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ELECTRONICALLY CONTROLLED RELAY

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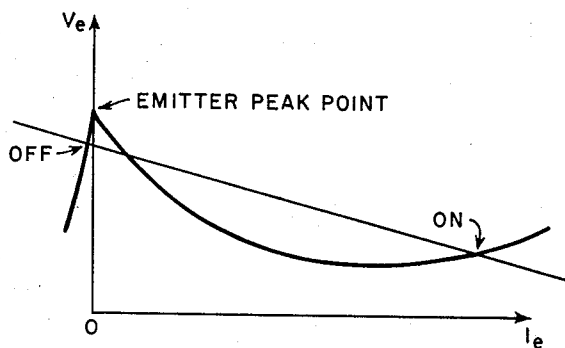


FIG. 2

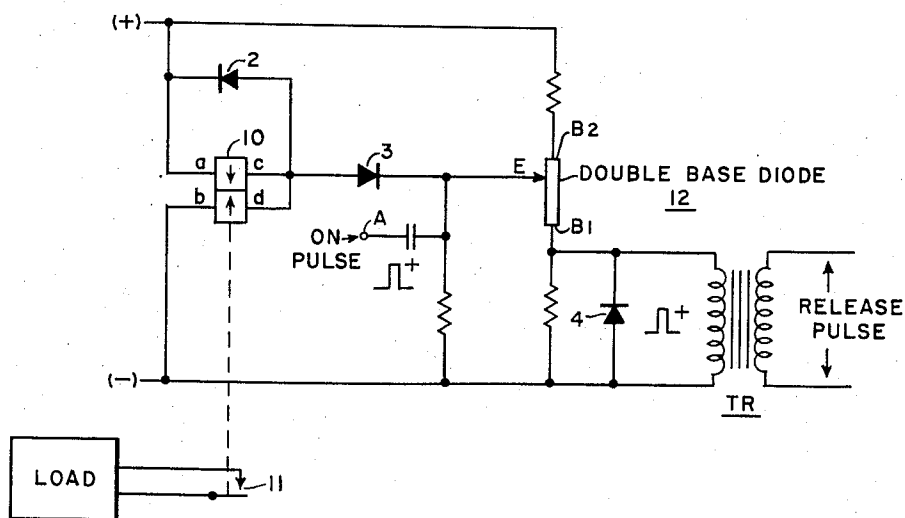


FIG. 1

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ELECTRONICALLY CONTROLLED RELAY

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This invention relates to relay control means and more particularly to means for electronically controlling such relays responsive to pulses of extremely short time duration.

It is old to use relays in strictly electromechanical systems. Recently, much research and development has been directed to replacing or controlling these electromechanical systems by electronic means, thereby creating interim problems during the time when mechanical and electronic parts and components must work together in the same system. For example, it may be necessary to control relays by electronically produced pulses having lengths which are measured in terms of microseconds. Also, there may be times when it is desirable to replace only certain electromechanical means by electronic means while retaining, in general, many other of the electromechanical means.

An object of this invention is to provide new and improved means for controlling electromechanical switching devices.

Another object of this invention is to provide means for electronically controlling relays.

Still another object of this invention is to provide means whereby a relay may be controlled by a double-base diode.

A preferred embodiment of my invention accomplishes the above cited and other objects by providing electromechanical means, such as a relay, controlled by electronic means, such as a bi-stable, triggered electronic switch means comprising a double-base diode. A description of a double-base diode may be found in an article by I. A. Lesk and V. P. Mathis, "The Double-Base Diode—A New Semi-Conductor Device," published in the convention record of the I.R.E., part 6, March 1953. The term "semi-conductor" is used hereinafter to describe an element such as germanium, for example, having an added impurity. The impurity, such as phosphorus, has an atomic structure which may have either an excess of electrons when compared with the atomic structure of germanium or a deficit of electrons when compared with the atomic structure of germanium. The impurity in an "N-type" semi-conductor has an excess of electrons so that current flow results primarily from flow of such excess electrons. On the other hand, the impurity in a "P-type" semi-conductor has a deficit of electrons so that current flow results primarily from electrons moving into or filling the atomic structure where there is such a deficit thereby causing what appears to be the formation of a hole in the atomic structure at the point from which the electron moved; hence, there appears to be a drift of holes in P-type semi-conductors. Semi-conductors may have a variety of characteristics. For example, a semi-conductor that is useful in an amplifier has characteristics that provide a continuous, enlarged reproduction of an input signal; whereas, another type of semi-conductor that is useful in "flip-flop" circuits has characteristics that provide a triggered or snapped "off"/"on" circuit condition. The following specification and claims refer to the trigger or snap type semi-conductor as one of "bi-stable operation."

