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Sir Frank Gill, K.C.M.G., O.B.E.

THE older generation of communication engineers in particular will have learned with sincere regret of the death at Geneva on October 25 of this year of Sir Frank Gill, K.C.M.G., O.B.E.

By them, Sir Frank Gill was regarded as one of the pioneers of telephony and his death severs one of the last remaining links with the early days.

It is a matter of history now that the development of the valve revolutionized telephone communication and made possible long distance communication by means of the telephone repeater, the carrier current system and the radio link.

The years immediately after the first world war saw a remarkable growth in communication schemes throughout the world, and from the comparatively few firms engaged in the development and manufacture of telephone equipment, grew the large radio, television, and electronic industry today. From these firms, too, came the engineers and scientists to engage in these new ventures, and many of the leading men of today received their early training in the old International Western Electric Company under Gill's leadership during the important years from 1919 to 1928.

A contemporary of Alexander Bell and Oliver Heaviside, Frank Gill was born in 1866 at Castletown, Isle of Man, and at the early age of 16 joined the United Telephone Company. In 1902 he became engineer-in-chief of the old National Telephone Company where he remained until the company was absorbed by the Post Office in 1912.

From then onwards he became a consulting engineer carrying out telephone development work in the United States of America, South America and Europe. After a period with the Ministry of Munitions during the first world war, he joined the International Western Electric Company in 1919 as European Chief Engineer, where his remarkable planning, administrative and organizing abilities had full play in stimulating the growth of long-distance telephony in the post-war years.

In 1922 Sir Frank Gill was elected president of the Institution of Electrical Engineers and it was his presidential address of that year which led later to the formation of the International Consultative Committee on Long Distance Telephony (C.C.I.F.).

This body is responsible for the establishment of European long-distance communication and it is symbolic that he should have died at Geneva while attending a meeting of the C.C.I.F.

At the time of his death he was chairman of Standard Telephones & Cables, Limited, and a director and vice-president of the International Standard Electric Corporation. He was a member of numerous professional bodies, a member of the Institution of Civil Engineers, past president and an honorary member of the Institution of Electrical Engineers, fellow of the American Institute of Electrical Engineers, honorary member of the Institute of Royal Engineers, a member of the Royal Institutio, a member of the Société des Ingenieurs Civils de France, and the Société Francaise des Electriciens.

In 1941 he was created K.C.M.G. for his services in the development of the telephone industry and of international telephony.

The Physical Realization of . . .
An Electronic Digital Computor

By A. D. BOOTH, Ph.D.

(*Director, Birkbeck College Electronic Computor Project*)

IN a previous paper[1] the design and construction of a magnetic storage device—for use with the relay computor A.R.C.—was described. It was mentioned, in the concluding paragraphs, that work was in progress to convert this storage to fully electronic operation and, by implication, to equip it with such auxiliary circuitry as to constitute a fully electronic calculating machine.

All of the logical design, and much of the physical construction, of the new machine has now been completed and it is proposed to detail, in several papers —of which this is the first—those circuits which may be of general interest.

It will be remembered that the original storage device was of the parallel operation type, that is in which all the digits of a number are read or recorded simultaneously. In the first electronic machine this arrangement is not being maintained and the serial mode of operation, in which digits become available in sequence, has been adopted. This decision is one of expediency made in order to permit of the rapid construction of a fully electronic machine; it in no way marks a change in our conviction of the superior qualities of the fully parallel arrangement.

Briefly speaking, the change to serial operation has made necessary the following alterations:—

(1) Reorganization of the "memory" control to permit the emission of 21 equispaced pulses, starting at a given position on the drum.

(2) Provision of a shifting register or staticizer unit to absorb and record those digits appearing opposite the above 21 "clock" pulses, on the digit track.

(3) Design of suitable circuits to permit the addition or subtraction of a number being emitted from the store into one already contained in the shifting register.

These modifications and additions will be taken up in the following sections.

The "Memory"

In order to avoid, as far as possible, changing existing circuits the otherwise wasteful scheme was adopted of dividing the 256 available digit positions on any one track into 8 groups of 32 and then of using only the first 21 positions of each of these groups. Thus, coincidence between the last three (most significant arithmetically) stages $C6$-$C8$ (Fig. 1) of the counter and the contents of three flip-flop storage register elements $R1$-$R3$ has to be sensed and a pulse emitted. The cycle of operations is as follows:—

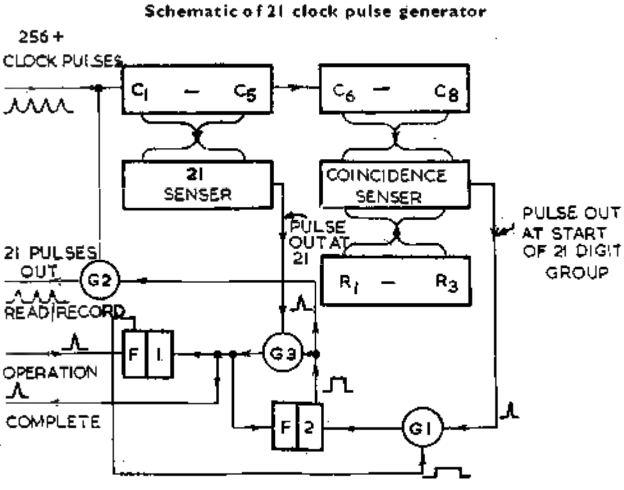
On receipt of a read/record pulse, the flip-flop $F1$ goes into the excited state and thus opens a gate $G1$ associated with its first anode (see Fig. 2). When next the start of the 21 pulse group required occurs, the coincidence senser between $C6$-$C8$ and $R1$-$R3$ emits a pulse which can now pass $G1$ and set a second flip-flop $F2$. $F2$ now opens gates $G2$ and $G3$, $G2$ transmits succeeding clock pulses to the machine until 21 have passed. When this occurs the 21 senser emits a pulse which passes through $G3$, resets $F1$ and $F2$ and passes, as an "operation complete" signal to the control of the machine.

The coincidence senser for the $C1$-$C5 \equiv 21$ pulse is simply a permanent wired-in version of the relay circuit previously described and need not be discussed further. The device for comparing $R1$-$R3$ with $C6$-$C8$ is quite different, however, as the relays, previously used to record $R1$-$R3$ are now replaced by purely electronic elements.

To facilitate the drawing the following notation (Fig. 2) will be used.

The element has two outputs, a and b, from its anodes and three inputs, c and e to the grids, and d to the cathode. Thus a negative pulse input to e sets the element into its standard (01) state, while a negative input at c results in transfer to the excited (10) condition. Positive pulses to c and e produce the reverse effect. So long as the 22 pF storage capa-

Fig. 1.
Schematic of 21 clock pulse generator



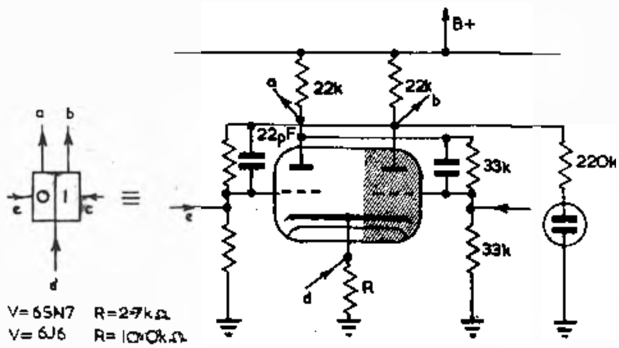


Fig. 2.
Notation for flip-flop in standard state.

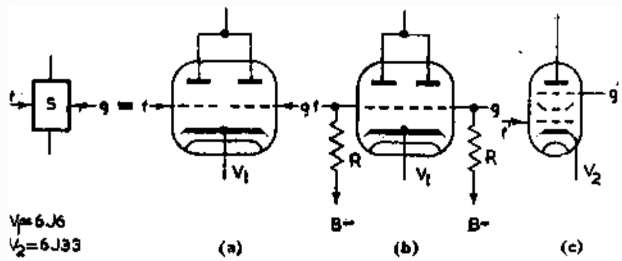


Fig. 4.
Various forms of senser element

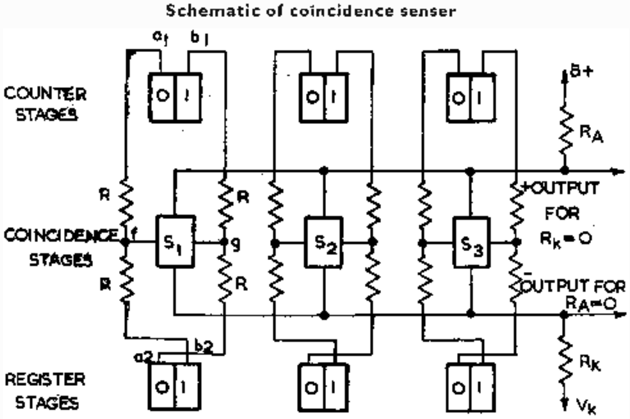
citors are present either positive or negative pulse input to *d* will cause the element to count. In applications where this function is not required these capacitors can be omitted and this is indicated by the absence of lead *d* from the block diagram. This omission has the advantage of reducing the dead time of the element by eliminating the recharging time constant, ideally of course the capacitance should be so chosen as to neutralize exactly the grid input capacitance of the stage; this, however, is seldom worth while.

The coincidence sensing device can now be described. One method is to sense anti-coincidence between groups of storage elements and the mode of doing this shown in Fig. 3.

In terms of the above argument, coincidence between the anode outputs (a,b) of the two flip-flops can be detected by sensing anti-coincidence between (a_1 and b_2) and (a_2 and b_1), and this, in turn, reduces to simple Kirchhoff addition of the anode voltages, which can be carried out using summing resistors *R* of such a value as not to cause mutual interference between the coupled stages of register and counter—220 kΩ to 0.5 MΩ usually proving adequate. The sensing elements *S*1-*S*3 can be engineered in a number of ways, two of the simplest being shown in Fig. 4.

In the first, the sum voltages are applied directly to the grids of a double triode. Considering a typical version of the element of Fig. 2. The anode voltages

Fig. 3.
Schematic of coincidence senser



are 200 V and 70 V. Thus the potentials at *f* and *g* (Fig. 4a) become 70 V, 200 V, and vice versa for non-coincidence; and 135 V, 135 V for coincidence. If now R_k is made zero and V_k = 150 V the sensing valve will have one side conducting for non-coincidence and both sides cut off for coincidence. Thus the potential at R_A can only rise appreciably when *all* of the senser stages are cut off, i.e., when coincidence between counter and register is attained. An alternative form of S is shown in Fig. 4(b). Here the necessity of a cathode supply is eliminated by adding a third resistor to the grid circuit taken to a suitable negative bias supply. The disadvantage of this procedure lies in the fact that the grid swing is less than in the previous case, and consequently components must be chosen with greater care. Probably the best version is obtained by making $R_A = 0$ $V_k = 0$. The circuit is then essentially a cathode follower. So long as at least one unit of *S* is non-coincident the common cathode potential remains at about 200 volts; at coincidence, however a drop to 135 volts occurs.

If sharp suppressor cut-off pentodes are available *direct* coincidence may be sensed by the circuit shown in Fig. 4(c). In this case a_1, a_2, and b_1, b_2 are added (and *not* a_1, b_2, b_1, a_2 as before), and if *either* of the combinations is 70 V the valve will be cut off. As before, an anode or cathode load can be used as the output element.

The output from these circuits always needs a stage of clipping to remove the small variations which occur without coincidence. For the anode output versions a simple amplifier stage biased beyond cut-off is adequate, and for the cathode output type the circuit of Fig. 5 has proved satisfactory.

One other change has been made in the counter circuitry described in the previous paper, this concerns the buffer stages between individual counting units. The circuit now adopted is shown in Fig. 6 and will be seen to minimize the number of components required.

Cathode triggering with negative pulses has proved to be exceedingly reliable and the 6J6 circuit given in Fig. 2 with the buffer of Fig. 6, will count reliably and easily at 1 Mc/s.

The Digit Amplifier and Output Stage

The basic digit amplifier circuit given previously has proved completely adequate for the new project. With identical circuit constants, but using 6AK5 valves and 2 mH compensating inductances in the anode the upper frequency limit has been measured to be 1.5 Mc/s. at 3 db down, well above that actually required. In order to feed the shifting register, a different form of output device from that previously adopted was required and this is shown in Fig. 7.

Here, it is necessary to set the output flip-flop, *F*, from the part of the output waveform immediately preceding the gate pulse. As the amplifier output may be either positive or negative and has to be clipped free from noise a centre-tapped pulse transformer, driven by a cathode follower, is used to produce inverse pulses which then set the output flip-flop via triode trigger valves held below cut-off. This procedure is considerably simpler than any of the purely electronic (i.e., non-transformer) ones which were tried, since it does not require the D.C. restoration which was needed when the large amplifier output pulses drove subsequent valves into grid conduction.

It should be noted that there is no actual gate in this circuit, the shifting register, fed by *F*, is insensitive to variation in the state of *F* unless receiving a shift pulse, so that no distinct physical gate is necessary.

The Shifting Register

In a serial (or indeed a parallel) machine of the type envisaged it is evidently necessary to have a device into which arrays of digits, emerging from the storage, can be fed serially and which will then hold these digits for subsequent operations. Such a device

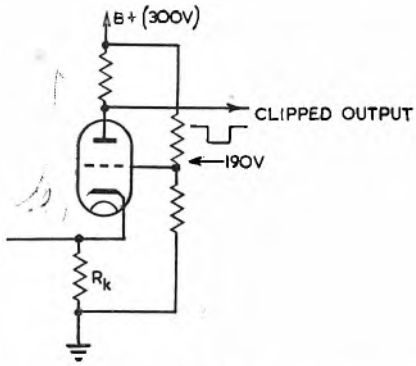
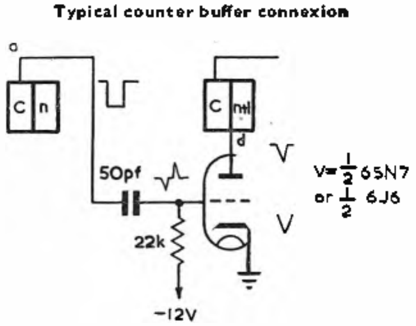


Fig. 5.
Cathode-coupled clipper for coincidence output

Fig. 6.
Typical counter buffer connexion



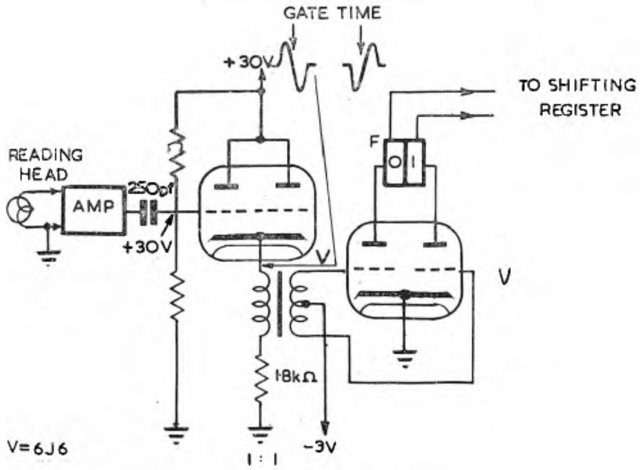


Fig. 7.
Digit output circuit

has been variously called a "Shifting register" (this project and most U.S.A. workers), "staticizer" (Manchester group), "flashing unit" (Cambridge group). There is a possible case for the use of the second of these terms, since it is not absolutely necessary to have a shifting register (vide infra) in order to get a number out of storage. This is shown in Fig. 8.

Here, the digits appear serially from the store, starting at time $t = 0$ and with spacing $t = \triangle$, the gates G_n are opened separately and in sequence from a master pulse source—usually a ring counter—and thus allow the correct digit pulse to set up its appropriate flip-flop *F*. In this type of register there is no shifting element involved and hence the name "staticizer" is quite appropriate.

The sense in which the term "shifting register" is used is rather more general, such a device is defined as being able to store a digit array statically and then, on receipt of a control pulse (or pulses), to be capable of shifting the whole array bodily one place to the left or right. It should be noted that this, unless the ends of the register are connected together, implies the loss of one digit per shift. Evidently such a device will also perform the simpler operation of staticizing, as it can absorb a sequential digit pattern incident upon its starting element.

There are several distinct types of shifting register; some of these are shown in Fig. 9.

In the first, or "clear" type register shown in Fig. 9(a), the flip-flop stores are cleared simultaneously, any stage containing 1 emits a pulse which, after a delay γ to allow the flip-flops to recover, arrives at the next stage and sets it to 1. Satisfactory registers of this type can be made and, in general involve one diode and one delay line per stage (additional to the flip-flop), the main objection to their use lies in the delay lines required which are neither cheaply nor readily available.

The second, or "delay storage", type register shown in Fig. 9(b), uses a gate system G_n, in which each gate is coupled to the preceding stage by a network whose time constant is long compared with the

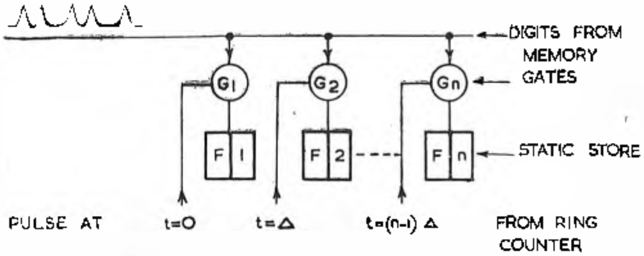


Fig. 8.
Staticizer as distinct from shifting register

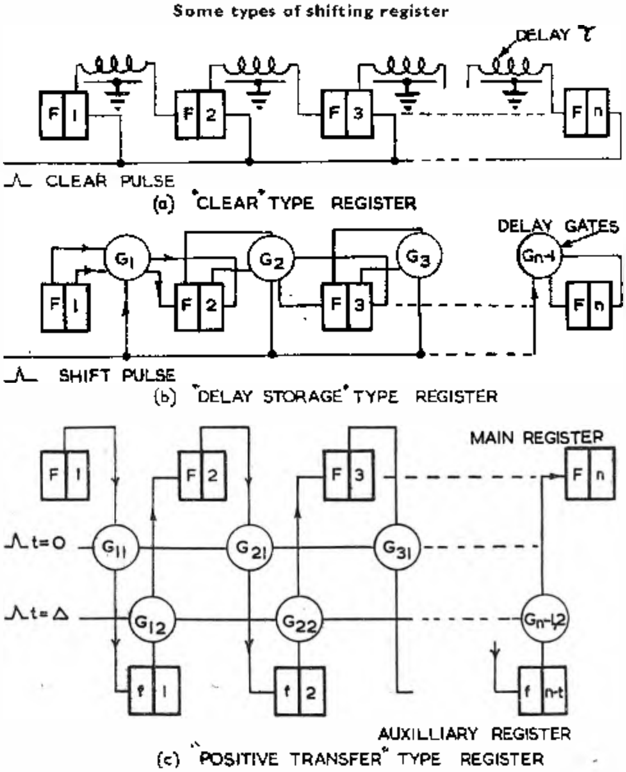
duration of the shift pulse. Thus the gate itself "remembers" the previous contents of the register during the shift; in general one or two diodes and a simple R-C combination are required per stage,

Lastly there is the "positive transfer" register typified by Fig. 9(c); in this the contents of the register *F* are transferred bodily to a subsidiary register *f*, *F* is cleared and then the contents of *f* are transferred back into it, displaced by one stage, *f* then being cleared ready for the next operation.

This type of register is the most costly in components, but its proponents claim increased reliability (very doubtful). It has, however, certain advantages in the execution of division, where the cancellation of a trial subtraction is sometimes needed.

In addition to the above main type of shifting register various combinational possibilities can be envisaged and many of these have been explored by

Fig. 9.
Some types of shifting register



the various groups. In the present case experiments have been made on types (a) and (b) and as a result of these the type (b) circuit shown in Fig. 10 has been evolved.

Here the 50 pF capacitors charge via the 33 kΩ resistors. The cathodes of the double diode *V* are thus always at a higher potential than the anodes (connected to the grids of the following flip-flop stage). On receipt of a negative pulse, however, that cathode initially at the lowest potential has its voltage reduced sufficiently for the associated diode to conduct, thus injecting a negative pulse on to the connected grid of the next flip-flop in the chain. It will be seen that this process causes the transfer of data from one stage to the next.

Several registers of this type have now been built,

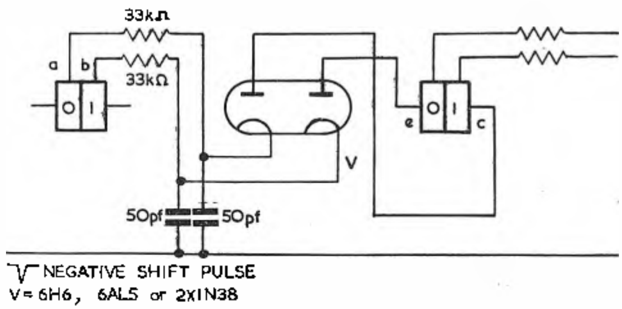


Fig. 10.
Delay storage gate

using widely different types of valve (6SN7 or 6J6 for the flip-flops 6H6, 6AL5 and 1N38 for the diodes) and all have worked reliably and without initial "debugging." Using 6J6 and 6AL5 valves the register shifts reliably at 1 Mc/s. and using 6SN7 and 6H6 at 400 Mc/s. The negative shift pulses used are obtained from a blocking oscillator with resistive anode load and have a duration of 0.25-0.5 μsec.

If the register is required for use in a parallel operation machine it has the desirable property that simultaneous negative pulses applied to the cathodes of the flip-flops (*d* in Fig. 2) cause each stage to invert, and thus the register contains the digital complement of the original number. Should this property not be required the 22 pF capacitors in the flip-flop stages can be omitted without ill effect on the behaviour of the circuits.

Experiments have also been made on type (c) registers using purely magnetic storage elements. Use is made of the new Telcon H.C.R. alloy to store data as remanent magnetism in toroids, the general scheme being shown in Fig. 11.

If one of the A_r toroids is magnetized by applying negative direct current to a suitable coil, the magnetic state, after removal of the current, will be that shown at *M*. A further negative pulse applied to the coil will thus produce only a very small change in B and no appropriate output from the secondary winding connected to B_r. However, if the initial magnetization had been positive, leaving the medium in state *L*, the negative clear pulse will produce a large change in B and thus lead to a considerable current in the secondary; this, after passing through the

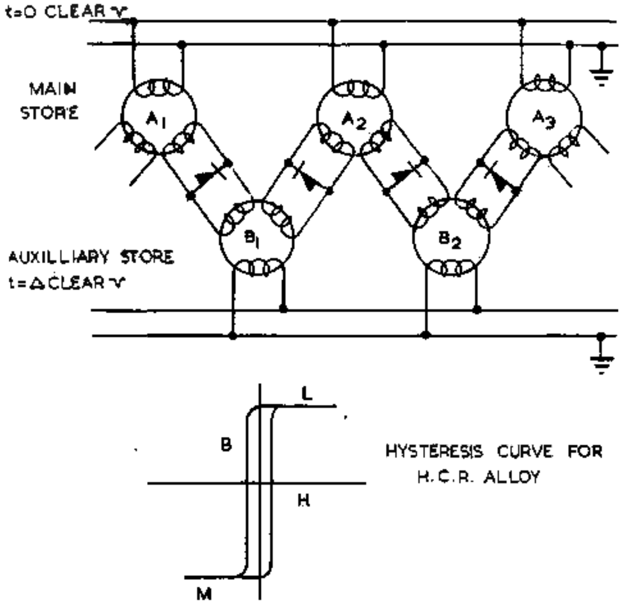


Fig. 11.
Magnetic register of type (c)

diode element sets the toroid B_r into the same magnetic state as that initially held by A_r. If now the B_r clear coils are pulsed, a similar transfer from B_r to A_{r+1} takes place and the initial contents of A are shifted one stage.

This type of storage device was described by the author several years ago under the title of the " iron nail memory "—it was originally tried using ordinary 1 in. nails. With these crude materials it was not possible to obtain shifts or more than two stages without excessive attenuation, but the new alloy makes possible registers of any reasonable length.

A type (a) register has also been designed, on the same principle, and works quite reliably at 100 Kc/s.; it uses 2 cm. diameter toroids with 50 turn windings and 0.25 µsec. shift pulses. Faster shift rates could almost certainly be attained but for the difficulty of obtaining the high current pulses required, and further work on this aspect of the problem is under way.

Magnetic Gate Circuits

In an attempt to find a gate circuit adequate for the isolation of the digit amplifier from the read-record lead during pulsing, work has been carried out on various magnetic devices. Two of the most promising are shown in Fig. 12.

In Fig. 12(a) a standard 1:1 transformer is wound upon the centre leg of a mu-metal stack; polarizing windings, in opposite senses, are wound upon the two outer legs. In the absence of a polarizing field the transformer behaves normally. When the field is applied, however, the two outer legs are saturated and the coupling of the 1:1 transformer coils is much reduced. A reduction factor of 5:1 is readily attainable, but without separating the windings this is about the best possible result. It should be noted that, because the polarizing windings are in opposite senses, the gating field through the centre limb is balanced out and no " pedestal " results.

Fig. 12(b) shows another variant using two identical transformers. Here, in the absence of a polarizing field, the outputs completely cancel one another; when the polarizing field—which just saturates the cores—is applied, however, one transformer responds only to positive pulses and the other to negative ones, so that an output is now obtained. Although great distortion occurs in this gate it may sometimes be useful, especially where noise about zero level is to be removed from double ended signals. The polarizing bias will generate a large output pulse, but this can be minimized in pulse applications, by giving it a much smaller rise time than that for which the transformers are designed.

The Adder

Before describing the particular adding circuit adopted for the present machine, it is perhaps worthwhile detailing various possible forms which this unit can take. In basic principle a serial adder and a single stage of a parallel adder are equivalent, although, with delay line type machines[2] the engineering details are apt to differ considerably from those here described (see for example[3]).

The very simplest form of adder is derived from the staticizer circuit shown in Fig. 8. If, instead of distinct storage flip-flops a binary counter is used and each non-zero digit of the incident number is gated as a negative pulse to the cathode of the appropriate register stage, time being allowed for carry propagation down the counter chain, then the circuit will act as a completely satisfactory adder. Fig. 13 is a schematic representation of this circuit.

An exactly similar circuit may be used as a parallel adder except that the input to the gates G_n would then be from distinct stages of another register. This circuit has the virtue of extreme simplicity and its

Fig. 12.
Magnetic gates

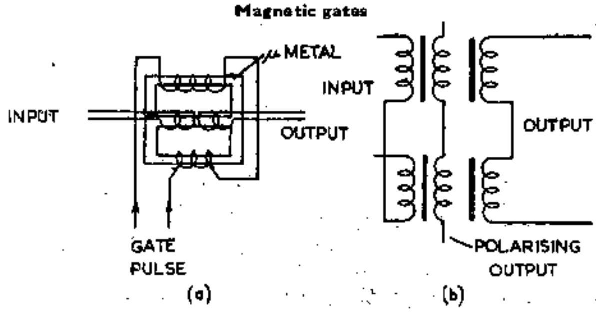
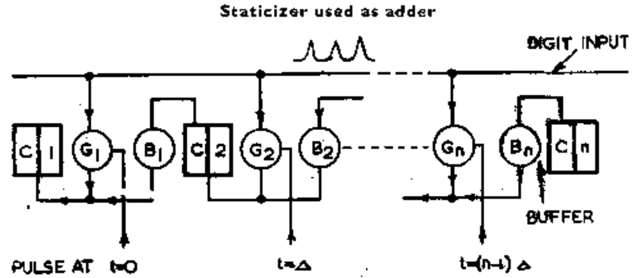


Fig. 13.
Staticizer used as adder



speed is not unreasonably slow, with the type of counting element described in this paper; not more than 2 μsec. would be needed for a complete 21 stage carry, so that an addition would require 42 μsec. Actually this could be reduced by observing that only a first carry would have to propagate down the whole 21 stages, succeeding carries passing through less stages in arithmetic progression, although the difficulties of making a ring counter to operate in this non-linear manner would probably outweigh the slight advantage of speed gain.

The next adder, in order of simplicity, is the double Kirchhoff parallel adder shown in Fig. 14.

