Oct. 8, 1946. D. A. CHRISTIAN 2,409,105

ELECTRICAL TIMING ARRANGEMENT

Filed Oct. 21, 1943 2 Sheets-Sheet 1

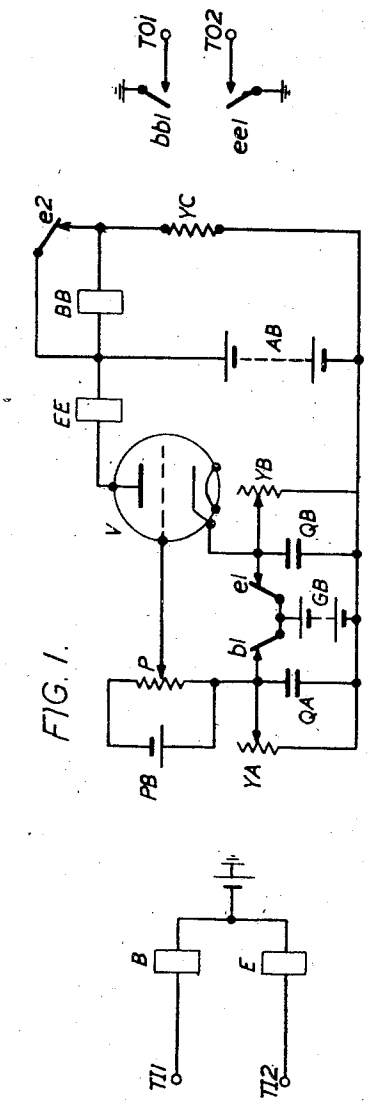


FIG. 1.

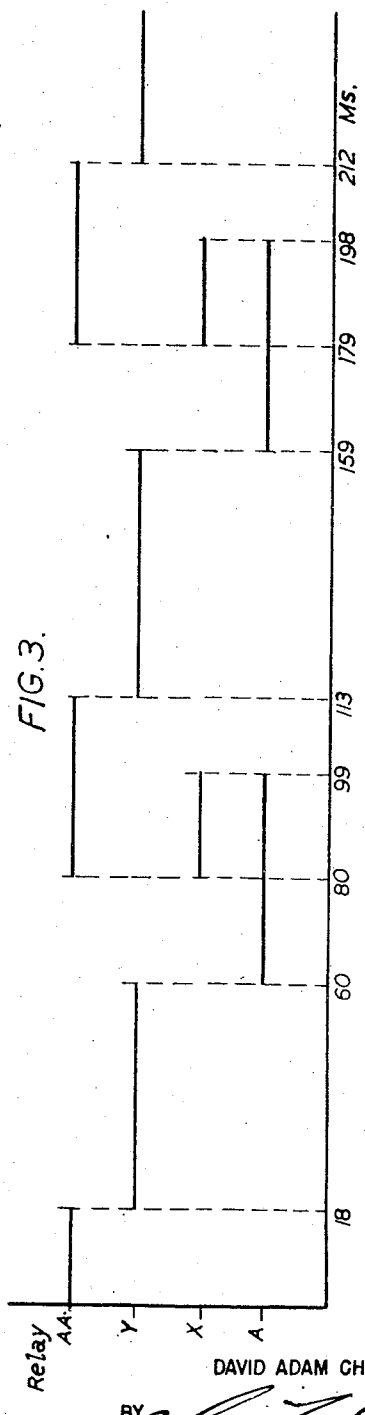


FIG. 3.

