March 16, 1965 E. D. SCOTT 3,174,080
RELAY FLIP-FLOP
Filed June 12, 1961

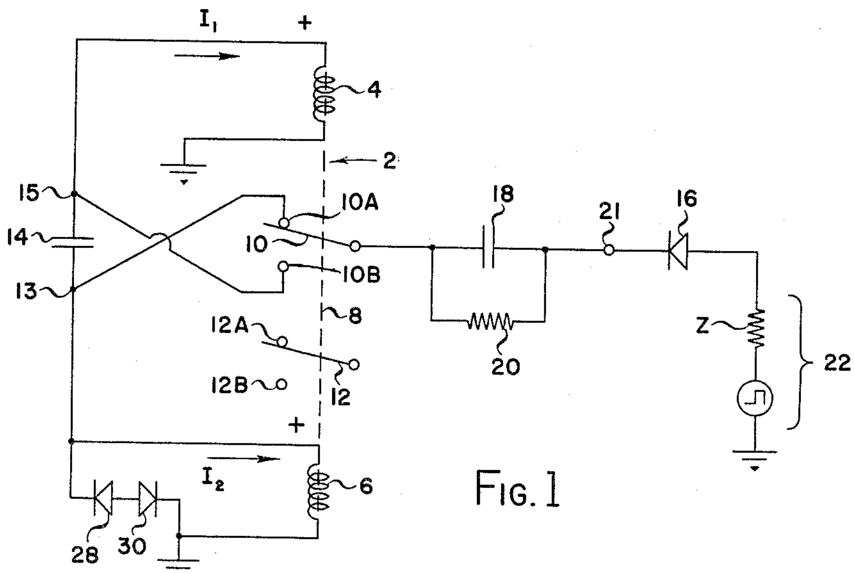

FIG. 1

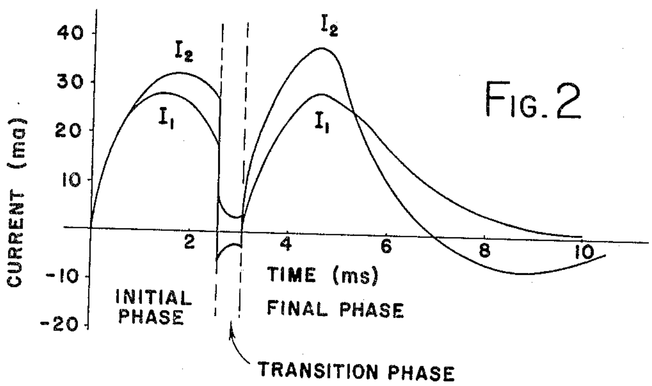

FIG. 2

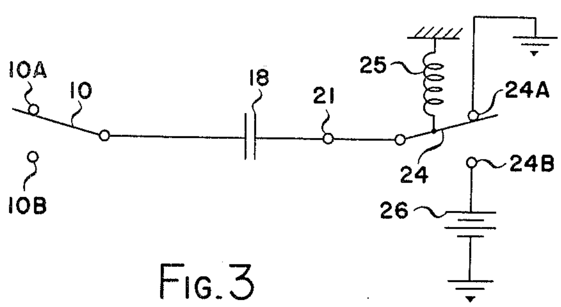

FIG. 3

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RELAY FLIP-FLOP

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4 Claims. (Cl. 317—155.5)

This invention relates to bistable flip-flops and more particularly to bistable relay flip-flips.

It is well known by those skilled in the art that bistable relay flip-flips are useful when high powered signals must be switched and when speed of operation is of secondary importance. All of the prior art relay flip-flops of which I have knowledge have required the use of two or more separate relays, for an example of which see Patent Number 2,960,635, and therefore require an unnecessarily large number of components. Furthermore, the relay flip-flops heretofore available have required electric power to maintain them in one or both quiescent states.

Therefore, it is an object of my invention to provide a relay flip-flop having only one relay therein.

Another object is to provide a relay having fewer components than has heretofore been possible.

A further object is to provide a relay flip-flop which requires no electric power to maintain it in either of its quiescent states.

A still further object is to provide a relay flip-flop wherein maximum utilization of the power in the input pulse is obtained.

Yet another object is to provide a relay flip-flop having output contacts completely isolated from the input circuitry.