In this circuit the carry output (if any) is first produced by summing the incident digit (I), resident digit (R) and input carry by means of the equal resistance network shown. *V1* is held cut off unless at least two of the incident digits are unity, for two-unit or three-unit inputs *V1* is fully conducting and its anode, because of RA_1, at low potential. In a similar

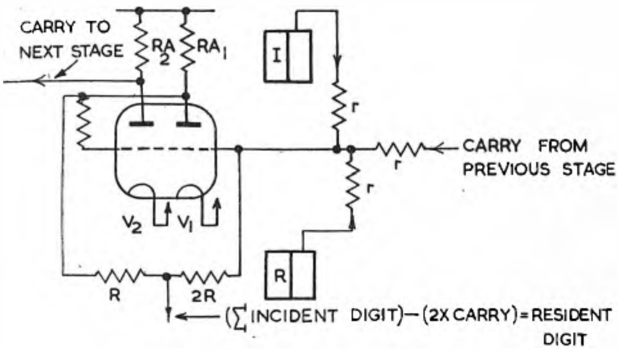


Fig. 14.
Kirchhoff adder

manner *V2* is held cut off or fully conducting by its grid connexion to the anode of *V1*, and the value of RA_2 is so chosen as to pass on a carry signal to the next stage and at the correct voltage level. The sum digit to be injected into (*R*) is generated by a second Kirchhoff net using the relation:

Resident digit = (sum of incident digits − twice carry) and can be placed in (*R*) by a suitable gate circuit.

A version of this circuit, using only one triode section per stage has been devised by Jan Raijkman of R.C.A., but it requires that alternate stages of the circuit have to be wired in reverse manner to correct for inversion of the carry polarity.

The disadvantages of this type of circuit are:

(1) Its slowness, as large resistors *r* and *R* must be used for the Kirchhoff nets;

(2) That very close tolerances on components and voltage levels are required to make a large number of stages work.

There has, in fact, been considerable discussion regardng the working of the circuit *at all* as a long-term entity in view of the effects of ageing on component values.

The Kirchhoff adder is a typical example of the

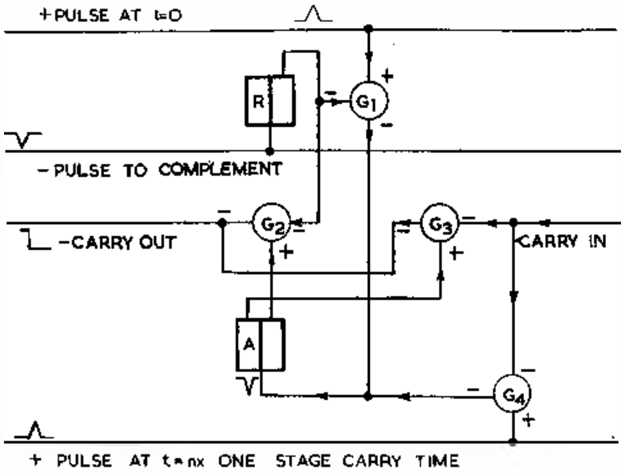


Fig. 15.
Logical adder (parallel)

sort of troubles which beset analogue circuits, the next circuit to be described (Fig. 15) is completely *logical* in operation and does not suffer from these disadvantages.

The incident digit is stored in (*R*) and the present contents of the accumulator register in *A*, the addition takes place in two parts. First a positive pulse is applied to the gate G_1; if (*R*) contains a 1 this gate is open and emits a negative pulse to the cathode of (*A*), thus causing it to change state. Next the carry is generated and propagated; if (*A*) is in state 0 while (*R*) is in state 1 this must have arisen from (*A*) being initially in state 1, hence a carry is required; this is generated by G_2. On the other hand, (*A*) may be in state 1 and a carry may be incident upon the stage; in this case propagation is again required and G_3 effects this. If (*A*) is in state 0 either no carry is possible whatever input carry occurs, or else it has already been generated as shown above. Finally, any incident carry prepares G_4, and after a time sufficient for all carry propagation to be complete, a positive pulse applied to G_4 which, if the latter is open, passes as a negative pulse to the cathode of (*A*), causing a change of state. It will be seen that the above process is precisely that required to effect addition in the binary scale.

The structure of the gate elements is shown in Fig. 16.

Normally the cathode of the double triode is held positive by the cathode follower action of *V1*; negative pulses applied at (a) reduce this potential but not sufficiently to let *V2* conduct. If, however, a positive pulse is present at (b), *V2* conducts and a negative output pulse is emitted from its anode. It is easily seen how, by the use of suitable resistive coupling network, this gate can be used in the circuit in Fig. 15.

As a final example of an adder, Fig. 17 gives the logical circuit of the serial adder used in the present machine.

On receipt of the addition instruction a step voltage appears at the input; this opens the gate G_0 in readiness for the 21 clock pulses from the memory (see Fig. 1), it also clears the carry store (C) to zero. As the 21 clock pulses arrive they pass through G_0 and arrive at G_1, which is closed if the incident and carrying stores (I) and (C) contain the same digits and open otherwise. This is effected by an anti-coincidence circuit of the type described above. Clearly, if the incident and carry digits are both the

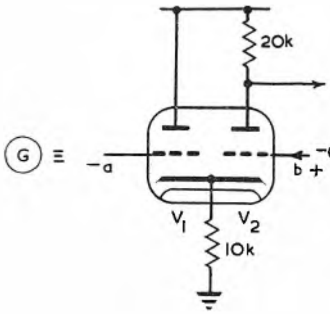


Fig. 16.
Typical gate element

same no change is to be made in the contents of ($R21$), whereas if they are different it has to be changed over; thus if G_1 emits a pulse it is applied to the cathode of ($R21$), causing a change of state. Consider now the carry to be stored for the next addition; if (I) and (C) have identical contents either (I) = 0, (C) = 0 in which case there is no carry to the next operation whatever the state of ($R21$) or (I) = 1, (C) = 1, in which case (C) already contains the necessary carry and need not be touched. Again, if (I) $\neq$ (C) the carry depends on ($R21$), if $R21 = 0$ there is no carry to be stored and thus G_2 transmits a pulse from G_1, to clear (C) to zero. Alternatively if ($R21$) = 1, G_3 transmits the pulse and sets (C) to state 1. It is thus seen that the circuit is adequate for the operation of serial addition.

To perform subtraction (using the complement system) a coincidence circuit can be used in place of the anti-coincidence one shown, and the subtraction

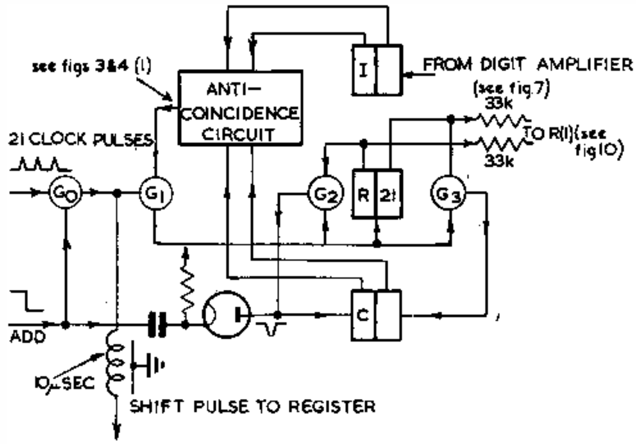


Fig. 17.
Serial adder

control gating pulse then sets (C) initially to state 1 thus producing the end round carry correctly. Alternatively, the connexions if G_2 and G_3 with (C) may be interchanged (electronically of course!), or again, the register shift pulse may be used to change (C) over by direct application to its cathode. As a final alternative the clock pulses may be delayed so that (I) is set to the second half of each digit pulse, which is the inverse of the first half.

Conclusion

It is hoped to present, in the next paper of this series, details of the multiplier circuit, decoding function table and overall control, all of which are at present either under test or construction.

The author's thanks are due to Messrs. T. J. Ringrose and N. Kitz for constructional help on the circuits and to Mr. C. Newman for the mechanical components.

References

[1] Booth, A. D., *Electronic Engineering*, 21, 234, 1949.
[2] Wilkes, M. V. and Renwick, W., *Electronic Engineering*, 20, 208, 1948.
[3] Hartree, D. R., "Calculating Instruments and Machines" University of Illinois Press, 1949.

High Speed Scaler

This unit, developed by the Atomic Energy Research Establishment, Harwell, is a fast scale-of-ten counter, including an input amplitude discriminator, which is designed for use in front of a normal type of scaler to extend the upper limit of counting rate into the range 10^5 to 10^6 counts per second.

Amplitude Discriminator

The amplitude range is 5 to 50 volts and it will operate on pulses of 0.05 microseconds or greater width. For a constant amplitude, constant width pulse the discriminator range between full count and no count is less than 0.1 volt.

Scaler

The resolution time of the complete unit (including discriminator) is 0.25 microseconds provided that the input pulse width, measured at the discriminator amplitude setting, is not more than 0.15 microseconds. If the input pulse width is greater than this figure the scaler will be ready to count a pulse 0.1 microseconds after the end of the previous pulse. On every fifth pulse the above figure of 0.25 microseconds is increased to 0.30 microseconds.

The maximum average count rate is 7×10^5 counts per second.

The output of the scaler is a 20 volt pulse of 1 or 2 microseconds width. A test oscillator giving pulses at about one a second is included to help in testing the unit.

Full details on application to A.E.R.E., Harwell, Berkshire, mentioning Specification 109.

Precision A.C. Voltage Stabilizers

By G. N. PATCHETT, Ph.D., B.Sc.(London), A.M.I.E.E., M.I.R.E.

(Bradford Technical College)

Part IV

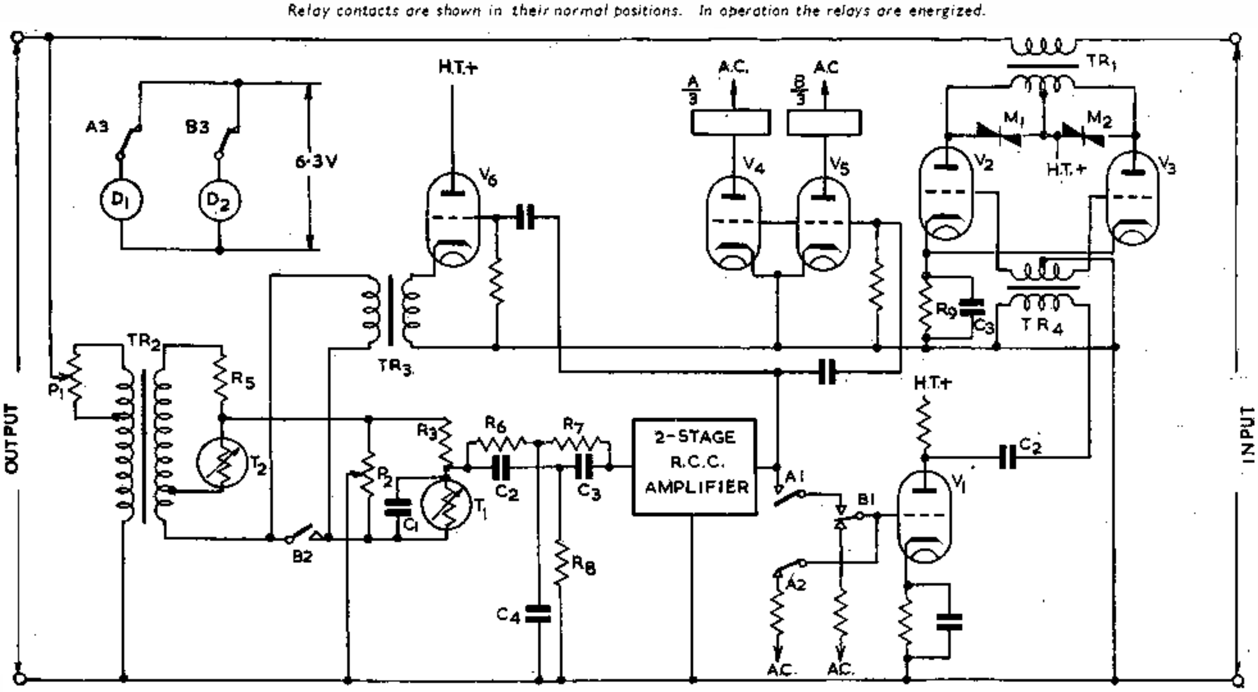
The Complete Stabilizer*

A SIMPLIFIED circuit of an A.C. precision voltage stabilizer using a Type *A* controller, and embodying the principles already detailed, is shown in Fig. 20. The input is fed, through the controller transformer TR_1, to the output, across which is connected the indicator transformer TR_2. A potential divider P_1 is arranged so that the voltage output of the stabilizer may be varied over a small range. The transformer secondary feeds the voltage sensitive bridge composed of the potential divider P_2 (forming the two "ratio" arms r_1 and r_2, the linear resistor R_3 and the thermistor T_1. The resistor R_5 and the thermistor T_2 form the potential divider used for temperature compensation, T_2 being a large type thermistor. Quadrature compensation is obtained by means of the capacitor C_1. In normal operation contact *B*2 is closed, shorting out the transformer TR_3. The output from the bridge is fed through the parallel-T network composed of C_2, C_3, C_4, R_6, R_7 and R_8, tuned to 150 c/s., so as to reject the third harmonic unwanted voltage of the bridge. The output from the bridge is now amplified by the two stage resistance-capacitance coupled amplifier from which it is fed, through the contacts A_1 and B_1, (which are closed under normal operating conditions) to the amplifier valve V_1. This feeds the controller valves V_2 and V_3, through the centre tapped transformer TR_4. Bias for the controller valves is obtained from the common cathode resistor R_9, by-passed by the capacitor C_3. The H.T. supply section (not shown in the figure) consists of a conventional full wave rectifier with a single stage *L-C* filter to the controller valves V_2 and V_3 and an additional *L-C* filter for the amplifier section.

The remainder of the circuit is used for protection purposes, should the supply go outside the normal range of input voltage, and is also used for starting. Suppose that the input voltage rises, then the drop across valves V_2 and V_3 increases, so as to maintain a constant output voltage and, eventually, if no protective features were incorporated, this voltage would become excessive and also cause the anode dissipation of valves V_2 and V_3 to become excessive. To prevent this, two suitable Metrosil disks, M_1 and M_2, are placed across the transformer TR_1. When the voltage across the primary of TR_1 reaches a certain value these disks pass appreciable current. This prevents the voltage from becoming excessive, and since

*Prov. Patent application No. 7887 and 16773

Fig. 20.
Simplified circuit of stabilizer
Relay contacts are shown in their normal positions. In operation the relays are energized.



it reduces the current in the valves, prevents the anode dissipation from becoming excessive. Since the disks prevent the controller voltage increasing, the stabilizing action fails and the output from the bridge rises rapidly, as the stabilizer output voltage rises. The output from the amplifier is fed to the valves V_4 and V_5, the anodes of which are fed with A.C. in antiphase. When this bridge voltage exceeds a certain value, the anode current of V_4 is reduced (the anode being fed with A.C. of the correct phase) causing relay A to be de-energized. This, by means of contacts A_1 and A_2, disconnects the controller valves from the bridge and connects them to suitable A.C. potential, such that the full voltage drop is maintained across TR_1, thus maintaining the stabilizer output voltage as near constant as possible. So long as the supply voltage to the stabilizer is high, the instrument remains under these operating conditions and no harm is done. When the voltage falls to normal, the bridge rebalances, the bridge output is reduced, relay A closes and the stabilizer reverts to normal operation. Indication of high input voltage is given by a signal lamp D_1 operated by contacts A_3.

If the stabilizer input voltage decreases so that the controller valves V_2 and V_3 fail to give sufficient output, again the stabilizing action will fail and the bridge will go off balance, producing a large voltage from the amplifier, but of opposite phase to the previous case. This causes relay B to be de-energized, disconnecting the controller valves from the bridge (by contact B_1) and connecting them to a source of A.C. such as to maintain them at full output. This keeps the stabilizer output voltage as high as possible, i.e., as near its correct value as possible. If no other action took place the bridge would not remain at its operating point X (Fig. 12) since the bridge is unstable when not connected to a stabilizing circuit but would take up some operating point to the left of the peak in the combined characteristic. To prevent this, an auxiliary controller, formed by the valve V_6 and the transformer TR_3, is brought into operation by the opening of relay contact B_2. This auxiliary controller is connected so as to continue to maintain the bridge voltage constant, but not the output voltage of the stabilizer. If the voltage remains low the stabilizer continues to operate in this manner and no damage is done. When the voltage returns to normal, the bridge rebalances, so reducing the amplifier output and energizing relay B, when the stabilizer reverts to normal operation. Indication that the input voltage is low is given by the signal lamp D_2, operated by contact $B3$. The stabilizer can normally be brought into range, in either of these cases, by changing the output voltage by operation of the potential divider P_1. In some cases this may be inconvenient and, in such cases, the input voltage may be adjusted by means of a Variac or a tapped transformer. The auxiliary controller is also used for starting. When the stabilizer is first switched on, the thermistor T_1 is cold, and bridge operates at some point to the left of the peak in the combined characteristics (Fig. 12). This results in a large output de-energizing relay B, which places the auilixary controller in circuit. This is arranged to raise the bridge voltage (but not the stabilizer output voltage) to a value corresponding to the peak of the combined characteristic, so heating the thermistor and bringing it to its correct operating point X, when relay B is again energized.

If the stabilizer is required to operate over a larger range of input voltage than can be conveniently covered by valves V_2 and V_3, relays A and B can be used to operate a motorized Variac so as to maintain the stabilizer input voltage within range. The motor can operate rapidly as the Variac has only to bring the input voltage within the range of the stabilizer and is not required to bring it to a particular voltage. A certain amount of overshoot is therefore permissible.

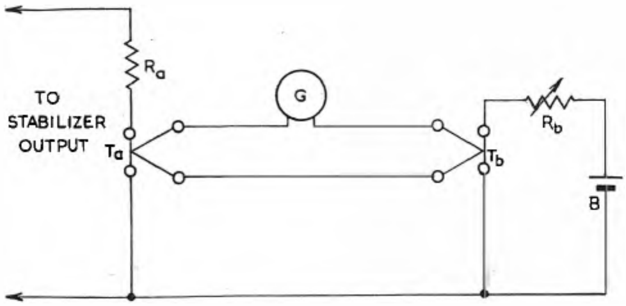


Fig. 21.
Circuit used for short term testing of stabilizer output

No details of valves have been given as these are not critical, so long as they are operated under the correct voltages. Five complete stabilizers have been constructed using different valves and components, all operating successfully.

If a Type B controller is used the circuit is simplified slightly since no action need be taken for high stabilizer input voltages (unless indication of failure to stabilize is required) as the controller is self-protecting. On low input voltages it is only necessary to bring into operation the auxiliary controller and, if required, a signal lamp. The H.T. supply power will be much reduced as it is now only required to feed the three amplifier valves and the auxiliary controller.

Performance

It has already been mentioned that the true criterion as regards the " size " of a stabilizer of this type, is the product of the output current and the range of input voltage over which it will operate. The power output of the stabilizer can therefore be increased by reducing the voltage over which it will operate, simply by altering the ratio of the transformer TR_1. Stabilizers have been constructed using Type A controllers for outputs of 100, 500 and 1,000 VA (using different controller valves) at 230 volts and having input voltage ranges of ± 10 per cent, ± 4.5 per cent and ± 6 per cent respectively. A stabilizer using a Type A controller has been constructed for an output of 2 kVA with an input range of ± 5 per cent.

The exact performance of a stabilizer will depend on the operating range, amplifier gain, etc., and the results given here are for a 230 volt stabilizer, with a Type A controller, designed for an output of 2.5 amperes with an input range of ± 3 per cent, i.e., a total variation of about 14 volts. It was designed to have a stability of 0.01 per cent or better under all normal operating conditions and a distortion of less than 1 per cent. Due to the high stability the changes in output voltage are small (0.01 per cent is only 23 millivolts in 230 volts) and difficult to measure. Two methods of measurement were used:

(a) For tests over long periods, such as the effect of temperature, a sub-standard voltmeter with a 6 in. mirror scale was used. Instead of actually reading

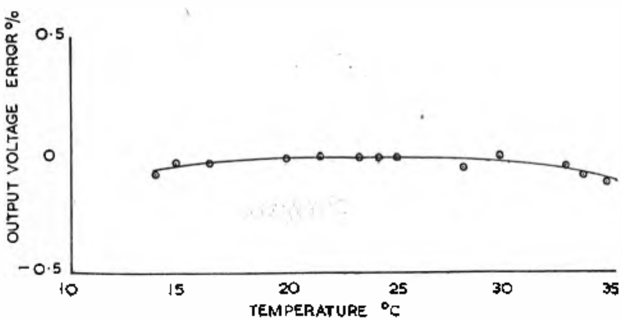


Fig. 22.
Relation between output voltage and ambient temperature

this instrument it was adjusted, by means of a known variable resistance, to some fixed point on the scale (about 90 per cent full scale) and the change in total resistance noted. By this means a change of 0.03 per cent could just be detected and a change of 0.05 per cent with certainty.

(b) For short period tests, such as changes of input voltage, load etc., the apparatus shown in Fig. 21 was used. R_a and R_b are standard resistors, T_a and T_b are similar 5 mA thermocouples connected (in opposition) to a sensitive galvanometer G. Initially, the current in T_b is adjusted so that there is no deflexion on the galvanometer. A change in the stabilizer output voltage will then cause a change of current in the thermocouple T_a and cause a deflexion on the galvanometer. The long period stability of this arrangement was not relied on and in most cases the readings were taken in less than one minute. The results that are given are the mean of a number of tests taken with this apparatus. Using this arrangement a change of 0.002 per cent could just be detected and a change of 0.004 per cent with certainty.

The following results were obtained:—

1. Effect of change of input voltage on the output voltage.

The results are given in Table 3 where it is seen that in all cases the changes in output voltage are considerably less than 0.01 per cent. Using the value of 0.004 per cent (0.009 volts) for a 10 volt change of input voltage, the regulation factor is 0.009/10 or 0.0009, resulting in a stabilization ratio of 1,100.

2. Effect of change of load on the output voltage

The results are shown in Table 3 and again it is seen that the changes are less than 0.01 per cent. Using the figure of 0.002 per cent for a 2 ampere change the internal impedance is

$$\frac{0.002 \times 230}{100 \times 2} = 0.0023 \text{ ohms}$$

The significance of this figure may be realized when it is noted that this is the resistance of approximately 1 ft. of No. 16 S.W.G. copper wire. It is obviously important that care is taken in the connexions between the stabilizer and apparatus under test if this low figure is to be utilized.

3. Effect of change of frequency on the regulation factor and the output voltage

From Table 3 it is seen that the regulation factor is practically independent of the frequency and that the change of output voltage with normal changes in frequency (48 to 52 c/s.) is negligible, being only 0.0006 per cent for 1 per cent change in frequency. Originally the change of output voltage with frequency was of the order of 0.02 per cent for 1 per cent change of frequency, which was considered undesirably high. This was traced to the indicator transformer which was being operated at a rather high flux density (similar to a small mains transformer as used for radio) and the trouble was cured by replacing it with a transformer operating at a lower flux density. This fact shows the care that must be taken in the selection of the components when high stabilities are required, the ratio of a transformer normally being assumed constant over this small range of frequency.

4. Effect of change of ambient temperatures on the regulation factor and output voltage

It is seen from Table 3 that the ambient temperature has little effect on the regulation factor. The relationship between the ambient temperature and the output voltage is shown in Fig. 22, these results being obtained by placing the indicator section in a box and varying the temperature by means of a heater. The rate of change of temperature above 20° C. was about 5° C. per hour, while the readings below were obtained *two days* later when the room temperature had fallen. It is seen that the output voltage is within 0.1 per cent (± 0.05 per cent) from 14 to 35° C. (57 to 95° F.) which is ample range for normal laboratory use. If the temperature range over which it is desired to operate the stabilizer is much greater, it would be advisable to place the thermistor in a small constant temperature oven. This could easily be done as the size of the thermistor is small and the self heating is negligible.

5. Effect of changing valves on the output voltage

The effect of changing valves on the regulation factor could not be detected and the change of output voltage on changing the valves in the amplifier

TABLE 3

Input Voltage	Output Current amps.	Power Factor	Frequency c/s.	Temp. °C.	Percentage Change in Output Voltage	Remarks
5 volt change	0	—	50	17	0.000	—
7 volt change	0	—	50	17	0.004	—
5 volt change	1	1	50	17	0.000	—
10 volt change	1	1	50	17	0.004	—
5 volt change	2	1	50	17	0.002	—
Constant ...	1 to 2	1	50	17	0.002	—
Decreased 6 volts ...	1 to 2	1	50	17	0.006	—
Decreased 5 volts ...	0 to 2	1	50	17	0.002	—
Decreased 6 volts ...	0 to 3	1	50	17	0.002	Over-load
Constant ...	0 to 2	0 lead	50	17	0.002	
Constant ...	0 to 1.3	0.5 lag	50	17	0.002	—
5 volt change	1	1	48.5	17	0.000	—
10 volt change	1	1	48.5	17	0.000	—
10 volt change	1	1	53	17	0.004	—
Constant ...	1	1	48-52 (8%)	17	0.005	—
5 volt change	1	1	50	20	0.000	—
5 volt change	1	1	50	24	0.000	—
10 volt change	1	1	50	24	0.005	—
5 volt change	1	1	50	27	0.000	—
10 volt change	1	1	50	27	0.006	—
5 volt change	1	1	50	33.5	0.002	—
10 volt change	1	1	50	33.5	0.006	—
5 volt change	1	1	50	40	0.003	—
10 volt change	1	1	50	40	0.004	—

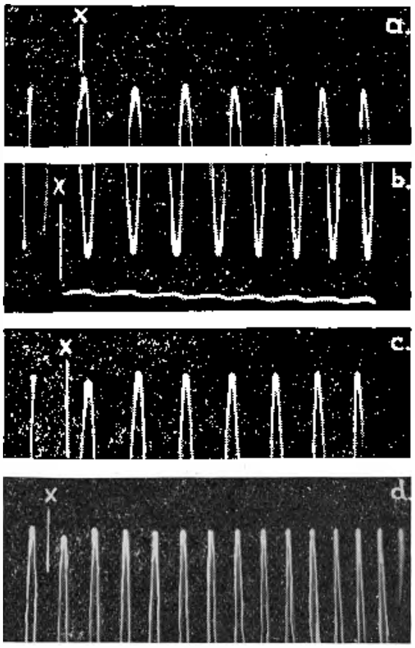


Fig. 23.

Output voltage of stabilizer. Change of voltage occurs instantly at point X.

a. and b. 10 volt increase in input voltage (positive and negative peaks of cycles respectively).

c. and d. 10 volt decrease in input voltage (positive peaks of cycles).

section was less than 0.007 per cent, allowing 3 minutes to settle down after switching on and off in order to change the valves. This indicates that the valves may be replaced without any need for adjustments to be made to the stabilizer.

6. Effect of change of amplification on the regulation factor

The gain of the amplifier was reduced by 25 db (17 times) and the change of output voltage for a change of 5 volts in the input was only 0.03 per cent. This rose to 0.09 volts for a change of 10 volts in input voltage. By more careful balancing of the bridge this could be reduced to 0.007 per cent. From this it is seen that any *normal* changes in the gain (which will be much less than the above) of the amplifier will have a completely negligible effect on the regulation factor. This conforms one of the advantages of placing the indicator across the output of the stabilizer, as referred to in Part I.

7. Effect of change of bridge balance on the regulation factor

The balance of the bridge is not critical and changing the balance point by ± 2.5 per cent resulted in output changes of only 0.014 per cent and 0.007 per cent for an input change of 10 volts.

8. Response Time

The response time was obtained by means of a cathode-ray oscillograph and a single stroke time base, synchronized with an artificially produced, sudden change in input voltage.[15] A large number of records were taken and in many cases no change could be detected, the actual magnitude of the transient depending on the instant in the cycle when the voltage change was made. Fig. 23 shows cases where a transient is visible, from which it is seen that the correction is completed in 1 to $1\frac{1}{2}$ cycles, i.e., 0.02 to 0.03 seconds. This is about 1/10th of the response time of the thermistor itself. This reduction is due to the feedback action of the stabilizer and the correction time was increased to about 20 cycles when the gain of the amplifier was reduced by 25 db. A reduction of this magnitude is not likely to occur in practice and this increase is not important. Oscillograph records of the voltage across the controller transformer are shown in Fig. 24, where again it is seen that the change is completed in about one cycle. The voltage across the controller transformer is rather distorted in these records (see also Section 9) due to the poor waveform used to feed the stabilizer during these tests.

