Sept. 28, 1965 C. L. DU VIVIER 3,209,211

TIMING CIRCUIT

Filed Aug. 10, 1962 2 Sheets-Sheet 1

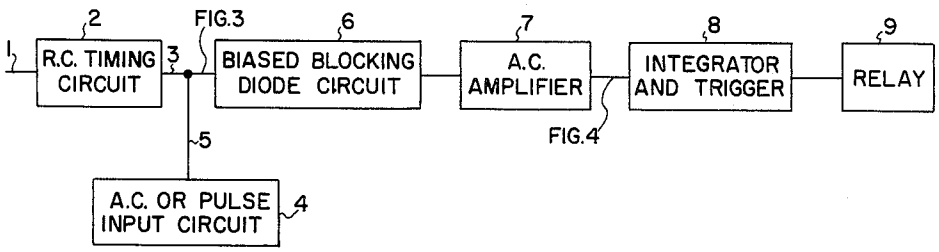


FIG. 1

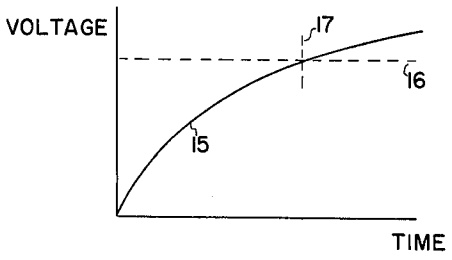


FIG. 2

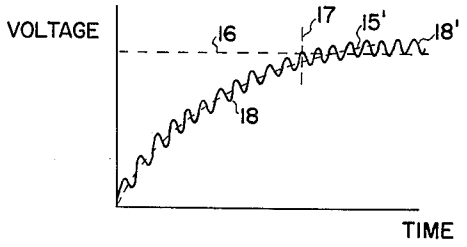


FIG. 3

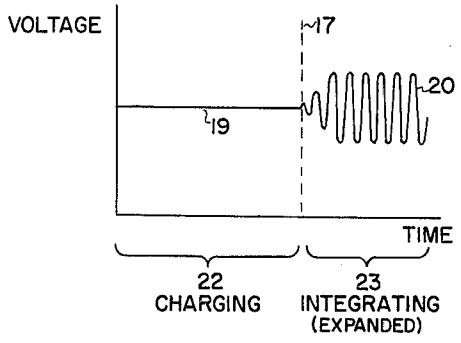


FIG. 4

INVENTOR.
CHARLES L. DUVIVIER

BY Edward H. Calvert

ATTORNEY

Sept. 28, 1965 C. L. DU VIVIER 3,209,211

TIMING CIRCUIT

Filed Aug. 10, 1962 2 Sheets-Sheet 2

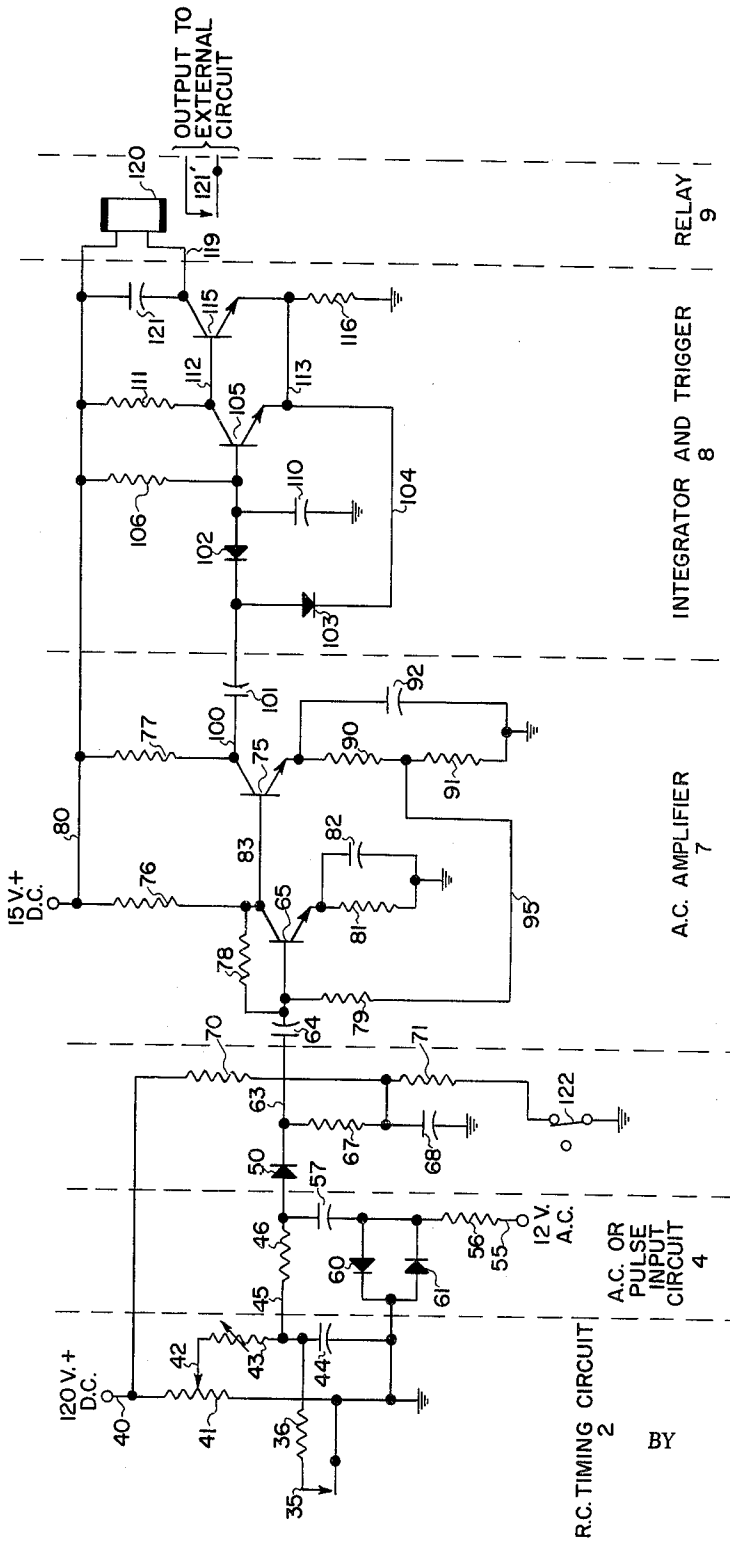


FIG. 5

INVENTOR.
CHARLES L. DUVIVIER

BY

Edward H. Raines

ATTORNEY

United States Patent Office 3,209,211 Patented Sept. 28, 1965

3,209,211

TIMING CIRCUIT

Charles L. Du Vivier, Darien, Conn., assignor to Laboratory for Electronics, Inc., Boston, Mass., a corporation of Delaware

Filed Aug. 10, 1962, Ser. No. 216,082
10 Claims. (Cl. 317—142)

This invention relates to a timing circuit adapted to be used as a part of a vehicle traffic controller or computer for example. In particular, it relates to a timing circuit which enables the use of transistors in lieu of vacuum tubes.

In the design of traffic control systems, timing circuits are utilized in a variety of ways, both in centralized controllers and in local controllers. Timing circuits are particularly needed for the purpose of timing intervals between traffic light changes. This timing may or may not be varied in accordance with a pre-set pattern, or in accordance with traffic flow actuating tripping mechanisms. Examples of timing circuits usable in traffic control actuation, and for which the present invention may be substituted, are the electronic timing