Oct. 25, 1949. B. M. HADFIELD **2,486,154**

ELECTRONIC IMPULSE GENERATOR

Filed Dec. 18, 1943

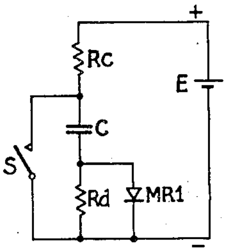

Fig. 1

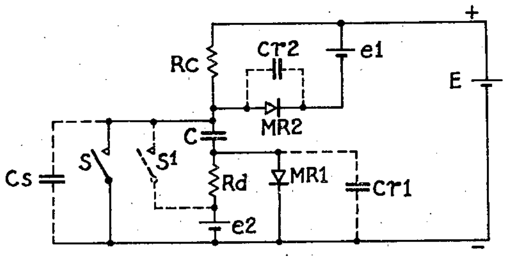

Fig. 2

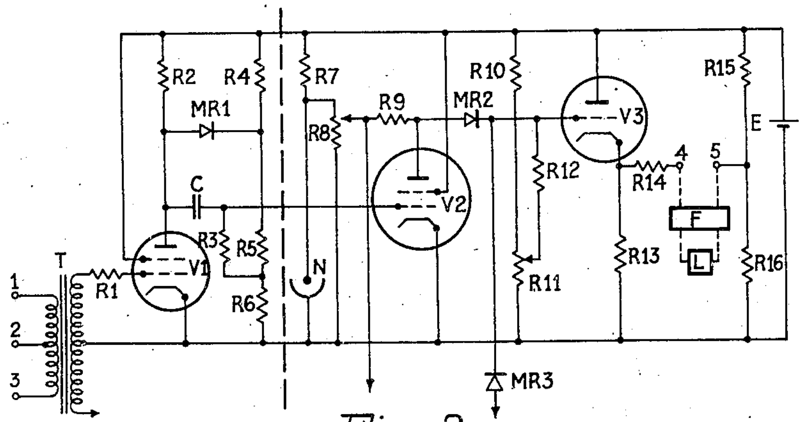

Fig. 3

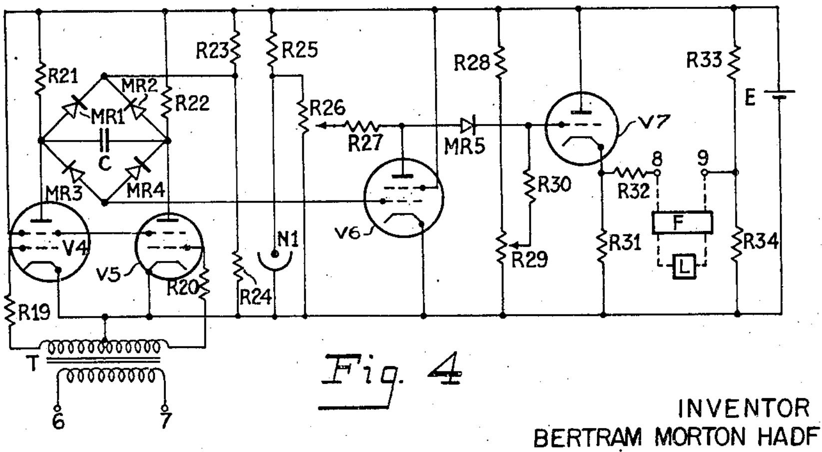

Fig. 4

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2,486,154

ELECTRONIC IMPULSE GENERATOR

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Application December 18, 1943, Serial No. 514,842
In Great Britain December 23, 1942

7 Claims. (Cl. 250—27)

The present invention concerns improvements in or relating to the generation or regeneration of impulses of predetermined duration and amplitude and has application among other purposes to the measurement of frequency or to an improved impulse generator or impulse regenerator or corrector for producing impulses of desired characteristics.

The object of the invention is to produce unidirectional voltage or current impulses of known time duration from a simple switch operation and having an amplitude which is not dependent upon or limited by the required known time duration of the impulses. If the simple switch operation is repeated and means are provided for indicating the mean output, the latter, being proportional to the number of operations within a given time, is a direct linear measure of the frequency of operation up to a frequency determined by the known time duration. At higher frequencies the output is constant and independent of frequency.