Inventor
DAVID ADAM CHRISTIAN

BY Chas. Fr. Condy.
Attorney

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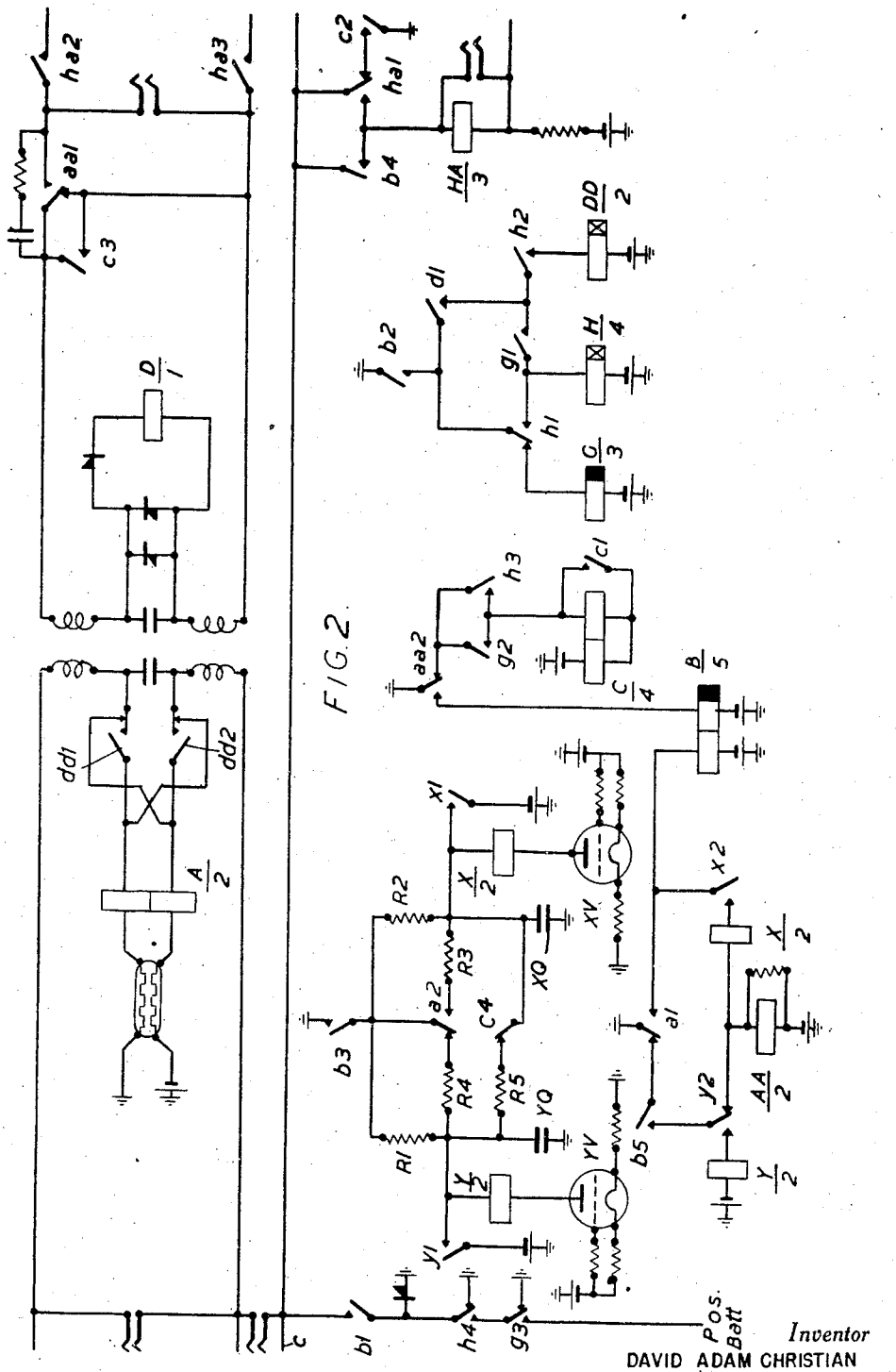


FIG. 2

Inventor
DAVID ADAM CHRISTIAN

BY Chas. L. Candy
Attorney

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UNITED STATES PATENT OFFICE

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ELECTRICAL TIMING ARRANGEMENT

David Adam Christian, Batley, England, assignor to Siemens Brothers & Co. Limited, London, England, a British company

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14 Claims. (Cl. 179—16)

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This invention relates to apparatus for or involving the measurement of an elapsed time interval. It is especially adaptable to the measurement of short intervals such as a fraction of a second.

If a function of an electric circuit be caused to vary linearly with respect to time it can be arranged that the function attains a predetermined value in a specified time. If during this time the rate of change of the function be altered it will reach the predetermined value in some other time which will depend on the time that elapsed before the alteration of rate took place and the difference between the time that would have elapsed before the predetermined value is reached if no alteration had taken place and the time that actually elapses if an alteration is made in a linear function of the original elapsed time. It can be shown that a similar condition applies if the function instead of varying linearly varies exponentially, the derived time varying linearly with the original elapsed time. In practice slight divergence from linearity or the exponential curve may be of no great consequence and a function which varies approximately linearly or exponentially over the working range of the apparatus to which it is to be applied may in some cases be sufficiently accurate for practical purposes. The use of an exponentially varying function is especially convenient in an electrical circuit as such a function is readily available in the charge or discharge circuit of a condenser and its rate is easily and readily variable and adjustable with considerable accuracy.

