

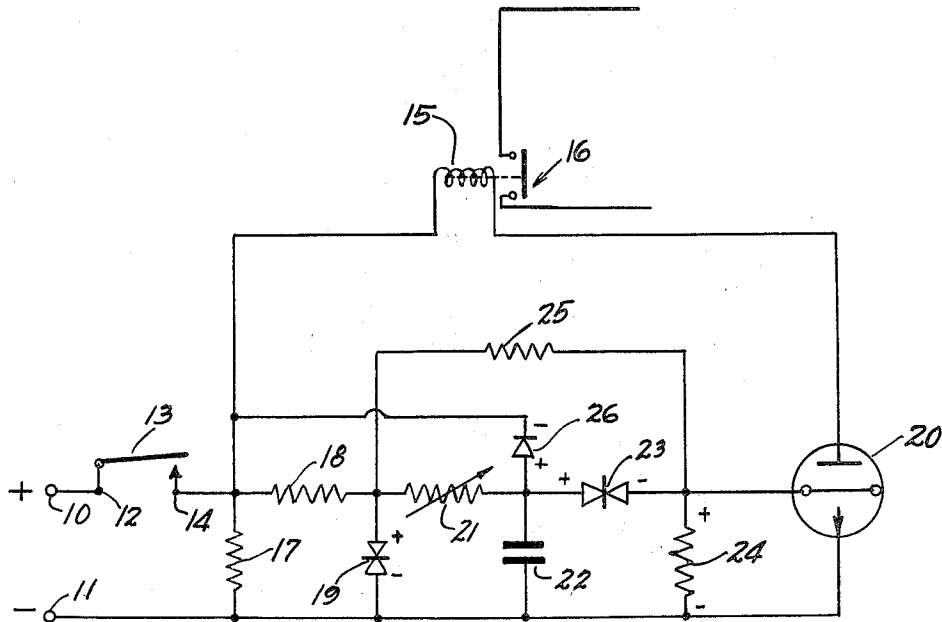
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G. W. O'BLENESS

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TIME-DELAY RELAY

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INVENTOR.

George W. O'Bleness

BY

Combs, McDougall, Williams, & Herck
Attorneys

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TIME-DELAY RELAY

George W. O'Brien, Skokie, Ill., assignor to Cook Electric Company, Chicago, Ill., a corporation of Delaware

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This invention relates to time-delay relay apparatus; in particular, it concerns a time-delay arrangement utilizing a transistor, which achieves remarkably effective performance with simple circuitry.

A major object of the present invention is to provide a simple time-delay relay, operable from a single conventional direct-current source such as the storage-battery power plant of an aircraft or other motor vehicle.

Another important object of the present invention is to provide a relay of the aforementioned type in which the time delay may be varied readily at the operator's will over the entire range from substantially zero to several seconds.

A further object of the invention is to provide, in a simple time-delay relay, positive delay characteristics that are substantially independent of changes in supply voltage and temperature over a substantial range of variation in those parameters.

A still further object of the invention is to provide a simple time-delay relay having no moving parts and which is not dependent for its operation upon the heating of any component thereof.

My invention, broadly speaking, makes use of a resistance-capacitance charging circuit as a time-delay element. This basic method of achieving time delay is per se old in the art; in my invention, however, I employ that basic concept in combination with a novel arrangement of other circuit elements to achieve operation which is positive, dependable, and substantially unaffected by changes in supply voltage and temperature. These desirable results are, in my invention, achieved without the use of complex circuitry, auxiliary power supplies, or expensive, critical components.

The foregoing and other objects and advantages of my invention will be apparent from the following detailed description of a typical embodiment.

In the single figure of the drawing I have shown the schematic diagram of a typical time-delay relay embodying the principles of my invention.

In the drawing, I have indicated by the terminals marked 10 and 11 the positive and negative poles, respectively, of a D.C. voltage source such as a storage battery. In a typical application, such as in an aircraft, the voltage source 10, 11 may be a 28-volt battery. Because the battery in such situations is connected to an engine-driven generator and is during normal operation subjected to widely varying loads, the terminal potential may change by several volts in either direction from the nominal value.

The same situation exists in other types of motor vehicles; thus, while the nominal terminal voltage of an automobile or truck battery may be 12 volts, that voltage also may range during operation from as low as 10 volts to as much as 14 or 15 volts.

The positive voltage-supply terminal 10 is connected to terminal 12 of a manually operable switch 13. The other terminal 14 of switch 13 is connected to one terminal of a sensitive relay coil 15, the other terminal of coil

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15 being connected to the collector electrode of a transistor 20. The emitter electrode of transistor 20 is connected to the negative terminal 11 of the voltage source.