A further object of the invention is to provide thermionic valves to act as switches and so provide a series of impulses so that a wide range direct-reading frequency meter may be obtained.

According to one feature of the invention a switching device intermittently controlled by alternating or pulsating currents is arranged to cause a reactance to be successively charged or energised over one path from a supply voltage and discharged or deenergised over another path.

According to a second feature of the invention a switching device is arranged to cause a reactance to be successively charged or energized over one path from a supply voltage and discharged or deenergized over another path characterised in that non-linear circuit elements and biasing voltages or currents are employed to terminate both the charging or energising of the reactance and the discharging or deenergising of the reactance at predetermined voltage or current limits.

According to a subsidiary feature of the invention the time of the selected effective function, charge or discharge, is adapted to be adjusted to be of a duration not less than the time of the selected ineffective function.

According to another feature of the invention a switching device consisting of a thermionic valve or valves controlled by alternate half cycles in the grid input wave form is arranged to cause a reactance to be successively charged or energised over one path from a supply voltage and discharged or deenergised over another path.

The above and other features of the invention will be better understood by referring to the following description for an understanding of which reference should be made to the accompanying drawings.

Referring to the drawings,

Fig. 1 illustrates in a diagrammatic manner the fundamental charge and discharge circuit on which the invention is based.

Fig. 2 shows a modification of Fig. 1 in which in accordance with the invention the charge and discharge functions are limited.

Fig. 3 illustrates a complete circuit using thermionic valves for switching.

Fig. 4 illustrates an alternative arrangement to that shown in Fig. 3 in which the thermionic charge and discharge circuit are designed for full wave working.

In order that a ready appreciation of the invention may be obtained, the basic charge and discharge circuits applied to a reactance will be described on the assumption that the reactance is a condenser, the charge and discharge paths are resistances, the supply voltage and biasses are batteries, the non-linear circuit elements are rectifiers, and the switches are of the contact type. The development of the circuits will however be described with the ultimate object of using thermionic valve switches, which it will be readily appreciated can only replace a simple make or break contact and then only if the current flow is from anode to cathode.

The fundamental charge and discharge circuit will be described with reference to Fig. 1. A series circuit comprising resistance R*c* condenser C and resistance R*d* is connected in this order between the positive and negative busbars of a direct current supply of E volts. A rectifier MR1 is shunted across R*d* with its positive pole to the negative busbar, and a contact of a switch S is connected between the junction of R*c* and C, the other contact of switch S being connected to a negative busbar. On breaking the switch contacts, C charges from E via R*c* and MR1 which is conducting, whilst on remaking C discharges via R*d* the voltage on MR1 then being in the non-conducting sense. Hence the charge and discharge circuits are substantially independent and comprised by R*c* and R*d* respectively.

As the circuit stands, C would ultimately charge to E volts and discharge to zero volts. As both these functions take an infinite time however, neither can be used with any accuracy as denoting a known finite time unless the time constants are vanishingly small. This in turn infers that the output will be correspondingly small, and dependent on the charge and discharge function.

To avoid both of these well known deficiencies the charge and discharge voltages are limited. One way of effecting this will be described with reference to Fig. 2. A further rectifier MR2 is connected with its negative pole to the junction of Rc and C, and its positive pole to the negative pole of a bias battery e1, whilst the positive of e1 is joined to the positive busbar of E. A further bias battery e2 is inserted between Rd and the negative busbar, the negative of e2 being connected to the negative of E.