In the present invention electrical time measuring apparatus operating at one rate measures an elapsed time interval and at the end of this interval the rate is changed and the apparatus continues in operation and a further interval is measured off, this interval being derived from the original elapsed interval. Instead of one apparatus operating at different rates two apparatuses may be used one operating at one rate during the original time interval and continuing in operation at that rate thereafter, the other operating at a different rate and being started in operation at the end of the original interval and continuing in operation until the two apparatuses reach a condition common to them. The derived interval which will be that measured off by the second mentioned of the two apparatuses will thus be seen to depend on the length of the original interval. Use may be made of the derived interval or of an interval hereinafter termed the

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dependent interval consisting of the original interval plus the derived interval.

In an electrical circuit a charged electrical condenser may be allowed to discharge through a resistance and the voltage of the condenser after the lapse of a time interval is a measure of that interval. If the resistance is then changed the condenser will discharge at a different rate and during its discharge to a specified lower limit a further interval will elapse. This interval will depend on the original interval and the change of rate of discharge of the condenser and as such is an interval derived from the original time interval. For instance, if the condenser would normally take time T to reach a voltage V and after a short interval x the resistance is reduced to one third of its original value the derived interval will be $\frac{1}{3}(T-x)$ which bears a linear relation to the original interval. The value T/3 may be looked upon as a constant, that is the time the condenser would take to discharge at the quicker rate from a fully charged condition to the voltage V. Instead of changing the resistance in the discharge circuit of a condenser two condensers may be employed, one discharging during the original time interval and the other commencing to discharge at a quicker rate at the end of the original interval. The two condensers starting from the same voltage will reach equal potentials after the lapse of a further time interval which will be a derived interval.

Instead of employing the discharge time of a condenser the charging time may be used or use may be made of the rise of flux in a coil having high inductance and low resistance for the measurement of time intervals.

The method of the invention is especially applicable to the modification of the ratio of the break to make intervals of a train of impulses of the kind used in automatic telephone systems.

Although the impulses of a train when generated may have a correct ratio of the break period to the make period, due to electrical distortion they may arrive with an incorrect ratio and again if the rate of impulse generation (due say to wear of dials) diverges from the standard the distortion of the impulses as received may be different.

In an application of the present invention the time elements (makes and breaks) of the received impulses of a train are measured one by one and the derived time intervals from the elements are used to produce the correct ratio.

This application may be made clearer by the following consideration.

If for a complete impulse the break period is represented by B and the make period by M and the complete impulse by I time units, then B+M=I.

A ratio of break to make commonly employed in automatic telephone systems is 2:1 and for a correctly generated impulse the length of the break should be twice that of the make.

The received impulses may not have a break to make ratio of 2; that is to say, B would not equal ⅔I, nor would M=⅓I.

Whatever the ratio may be, ⅔I=⅔B+⅔M, or, put in another way, a correct break period is obtained if a break period is diminished by one third and two thirds of a make period is added thereto.

The diminution of the break (which has first to be measured) involves at first sight a phase displacement of the impulse. The necessity for a large phase displacement can be overcome as the following indicates.

The above expression for ⅔I can be written as

$$B-\frac{B}{3}+\frac{2M}{3}$$

and further as

$$B+\left(C-\frac{B}{3}\right)-\left(C-\frac{2M}{3}\right)$$

where C is a suitable constant. This again can be written

$$B+⅓(3C-B)-⅔(½C-M)$$

The expression ⅓(3C—B) it will be noticed corresponds to the ⅓(T—x) previously mentioned. The ⅔ in the case of the expression ⅔(½C—M) represents a different variation of the rate of decay and the ½C a different value of T which corresponds to the shorter value of M.

The corresponding expression for the make period is

$$⅓I=M+⅔\left(\frac{3C}{2}-M\right)-⅓(3C-B)$$

It will be noted that the method of correction indicated is independent of the rate of impulsing, and so long as the ratio of the received impulses of a train remains constant the ratio of the repeated impulses will be constant throughout the train of impulses.

