instead of a variable standard. (b) Use of three standards to give a three-decade read-out. (c) Use of a tapped current transformer T2 to increase the effective value of the standard Z_s . (d) Application of Fig. 4(c) to give a four-decade read-out.

Equating this to zero, the balance-condition expression becomes:—

$$Z_u = \frac{N_1 Z_s N_3}{N_2 N_4} \dots \dots \dots (3)$$

Comparing expression (3) with expression (1), it is evident that the effective value of Z_s , has been changed by the ratio N_3/N_4 .

It follows, then, that a number of tapings on the current-transformer primary winding can be used in order to provide decade-impedance steps. Fig. 4(d) shows the application of this reasoning. The primary winding of T2 has N_3 turns, and it is tapped at N_4 turns, N_5 turns, and N_6 turns, where $N_4 = N_3/10$, $N_5 = N_3/100$ and $N_6 = N_3/1000$.

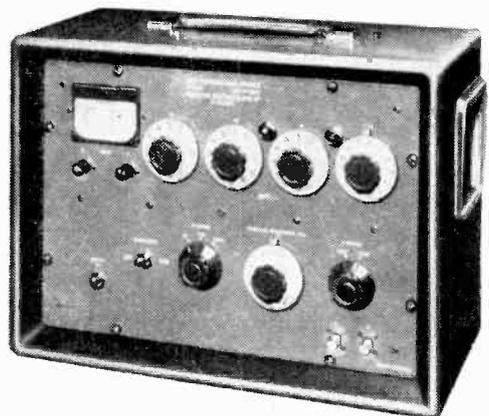
Four standards are used having an equal impedance value, Z_s . But, due to the action of T2, their effective impedances are in decade relationship. The balance-condition expression is thus a composite of expressions (2) and (3) as follows:

$$\frac{1}{Z_u} = \frac{1}{n_1 Z_s} + \frac{N_4}{N_3 n_2 Z_s} + \frac{N_5}{N_3 n_3 Z_s} + \frac{N_6}{N_3 n_4 Z_s} \dots \dots (4)$$

It has already been stated, however, that the turns at N_3 , N_4 , N_5 and N_6 are in decade relationship. This being so, the general expression (4) can be simplified to:—

$$\frac{1}{Z_u} = \frac{1}{Z_s} \left(\frac{1}{n_1} + \frac{1}{10n_2} + \frac{1}{100n_3} + \frac{1}{1000n_4} \right) \dots \dots (5)$$

Complex Impedances.—Any complex impedance measured at a single frequency can be resolved into an equivalent series or parallel network; and it has already been shown that the transformer-ratio-arm bridge indicates the sum of the effective admittances of its standards. So it is logical to regard the impedance being measured as a reactance in parallel with



The Marconi Low-Capacitance Bridge Type TF 1342 is suitable for the measurement of capacitance down to $0.002 \mu\mu F$. It is a transformer-ratio-arm bridge of the form shown in Fig. 4(d).

a resistance. These two parts are then balanced against reactive and resistive standards respectively.

It appears then that the transformer-ratio-arm principle is particularly applicable to multi-decade capacitance bridges. For example, expression (5), rewritten for the measurement of pure capacitance, simplifies to:—

$$C_u = C_s \left(\frac{1}{n_1} + \frac{1}{10n_2} + \frac{1}{100n_3} + \frac{1}{1000n_4} \right)$$

where C_u is the unknown capacitance and C_s is the value of the capacitance standards.

Multi-decade resistance or inductance measurement, however, is not nearly so straightforward. Indeed, where the required accuracy is such that a multi-decade system is necessary, the bridge is usually calibrated in terms of conductance and susceptance rather than resistance and reactance.

Continuously-Variable Controls.—Where a high degree of accuracy is not required, a single continuously-variable balance control is sometimes preferable to a series of decade switches. This applies particularly to resistance and inductance measurement; for a variable control with direct calibration is likely to be more convenient than switched decade controls with reciprocal calibration. A continuously-variable control is also usually desirable to indicate the last significant figure on a bridge with decade controls.

There are two ways of providing continuous variation. The more obvious is by the use of a variable standard; i.e., a variable capacitor or resistor. The other method, which is more convenient when a high effective impedance is required, is shown in Fig. 5.

Here a variable potentiometer is connected across the ratio-arm winding, and the standard impedance is connected to its slider. The action of varying the potentiometer is then exactly analogous to that of switching through a series of tappings on the transformer winding. And, providing the resistance of the potentiometer is small, the behaviour of the ratio arm remains that of a low-impedance e.m.f. generator.

Very high effective impedances can be produced by this second method since the voltage at the slider can be reduced almost to zero. In fact this method gives an effective impedance many times greater than could reasonably be attained with a variable impedance connected to the end of the winding.

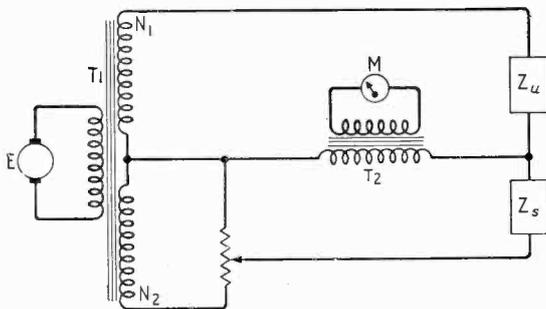


Fig. 5. Continuously-variable standard arm.

Correction of Standard Impedances.—Although high-quality components are naturally used for the standard impedances, some phase-angle errors in the standards are inevitable; a standard capacitor is bound to have some loss, and the standard resistor may possibly have some stray reactance.

