

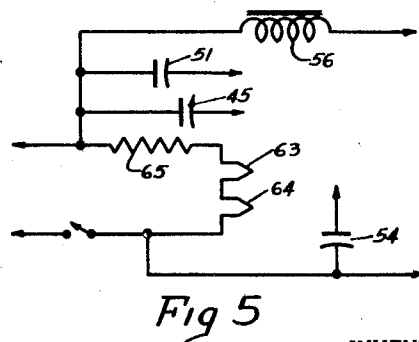
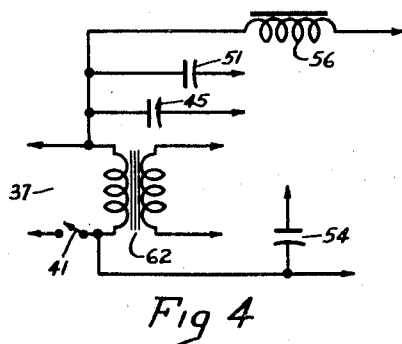
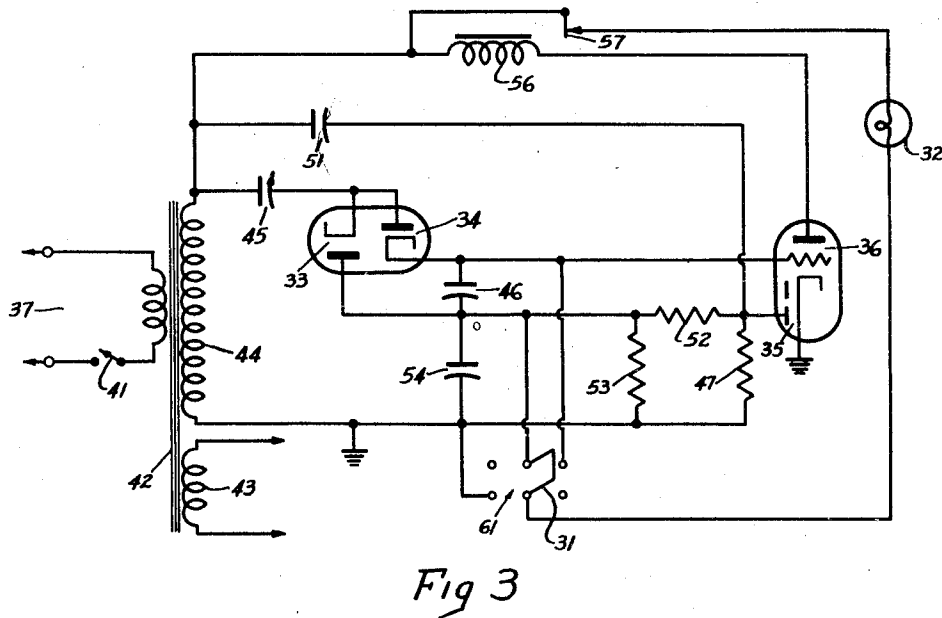
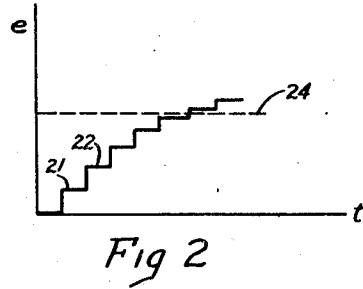
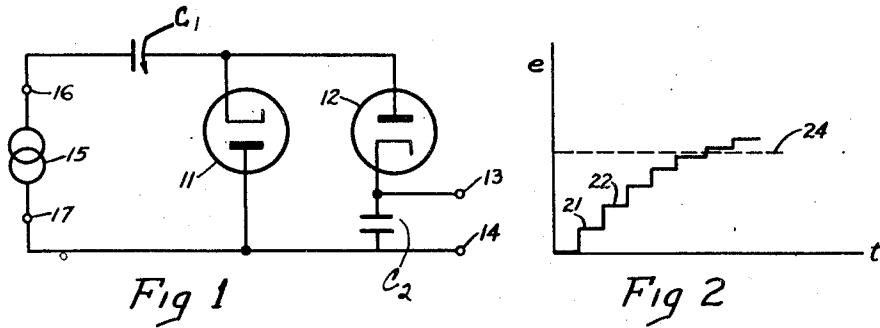
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J. C. TELLIER