circuit disclosed in Brockett Patent No. 2,964,625, and in particular, the disclosure of FIG. 1 thereof; and in Barker Patent No. 2,989,728 in the timing circuit, shown in FIG. 2 thereof, used to actuate the stepping switch. In the latter patent, the timing is performed by the familiar method of charging a capacitor 74 slowly to the conduction voltage of a gas discharge tube 75 to operate a time interval termination relay 76.

As shown in these two patents, the usual timing device used is the RC (resistance-capacitance) timing circuit.

The output voltage of the RC timing circuit, whether or not it has added to it the alternating current or pulse, is normally passed through an amplifier and used to actuate a relay for purposes of running a stepping switch (see, for example, stepping switch 48 in FIG. 1 of the Brockett patent). Until the present invention, it has not been practical, however, to use a transistor amplifying circuit because, as is well known, the input to a transistor is essentially a low impedance circuit. It is, therefore, extremely difficult to time intervals of the order of magnitude required in controllers (from one second to ninety seconds), largely due to the shunt circuit path and consequent leakage currents associated with transistors connected to the timing capacitor. In order to obtain the desired time intervals and still be able to use such a low impedance amplification circuit, the timing circuit would require capacitors of extremely large value and, for their capacity, low leakage and very low charging resistance; such combinations are physically and economically undesirable.