Such errors can easily be compensated for by the deliberate introduction of the right amount of loss or stray reactance into the opposite arm of the bridge as shown in Fig. 6(a). In this diagram C_s is the standard having an equivalent shunt loss of R_L . Resistor R_c balances R_L , so that the resistive component of Z_u is balanced against the standard resistance R_s . The value of R_c is obviously given by:—

$$R_c = \frac{N_1 R_L}{N_2}$$

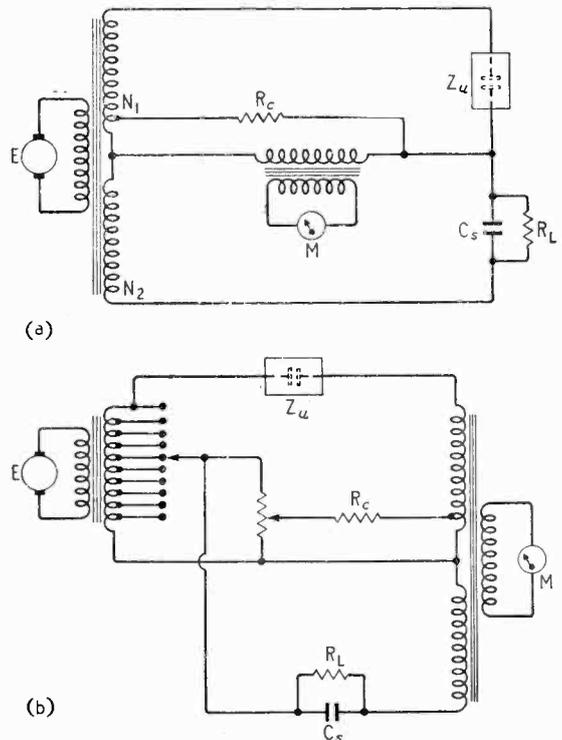


Fig. 6. (a) Use of a compensating resistance R_c to balance the loss, R_L , in the capacitive standard. (b) Reversed arrangement to Fig. 6(a) keeping a constant ratio between R_L and R_c .

But, referring to a practical arrangement of the bridge as shown in Fig. 4, an obvious difficulty becomes evident. For balance is achieved by varying the ratio N_1/N_2 and this implies a different value of R_c for each setting of the balance control.

The difficulty can be overcome by rearranging the bridge as shown in Fig. 6(b). Here the transformers have been interchanged; the ratio arms are in the current transformer and a single voltage-transformer winding feeds both the standard and the unknown impedance. With this arrangement, the ratio N_1/N_2 remains constant for all settings of the balance-control switch; so a

(Continued on page 333)

single value of R_c can be selected to offset the loss in the standard capacitor.

Fig. 6(b) also shows a preset-variable-adjustment arrangement, obviating the need for individual selection of R_c . This uses the principle illustrated in Fig. 5. The potentiometer is adjusted during the initial calibration of the instrument to give correct phase balance using a capacitor with known shunt loss connected to the unknown terminals.

This inverted arrangement also simplifies the design of a multi-decade bridge for measurement of both inductance and capacitance. Capacitive standards are almost invariably used, and, for inductance measurement, they are switched into the same arm of the bridge as the unknown.

Inductance is then indicated in terms of "negative capacitance", which may be converted by the formula:—

$$L_u = \frac{1}{\omega^2 C_i}$$

(Z_2 in Fig. 2) across the detector cannot produce an error.

Regarding the ratio-arm windings of the transformer as voltage generators, leakage inductance and loss can be regarded as an inductance, L_b , and a resistance, R_b , in series. For simplicity let $R_b + j\omega L_b = Z_t$.

Providing Z_t is small compared with Z_u , the normal condition for balance remains:—

$$Z_u = \frac{E_1 Z_s}{E_2}$$

Any stray impedance, Z_1 , across the winding will, however, drop the voltage applied to the unknown to a value given by $E_1 Z_1 / (Z_1 + Z_t)$. The conditions for balance are then:—

$$Z_u = \frac{E_1}{E_2} Z_s \frac{Z_1}{Z_1 + Z_t}$$

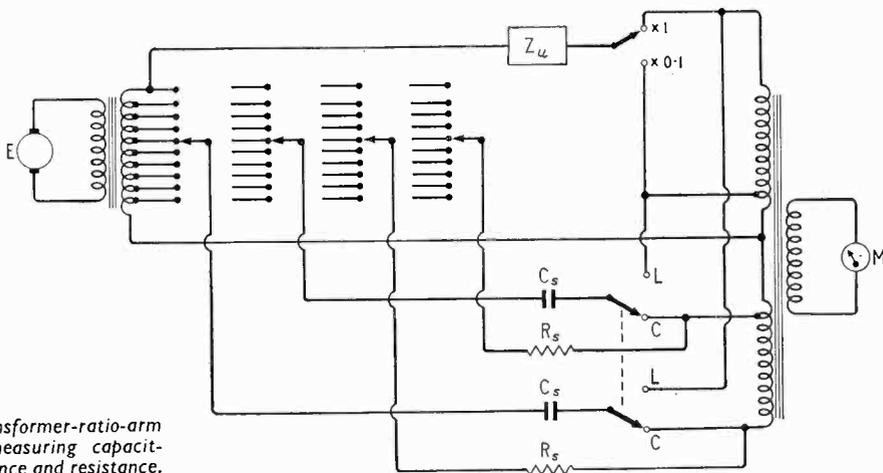


Fig. 7. Transformer-ratio-arm bridge for measuring capacitance, inductance and resistance.

where L_u is the unknown, C_i is the indicated capacitance and ω is 2π times the measurement frequency.