The voltage on C on discharge termination will still be zero, and on breaking the contacts of S, charging proceeds as before until the condenser voltage attains a value E—e1. MR2 then becomes conducting and the charging function is stopped. On remaking the contact, MR1 again becomes nonconducting and C discharges via Rd with the aid of e2. When the condenser voltage attains zero, MR1 conducts and the discharge is stopped instead of proceeding to a condenser voltage of —e2. Hence the fractional charge on C is the potential acquired by the condenser at the point of charging termination by MR2, proportional to the supply voltage, and in equation form, is

$$\frac{E-e1}{E}$$

The discharge is the potential of the discharge bias battery expressed as a proportion to the fractional potential charge plus the potential of the discharge bias battery, and in equation form is,

$$\frac{e2}{E-e1+e2}$$

Knowing the respective charge and discharge time constants these fractions will aid in determining the charge and discharge times. These charge and discharge time values are independent of the time intervals between the changes of state of the contact, provided only that the time intervals are longer. By making all three battery voltages proportional to each other, these times are also rendered independent of changes in the supply voltage. This can easily be arranged, since it will be noticed that e1 and e2 can be provided by taps on the main battery E; these taps can be potentiometers across E provided account is taken of the effect of the impedances of e1 and e2 on the charge and discharge. In practice it is convenient to make e1 equal to e2 and both about one-third of E, when the charge and discharge times will be 1.1 times the respective time constants C—Rc and C—Rd.

Since Rc and Rd independently control the two circuit functions it can be arranged that the charge or discharge function which is not utilized as an output takes the lesser time. With this arrangement of resistors, when the half cyclic operating time period of the alternating current input becomes equal to or less than the finite utilized function time, the output reaches its maximum value and remains at that maximum value regardless of any increase in frequency.

An alternative position for S is shown at S′, the only effect of which is to introduce a permanent voltage e2 into the voltage changes on C. The main use of this alternative position is when the switch is comprised by a thermionic valve, and the latter must be initially biassed to cutoff by introducing cathode bias from the main battery E.

Sundry typical stray capacitances Cs and Cr1 and Cr2 appropriate to the components which they shunt, are also shown because the circuit is particularly amenable to their presence. For instance, Cs and Cr2 add to C during charge, and can be separately accounted for by altering Rc or e1 appropriately if a given charge time is required; Cr1 acts in parallel with C on discharge, and time adjustments can be made on Rd or e2. The instantaneous loss of voltage on C when it is switched on to MR1 and Cr1 for discharge can also be accounted for, and will not be of material effect on the rest of the circuit provided the remaining voltage is large compared with that necessary to operate the succeeding stage. For this reason a high gain switching valve is preferably employed between these constant time waveforms and the output stage. Furthermore this facility of being able readily to account for and overcome the effects of residual capacitances, also permits the use of a high gain switching valve in place of S because the gain can only be obtained with economy by using high anode resistances (i. e. Rc for instance), and this in turn infers a low capacitance for C for a given time constant.

Fig. 3 shows a typical circuit, arranged for half wave operation, for measuring the frequency of an alternating input at terminals 1, 2 and 3. The input is applied via transformer T and grid current limiting resistance R1, to the grid/cathode path of the pentode valve V1. The latter pentode tube V1 replaces S in Fig. 2 and acts as a high gain amplifier over a very limited input grid voltage range. Rc then becomes the anode resistance and in order that the finite valve impedance shall be negligible when the valve is "on," both Rc and Rd must be much larger than the finite valve impedance. It should be noted that the significant value of the valve impedance is its minimum direct current value, which normally is limited by the flow of grid current. In order to obtain the lowest possible "on" valve impedance, and yet require a minimum of grid voltage change to effect the transition from infinite to finite impedance, it is preferred to use a pentode valve arranged so that Rc intersects the anode voltage/anode current characteristic well below the well known "knee" value. If no grid bias be used, as is convenient and is illustrated in Fig. 3 then the valve will be "on" normally, and the circuit is operated by a negative grid input exceeding the cutoff voltage. If grid bias is used, it must be such as to render the valve "off" normally (i. e. no anode current), and the action is reversed. In either case grid current is bound to flow at some input level, so that a grid current limiting resistance will be needed.

Comparing the circuit to the left of the dashed line with Fig. 2, R2 replaces Rc, MR1 replaces MR2, the voltage drops on R4 and R6 replace e1 and e2 respectively. R3 replaces Rd, the grid/cathode path of V2 replaces MR1, and C is the same. It is necessary of course that resistances R4 and R6 shall be small compared to R2 or R3, if close approximation to the batteries e1 and e2 is to be obtained. As a matter of convenience in the present circuit, the discharge waveform is used to energize the output stages. Therefore, to prevent the half cyclic operating time period of the alternating current input from being less than or equal to the finite charge time before it is equal to or less than the finite discharge time, the value of the charging resistance **R2** must be less than the value of the discharge resistance **R3**.