The following description taken in conjunction with the accompanying drawings shows by way of example methods of carrying out the invention.

Fig. 1 of the drawings shows in diagrammatic fashion an electric circuit for obtaining a derived time interval dependent on an elapsed time, Fig. 2 shows the circuit arrangements of an impulse repeater of the kind used in automatic telephone systems arranged for the correction of distorted impulses and their repetition with a constant desired ratio and Fig. 3 shows by means of a diagram the periods during which the relays controlling the reception, correction and repetition of the impulses in the repeater of Fig. 2 are operated.

Reference will first be had to Fig. 1 in which the circuits are in diagrammatic form, the contacts of the several relays being dissociated from their windings and shown in the circuits they control at convenient places in the drawings. B and E are relays operated at the beginning and end of an elapsing or original time interval from which a time interval is to be derived. Relays BB and EE determine by their operation the beginning and end of the derived interval. Relay EE is connected in the anode circuit of a thermionic valve V and relay BB in a circuit having an effective resistance similar to that of the valve.

Connected to the grid and cathode of the valve respectively are condensers QA and QB shunted by variable resistances YA and YB. AB is the anode battery, GB the grid bias battery and PB a battery connected across a potentiometer P for adjusting the potential on the grid of the valve to a value just sufficiently negative to prevent the flow of sufficient anode current to operate the anode circuit relay. Condensers QA and QB are normally charged from battery GB and the grid and cathodes are maintained at suitable potentials determined by the tapping point on potentiometer P.

At the commencement of the original time interval positive potential is applied to terminal TI1 and relay B is operated. Contact *b*1 opens and disconnects the positive end of battery GB from condenser QA. The condenser now commences to discharge through resistance YA and the potential on the grid of valve V becomes less positive with respect to the cathode. At the end of the original time interval positive potential is applied to terminal TI2 and relay E is operated. Contact *e*1 disconnects the positive end of battery GB from condenser QB and contact *e*2 removes a short circuit from relay BB. Relay BB operates in an obvious circuit from the battery AB and at contact *bb*1 applies positive potential to terminal TO1 to commence the derived time interval. At the same time condenser QB commences to discharge through resistance YB thereby reducing the positive potential on the cathode of the valve V. Condenser QB discharges at a quicker rate than condenser QA and after the lapse of a period determined by their discharging rates the potentials of the two condensers become equal. Immediately this point is passed the grid becomes less negative with respect to the cathode and sufficient current will flow through the valve to operate relay EE. When relay EE operates contact *ee*1 applies positive potential to terminal TO2 to determine the end of the derived time interval. It will thus be seen that a period has been derived from the original time interval, the derived period being determined by the discharge rates of the condensers QA and QB, and being a constant fraction of the elapsed time interval.

It is desirable that relays B and E be similar relays so that the commencement of the discharge of the two condensers will take place at the same interval after the application of the positive potential to terminals TI1 and TI2. Likewise it is desirable that relays BB and EE behave similarly and to achieve this resistance YC in the circuit of relay BB is adjusted to correspond to the effective resistance of the valve V. The condensers QA and QB may be of similar capacities and their discharge rates adjusted by means of the resistances YA and YB. It will be apparent that by employing different discharge rates a derived period of any desired value may be obtained.

The impulse repeater of Fig. 2 includes a feeding bridge with high speed impulse receiving relay A connected to the incoming side and back bridge relay D connected to the outgoing side. Received impulses are repeated over the outgoing circuit by high speed relay AA. This relay is shunted by a resistance to enable it to hold up during the change over of the controlling contact of relay A. There is a release relay B which is of the slow releasing type, dialling relay C, a metering relay G, a metering preparatory re-