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ELECTRICAL TIMING CIRCUITS

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INVENTOR.
JOSEPH C. TELLIER
BY
Ostrolenk & Fisher
ATTORNEYS

UNITED STATES PATENT OFFICE

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ELECTRICAL TIMING CIRCUITS

Joseph C. Tellier, Penn Wynne, Pa., assignor, by mesne assignments, to Philco Corporation, Philadelphia, Pa., a corporation of Pennsylvania

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This invention relates in general to electronic timing circuits and more particularly to circuits providing variable time delays and useful in connection with photographic operations and the like.

Timers or time delay devices are used, as is well known, for obtaining proper exposures in the preparation of photographic prints and enlargements, and for reproducing these exposures as often as required. Heretofore, such timers have operated almost always on mechanical principles, using chronometric escapement mechanisms and small synchronous motors when long delays have been required. Time delay relays operating on electrical principles are available where comparatively short, non-adjustable delays are needed. All mechanical delay systems are seriously limited by cost of manufacture and lack of simple, uniform adjustment.

There have been proposed a number of electronic circuits for obtaining time delays for application as hereinabove described. Such circuits generally obtained a time delay in a chargeable resistance-capacitance, or RC network, and for this reason have never been successful. Thus to obtain a long time delay, the RC time constant is correspondingly large. Large capacitors are bulky and expensive since low loss is a requirement. Large resistors, of the order of several hundred megohms, are unstable. Moreover, it is costly and impractical to construct very large variable capacitors and very large variable resistors. Some systems utilize a series of fixed resistors and a selector switch, but this provides a delay variable only in fixed steps.

The present invention contemplates and has as a primary object the provision of a novel electronic means for obtaining a continuously adjustable time delay, covering a desirable timing range from seconds to many minutes.

In the resistance-capacitance timer systems, the circuit resistance functioned to limit an electrical capacitor charging current to a small value.

Another object of the present invention is thus to provide means for slowly and accurately charging a capacitor by a current which flows, in short, periodic pulses at a predetermined frequency.

As will herein be disclosed in greater detail, a conventional 60 cycle alternating current power line may be used as a source from which the charging pulses may be derived. A pulsed current has an average value which is dependent upon frequency, amplitude and pulse duration.

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A further object of the present invention is to provide a simplified electrical network, involving the use solely of inexpensive, stable, components, for varying the pulse duration so as to correspondingly vary the average current. The latter variation is smooth and may extend over a wide range, and a particular value is readily reproducible.

The instantaneous charging current in a resistance-capacitance network is a function of the applied potential, and for this reason accuracy can only be obtained when a stabilized power source is used. In the present invention accurate timing is obtained when used on an unregulated power line, independent of line voltage fluctuations.

These and other objects of the present invention will now become apparent from the following detailed specification taken in connection with the accompanying drawings, in which:

Figure 1 is a schematic diagram of a frequency dividing and pulse counting circuit illustrated to facilitate an understanding of the present invention;

Figure 2 is a graphical illustration of the voltage waveform obtained in the operation of the circuit of Figure 1;

Figure 3 is a complete schematic diagram of the novel electronic timer utilizing the circuit principles shown in Figure 1;

Figure 4 is a schematic diagram of a possible modification and simplification of the circuit shown in Figure 3; and

Figure 5 is a further modification of the circuit illustrated in Figure 3.