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Briefly, a double-base diode comprises semi-conductive material having two base electrodes (sometimes called ohmic connections) and an emitter electrode (sometimes called a rectifying junction). Each base electrode makes an ohmic connection with opposite portions of the semi-conductor while the emitter electrode makes a rectifying junction connection to the semi-conductor at a point which may be displaced from one of the base connections by a distance which is approximately 0.7 of the total distance between the bases. When the emitter junction is biased in the reverse direction, the resistivity of the semi-conductor is relatively high. Since a semi-conductor is essentially a linear resistance over the distance between the two base electrodes, the voltage of the area of the semi-conductor at the rectifying junction is approximately 0.7 of the voltage applied between the two base electrodes. When the emitter junction is biased in the forward direction, either holes or electrons, depending upon whether the semi-conductor is N or P type, are injected into the bar from the emitter so as to lower the resistivity of the semi-conductor between the emitter and the first base electrode. As a result, the potential of the semi-conductor is lowered at the junction point toward the potential of the first base electrode so that the rate of injection of holes or electrons is increased. Thus, the emitter input characteristic shows a negative impedance region and the device is bi-stable in operation.

According to the invention, a first circuit is connected between the first base of the double-base diode and a reference potential such as ground, for example. A second circuit is connected between the emitter electrode and a source of control potential. When the semi-conductor is in its low current conducting state, it presents a very high impedance between the two circuits. On the other hand, when the semi-conductor is in its high current conducting state, signals appearing in either circuit may be passed by the semi-conductor in a bi-lateral manner with virtually no attenuation. The semi-conductor may be triggered from its low current conducting state to its high current conducting state or vice versa by the application of suitable pulses to either a base or emitter electrode.

Other objects will be apparent by making reference to the attached drawing, in which:

Fig. 1 shows a relay arranged so that it may be controlled by a double-base diode; and

Fig. 2 shows the characteristics of the double-base diode.

The following specification and the attached drawing illustrate a particular embodiment of my invention. Further, simple and specific terms are used herein to facilitate an understanding of my invention. However, it should be understood that the showing of such particular embodiment and the using of such simple and specific terms are not to act in any manner as a disclaimer of the full range of equivalents which is normally given under established rules of patent law. For example, the semi-conductor has been explained in terms of germanium and phosphorus when other materials may be equally useful.

Turning to the drawing in greater detail, there is shown a differential relay 10 which may be provided with any number of contacts. For purposes of illustration only, the contacts have been shown as simple make contacts 11 which may be used to control a useful work load. Quite obviously any other type or number of contacts may be substituted therefor. Differential relay 10 is provided with two windings having an equal number of turns so that the flux produced by each winding is equal and opposite to that produced by the other winding when the relay is equally energized over its upper and lower windings. A source of power is shown by plus (+) and minus (—) signs which represent two potentials that may

be connected to the windings of the differential relay 10 and to the two bases or ohmic connections B1 and B2 of double-base diode 12.

When double-base diode 12 is in its "off" condition, there is practically zero current flowing through emitter or rectifying junction E and its associated circuit. Differential relay 10 does not operate, because the currents flowing through windings *a-c* and *b-d* are in opposition so that no useful flux is developed. To turn double-base diode 12 "on," it is only necessary to introduce a positive pulse at terminal A.

Referring to Fig. 2, the heavily inked curve shows typical characteristics of a double-base diode, such as element 12, for example. That is, a double-base diode conducts emitter current only when the voltage emitter E is at a point on the curve (Fig. 2) which is to the right of the vertical line marked " V_e ." The semiconductor is triggered to its "off" position when the voltage on emitter electrode E is at the point marked "off." The resistances of relay windings *a-c* and *b-d* are proportioned to form a voltage divider which maintains points *c* and *d* at a potential that is slightly below the emitter peak point (Fig. 2) so that emitter E is biased in the reverse direction during the "off" condition.

A positive pulse introduced at terminal A (Fig. 1) causes the voltage on emitter electrode E to be elevated to the emitter peak point (Fig. 2). At this point emitter E of double-base diode 12 begins to conduct current; however, it has a negative-resistance characteristic so that the voltage at emitter E immediately falls as the current builds up until the point marked "on" is reached. At this point, double-base diode 12 is stable and its conduction is controlled by the resistance of the circuit including winding *a-c* of relay 10. In this stage, there is a minimum resistance path between emitter E and base B1, and another minimum resistance path between base B1 and base B2, thereby increasing the current flow through winding *a-c* of relay 10. The low resistance path between emitter E and base B1 in effect shunts the lower or *b-d* winding of relay 10. Under these conditions, the magnetic flux produced in the upper or *a-c* winding overpowers that produced in the lower or *b-d* winding, thus causing relay 10 to operate and close its contacts 11 thereby performing a useful work load function.