lay H, a back bridge auxiliary relay DD and a preparatory relay HA. Relays X and Y together with condensers XQ and YQ and resistances R1, R2, R3, R4 and thermionic valves XV and YV comprise the correcting device. The valves XV and YV are of the type in which once an anode current is started it will continue to flow until its circuit is interrupted irrespective of the grid potential. The charging source for the condensers XQ and YQ is the exchange battery usually of 50 volts and the condensers and the associated resistances are so proportioned and arranged that the discharge of a condenser to a value which will permit the associated valve to strike will be at least as long as the longest element of an impulse that the device will be required to deal with. In the present example the charging source will be assumed to be the exchange battery of 50 volts and the grid of the valve is connected to the negative end of this battery. The anode-cathode potential at which the valve strikes is 40 volts and with the condenser fully charged the anode and cathode of the valve will both be at 50 volts negative potential. The potential on the anode has then to rise by 40 volts due to the discharge of the condensers for the striking voltage of the valve to be reached. The ratio of break to make of impulses usually employed is 2:1 and the limits of impulse speed are usually taken at 7 and 12 impulses per second and, allowing for distortion a period of 120 milliseconds should cover the longest component of any impulse to be dealt with. This is usually the break component. Taking a size of condenser usual in telephone systems, namely 4 microfarads it will be found that to discharge it from 50 to 10 volts in 120 ms. will require a resistance of 18,600 ohms in the discharge circuit during the break period of an impulse. This is the value then to be given to resistance R2. Since the ratio of break to make of an impulse is to be taken as 2:1 resistance R1 will require to be half the value of resistance R2, namely 9300 ohms and in order to measure off the period of ⅓ the break, which is equal to ⅔ the make period the resistance required in the discharge circuit will need to be 6200 ohms. This is conveniently obtained by the parallel connection of 18,600 and 9300 ohms, i. e. the resistances R3 and R4 will equal the resistances R1 and R2 respectively. With these values the valve XV will strike after a period of 120 ms. with relay A unoperated and after 40 ms. with relay A operated and valve YV will strike after 60 ms. with relay A operated and after 40 ms. with relay A unoperated. Reference to resistance R5 will be made later.

The general operation of the circuits will now be described. When the repeater is taken into use it tests free by reason of the absence of earth potential on the test wire *c* and relay A is operated over a preceding loop. Contact *a1* closes an operating circuit for relay B which operates and at contact *b1* connects earth to wire *c* to mark the circuit engaged. Contact *b2* operates relay G and contact *b4* operates relay HA. Relay G at contact *g1* prepares a circuit for relay H, at contact *g2* prepares a circuit for relay C and at contact *g3* prepares the metering circuit. Relay HA operating, a locking circuit for it is closed over contact *ha1* and the *c* wire and contacts *ha2* and *ha3* close in the outgoing circuit preparatory to impulsing. At the time relay A operates condensers XQ and YQ are discharged and on the closure of contact *b3* relay X operates immediately and at contact *x2* closes a circuit over contact *a1* for relay AA. Relay AA operates, closes the outgoing loop at contact *aa1* and at contact *aa2* opens the circuit which would be closed by the operation of relay G and closes a holding circuit for relay B over a second winding of that relay. Contact *x1* connects battery directly to condenser XQ and thus extinguishes the valve XV by the connection of negative potential to its anode. Relay X however, remains held over contact *a1*.

When the first impulse break occurs, relays A and X release but relay AA remains held over back contact *a1*, contacts *b5* and *y2*. Condenser XQ commences to discharge over resistance R2. Consequent on the release of relay A relay Y is operated in a manner which will be explained subsequently, and at contact *y2* releases relay AA and closes a locking circuit for itself, contact *y1* extinguishing valve YV and charging condenser YQ. Consequent on the release of relay AA, the outgoing loop is opened at contact *aa1* initiating the break period of an impulse, and relay C is operated over contacts *aa2* and *g2*. Relay C on operation short-circuits its right-hand winding to delay its release and at contact *c3* closes a low impedance impulsing circuit over the outgoing loop.

Neglecting for the moment a full description of the effect of the first impulse, consideration will now be given to the operations that ensue after the first impulse has been transmitted. When relay A releases for the second time, condenser XQ commences to discharge over resistance R2 as has been previously mentioned and the negative potential on the grid of valve XV falls gradually. When relay A re-operates in response to the re-closure of the incoming impulse circuit, the discharge circuit for condenser XQ includes resistances R2 and R3 in parallel and discharge proceeds at 3 times the previous rate. When the potential on the anode of valve XV reaches the striking value of the valve, taken in the present example as 40 volts with respect to the cathode the valve strikes and relay X operates and locks up during the remainder of the make period of the impulse and operates relay AA to close the outgoing loop. At the commencement of the received make period, relay Y is released at contact *a1* and condenser YQ commences to discharge over resistance R1 until the end of the make period whereupon contact *a2* connects resistance R4 in parallel with resistance R1 and condenser YQ discharges at 1½ times its previous rate. When relay A releases, relay X releases but relay AA remains held over contact *y2* until relay Y operates consequent on the potential on condenser YQ reaching the striking value of valve YV. When this occurs relay AA releases and the repeated make is terminated. During the release period of relay A condenser XQ, which was recharged following the operation of relay X, commences to discharge again over resistance R2 and after the re-operation of relay A over resistances R2 and R3 in parallel until the striking potential of valve XV is reached whereupon relay X re-operates to close the circuit of relay AA to terminate the repeated break period.