These and other objects will be more apparent after referring to the following specification and attached drawings in which:

FIGURE 1 is a schematic diagram of a relay flip-flop made in accordance with my invention,

FIGURE 2 is a graph of current in milliamperes through the relay coils versus time in milliseconds when the circuit of FIGURE 1 is changing states, and

FIGURE 3 is a schematic view of an alternate input circuit for FIGURE 1.

Referring more particularly to the drawings, FIGURE 1 reference numeral 2 indicates a conventional polarized latching relay such as model SL11DB manufactured by Potter and Brumfield Company and having coils whose nominal operating voltage is preferably 24 volts. Relay 2 has a latch-up coil 4 and a latch-down coil 6 with an armature 8 responsive to the magnetic fields of coils 4 and 6. The fact that relay 2 is a polarized relay means that current in the forward direction of either of the coils 4 and 6 urges armature 8 toward the respective coil whereas reverse current in either of the coils 4 and 6 causes such coil to repel the armature. Attached to armature 8 is a movable contact 10 which is alternately connected to fixed contact 10A and fixed contact 10B, and a movable contact 12 which is alternately connected to a fixed contact 12A and a fixed contact 12B. Fixed contact 10A is connected to one terminal 13 of a transfer capacitor 14 and to the positive side of coil 6, the other side of which is grounded. Fixed contact 10B is connected to the other terminal 15 of transfer capacitor 14 and to the positive side of coil 4, the other side of which is grounded. Movable contact 10 is connected to the cathode of a diode 16 through an input capacitor 18 which has a resistor 20 connected parallel therewith and through an input terminal 21. To the anode of diode 16 is connected any suitable pulse source 22 having an output impedance Z. In the preferred embodiment of my invention capacitor 14 has a value of 2 microfarads at 75 volts, input capacitor 18 has a value of 12 microfarads at 75 volts, resistor 20 has a resistance of 10,000 ohms and pulse source 22 has an output impedance Z of 60 ohms.

The operation of my device is as follows: With movable contact 10 connected to fixed contact 10A, a positive input pulse through diode 16 having an amplitude of preferably from 20 to 30 volts and a duration of about .005 second will cause a current I_2 to flow through input capacitor 18, contact 10A, and coil 6, and a current I_1 to flow through input capacitor 18, contact 10A, transfer capacitor 14 and coil 4. Since I_2 encounters less impedance than I_1, greater current will flow through coil 6 as shown in FIGURE 2, initial phase, with the result that the magnetic field produced by coil 6 will exceed that produced by coil 4. Armature 8 is thereby urged toward coil 6 and will cause the connection between contacts 10 and 10A to be broken. At the instant of the contact separation the currents I_1 and I_2 will decrease appreciably and I_1 will reverse its direction of flow as transfer capacitor 14 begins to discharge. Such reversal of current aids in the transfer of armature 8 toward coil 6 with the reverse current through coil 4 repelling the armature 8. The last named condition is shown by FIGURE 2, transition phase. When movable contact 10 meets contact 10B at the end of the transition phase, the pulse from pulse source 22 is still present and transfer capacitor 14 is still charged with terminal 13 being positive with respect to the terminal 15. In such condition coil 4 will be supplied with energy from only pulse source 22 while coil 6 will be supplied with energy from the pulse source 22 as well as transfer capacitor 14. Therefore, the current I_2 through coil 6 will exceed the current I_1 through coil 4 and armature 8 will be urged toward coil 6 in the final phase as shown in FIGURE 2. When the pulse from source 22 is no longer present, the input capacitor 18 will discharge through resistor 20 thereby readying the circuit for another pulse. It will be obvious to those skilled in the art that the resistance of resistor 20 must be decreased as the repetition of the pulses from source 22 is increased. I have found that with resistor 20 having a resistance of 10,000 ohms, an input rate of 10 pulses per second can be accommodated, since it takes input capacitor 18 about 1/10 of a second to discharge through the resistor 20. When a subsequent pulse is supplied by pulse source 22 with contact 10 resting against 10B the armature 8 will be moved toward the coil 4 in a manner precisely opposite that described above; that is, during the initial phase the current through the coil 4 will exceed the current through coil 6, during the transition phase the current through coil 6 will reverse, and during the final phase current through coil 4 will exceed the current through coil 6, all of which promote the change of state of the flip-flop.