Differential relay 10 remains operated until double-base diode 12 is triggered to its "off" condition by a pulse which may be applied over the conductors marked "Release Pulse" to cause a positive potential at base B1 due to the inductive effect of the transformer TR. When base B1 becomes more positive, emitter E becomes more negative or less positive with respect to base B1. In effect, the voltage V_e , shown in Fig. 2, is lowered to a point which, on the graph of Fig. 2, is below the heavily inked line. Double-base diode 12 is then in an unstable condition, and its conduction characteristics are triggered or snapped over to the extreme left-hand portion of the heavily inked curve (Fig. 2) at which time current is flowing at emitter E. At this point, the internal characteristics of double-base diode 12 correspond to the point on the curve which is marked "off" and virtually no current is flowing in emitter circuit E thus causing differential relay 10 to release. In this manner, a plurality of pulses such as those which may be produced by an electronic switching circuit may be used to control an electromechanical relay.

Next, attention is directed to the function of the windings of relay 10. Usually a separate power source is provided for emitter E to bias double-base diode 12 to the point on the curve of Fig. 2 that is indicated by the word "off." This bias potential may be either a separate battery or a voltage divider connected between the plus (+) and minus (-) terminals as shown in the drawing. My invention avoids the requirement for an

extra battery or a separate voltage divider since I use the resistance of the two windings of relay 10 to divide the voltage or potential existing between the plus (+) and minus (-) terminals thereby providing a proper bias potential for emitter E.

Diode 2 is provided to prevent false operation when double-base diode 12 is turned "off." Otherwise, when the "off" pulse is effective, there might be a surge current which would tend to turn "on" double-base diode 12. Diode 3 is provided to prevent loading of the "on" pulse source by the relay windings. Diode 4 is provided to prevent a false "turn-on" which otherwise might result from a negative transient, if any, which may follow the release pulse.

While I have shown and described a single embodiment of my invention, it should be obvious that various modifications may be made without departing from the scope thereof. Hence, it is my intention to cover in the attached claims not only the particular circuit shown in the drawing, but also all modifications which fall within the true spirit of my invention.

What is claimed is:

1. An electronic device comprising semi-conductive material, means providing two ohmic connections with said material, means providing a rectifying junction with said material, means comprising a source of potential having at least two terminals, means for coupling one of said terminals to one of said connections and means for coupling the other of said terminals to the other of said connections, means for producing two fields of equal and opposite magnetic flux when energized from said source of potential, and means for connecting said two terminals of said source through said flux producing means to said rectifying junction means.

2. The electronic device of claim 1 and means for introducing a control voltage in said connection between said flux producing means and said rectifying junction means, said control voltage being of sufficient voltage to trigger said device to an "on" condition.

3. Electronically controlled relay means comprising semi-conductive material, means for making two ohmic connections with said material, means for making a rectifying junction with said material, means comprising a source of potential having two terminals, electromechanical means having a plurality of windings which are turned to provide opposing magnetic flux, means for connecting one of said terminals to a first of said ohmic connections, means for connecting the other of said terminals to a second of said ohmic means, means for connecting said one terminal to said rectifying junction through one of said windings, and means for connecting the other of said terminals to said rectifying junction through the other of said windings.

4. In combination a bi-stable, triggered electronic device comprising semi-conductive material, said semi-conductive material having a stable state of low current conduction and another stable state of high current conduction, means including a pair of electrodes each having ohmic connection with said material, means including a third electrode forming a rectifying junction with said material, means for providing a source of potential comprising two terminals of opposite polarity, means for coupling one of said terminals of said potential source to one of said connections and means for coupling the other of said terminals of said potential source to the other of said connections, means having two windings, each of said windings having two terminals, said windings providing equal and opposite magnetic flux when energized simultaneously, means for connecting a first terminal of one of said windings to one of said terminals of said potential source, means for connecting a first terminal of the second of said windings to said other terminal of said potential source, means for interconnecting the second terminals of each of said two wind-

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ings, and means for connecting said interconnected second terminals to said third electrode whereby the resistance of said two windings form a voltage divider for providing a bias voltage for said third electrode.

5. The device of claim 4 and means connected between said windings and said rectifying junction for biasing said material toward a conductive state.

6. The device of claim 5 and means connected to one of said ohmic connections for biasing said material toward a non-conductive state.

7. The device of claim 4 and means connected to one of said ohmic connections for biasing said material toward a non-conductive state.

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