In the typical embodiment shown in the drawing, the transistor 20 is a junction transistor of the n-p-n type. Persons skilled in the art will realize, upon study of the drawing and this description, that transistors of other types may be used with obvious circuit modifications.

With relay coil 15 a pair of relay contacts 16 are associated. They may be connected into any desired secondary circuit (not shown). As will be understood by skilled readers, the function of my invention is to provide controlled actuation of the contacts 16 responsively to the closing of the switch 13, after a predetermined time delay. While contacts 16 are shown in the drawing as normally open, they may, if desired, be of the normally closed type. Similarly, the relay actuated by coil 15 may be of the multiple-pole type having a plurality of contacts 16.

A resistor 17 is connected between switch terminal 14 and negative terminal 11. Shunted across resistor 17 is a series circuit consisting of resistor 18 and a Zener diode 19.

Bridged across Zener diode 19 is a series circuit consisting of a variable resistor 21 and a capacitor 22.

Another Zener diode 23 is connected between the base electrode of transistor 20 and the junction between resistor 21 and capacitor 22. Resistor 24 is connected between the base electrode of transistor 20 and the emitter electrode thereof. A resistor 25 is connected between the base electrode of transistor 20 and the junction of resistor 18 and Zener diode 19.

A conventional diode 26, which may be of the silicon or germanium type, is connected between switch contact 14 and the junction of resistor 21 and capacitor 22. Diode 26, as may be noted from the drawing, is connected with its negative terminal joined to switch contact 14, so that it is normally non-conducting.

The conducting potentials characteristic of Zener diodes 19 and 23 are not critical, although the conducting potential of Zener diode 19 should be substantially higher than that of Zener diode 23. Typical characteristic voltages for these two Zener diodes might be 10 volts for Zener diode 19 and perhaps 6 volts for Zener diode 23, assuming that the relay is to be operated from a supply voltage having a nominal value of 28 volts. If a lower supply voltage is to be employed, Zener diodes having correspondingly lower characteristic voltages should be selected.

The operating characteristics of relay 15, 16 should be so chosen that the relay will be actuated upon passage through coil 15 of the normal collector current of transistor 20 when the transistor is in a freely conducting condition. Typical values of such collector current will range between 10 ma. and perhaps 50 ma. Relay coils responsive to currents of that order of magnitude are readily obtainable.

The values of the other circuit elements in the illustrated embodiment of my invention will depend in large part on the range of time delays desired, the characteristics of the transistor and Zener diodes selected, etc. Hence, I do not wish to be limited to any specific values for those circuit elements. Typical values, however, are those given in the following table:

Resistor 17	-----ohms--	1,000
Resistor 18	-----do----	1,000
Resistor 21	-----do----	0-10,000
Resistor 24	-----do----	1,000
Resistor 25	-----do----	30,000
Capacitor 22	-----mf--	600

In the operation of my invention, the switch 13 is closed, and current immediately flows through resistor 18 and Zener diode 19, establishing across Zener diode 19 a fixed reference potential which in a typical case may be in the neighborhood of 10 volts. At the same time, charging current flows through resistor 21 into capacitor 22, and the potential across capacitor 22 gradually increases.

Meanwhile, the voltage divider comprising resistors 23 and 24 imposes on the base electrode of transistor 20 a small potential, normally a fraction of one volt. This produces a small leakage current through the collector-emitter circuit of transistor 20, but such leakage current is much too small to actuate the relay 15, 16. This leakage current performs the important function of initiating transistor operation on a stable basis with definite bias potentials, thereby making the transistor operation accurately predictable and independent of temperature within wide limits.

As capacitor 22 charges, the potential across Zener diode 23 rises and ultimately reaches its characteristic conduction voltage. When that occurs, Zener diode 23 starts to conduct and immediately impresses on the base electrode of transistor 20 a positive bias voltage, thus causing the collector current of the transistor to increase. This produces actuation of the relay 15, 16, and the external secondary circuit connected to the contacts 16 is closed, or opened if contacts 16 are of the normally closed type.

When the switch 13 is opened, capacitor 22 discharges quickly through diode 26 and resistor 17, so that transistor 20 very rapidly becomes non-conducting and the relay 15, 16 is quickly de-actuated.

The amount of the time delay elapsing between the closing of switch 13 and the actuation of relay 15 will depend on the setting of variable resistor 21. If the characteristics of the Zener diodes and of the other circuit elements are in the neighborhood of the typical values given herein, the delay produced will be of the order of 4-7 seconds when resistor 21 is set at its maximum value, and a continuous range of shorter time delays, down to a fraction of a second, can be obtained by setting resistor 21 at smaller values of resistance.