Accordingly, the object of this invention is to eliminate the difficulties normally encountered in the use of transistorized circuits in conjunction with timing circuits by converting the output of the timing capacitor to a series of gated pulses which can be amplified by an alternating current coupled device.

Another object of this invention is to provide an improved timing circuit including a solid state biased diode in conjunction with an R-C circuit. It is economically practical to get diodes with very low reverse leakage at relatively high voltage. The employment of such diode in the circuit permits the use of a charging voltage as a timing capacitor much in excess of that which economical transistors would ordinarily stand, and, in addition, have much lower leakage, thus allowing the use of smaller capacitors and larger resistors to obtain the desired time range.

Another object of this invention is to provide for a

transistorized timing circuit using a condenser charging curve where the supply voltage may vary wthout inducing substantial errors in the timing.

A further object of this invention is to provide a timing circuit of the above nature that is adjustable so that the controlled interval may be set over a wide timing range within the limits of the circuit elements and yet remain sufficiently precise for the purposes.

A further object of this invention is to provide a timing circuit having a combined integrator and trigger unit for actuating a relay, which integrator and trigger unit, has an accelerated action at the time of triggering.

A still further object of this invention is to design a timing circuit using transistors and thereby having smaller size, smaller power consumption, less heat output, greater stability, and longer life.

These and other objects of the invention are obtained through the circuit shown in the attached drawings, and as described below:

FIG. 1 of the drawing is a block diagram showing the preferred circuit arrangement of this invention;

FIGS. 2, 3, and 4 are curves showing voltage time relationships in the prior art and in the circuit of this invention; and

FIG. 5 is a schematic diagram showing the preferred form of circuit arrangement for this invention.

FIG. 1, applied D.C. (direct current) voltage is provided at lead 1 going into R.C. timing circuit 2. This R.C. timing circuit provides an output at lead 3 on which is an exponential variation of voltage with time typical of a condenser charging through a resistance. A.C. or pulse circuit 4 produces a low voltage alternating current, or periodic pulses or clipped alternating current waves, as may be preferred, passing through lead 5 and applied to the output of R.C. timing circuit.

The combined voltage then passes to biased blocking diode circuit 6. Semiconductor or diode 6 allows passage of only that component of the output of this timing circuit 2 and the A.C. circuit 4 above the desired preset bias level of the biased diode, and passes it to alternating current amplifier 7. After amplification, the signal then enters integrator and trigger circuit 8, and as a result of amplification and integration in this circuit will operate relay 9.

FIG. 2 shows a typical exponential condenser charging curve, and shows voltage plotted against time. The horizontal line 16 on the curve is shown as representing some desired and convenient level such as the one lambda point (about 63% of applied voltage for example) at which it is desired to respond to the charge or voltage on the capacitor as completion of a desired time period at time line 17. This curve does not have any A.C. voltages impressed upon it. The voltage shown in the curve of FIG. 2 would be typical of the output voltage of R.C. timing circuit 2 without applied A.C. 4.

FIG. 3 shows the voltage of FIG. 2 with impressed upon it an additional alternating current voltage such as would be produced by the alternating current circuit 4. The curve 15 of FIG. 2, as recalibrated to a slightly lower characteristic 15', is shown in a dotted line underlying the total curve of FIG. 3. The curve 15' is slightly lower than curve 15 so that the added voltage of the wave in curve 18 will reach line 16 at line 17, i.e. at the desired time. For ease of illustration, the alternating current impressed upon the curve 15 as shown in FIG. 3, is of much lower frequency relative to the time interval represented in FIG. 3 than would occur in practice, i.e. the period of the A.C. wave is greatly exaggerated in FIG. 3. It will be noted that curve 18 becomes horizontal and is identified as 18' after it passes above line 16 because the blocking diode 6 has been so biased as to pass the voltage above

the level of line 16. Accordingly, the bottom portions of the A.C. input impressed upon curve 15' and shown in curve 18' are clipped after curve 18 reaches the line 16. Likewise, the curve 18' becomes horizontal as shown with the impressed alternating current voltage from that time forward during this particular cycle of operation of the timing circuit.