The charge and discharge waveforms on C are essentially voltage waveforms of exponential form with a discontinuity after the given time duration. These waveforms are not suitable for use directly as an output since their energy content is small. It is preferred therefore to use the most convenient one to actuate another switching valve similar to **V2** so that rectilinear constant time waveforms may be obtained.

The discharge exponential wave-form is convenient, since it is large and negative with respect to the negative busbar.

Valve **V2** is similar in type and action to **V1**, and since the discharge voltage waveform of the condenser is large (maximum value about two-thirds E) and negative to the grid of **V2**, it follows that this valve is switched "off" for a time equal to the finite discharge time, and that the anode voltage output on **R9** is a substantially rectilinear positive voltage pulse of the same time duration as that of the finite discharge time and of magnitude dependent only on the ultimate anode voltage. This anode voltage is independently controlled by the tapping arm of **R8** and stabilised against changes of E by the neon lamp circuit **R7**, N. The main purpose of the invention has now been accomplished, since the output is of constant time duration and amplitude, has a maximum of energy content, is initiated by an input voltage change of one sense, and is unaffected by the time duration of the input change provided only that this be longer than the output time duration. If such an input change be repeated at a given rate, then the mean value of the voltage pulses on the anode of **V2** will be strictly proportional to the repetition rate, i. e. the frequency, until the half cyclic operating time period of the input becomes equal to or less than the finite discharge time. When the latter occurs the output pulse time is the same as the input, and the mean value remains constant up to infinite frequency. This feature is of value in preventing overload of the output indicating device by an unknown frequency. By using a pentode valve similar to **V1**, the anode voltage will consist of the desired rectilinear voltage waveforms of constant time and of large amplitude.

Having now obtained the desired form of output pulse and as a positive voltage with respect to the negative busbar, it is now possible to convert this into a similar current pulse in the desired load resistance.

The conversion of these voltage pulses on the anode of **V2** into similar current pulses in the desired output load, is accomplished by valve **V3** which is a conventional cathode follower with some circuit refinements. The anode of **V2** is directly connected to the grid of **V3** via a rectifier **MR2**, so that a positive grid/negative busbar voltage can be sustained without being affected by the residual "on" anode/cathode voltage of **V2** (i. e. in the unoperate condition), and yet permit the passage of larger anode potentials to the grid of **V3**. The positive grid voltage on **V3** is provided by the busbar potentiometer **R10**, **R11**, the latter having a variable tap connected to the grid via **R12**. The anode pulse voltage of **V2**, less the positive grid voltage provided by **R11**, appears across **R12**, so that the latter must be high compared to **R9** if a reasonable fraction of the pulse voltage is to be effective. **R13** enables a reasonable value of steady anode current to be passed by **V3**, so that an adequate minimum working slope is available, whilst the load is connected between cathode and a point positive with respect to the negative busbar, such as the junction of **R15** and **R16**, at terminals **4**, **5**. **R14** is a padding resistance to make up the source impedance of the cathode follower to any convenient value. The object of the positive grid voltage and the positive load voltage is to ensure that the normal load current can always be brought to zero with any valve **V3**, and also remain zero independent of the normal anode voltage of **V2** and changes in the supply voltage E. The tap on **R11** is therefore a zero adjustment. By these means the output current pulses in the load are still independent of supply changes, and independently controllable for magnitude by the tap on **R8**. The power output is only limited by the choice of **V3** and the supply E.

The output load is shown at L, and in cases where only the mean D. C. value of the pulses is required in L, it can be preceded by a conventional filter F. When a meter reading is only required, the filter F is generally unnecessary if the mechanical inertia is sufficient.