Bridges employing this system usually operate at such a frequency that ω is equal to some convenient power of 10, so that the conversion can easily be made with the aid of a set of reciprocal tables.

An example circuit of a bridge suitable for measuring capacitance, inductance, and resistance is given in Fig. 7. (For simplicity, only two capacitance and two resistance decades are shown.) Such a bridge should be regarded as an admittance bridge and would normally be calibrated in positive and negative capacitance and conductance.

Quantitative Analysis

Three-Terminal Measurements.—The accuracy of three-terminal measurements with low-value shunt impedances is directly related to loss and leakage inductance in the transformers.

For assessment of the errors caused by shunt impedance, consider first the bridge arrangements shown in Fig. 4.

The simplest practical form of the bridge is that of Fig. 4(b). In this arrangement no current transformer is used, so that any shunt impedance

But $E_1 Z_s / E_2$ is the indicated impedance, and calling this Z_{ind} we have:—

$$Z_u = Z_{ind} \frac{Z_1}{Z_1 + Z_t}$$

$$\text{or, } Z_u = Z_{ind} \left(1 + \frac{Z_t}{Z_1}\right)^{-1}$$

This can be expanded to a binomial series:—

$$Z_u = Z_{ind} \left(1 - \frac{Z_t}{Z_1} + \frac{1}{2!} \cdot \frac{Z_t^2}{Z_1^2} - \frac{1}{3!} \cdot \frac{Z_t^3}{Z_1^3} + \text{etc}\right)$$

Unless the shunt impedance is so small that it reduces the bridge sensitivity, the second order and subsequent terms can be neglected and the expression written:—

$$Z_u = Z_{ind} \left(1 - \frac{Z_t}{Z_1}\right) \dots \dots \dots (6)$$

The bridge thus reads high by a percentage error equal to $(Z_t / Z_1) \times 100$.

The value of Z_t of course varies with the number of secondary terms, and this is directly related to the impedance range. However, Z_t seldom exceeds 1 part in 10^4 relative to Z_u , the unknown. Accepting this value of Z_t , if Z_1 is as low as a tenth of Z_u the error will be only 0.1%.

In practice the output impedance of the transformer is usually much lower relative to the unknown so that even lower value shunt impedances can be tolerated.

Where a current transformer is used as shown in Fig. 4(d), the loss and leakage inductance become significant only in relation to those standards which are tapped down the winding. The error due to shunt impedance across the detector is thus more difficult to evaluate.

However, the worst possible condition occurs when the bridge is operating at the extreme high-impedance end of its range so that the standard impedance tapped lowest on the primary of the current transformer is the only one in use. The conditions in the current transformer are then similar to those in the voltage transformer, and the leakage inductance and loss can also be represented as a series impedance Z_i .

The current in the transformer winding is thus lowered by the introduction of shunt impedance Z_s , to a value given by $I Z_s / (Z_i + Z_s)$. Similar reasoning to that used for assessing the error due to Z_i can thus be followed giving:—

$$Z_u = Z_{ind} \left(1 - \frac{Z_i}{Z_s} \right) \dots \dots \dots (7)$$

Depending on the position of the tap on the primary windings, Z_i may vary from zero to something approaching 1 part in 10^4 relative to Z_u ; and the probable error due to shunt impedance across the detector is likely to be very much less than that due to impedance across the voltage transformer.

Measurement Range.—An important attribute of the transformer-ratio-arm arrangement is its facility for very wide ranges of impedance measurement with a single bridge. Range switching is normally accomplished by switching the unknown impedance to an appropriate tapping on the ratio-arm winding, the switch being calibrated as a range multiplier. Such an arrangement is incorporated in the example shown in Fig. 7.

This diagram shows range switching through only one decade; but, assuming that the low-impedance tapping is across 10 turns, the use of three decades is not unreasonable. A 10,000 turn winding would, thus, be required with tappings at 1,000 turns, 100 turns, and 10 turns. Impedance-range multiplication would then be possible from $\times 1$ to $\times 1,000$.

Such a multiplier arrangement used in a bridge with four decade controls, as shown in Fig. 4(d), would provide an overall ratio of ten million to one between the lowest and highest impedances that can be measured.

Measurement Accuracy.—The accuracy of any bridge is a function of the accuracies of its standard impedances and its ratio arms. Furthermore, in practice, the attainable bridge accuracy can be assessed in terms of the stability of its components; for, by the use of suitable padding, the value of any component can be effectively corrected to any desired accuracy within the limits of its stability.

In conventional—impedance-ratio-arm—bridges stability of the ratio-arm components is an important factor affecting the accuracy of the bridge. Transformer ratio arms, however, are intrinsically com-

pletely stable; for the turns ratio cannot possibly vary.

The bridge stability is thus the stability of its standards alone. Also, the use of transformer multiplication at the detector as well as at the voltage source permits selection of standard-impedance values for maximal stability regardless of the range of the bridge.

Transformer-ratio-arm bridges having accuracies of the order of 0.1% are, therefore, simple to construct and are normally modestly priced.

Application Notes

It is evident from the foregoing that the transformer-ratio-arm system exhibits clear advantages for certain applications. A tendency thus arises to suppose that the system is superior to the conventional bridge arrangement for all applications. This, of course, is not so; and the following comparison notes may be helpful in assessing the suitability of a transformer-ratio-arm bridge for any particular purpose.

Capacitance Measurement.—Unlike resistance and inductance, capacitance is a direct measure of admittance rather than of impedance. As the transformer-ratio-arm bridge is basically more suitable for measurement in terms of admittance, it is automatically admirably suited to capacitance measurement.