FIG. 4, therefore, shows the amplified output that will be produced from the blocking diode 6. For the time interval that the condenser of R.C. timing circuit 2 is charging until it reaches the bias level, the blocking diode offers high impedance and passes no current. Consequently, during such charging period 22, the output of blocking diode 6 as amplified by A.C. amplifier block 7 is a horizontal line 19 such as shown in the left-hand portion of FIG. 4. When the voltage on the R.C. timing circuit reaches the selected level the blocking diode 6 will pass the alternating current portion, and a wave form 20 such as shown in the right-hand portion of FIG. 4 will appear and commence an integrating period 23 in the timing cycle. The integrating period 23 as shown in FIG. 4 is greatly expanded in time for convenience of illustration and will actually involve a fraction of a second and thus be a negligible part of the timing period desired.

FIG. 5 shows the preferred form of circuit arrangement to accomplish the above objects. A direct current power supply 40 is applied across voltage divider resistance 41 to ground. This voltage is tapped at tap 42 and led to variable resistor 43 and capacitor 44 to ground. Resistor 43 and condenser 44 together are the R.C. timing circuit. The condenser voltage then is fed through lead 45 and resistor 46 to blocking diode 50. This voltage will be as shown in FIG. 2. An alternating current voltage, or if preferred, a pulse voltage is impressed on the circuit at lead 55 and passes through resistor 56 and condenser 57 to the input of blocking diode 50. If desired, oppositely connected clipping diodes 60 and 61 may be connected from one end of resistor 56 to ground in order to clip off the top rounded portions of the alternating current wave form applied.

The A.C. output of diode 50 passes through lead 63 and condenser 64 to the base of transistor 65. A load for the output of diode 50 is provided by resistor 67 and series condenser 68 leading to ground. Series resistors 70 and 71 connected between the power supply 40 and ground with the intermediate point connected to resistor 67, provide the bias for the blocking diode 50.

Transistor 65 and its associated transistor 75 provide a two-stage alternating current amplifier circuit for amplifying the output of the diode 50. Utilization of an alternating current amplifier in the circuit of this invention has the advantage of eliminating errors normally found in direct current amplifiers due to varying temperatures and other factors, since it eliminates the effect of variation of direct current characteristics. As is well known in the art, it is very difficult to build a stable D.C. amplifier, whereas A.C. amplifiers are easily made both stable and reliable.

Associated with transistors 65 and 75 are load resistors 76 and 77 respectively, and stabilizing resistors 78 and 79 respectively. The load resistors are connected to a power supply 80, which is 15 volts positive for example.

The emitter of transistor 65 is connected to emitter resistor 81 and by-pass capacitor 82 in parallel to ground. The collector of transistor 65 is connected to lead 83 to the base of transistor 75, and so into the second stage of the A.C. amplifier. The emitter of transistor 75 is connected to emitter resistor 90 and biasing resistor 91 in series to ground. The emitter is also connected to by-pass capacitor 92. It will be noted that stabilizing resistor 79 is connected between capacitor 64 and the point between resistors 90 and 91 through lead 95.

The output of the two-stage A.C. amplifier circuit is from the collector of transistor 75 and passes through lead 100 and coupling condenser 101 to diode 102 and diode 103 to transistor 105. Diode 102 is biased to pass the negative portion of the A.C. wave only. Positive portions of the wave passing through coupling condenser 101 go through diode 103.

The output of diode 102 leads to the totalizing condenser 110. A positive voltage is applied to totalizing condenser 110 from power supply 80 through resistor 106. Thus, condenser 110 is normally positively charged. The positive charge is discharged when a signal is passed through blocking diode 50 and through the A.C. amplifier circuit represented by transistors 65 and 75 to diode 102.

The collector of transistor 105 has load resistor 111 connecting it to the power supply 80. The emitter of transistor 105 is connected to lead 104 to the above-mentioned diode 103 adapted to pass positive portions of the input wave received from A.C. amplifier 7.

The collector voltage of transistor 105 is passed through lead 112 to the base of the transistor 115. The emitter voltage of transistor 105 passes through lead 113 to resistor 116 to ground. The direct current component of the current in the collector circuit of transistor 115 passes through coil 120 of the relay. Alternating current voltages are by-passed through condenser 121. Relay coil 120 is the coil of relay 9 shown in FIG. 1.

The circuitry represented by totalizing capacitor 110 and transistors 105 and 115 represent the integrator and trigger circuit 8 of FIG. 1.

In operation, a direct current power supply is applied at 40 through resistor 41 and is tapped for the desired potential at 42. The R.C. timing circuit 43, 44 is set for the desired time period by varying resistor 43. Thus when potential is applied at 40, capacitor 44 charges exponentially and the voltage on capacitor 44 and the output line 45 is similar to that shown in FIG. 2.