The circuit of Fig. 3 as described, is operative only to one half cycle of the alternating input i. e. that which causes the grid of **V1** to be negative. However the insertion of the rectifier **MR2** between the preceding anode **V2** and the cathode follower grid circuit of **V3**, also has the advantage that the **V3** can be worked from more than one preceding valve. By duplicating the secondary of the input transformer and the circuit of **V1** and **V2** up to the grid input rectifier **MR3**, it can be arranged that each half cycle produces an output pulse, so that the output frequency and mean value will be doubled. It is unnecessary to duplicate the output magnitude control **R8**, and the essential interconnections are shown in Fig. 3. This full wave operation is useful when an output filter such as F must be used, as is the case in the application of the invention to the Vocoder since the cutoff frequency of the filter may then be double the value normally required for half wave operation. It is interesting to note that when the input frequency attains the value where its half cyclic operating times are equal to or less than the finite utilized function times, the output current is literally D. C. Higher frequencies cause no change in this condition. A frequency meter of this type cannot therefore be overloaded. Used in this full wave manner, the input impedance can now be made resistive and linear, since the grid limiting resistances **R1** are alternately thrown across the half secondaries of T by the alternate diode actions of the input valves **V1**.

By providing a range of condensers in given ratios to the input frequencies and operative by switch selection, the combination will embrace with adequate reading accuracy a wide range of frequencies. Alternatively, the condensers may be of commercial accuracy and the output for each range may be correctly adjusted by separate and adjustable values for the biasses.

It will be appreciated that the above specific embodiments do not constitute the only methods whereby the objects of the invention may be attained, but represent only those which have been found most convenient up to the present. For instance if individual adjustment of the biasses (*e1* and *e2*, Fig. 2) are required on each range, it may be more economical to use a high resistance potentiometer across the busbars, the arm being taken to the junction of **C** and the negative pole of the rectifier in the discharge path (**MR1**, Fig. 2). Again where it is known that an output pulse is desired from each positive and negative input alternation, so that the presence of two first switching valves is assumed, then a variation of the charge and discharge circuits using only one condenser and one second switching valve can be used with economy. This embodiment will now be described with reference to Fig. 4.

Valves **V4**, **V5** are of the same type as **V1** (Fig. 3) and in conjunction with the input transformer **T**, grid current limiting resistances **R19**, **R20** and anode resistances **R21**, **R22**, perform the same functions as **V1**; that is they act alternately as switches. The condenser **C** is therefore alternately charged in opposite senses from the supply **E**, and by means of **MR1**, **MR2**, the voltage on **C** is alternately limited to a positive maximum equal to **E** minus the steady drop *e* on **R23** corresponding to *e***1** of Fig. 2, with respect to the negative busbar. This value is also the maximum negative voltage on **C** with respect to the negative busbar, since the waveform on **C** is alternating having equal positive and negative excursions of *E—e*. Since one or the other side of **C** is always connected to the negative busbar, it follows that use can be made of either the positive or the negative excursion. In the present case, it is preferred to use the negative excursion, since when this is applied to the succeeding valve **V6** it will result in positive anode voltage pulses. In order to do this selectively and without shunting **C** by the grid circuit of **V6** when the positive excursion obtains, rectifiers **MR3**, **MR4**, are inserted in the grid lead. Hence only the negative voltage excursions of **C** are applied to **V6**, and the positive excursion time interval merely results in a hiatus in the waveform. The time taken to reverse the voltage on **C** is again independent of **E**, since *e* is a fraction thereof, and independent of the input half cyclic time provided only that this be larger; it is dependent only on the alternate time constants **C.R21** and **C.R22**, and if simultaneous breakdown on a symmetrical alternating input waveform is desired, then the resistances should be equal. It follows that the time taken for either positive or negative voltage excursion is also constant, and so the output voltage pulses of **V6** will be rectilinear, of constant time, and controllable, constant amplitude, if the action and circuit of **V6** is similar to that of **V2** in Fig. 3. The remainder of the circuit is similar in action and characteristics with that of Fig. 3, **R23** and **R24** of Fig. 4 acting as a potentiometer like **R4**, **R5**, **R6**, of Fig. 3, **R25**, **R26**, **R27**, **R28**, **R29**, **R30**, **R31**, **R32**, **R33**, **R34** of Fig. 4 corresponding respectively to **R7**, **R8**, **R9**, **R10**, **R11**, **R12**, **R13**, **R14**, **R15** and **R16** of Fig. 3. **MR5** corresponds to **MR2**, **N1** to **N**, **V7** to **V3** while **F** and **L** and **E** have the same references in the two figures.