TABLE 4

HARMONICS IN OUTPUT VOLTAGE OF STABILIZER (PERCENTAGES)

	Fundamental	3rd	5th	7th
Input voltage to stabilizer ...	100	0.2	0.13	0.45
Output voltage of stabilizer ...	—	—	—	—
No load. Zero controller volts	100	0.44	0.14	0.37
1 amp. load. Zero controller volts	100	0.45	0.14	0.40
2 amp. load. Zero controller volts	100	0.50	0.13	0.36
1 amp. load. +5 volts across controller	100	0.35	0.13	0.40
1 amp. load. −5 volts across controller	100	0.27	0.25	0.36

9. Output Waveform

Table 4 shows some tests of the output voltage taken with a harmonic analyzer. The maximum difference compared with the input voltage is 0.3 per

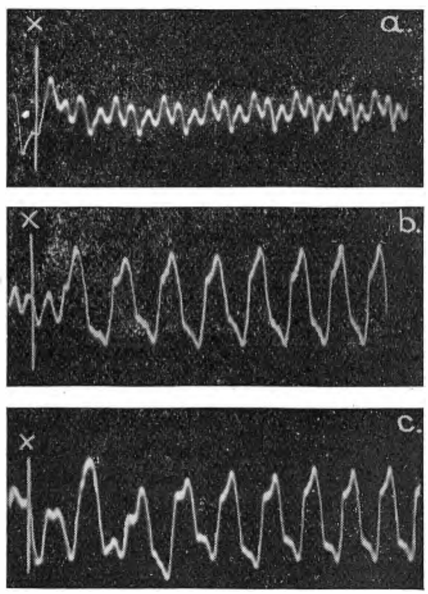
Fig 24.

Voltage across controller transformer. Change of input volts takes place instantaneously at point X.

a. 6V increase in input voltage showing reduction in controller voltage.

b. 6V increase in input voltage showing increase in controller voltage (opposite phase to a.)

c. 10V increase in input voltage showing reversal of phase of controller voltage



cent third harmonic, which is well within the limit of 1 per cent quoted earlier. The voltage across the controller transformer may be considerably distorted, without producing appreciable distortion of the stabilizer output voltage, since it only forms a small percentage of the total ouptut voltage, e.g., 10 per cent harmonic across the controller transformer will, if the controller voltage is only 5 per cent of the total, produce only 0.5 per cent harmonic in the output voltage.

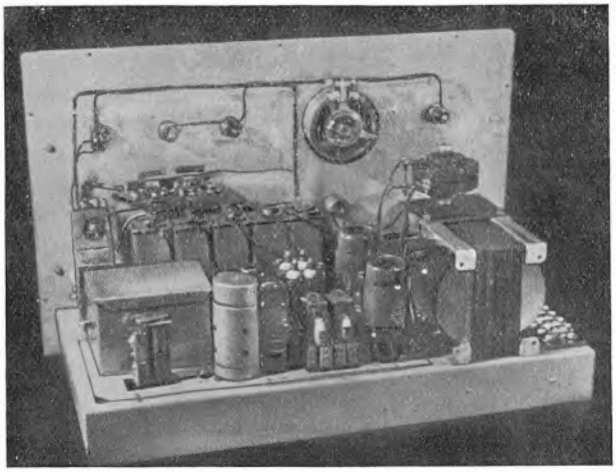


Fig. 25.
Photograph of a complete stabilizer

10. Stability

The stability of the stabilizers with time appears to be good. One stabilizer has been in use for 12 months without any adjustments being necessary. Another stabilizer travelled 200 miles by rail and, when tested a week later, the change of output voltage for a 10 volt input change was of the order of 0.002 per cent, no adjustments having been made to the balance of the bridge.

No trouble has been experienced due to hunting, probably due to the fact that only one section, the thermistor bridge, of the feedback loop has a large time constant, the response of the amplifier and controller being practically instantaneous. To reduce the very high and very low frequency response of the amplifier, simple *R-C* filters are used between the valves of the amplifier. A photograph of one of the stabilizers is shown in Fig. 25.

Finally, the stabilizers are completely automatic, do not require frequent adjustment and are not damaged by changes of input voltage well outside the normal range of operation—a point which appears to be overlooked in many designs. Positive indication of failure to stabilize is given by the indicator lamps which could be supplemented by buzzers if required. On a normal mains supply no movement of the pointer of a sub-standard voltmeter can be detected, even with a magnifying glass.

From the figures given, it is seen that the stabilizer completely fulfils the original specification of a stability of 0.01 per cent under normal operating conditions.

Conclusions and Acknowledgments

These stabilizers appear to fill a gap where no such instruments have been available previously with this degree of accuracy. The stabilizers were originally developed, and will probably be mainly used, for accurate potentiometer work where a highly stable supply is essential if misleading results are not to be obtained. Other applications have already been found for them. Although the author has considered a stabilizer for 230 volts 50 c/s. there is no reason why similar equipment could not be made for other voltages and frequencies.

The author wishes to thank Principal H. Richardson, M.Sc., F.Inst.P. for permission to publish this information and also Messrs. H. Tinsley and Co. for their help and interest in this work.

Reference

[4] G. N. Patchett: "Some Unusual Applications of Cathode Ray Oscillograph," *Electronic Engineering*, 15, p. 195, 1943.

G.E.C. Picture-Telegraph Equipment

THE new picture-telegraph equipment made by The General Electric Co., Ltd., can be used for sending and receiving photographs, drawings, maps, and facsimile messages between points linked by physical telephone lines, carrier circuits (including power line carrier circuits) and radio links. It is already in use in Britain and overseas and is suitable for use by newspapers, news agencies, police forces, shipping and airline companies.

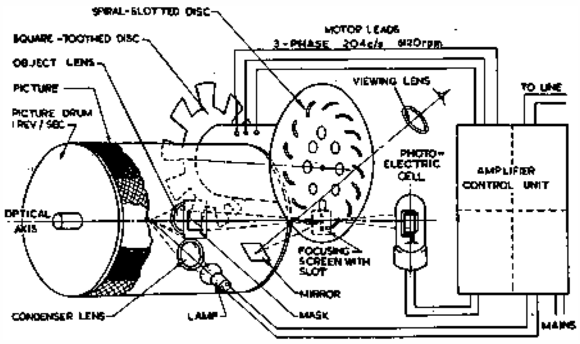
Definition is the highest possible within the limits prescribed by the *Comite Consultatif International Telegraphique* (C.C.I.T.), and the equipment will work in conjunction with any other picture-telegraph equipment which complies with these standards. Pictures can be received as positives on photographic paper for direct blockmaking or viewing, or as negatives on photographic film in cases where many positive prints are wanted.

The maximum size of picture that can be accommodated is 10 by 8 in., but large pictures, maps, etc., can be sent by being cut up into sections and transmitted in sequence. At normal transmission speed a 10 by 8 in. picture can be sent in 14 minutes. When, however, transmission charges are heavy, the time can be reduced to 7 minutes at the expense of picture quality.

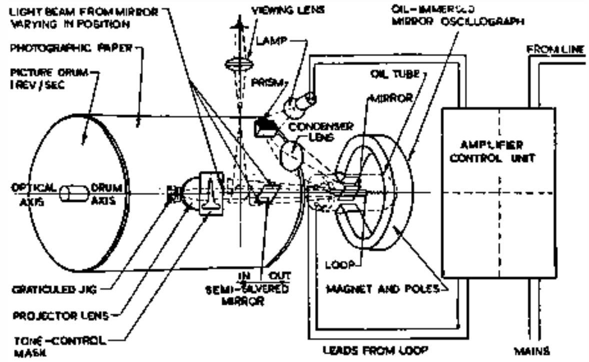
The apparatus is divided into two main parts; transmitter and receiver, each of which has a machine sub-unit, optic head and two amplifiers. A transmitter can be converted for use as a receiver by the simple interchange of parts, and this convertability is of considerable value for users who wish to transmit and receive but do not wish to do both simultaneously.

Transmitter

The picture to be transmitted is clipped to a drum which is slowly rotated and scanned by an optic head mounted on a carriage driven by a lead screw. The speed of traverse is such that the head moves 0.01 in. for each revolution of the drum, thus scanning the picture as a spiral band 0.01 in. wide. To keep the definition high the area being scanned



Principle of operation of the G.E.C. picture telegraph system transmitter, with . . .



. . . a similar representation of the receiving equipment. If required, a single drum unit can be used both for sending and receiving.

must be very small because the photocell reacts only to the average value of the light from each unit area of the picture. In this equipment the area of each picture element is 0.01 by 0.008 in., and during the transmission of a 10 by 8 picture one million of these areas are scanned.

If the varying light intensities from the picture were allowed to fall directly on the photo-electric cell the output of the cell would contain a wide range of frequencies, even down to zero. The design of amplifiers with linear characteristics to cover such a large frequency range presents substantial difficulties, and therefore to allow the cell output to be satisfactorily amplified a fundamental frequency or carrier is introduced into the light beam by means of a slotted disk, which rotates to interrupt the beam at a frequency of 1,326 c/s. The light which then falls on the photo-electric cell contains two varying components, a cyclic variation of intensity, due to the rotation of the slotted disk, and a random variation resulting from changes in picture tone. The output of the cell therefore contains a frequency of 1,326 c/s., amplitude modulated in sympathy with the mean brightness of the picture element that is being scanned at any instant. The slotted disk is a square-toothed wheel with 13 apertures and is mounted close to a lens at one end of a motor shaft. At the other end of the shaft is another disk, with 13 spiral slots in it and mounted opposite the apertures of the toothed wheel. The function of this second wheel is to ensure that each picture element being scanned is held in view during each cycle of the carrier frequency, i.e., to ensure that the cell sees only one picture element at a time.

Output from the photo-electric cell is amplified by a three-stage resistance-capacitance coupled amplifier to a voltage of 1.5-2 volts, which is suitable for applying to a telephone line.

To ensure fidelity of reproduction the picture drum in the transmitter and receiver must rotate in synchronism. An error of only 1 part in 80,000 will produce an error of 0.1 in. in a 10 by 8 in. picture. Synchronism is controlled by tuning forks vibrating at 1,020 c/s. The forks are matched in frequency to within about 5 parts in a million and have a temperature coefficient of less than 1 part in a million per degree Centigrade. Means are provided for adjusting the frequencies of the forks over a range of ± 150 parts in a million. This adjustment allows the forks to be matched with each other or with equipment used in other systems. The tuning fork controls the frequency of a multi-vibrator working at one-fifth of the tuning fork frequency, i.e., at 204 c/s., and after amplification the power output at this lower frequency is used to drive the picture drum motor. Power for the scanning disk motor is derived from an earlier stage of the same amplifier.

Receiver

In the receiver, light from a steady source impinges on the mirror of an oil-immersed oscillograph and the reflected beam is brought by a parabolic lens to a focus on the surface of photographic paper clipped to a revolving drum. Between the mirror and lens is a tone control mask, which, in conjunction with tone correction circuits in the receiver amplifier, can vary the intensity of the light reaching the paper.

The oscillograph mirror swings in response to the incoming signals, and the tone correction mask is so positioned that minimum deflexion (corresponding to dark tones in the original picture) sheds the greatest amount of light while maximum deflexion sheds the least light on the paper. The surface area of the mirror is 0.06 by 0.02 in. and the focused image on the paper is 0.01 by 0.003 in.

The width of the spot focused on the paper must obviously be precisely 0.01 in., to correspond with the transmitted spiral. If it is wider there will be overlapping and consequently a black spiral across the picture, while if it is narrower there will be a white spiral across the picture. Accurate focusing is accomplished with the aid of two small jigs, one of which is graticuled with lines 0.01 in. apart.

An interesting feature of the receiver is that the total length of the light path is only 6 in., which results in a very small optic head and excellent light efficiency. In the receiver, as in the transmitter, the illumination is derived from a 6-watt motor-car lamp. All lenses are bloomed to reduce flare.

For the reception of film negatives for use in making multiple prints at the receiving end, the equipment can be suitably altered so as to ensure the correct reversal of the image.

A Simple Slow Running Time Base

By C. J. DICKINSON, B.A., B.Sc.
(Oxford University Laboratory of Physiology)

ANY normally designed time base whose flyback depends on a capacitative coupling or on an inductive coupling will not run satisfactorily at low speeds. The time constant of the flyback mechanism cannot be made sufficiently long; hence if the time base is run slowly the sweep becomes cramped and non-linear towards the end of its traverse of the screen. With very large values of charging capacitor in a Puckle circuit, for example, the sweep can be made so slow that flyback will never take place at all. The time base to be described will always fly back at a predetermined point on its sweep, however slowly it approaches this point, and there is no theoretical limit to the lowest sweep speed and repetition rate of which the time base is capable. Large capacitors are not necessary for low sweep speeds, and for a 30-second sweep a 0.5 μF capacitor is adequate. Lack of linearity at all velocities is not perceptible by eye. Maximum frequency is approximately 10 kc/s., and output voltage is over 200 with the circuit illustrated.

Clearly, in the design of such a time base (which might be required for the display of any slow electronic or electro-mechanical phenomena) a trigger sensitive to small changes in steady voltage will be required. A Schmitt trigger was used by Gibbs and Rushton[1] to operate the flyback in a time base for biological purposes where the repetition rate was controlled independently by another oscillator. The time base itself was a "Miller" with a special form of grid leak circuit which will be mentioned later. The fall in anode potential of the Miller valve during the sweep was communicated by a resistance network to the input grid of a Schmitt trigger. The appropriate anode of the latter was directly coupled to the suppressor grid of the Miller valve, so that during flyback the Miller was cut off by the application of a negative voltage. The time base could be arranged to run repetitively by using the "backlash" of the Schmitt trigger. It is a property of this circuit that it can be so adjusted that there will be a difference of potential of 20-30 volts between the input voltages alternately required to switch it from one limiting state to the other. If, therefore, the waveform at the anode of the Miller valve is made to appear, attenuated, at the input grid of the Schmitt trigger, it can be made to switch the trigger on and off; and therefore the time base will be self-repeating.

Such a circuit has a few inherent disadvantages. The original design used a 500 volt negative supply line, in addition to a 400 volt positive one, so that direct coupled networks could more easily be used. Also, if a maximum output voltage of 200 is required, it must be attenuated 10 times to fall within the range of the 20 volts "backlash" of the Schmitt trigger. This leads to uncertainty of operation, requiring very careful adjustment of the trigger part of the circuit. The author attempted to adapt this circuit for use without a negative supply rail, by employing capacitative flyback coupling to the suppressor of the Miller valve; but it is only with the greatest difficulty that a time base of even 50 volts output can be obtained. If, however, a form of "flip-flop" is used as a trigger, the voltage output will not be limited by the "backlash" of a Schmitt. If the duration of the unstable limiting state of the flip-flop is just sufficient to cut the Miller off on its suppressor while the anode potential rises from, say, 150 volts positive to 350 volts positive, the full maximum linear sweep will be available. The standard forms of flip-flop (transitron, or two valve) require an input of short pulses, but for the specific purpose outlined, a flip-flop triggered from a slowly falling steady voltage was required. The type of trigger described here is a combination of a Schmitt with a back capacitative coupling. Fig. 1, showing the time base complete, should make the design clear. The coarse frequency control is provided by S_1 and S_2, which are ganged for a reason which will later be explained. Fine frequency control is provided by a potentiometer control of the grid leak return.

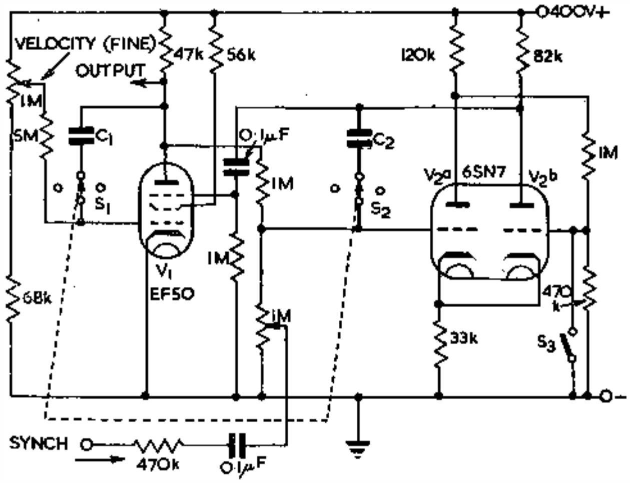


Fig. 1.
Schematic of the time-base described

To explain fully the action of the circuit, let us suppose that V_1 (the Miller valve) is originally cut off on its suppressor grid. Its anode will be nearly at the full H.T. voltage, and thus the grid potential of V_2a will be positive to the common cathode. As V_2a is passing current, therefore, it follows that V_2b will be cut off, and that its anode potential will be high. If the suppressor grid of V_1 is brought to earth potential, the valve will pass increasing current at a rate which depends on the value of the anode/grid coupling capacitor, the resistance in the grid circuit, and the potential of the grid leak return. When the anode potential of V_1 has thus fallen (linearly) to about 150 volts positive to earth, the lowered grid potential of V_2a will start to reduce the current flowing through that valve. The familiar cumulative trigger action of the Schmitt will be further assisted by the back coupling through C_2. The trigger will obviously remain in its unstable state until the negative charge on the grid of V_2a has leaked away, since the anode of V_1 will be at a high positive potential. The sudden fall in anode voltage of V_2b is not only communicated to the input grid of the trigger, but also to the suppressor grid of V_1, cutting that valve off. The anode potential will rise at a rate limited by the time constant of the anode load and the anode/grid coupling capacitor. If the time for this "flyback" bears a suitable relation to the rate at which the grid of V_2a can become positive, the reverse trigger action will take place just before the anode potential of V_1 reaches the full H.T. voltage. As soon as the trigger is reset, the suppressor of V_1 will become rapidly positive, and the cycle will repeat.

Various features of interest become apparent when this circuit is studied in detail. There appears to be no limitation to the lowest frequency at which it can be operated, except the practical one of obtaining good quality large capacitors. If the flyback becomes too slow, the negative-going square wave at the suppressor may be differentiated; and at very long duration flyback times, the positive-going pulse at the beginning of the sweep might have to be removed by a diode, if it caused the suppressor grid to take current. For sweep durations of even 30 seconds, however, this is quite unnecessary.

For very slow speed operation the cathode follower of the original circuit of Gibbs and Rushton should be used instead of the grid leak illustrated, to permit a slow sweep velocity without the use of large capacitors, and also to improve linearity. Lack of linearity in the circuit of Fig. 1 is, however, not apparent to the eye at any sweep speed. If the type of non-linearity which occurs as an expansion of the first part of the sweep is encountered, the cause will almost certainly be a leak in the anode-grid coupling capacitor. If the leak resistance of this capacitor is at all comparable with the high value of grid leak used, the effective charging voltage of the capacitor will vary with the anode potential, and will be highest at the beginning of the sweep, when the anode potential is high. A good range of velocity control is provided by the "smooth" potentiometer control in the grid leak circuit of V_1, while a coarse control is provided by the ganged switch S_1 and S_2. Except at repetition rates where stray capacitances must be considered, the capacitor C_2 should be about 1/10 the capacitance of C_1, to ensure maximum amplitude and good linearity. If C_2 is made too *large*, there will be a "waiting" time at the beginning of the sweep, which could be utilized for certain purposes. If C_2 is too *small*, not enough time will be allowed for the anode of V_1 to rise to the full positive H.T. potential. It is obvious, therefore, that a variable resistance in series with C_2 will serve to control the waiting period of the time base; or if C_2 is smaller, it will act as an effective amplitude control. Disregarding the possible effect of stray capacitance, if the ratio of capacitances $C_1:C_2$ is kept constant for all positions of the capacitance selector switch, the amplitude will be the same on all ranges. It will not, of course, be affected by the position of the fine velocity control, except at high speeds. The grid-cathode capacitance of V_2a is obviously the chief limiting factor for high speed operation, on account of the high impedance coupling circuit from the anode of V_1. However, perfectly satisfactory time base operation can be obtained up to at least 10 Kc/s. by the use of rather smaller values of C_2 than would be calculated if stray capacitances were ignored.

Synchronization is best effected as shown, and not by the application of signals to the grid of V_2b. Such signals, although not quite large enough to trip the trigger, can cause velocity modulation of the trace through variations in suppressor voltage conveyed from the anode of V_2b. The same objection does not apply to V_2a, and only 1/200 of any voltage applied to its grid can appear in the time base output (even assuming an infinite anode impedance for V_1). The 470 kΩ series resistor in the synch. input lead may be omitted if synchronization is only required from high impedance sources, with a resultant increase in synch. efficiency.

It will be obvious from a study of the diagram that there will be a stable state of the circuit in which oscillation cannot occur. If the suppressor of V_1 is at earth potential, and its anode potential is low, and if *at the same time* V_2b is passing current while V_2a is cut off, the circuit cannot function. In the event of this state occurring when the power supplies are switched on, the closing of a switch S_3 (which may equally well be between grid and cathode of V_2a) and its release after the suppressor grid of V_1 has returned to earth potential will start the time base again. S_3 may, of course, be used to control single sweep operation. Once the time base has started, it can only be brought back to this state by a disconnexion in the circuit, or a direct short circuit of the output to earth. Therefore, the alternative of delaying the application of anode voltage to V_1, for example, or of heater supply to V_1, will ensure that the time base will start automatically. Probably, with power supplies for the high tension line derived from an indirectly heated rectifier, the normal time delay in the application of H.T. would be sufficient.

One further warning should be given. If long leads are used to pass from the valves to the panel controls (selector switch and potentiometer) there may be a danger of high frequency oscillation (using the wire inductance) which may be exceedingly difficult to locate, and which may cause anomalous behaviour of the circuit. This type of oscillation should be at once suspected if the anode potential of V_1 appears to be stationary between the limits of about 50 volts and 400 volts positive. However, the use of small stoppers of 200-500 Ω in the control grid, screen and anode leads of V_1 and in the control grid leads of V_2 should eliminate any trouble of this type.

Reference.

[1] D. F. Gibbs and W. A. H. Rushton, *J. Sci. Instrum.* 23, 270, 1946.

The Baldwin Electronic Organ

By

ALAN DOUGLAS

AS is well known, instruments of this type have been under development ever since the valve became stabilized in characteristics. A considerable number of inventors had anticipated this condition, but had to wait until their ideas could materialize.

The most successful of the earlier electronic organs used some form of electro-mechanical generator, probably because the required stability and consistency could not be obtained from valves. In recent years, however, the valve has become completely reliable, and, even more important, the design, size and characteristics of all kinds of inductors, resistors and similar components have been quite revolutionized. New materials and manufacturing techniques have been largely responsible for this.

The superiority of the valve as an oscillation generator is borne out in a striking manner in the Baldwin organ. It is possible to obtain almost any desired form or complexity of oscillation by circuit manipulation, at a relatively low cost as compared with the electro-mechanical systems.

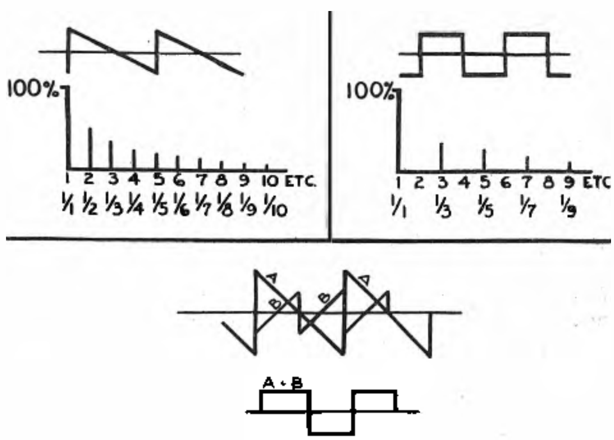
For accurate musical synthesis, the generator, of whatever type, must provide an adequacy of harmonics.[1] As greater realism is demanded, and as this class of instrument comes more and more into competition with the pipe organ, the complexity of the electro-mechanical generator assumes uneconomical proportions. This is especially true if additive synthesis is employed, since tempered scale interference demands many extra generators, should these be of the single wave per note type.

It is not too much to say that recent intensive researches into filter and resonant network design have enabled the designer of the complex wave music generator to synthesize most organesque tonecolours with striking success. Without these advances, it is probable that the electro-mechanical generator would remain the more highly developed of the two methods.

In any organ of full compass, it is necessary to provide a series of harmonics for each note extending to at least the 30th, almost to the top of the keyboard. It is sometimes argued that there is little point in carrying these above the audible range; but experience has shown that many complex beating effects obtain at these high frequencies, the effects of which in combination with lower frequencies cannot be ignored.

The Baldwin organ, therefore, sets out to provide a complete harmonic series for each note, and to

Fig. 1.
Illustrating the combination of two sawtooths to give a square wave



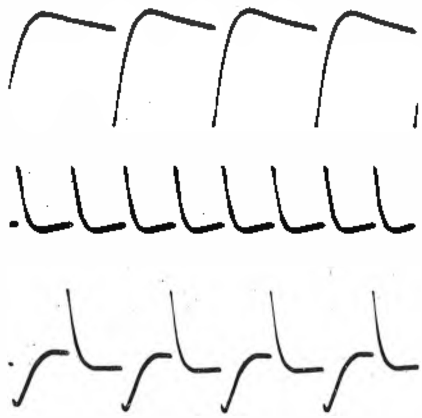


Fig. 2.
The form of square wave actually used is shown at the top, with the component sawtooth waves below

this end the initially generated wave is a sawtooth. This has an infinite harmonic series, the amplitudes of which are inversely proportional to their harmonic order. Most of the sounds produced by open organ pipes contain even and odd harmonics, and can be synthesized from such a waveform.

The stopped class of pipe sounds, or at least has most predominantly, odd harmonics. These are also powerful colour-forming constituents of reed pipe tone. Such harmonics are readily to be extracted from a square wave. It would appear logical to provide both types of waveform in an electronic organ, but normally this would increase the cost of the generating system and the complexity of the keying devices to an uneconomical degree.

Dr. W. E. Kock is responsible for an ingenious circuit whereby a square wave can be formed from two sawtooth waves. The method is to take a sawtooth wave an octave above the required fundamental; reverse its phase by means of a valve; reduce its amplitude by half, and re-combine it with the fundamental frequency. In Fig. 1 is shown a sawtooth wave, a square wave, and the process of combination just referred to. In practice, with the circuits employed, it is not possible to produce an exact sawtooth wave as shown, and the form shown at the top of Fig. 2 is actually employed. The process is again shown complete in this illustration, and while the cancellation is not complete for the higher harmonics, it is effective for those which lie within the audible range.

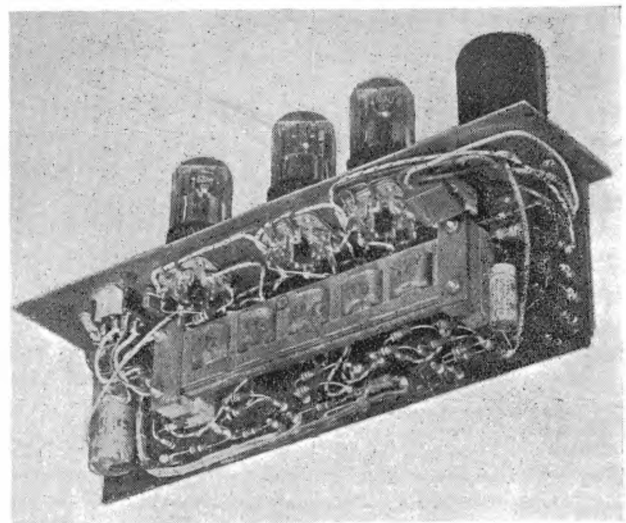


Fig. 4.
The divider unit

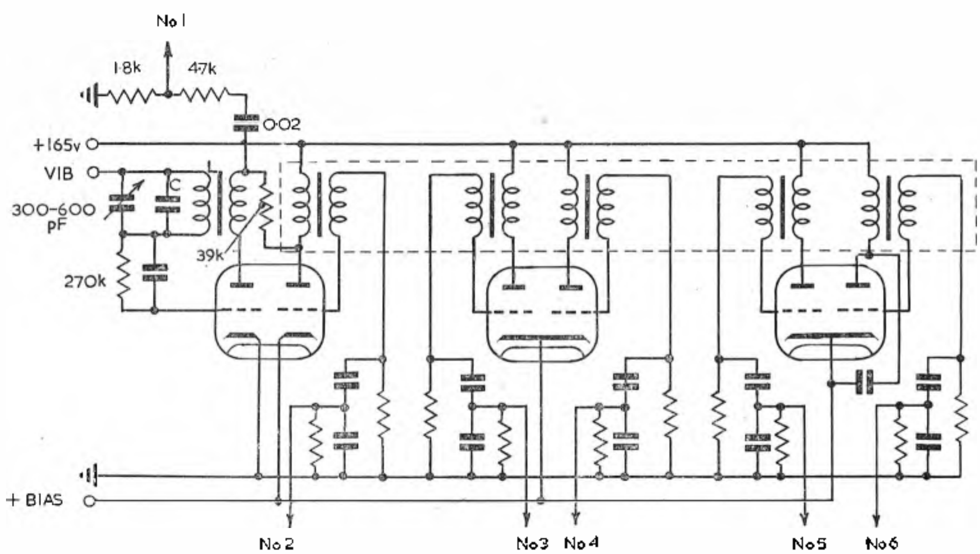


Fig. 3.
Basic sawtooth generator circuit as used in the Baldwin organ

There are many generators for producing a sawtooth wave. In designing an electronic organ for production, it is most desirable to reduce the number of components to the minimum in the present state of the art. The Baldwin generator is extremely ingenious and effective.