An alternating current voltage is impressed at 55 and, after being clipped through clipping diodes 60 and 61, it is impressed on an output of the RC timing circuit so that the total voltage wave form is fed to diode 50. This voltage has the appearance shown in curve 18 of FIG. 3.

Biasing resistors 70 and 71 have been so chosen and the tap 42 has been so adjusted that the blocking diode 50 will pass the output voltage shown as curve 18' in FIG. 3 when that voltage reaches the preset-level 16 in the desired length of time. Diode 50 will begin to conduct at this preset point in the timing cycle due to the fact that the voltage at the junction between resistor 46 and condenser 57 exceeds the voltage at the point between resistors 70 and 71.

There will be no output from diode 50 until the critical voltage for the selected point is reached. There will therefore be no output from the A.C. amplifier, as shown by 19 of FIG. 4. After the necessary time interval has passed, and the condenser has reached the required degree of charge, the blocking diode will allow the alternating voltage to go through and the output of the amplifier will be as shown at curve 20 of FIG. 4.

The alternating current component of the output of diode 50 passes through coupling capacitor 64 into the two-stage alternating current amplifier circuit previously described. The amplified output of this two-stage amplifier circuit passes through the capacitor 101 to the integrator and trigger circuit 8 previously described. While condenser 44 is being charged, transistor 105 is passing current to such an extent that transistor 115 is essentially cut off.

Totalizing capacitor 110 is normally positively charged through charging resistor 108 from power supply 80. When a signal passes through blocking diode 50 and the alternating current amplifying circuit, the negative portions thereof are applied to condenser 110 to discharge the condenser. As the voltage on totalizing capacitor 110 becomes less, the base to emitter current of transistor 105 decreases. This, in effect, decreases the collector current of that transistor, and so decreases the voltage

drop across resistor 111 which results in an increased voltage on the collector of transistor 105. Such increased voltage will, of course, increase the emitter current in transistor 115 and thereby increase the voltage drop across resistor 116.

The increased positive potential resulting on resistor 116 is applied to lead 113 to the emitter of transistor 105 and, consequently, further reduces the emitter current in transistor 105.

The resultant cumulative effect, is to rapidly change transistor 105 from conducting to non-conducting, and change transistor 115 from cut-off to conducting.

As can be seen, the collector current of transistor 115 must pass through the relay coil 120. Consequently, when transistor 115 is conducting, relay 120 will operate.

When the timing condenser 44 is discharged through the associated circuitry such as contact 35 and resistor 36 provided for that purpose in traffic control equipment and resulting from termination of an interval or from reset by vehicle actuation (such as circuitry disclosed in Brockett Patent 2,964,625), then pulses will cease to pass through blocking diode 50 to the A.C. amplifier circuit 7 into totalizing capacitor 110. When this occurs, the power supply 80 again charges capacitor 110 through resistor 106 and, by a process opposite to that, previously described, transistor 105 again becomes conducting and transistor 116 becomes non-conducting. This means that no current passes through relay coil 120, and so the relay drops out.

On FIG. 5 the lower end of resistor 71 has been connected to ground through switch 122. During normal operation switch 122 remains closed as shown in FIG. 5. However, if it is desired to allow this timing circuit to time an interval without permitting actual termination of the interval as is frequently required in traffic control apparatus, switch 122 may be opened. When switch 122 is open, the full voltage of power supply 40 is applied as bias to diode 50. If tap 42 is not permitted to be above the voltage of power supply 40 less the peak value of the applied A.C. wave or pulses passing through condenser 57, it will be obvious that diode 50 may not become conductive and relay 120 will remain deenergized even though the timed interval may be completed. When switch 122 is closed, if no reset has occurred and the timed period has expired, the relay 120 will operate.

Switch 122 may be controlled by traffic actuation (as by a traffic actuated relay) by the first vehicle arriving on a red signal on one traffic phase when the present timing circuit is timing the green signal period for another traffic phase of a signal control cycle, or switch 122 may be controlled by other traffic controller elements to defer or prevent operation of relay 120 temporarily, without resetting the timing, for example.

It will be noted that the terms "capacitor" and "condenser" are used interchangeably herein.

Thus, the preferred form of the invention has been shown and described. It will be obvious to those skilled in the art that various other changes may be made in the circuit arrangement, or in circuit components, without departing from the spirit of the invention.