A basic electrical circuit for obtaining a potential which rises at a slow, predetermined rate is illustrated in Figure 1 and reference is now made thereto. The circuit comprises essentially a pair of oppositely phased diodes or other suitable rectifiers 11 and 12, and a pair of timing capacitors C1 and C2. Capacitor C2 is connected in the cathode circuit of diode 12. The output potential of the circuit appears at terminals 13 and 14, across capacitor C2. The system is energized by an alternating current source 15 of stable frequency at input terminals 16 and 17.

Assume that capacitor C2 is initially discharged so that the output potential is zero. From the connection of the diodes, it is evident that on the first negative half-cycle, that is, when terminal 16 is driven negative with respect to terminal 17, diode 12 will be non-conductive or insulating and diode 11 will be conductive. Con-

duction through diode 11 will charge capacitor C₁ to the peak of the applied input voltage.

On the positive half-cycle which follows, the diode 11 is non-conductive while diode 12 conducts. As a result, capacitors C₁ and C₂ are charged in series from the power source. As is well understood, the potential distribution in a series capacitor circuit is a function of the relative capacitance of the two capacitors. It is readily shown that at the termination of this first complete cycle, the fraction of the peak-to-peak input voltage appearing across the output capacitor C₂, would be:

$$(1) \quad \frac{C_1}{C_1 + C_2}$$

Thus, capacitor C₂ is charged a definite amount during the first cycle.

At the end of the next full cycle of the source 15, through the conduction of the diodes in a manner as previously described, another increment of charge is added to the output capacitor C₂, raising the potential thereof by another definite amount. The amount of the latter increase is a fraction, equal to that of (1) above, of the difference between the peak-to-peak input voltage and the voltage already present on the capacitor C₂.

The fact that the voltage added in the period of one cycle is a function of the existing voltage across C₂, results in an overall potential rise, which is non-linear, and which in the absence of other phenomena, increases in periodic steps of ever decreasing magnitude, asymptotically toward a value to the peak-to-peak input voltage.

The voltage rise across capacitor C₂ and that appearing at output terminals 13 and 14 is graphically illustrated in Figure 2. Thus, at a time equal to zero, the output voltage is zero. At the end of the first input cycle, the voltage is stepped to value 21. At the end of the second cycle, the value is 22 and so on as the stepped wave approaches the peak-to-peak input. The graph of Figure 2 illustrates that the capacitor C₂ is charged in pulses, and that for a constant amplitude input signal, the rate of rise is a function of the input frequency.

In the actual application of the circuit of Figure 1 to practical counting or timing devices, the stepwise rise of potential across capacitor C₂ is utilized to trigger an electrical device when this rising potential exceeds a predetermined triggering potential. Upon triggering the output capacitor is discharged so that the process may be initiated again when required. When used as an electronic frequency divider, it has been the practice to establish a triggering potential, such as 24, Figure 2, which was between the output voltages for two successive steps and a definite, small number of steps from the zero. In this manner triggering would always occur after said definite number of steps so that the trigger rate was a definite sub-multiple of the input voltage frequency.

If the circuit input frequency is not constant, but of a constant peak-to-peak amplitude, then the number of output triggers is a measure of the number of input cycles. This fact is made use of when this circuit is used for the counting of rapidly applied but irregularly spaced input pulses, such as encountered in the use of the Geiger-Müller counter tubes for measuring certain forms of radiation.

In all of the above described applications of the circuit of Figure 1, it was essential that the steps

of voltage, as 21 and 22 in Figure 2, be comparatively large so that the subsequent circuit could be triggered upon the completion of a certain small number of input voltage cycles. As mentioned before, the rate of output voltage rise is a function of frequency, and is also a function of the ratio of the capacitances of C₁ and C₂. Thus, for counting and frequency dividing purposes, the capacitance ratio, say:

$$(2) \quad \frac{C_1}{C_2}$$

must not be smaller than 1/25, or the voltage steps would be indistinct and unable to repeatedly function to perform a specified count.