Fig. 3 shows the generator circuit. The coil *L* is part of an ordinary plate-to-grid oscillator, and is tuned by *C*. The fundamental for this stage is taken out at No. 1. This signal also passes to the first of organ, e.g., CC, C, C¹, C², C³, C⁴. It will be observed that the cathodes of all but the actual oscillator valve are returned to a biasing potential. The dividers are thus of the blocking type, and this is done to prevent off-pitch tones in the event of any oscillator failing. A vibrato can be injected as shown; the circuit for this is described later. A photograph of a complete divider unit is given in Fig. 4, and the small size of the pulse transformer can be seen by comparison with the 6SN7 valves on

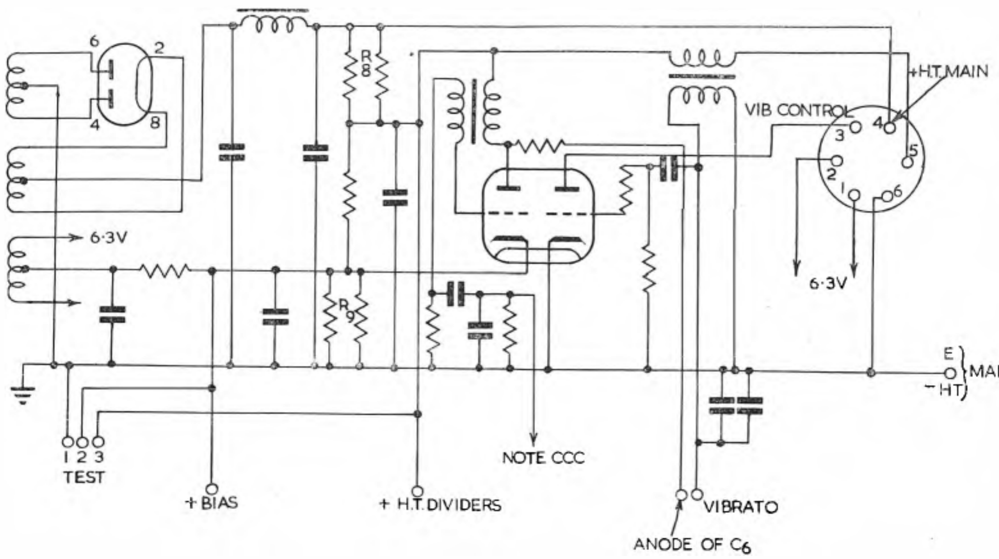
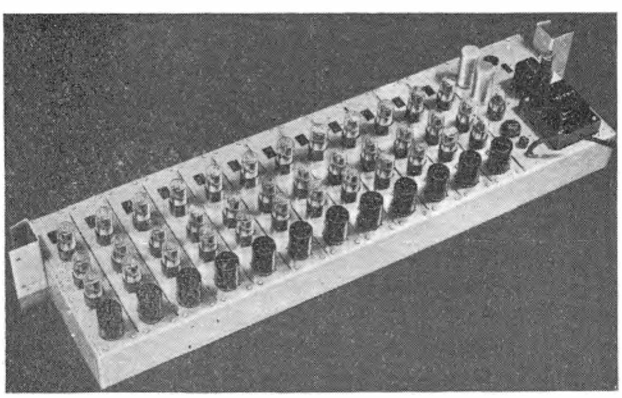


Fig. 6.
Power supply and vibrato generator

a series of five cascaded transformers coupled by a common iron core. The cores have pairs of inductively-coupled coils which feed a chain of valves in sequence. These coils are so proportioned that each can hand on enough energy to excite the next one. The frequency selecting network shown connected to the respective outlets 2, 3, 4, 5 and 6 determines the actual pitch at these outlets. The resistor shunted to earth across each outlet is a voicing resistor, to adjust the level of each note. Any one divider unit provides all the notes of one sign for the whole

Fig. 5.
Complete oscillator, dividing unit and power pack



the top deck. The oscillator coil is in the black container, and it will be apparent that once the divider constants are set there will only be twelve oscillators to tune to maintain the whole organ in tune. The complete oscillator and dividing unit for the whole instrument, including the power pack, is shown in Fig. 5. This is the entire music generator.

Since there are 61 notes on the keyboard, and a tempered scale octave has twelve notes, one extra generator must be provided for the additional note at the end of the 5th octave. One half of a 6SN7 valve is used for this purpose, in a straightforward oscillator, the other half being a low frequency oscillator of 6 or 7 c/s. to provide the vibrato voltage. This valve can be seen on the right of the power unit, Fig. 6. It is a characteristic of the frequency dividing system used that it will not provide the correct value of pulse unless a definite ratio is maintained between the H.T. line voltage and the cathode bias voltage. This value is critical, and is accurately set by the vernier resistors *R*8, *R*9 across the main positive to negative load resistor. The remainder of the power unit is conventional, and the economical working of the dividers is clearly shown in the fact that a single 5Y3 rectifier can supply the entire system, with a margin of safety.

So far, a series of sawtooth waves has been provided by the divider units. None of these has yet been turned into square waves. To control the generator outputs, the signals are fed to switches

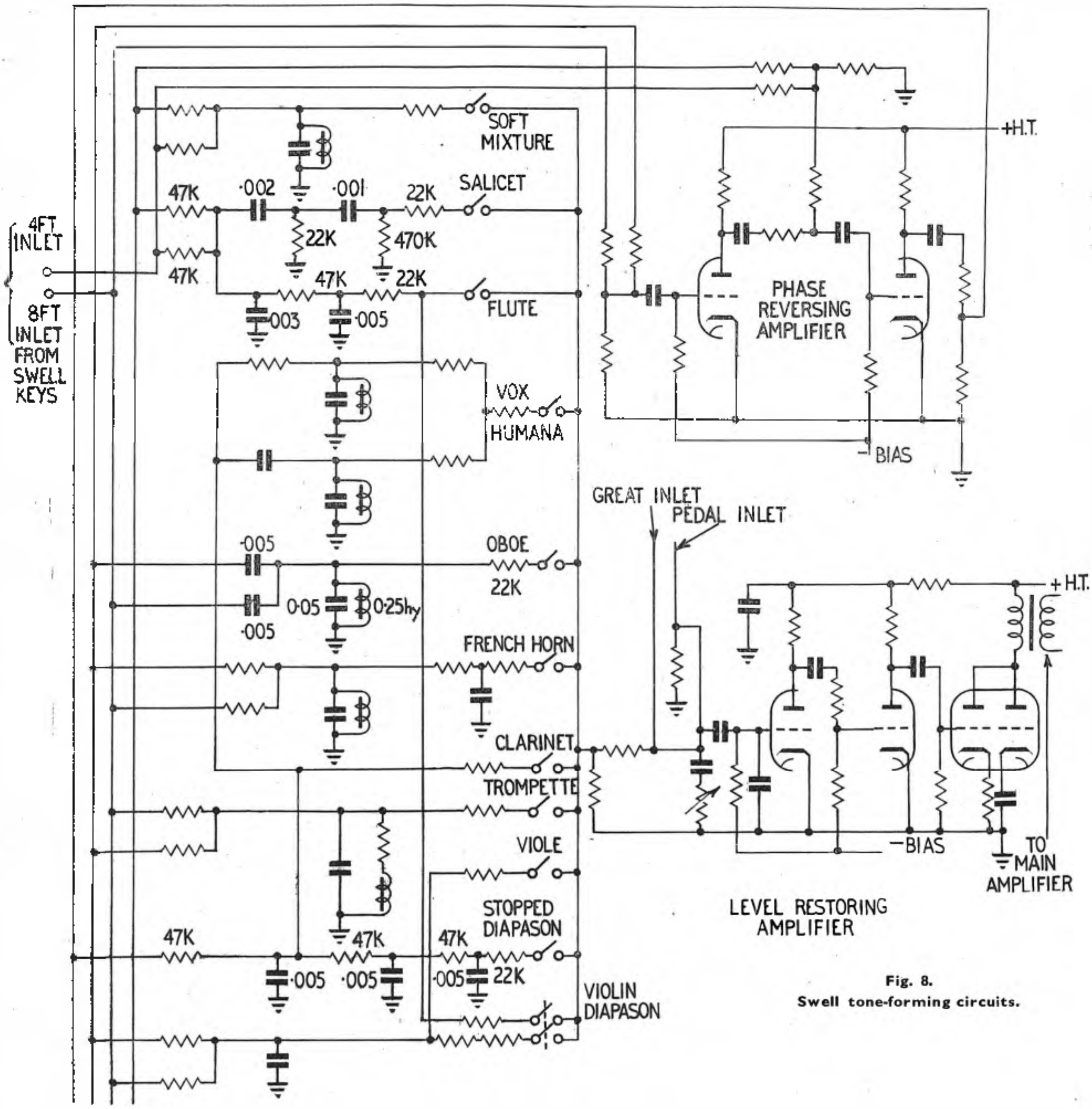


Fig. 8.
Swell tone-forming circuits.

under the playing keys. It is common knowledge that no organ pipe speaks instantly, and equally well known that to break into a continuously-energized signal line will result in a very abrupt attack to the sound, and most unpleasant transients of a clicking, spitting or thumping nature.

The Baldwin organ overcomes these difficulties in a most elegant manner. Underneath each playing key is a series of switches. Actually there are two ganged sets under the upper manual, three under the lower manual, and two under the pedal keys. That is because pitches of 8 and 4 ft., 16, 8 and 4 ft., and 16 and 8 ft. are fed to these respective claviers.

The author regrets that it is not permissible to disclose the exact construction of these switches, but they are essentially of a variable resistance type, having a value which decreases logarithmically with a linear depression of the key, and having a resistance from infinity to a few thousand ohms. The mechanical resistance, or touch, is less than half an ounce for the three gangs, and they operate noiselessly for five to six million working cycles. The switches are fitted in octave groups, and can readily be replaced if a bad contact should develop. This process is much easier than in a pipe organ with electric action.

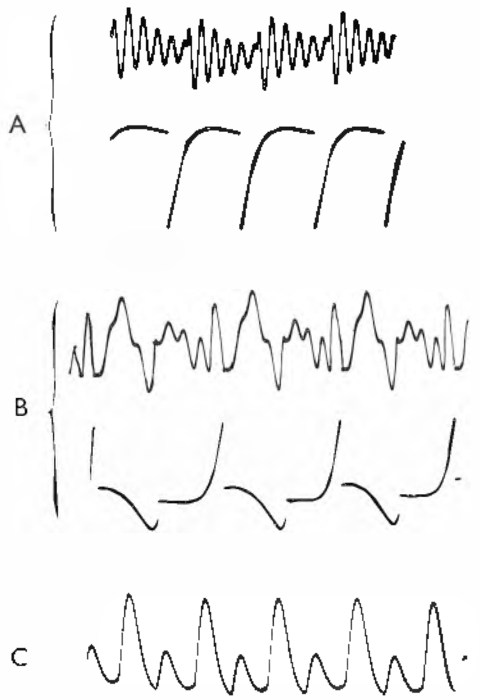


Fig. 7.

A. Oboe tone formed by applying generated wave applied to a resonant filter.

B. Vox Humana formed by applying a phase-reversed wave to a double resonant filter

C. Open diapason formed from the wave used for A

From the sawtooth wave, or combination of waves in different pitches, it is necessary to form the required tonecolours. This is done by means of filter circuits.[2] There are three principal types of filter in this instrument. Firstly, resistance-capacitance high pass filters which are for simulation of organ string tone; secondly, *R-C* low pass filters which are essentially for the flute type of stop; and, thirdly, resonant filters for the simulation of orchestral tonecolours. One or two examples may help to illustrate the effect of these. Fig. 7 shows at *A* the generated wave applied to a resonant filter to form an oboe tone; *B*, a phase-reversed wave applied to a double resonant filter to produce a *Vox Humana*; and *C*, an open diapason formed from the wave used for *A*. In this instance, more second harmonic is required than would normally be available in the generated wave, so voltage is borrowed from another similar filter supplied by a generator an octave above, and added to the original wave; this is made possible by the arrangement of the ganged switches.

To turn to the actual tone-forming circuits. These are partly shown in Fig. 8. Again, it is impossible to reproduce the whole of the circuits on this size of page. The swell manual has been selected because it employs the phase-reversing amplifier to the greatest extent. This can be seen in the top right-hand corner. There is some loss of signal strength in the filters, so a three stage preamplifier (*bottom right*) is introduced to restore the level. The mixed signals pass from this to the main amplifiers and loudspeakers. For the benefit of those experimentally inclined, the correct values for the components are shown on one or two of the filters.

The whole of the filter, phase reversing and pre-amplifier circuits are neatly disposed in the box shown open in Fig. 9.

In the organ described, there is a single expression pedal for the whole instrument. The console is quite standard, and the small size can be seen from the photograph of the complete organ, p. 507. The actual dimensions are 52½ in. wide, 44 in. high, 42¾ in. deep, including 32-note pedal board.

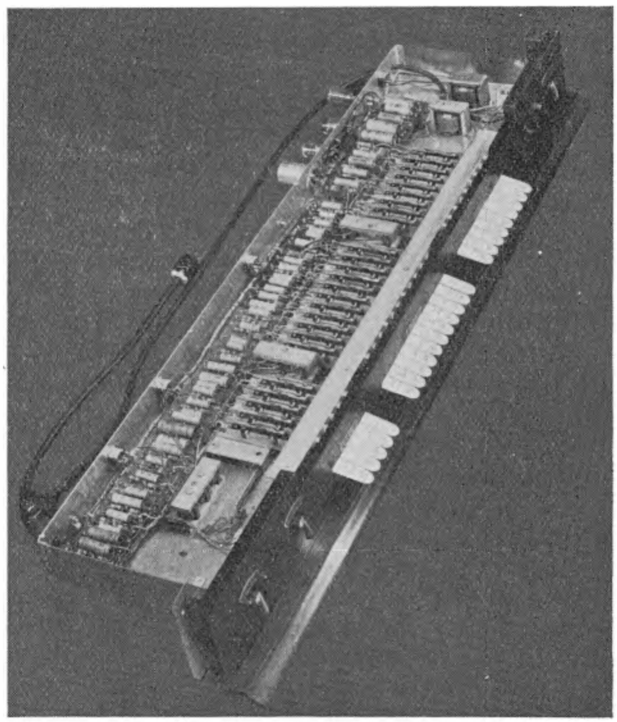
The author undertook a special investigation into all the electronic musical instruments produced in the U.S.A. in 1949, and heard many examples under all kinds of conditions. The Baldwin organ is outstanding both to hear and to play. Perhaps the fact that this company has spent over sixteen years developing the instrument before it was released is largely responsible. From an organist's point of view, the touch and expression are ideal, and the different tonecolours are incredibly realistic. There are some fundamental differences between the voicing of American pipe organs and ours, but the author was able to satisfy himself during a week at the Baldwin plant that English voicing was readily obtainable with this instrument. A model is now under construction in this country.

References

[1] A. W. Ladner, *Electronic Engineering*, October, 1949.
A. Douglas, *Musical Opinion*, June-October, 1949.
[2] A. T. Starr, Electric Circuits and Wave Filters. Pitman.
Electric Filters, T. H. Turney. Pitman.
A. Douglas. Electronic Musical Instrument Manual. Pitman.
Transmission Networks and Wave Filters, T. E. Shea. Van Nostrand Pub. Co.
Network Analysis and Feedback Amplifier Design, H. W. Bode. Van Nostrand Co.
Wave Filters, L. C. Jackson. Methuen.

Fig. 9.

Filter, phase reversing and pre-amplifier circuit assembly



Stabilized Power Pack

Running two stabilizing valves in parallel to provide high current output.

By R. E. HARVISON, B.Sc. (Hons.)

(Electrical Engineering Dept., Manchester University)

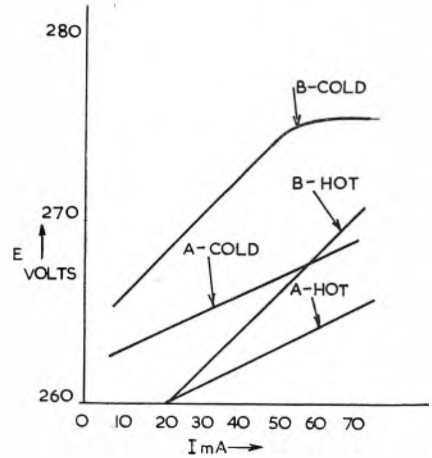


Fig. 2.

Enlarged portion of Fig. 1 to show difference in slope resistance

Possible Circuit Action with Valves in Parallel

THE characteristic curves for two Stabilovolt STV 280/80 valves are shown in Fig. 1 and in Fig. 2 an enlarged portion of Fig. 1 over average working region of valves. These show that the slope resistance of one valve differs from that of the other, but that this difference is constant whether the valves are hot or cold. No explanation is offered for the "tailing off" effect of cold curve *B*, as in the final consideration only the hot curves are used.

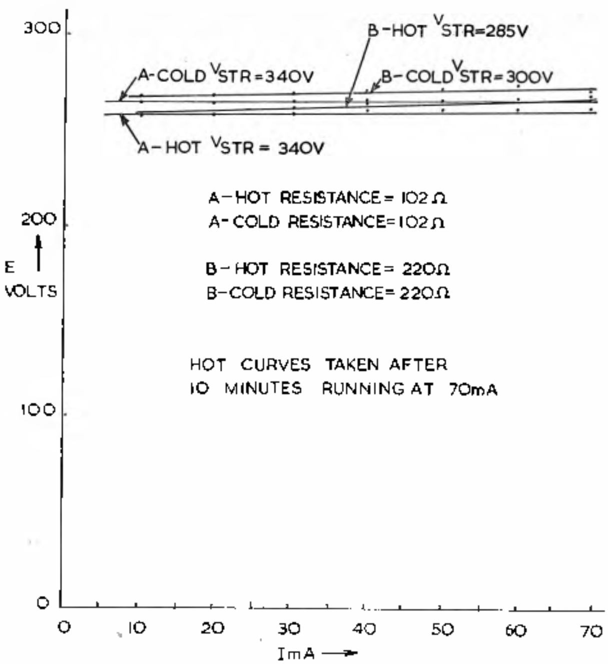
Fig. 3 shows a schematic arrangement of valves *A* and *B*. The limiting resistors R_A and R_B have the same value, which is calculated by considering each valve to take half the total current output.

Two aspects of this circuit are considered:

1. Valves *A* and *B* connected in parallel (by joining *X* and *Y*) *before E* is applied.

Fig. 1.

Characteristic curves of stabilovolts after striking has occurred



2. Valves *A* and *B* connected in parallel (by joining *X* and *Y*) *after E* is applied, i.e., valves are hot.

Case 1. Since *B* has the lower striking voltage (see Fig. 1) it will strike first. Thus voltage at the anode or top electrode of *A* is stabilized at a value below its striking voltage. So *A* cannot strike and valve *B* will take the full current—up to twice its maximum rated value—and will be damaged. The limiting resistor R_B alone would allow only half the surge to pass via *B*, but since R_A and R_B are in parallel the full current is taken.

Case 2. Consider $E = 264$ volts; then from Fig. 2 before X and *Y* are connected, *A* passes 60 mA and *B* 39 mA. On connecting X and *Y* all the current is drawn via the lower resistance path *A*, and *B* is extinguished. The result is the same as that for Case 1, i.e., shift of all current to one valve, but the mechanism is different.

In the light of the above, two requirements must be met before the valves can safely be put in parallel. These are:

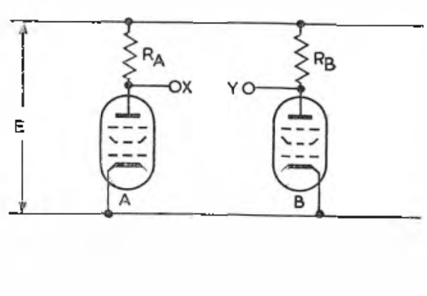
(i) The currents passed by individual valves must be made approximately equal.

(ii) The points which are joined in the two arms shall be at the same potential.

A schematic circuit which satisfies both these conditions is given in Fig. 4. $R_A = R_B = R$, the value of *R* is calculated (see later) to limit the current in each valve to below the specified maximum rating.

Fig. 3.

Connexion of tubes in parallel under unbalanced conditions



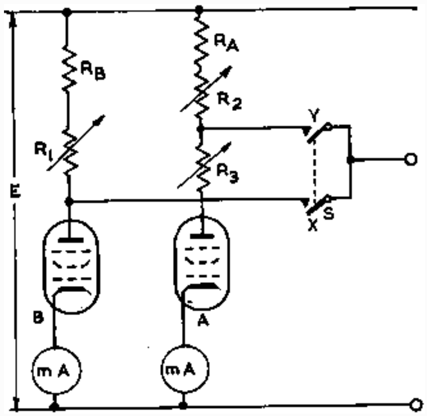


Fig. 4.
Use of padding resistor to correct for difference in striking voltage and self resistance of tubes

The variable resistors R_1 and R_2 enable the currents in A and B to be balanced before X and Y are joined by S. Visual indication of this balance point is given by the milliammeters in the negative return leads. A small padding resistor R_3 is placed in series with the valve which has the smaller working voltage, and varies the potential of point Y so that condition (ii) above is satisfied. The value of R_3 should be as low as possible, since point Y is "unstabilized" by any supply fluctuation, by an amount which is proportional to R_3. Values of R_1 and R_2 are chosen to give an adequate current variation in each valve.

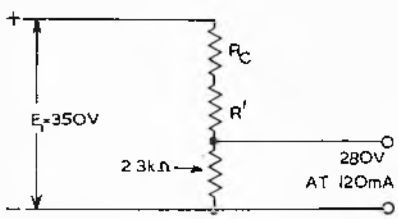
It has not been found possible to connect intermediate electrodes in parallel, but these can be used separately to give stabilized voltages at small current drain (diode clipping supply, bias voltage, etc.). Any variation in valve current due to intermediate electrode drain after valves are in parallel can be balanced out by R_3.

Practical Application of Power Supply using Tandem Stabilizing Valves

The calculation of component values for a circuit using valves A and B (Figs. 1 and 2)—STV 280/80—is as follows:

Maximum load required is 280 volts at 120 mA. This is equivalent to a resistance load of approximately 2,300 ohms. The equivalent diagram of the stabilizing section at *full load* is shown in Fig. 5, in which R_C is the resistance of the choke in the smoothing circuit of rectifier supply E_1 and R' limits the current to 120 mA assuming that both valves are conducting equally. Then by potential divider

Fig. 5.
Calculation of limiting resistance and equivalent output load.



action, taking E_1 = 350 volts and R_C = 150 ohms, we have:

$$\frac{280}{350} = \frac{2{,}300}{2{,}300 + R' + 150}$$

this gives R' = 425 ohms. Thus $R_A = R_B$ = 850 ohms, and $R_1 = R_2$ = 1,000 ohms gives satisfactory current control. R_3 = 200 ohms was found to give adequate coverage for possible current variations.

The complete layout is shown in Fig. 6. Two 1,700 ohms, 2 watt resistors are used in parallel to replace the 850 ohms due to wattage requirements, and also because 1,700 ohms is a standard value in carbon resistors.

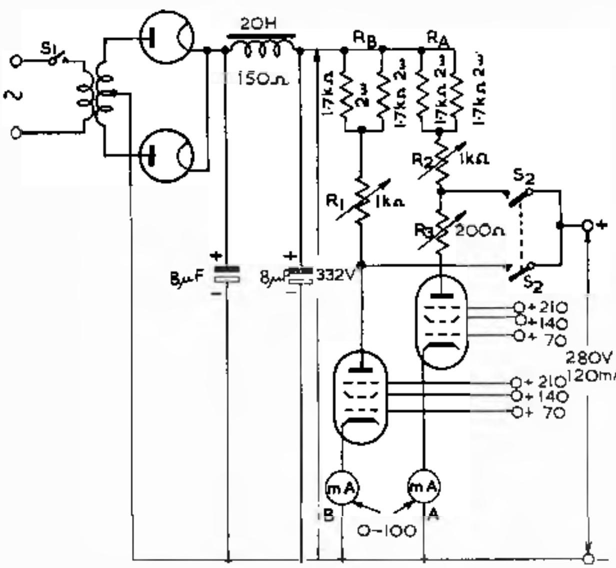
The following procedure is recommended when using this circuit:

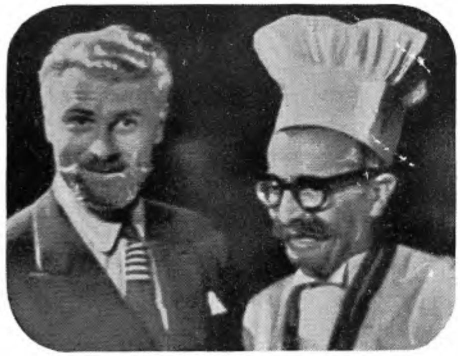
1. Switches S_1, S_2 open, R_1, R_2 and R_3 set to mean positions.
2. Close switch S_1, one valve conducts first and as rectifier warms up the current will increase to nearly maximum value, when the other will in most cases strike. If it does not, striking may be stimulated by rapidly closing and opening S_2 which is returned to the open position when both valves are conducting. Allow about five minutes for warm-up time.
3. Adjust the currents to balance by means of R_1 and R_2.
4. Close S_2 and adjust R_3 to give equal currents in both valves.

After the preliminary setting up, R_3 is used to correct any unbalance introduced by variation in current drain.

This arrangement of D.C. power supply has proved very useful in general experimental laboratory work, and in particular in the field of waveform generation and shaping, in which the technique adopted is one of step-by-step construction, resulting in a current drain which varies considerably as the component stages are built in.

Fig. 6.
Typical circuit values



Photographs taken from a television receiver screen during the actual relay (Telesnaps by J. Cura.)

The Dover-Calais Television Transmission

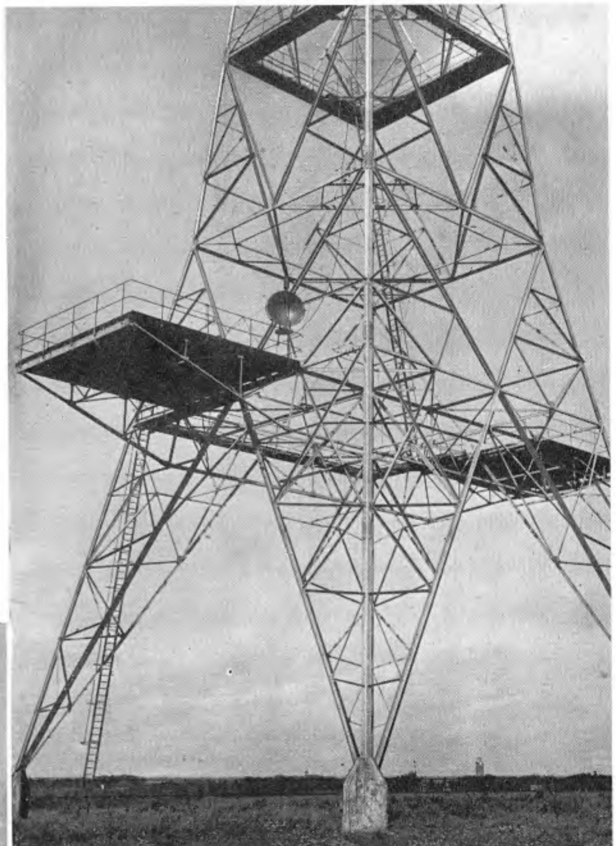
On August 27 of this year, the B.B.C., in collaboration with the Radiodiffusion Française, televised the celebrations of the centenary of the laying of the submarine cable between England and France.

From Calais, where the main celebrations took place, the programme was transmitted by portable microwave equipment installed in the Clock Tower of the Hotel de Ville across the Channel to a receiver at Dover. From there it was retransmitted by V.H.F. to a water tower at Warren Street, Lenham, and thence to Harvel near Wrotham.

The signal from Harvel was transmitted by a Microwave Link to the Senate House, London University, whence it was conveyed by cable to Alexandra Palace.

(*left*) : Portable Microwave Television Receiving Equipment supplied by Marconi's Wireless Telegraph Co., Ltd. installed on a water tower at Warren Street near Lenham.

(*right*) : The microwave receiving aerial manufactured by Standard Telephones and Cables, Ltd., mounted on an R.A.F. radar tower at Dover.



(*left*) : Microwave receiving apparatus at Senate House, London University together with monitoring and V.H.F. communication equipment.