Furthermore, it follows that with the transformer-ratio-arm system the loss is more conveniently indicated in terms of equivalent shunt resistance. This is fairly realistic as applied to most capacitance measurements. If the loss is small it is unimportant whether it is regarded as shunt or series loss. In capacitors having an abnormally high power factor, the loss is generally due to poor dielectric so that the representation as equivalent shunt resistance is largely the true one.

The transformer-ratio-arm bridge is particularly suitable for measurement of very-low capacitance values. Such measurements with a conventional bridge are susceptible to errors due to the stray capacitance between connecting leads and between bridge terminals. When short rigid connecting leads are used this stray capacitance is sensibly constant, and errors can be largely eliminated by evaluating the strays and correcting accordingly.

There are many applications, however, where short rigid connections cannot be used. Determination of a capacitor's temperature coefficient is a typical example.

With the component under test housed in a temperature-controlled oven comparatively long leads must inevitably be used for connection to the bridge. Such a test is likely to involve a protracted series of measurements; the changes in capacitance may be quite small; and, even though care is taken to prevent physical movement of the leads, the magnitude of possible error due to quite small changes in stray capacitance introduces an element of uncertainty in the final result.

The difficulty can be completely overcome if a transformer-ratio-arm bridge is used. The test leads may then take the form of screened cables with the screens taken to the neutral point of the bridge. The stray shunt capacitance is then divided into two capacitances effectively in series and is

automatically cancelled by the three-terminal measurement.

Inductance Measurement.—Measurement of inductive reactance by means of a transformer-ratio-arm bridge is normally made by switching the standard capacitors into the "unknown" arm as shown in Fig. 7.

For bridges having accuracies up to about 1%, the continuously-variable arrangement can be used (see Fig. 5) with a direct inductance calibration on the dial. For higher-order accuracies a multi-decade bridge must be used; and the inductance is indicated in terms of "negative capacitance". This is converted to inductance by the formula $L = 1/\omega^2 C$.

Apart from the inconvenience of making this conversion, it is immediately evident that the accuracy of the bridge is very dependent upon the frequency of its exciting voltage. The conventional Maxwell bridge, on the other hand, is independent of frequency, and the Hay bridge is largely independent of frequency providing the loss tangent is less than 0.1.

As with capacitance measurement, the loss in an inductance is indicated in terms of effective shunt resistance by the transformer-ratio-arm bridge. Where the loss is small this is unimportant; but inductors frequently have a noticeable loss tangent, especially at low frequencies. At low frequencies the loss in air-cored inductors is principally due to the resistance of the conductors and is therefore effectively series resistance. This must be taken into account when determining the inductance, because, for loss tangents greater than 0.1, the measured inductance with effective shunt loss may be appreci-

ably different from that with effective series loss. This is explained fully in the appendix to this article.

Three-terminal measurement of inductance at low frequencies is useful mainly for measurement of components *in situ*. With low-value inductors the impedance of any shunt strays is unlikely to be low enough to produce any noticeable error, the main source of error being the series inductance of the connecting leads. With high-value inductors the self-capacitance of the inductor itself is usually a more important source of error than stray shunt capacitance between the connecting leads or bridge terminals.

Resistance Measurement.—Being essentially an a.c. measuring device, the transformer-ratio-arm bridge measures both the reactance and the resistance of any impedance. This has no particular advantages or disadvantages; but it will be appreciated that "universal" or "LCR" versions of transformer-ratio-arm bridges are switched for capacitance or inductance measurement, and there is no condition equivalent to the "Wheatstone-bridge" setting of the conventional universal bridge.

Bridges having measuring accuracies better than 0.5% are normally multi-decade bridges (see Fig. 7) and are necessarily calibrated in terms of conductance. Simple resistance measurement is thus less direct than with conventional bridges. Where the measuring accuracy is of the order of 1%, however, a continuously-variable standard can be used having direct calibration.

For measurement of very-high resistance values the transformer-ratio-arm arrangement has the advantage that shunt leakage resistance can often be cancelled by three-terminal measurement.

APPENDIX

Effective Series and Shunt Loss in Reactive Components.—A series impedance combination $R_1 + jx_1$, in one arm of a bridge can be balanced by a shunt impedance combination, $jxR/(R + jx)$, in the opposite arm. Assuming the ratio arms are equal, conditions for balance are:—

$$R_1 + jx_1 = jxR/(R + jx)$$

$$\text{so that, } x_1 = \frac{x}{1 + x^2/R^2} = \frac{x}{1 + \tan^2 \delta}$$

$$\text{and, } R_1 = \frac{R}{1 + R^2/x^2} = \frac{R}{1 + Q^2}$$

If R is large compared with x —i.e., the loss tangent is small:—

$$x_1 = x, \text{ and } R_1 = \frac{1}{R + R}$$

which is approximately equal to $1/2R$.

Thus, when the loss is small, it is relatively unimportant whether the bridge measures in terms of equivalent shunt or series resistance. For loss tangents greater than 0.1 however, the error in measured reactance becomes comparable with the accuracy of the bridge, and a correction should be made if it is possible to determine whether the unknown has series or shunt loss.

The table gives correction factors to be

applied when an impedance having series loss is measured with a transformer-ratio-arm bridge—the indicated inductance or capacitance should be multiplied by the correction factor.