Considering the other extreme, however, it is evident that if the capacitor ratio (2) is extremely small, then the output voltage, Figure 2, will comprise a stepped or pulsed voltage wherein the individual steps are so small as to provide effectively a gradually rising output voltage, for a fixed alternating input voltage. An exponentially rising potential may be obtained across a capacitor in a charging resistance-capacitance network. However, to accomplish a rise of potential over a period of time of the order of minutes, the values of resistance and/or capacitance would be wholly impractical and the output unstable.

In Figure 1, the capacitor C₁ is made small relative to capacitor C₂. Furthermore, the capacitor C₁ is variable, whereby for an input voltage source 15 of constant frequency and substantially constant amplitude, the output potential rate of rise to the peak-to-peak input is a function of the magnitude of the capacitor C₁. Actually the time required for the output potential to rise to a particular value is an inverse function of the size of capacitor C₁, so that for a convenient, readily available capacitor combination C₁, C₂, a wide range of charging rates is obtained upon the adjustment of C₁. Extreme slowness of charging may be obtained with a value for C₁ which offers no practical difficulties.

If the input voltage source 15 is the conventional 60 cycle power line, then the pulses of current applied to charge capacitor C₂ are at the same frequency. Generally the power line frequency is extremely stable so that it may be used as a standard of time. For an output voltage which rises slowly in steps of 1/60th of a second, the voltage may for all practical purposes be considered a continuous variation of the type obtained in an RC network charged by a D. C. source. The rising output voltage is employed to trigger subsequent electrical apparatus when it exceeds a pre-arranged triggering potential. Of course, it is not practically possible to have the tripping occur at a precisely numbered step with respect to zero, since the steps are small, but this is not important since the present application of the circuit does not require accuracy of that order. Actually, triggering within a range of a few steps of a 1/60th second each is sufficient from a practical standpoint.

In Figure 3 there is illustrated an electronic timer incorporating the principles hereinabove discussed in connection with Figure 1. The timing circuit shown has many applications and will herein be discussed in connection with the problem of timing the exposure of photographic prints. It is the purpose of the circuit, when switch arm 31 is thrown to the left, to energize a printing lamp 32 for a specific amount of time, the latter being adjustable at will in the range of seconds or minutes. It will be shown that the

timer of Figure 3 embodies the features of the circuit of Figure 1.

Basically the circuit comprises a double diode electron tube having rectifier sections 33 and 34, and a diode-triode electron tube having a diode section 35 and triode section 36. The circuit is energized from an alternating current power line at terminals 37 when on-off switch 41 is closed. The input circuit consists of a transformer 42, the primary of which is connected to the line terminals 37. A low voltage secondary winding 43 is used to energize the tube heaters. The other transformer secondary winding 44 is grounded at one end thereof, and connected at the other end to the cathode of diode 33 and plate of diode 34 through a variable capacitor 45, the latter corresponding to variable capacitor C₁ in Figure 1. The diodes 33 and 34 correspond to diodes 11 and 12 respectively in Figure 1.

The cathode of diode 34 and plate of diode 33 are connected by an output capacitor 46 which is the equivalent of capacitor C₂ in Figure 1. The output potential is applied to triode 36 by connecting the control grid thereof to the cathode of diode 34. The cathode of triode 36 is grounded. The diode section 35 is used to provide a negative D. C. voltage. Thus, the plate of diode 35 is connected to the grounded end of secondary 44 through a resistor 47 and to the other end of transformer 44 through a capacitor 51.

In operation, conduction in diode 35 charges capacitor 51 and maintains the plate of the latter diode at a negative potential equal to the peak secondary voltage. The series combination of resistors 52 and 53 form a voltage divider across this negative potential; capacitor 54 shunting resistor 53 forms, in combination with resistor 52, a filter for this rectified, negative potential. The capacitor 54 functions also to establish an alternating current connection from the anode of diode 33 to ground.

The plate of triode 36 is returned to the secondary winding 44 through the coil 56 of a single pole relay having normally closed contact 57 thereon. The contact 57 is in series with the lamp 32.