The correction so applied will be more clearly appreciated from a consideration of Fig. 3. This figure shows, by means of horizontal lines the periods during which relays A, AA, X and Y are operated. The impulsing speed has been assumed to be such as to give a total impulse length

of 99 ms. approximating to 10 impulses per second with a correct ratio of 2:1 but the received impulses are distorted so that they have a ratio of 60:39. Neglecting the first impulse for the time being and assuming the values for the resistances, condensers and voltages already given, the explanation will be commenced at the point denoted 99 ms. At this point the second impulse break commences on the release of relay A. Relay X which had been previously operated is released and condenser XQ commences to discharge over resistance R2. This discharge will continue for 60 ms. at the end of which time relay A re-operates and connects up resistance R3 so that the discharge will proceed at three times the previous rate. After a further 20 ms. valve XV will strike and relay X will be operated to operate relay AA and recharge the condenser. The repeated make will therefore commence at the point 179 ms. Thus a period of 20 ms. equal to 40—⅓ of the break has been added. At the end of the received break at 159 ms. when relay Y is released, condenser YQ commences to discharge over resistance R1 and this continues for 39 ms., that is to the point 198 ms. at which point relay A releases and the condenser then discharges at the quicker rate over resistances R1 and R4 in parallel until the point 212 is reached at which valve YV strikes and relay Y operates, releasing relay AA and re-charging condenser YQ. Thus a period of 14 ms. equal to 40—⅔ make has been added. The repeated make will therefore be terminated at the point 212, that is it will have had a duration of 33 ms. At 198 ms. when relay A released condenser XQ commenced to discharge over resistance R2 and discharge continues at this rate for 60 ms., the length of the received break, after which it discharges at the higher rate for 20 ms. until the point 278 would be reached whereupon the valve XV strikes and relay X is operated and operates relay AA thus terminating the repeated break which commenced at the point 212. The duration of the repeated break period has thus been adjusted to 66 ms. Provided the duration of the components of the impulses of a train does not vary, and this is usually the case, all the succeeding impulses of the train will be repeated with a constant ratio of 2:1 at the speed at which they are received.

As mentioned above a full description has not yet been given of the circuit operations relating to the first impulse of a train. When the circuit is taken into use relay A is operated for an indefinite time although this make is followed by a release period of the same length as that of the other impulses. In what has gone before an impulse has been taken as consisting of a break period followed by a make and it has been shown how the length of the repeated break depends on the duration of the preceding make. In the case of the first break the length of the preceding make is indeterminate with the result that with the operations so far described the length of the first break would be too long; in the example taken it would be 80 ms. To overcome this objection it is arranged that a priming charge shall be given to condenser YQ on the first operation of relay A so that at the end of the first received train of impulses instead of finding the condenser discharged the valve YV will find it at a potential such as it would have acquired had the ensuing break been preceded by a make of correct length. This is arranged for by charging the condenser in a potentiometer circuit to the required voltage. Turning again to Fig. 2 a potentiometer will be seen to be formed by the resistances R1 and R5 in series, the circuit including contact *c*4. When relay X operates this charging circuit is effective and the condenser assumes the desired potential. At the commencement of the first transmitted break, relay C is operated, opening the priming circuit at contact *c*4 and maintaining it open throughout the impulse train.