The circuit of Fig. 4 will therefore produce a strictly linear mean output current proportional to the input frequency up to a frequency whose half cyclic times equal the respective finite charge times of **C**; higher frequencies will then produce only the same constant output. In these respects its action is precisely the same as Fig. 3, but it suffers two defects . The first is that the output under comparable conditions, can never be greater than one half that of Fig. 3, because only half of the total condenser voltage change can be used. The second is that is depends entirely for its consistent functioning on the simultaneous alternate switching of **V4** and **V5**, with no hiatus or overlapping. However, provided the grid circuit time constants can be kept negligibly small compared with the desired range of half cyclic input times, this operation error is also negligible. The invention as described, or modified as regards circuit details to achieve the desired objects of constant time and amplitude pulses by methods familiar to those skilled in the art, may be applied to a variety of uses. It may be used as a direct reading frequency meter by smoothing the output with mechanical inertia (i. e. a direct current meter) or by the use of electrical filters. In the latter case it may be applied as the control element for a remote source of alternating energy as in the well known "Vocoder" system of speech transmission, referred to in "Bell Laboratories Record," vol. 18, p. 122.

The performance of the invention as a frequency meter depends largely on the efficiency of the switching valves, such as **V1** and **V2**. If pentodes having a high value of control grid to screen grid amplification factor and low grid and anode capacitances are used, no difficulty is experienced in obtaining the desired linear characteristic up to at least 25,000 cycles. The modern high-frequency pentode such as the **EF50** is quite adequate, if used in conjunction with anode resistances of the order of 50,000 ohms (i. e. **R2**, for instance).

The circuits are amenable to the use of commercial components, provided their stability is good, seeing that the maximum range frequency can be adjusted in situ by coverting **R6** into a potentiometer and taking **R3** to the tap. All that is than necessary, is to move the tap away from the negative busbar when operating to the desired highest range frequency, until the output just begins to fall. The main ranges can of course be altered at will by selecting condensers for **C** in the desired ratio to the input frequency supplied. For instance for a range of 0–250 cycles, **C** can be 0.02 μf.; for 0–2,500 cycles, **C** can be 0.002 μf. and so on, assuming **R3** is 100,000 ohms.

The mean D. C. output is truly linear, as tested by a precision oscillator and mirror scale output meter, up to the desired maximum range frequency. This feature is of great importance not only in facilitating its production and use, but in its applications. In the case of the well known Vocoder application, for instance, where this device measures the instantaneous pitch frequency of the voice and transmits the pitch control current to the reception apparatus, it enables rapid setup of the overall circuit since any error can only be one of overall gain. Also attenuation variations of the transmission medium give a linear error in the reproduced pitch frequency, and more important, in the harmonics of the pitch frequency which are used to provide the essential speech outputs of the various channels. A non-linear frequency meter of the conventional type, in which the slope of the output decreases with increase of frequency is liable to give great errors of frequency with decrease of attenuation in the medium, apart from needing an inverse nominal reproducing characteristic. With a well known arrangement, for instance a pitch frequency of 250 cycles in the originating voice, will be reproduced as 350 cycles with 1 db. gain on the medium or as 540 cycles with 2 db. gain, or as 950 cycles with 3 db., and so on. With the present meter and a linear reproducer, the corresponding pitch frequency errors are 280, 315 and 350 cycles.

The output is independent of supply variations at any input frequency, and of input level above a peak value of about 4 volts between the grid and cathode of the first valve. The input impedance per grid can normally be made as high as 1 megohm (i. e. R1) and is only limited by the time constant of the grid circuit, which has the effect of delaying the switching on of V1, so that the available half cyclic time for discharging is reduced. Output is also substantially independent of input waveform, provided this is not re-entrant to less than about 4 volts above its mean value, although the upper limit of frequency may be curtailed if there is marked difference between the half cycle periods.