(*below*) : Television transmitting equipment in the Hotel de Ville, Calais, together with monitoring and V.H.F. communication equipment. The transmitting microwave paraboloid can be seen on the extreme right of the photo.

(*left*) : Microwave receiver on the roof of the Senate House, London University.

Equipment was supplied as follows :

Cameras and camera control equipment : Marconi's Wireless Telegraph Co., Ltd.

Microwave television links : Standard Telephones & Cables, Ltd., and Marconi's Wireless Telegraph Co., Ltd.

V.H.F. television links : Marconi's Wireless Telegraph Co., Ltd., and Pye, Ltd.

V.H.F. links for speech communication between stations : Mullard Electronic Products, Ltd.

Design of Iron Cored Inductances Carrying D.C.

By N. H. CROWHURST, A.M.I.E.E.

SEVERAL methods of designing iron cored inductances have been developed in the past, but each method lacks directness in one way or another. It it is not possible to arrive directly at the required design data from the three electrical quantities, inductance, D.C. polarizing current, and D.C. resistance. The charts presented in this data sheet enable such a direct method to be used for the majority of applications. While in theory no direct method is capable of giving accurate results, in practice it has been found that the direct method employing these charts can give values as close in prediction as those obtained by more lengthy methods.

The inductance of an iron cored component carrying D.C. depends in a somewhat complex manner upon not only the D.C. magnetizing component, but also the amplitude of the A.C. component of flux, so that accurate prediction of the inductance obtainable over a variety of combinations of D.C. and A.C. magnetization becomes so involved that even the more academic methods have to restrict themselves to prediction at limited selections of these combinations only.

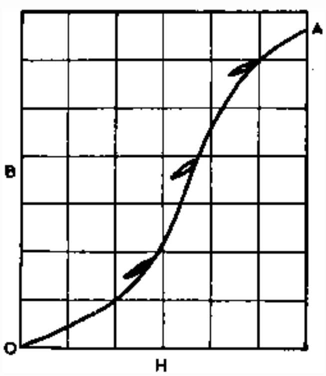
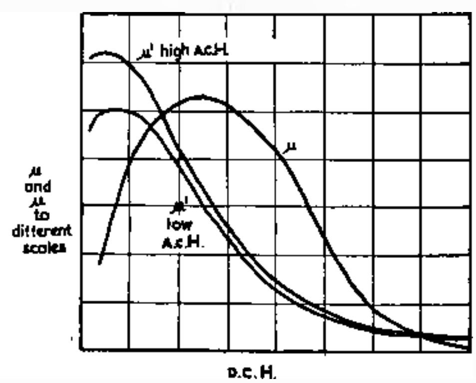


Fig. 1. (left). Magnetization of iron with combined D.C.- and A.C.-H.

Fig. 2. (right) Properties of iron cores related to the design of inductances carrying D.C.



Basis of Charts

Fig. 1 illustrates the magnetizing characteristic of the material in an iron core as it applies to the problem. The permeability with D.C. magnetization, given the symbol μ, is the relation between B and H on the D.C. magnetization characteristic OA, but the effect of variations in current about a mean D.C. value, by superimposing A.C. magnetizing current upon the D.C. polarizing, is to produce small hysteresis loops tangential to the D.C. magnetization characteristic, as shown. The average slope of these loops is the permeability of the iron to the small degree of change in magnetizing force represented by the superimposed A.C., and it is this incremental permeability μ', that must be used to determine the inductance for various combinations of A.C. and D.C. magnetizing force.

Fig. 2 shows a typical plot of permeability μ to D.C. magnetization, as well as two plots of μ' for two specific values of A.C. magnetizing force superimposed. The plots of μ' are to a scale of 1/10th that for μ. Assume that a given number of D.C. ampere turns are provided on a specific iron core having no air gap: this D.C. magnetization will bring the value of μ' well down the slope of the characteristic shown in Fig. 2; if an air gap is introduced into the iron circuit, it will add an equal increment of reluctance to that of the magnetic circuit for both D.C. and A.C. magnetization; due to the increased reluctance to D.C. magnetization, the operating point on the iron characteristic will be changed, so that the effective value of μ' for the iron part of the circuit will be raised to a point higher on the characteristic of Fig. 2; this increased value of μ' will reduce the reluctance of the iron part of the circuit to A.C. magnetization, while the air gap will introduce an increase in reluctance. Variation of the air gap will produce a maximum overall reluctance to A.C. magnetization, for some value of air gap where the rate of change of reluctance due to variation of μ' with air gap is equal to the rate of change of reluctance due to the air gap itself. At this operating point in the magnetization characteristic of the iron, a coil will show its maximum value of inductance for the values of A.C. and D.C. magnetization applied.

It is possible empirically, by adjusting the air gap for various values of D.C. magnetization with superimposed A.C. magnetization, to find a proportion of air gap length to the length of iron path that will give a maximum inductance value for the particular combination of A.C. and D.C. magnetization employed. By varying the D.C. magnetization, and adjusting the air gap for optimum inductance, a plot of the effective maximum overall incremental permeability of the magnetic circuit can be obtained, and also a plot of the relative air gap length expressed as a fraction of the total magnetic circuit length, both against the D.C. magnetization per unit length of iron core.

It is found that, using standard quality trans-

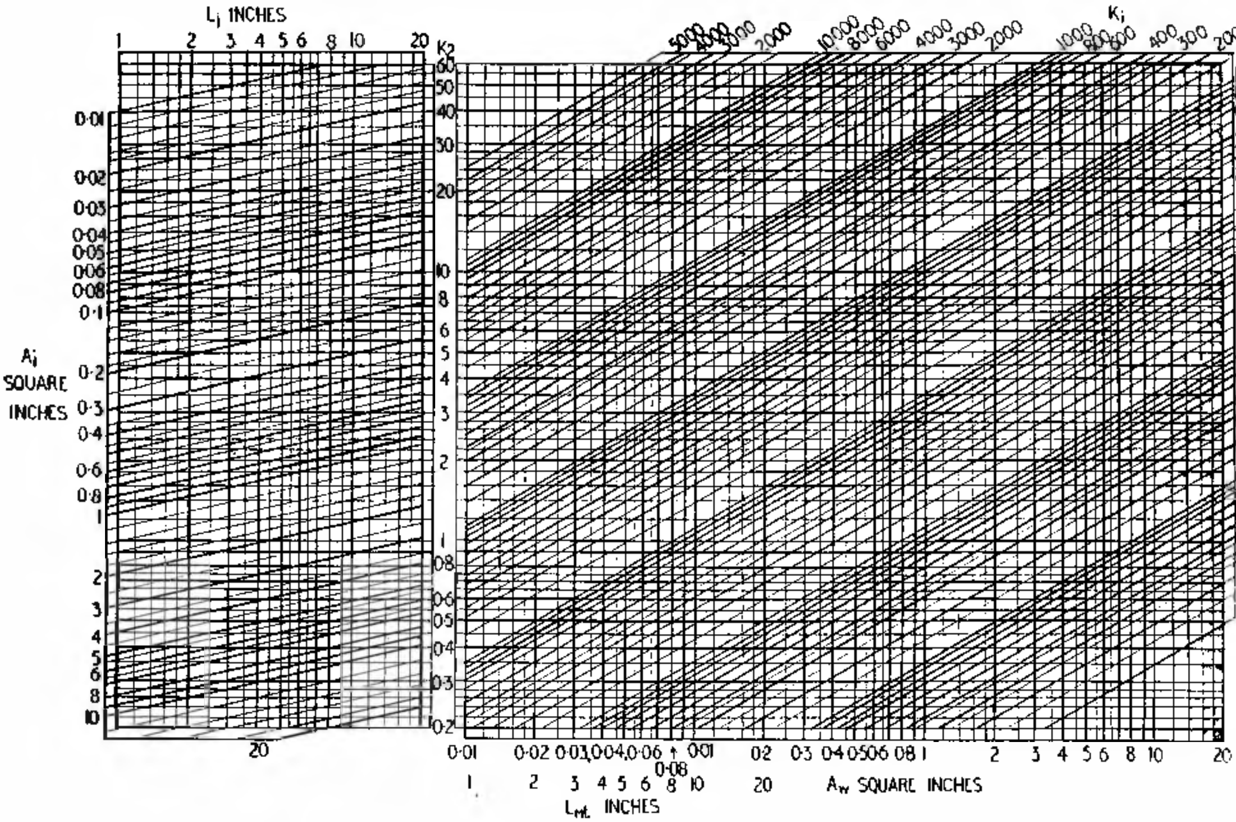


CHART I

To obtain values of K_1 and K_2 for various core sizes and winding arrangements

former iron, these plots can be approximated within a reasonably close degree of accuracy by the following laws. Writing μ'_m for the maximum overall incremental permeability, the law

$$\mu'_m = F[IT/L_i]^{-\frac{2}{3}} \quad \ldots\ldots\ldots\ldots \quad (1)$$

holds for values of IT/L_i above 3 ampere turns per inch, where I is the D.C. magnetizing current, T is the number of turns, and L_i is the path length of the iron core.

The relative air gap length can be approximately expressed, over the same range of D.C. magnetization as

$$L_g/L_i = F[IT/L_i]^{0.3} \quad \ldots \quad (2)$$

In these approximate forms the formulæ can be applied to produce direct design formulæ that will eliminate the necessity for reference to curves which do not have any direct relation to the electrical quantities specified. The inductance with D.C. at such maximum value can be written in the form

$$L = F[T^2 A_i/L_i][IT/L_i]^{-\frac{2}{3}}$$
$$= F[T^{4/3} I^{-\frac{2}{3}} A_i L_i^{-\frac{1}{3}}] \quad \ldots\ldots\ldots \quad (3)$$

Assuming that the inductance and D.C. magnetizing current are fixed by specification, and a specific iron core has been chosen, so that A_i and L_i are also fixed, the turns can be expressed in terms of the other quantities by a formula of the form,

$$T = F[L^{\frac{3}{4}} I^{\frac{1}{2}} A_i^{-\frac{3}{4}} L_i^{\frac{1}{4}}] \quad \ldots\ldots\ldots \quad (4)$$

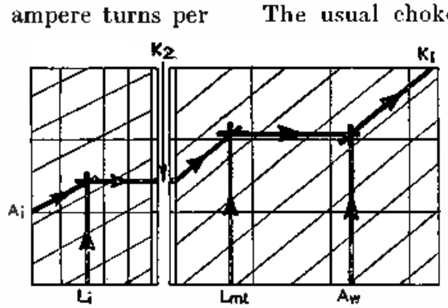


Fig. 3.

Use of Chart I for the determination of constants K_1 and K_2

The usual choke specification calls for a certain inductance at a specified D.C. magnetizing current, with a maximum D.C. resistance. The winding specified by (4) will have a resistance proportional to the square of the number of turns, directly proportional to the length of mean turn, and inversely proportional to the winding cross-section and space factor. So the resistance of the inductance coil can be expressed,

$$R = F[L^{\frac{3}{4}} I^{\frac{1}{2}} A_i^{-\frac{3}{4}} L_i^{\frac{1}{4}}]^2 \times [L_{mt} A_w^{-1}]$$

Collecting together the terms consisting of core size and winding arrangement constants, this becomes

$$R = F\,\frac{L_i^{\frac{1}{2}} L_{mt}}{A_i^{3/2} A_w} \times L^{3/2} I \quad \ldots\ldots\ldots \quad (5)$$

The factors depending upon the core size and winding arrangement can be reduced to a constant for that particular frame size, so that with reference to a particular frame size,

$$R = K_1 L^{1/3} I \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5a)$$

Equation (4) can also be rewritten as

$$T = K_2 L^{\frac{1}{2}} I^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4a)$$

where K_1 and K_2 are both constants associated with a particular core size and method of winding, etc.

Likewise, Equation (2) can be rearranged into the form

$$L_g = K_3 (IT)^{0.9} L_1^{0.1} \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

where K_3 is an empirical constant for the core material.

Use of Charts

Chart I is used to obtain values of K_1 and K_2 for various core sizes and winding arrangements set out in Figs. 8-11. It is a good plan to tabulate values of K_1 and K_2 for different standard core sizes, methods of winding, etc., after the manner shown in Table 3. This not only saves repeated use of Chart I, but also gives a direct indication of the relative "goodness" factor of different designs, the lower values of K_1 corresponding to the better designs. Sometimes other considerations will limit the choice to one particular design of a number whose K_1 values fall below the value dictated by the electrical specification.

Chart II will enable an appropriate core size to be chosen directly from the table, to conform to the desired electrical specification. Given values of L, I and R, a value of K_1 is obtained. A core size and arrangement that gives a value of K_1 not greater than this can then be chosen from the table compiled by means of Chart I.

Chart III gives the required number of turns, from the given values of L and I, and the value of K_2 obtained from Chart I, or the table compiled from it.

Chart IV, from the known number of turns and values of I and L_1 gives the requisite air gap length. The value obtained is the total magnetic circuit air gap length. For most designs employing the usual E and I or T and U shaped laminations, the magnetic circuit will include two gaps of equal length, so that the length of each gap will be half that given by the chart. The spacing washer used to maintain the gap will not necessarily be determined accurately by the figure obtained from this chart, as it cannot take into consideration the irregular effect produced by the lamination edges due to stamping, in the case of small gaps, or the effect of fringing in the case of large gaps.

The vertical reference lines on Chart IV represent ampere turns, while the horizontal ones in the top section represent values of L_1. By arranging that one boundary of this section of the chart consists of values of IT and L_1 having a ratio of $IT/L_1 = 3$, interpolation of air gap values below the range at which the formulæ are applicable is prevented. This boundary is the sloping line at the top left-hand corner of the chart. Should a design lead to an interpolation of this chart which lies beyond this line, the designer will know that the D.C. magnetization is below the range for which the charts are applicable, and that therefore some other method must be employed. Completion of the design using these charts in such a case would lead to an impossibly optimistic prediction, because the assumed value of μ' would be above its true value.

The method of using the charts will be clear from a study of Figs. 3-6. The following notes and examples will serve as a check, and at the same time introduce certain practical aspects. For illustration, a series of core sizes have been chosen using the "wastefree" shape of lamination. It should not be inferred from this that these are always the best shape to use for iron cored inductances carrying D.C., but the comparison will show how different stacks of various lamination sizes yield similar K_1 factors.

Fig. 7 shows the outline of a wastefree type pair of laminations to scale. Table 2 lists the values of L_1, A_i, L_{mt} and A_w obtained from the formulæ given in Table 1, for the winding arrangements shown in Figs. 8 and 9, for a succession of wastefree sizes. A_w is calculated on the basis of the bobbin thickness shown in the second column, while A_w' makes allowance for a clearance at the top of the winding equal to the bobbin thickness. For those more conversant with lamination numbers, the following information is given:

Lamination Size	Magnetic and Electrical Alloys	Numbers: Sankeys	G. L. Scott	British Rola
$\frac{9}{16}$"	18	—	—	1
$\frac{11}{16}$"	74	74	—	2
$\frac{3}{4}$"	35 or 135	70	120 or 154	—
1"	29	111	43	4
$1\frac{1}{4}$"	78	—	174	6
$1\frac{1}{2}$"	120	—	173	8

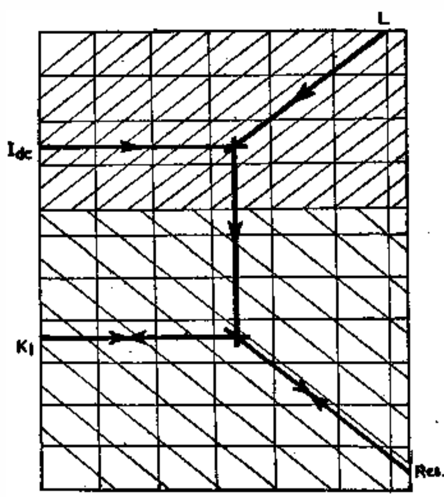


Fig. 4.
Use of Chart II for choice of suitable core size

Table 3 is tabulated by means of Chart I, using the values of L_1, A_i, L_{mt} and A_w tabulated in Table 2, for the arrangement of Fig. 8. The values of K_1 and K_2 for any other arrangement can be tabulated in a similar way, if desired. The values listed under K_1' are obtained by using the value given under the heading A_w' in Table 2. For example, take the first size listed: interception between $L_1 = 3.4$ and $A_i = 0.32$ gives K_2 as 3.8 in the centre space of the chart; referring up the sloping lines from the left-hand edge of the right-hand section from $K_2 = 3.8$ (at a position

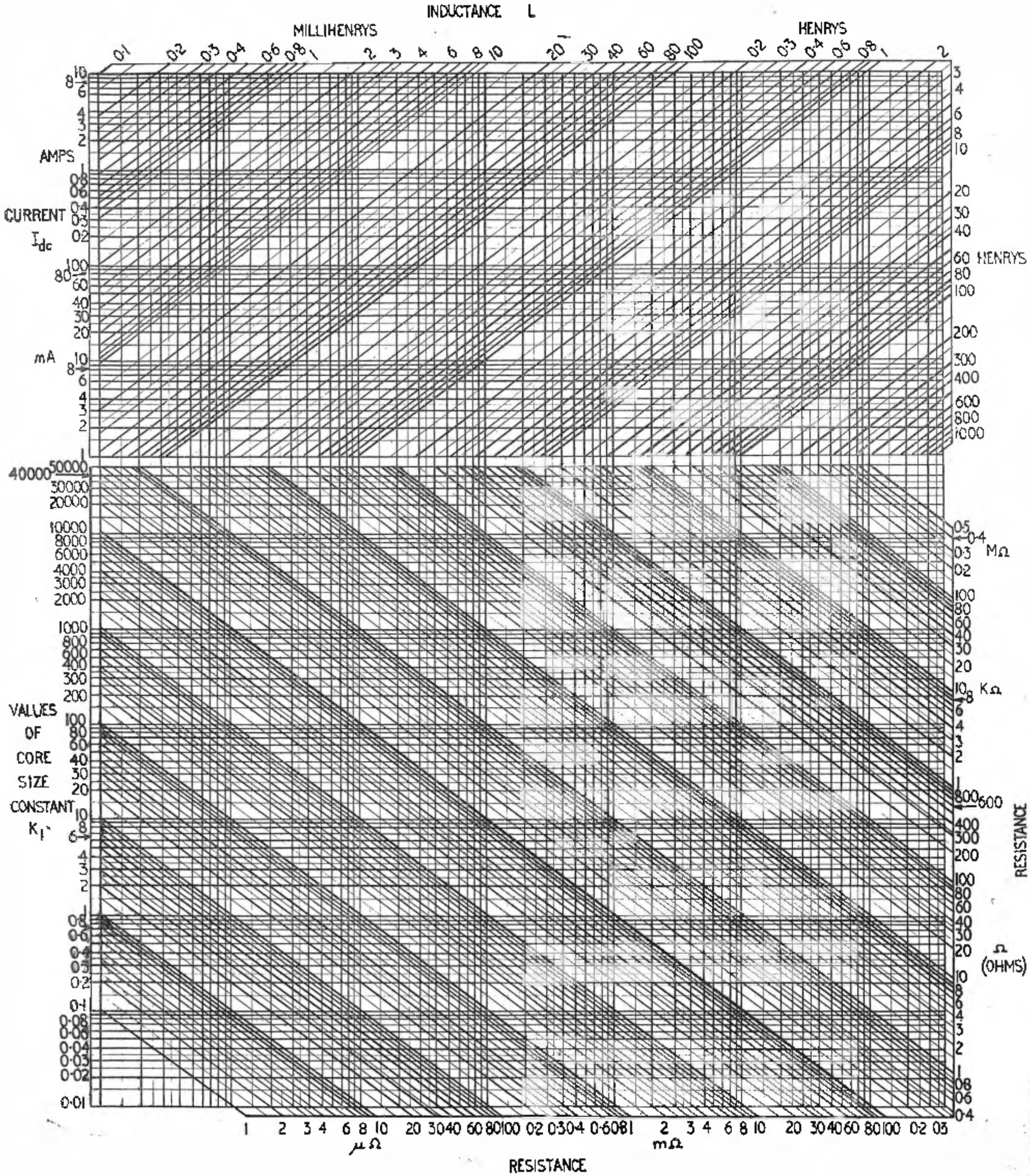


CHART II

For choice of suitable core size

corresponding to $K_1 = 1150$ on the sloping scale) to intersect with $L_{mt} = 3.4$ finds a position among the horizontal lines corresponding to $K_2 = 6.9$; referring along to intersect with $A_w = 0.195$ or 0.17 gives $K_1 = 190$ or 220 respectively. The other values in the 3rd, 4th and 5th columns of Table 3 are similarly obtained.

The values of K_1 thus obtained assume that copper conductor fills the specified winding space with a space factor of 100 per cent. In practice round copper wire is generally used, giving a space factor of 78.5 per cent, neglecting insulation. Enamel covered wire, random wound, can give space factor ranging between 60 per cent and 75 per cent, according to the wire gauge used, and the quality of winding. If layer insulation is included, the space factor will be still further reduced, while provision of a clearance space between the top of the winding and core will result in further loss of space and increase in the value of K_1 to be used for a given core size. The working values of K_1 given in Table 3 are obtained by dividing the value of K_1' by the space factor at the head of the column.

Turning to the use of Charts II, III and IV, the following examples will serve as a check:

Example 1

Specification: 50 henry, 10 mA, 1,000 ohms. Reference to Chart II shows that the maximum value of K_1 will be 300; assuming that a space factor of 75 per cent can be achieved, a 9/16 in. stack of 9/16 in. wastefree will produce a K_1 of 295; K_2 for this size is 3.8; referring to Chart III, the turns required are found to be about 7,200; using this value on Chart IV shows the total air gap required to be about 0.004 in., which means that two gaps in series, each 0.002 in. could be used, utilizing the usual *E* and *I* or *T* and *U* laminations.

Example 2

Specification: 20 henry, 100 mA, 100 ohms. From Chart II, the maximum value of K_1 is found to be 13; assume that here an H.T. insulation requirement reduces the workable space factor to 50 per cent on the larger sizes, then either a $2\frac{1}{2}$ in. stack of $1\frac{1}{4}$ in. wastefree, or a $1\frac{1}{2}$ in. stack of $1\frac{1}{2}$ in. laminations will produce the required design; if it is desired to minimize A.C. flux in the core, the former will give the best results because it employs an iron cross section of $3\frac{1}{8}$ square inches, as against $2\frac{1}{4}$ for the latter; applying Chart III, the turns required are about 2,650; using this value with Chart IV gives a total air gap length as about 0.013 in., or two gaps of 0.0065 in. The alternative size requires about 3,200 turns, and an air gap of 0.016 in. (2×0.008 in.). This results in a design that will work at a slightly lower D.C. flux, but a rather higher A.C. flux, in the same circuit.

Example 3

Specification: 2.5 henry, 10 mA, 5 ohms. (These values are unusual, but serve to show how use of the charts avoids a false prediction). Reference to Chart II shows a K_1 of about 125 is required; allowing a 60 per cent space factor a $\frac{3}{8}$ in. square cross section could be used, with a K_2 of 2.6; reference to Chart III gives turns required as 510. The intersection of the 510 turns with 10 mA, when referred up the vertical reference lines of Chart IV to intersect with $L_i = 4.5$ in. indicates a point beyond the sloping boundary at the top left-hand corner of the chart, indicating that the design figures obtained represent a D.C. magnetization below that at which this method is applicable. Other methods will have to be employed according to the exact nature of the problem.

For the values of D.C. magnetization lying within the range covered by these charts, there is little difference between the results obtained with various core materials, so that, on economic considerations, ordinary transformer iron will normally be used. Some applications may arise where the core losses due to A.C. magnetization are of importance in the design, in which case, as in example 3 above, other methods must be applied.

In the design of directly coupled intervalve transformers, the method to be followed will depend largely upon the anode current and impedance of the preceding stage. For high impedance, low current valves, parallel feed coupling is preferred.

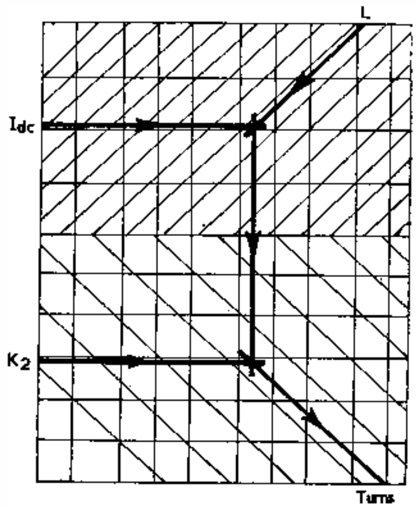


Fig. 5.
Use of Chart III for determining the number of turns required

For lower impedance, high current valves, the design charts in this series can be used, following the procedure outlined above to obtain the necessary primary inductance. The winding area allowed must take into account the necessity for a secondary winding. Generally, the heating effect of the D.C. in the primary will not be important, and provided that adequate primary inductance at the operating current is obtained, the transformer should be designed for optimum transfer efficiency, which means that primary and secondary should occupy approximately equal space in the winding. Sometimes it may be advantageous to allow slightly more space for the secondary, to make room for the necessarily high number of turns, to obtain a high step-up combined with suitable primary inductance. On the other hand, it may be desirable to give more space to the primary so as to reduce the primary resistance, where it is necessary to utilize all the available H.T. supply voltage.