I claim:

1. A timing circuit including

a resistance-capacitance timing circuit providing an exponential voltage,

means coupled to said resistance-capacitance circuit for impressing on said exponential voltage a relatively smaller alternating current voltage to provide a combined exponential voltage having a small alternating current component as an output,

a biased blocking diode circuit coupled to receive the combined voltage output to pass said alternating current voltage component upon said combined voltage reaching a predetermined level,

an alternating current amplifier having its input coupled

to said blocking diode circuit to amplify the alternating current component passed by said blocking circuit, said amplifier having at least one transistor stage,

and an integrating trigger circuit coupled to the output of said amplifier to integrate the amplified alternating current waves to provide a rapid change of output from one level to another in response thereto.

2. A timing circuit as in claim 1 in which said integrating circuit includes

an integrating capacitor,

two transistor amplifier stages for amplifying the charging voltage on said integrating capacitor,

and a feedback circuit coupling last mentioned transistor amplifier stages to provide said rapid change of the output of the said integrating trigger circuit.

3. A timing circuit as in claim 1 in which said integrating trigger circuit includes

a totalizing capacitor normally biased positively,

a semi-conductor diode coupled between the output of the first mentioned alternating current amplifier and said totalizing capacitor and polarized to pass only negative portions of the last mentioned output whereby said integrating capacitor will be discharged by said negative portions of the alternating current output,

a further two stage transistor amplifier-trigger circuit coupled to said totalizing capacitor to provide said rapidly changing characteristic of the output of said integrating trigger circuit.

4. A timing circuit as in claim 1 in which said integrating trigger circuit includes

a semi-conductor diode and capacitor coupled to the output of said alternating current amplifier to provide a rectified voltage on the last mentioned capacitor varying in accordance with a series of waves in said output of said alternating current amplifier,

a first transistor stage having an input coupled to said last mentioned capacitor to have its conduction controlled by the voltage thereon

and a switching transistor stage coupled to the output of said first stage to be controlled thereby to switch between non-conduction and conduction conditions in response to change in conduction of said first transistor stage by variation in voltage on said last named capacitor by said alternating current output of said amplifier.

5. A timing circuit as in claim 1 and including means for resetting the exponential voltage on the first mentioned capacitor for restarting the timing action of the timing circuit.

6. A timing circuit as in claim 1 in which said biased blocking diode circuit includes

switch means for controlling the blocking action of said blocking diode circuit.

7. A timing circuit as in claim 1 and including

an electromagnetic relay coupled to the output of said integrating trigger circuit to be operated thereby.

8. A control circuit for responding to a substantially predetermined level of exponential voltage in a resistance-capacitance timing circuit, said voltage having impressed thereon a relatively smaller alternating voltage as a component of the combined exponential and alternating current voltages applied to the input of said control circuit, said control circuit including

a biased blocking diode circuit coupled to said input to pass said alternating current voltage component upon said combined voltage reaching a predetermined minimum level,

an alternating current amplifier including a transistor stage coupled to said biased blocking diode circuit to receive and amplify the alternating current passed thereby,

and an integrating trigger circuit coupled to the output

of said amplifier to provide a rapid change in output from said integrating circuit in response to the alternating current waves in the output of said amplifier.

9. A circuit as in claim 8 in which said integrating trigger circuit includes

a capacitor,

a semi-conductor diode coupling said capacitor to said output of said amplifier for providing a voltage on said capacitor varying in response to a series of said waves,

a first transistor stage having an input coupled to the last named capacitor to be controlled by said voltage thereon,

and a transistor switching stage coupled to the output of said first transistor stage to be controlled thereby to provide a further output changing rapidly from one level to another in response to a change in the voltage on said last named capacitor from said alternating current waves.

10. A circuit as in claim 9 and including

a relay coupled to said transistor switching stage to be controlled by the output thereof.

References Cited by the Examiner

UNITED STATES PATENTS

2,958,005	1/61	Patmore	330—9
3,047,745	7/62	Frank	307—88.5
3,060,351	10/62	Robbins et al.	317—149
3,115,595	12/63	Marshall	317—149
3,118,601	1/64	Robb	317—148.5 X

OTHER REFERENCES

Szmauz and Bakes: Transistor Time Delay for Industrial Control, Electronics, Sept. 25, 1959, pp. 74, 75.

SAMUEL BERNSTEIN, *Primary Examiner.*