The output is unlimited over the given frequency range, the maximum being only dependent on the D. C. output of V3 from the supply voltage E. A typical design using a valve having $u=12$, and internal impedance 1,000 ohms, with E at 150 volts nominal, gives a maximum output of 80 volts D. C. on 2,200 ohms or 3 watts. The well known frequency meter with a fundamentally non-linear out/frequency characteristic, is incapable of delivering large outputs if any approximation to a linear law is desired, because it is only linear to 3% over about one third of its total output range.

The invention may also be used as a frequency selective device, by allowing only the desired range of mean D. C. outputs to be effective. In this connection the smoothed D. C. output would be applied to a non-linear resistive circuit, which by appropriate biasses, would only pass a certain range of D. C. voltages or currents. In this latter connection it can be used to discriminate against speech over a given transmission medium, provided the signalling frequency is higher, and the output is also independent of received level over a wide range above that necessary just to operate the first switching valves. To a very large degree the output is also independent of applied waveform, provided the latter is not re-entrant below the lower operating level. It may also be used to convert frequency modulated signals into amplitude modulated signals, since it operates essentially on the input half cyclic time, and incorporates a limiting action as regards any fortuitous input amplitude changes above the minimum operating level.

The above applications all infer that the pulse output is smoothed so that only a substantially steady D. C. current is used. However, it is possible to use the actual individual output pulses, since they represent known time intervals of constant amplitude whose initiation is only dependent on the sense of the input change.

Thus as the invention stands, it may be used to restore a measure of uniformity to input pulses whose time periods have suffered distortion over the transmission medium. By dispensing with the transformer T and applying the input pulse waveforms directly to V1, it can be arranged that a constant time, constant amplitude, rectilinear output pulse is generated, whenever, the input changes from a negative to positive grid voltage. The device is then a constant time impulse corrector, and the output of V2 or V3 may directly energise an electromechanical relay. Furthermore this function can be carried on independent of input level, provided the input change exceeds the minimum operating level. This action is also substantially independent of input wavefront slope, if the latter be constantly repeated, because only the arrival of the succeeding positive input wavefront is necessary, and any delay due to the low slope is passed on solely as a time delay.

With some small additions to the circuit, it can be arranged that it functions as an impulse corrector giving a constant pulse time percentage of the input cyclic time, this being sometimes preferable in pulse signalling systems which involve the operation of slugged relays. Referring to Fig. 2, the output pulse time is an exponential function of the three voltages E, $e1$, $e2$, and the discharge time constant. For instance, if a be the reciprocal of the discharge time constant and t the output pulse time, then we have

$$\frac{e2}{E-e1+e2}=\epsilon-at$$

Now let $e1$ be equal to $e2$, and also let $e2$ be equal to $E\epsilon^{-bT}$, where b is the reciprocal of another time constant and T is the cyclic time of the input pulses, then it is obvious that $at=bT$, whence we have

$$t=\frac{bT}{a}$$

Thus the output pulse time is a constant fraction of the cyclic time, if b and a are constants.

Alternatively we have

$$\frac{t}{T-t}=\frac{b}{a-b}$$

and as $T-t$ is the remaining portion of the input cyclic time then equating $e2$ to a function $E\epsilon^{-c(T-t)}$ will give the same effect, namely an output of constant percentage, where c is $a-b$.

Thus if $e1$ equals $e2$, and is made exponentially dependent on either the cyclic input time or the remaining period, then the object is attained. Putting this into conventional language for an automatic telephone system, this means that $e2$ must be exponentially dependent on either the sum of the make and break times, or on that one of these which initiates the output pulse.

Now if R5 in Fig. 3 be replaced by a valve (i. e. anode and cathode) and R4 and R6 be equal and large compared to the valve impedance, then the voltages $e1$ and $e2$ will be equal and controllable by the positive grid input. It now remains to sustain on the grid a voltage proportional to $E\epsilon^{-yt}$, where t is the input cyclic time or the unused portion thereof, and y is the reciprocal of a time constant related to the discharge time constant C.R3 by the desired output percentage. Such a grid voltage can be obtained with respect to the negative busbar, by allowing a further condenser to charge via a further resistance from the busbars, the condenser being connected to the positive busbar. The condenser charge is initiated by the beginning of the input cycle, or by the beginning of the unused period as the case may be, with the aid of a further switching valve operated from the input. At the completion of the charge, due to the input, the condenser voltage is transferred via a rectifier to a small condenser connected between the positive busbar and the grid of the control valve (i. e. controlling $e2$). Thus the steady grid voltage is made proportional to $E\epsilon^{-yt}$, and the succeeding pulse output of the circuit will be corrected to have a constant percentage.