When the switch arm 31 of the double pole-double throw control switch 61 is closed to the right, the circuit from secondary 44 through the lamp is opened at the switch. The switch, in this position, also short-circuits capacitor 46, placing the control grid of triode 36 at a negative potential with respect to ground equal to the drop across resistor 53. This potential is more than that required to cut the triode 36 off, leaving relay contact 57 in the position shown.

When the switch arm 31 is now thrown to the left, the circuit through contact 57 is complete and the lamp 32 is energized. Simultaneously, the short across capacitor 46 is removed, and the comparatively smooth but stepped charging waveform is developed across capacitor 46 as described in detail in connection with capacitor C₂, Figure 1. The charge on capacitor 46, passing through diode 34, is such as to drive the grid of triode 36 positive with respect to the initial potential at this point. As the charging of capacitor 46 continues, the potential difference between grid and cathode of triode 36 diminishes, until the triggering point, when triode 36 conducts sufficiently to cause relay 56 to open its contact 57, de-energizing lamp 32.

It is to be noted that insofar as the charging is concerned, capacitors 46 and 54 are in series. These are large compared to capacitor 45, so that

the latter effectively determines the charging rate. Furthermore, the potential across capacitor 54 remains practically constant, for although it charges up on one-half cycle as does capacitor 46, it discharges an equal amount through diode 33 on the reverse half-cycle.

To place the circuit of Figure 3 in condition for operation once again, it is only necessary to throw switch arm 31 to the right. This instantly discharges capacitor 46, so that the cycle may be repeated by throwing the switch to the left. The time of exposure, or time during which lamp 32 is on, is determined by the setting of variable capacitor 45. Accordingly, its controlling dial (not shown) may be calibrated directly in terms of exposure time accomplished with each setting thereof. A completely electronic, adjustable timer is hereby attained. The variable element is a readily realizable, small trimmer capacitor and all other elements are likewise conventional, inexpensive radio components.

Figures 4 and 5 illustrate possible modifications of the circuit of Figure 3 for the purpose of simplifying the manufacturing procedure and reducing the cost thereof. The circuits of Figures 3, 4 and 5 are similar except for the input circuits. All like elements are correspondingly designated.

In Figure 4, a small transformer 62 is used solely to energize the heater circuits of the two tubes. The charging current flowing through variable 45 is taken directly from the line 37 without an isolating transformer.

In Figure 5 the circuit is still further simplified by the elimination of the filament transformer. Thus, the heaters 63 and 64 are connected in series with a dropping resistor 65 of suitable value. Again, the charging circuits are connected directly to the line. The remainder of the circuits of Figures 4 and 5 are as shown in Figure 3 and have been omitted for clarity.

It will be noted that in all three embodiments, Figures 3, 4 and 5, the initial bias placed on the control grid of triode 36 is equal to the drop across resistor 53, which in turn is a function of the line voltage as is the voltage applied to the charging circuit. Hence, if the input voltage varies, the consequent variation in charging rate is accompanied by a variation in the level which the triggering voltage must attain to operate triode 36. The latter variations tend to compensate for each other and provide accuracy upon an unregulated supply line.

As an example of circuit operation, the embodiment of Figure 3 was operated with component values as follows:

Input voltage	110 volt—60 cycle line
Capacitor 45	10 mmf.
Capacitor 46	0.5 mf.
Tubes	6H6
Tubes	6SR7

and it was found that an accurately reproducible delay of eight minutes was obtained. An RC circuit capable of accomplishing the same result would require a resistor of 2400 megohms for a capacitor of 0.5 mf. and a stabilized charging potential of 250 volts. A resistor of this value, particularly in variable form, is practically impossible to obtain with a degree of stability. No difficulty is experienced in obtaining capacitor 45, however.

Thus, in accordance with the principles of the present invention, long delays are obtained by the process of charging a capacitor, not by a

small current limited in value by resistance, but by a pulsed or discontinuous current. The charging takes place in small definite steps governed by the value of a small variable capacitor.