It is desirable that the circuit including resistance R5 should be opened as quickly as possible after the release of relay A and if relay C does not operate quickly enough it may be necessary to employ other means to do this such as by a contact of a quick operating relay operated in parallel with relay C and held operated by that relay. Condenser YQ then discharges at the higher rate until the striking voltage of the valve is reached. The result is that a period of 18 ms. is added to the initial make, or, in other words the length of the first repeated break is reduced by 18 ms. bringing it from 83 to 62 as shown in Fig. 3. The commencement of the first repeated make depends on the duration of the preceding break and as this is the same as that of any other break the arrangements earlier described operate to effect the necessary correction. The period of 18 ms. referred to is the amount by which the termination of a 33 ms. make at a speed of 10 impulses per second would be delayed.

If impulses of any other speed are received the ratio of the second and succeeding impulses will still be corrected automatically to 2:1 in the manner described and the result of the priming of condenser YQ will be to tend to bring the length of the first break nearer to the length that it should be at the speed for which the priming charge is set.

Continuing now with the general operation of the repeater, it will be found that the usual operations take place. At the end of the impulse train, relay A remains steadily operated, and relays X and AA are held. Relay Y will operate momentarily after 60 ms. but will bring about no useful result. Relay C releases due to the continued operation of relay AA and opens the shunt across the outgoing loop and also again closes the circuit for priming condenser YQ. Further impulse trains are repeated in a manner similar to that described and after the end of the last train the called subscriber is rung in known manner. Up to now relay D has not operated as the polarity of the line wires has been such that the path through relay D was blocked by the series connected rectifier, the shunting rectifiers forming a low resistance shunt to the condenser in the repeating coil connection. When the called subscriber answers, the line polarity is reversed resulting in the operation of relay D. Contact *d*1 thereupon closes a circuit for relay H which operates and locks over contact *h*1 releasing relay G. Contact *h*2 completes an operating circuit for relay DD and contact *h*4 completes the metering circuit. Relay G releases slowly, measuring off the metering pulse which is transmitted back over the *c* wire and on its release the relay reconnects the holding earth at contact *g*3. Contact *g*1 opens the operating circuit for relay H. When relay DD operates, contacts *dd*1 and *dd*2 reverse the polarity of the incoming line wires for supervisory purposes in known manner.

At the end of the connection release is initiated by the opening of the incoming loop consequent on the calling subscriber replacing his hand set.

Relays X and AA are released at contact *a1* and relay B is released consequent on the release of relay AA and in turn releases relays HA, H and DD. Contact *aa1* opens the outgoing loop to initiate release of succeeding switches and by the closure of back contact *aa2* relay C re-operates during the releasing period of relay H. When relay HA releases the outgoing loop is opened at contacts *ha2* and *ha3* and earth over contacts *c2* and *ha1* is applied to the *c* wire to guard the repeater for a period long enough for the release of succeeding switches to be effectively initiated. Relay D releases and on the release of relay H relay C releases and the circuit is restored to normal. During the release period of relay B any charge in condensers XQ and YQ leaks away so that the condensers will be in a discharged condition when the repeater is again taken into use.

What I claim as new and desire to secure by Letters Patent is:

1. Electrical timing apparatus for deriving a time interval which bears a linear relation to a given time interval comprising first and second timing means arranged to be operated at different rates, means for starting the first timing means at the beginning of the given time interval, means for starting the second timing means at the end of the given time interval, and means controlled by said two timing means responsive to their reaching a common condition for determining the duration of the derived time interval.

2. An electrical circuit arrangement for deriving a time interval from a given time interval comprising two aperiodic circuits having different time constants, means for initiating the flow of an aperiodic current in one of said circuits at the beginning of the given time interval, means for initiating the flow of an aperiodic current in the other of said circuits at the end of the given time interval, and means differentially acted upon by the currents in said two aperiodic circuits for determining the duration of the derived time interval.

3. An electrical circuit arrangement for deriving a time interval from a given time interval comprising two aperiodic circuits having different time constants, means for initiating the flow of an aperiodic current in one of said circuits at the beginning of the given time interval, means for initiating the flow of an aperiodic current in the other of said circuits at the end of the given time interval, and means jointly controlled by the currents in said two aperiodic circuits for determining the duration of the derived time interval.

4. An electrical circuit arrangement for deriving a time interval from a given time interval comprising an aperiodic circuit, means operated to initiate the flow of an aperiodic current in said circuit at the beginning of said given time interval, means operated to change the time constant of said aperiodic circuit at the end of the given time interval, and means operated to terminate the derived time interval when said aperiodic current reaches a predetermined value.