Tan δ (x/R)	Correction Factor	
	Inductance	Capacitance
0.01	1.000	1.000
0.02	1.000	1.000
0.04	1.000	1.002
0.05	1.000	1.004
0.08	0.990	1.006
0.10	0.990	1.010
0.15	0.980	1.023
0.20	0.962	1.040
0.25	0.943	1.063
0.30	0.917	1.090
0.33	0.901	1.109
0.35	0.893	1.123
0.40	0.862	1.160
0.45	0.833	1.203
0.50	0.800	1.250
0.60	0.735	1.360
0.70	0.671	1.490
0.80	0.610	1.640
0.90	0.553	1.810
1.00	0.500	2.000

TECHNICAL NOTEBOOK

Parametric Amplifier using only electrostatic fields to produce focusing and interaction of an electron beam is proposed by B. J. Udelson in a letter in the August 1960 issue of *Proc.I.R.E.* (In previous parametric amplifiers using electron beams, as well as electrostatic fields, magnetic fields have had to be used, either to focus the beam or, as in Adler-type valves using cyclotron resonance, to produce interaction.) In the new proposed valve the electron beam would pass between a linear array of pairs of parallel plates divided into input, pump and output sections and fed alternately from two different direct voltage sources. The voltage differences between adjacent pairs of plates produce forces which both focus the beam and also give rise to transverse oscillations of the electrons (at a frequency determined by the voltages and dimensions of the plates). These transverse oscillations can be made to interact with a signal at the same frequency and pump at twice their frequency by superimposing the signal and pump voltages on to the direct parallel plate voltages. Low-noise fast-wave interaction should be possible in such valves.

Permanent Marking of Teflon-insulated wires is difficult because the insulation is one of the least-easily damaged materials used. However, a process for the production of identifying markings which are as durable as the insulation itself has been developed by the Martin Company of Baltimore, Maryland, U.S.A. Teflon foil, bearing identifying letters or figures of darker colour than the insulation, is placed on the wire which then passes into an infra-red oven. The dark legend heats up rapidly and "sinters" on to the insulation, forming an indelible marking, whilst a fan draws in cool air to prevent the air temperature rising to the point where the whole covering is melted.

Interstellar Communication possibilities using optical masers are discussed by Dr. R. N. Schwartz and Prof. C. H. Townes in an article in the April 15, 1961, issue of *Nature*. Because of the intense beams available from such masers, such communication seems reasonably possible. The best chance of producing a signal distinguishable from the background light of the local star would be to transmit within one of the absorption spectral lines of this star, since the stellar intensity is re-

duced by a factor of 10 or more in such lines. The authors therefore suggest a search for very narrow emission lines (such as would be produced by optical masers) within the absorption lines of the spectra of neighbouring stars. (Possibilities of using radio waves for interstellar communication were discussed by G. Cocconi and P. Morrison on p. 844 of the Sept. 19, 1959, issue of *Nature* and in this section of our February 1960 issue.)

Computer-Designed Computer has been recently constructed using the Bell Laboratories Automatic Design System (abbreviated to BLADES). In this system the computer is designed as far as possible around a single general-purpose type of logic unit. (Each such unit contains four independent switching circuits which can be interconnected in different ways to produce various types of logic circuit.) The required computer functions are expressed in logical and geometrical terms, which are then used to programme an ordinary general-purpose digital computer. This then specifies the number of general-purpose logic units required for each sub-assembly of the computer being designed, the logic unit pins to be interconnected, the sizes of wire to be used in connecting them, the connecting wire paths to be followed for minimum path length, any special logic units required, and finally a complete parts list. Power wiring is also arranged so that no two successive functions are supplied from the same power line.

Magnetic Tape Tester used by M.S.S. uses a high-quality tape recorder to record signals at 1 and 10kc/s on the tape. These signals are replayed through the same recorder, and the replay output rectified and displayed on a c.r.t. This enables any fluctuations in the tape output to be observed. Both the rise and fall times of the rectified output display are made independently variable to allow different phenomena to be observed under the best conditions. For example, for observing modulation noise (which can be very "peaky") fast rise and slow fall response times are required, whereas just the opposite—slow rise and fast fall response times—are required for observing short dropouts.

New Magnetic Tape introduced by Gevaert—Type F—has been given a rough backing so as to reduce the risk of spillage when using large

professional open- and single-sided spools. The roughness is produced in this tape by applying a coating to the normal tape backing, rather than by mechanically roughening the backing itself.

Audio-Frequency "Comb" Filter described by L. H. Bedford in the April 1961 issue of *Electronic Technology* consists simply of a stretched (non-magnetic) conductor, the centre portion of which lies in a transverse magnetic field. At frequencies at which the stretched conductor is mechanically resonant, its electrical impedance rises. This rise can be made use of, for example by connecting the string in a feedback path, to produce a "comb" filter, i.e. a filter having pass or stop bands spaced at uniform frequency intervals. Quite high Q's can be achieved in this way; for example in the phosphor bronze wire 50c/s fundamental filter for reducing hum described in the article, the fundamental Q was 220. At harmonic resonant frequencies even greater Q's (of the order of 1500) were observed. This last factor usefully counteracts the reduction in the attenuation at exact harmonic frequencies which would otherwise be caused by the small (of the order of 0.4%) departures of the mechanical harmonic resonant frequencies from a true harmonic series. Resonant attenuations of the order of 20dB were observed.

New Ultrasonic Transducer being developed at the Bell Telephone Laboratories consists simply of a plate of a piezoelectric semiconductor (such as gallium arsenide) on which a thin metal film is deposited. Since the charge carriers in these two materials have different Fermi quantum energy levels, an electric field is produced across their junction. This field decreases the density of charge carriers around this junction, producing a high-resistivity region which is known as a depletion layer. If a voltage is now applied across the transducer, most of this voltage is dropped across the high resistivity depletion layer, so that this layer behaves as a very thin (10^{-5} – 10^{-3} cm thick) piezoelectric crystal. Because of this extreme thinness large piezoelectric stresses are produced, and the efficiency is greatest at very high frequencies. (In the 1 to 10kMc/s range, efficiencies as high as 100 times those of other known ultrasonic transducers should be achievable.) Another advantage of the new

CONFERENCES AND EXHIBITIONS

Latest information on forthcoming events both in the U.K. and abroad is given below. Further details are obtainable from the addresses in parentheses.