It is obvious of course, that the first input period cannot be adjusted, since one must wait for the completion of the cycle. Hence the first output pulse will be of constant time type, and in order to cover a wide range of cyclic times it is necessary that this first pulse be less than the lowest cyclic time (i. e. at the highest input "speed"). This will limit the percentage correcting properties of the circuit to inputs having cyclic times lower than that which would give the constant time pulse at the correct percentage; for greater cyclic times the output will be of constant time pulse type. However this is of no great practical disadvantage, since the percentage functioning of automatic circuits is most apparent of higher speeds.

These impulse correcting circuits can of course be applied to the conversion of one pulse system to another, in terms of time or percentage. For instance the two most common systems, employing time periods in the ratios of 66:33 and 50:50 can be worked together by interposing the above correcting devices at the transition point.

I claim:

1. In an impulse generator; a source of potential; a pair of resistors, a condenser, and a second source of potential serially connected across said first source; means for at times shunting one of said resistors, said condenser, and said second source of potential; a rectifier and a third source of potential serially connected in shunt of the other one of said resistors; and a second rectifier connected in shunt of said one resistor and said second source of potential; whereby the condenser is charged and discharged between predetermined limits in finite time intervals in response to removal and replacement of said first shunt.

2. An impulse generator as claimed in claim 1 in which said second and third sources of potential are derived from said first source of potential.

3. Apparatus, having input and output branches which is arranged to produce in its output branch a direct current having an average value proportional to the frequency of a source of alternating current connected to its input branch, comprising a source of direct current, a condenser, a pair of resistors, a circuit for charging said condenser from said source of direct current in series with one of said resistors, a circuit for discharging said condenser in series with the other of said resistors, means controlled by the alternating current wave in the input circuit for causing said condenser to be charged and discharged in said circuits at least once for each cycle of the input wave, a voltage responsive device connected between the condenser and the output branch, said device controlled by the voltage across the condenser for producing in the output branch a square wave impulse of fixed amplitude and time duration for each cycle of charge and discharge of the condenser.

4. Apparatus, having input and output circuits, which is arranged to produce in its output circuit a direct current having an average value proportional to the frequency of a source of alternating current connected to its input circuit, comprising a source of direct current, a condenser, means controlled by the alternating current wave in the input circuit for causing said condenser to be charged from said source of

direct current and to be discharged at least once for each cycle of the input wave, and means comprising a thermionic valve and a source of constant potential connected so as to be controlled by the voltage across the condenser for producing in the output circuit a square wave impulse of fixed amplitude and time duration for each cycle of charge and discharge of the condenser.

5. In an apparatus as claimed in claim 4, means for adjusting the amplitude of said square wave impulse to change the ratio between the average value of the output current and the input frequency.

6. In an apparatus as claimed in claim 4, a filter interposed between said last means and the output circuit to convert the square wave impulses into a steady direct current.

7. Apparatus having input and output circuits which is arranged to produce in its output circuits a direct current having an average value proportional to the frequency of a source of alternating current connected to its input circuit comprising a source of direct current, a condenser, means controlled by the alternating current wave in the input circuit for causing said condenser to be charged from said source of direct current and to be discharged at least once for each cycle of the input wave, means controlled by the voltage across the condenser for producing a unidirectional current in the output circuit having an average value proportional to the number of charges and discharges of said condenser per unit of time, and means comprising an asymmetrical conductance element and a source of biasing potential connected in circuit relation with the condenser for causing the potential across the condenser to reach a constant value in a finite time interval during the charging or discharging thereof whereby a linear relationship between output current and input frequency is obtained through the elimination of the asymptotic portion of the condenser charging or discharging curve.

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