5. An impulse repeater for use in a signaling system employing trains of impulses consisting of breaks and makes of an electrical circuit comprising means for measuring the lengths of the break and make components of received impulses, means for deriving time intervals therefrom which bear a linear relationship to each of said break and make components, and means for combining said derived time intervals with the break and make components of the received impulses in such a manner as to produce corresponding output impulses having a constant desired break to make ratio.

6. An impulse correcting repeater for use in a signaling system employing trains of impulses comprising input and output circuits, a pair of condensers, a source of voltage for charging said condensers, a relay connected to said input circuit operative to cause one of said condensers to be partially discharged at one rate during the break period of a received impulse and to be further discharged at a higher rate during the subsequent make period, said relay also being operative to cause the other of said condensers to be partially discharged at a second rate during the make period of a received impulse and to be further discharged at said higher rate during the subsequent break period, the ratio between said second rate and said one rate being equal to a desired output impulse break to make ratio, and relay means controlled by the voltages across said condensers for repeating impulses corresponding to the received impulses over said output circuit at the desired break to make ratio.

7. An impulse correcting repeater as claimed in claim 6 including means for maintaining the other of said condensers partially charged prior to the reception of a train of impulses so as to cause the first repeated impulse of a train to have the desired break to make ratio at a given speed of impulsing.

8. Impulse correcting arrangements for use in an impulse repeater comprising a pair of condensers and a source of charging potential therefor, a relay and a thermionic valve associated with each of said condensers, a third relay responsive to received impulses for causing said condensers to be discharged during the break and make periods respectively through resistances having a similar ratio to that of a desired break to make ratio of the repeated impulses, said relay means also causing said condensers to be further discharged during the subsequent make and break periods respectively through a resistance having a value equal to that of the preceding two resistors in parallel until the potential across a condenser reaches a point where the associated tube and relay is operated, and a fourth relay for reproducing the received impulses at the desired constant break to make ratio arranged to be operated in response to the operation of one of the first two relays and to be released in response to the operation of the other of the first two relays.

9. The method of correcting the impulse ratio of a train of impulses which comprises measuring the duration of the break and make components of each received impulse, deriving a time interval from each of said components bearing a linear relation thereto, adding one of said derived time intervals to each break component, adding the other of said derived time intervals to each make component, subtracting said one derived time interval from each make component, and subtracting said other derived time interval from each break component, whereby repeated impulses having a constant desired break to make ratio which is independent of the original impulse ratio or speed are obtained.

10. The method of correcting the impulse ratio of a train of impulses which comprises measuring the duration of the break and make components of each received impulse, deriving a time interval from each of said components bearing a linear relation thereto, and combining said derived time intervals with the break and make

components of the received impulses so as to produce corresponding impulses having a constant desired break to make ratio.

11. Apparatus for deriving a time interval from, and bearing a linear relation to, a given time interval comprising a timing means operable at either of two rates, means operated at the start of the given time interval for causing said timing means to operate at one of said rates, means operated at the end of the given time interval for causing said timing means to continue in operation at the other of said rates, and means responsive to said timing means reaching a predetermined condition for terminating the derived time interval.

12. Apparatus for deriving a time interval from, and bearing a linear relation to, a given time interval comprising a timing means operable at either of two rates, means operated at the start of the given time interval for causing said timing means to operate at one of said rates, means operated at the end of the given time interval for changing the rate at which said timing means operates to initiate the derived time interval, and means responsive to said timing means reaching a predetermined condition for terminating the derived time interval.

13. An electrical circuit arrangement for deriving a time interval from a given time interval comprising an aperiodic circuit, means operated to initiate the flow of an aperiodic current in said circuit at the beginning of the given time interval, means operated to change the time constant of said aperiodic circuit at the end of the given time interval, said first means operated to terminate the derived time interval when said aperiodic current reaches a predetermined value.

14. An electrical circuit arrangement for deriving a time interval from a given time interval comprising an aperiodic circuit; and relay means first operated to initiate the flow of an aperiodic current in said circuit at the beginning of the given time interval, subsequently operated to change the time constant of said aperiodic circuit at the end of the given time interval, and later operated to terminate the derived time interval when said aperiodic current reaches a predetermined value.

DAVID ADAM CHRISTIAN.