The illustrated embodiment of my invention is remarkably stable in the face of changes in temperature and supply voltage. Increases in the potential of voltage source 10, 11 have virtually no effect on the time delay produced by the apparatus, and decreases in such voltage are likewise negligible in their effects so long as the supply voltage remains substantially greater than the characteristic voltage of Zener diode 19. Temperature changes likewise have negligible effect on the time delay throughout the full range of variation likely to be encountered in normal applications—that is, between about 0° F. and 150° F. I have found that this temperature stability is greatly contributed to by the base-bias circuit which includes resistor 25. While the apparatus will function successfully without resistor 25 in the circuit, it will under those conditions exhibit considerable temperature sensitivity.

While I have in this specification described in considerable detail a typical embodiment of my invention, it should be understood that this description has been illustrative merely. Persons skilled in the art can make many changes and variations in details of the structure without departing from the spirit of my invention. It is accordingly my desire that the scope of my invention be determined primarily by reference to the appended claims.

I claim:

1. Time-delay relay apparatus comprising input means adapted to be connected to a D.-C. voltage source, a transistor having a pair of primary electrodes and a control electrode, a capacitor, first circuit means including a resistance element and a switch connecting said capacitor to said input means for charging said capacitor from

said voltage source when said switch is closed, second circuit means comprising a Zener diode and a second resistance element shunted across said capacitor, said Zener diode having a critical conduction voltage substantially smaller than the voltage of said source, means applying the potential across said second resistance element between the control electrode and one of the primary electrodes of said transistor, a current-responsive relay, and other circuit means connecting said relay in circuit with said primary electrodes and said input means, operative to pass primary-electrode current from said transistor through said relay for actuating the same, the potential across said second resistance element being applied to said control electrode in the polarity tending to render the path between said primary electrodes in said transistor conductive when current is flowing through said Zener diode.

2. Time-delay relay apparatus comprising input means adapted to be connected to a D.-C. voltage source, a transistor having a pair of primary electrodes and a control electrode, a first Zener diode having a critical conduction voltage substantially smaller than the voltage of said source, first circuit means including a switch and a resistance element connecting said first Zener diode to said input means, a capacitor, second circuit means including a second resistance element connecting said capacitor across said first Zener diode for charging said capacitor from said voltage source through said first and second resistance elements when said switch is closed, third circuit means comprising a second Zener diode and a third resistance element shunted across said capacitor, said second Zener diode having a critical conduction voltage substantially smaller than the critical conduction voltage of said first Zener diode, means applying the potential across said third resistance means between the control electrode and one of the primary electrodes of said transistor, a current-responsive relay, and other circuit means connecting said relay in circuit with said primary electrodes and said input means, operative to pass primary-electrode current from said transistor through said relay for actuating the same, the potential across said third resistance element being applied to said control electrode in the polarity tending to render the path between said primary electrodes in said transistor conductive when current is flowing through said second Zener diode.

3. Time-delay relay apparatus according to claim 1 having also means for impressing a small bias voltage on said control electrode whenever said switch is closed, said bias voltage being less than that necessary to render the path between said primary electrodes in said transistor sufficiently conducting to actuate said current-responsive relay.

4. Time-delay relay apparatus according to claim 1 having also rectifier means connected in circuit with said capacitor operative rapidly to discharge the same whenever said switch is opened.

5. Time-delay relay apparatus comprising input means adapted to be connected to a D.-C. voltage source, a first Zener diode having a critical conduction voltage substantially smaller than the voltage of said source, circuit means including a switch and a first resistance element connecting said first Zener diode to said input means, a transistor having a pair of primary electrodes and a control electrode, a capacitor, second circuit means including a second resistance element connecting said capacitor across said first Zener diode for charging said capacitor from said voltage source through said first and second resistance elements when said switch is closed, third circuit means comprising a second Zener diode and a third resistance element shunted across said capacitor, said second Zener diode having a critical conduction voltage substantially smaller than the critical conduction voltage of said first Zener diode, means applying the potential across said third resistance element between the control electrode and one of the primary electrodes of said transis-

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tor, a current-responsive relay, other circuit means connecting said relay in circuit with said primary electrodes and said input means operative to pass primary-electrode current from said transistor through said relay for actuating the same, the potential across said third resistance element being applied to said control electrode in the polarity tending to render the path between said primary electrodes in said transistor conductive when current is flowing through said second Zener diode, biasing means operative to impress a small bias voltage on said control electrode whenever said switch is closed, said bias volt-

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age being less than that necessary to render the path between said primary electrodes in said transistor sufficiently conducting to actuate said relay, and rectifier means connected in circuit with said capacitor operative rapidly to discharge the same whenever said switch is opened.

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