LONDON		
June 12-16	Components and Materials used in Electronic Engineering (Conference) (I.E.E., Savoy Place, W.C.2.)	Central Hall
June 19-22	Laboratory Apparatus and Materials (U.T.P. Exhibitions, 9 Gough Sq., E.C.4.)	Horticultural Hall
June 21- July 1	International Plastics Exhibition and Convention (British Plastics, Dorset House, Stamford Street, S.E.1.)	Olympia
June 26-28	European Symposium on Space Technology (British Interplanetary Society, 12 Bessborough Gardens, S.W.1.)	21 Tothill Street
July 7-29	Soviet Trade Fair (Industrial & Trade Fairs, Russell Street, W.C.2.)	Earls Court
Aug. 23- Sept. 2	National Radio and Television Show (Radio Industry Exhibitions, 59 Russell Sq., W.C.1.)	Earls Court
Sept. 6-8	Microwave Measurement Techniques Conference (I.E.E., Savoy Place, W.C.2.)	Savoy Place
Sept. 13-15	Symposium on Photomultiplier Tube Applications (E.M.I. Electronics, Valve Division, Hayes, Middx.)	Manchester Sq., W.1
Oct. 4-12	Computer Exhibition and Symposium (E.E.A., 11 Green Street, W.1.)	Olympia
Nov. 8-10	Non-Destructive Testing in Electrical Engineering (Conference) (I.E.E., Savoy Place, W.C.2.)	Savoy Place

FARNBOROUGH

Sept. 4-10 **Farnborough Air Show**
(S.B.A.C., 29 King Street, London, S.W.1.)

NORWICH

Aug. 30-
Sept. 6 **British Association for the Advancement of Science annual meeting**
(B.A.A.S., 19 Adam Street, London, W.C.2.)

OXFORD

July 5-9 **Communications and Space Research Convention**
(Brit. I.R.E., 9 Bedford Square, London, W.C.1.)

Sept. 2-8 **Engineering Inspection and Non-Destructive Testing**
(Institution of Engineering Inspection, 616 Grand Bldgs., Trafalgar Sq., London, W.C.2.)

OVERSEAS

June 12-25	International Exhibition of Electronics, Nuclear Energy, Radio, Television and Cinematography (Fairs & Exhibitions, 2 Dunraven St., London, W.1.)	Rome
June 26- July 1	International Measurement Conference (Prof. J. F. Coales, The University, Cambridge.)	Budapest
June 28-30	Joint Automatic Control Conference (Dr. R. Kramer, M.I.T., Cambridge 39, Mass.)	Boulder
July 9-14	Bio-Medical Electronics Conference (Dr. A. Rémond, 131 Boulevard Maiesherbes, Paris 17.)	New York
July 16-21	Medical Electronics Conference (Dr. A. Nightingale, St. Thomas's Hospital, London, S.E.1.)	New York
Aug. 22-25	Western Electronics Show and Convention (Wescon, 1435 LaCienega Blvd., Los Angeles.)	San Francisco
Aug. 25- Sept. 3	German Radio Exhibition (Berliner Ausstellungen, Charlottenburg 9, Berlin.)	Berlin
Sept. 1-8	Firato-International Radio Show (Firato Secretariat, Emmalaan 20, Amsterdam.)	Amsterdam
Sept. 1-10	Danish Radio Exhibition	Copenhagen
Sept. 11-15	International Cybernetics Congress (International Association of Cybernetics, 13 Rue Basse-Marcelle, Namur, Belgium.)	Namur
Sept. 11-19	International Congress of Navigation (Permanent International Association of Navigation Congresses, 60 rue Juste Lipse, Brussels, Belgium.)	Baltimore
Sept. 14-25	French Electronics, Radio & Television Show (F.N.I.E., 23 rue de Lubeck, Paris XVI.)	Paris
Sept. 20-21	Industrial Electronics Symposium (I.R.E., 1 E. 79 St., New York, 21.)	Boston
Sept. 25-30	Irish Television and Radio Show (Castle Publications Ltd., 38 Merrion Square, Dublin.)	Dublin
Oct. 2-4	I.R.E. Canadian Convention (I.R.E. Convention, 1819 Yonge Street, Toronto 7.)	Toronto
Oct. 9-11	National Electronics Conference (N.E.C., 228 N. LaSalle St., Chicago.)	Chicago

type of transducer is that, by varying a direct bias voltage across the transducer, the thickness of the depletion layer and thus also the transducer resonant frequency can be varied: this is not possible with normal piezoelectric transducers. Bandwidths of the order of 5% or more, i.e., considerably more than at present obtainable, should also be possible. The main use of the new transducer is expected to be to allow longer delay lines to be produced since the higher efficiency will make up for the greater delay-line losses. The longer delay and greater bandwidth should allow a considerably greater amount of information to be stored in such lines. Work at higher frequencies should also be possible with the new transducer: although still in the early research stage, operation up to 830 Mc/s has already been achieved.

Character Readers using an area covered by a number of small detectors are not, of course, a new idea. An unusual feature of such a reader developed by the Electrical Engineering Department of the University of Birmingham, however, is that the outputs from the detectors (in this case photo-diodes) instead of being individually processed in logic circuits, are summed in a resistive matrix to give an output level corresponding to the character being read. In this way the interfering effects of noise (character imperfections) can be greatly reduced.