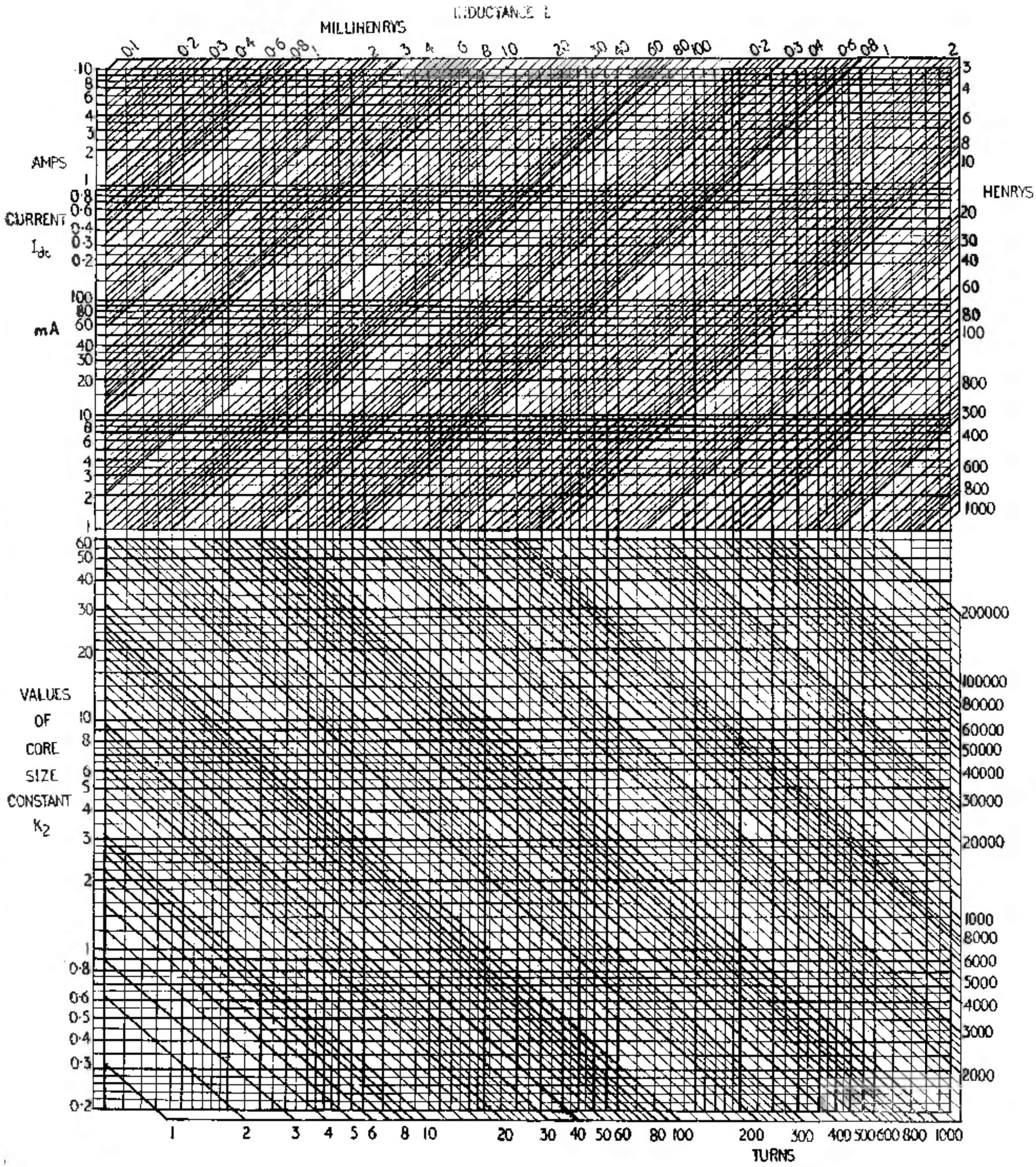


CHART III

Required number of turns, from the given values of L and I

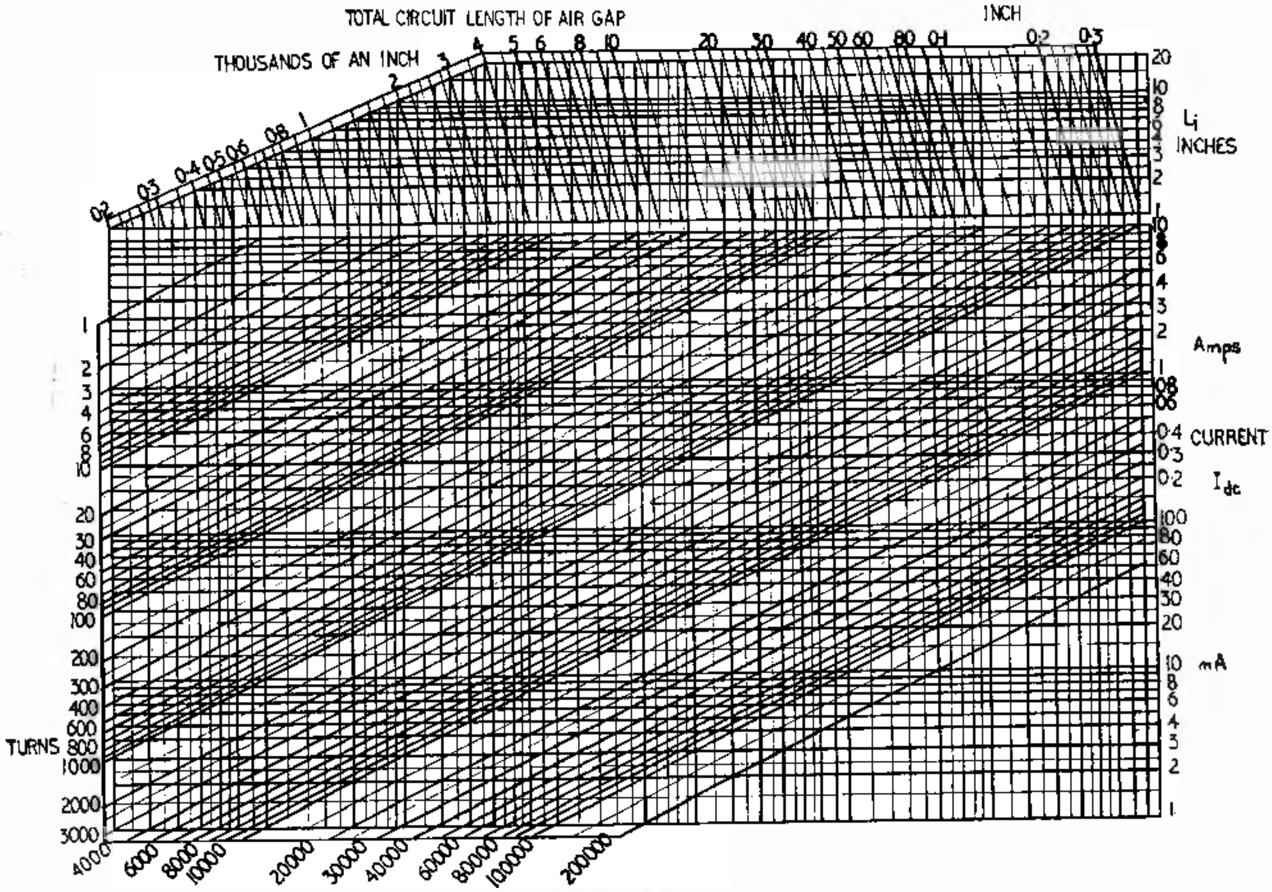


CHART IV

To find the requisite air gap, from the number of turns and values of I and L_i

Factors Controlling Core Shape

A variety of shapes may provide the required electrical values in a component of approximately the same bulk, and factors other than those specified in these design charts usually decide which is the best shape for a specific purpose.

The wastefree shapes are well suited where provision has to be made for a large operating A.C. potential, and as stated in example 2, a large stack of a smaller size is better from this viewpoint than a square section of a larger size.

If an important factor in design is heat dissipation, the shape chosen will depend upon the way the heat is to be carried away. Where ventilation is good, and convection is the principal means of disposing of heat, a design should be chosen with a large proportion of copper and less iron. A solid square section of winding should be avoided, but in the larger sizes it may be practicable to include a ventilating duct.

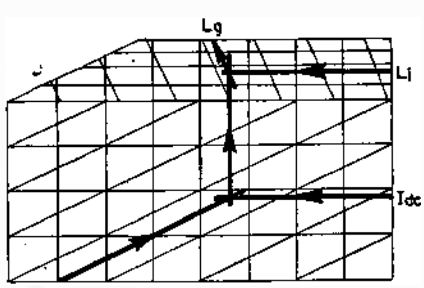


Fig. 6.
Use of Chart IV for determination of air gap

Where conduction through the chassis is to be the chief means of heat disposal, a design having a large proportion of iron, and providing good thermal contact over a large area between windings and iron, should be chosen. Here the economy effected by filling the winding space will be two-fold: by reducing the D.C. resistance to a minimum for the necessary number of turns, dissipation will be reduced; by making for better thermal contact between winding and core, the temperature gradient between them will be reduced for a given dissipation.

For inductances used in audio-frequency circuits, it is usually important that self capacitance shall be kept within certain limits. A squarish section rather than a long narrow one such as the wastefree shape produces, will best serve this end, and sectionalizing of the winding can be used if necessary to reduce capacitance further, as explained in the data sheet on winding capacitance.

TABLE 1

Values of Core Constants for the Arrangements shown in Figures 8-11

Constant	L_i	A_i	L_{mt}	A_w
Figure 8	2 (a+b+c)	cd	2 (2b+c+d)	ef
Figure 9	2 (a+b+c)	$\frac{cd}{2}$	4b+c+2d	ef
Figure 10	2 (a+b+2c)	cd	2 (2b+c+d)	ef
Figure 11	2 (a+b+2c)	cd	2 (b+c+d)	ef

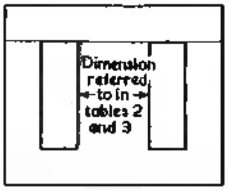


Fig. 7.
Proportions of wastefree type laminations

TABLE 2

Values of Core Constants for Series of Stock Sizes

Lam. Size	Bobbin thickness	L_i	A_w	A_w'	Stack	Fig. 8 L_{mt}	Fig. 8 A_i	Fig. 9 L_{mt}	Fig. 9 A_i
in.	in.				in.				
9/16	3/32	3.4	0.195	0.17	9/16 3/4 1 1/8	3.4 3.75 4.5	0.32 0.42 0.64	2.8 3.4 3.94	0.16 0.21 0.32
11/16	1/32	4.13	0.3	0.27	11/16 1 1 3/8	4.13 4.75 5.5	0.47 0.69 0.94	3.44 4.06 4.81	0.23 0.34 0.47
3/4	1/32	4.5	0.365	0.33	3/4 1 1 1/2	4.5 5.0 6.0	0.56 0.75 1.12	3.75 4.25 5.25	0.28 0.37 0.56
1	3/64	6.0	0.64	0.57	1 1 1/2 2	6.0 7.0 8.0	1.0 1.5 2.0	5.0 6.0 7.0	0.5 0.75 1.0
1 1/4	1/16	7.5	0.98	0.875	1 1/4 1 3/4 2 1/2	7.5 8.5 10.0	1.56 2.19 3.12	6.25 7.25 8.75	0.78 1.09 1.56
1 1/2	1/16	9.0	1.46	1.33	1 1/2 2 1/4 3	9.0 10.5 12.0	2.25 3.37 4.5	7.5 9.0 10.5	1.12 1.68 2.25

TABLE 3

Working Values of K_1 and K_2 for Stock Core Sizes listed in Table 2

Lam. Size	Stack	K_1	K_1'	K_2	Working Values of K_1, Space Factors: 75 per cent	60 per cent	50 per cent	40 per cent
in.	in.							
9/16	9/16 3/4 1 1/8	190.0 150.0 90.0	220.0 170.0 103.0	3.8 3.1 2.3	295.0 230.0 140.0	370.0 285.0 175.0	440.0 340.0 210.0	550.0 425.0 260.0
11/16	11/16 1 1 3/8	95.0 66.0 41.0	105.0 73.0 45.0	2.95 2.55 1.75	140.0 98.0 60.0	175.0 125.0 75.0	210.0 145.0 90.0	260.0 185.0 115.0
3/4	3/4 1 1 1/2	65.0 54.0 32.5	70.0 59.0 35.0	2.6 2.1 1.55	93.0 79.0 47.0	120.0 98.0 58.0	140.0 120.0 70.0	175.0 140.0 88.0
1	1 1 1/2 2	24.0 14.0 11.0	27.5 16.0 12.5	1.8 1.33 1.08	37.0 21.5 17.0	46.0 27.0 21.0	55.0 32.0 25.0	69.0 40.0 31.0
1 1/4	1 1/4 1 3/4 2 1/2	11.5 7.8 5.5	13.0 8.8 6.2	1.37 1.08 0.82	17.5 11.8 8.3	22.0 14.7 10.3	26.0 17.5 12.5	32.5 22.0 15.4
1 1/2	1 1/2 2 1/4 3	5.7 3.0 2.65	6.2 3.3 2.85	1.08 0.74 0.63	8.3 4.4 3.8	10.3 5.5 4.75	12.5 6.6 5.7	15.5 8.25 7.1

Methods of arranging cores and windings

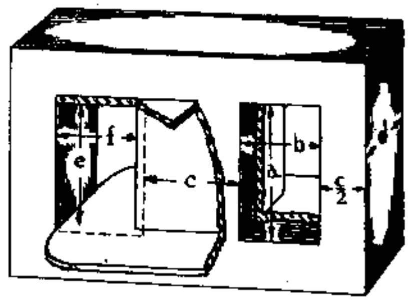


Fig. 8.

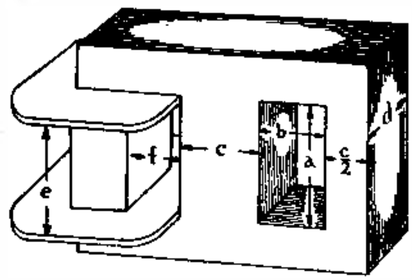


Fig. 9.

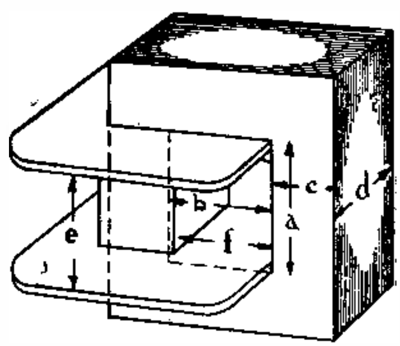


Fig. 10.

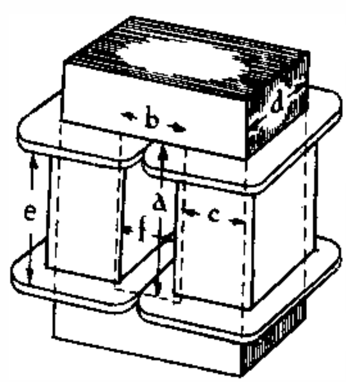


Fig. 11.

The Speed of Light . . .

Measured with Greater Accuracy

AN experiment recently completed at the National Physical Laboratory has shown inaccuracy in the normally accepted figure for the speed of light. The difference is not great—only 11 miles per second. It is, however, far from being a matter solely of academic interest, for the speed of light is used for many of the fundamental calculations in atomic theory. The more accurate figure is of immediate practical value in radio and radar.

The speed of light is, in Einstein's theory of relativity, the highest speed at which anything can travel. It is therefore an important physical constant and its measurement has provided a problem for scientists for many years. A great deal of time and money has been spent since Romer first obtained a value of 192,000 miles per second from astronomical observations in 1676. The first direct experimental measurement was made by Fizeau in 1849. A beam of light was focused on the rim of a toothed wheel and after passing through a tooth it travelled a distance of four miles and was reflected back to the wheel. If on its return the light fell upon one of the teeth it could no longer be seen from behind the wheel. The wheel was therefore speeded up until the light disappeared, and the time of travel was calculated from the rapidity with which the wheel was turning. In more recent times, in 1935, Michelson in the U.S.A. made a famous experiment in which a beam of light travelled in a metal tube a mile long; the tube could be evacuated in order to remove the small effect of the atmosphere on the speed. The final value he obtained was 186,271 miles per second. This figure was confirmed in other experiments and has been accepted ever since.

When Dr. L. Essen of the National Physical Laboratory announced in 1947 that the figure should be 186,282 miles per second, the result was received with some scepticism; he has now confirmed the result, using more refined apparatus, and results recently obtained in Sweden and in the U.S.A. agree with this value to within one kilometre a second.

Dr. Essen is in the Electricity Division of the N.P.L. where his work is concerned with the propagation of radio waves. Radio waves differ from light waves only in their wavelength, and it is generally assumed that they travel at the same speed. During the war, Dr. Essen was frequently asked what was the correct value of the speed of light and he began to suspect that, although they had been carried out on such an impressive scale, the experiments were perhaps not as accurate as was generally believed. He thought that the N.P.L. might do better by using radio waves, and started work on the problem as soon as possible after the war.

The method is similar in principle to Michelson's but, whereas he used a tube a mile long, Essen's tube is only seven inches long. A radio wave was sent down this metal tube and reflected backwards and forwards between the two ends. When the time of travel between the ends equals the time interval between successive waves, they build up to produce an electrical resonance which can be detected with very high precision.

In this experiment the time of travel is about one ten-thousand millionth of a second (1/10,000,000,000) or, in other words, the waves follow one another at a frequency of 10 thousand million per second, and it was necessary to measure this frequency with an accuracy better than one part in a million. This is just the kind of problem that Essen was working on during the war and the equipment that was built then was ideally suited to this velocity experiment. The construction of the tube called for very skilled workmanship and its dimensions had to be accurate to one hundred thousandth of an inch. The Metrology Workshop, where the tube was made, achieved a result ten times better than they would previously admit was possible, and the Gauge Section of the Metrology Division had to devise new techniques to give the required accuracy of measurement.

The speed of light was not wanted accurately for any practical purpose until the advent of radar in World War II. In radar the distance to an object is calculated from the time taken by a pulse of radio waves to travel there and back, the speed of the waves being the same as that of light. The new figure will therefore enable radar to be used more accurately. This will be particularly valuable for aerial survey work where the shape of the ground is plotted by means of radar.

The speed of light also is used in calculating a great number of physical constants. The most significant changes will probably be in astronomy, in atomic research, and in the field of radio.

A New Type Radiation Pyrometer

AT the new continuous strip aluminium mill at Rogerstone, British Electronic Products, Ltd., have made the first installation of a new type of low temperature radiation pyrometer, which was developed for Northern Aluminium Co., Ltd. This equipment enables the temperature of the aluminium strip to be measured at temperatures from 150° C. upwards without physical contact being made with the actual metal.

Three units are installed on the hot rolling mill, these measuring the temperatures of the billets prior to rolling, the temperature of the rolled material at an intermediate stage, and the final temperature of the strip as it leaves the mill.

The actual temperature readings are provided on indicating meters on the main control desks on each of the control cabins, together with a repeat indication in the central control cabin for the whole line. In this manner, a complete check on material temperature throughout the process can be obtained.

Previously, it was necessary to stop the line and utilize contact pyrometers in order to obtain measurements of the strip temperature.

Geometrical Solution of Some Transmission Line Problems

By Q. C. GUPTA, M.A., and F. DUERDEN, B.Sc., A.M.I.E.E.

IT is unfortunate that the mathematical beauty of the Differential Equation approach to transmission line problems has led to the disuse of the method using vector diagrams. This presents a more satisfactory physical picture, requires much less mathematical knowledge, and often gives a more direct solution of the problems encountered in practical work on transmission lines.

A voltage, amplitude V and phase angle θ, may be

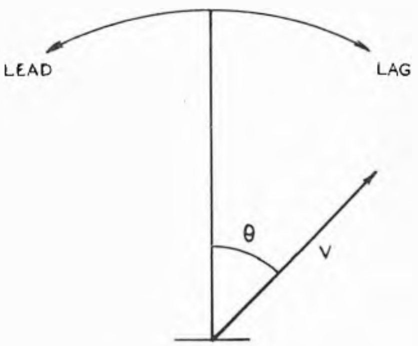


Fig. 1.

represented vectorially as in Fig 1 (provided that only processes of addition and division, and not multiplication, are contemplated). It may be used, for example, in finding the sum of two voltages of different amplitude and phase, or in finding an impedance by dividing a voltage by a current (but not, as it stands, in power problems, where a more complete representation is necessary).

This method of representation often leads to fairly easy geometrical constructions for the solution of common problems. Two examples of such constructions are given.

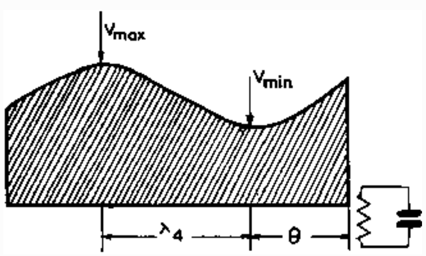


Fig. 2.

The Stub Matching of a Mismatched Line

In the case of a transmission line having a load not equal to Z_0, the characteristic impedance of the line, the voltage distribution along the line will be as shown in Fig. 2, because a wave incident at the load will be partly reflected, and the reflected wave will in some places add to, and in others subtract from, the oncoming incident wave. It can be shown vectorially, or otherwise, that if $V_{max}/V_{min} = S$ (the standing wave ratio), then the impedance at V_{max} is resistive, and equal to SZ_0, and the impedance at V_{min} is resistive, and equal to Z_0/S. Somewhere between the two must be a point where the impedance has a resistive component equal to Z_0, but a reactive component will also be present. The problem of stub matching lies in first locating this point correctly, finding the magnitude of the reactance there, and cancelling it out by the equal and opposite reactance of a section of open or short-circuited transmission line, placed, usually, in parallel with the original line. The position of the matching point and length of stub needed are the two quantities required to be found in order to match the line correctly. Both quantities are given by a very simple geometrical construction.

Geometrical Construction

If the amplitude of the incident wave is V_i and of the reflected wave V_R, then $V_{max} = V_i + V_R$ and $V_{min} = V_i - V_R$.

$$S = V_{max}/V_{min} = (V_i + V_R)/(V_i - V_R)$$

Hence $V_R/V_i = (S-1)/(S+1)$

Knowing the standing wave ratio, which is easily obtained from a measurement of V_{max} and V_{min}, the ratio V_R/V_i may be found.

Knowing this, draw a vector to represent V_i and a circle of radius equal to V_R on the same scale, centre at one end of the V_i vector. From the other end draw a tangent to the circle and complete the construction as in Fig. 3.

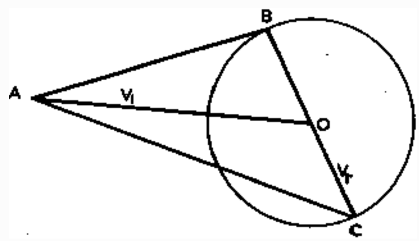


Fig. 3.

Then half angle AOB gives the distance of the matching point from V_{min}.

E.g.: If $\angle AOB = 60°$, $\frac{1}{2}\angle AOB = 30°$, and the required distance is $30/360 = 1/12$ wavelength from V_{min}.

Notice that it is possible to draw *two* tangents from

A to the circle, giving two possible matching points at equal distances on each side of V_{min}. The reactance at the one on the load side of V_{min} is capacitative, requiring an inductive stub, and the reactance at the other matching point is inductive.

The angle $\angle$ACB in Fig. 3 gives the required stub length at the point demanding an inductive stub.

The angle $\angle$BAC gives the stub length if matching is done at the point requiring a capacitative stub.

E.g.: If $\angle ABC = 45°$, the required stub is a short-circuited line $45/360 = \frac{1}{8}$ wavelength long, or if the other matching point is used and $\angle BAC = 45°$, the required stub is a $\frac{1}{8}$ wavelength open circuited (i.e., capacitative) stub.

The above assumes that the stubs are made from the same type of transmission line as the main feeder. If it is desired to use a *short-circuited* line for the *capacitative* stub, a quarter wavelength must be added to the length given by the construction for this stub.

Matching conditions for the inductive stub are shown in Fig. 4(a), and for the capacitative stub in Fig. 4(b).

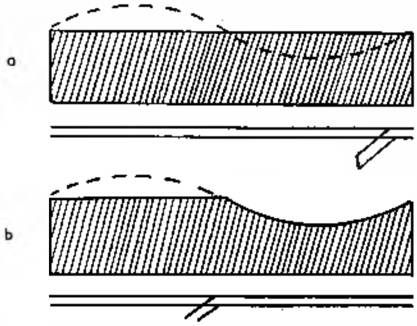


Fig. 4.

Proof of Construction

Vectors at a voltage minimum are shown in Fig. 5. Now $V_i = Z_oI_i$ and $V_R = Z_oI_R$, by definition of Z_o, and it can be shown that V_R/V_i and I_R/I_i are equal numerically, so that a common vector diagram for

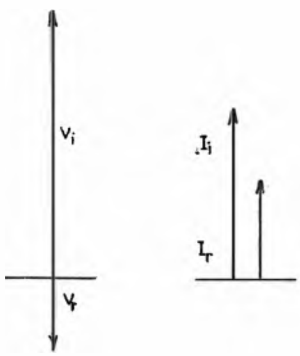


Fig. 5.

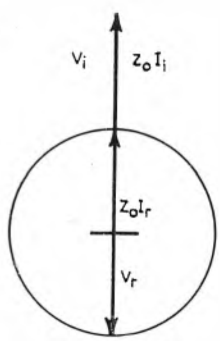


Fig. 6

voltages and currents can be drawn as in Fig. 6.

If we move towards the load from the V_{min} point, V_i and Z_oI_i will turn in the lagging direction, since the incident wave is being considered at progressively later instants in its career. The vectors will turn through 360° for every wavelength we move along the line, or through $\theta_1 = 306\, l/\lambda$ in moving a distance l along the line. The V_R and Z_oI_R vectors will turn through an equal angle in the leading direction.

The vector diagram for the point l towards the generator V_{min} may be redrawn as in Fig. 7.

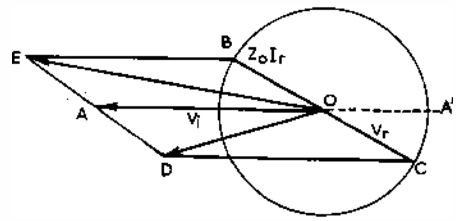


Fig. 7.

Angle $\angle$COA′ will equal 2θ, since V_i and V_R have each turned through θ in opposite directions, so that if the diagram is drawn relative to V_i as in Fig. 7, V_R will have turned through 2θ with respect to V_i.

OD is the vector sum of V_i and V_R and must therefore represent the total voltage at the point l.

OE is the vector sum of Z_oI_i and Z_oI_R and represents Z_o times the total current.

BA is equal and parallel to OD, and therefore may also represent the total voltage. Similarly CA may be used to represent Z_o times the total current.

We therefore arrive at Fig. 8.

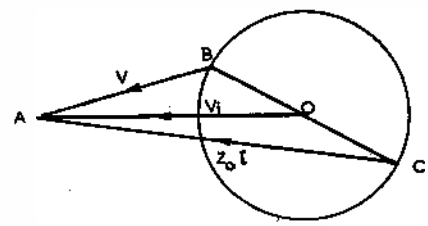
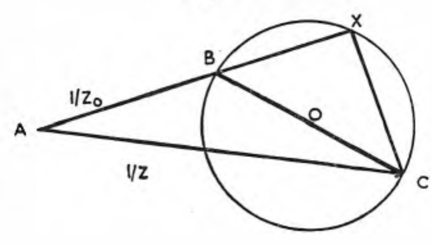


Fig. 8.

Fig. 9.



If we now divide all the quantities in Fig. 8 by a numerical factor equal to VZ_o, V becomes $1/Z_o$, and Z_oI becomes I/V, the admittance at the point l. AB is the direction of pure conductances, such as $1/Z_o$.

Then CA represents the admittance at l in phase (as well as magnitude) since $\angle$CAB is the phase angle between the total voltage and current.

Then in the admittance diagram, Fig. 9, AX must represent the conductive and CX the susceptive part of the admittance $1/Z$ represented by AC (CX is the perpendicular drawn from C on to AB produced). X will, in fact, also lie on the circle B since BC is a diameter.

Now if the position of C is such that B and X coincide (i.e., AB is a tangent to the circle), AX, the conductive part of $1/Z$ must equal $1/Z_0$, which is the condition for parallel matching.

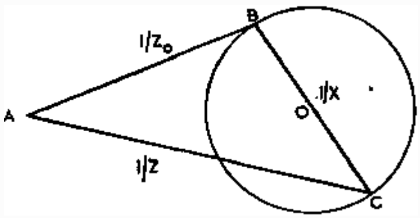


Fig. 10.

If, therefore AB were drawn a tangent to the circle in the first place (Fig. 10) the vectors lie in the correct positions for the matching point, and in particular $\angle$AOB equals 2θ where $\theta = 360\ l/\lambda$ and l is the distance from V_{min} to the matching point. (Compare Fig. 7).

Stub Length

CB, perpendicular to AB, represents the susceptance $1/X$ on the line at the matching point. The stub susceptance must be numerically equal to this, but opposite in sign, if it is to produce a match.

Now $CB = AB \cot \angle ACB$

i.e. $1/X = 1/Z_0 \cot \angle ACB$

$X = Z_0 \tan \angle ACB$

But this is the expression for the reactance of a short circuited line of length l where

$$360/\lambda = \angle ACB,$$

and since $\angle$ACB is less than 90°, this short circuited line is inductive. ACB therefore gives the stub length required at the point where the impedance on the line is capacitative, i.e., the point nearer the load from V_{min}.

Similarly $CB = AB \tan \angle BAC$

$1/X = 1/Z_0 \tan \angle BAC$

$X = Z_0 \cot \angle BAC$

which is the expression for the reactance of an open-circuited line length l, where $360\ l/\lambda = \angle BAC$, and characteristic impedance Z_0. This stub reactance is capacitative (open circuited line less than $\lambda/4$ long), so that $\angle$BAC gives the stub length if matching is to be carried out at the point where the line reactance is inductive, i.e., at the matching point on the side of V_{min} away from the load.

It will be seen that Fig. 3 will very rapidly give the position, and the length of the stub required for parallel matching. Since $\angle ABC = 90°$ the angles may readily be calculated once the ratio V_R/V_i has been found, and accurate drawing is therefore eliminated.

The construction may equally be proved for series matching, when it is found that $\angle$AOB is now measured from V_{max}, that $\angle$ACB represents the capacitative and $\angle$BAC the inductive stub length. Fig. 11 (a), (b), (c) and (d) shows the vector diagram with V_R in each of the four quadrants. In (a) and (d) division by IZ_0 gives the admittance diagram and parallel matching conditions; in (b) and (c), division by I gives the impedance diagram and series matching conditions. It will be seen that, since a tangent can only be drawn from A to the circle when 2θ is less than 90°, series stub matching is only possible within $\pm\lambda/8$ of V_{max} and parallel stub matching within $\pm\lambda/8$ of V_{min}.

Example

The measured standing wave ratio on a transmission line working at 50 Mc/s. is 2 : 1. Find the position and length of the inductive stub required to match the line.

If $V_{max}/V_{min} = 2 : 1$

then $V_R/V_i = (2 - 1)/(2 + 1)$
$= 1/3$

The construction will be as in Fig. 3.

$\cos \angle AOB = 1/3$
$\angle AOB = 70.5°$
$\frac{1}{2} \angle AOB = 35.25°$

Matching point is 35.25/360 of a wavelength from $V_{min} = .098\ \lambda$. At 50 Mc/s. $\lambda = 6.66$ metres
$.098\ \lambda = 65.2$ cm.

Match point is 65.2 cm. from V_{min} (towards load if an inductive stub is to be used).

The length of the inductive stub is given by $\angle$ACB :

$\tan \angle ACB = AB/BC$
$= \sqrt{3^2 - 1^2}/2$
$= \sqrt{2}$
$= 1.414$
$\therefore \angle ACB = 54.75°$

Stub length $= 54.75\ \lambda/360$
$= .152\ \lambda$
$= 101.2$ cm.