The particular circuit components hereinabove illustrated are subject to considerable modification. As an example, the triode control tube may be, for heavier duty applications, substituted for by a gas thyatron or the like. Furthermore, the application of the circuit need not be limited to photographic systems as mentioned. Conduction in the triode may be used to turn on or off various apparatus, as desired.

Since many variations and modifications of my novel time delay device will now be apparent to those skilled in the art, I prefer to be bound not by the specific illustrative embodiments described above, but only by the appended claims.

I claim:

1. Electrical time delay apparatus operative to energize an electrical device for a definite period of time comprising a fixed capacitor and switching means normally operative to substantially short circuit said fixed capacitor and de-energize said electrical device, an alternating current source including a transformer having a primary winding connected to said source and a secondary winding, circuit connections including said switching means operable to connect said electrical device to said secondary winding and to simultaneously permit the charging of said fixed capacitor, a variable capacitor and a first rectifier in said circuit connections, said fixed capacitor charging from said alternating current source through said secondary winding, said variable capacitor, and said rectifier element, a second rectifier, said fixed capacitor discharging through said second rectifier and said secondary winding, said variable capacitor determining the rate of charging of said fixed capacitor, an electron tube, a relay in circuit with said electron tube and normally de-energized, means including circuit connections whereby said fixed capacitor when charged to a predetermined potential is operative upon said electron tube to energize said relay and disconnect said electrical device from said alternating current source.

2. Electrical time delay apparatus operative to energize an electrical device for a definite period of time comprising a fixed capacitor and switching means normally operative to substantially short circuit said fixed capacitor and de-energize said electrical device, an alternating current source including a transformer having a primary winding connected to said source and a secondary winding, circuit connections including said switching means operable to connect said electrical device to said secondary winding and to simultaneously permit the charging of said fixed capacitor, a variable capacitor and a first rectifier in said circuit connections, said fixed capacitor charging from said alternating current source through said secondary winding, said variable capacitor, and said rectifier element, a second rectifier, said fixed capacitor discharging through said secondary rectifier and said secondary winding, said variable capacitor determining the rate of charging of said fixed capacitor, an electron

tube, a relay in the plate circuit of said electron tube, additional rectifier means electrically connected to said tube for obtaining a fixed negative potential for said tube, a common cathode for said electron tube and additional rectifier, said negative potential providing a bias cutting off said electron tube and de-energizing said relay, said fixed capacitor when charging altering the bias on said electron tube and operative thereon when charged to a predetermined potential to overcome said cut off bias to energize said relay, said relay when energized disconnecting said electrical device from said alternating current source.

3. An electrical timing circuit comprising a transformer having a primary winding connected to a source of power and a secondary winding, a first and a second diode, a variable capacitor connecting the cathode of said first diode and the anode of said second diode to one terminal of said secondary winding, an output capacitor for connecting the anode of said first diode to the cathode of said second diode, a triode, and circuit connection for connecting the cathode of said second diode to the control grid of said triode, a further diode, the cathode of said further diode being also the cathode for said triode, a resistor for connecting the anode of said further diode to one terminal of said secondary, a capacitor for connecting the anode of said further diode to the other terminal of said secondary, and a capacitor connecting the anode of said first diode to the cathode of the second diode.

4. An electrical timing circuit comprising a transformer having a primary winding connected to a source of power and a secondary winding, a first and a second diode, a variable capacitor for connecting the cathode of said first diode and the anode of said second diode to one terminal of said secondary winding, a capacitor, circuit connections for charging said capacitor from said secondary winding through said first rectifier and discharging said capacitor over a circuit including said secondary winding and said second diode, a triode, a further diode, the cathode of said further diode being also the cathode for said triode, circuit connections for connecting said first diode to the control electrode of said triode, circuit connections including said secondary winding and said further diode for energizing said triode and an electrical device connected to the anode of said triode.

JOSEPH C. TELLIER.

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