"Potting" of sub-assemblies in polyester or epoxy resins is often carried out to protect the components and wiring from deterioration due to vibration or moisture. Heat is another potential source of danger though, whether applied externally as in the case of an exothermic reaction of the potting resin or internally from electrical dissipation within the components themselves.

Croxton and Garry Ltd., of High Street, Kingston-on-Thames, Surrey, are the sole licensees of a process employing an aluminium wool which, when added to the "mix," increases considerably the heat conductivity of potting resins.

Typically, heat conductivities of the treated resin range from 20 B.Th.U./hr/ft²/ft²/°F for added aluminium wool 30% of the weight of the total mix, to 100 B.Th.U./hr/ft²/ft²/°F for just over 90%; both results being obtained with a pure resin of conductivity 0.13. These values are far better than those obtained either by the addition of steel wool (90%, conductivity about 15) or aluminium powder (negligible effect until almost 100% concentration).

Naturally, electrical conductivity is also increased by the added metal and an insulating skin may have to be used between the components and aluminium loaded resin.

RANDOM RADIATIONS

By "DIALLIST"

A Remarkable TV Feat

THE B.B.C., having made all arrangements for the May Day television transmissions from Moscow, was in the fortunate position of being able to broadcast Yuri Gagarin's reception in Moscow after his space flight. It was a wonderful achievement as was the May Day transmission. Signals travelled over a rather complicated route: Moscow, Leningrad, Tallinn, Helsinki, Stockholm, Copenhagen, Brussels and so to London. Considering the length of their journey and the many stages of reception and retransmission through which they had to pass, the signals gave remarkably good and steady pictures in this country. Now that a link with Moscow has proved successful the accomplishment of round-the-world television could become a reality while we are waiting to see whether satellite communications are practicable. Relays would cross Siberia to somewhere near the Bering Strait and go thence to Canada and the U.S.A. thus linking the two hemispheres. France has already a tropospheric scatter link with Algeria and in time to come Europe and many parts of Africa should be able to exchange programmes. What a wonderful world it'll become when the say-

ing that one half of it doesn't know how the other half lives ceases to be true.

Inter-school Television

SOMEHOW, I'm personally not at all enthusiastic about the use of TV for teaching purposes. For lectures, yes: classes get a chance of listening to someone eminent in his or her own line which might not otherwise come their way. But there's a world of difference between lecturing and teaching. The former is more or less impersonal: the lecturer tries to put his subject over in a clear and interesting way; but he's little chance of discovering whether or not it's sinking in as it should. Teaching on the other hand is (or should be) a closely personal business. The teacher knows the members of his class and has every opportunity of finding out that what he says is learnt and not just listened to.

'Phone Cable Round the World

ON 8th April *Monarch*, the world's biggest cable-laying ship (owned by Cable & Wireless), sailed from Oban

and began to pay out cable for CANTAT, the transatlantic link of what by 1964 will provide the British Commonwealth round-the-world telephone cable system. The other end of this link is Hampden in Newfoundland, 2,100 miles away. As *Monarch* can't carry more than 700 miles of cable she'll twice have to buoy the end and return here for another consignment. From Newfoundland the link is to cross Canada partly by cable and partly by wireless to Vancouver. There it will connect with the cable to be laid to Hawaii, Fiji, New Zealand and Australia. The cable now being laid is of an entirely new type, developed at the G.P.O.'s Dollis Hill research station, and made by Submarine Cable, Ltd. It has a steel core and round this is the first conductor, a copper tube. A layer of polythene insulation and then comes an aluminium tube as the second conductor. Then after further layers of insulation and screening a strong polythene outer casing. With the exception of the sections laid in shallow water the cable is not armoured. It is so much more efficient than earlier cables that repeaters will be 26 miles apart instead of 16. The new cable will provide 60 two-way circuits. An interesting little booklet outlining the "Story of the Submarine Cable" from 1849 to this latest project has been produced by Submarine Cables Ltd. which, as you may know, is owned jointly by A.E.I. and B.I. Callender's Cables.

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ILIFFE BOOKS LTD., Dorset House, Stamford Street, London, S.E.1.

Electronic Locks

IN the United States (and for all I know in this country, too) work on the production of electronic locks for safes and strong rooms is going ahead. The bolt is thrust home by an electro-magnet or by a motor and with power of that kind doing the job it can be made to engage much more securely than is possible with a key-operated bolt. Outside the door to which it is fitted is a panel carrying ten numbered buttons, which must be pressed in a predetermined order to actuate the lock. Should would-be burglars try to work the lock and get the combination wrong an alarm signal is radi-

ted. The idea looks pretty good to me and I expect we'll hear much more in days to come of electronic locks.

"Lifeline"

THE use of inflatable life rafts by ships of all kinds is rapidly increasing. For use in these Marconi's have marketed a special small light-weight transmitter receiver. "Lifeline," as it's called, weighs less than 20 lbs and measures only 17x7x5 inches. There's a telescopic aerial which is very easily erected. In use, the equipment is strapped to the operator's knee. Only two controls are needed: one selects speech or an automatic alarm signal; the other tunes the transmitter for the best possible performance. The equipment is pretuned to 2,182kc/s, the international distress and calling frequency. Much use is made of transistors to keep down both size and power demands. Power is supplied by a generator worked by a handle and it is stated that little effort is needed to turn this.