Consideration of Fig. 11 shows that in (a) and (b) Z_0I lags on V so that the line impedance is inductive; in (c) and (d) I leads and Z is capacitive. Hence the line impedance is inductive for $\lambda/4$ towards the generator from V_{min}, capacitive for $\lambda/4$ from V_{max}.

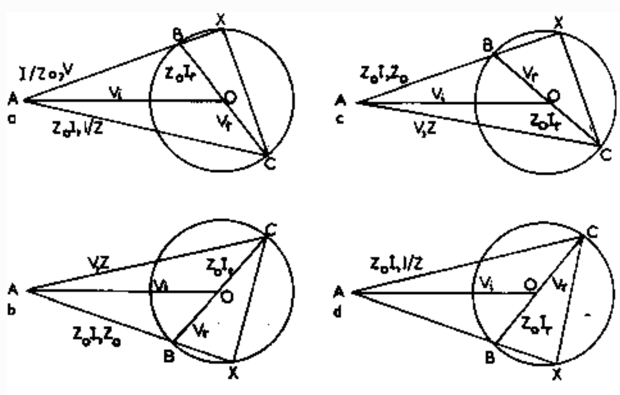


Fig. 11.

So far this paper has dealt with the approach to transmission line problems using vector diagrams. This method permits the solution of these problems by purely geometrical means, and does not require the use of more advanced mathematics likely to be outside the scope of the majority of men engaged upon practical work involving the efficient use of aerials for radar, television, etc. The method has the further advantage of maintaining a close link throughout with those quantities which are actually measured experimentally. A few textbooks[1,2,3] give the fundamentals of the method. At the beginning of this article the vector method was used to obtain a geometrical construction, very simple in use, giving the position and length of a matching stub.

Proof of Circle Diagram Calculator

In this section it is proposed to develop the Circular Transmission Line Calculator, or Circle Diagram[4,6] by vector methods.

In p. 526 the voltage and current vectors were used to produce the impedance and admittance diagrams of Fig. 11. The impedance diagram of Fig. 11(c) has been used as the basis of Fig. 12, with the following

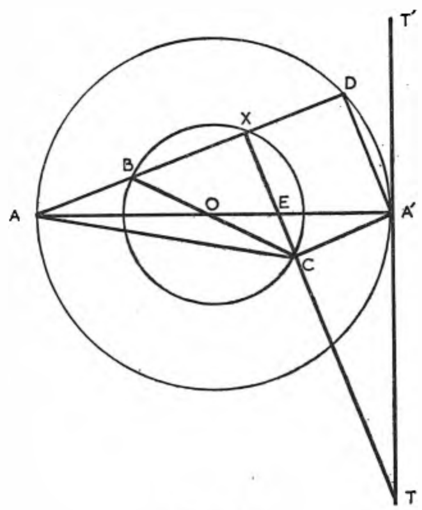


Fig. 12.

additional construction. A second circle, centre O, with OA as radius, has been drawn. AA′ is a diameter of the circle and T′A′T the tangent at A′. AX produced meets the circle again at D.

It was previously shown that AC would represent the impedance at a point distance l towards the transmitter from a voltage maximum, in both magnitude and phase, if AB represents Z_0 the characteristic impedance of the line, i.e., $AC/AB = Z/Z_0$ in magnitude, and $\angle BAC$ = phase angle of Z. The position angle $\angle AOB = 2 \times 306\ l/\lambda$ in degrees.

In Fig. 12 it can be shown that CXDA′ is a rectangle, as follows: $\angle XTA' = \angle XAA'$, since XC is perpendicular to AB and A′T is perpendicular to OA. But $\angle XAA' = DA'T'$, being the angle on chord DA′. Also triangles ABO and A′CO are congruent (since $\angle AOB = \angle A'OC$, and $AO = A'O$, and $BO = CO$ [radii of circles]). Therefore $\angle BAO = \angle CA'O$ and XD is parallel to CA′, so that CXDA is a parallelogram. But $\angle CXD$ is a right angle, hence CXDA′ is a rectangle.

Resistance Circles

Now since XC and DA′ are parallel, $EA'/AA' = XD/AD$. Also $XD = CA' = AB$ (from the rectangle CXDA′ and congruent triangles AOB + A′OC).

So that $AD = AX + XD = AX + AB$

$\therefore EA'/AA' = AB/(AX + AB)$

$= Z_0/(R + Z_0)$ since AX represents the resistive part of Z.

$$\frac{EA'}{AA'} = \frac{1}{R/Z_0 + 1}$$

If R/Z_0 is constant, EA′ is constant since AA′ is a fixed length.

But $\angle ECA'$ is a right angle. Therefore for all conditions of transmission lines for which R/Z_0 is constant, C must lie on a circle having EA′ as diameter. That is, the locus of C for R/Z_0 = constant is a circle passing through A′, diameter $1/(1 + R/Z_0)$ where $AA' = 1$, and with centre on AA′. This gives sufficient information to draw the circles for each value of R/Z_0.

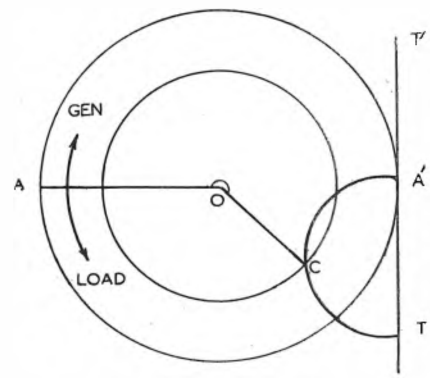


Fig. 13.

Fig. 13 shows one such circle, also the original circle centre O on which C lay. This original circle has radius OC, where $OC/OA = V_R/V_i$, the ratio of reflected to incident voltage, or $OC/OA = (1 - S)/(1 + S)$ where S is the standing wave ratio defined as V_{min}/V_{max}. Knowing the standing wave ratio on a given transmission line therefore, the circle, centre O, can be drawn.

Movement a distance l along the transmission line towards the generator end is represented by a clockwise movement through an angle $\angle A'OC = \angle AOB = 2.360\ l/\lambda$ from V_{max} position round the circle of constant standing wave ratio, and in doing so, various circles of constant resistance will be intersected in turn. The value of resistance at a given point l can be read off from the resistance circle intersected when $\angle AOB$ corresponds to the length l.

Reactance Circles

Similarly the reactance at any point on any transmission line may be found once the standing wave ratio is known by drawing a series of circles for which X/Z_0 is constant. The locus of C for constant X/Z_0 is found as follows, (see Fig. 12).

In triangles DAA′, CTA′, angles $\angle DAA'$, $\angle CTA'$ are equal, and $\angle A'CT = \angle A'DA$, both being right angles. The triangles DAA′, CTA′ are therefore similar, and

$A'T/AA' = CA'/DA'$

But $CA' = AB = Z_0$

and $DA' = CX = X$ the reactive part of Z.

Hence $A'T/AA' = Z_0/X$
$= 1/(X/Z_0)$

T is therefore a fixed point if X/Z_0 is fixed, and since $\angle A'CT$ is a right angle, the locus of C for constant X/Z_0 is a circle passing through A′ with its centre on the line through A′ perpendicular to AA′ and diameter (A′T) equal to $1/(X/Z_0)$. (AA′ is taken as unit length).

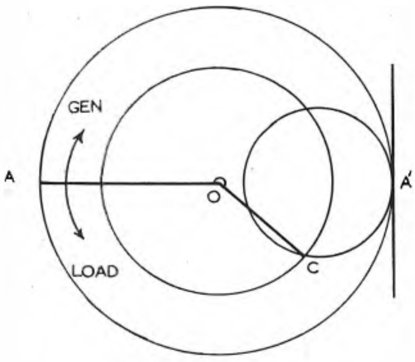


Fig. 14.

One such circle is shown in Fig. 14, as well as the constant SWR circle to represent conditions on any particular transmission line.

The Complete Calculator

We now possess sufficient information for a complete transmission line calculator, since we can draw a set of constant R, constant X, and constant SWR circles; and moving around the constant SWR circle through the angle corresponding to the distance moved along the line (clockwise for movements towards generator, anti-clockwise towards load) enable us to read off the values of R/Z_0 and X/Z_0 at that point, or to interpolate if falling between R or X circles. (Fig. 15).

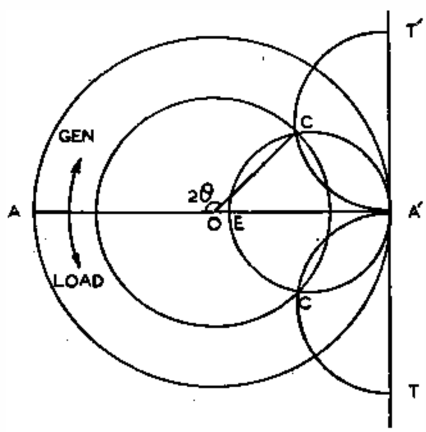


Fig. 15.

The reactance circles, centres on A′T′ represent inductive reactances, those centred on A′T, capacitative, so long as the convention of clockwise rotation for movement towards the generator is used.

The direction OA represents a voltage minimum, since C originally was the tip of the Z_0/I_R vector, and OA the V_i vector, so that when OC lies along OA, V_R and V_i exactly oppose each other—the V_{min} condition. Similarly OA′ is the V_{max} direction.

The circle through A and A′ for which the radius = 1, so that $V_R/V_i = 1$, is the circle representing conditions on an open or short circuited line, useful in work with stubs. A, being the V_{min} point, must represent conditions at a short circuit; A′ conditions at an open circuit. The point O (radius zero) represents conditions on a matched line, since $S = 1$ and $V_R = 0$.

The circle through O and A′ is of great importance in stub matching, since it is the resistance circle, diameter $\frac{1}{2}$.AA′ for which $1(1 + R/Z_0) = \frac{1}{2}$; i.e., $R/Z_0 = 1$, and all possible stub matching points for all lines must lie on this circle.

Admittance Diagram

Using the admittance diagram Fig. 11(a), precisely the same form of calculator will be obtained, except that the circles will be circles of constant conductance (Z_0/R) and susceptance (Z_0/X), the diameters being $1/(1 + Z_0/R)$ and $1/(Z_0/X)$, and the V_{min} and V_{max} directions being interchanged as compared with the impedance diagram. The half of the diagram which represented inductive reactances in the impedance diagram now represents capacitative susceptances and vice versa.

This diagram is useful in case of parallel connexions to lines. The Z_0/R circle on OA′ as diameter represents all possible line positions for parallel stub matching. Conditions on the stubs themselves are represented by the circle on AA′ as diameter as before, except that A is now the open circuit (V_{max}), A the short circuit (V_{min}), point.

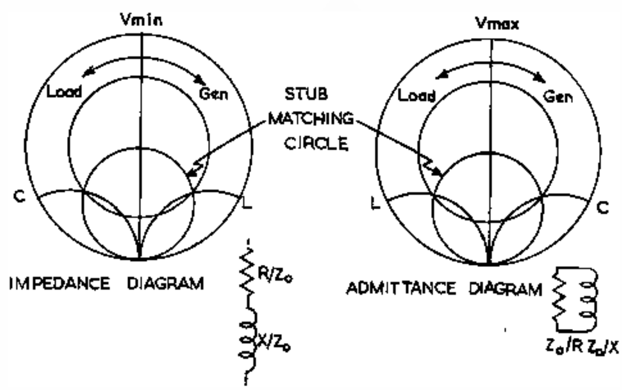


Fig. 16.

Fig. 16 illustrates the use of the diagram in stub matching. It will also be seen that the diagram evolved by no more advanced mathematics than fairly easy geometry is capable of solving any problem involving impedance on a transmission line.

References

[1] C. J. Mitchell: "Introduction to Transmission Lines." (Harrap.)
[2] King, Mimno, Wing: "Transmission Lines, Antennas and Wave Guides." (McGraw-Hill.)
[3] "Principles of Radar," M.I.T. Radar School. (McGraw-Hill.)
[4] P. H. Smith: "Transmission Line Calculator," *Electronics*, Jan., 1944.
[5] Willis Jackson: "High Frequency Transmission Lines." (Methuen.)

Mechano-Electric Transducer

RCA-5734 is a triode transducer intended to provide a method of translating mechanical vibration into electrical current variations which can be observed and measured. It has a deflexion sensitivity of 40 volts per degree deflexion of the plate shaft. The part of the plate shaft within the valve has a minimum free cantilever resonance of 12,000 cycles per second permitting, with suitable mechanical coupling to the external end of the plate shaft, measurements of vibration up to 12,000 cycles per second. The moving element of the 5734 is designed to have very low inertia.

The 5734 weighs but a 1/16 of an ounce (1.75 grams) has a length of only 1-9/32 in. and a diameter of 5/16 in. Its small size and light weight provide flexibility of installation.

This versatile valve may be applied to:—

Development of special gust recording anemometers to be used in a wind velocity survey.

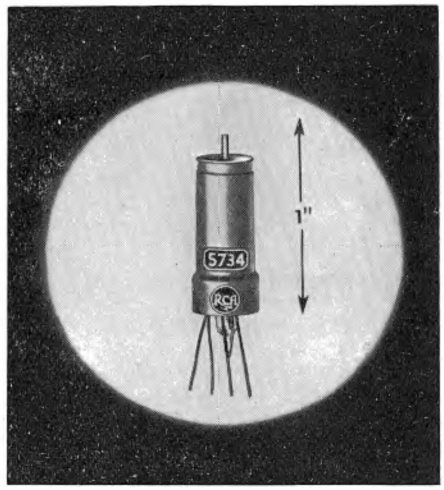
Oscillograph recording, through a diaphragm attached to the 5734 plate shaft of tank pressures set up during the short-circuit testing of circuit-breakers.

A sensitive method of amplification in the measurement of the fine limits met with in optical processes.

Biological applications for the development of a miniature head to measure directly arterial and venous blood pressures, and to record pulsations in the arteries.

Neuro-surgery for the development of a miniature probe for comparison of mechanical movements of very small excursion and at frequencies within the audio range. In this application, the very small physical size of the 5734 is of the greatest importance as the probe must be capable of easy manipulation by the surgeon.

Research work in connexion with stress evaluation and vibration phenomena in the motor, aircraft and shipbuilding industries.



As a preliminary aid in the surgical treatment of congenital heart disease, the 5734 is used in a developmental anemometer to record pressures through a cardiac catheter in the interior of the human heart.

Board of Trade authority has been granted for the importation of a small stock of these for the benefit of approved institutions. Colleges, medical schools and research organisations interested should apply for further particulars and price to RCA Photophone, Ltd., 36 Woodstock Grove, W.12.

International Relaying of Television Programmes

THE success of the recent outside broadcast transmission from Calais is likely to act as a stimulus to the relaying of television programmes from other countries. Such international broadcasting has also the advantage of spreading the cost of television productions, well known to be so great, over a large number of stations, and any arrangements it may be possible to plan will, no doubt, be particularly well supported by those countries of lesser resources.

The main difficulty that stands in the way of this scheme, apart from that of achieving common standards of transmission, is associated with the question of languages. It is scarcely possible, for instance, to apply the method known in the film industry as dubbing since this practice requires considerable rehearsal in order to synchronize the sound with the actions occurring in vision.

It seems, therefore, necessary to attempt some simpler, if less adequate, practice, and it is possible that a satisfactory result may be achieved by resorting to the method of captions. It would be possible, for instance, for a play produced in a London studio to be transmitted to relay stations, say in Paris, Amsterdam and Copenhagen, and for suitable captions in the respective languages to be superimposed on the relayed vision signals at the relay stations to fit in with a pre-arranged programme. The timing of the respective captions could be effected from the London station by means of timing signals radiated from that station. They could be sent along with the standard waveform by various methods, for instance, by width modulation of the line or frame synchronizing pulses, or by signals transmitted over a separate channel such as the channel normally occupied by the sound programme. The captions set up at the relay stations could be produced by means of a caption scanner which might conveniently be of the flying spot type, and the captions could be either in the form of film or of slides. The caption scanner would then, of course, be synchronized with the incoming standard waveform from London, and the locally generated caption signal would be mixed with the vision programme signal before being radiated by the relay station. By using timing signals, the various captions are changed automatically and no programme personnel are required at the relay stations.

The scheme is applicable to the recording of telefilms so that a number of telefilms with captions in different languages can be produced in one recording session. *—Communication from E.M.I., Ltd.*

LETTERS TO THE EDITOR

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

Frequency Generation and Measurement

Dear Sir,—In the opening paragraph of Mr. Finden's article "Frequency Generation and Measurement" in the June issue, is the author implying that the "Frequency Standard" controlling the frequency synthesizer is better than 1 in 10^8 stability?

In the Marconi TME2 Frequency Measuring Equipment, a 5 Mc/s. "frequency standard" is used which usually performs well enough to be maintained within about 1 in 10^8 by daily reference to standard-frequency transmissions, averaging the results over about 10 days. Such averaging is necessary because even the Royal Observatory Magnetic Station at Abinger cannot be sure of their frequency *until later* to better than about 1 in 10^8, in spite of precise comparisons between a large number of oscillators (not merely three).

The Marconi Equipment employs the synthesis principle to combine 1 Mc/s. harmonics (up to 30 Mc/s.) with a smoothly variable 1 to 2 Mc/s. oscillator with 20,000 locking points at 100 c/s. intervals, the lock signal being switched manually when the decade controls of the oscillator have been set. The interpolation between these intervals is accomplished by means of a 10-interval synchronous phototone-generator and a 10 numeral stroboscope. This is superior to the method described by Mr. Finden, in which a calibrated 500 to 1,500 c/s. L.F. oscillator is used. In the stroboscopic method any degree of accuracy may be achieved by timing the transits of the 1 c/s. figures across an index line. The whole of the measurement on the TME2 is carried out on directly calibrated decade dials and is very quick and simple.

An interesting series of daily measurements made over a period of six weeks will illustrate the kind of accuracy which may be achieved. A Marconi oscillator in Rome drove a chain of frequency-dividers producing a tone of 1 kc/s. This tone was transmitted to Florence, where another oscillator of the same type was used to drive a broadcast transmitter at 610 kc/s. The transmitter was adjusted, daily, so that its frequency was precisely equal to the 610th harmonic of the tone. The carrier frequency was measured at Chelmsford by means of a TME2 equipment which was checked against signals from station G.M.T. at Abinger.

All of this long chain of measurement resulted in a plot of the crystal in Rome which never deviated by more than ± 1 in 10^8 from a straight line with a slope of $+2.5$ in 10^8 per month, this being the rate of the Rome crystal.

Your faithfully,

W. S. Mortley, A.M.I.E.E.,
Marconi's Wireless Telegraph Co., Ltd.
Chelmsford,
Essex.

Mr. Finden replies :

Dear Sir,—It is implied that the method of generating described justifies the use of the highest accuracy frequency standards which are available. I am interested to see that Mr. Mortley confirms the target of 1 in 10^8. The frequency synthesizer is essentially a source, and the example described gives 10,000 frequencies at 1 kc/s. intervals individually to an accuracy controlled by a single crystal frequency standard, whereas the TME2 equipment mentioned is a measurement device.

A 500-1,500 c/s. L.F. oscillator was adopted for ease of measurement. Where greater accuracy is required, the frequency is counted in a scale of ten counter when it is possible to determine this frequency to 0.001 c/s. in 1 second. We have found the stroboscope method distressing to use over long periods.

It is suggested that the great advantage of the synthesis method adopted is the ability to generate a frequency spectrum without gaps over a very wide ratio.

Further developments since this paper was written show that the scheme can be extended to 100 Mc/s., thus providing 100,000 frequencies with no gaps in the spectrum 1 kc/s. to 100 Mc/s.

Yours faithfully,

H. J. Finden,
Woodford Wells,
Essex.

Radiation ?

Dear Sir,– Attention should, I think, be drawn to the error in common practice of referring to interference close to its source as "radiation." While it is, of course, true that radiation exists there, in most of the cases in question it is of negligible practical importance. Within a radius of $\lambda/2\pi$ from the source, interference is due predominantly to the induction fields—magnetic and electric.

The interference issuing from television receivers, for example, is worst on the long waveband. At 200 kc/s., $\lambda/2\pi$ is about 260 yards, and interference outside that range is normally quite negligible. Although the range of induction-field predominance is less at higher frequencies, so also is the effective range of the interference; and for all practical purposes it is incorrect to talk of radiated interference from this source. It is different with interference to television receivers from ignition systems, in which radiation is only too effective.

The distinction is not merely academic, because while in radiation the electric and magnetic fields are necessarily equal, induction fields can be of either kind in any proportion, and methods effective against the electric field may not reduce the magnetic field to any useful degree. Interference from television receivers to portable sets with frame aerials will then remain.

Yours faithfully,

M. G. Scroggie.
Bromley,
Kent.

BOOK

Threshold Signals M.I.T. 24

By J. L. Lawson & G. E. Uhlenheck. Volume 24 of the Radiation Laboratory Series. 388 pp. 1st Edition. McGraw Hill Book Co., New York, 1950. Price 42s. 6d.

THE study of noise in electrical and radio systems has progressed greatly in the last decade, largely due to the war-time impetus provided by the need to detect weaker and still weaker radar echoes in presence of interference which may be internal or external to the equipment. The analytical techniques in this field have advanced considerably although to a large extent they have sprung from the application of established results in probability theory to the problems arising in radio reception. Apart from the notable work by Kurt Fränz in Germany the major contributions have been made by American and British workers. The present volume presents a connected amount of the work at the Radiation Laboratory on the discrimination of signals in the presence of noise—with particular emphasis on pulsed signals, visually displayed in the presence of random noise. Little of the material in this book has been published before although much of it had a restricted war-time circulation in the form of confidential reports. It is of interest to recall that one of the editors, G. E. Uhlenbeck, had already laid some of the theoretical foundation stones 20 years before in his published work on the Brownian notion and on the general methods of analysis of such stochastic problems.

The first five chapters are introductory and give a general account of signal modulation systems, the statistical properties of random noise, and the physical origin of noise in circuits and valves and their contributions to the noise output of a receiver. Chapter 6 deals with external noise which may take the form of either "clutter" (i.e., undesirable echoes from more or less randomly distributed scatterers) or "interference" whose characteristics may range from those of the transmitted pulse to those of random noise.

The following chapters are concerned with the detection of signals in noise and the factors determining the threshold condition. These factors are a combination of objective factors such as the system parameters and subjective factors which are determined by the observer. Both A-scope and P.P.I. displays are considered and are illustrated well by photographs. Expedients for reducing clutter and interference, e.g., instantaneous A.G.C. and time-varied gain, are discussed and practical circuits given. Chapter 10 is concerned with modulated pulse trains and the "boxcar generator" which is used to extract the desired audio frequency components from the video frequency pulses.

The last chapter is concerned with the threshold properties of continuous wave systems (A.M. and F.M.) in the presence of random noise.

There are a few errors which have escaped proof reading but they should not prove troublesome. Omissions in both the theoretical and experimental sections arise from the admittedly almost complete concentration on work carried out at the Radiation Laboratory.

The volume can be highly recommended both to the newcomer and to the specialist, and the references to published work are just adequate to compensate for the condensed presentation, which conveys a considerable amount of information in the space available.

R. E. BURGESS.

Phenomena, Atoms and Molecules

By Irving Langmuir. 436 pp., 28 figures. Philosophical Library Inc., 1950. Price 1 dollar.

THIS book is a collection of some 20 papers representing about one-tenth of the author's well known contributions to modern science. His wide range of interests and his remarkable ability are reflected in its pages. The first three chapters consider the social implications of science such as scientific legislation, use of atomic energy and the doubtful position of science as the basis for running human affairs. The author makes some interesting observations on the status of Soviet science and scientists, these being gleaned from his own experience.

In the rest of the book we find the author's own special field of science beginning with chapter IV on surface chemistry. This is followed by a discussion of surface tension and liquid structure. Chapter seven reaches the real heart of the book and tells of the discovery of atomic hydrogen produced by molecular dissociation on tungsten surfaces. The story is continued in chapter eight, with an extensive theoretical discussion in chapter nine. The author remarks that "discoveries cannot be planned or foreseen." It is not strange therefore that pure research on the effects of different gases on

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tungsten filaments should lead, not only to the modern gas-filled lamp, but to the development of atomic hydrogen arc welding. Later chapters provide discussions of topics such as the nature of inter-atomic forces, condensation on and evaporation from surfaces, a note on metastable states in neon gas and a final chapter on types of valence, taken from early papers published in 1920-21. Detailed reference and subject indices are given.

The reader should remember that this is not a text book but a collection of scientific memoirs which give valuable glimpses into the activities of one of America's leading men of science over a period of forty years. It is a book worthy of a better printing and paper and of a more careful correction. One or two equations and one diagram appear inverted in the text.

G. E. J. Garlick.

Recent Advances in Radio Receivers

By L. A. Moxon (Modern Radio Series). ix plus 183 pp. Cambridge University Press, 1949. Price 18s.

SINCE 1938 considerable progress has been made in radio receiver technique to meet some exacting specifications of radio receiver design. The book deals with the advance made in reducing the internal noise level of a receiver to as low a value as possible, and the advance made in obtaining a faithful response of a receiver to impulses of very short duration. In a further section, the general tendencies in the design of broadcasting, television, and communication receivers are reviewed and new kinds of receivers and associated circuit techniques are described.

The subject is divided into the following chapters, viz.: (1) Concept of noise factor, (2) Theory and practice of amplifier design for minimum noise factor, (3) Noise factor of mixers, (4) Measurements of noise factor, (5) Intermediate-frequency amplifiers, (6) Trends in practical receiver design, (7) Some new kinds of receiver, (8) Some new circuit tricks. The Appendix contains design formulae for intermediate-frequency amplifiers.

The subject is presented in a pleasant style, and the story is coherently told, in logical sequence, from a rich store of practical knowledge and first-hand research experience. Emphasis is placed on describing basic physical concepts rather than discussing solutions of specific problems.

This is an important book, excellently printed, for advanced students and research workers, and for designers and users of receiving circuits in the short-wave ranges, including radar and television, who wish to bring their knowledge up-to-date.

R. Feinberg.

Luminescence of Solids

By H. W. Leverenz. 569 pp., 140 figures. John Wiley & Sons, Inc. and Chapman & Hall, Ltd., 1950. Price 96s.

THIS impressive book begins with sections on atomic and molecular theory, and on crystallography, which provide the basis for interpretation of phosphor constitution and behaviour. The synthesis of some typical inorganic phospors is briefly described. Half the book is then devoted to a most informative discussion of the diverse phenomena of excitation and emission. Finally practical applications are considered, and there are appendices, an immense bibliography, good indices, and a remarkable (unbound) periodic table. The author has long been associated with the C.R.T. industry, and this aspect of luminescence predominates; hence the space given to the fluorescent lamp is disappointingly brief, and one could also wish for longer sections on topics of current interest like infra-red stimulation, sensitized fluorescence, and emission band structure.

There is much use of fashionable theory in this book, often treated critically (e.g., energy level diagrams). Many will disagree with the author's views on the discrimination of fluorescence from phosphorescence, and perhaps doubt the value of his system of phosphor notation. A more serious criticism concerns his statement that "history is generally omitted." Pioneer European work is indeed ignored in some cases, for example on the cadmium borate and magnesium and zinc fluoride phosphors, and on cascade screens. Again, zinc beryllium silicate was discovered in Germany and England at least as early as in U.S.A. The references quoted imply, however, that these subjects were all of American origin. Naturally American references predominate, but some comment on this point is justified since the book claims to "furnish a critical guide to the general literature."

The English reader may be amused by some phrases ("some descriptions . . . may incorporate verity"), and be irritated by fabricated words (amorphicity, bitwise,

BOOK REVIEWS (Continued)

to tenebresce, radiescence), but on the whole the style is lively and readable, and no worker in this field can fail to profit from what Leverenz calls "the present small volume" (of 579 pp.). He hints at a much larger book on the art of making phosphors: this will be received with as much pleasure as the present work, though probably no-one in this country will be able to afford to buy it.

S. T. HENDERSON.

Radio Servicing, Theory and Practice

By Abraham Marcus. 775 pp. Allen & Unwin, Ltd., 1950. Price 35s.

AMONG the spate of books arriving here from the other side of the Atlantic, it is a pleasure to welcome a volume as useful and carefully written as this one. Its strength lies in the fact that the author is quite certain of the purpose of his book—it is "to teach the theory of the radio receiver, and how to service it." It is directed to readers who are not beginners in radio, not yet advanced enough to study the subject on an engineering level.

The first three chapters deal briskly with the fundamental theory, the components and parts and the valves used in normal radio equipment. Physical descriptions are preferred to the briefer but sometimes more obscure mathematical explanations. A comprehensive collection of photographs of radio components would be improved if some idea of dimensions had been given.