Radio Towers

IN a recent number of the *Journal of the Institution of Electrical Engineers*, J. F. Goodger described the television tower at Stuttgart as a smokestack surmounted by a crow's nest. And that's just what it looks like. In this stack are high-speed lifts which carry visitors to restaurants and viewing galleries 500ft above the ground. We're told that in the five years since the tower was built four million people have visited it and have more than repaid the cost of putting it up. This makes one wonder whether there'll be similar happenings in London, where a 500-ft radio link tower is to be built at the Museum telephone exchange, and is due to be completed by the end of 1963. It will replace the existing radio mast with which an effective height of only 180ft is obtained. The tall buildings that have gone up in London during the past few years and the many more that are planned make a much greater effective height necessary. It will be used by the Post Office as a radio link for the telephone and television services. Like the Stuttgart tower, it is to have a public viewing platform—at a height of 463 feet. If a moderate admission fee is charged, it, too, should pay for itself within a few years.

WIRELESS WORLD, JUNE 1961



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RECMF

EXHIBITION

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By "FREE GRID"

Jiggers and Gee-gees

IN our Jubilee issue the learned contributor of the historical survey drew attention to our ignorance of the origin of the word "jigger," which was used in the early days of wireless to describe the r.f. transformer which linked aerial and closed circuit. I hope to lighten his darkness forthwith, and if I'm wrong I feel sure some of you will put me right.

The word "jigger" had, and still has, certain particularized meanings aboard ship and also ashore but, in general, it means an auxiliary device; it is, in fact, something which carries out a function described by the verbal expression "to jig up," which means to increase or step-up something. Surely this meaning of stepping up or increasing describes precisely the function of the early wireless jigger which did indeed jig up the volts as our contributor indicated (April issue, page 158).

The expression "to jig up" was, and probably still is, in very common use among certain horse dealers, particularly Irish ones, and when we



Common among horse dealers

recall that Marconi's mother was Irish, and he paid many visits to his Irish grandparents in his boyhood, we begin to see daylight.

For the benefit of non-horsey people, I should explain that the term "jigged up" describes the result of dosing a horse to make it prance in a lively manner, reminiscent of an Irish jig, in front of its intending buyer. Such treatment involves the use of ginger and is sometimes referred to as gingering up.

Without doubt, Marconi, in his boyhood visits to his mother's native land, would have become acquainted

with the expression "jigging up," as applied to horses, and he would also have recognized in the Irish jig, a dance which, in his native Italy, was called *giga*, pronounced "jeegah."

Ham and Eggs

MY enquiry in the March issue as to the precise meaning and derivation of the "x" in the well-known abbreviation xtal has provoked some interesting replies. Many correspondents seem to think the "x" is the Greek letter "chi" which is used in Xmas. This seems all wrong because there is no "ch" in crystal as there is in Christmas.

At the same time I dropped a brick when I suggested that the "x" in the common abbreviation xmitter came from the Latin "trans." A German correspondent, Paul Hameyer, to whose excellent English I pay tribute, has made it clear to me that it is a natural abbreviation of the Latin word "ex."

He also convinces me that the "x" in xtal was the work of the American Hams who delighted in such abbreviations as rx for receiver to an even greater extent than their British opposite numbers, who might well have been called Eggs, so closely have the amateur transmitters in the two countries always been linked together.

Morphean Music

IT is far too late for me to make any comments on the Audio Festival and Fair, but I feel that I cannot refrain from calling attention to the lack of a very necessary audio service in our good-class hotels such as the one in which the Fair was held.

When in the various bedrooms in which demonstrations were given, I could not help noticing that over each basin a socket for an electric shaver was provided, this being of the very latest type with a built-in isolating transformer. But I looked in vain for a socket into which a pillowphone could be plugged so that a sleepless guest might lull himself into dreamland with morphean music.

All-night music is not available from the B.B.C., but surely in these days of tape recorders it is not too much to expect an hotel to provide an all-night service from recorded tapes. No expensive disc-jockey would be needed as in these days of long-playing multi-track recorders, an automatic all-night service could be

provided. By using a three-wire circuit and a simple switch, it would be possible to give the sleepless guest the choice of two programmes; after all, the cost of a couple of tape recorders should be a small matter to an hotel.

Reverting to the electric-shaver socket, there is one curious thing which I observed in this particular hotel which I have also noticed in all others where this facility is provided, and that is that the majority of the guests expected would seem to be monks. The reason is that one bar light is provided, and this is invariably above the mirror where it shines on the top of the head, and could, therefore, only be of real use to a monk desiring to trim his tonsure.

Experience has taught me that a bar light on the top of the mirror is almost useless for shaving, especially under the chin. What I have at home is a bar light on each side of the mirror. Perhaps the various hotel managements would attend to this small point when putting in the wiring for the morphean music service I have suggested. An even better idea to my mind would be that the shaver makers should provide their products with a small floodlight such as is fitted to certain vacuum cleaners. This is, however, really more a matter for our sister journal, *Electrical Review*, than for *Wireless World*.

Photaural Fair

JUST about the time some of you are reading these lines the biennial Photo Fair will be on at Olympia (May 29th to June 3rd). I am not getting any bribe from our sister journal *Amateur Photographer*—not even a free ticket—for this free advertisement. I only mention it because I always think it a pity it does not join forces with the Audio Festival and Fair because both exhibitions are really for more or less the same type of people.

I find that most people like myself, who take a serious interest in hi-fi audio, are also interested in hi-fi fotos, and most, again like myself, have about the same technical knowledge of each art or science.

At the Photo Fair there are a certain number of inexpensive "snap-shot" cameras, but on the whole, the show is not intended for the soot and whitewash brigade any more than the Audio Fair is meant to attract those whose taste in music is the jungle jangling of juke boxes.

If these two fairs put their resources together they could afford to rent the main Olympia hall as well as the lesser ones and so be able to erect properly designed demonstration theatres for both the audio and video arts, and for the best of stereo in both the arts.