The next six chapters discuss the various uses to which valves are put. Naturally enough all examples use American type valves, but this, once noted, should cause little concern. Each chapter concludes with service notes on faults located in the appropriate stage, and with a group of test questions. The final chapter of this group deals with "special tubes used in radio"—glow tube, thyratron, magic eye, cathode ray tube, phototube and ballast tube.

Chapter 10 deals with various control circuits—volume, tone A.V.C., selectivity, A.F.C.—thus clearing the ground for a synthesizing chapter on the complete receiver, including a description of F.M. receivers. Power supplies occupy a further chapter, completing the general radio theory. Chapter 13 is a useful discussion of instruments used for servicing, and is particularly good, laying down a logical procedure for the service man which should, if adopted, go far to remove the too frequent hit-and-miss technique used by so many engineers engaged in servicing. Mr. Marcus has done an excellent job in writing this book, and his publishers have printed and bound the volume worthily.

K. G. LOCKYER.

Applied Acoustics

Traité de Prise de son. Par José Bernhart (Chef du service de la Prise de son à la Radiodiffusion — Francaise). 382. pp. Eyrolles, 1949. Price 2,950 francs.

BROADCASTING unfortunately imposes an artificial link between the artist and the audience. Imperfect studio acoustics and sound collecting systems limit and constrain interpretation, yet few producers or presentation assistants are aware of these limitations and still less are able to exploit them to advantage. Information of prime importance to both has been collected from many sources and is presented in this book, mainly in the form of graphs and diagrams, rather than mathematically, but always with a view to wedding technique to art.

The evolution of the studio is traced, and the classical acoustic theories developed, including the more modern concepts of the importance of first order reflexions. The influence of corrugated walls and break up surfaces on the apparent reverberation time is discussed and illustrated by examples of studios in both France and Britain, including live and dead end types. Later sections deal with polar diagrams of microphones and also the more common orchestral instruments. No one who has attempted to reproduce good string tone from violin or harp need be reminded of the importance of the latter.

The position of the microphone in relation to the solo instrument, small ensemble, and large orchestra is considered, and although there will always be differences of opinion on "close" and "distant techniques," the principles upon which balance is founded are clearly enunciated. Figure 24 page 135, however, suggests that the image of the speaker in the top of a normal type table may be eliminated by suitable positioning of the microphone. Such an arrangement in the absence of good studio acoustics, often results in loss of diction. The open mesh table top is preferable. Problems in drama, in mixing and in the control of the dynamic range are all examined and finally the author outlines for those concerned, a suitable course on score reading and critical listening.

There is no doubt that this book is the outcome of long and varied experience. No text in English provides a comparable service to those important technicians who act as liaison between the artist and the engineer. I would recommend it not only to them and their fellow broadcasting and recording engineers, but also to all who are directly responsible for the presentation of the programme and who would like to learn something of the medium in which they work.

A. E. ROBERTSON.

Vade-Mecum 1950

By P. H. Brans' Technical Staff. 508 pp. 8th Edition. Bailey Bros. and Swinfen, Ltd., 1950. Price 24s.

IN November 1947 P. H. Brans died suddenly, but left his technical staff a great many ideas to fulfil in this new edition. The system of classifying the data remains unchanged, but the "How to Use It" section has been simplified and shortened.

The new seven-grid valves, the nonodes and phasitrons, planar-triodes, transducers, projection tubes and accelerometers have been incorporated, and new sections are included on the crystal diodes and triodes.

The edition has been revised and completed with modern valve data, special attention being given to V.H.F. and television types.

Short-wave Radio and the Ionosphere

By T. W. Bennington. 2nd Edition. 138 pp., 61 illustrations. Iliffe and Sons, Ltd., 1950. Price 10s. 6d.

THIS book presents all the available information on the role of the ionosphere in simple form so that it is of use to those with only a limited technical knowledge. The author is a member of the Engineering Division of the British Broadcasting Corporation and has been able to draw on the Corporation's experiences in the development of short-wave overseas services.

The use of mathematics has been avoided and the physical processes involved are explained in simple descriptive language. The author has kept the practical side of the subject in mind throughout and shows how existing ionospheric data can be aplied to everyday problems of short-wave transmission and reception.

NOTES FROM THE INDUSTRY

1951 National Radio Show

The 18th (British) National Radio Show is to be held at Earls Court, London, from August 28 to September 8, 1951, the first day being reserved for distinguished visitors, overseas buyers and the Press.

This announcement is made by the Radio Industry Council whose exhibition organizing committee is already planning the exhibition.

The show will include British radio, television and electronic equipment of all kinds, as well as valves and components. The B.B.C. will co-operate in demonstrations and performances of television from a large and fully equipped studio in the exhibition hall.

The Engineers' Guild

Owing to pressure of professional and private business, Mr. W. A. M. Allan, A.C.G.I., M.I.C.E., who has held the position of Honorary Secretary to the Engineers' Guild for the past 11 years, has been compelled to relinquish his appointment. Mr. W. A. M. Allan is employed as an Assistant Divisional Engineer with the London County Council.

In his stead, the General Council have appointed Mr. J. H. W. Turner, B.Sc.(Econ.), B.Sc., A.M.I.C.E. Mr. Turner has been the Honorary Editor of the Guild's Journal and a member of Council since 1946. He has served on various Committees of the Guild and has been chairman of both the Discussions Committee and the Branches Committee. Mr. Turner continues as Editor of the Journal.

"Engineers in the B.B.C."

A booklet entitled "Engineers in the B.B.C." has been compiled for issue to universities and training colleges as a guide to graduates and undergraduates contemplating careers as engineers.

It mentions briefly the wide scope of work of the Engineering Division of the B.B.C., its conditions of service, and includes a helpful forward.

The book is well produced, with many illustrations of a high standard, and should have great appeal.

V.H.F. Converter for Broadcast Receivers

Pye, Ltd., of Cambridge, announce that they have produced an adaptor which allows any standard radio set to receive V.H.F. broadcasting. V.H.F. broadcasting is thought to be the solution to the congestion that is taking place all over Europe in the normal broadcasting bands.

R.E.C.M.F. Exhibition 1951

The Eighth Annual Private Exhibition of British Components, Valves and Test Gear for the Radio, Television, Electronic and Telecommunication industries, will be held in the Great Hall, Grosvenor House, Park Lane, London, W.1, during the period Tuesday 10 to Thursday 12 April 1951.

Admission will be by invitation only. Further details will be issued in due course by the organizers, the Radio and Electronic Component Manufacturers' Federation, 22 Surrey Street, Strand, London, W.C.2.

B.S.I. Manchester Office

The British Standards Institution has opened a branch office at 12 Hilton Street, Manchester. 1. Telephone: Central 4856, Telegrams: Bristandin, Manchester.

The British Instrument Industries' Exhibition

The first British Instrument Industries' Exhibition takes place at the National Hall, Olympia, from July 4 to 14, 1951. It is supported by the following: British Electrical & Allied Manufacturers' Association, British Industrial Measuring & Control Apparatus Manufacturers' Association. British Lampblown Scientific Glassware Manufacturers' Association, Drawing Office Material Manufacturers' & Dealers' Association and Scientific Instrument Manufacturers' Association of Gt. Britain, Ltd.

The purpose of the exhibition is to show scientific and industrial instruments of entirely British manufacture and, with the export market in mind, supporting associations and the organizers, Messrs. F. W. Bridges & Sons, Ltd., are approaching potential overseas buyers through all appropriate Government, commercial and professional channels.

Firms having instruments which are germane to the exhibition which they wish to exhibit, may submit an application for space together with a description of their proposed exhibit to British Instrument Industries' Exhibition, 641 Grand Buildings, Trafalgar Square, London, W.C.2.

1950 INDEX

This 1950 Index, Volume 22, is now available. Copies may be obtained, post free, on application to the Circulation Department of this Journal, without charge.

Publications Received

Noise and Vibration in Industry. This small book is a summary of experience gained by *A. E. Cawkell, 7 Victory Parade, The Broadway, Southall, Middx.*, in the investigation, measurement and reduction of noise and vibration in industry.

Nickel Alloys in Gas Turbines is an interesting booklet dealing with Nickel Alloys in aircraft construction. *The Mond Nickel Co., Ltd., Sunderland House, Curzon Street, London, W.1.*

The British Council—Report for the Year 1949-1950. This report is presented mainly in the form of articles covering the Council's work in the main territorial regions and in a number of special fields. *The British Council, 65 Davies Street, London, W.1.*

Plessey Television Components is a 24-page catalogue, available to manufacturers, describing their recently introduced range of television components. *The Plessey Co. Ltd., Ilford, Essex.*

The Castle Engineering Co. (Nottingham), Ltd. This beautifully produced brochure illustrates, in full colour in many cases, the part played by Castle components in many engineering fields. *The Castle Engineering Co. (Nottingham), Ltd., Haslam Street, Castle Boulevard, Nottingham.*

The Marconi Companies and their People. This is an excellent little house magazine dealing with the interests of *Marconi's Wireless Telegraph Co., Ltd., Marconi House, Chelmsford* and *Marconi Instruments, Ltd.*

Loudspeakers and Transformers is an illustrated leaflet on the range of Elac equipment. It is obtainable from *Electro Acoustic Industries, Ltd., Stamford Works, Broad Lane, Tottenham, London N.15.*

Hivac—The Scientific Valve. This is a loose leaf catalogue which Hivac, Ltd., will keep up to date by revised and new catalogue sheets. *Hivac, Ltd., Greenhill Crescent, Harrow-on-the-Hill, Middx.*

Asbestos Textiles and the Electrical Industry. This is a well presented brochure containing much information about the use of asbestos textiles, such as "Pyroflex" asbestos tape for electrical insulation. This publication is distributed by *Turner Bros. Asbestos Co., Ltd., Rochdale, Lancs.*

Miniature Neon Indicators

A SMALL range of miniature neon indicators is being marketed by The General Electric Co., Ltd., for use in all branches of industry, chiefly as visual indicators for "live" electrical circuits. The small space which the indicators occupy and their negligible power consumption make them ideal for use with practically any type of electrical equipment. They are designed to operate from 200-250 volt supply mains with an external resistance of 0.25-0.5 megohm in series. This resistance is essential but it can be of the 1-watt radio variety.

Details of the range of indicators are summarized below.

Type of Indicator	Class of Supply for which suitable	Nominal Operating Current	Type of Cap.
F	A.C.	0.5 mA	Small Edison screw.
G	A.C.	0.15 mA	Miniature bayonet, centre contact
"Tuncon"	D.C.	0.5 mA	Small Edison screw.

The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.

Halogen Quenched Low Voltage G.M. Tubes

(Illustrated below)

THE photograph shows a Gamma Counter tube, type G.10H for use in portable prospecting gear. The tube was developed in collaboration with A.E.R.E., Harwell under a Ministry of Supply Contract.

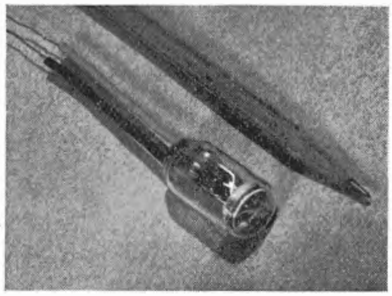
Normal Geiger Counter tubes operate at above 1,000 volts and have a temperature coefficient of between 1 and 5 volts per degree Centigrade. They cannot be operated below about —20° C. This new tube operates between —55° C. and +60° C. with a negligible temperature coefficient at a voltage between 340 and 410 volts. These characteristics together with extremely robust construction and special resilient anode wire mounting make the tube ideal for portable equipment.

The filling efficiency is 100 per cent and the average slope of the plateau is 0.06 per cent per volt over 100 volts. The filling is a neon-argon mixture with a critically adjusted trace of a halogen. The cathode is of stainless iron.

It is a peculiarity of halogen quenched tubes that they are not permanently damaged by a severe over-voltage or by being accidentally operated with reversed potentials.

Other halogen quenched tubes are available including an End Window Beta Counter and an X-ray Counter tube.

20th Century Electronics, Dunbar Works, Dunbar Street, West Norwood, London, S.E.27.



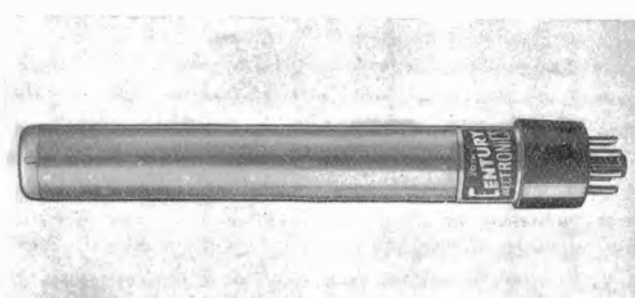
A New Miniature Photocell

(Illustrated above)

A PHOTOCELL, of particular value for use in conjunction with small and compact lens systems, has recently been introduced by the Communications and Industrial Valve Department of Mullard Electronic Products Limited. This new photocell, type 58CV, which is $1\frac{3}{16}$ in. in length and has a diameter of no more than $\frac{5}{8}$ in., is specially designed for an end-on aspect of illumination. It can thus be made to form part of a cylindrical optical system of very small dimensions. These photocells are useful where it is desired to have multiple banks of photocells in operation.

The 58CV is a vacuum photocell having a caesium/silver-oxide cathode which is highly sensitive to incandescent light and near infra-red radiation. The makers claim that the cathode presents the largest possible activated surface consistent with the small dimensions of the cell, the projected cathode area being 0.17 sq. in. (1.1 sq. cm.).

In spite of its small size, the 58CV cell has a sensitivity of better than 15μA per lumen. Other characteristics are as follows: Maximum anode voltage, 100 V; maximum cathode current, 3mA; dark current at an anode voltage of 100 V, 0.05 μA.



Electronic

A monthly record of British elec-

accessories, compiled from information

A gas-filled version, the 58CG, is also available for "stop-go" applications where the light changes are large and sudden.

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

Frequency-Shift Receiving Terminals

B.T.R. Ltd. range of frequency-shift receiving terminals is designed for the conversion of any stable conventional communications receivers for frequency-shift reception. Each terminal accepts frequency-shift signals at audio frequency from the receiver or receivers, and filters, amplifies and converts these signals to D.C. impulses for operation of teleprinters, tape recorders, etc.

Three types of unit are used in different combinations to provide for a single receiver, or for space or frequency diversity. These units are :—

(1) Frequency-shift converter unit model FSR1.1.

(2) A.F.C. and B.F.O. unit, model FSR4.1.

(3) Power unit, model FSR1.2.

(1) This is the basic unit of the frequency-shift receiving terminals. The unit is designed for single channel reception of both hand and automatic radio telegraph or radio teleprinter frequency-shift signals, with or without 200 c/s. phase modulation. It is also suitable for the reception of facsimile signals when the keying characteristic is similar to that of high-speed telegraphy.

(2) A.C.F. and B.F.O. unit, model FSR4.1 is designed to work in conjunction with any frequency-shift receiving terminal using double diversity or single receivers with 2,550 c/s. centre frequency and 850 c/s. shift.

Conversion of the receivers to include automatic frequency control is a simple matter using this unit. No extensive modifications are required, the only additions to receivers being coaxial sockets and short lengths of coaxial cable to the points of injection of the B.F.O. voltage.

(3) The Power Unit, model FSR1.2 is designed to work from a 50 c/s. mains supply.

This unit provides all the necessary L.T. and H.T. supplies for the converter unit and A.F.C. and B.F.O. unit. The output is sufficient for up to three converter units or one converter unit and one A.F.C. and B.F.O. unit.

British Telecommunications Research Ltd., Taplow Court, Taplow, Bucks.

Equipment

tronic apparatus, components and supplied by the manufacturers.

Ekco Schools Radio

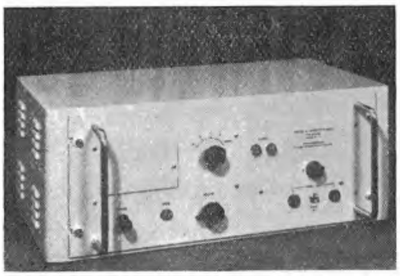
(Illustrated below)

THIS new model of school radios has been developed for use where three or four loudspeakers are sufficient.

The radio feeder unit and the amplifier unit are housed in a single rack with one front panel, and carrying handles are incorporated. Provision has been made for two loudspeaker outlets : 3Ω for the monitor speaker and 1,500Ω for the operation of loudspeakers in remote classrooms. A socket is incorporated which enables the equipment to be used with a gramophone playing desk.

Controls are reduced to a minimum and are as follows : On/off switch, volume control, and station selector. Four preset stations are offered, three medium and one long wave. It has a power consumption of 45 watts A.C. only. An "Essex Grey" model of loudspeaker has been matched for use with this equipment.

E. K. Cole Ltd.,
Ekco Works,
Southend-on-Sea,
Essex.



Cable End Identification Simplified

TO simplify indentification in complicated electrical circuits, the use of some form of cable marker is now becoming standard practice. Various forms of marker have been employed, ranging from the hand-written paper tag to the more elaborate thimble-shaped, engraved plastic cable-end ferrule.

Due to its durability, neatness and legibility the last has always been regarded as the most satisfactory method of identification, but even this has its disadvantages as many firms find it impracticable to carry large stocks of these specially engraved ferrules. In order to eliminate this difficulty, a fully interlocking plastic ferrule consisting of several units, has been designed, each unit being engraved with a single digit or letter. From these an almost unlimited number of code numbers or combinations can be built ; in fact, more than 1,000 different identifications can be made up from a stock of ferrules numbered from 0-9, using only a three-figure code.

To prevent the digits or letters from movement, each ferrule unit is made with a key and keyway which ensures that they can only be assembled with the engravings in line and cannot come out of alignment at any time. These ferrules can be supplied in black with white engraving or vice-versa and other colours can be supplied to order.

Entry of cables from both right and left, without one side reading "upside down" is provided for by ferrules being engraved for either hand as required.

Critchley Bros., Ltd.,
Brimscombe, Glos.

"Elac" Mark II P.M. Focus Unit

(Illustrated top right)

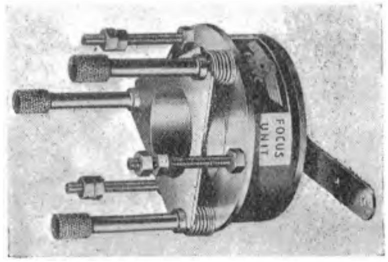
THIS new model has been designed for simple focusing and positioning of the picture.

The unit is fixed rigidly to the receiver chassis. Picture positioning and rough focus is obtained by adjustment of the three knurled headed screws which are easily accessible. Vernier adjustment of focus is provided by a lever operated threaded sleeve.

The method of focusing, claim the manufacturers, enables the "lens" to be placed at the correct point along the neck of the cathode ray tube. Adjustments for picture positioning and focus are made by varying the gap, not by moving the focus unit.

Owing to variations in the construction of the cathode ray tubes, three models having the same basic design, but with different field strengths, are available.

Electro Acoustic Industries, Ltd.,
Stamford Works,
Broad Lane,
Tottenham, N.15.



Electro-Encephalograph

(Illustrated below)

THE Ediswan Mark II 8-channel Electro-Encephalograph is intended to cater both for the clinical requirements of most hospitals and for research purposes where a higher standard performance is essential.

The provision of 8 channels considerably reduces the recording time per patient for routine clinical examination. It permits simultaneous observation of occasional phenomena over a larger area than is possible with a smaller number of channels, this being of particular value in the location of focal activity.

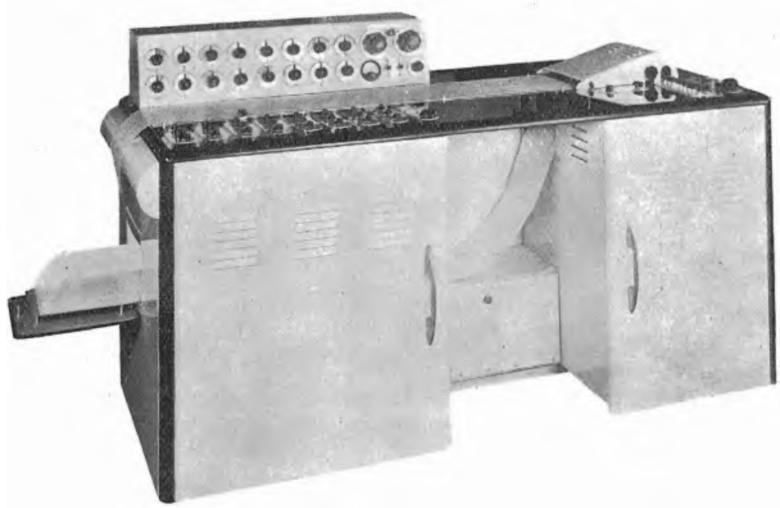
The instrument incorporates a new moving coil recorder specifically designed for E.E.G. recording, together with a built-in comprehensive input selector unit.

Particular attention has been given to the layout of the instrument so that from a seated position all controls are easily available and observation of the patient is not obstructed.

The photograph below clearly shows the neat method of paper feed and delivery using folded and perforated pack paper.

All features of the encephalograph design have been subject to consideration of the recommendations for Electro-Encephalographs which have been published by the E.E.G. Society and have been accepted by the Ministry of Health.

Edison Swan Electric Co., Ltd.,
155, Charing Cross Road.
London, W.C.2.



MEETINGS THIS MONTH

INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, at 5.30 p.m.

Measurements Section

Date: December 12.
Lecture: The Effect of Friction on the Behaviour of Servo Mechanisms at Creep Speeds.
By: J. G. L. Michel, M.Sc., and A. Porter, M.Sc., Ph.D.

Radio Section

Date: December 6.
Lecture: Crystal Diodes.
By: R. W. Douglas, B.Sc., and E. G. James, Ph.D.
Date: December 18.
Discussion: Have Post-War Broadcast Receivers taken Full Advantage of War-time Development?
Opened by: R. B. Armstrong, B.Sc.

District Meetings

Date: December 4. Time: 7.30 p.m.
Held at: New Inn, Sandling Road, Maidstone, Kent.
Lecture: Aerial Cables for Telecommunication Purposes.
By: A. G. Robins.
Date: December 11. Time: 7 p.m.
Held at: Great Western Hotel, Reading, Berks.
Lecture: Television Engineering.
By: D. C. Birkinshaw, M.B.E., M.A.

Cambridge Radio Group

Date: December 5. Time: 6 p.m.
Held at: Cambridgeshire Technical College, Cambridge.
Lecture: A Review of some Television Pick-up Tubes.
By: J. D. McGee, M.Sc., Ph.D.
Lecture: The Design of a Television Camera Channel for Use with the C.P.S. Emitron.
By: L. E. L. C. White, M.A., Ph.D., and M. G. Harker, B.Sc.(Eng.).

North-Eastern Radio and Measurements Group

Date: December 18. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: Electronic Counters and Some Applications.
By: R. B. Conn, B.Sc.

Sheffield Sub-Centre

Date: December 13. Time: 6.30 p.m.
Held at: Grand Hotel, Sheffield.
Lecture: Some Electromagnetic Problems.
By: Professor G. W. O. Howe, D.Sc., LL.D.

North Lancashire Sub-Centre

Date: December 20. Time: 7 p.m.
Held at: Harris Institute, Corporation Street, Preston.
Lecture: The General Aspects of Television.
By: A. J. Biggs, Ph.D., B.Sc.

Southern Centre

Date: December 13. Time: 7.30 p.m.
Held at: R.A.E. College, Farnborough, Hants.
Lecture: Magnetic Amplifiers.
By: A. G. Milnes, M.Sc.

Date: December 20. Time: 6.30 p.m.
Held at: The Grand Hotel, Bournemouth.
Lecture: The Design and Operation of a 30-MeV Synchrotron.
By: D. W. Fry, M.Sc., J. Dain, M.A., H. H. H. Watson, and H. E. Payne, B.Sc.(Eng.).

BRITISH SOUND RECORDING ASSOCIATION

Date: December 6. Time: 7 p.m.
Held at: E.M.I. Studios, Ltd., 3, Abbey Road, St. John's Wood, London, N.W.8.
Lecture: The Applications of Magnetic Coatings to Film Stock.
By: G. F. Dutton, Ph.D., D.I.C.
(Joint Meeting with the British Kinematograph Society.)

SECRETARIES OF ASSOCIATIONS

INSTITUTION OF ELECTRICAL ENGINEERS

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

Cambridge Radio Group

G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

North-Eastern Radio and Measurements Group

G. A. Kysh (Asst. Sec.), Carliol House, Newcastle-on-Tyne, 1.

North-Western Radio Group

A. L. Green (Asst. Sec.), 244, Brantingham Road, Chorlton-cum-Hardy, Manchester, 21.

South Midland Radio Group

W. H. Brent, B.Sc., Regional Director's Office, Midlands Region (G.P.O.), Civic House, Great Charles Street, Birmingham, 3.

BRITISH INSTITUTION OF RADIO ENGINEERS

The General Secretary, 9, Bedford Square, London, W.C.1.

West Midlands Section

R. A. Lampitt, A.M.Brit.I.R.E., 20, Northfield Grove, Merry Hill, Wolverhampton.

INC. RADIO SOCIETY OF GT. BRITAIN

General Secretary, New Ruskin House, Little Russell Street, W.C.1.

BRITISH SOUND RECORDING ASSOCIATION

Richard W. Lowden, "Wayford," Napoleon Avenue, Farnborough, Hants.

TELEVISION SOCIETY

Lecture Secretary: T. M. Lance, 180, Bromley Road, Beckenham, Kent.

Engineering Group

G. T. Clack, 10, Tantallon Road, Balham, London, S.W.12.

RADAR ASSOCIATION

The Secretary, 83, Portland Place, London, W.1.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

W. H. Fox, A.M.I.E.E., Engineer-in-Chief's Office (T. P. Branch), Alder House, E.C.1.

INSTITUTION OF ELECTRONICS

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

North-West Branch

L. F. Berry, 105, Birch Avenue, Chadderton, Lancs.

SOCIETY OF RELAY ENGINEERS

T. H. Hall, M.Brit.I.R.E., 23, Dalkeith Place, Kettering, Northants.

SOCIETY OF INSTRUMENT TECHNOLOGY

L. B. Lambert, 55, Tudor Gardens, London, W.3.

Date: December 20. Time: 7 p.m.
Held at: Royal Society of Arts, John Adam Street, Strand, W.C.2.
Lecture: The Crystal Pick-up with Particular Reference to Long Playing Records.
By: S. Kelly.

THE RADAR ASSOCIATION

Date: December 5. Time: 7.30 p.m.
Held at: Albert Tavern, Victoria Street, S.W.1.
Monthly Meeting.

East Anglian Branch

Date: December 30.
Held at: The Lamb Inn, Norwich.
Monthly Meeting.

RADIO SOCIETY OF GREAT BRITAIN

Date: December 15. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Annual General Meeting.

INSTITUTION OF ELECTRONICS

Midlands Centre

Date: December 5. Time: 7 p.m.
Held at: Imperial Hotel, Birmingham.
Lecture: Electronic Dynamic Balancing Machines.
By: S. A. Rybczynski, B.Sc.(Eng.), Grad.I.E.E.

INSTITUTE OF NAVIGATION

Date: December 15. Time: 5 p.m.
Held at: The Royal Geographic Society, 1, Kensington Gore, S.W.7.
Lecture: Psychological Aspects of Instrument Presentation.
By: Wing Commander H. P. Ruffell Smith.

INSTITUTION OF POST OFFICE ENGINEERS

Date: December 5. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Shared Service.
By: N. V. Knight, B.Sc., A.M.I.E.E.

THE ROYAL SOCIETY

Date: December 14.
Held at: The Royal Society, Burlington House, London, W.1.
Wilkins Lecture for 1950.
By: Professor F. J. Cole, F.R.S.

BRITISH INSTITUTION OF RADIO ENGINEERS

Date: December 15. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Discussion: Progress in Loudspeaker Design.
Opened by: R. L. West, B.Sc.

North Eastern Section

Date: December 13. Time: 6 p.m.
Held at: Neville Hall, Westgate Road, Newcastle.
Lecture: A Survey of Television Development and its Problems.
By: H. J. Barton Chapple, B.Sc.

THE TELEVISION SOCIETY

Engineering Group

Date: December 14. Time: 7 p.m.
Held at: The C.E.A., 164, Shaftesbury Avenue, London, W.C.2.
Lecture: Television Transmission for the Amateur.
By: M. Barlow.

Main Society

Date: December 29. Time: 7 p.m.
Held at: The C.E.A., 164, Shaftesbury Avenue, London, W.C.2.
Annual Social and Exhibition.