It should be particularly noted that input capacitor 18 functions to limit the current which will be transmitted through the coils after arm 10 has switched from its initial position to its final position. Input capacitor 18 would be unnecessary during the initial phase or that period of time when arm 10 is in contact with fixed contact 10A as well as during the transition phase. However, it is essential during the final phase of operation.

During the initial phase, input capacitor 18 provides a relatively low impedance and therefore substantial current, say 30 milliamps for a 30 volt source, will be transmitted through coils 4 and 6. When the current in the transfer coil (when the relay is in the position shown in FIGURE 1, i.e., arm 10 at contact 10A, the transfer coil is coil 6) exceeds the current in the opposite coil by approximately 10 milliamps, the relay transfer. It requires current of this magnitude to transfer or to cause the relay to switch. During the initial phase input capacitor 18 will charge to approximately 20% of its full charge and capacitor 14 to about 80%. This set of conditions results in a total driving voltage of about 48 volts [i.e. 80% (30v)−20% (30v)+30v] across coil 6, and the voltage across coil 4 would be about 24 volts [i.e. 30v−20% (30v)]. Thus the current (I_2) in coil 6 will be greater than the current (I_1) in coil 4 during the initial phase and the first part of the final phase.

Referring to FIGURE 2, it is noted that I_2 is greater than I_1 up to approximately 5.5 milliseconds. From this time onward the current (I_1) in coil 4 is rapidly decaying due to the increasing voltage across input capacitor 18 which provides an increasing impedance. If input capacitor 18 were not provided then current I_1 would not decay after 6 milliseconds and the difference between I_1 and I_2 would be such as to cause arm 10 to switch in the opposite direction. It should be noted that if input capacitor 18 were not in the circuit that current I_2 would decay in much the same manner as shown in FIGURE 2 and finally reach a zero magnitude. Therefore, if input capacitor 18 were not provided, current I_1 would remain at a high level and current I_2 would decrease to zero and the relay would switch back to the original position and the process would repeat and thereby result in oscillations.

For operation of my device at a very slow repetition rate (e.g., 1 cycle per hour) resistor 20 may be omitted because input capacitor 18 will have sufficient time to discharge through its own leakage resistance.

An alternate input circuit for my device is shown in FIGURE 3. In this modification the movable contact 10 is connected to a movable contact 24 through input capacitor 18 and input terminal 21. Movable contact 24 is arranged for alternate connection with fixed contacts 24A or 24B. Contact 24 is normally connected to contact 24A, for example, due to an expansion spring 25. The contact 24A is connected to ground and contact 24B is connected to the positive terminal of a battery 26, the negative terminal of which is connected to ground.

With the input circuit of FIGURE 3, my device operates as follows: Connection of movable contact 24 with fixed contact 24B for approximately .005 second will cause the armature 8 to be urged toward coil 6 in a manner hereinabove described. When movable contact 24 is connected to fixed contact 24A input capacitor 18 discharges to ground, thereby readying the circuit for another pulse produced when contact 24 is subsequently connected to contact 24B. Because the discharge path for input capacitor 18 has virtually no resistance, the use of the input circuit of FIGURE 3 permits much faster operation, for example, up to 100 cycles per second.

I have found that the operation of my device may be improved by the addition of diodes 28 and 30 connected in a back-to-back relationship across one of the relay coils, for example, coil 6. When diodes 28 and 30 are included in the circuit I have observed that arcing between contacts 10A and 10B and contact 10 is suppressed, thereby lengthening contact life and decreasing radio frequency noise caused by the arcing. Diodes 28 and 30 preferably have a breakdown voltage in the reverse direction of approximately 150 volts, so that voltage pulses in excess of 150 volts caused by the self-inductance of the coils 4 or 6 will be grounded rather than cause arcing across the relay contacts.

While one embodiment of my invention has been shown and described it will be apparent that various adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. A relay flip-flop comprising a polarized latching relay having a first coil, a second coil, a first fixed electrical contact, a second fixed electrical contact, and an armature responsive to said coils with an electrical contact movable therewith for alternate connection with said fixed contacts, an input terminal, an input capacitor connected between said movable contact and said input terminal, and a transfer capacitor having a first terminal and a second terminal, said first terminal being connected to one side of said first coil and said second fixed electrical contact, said second terminal being connected to one side of said second coil and said first fixed electrical contact and the other sides of said first and second coils being electrically connected to ground, a direct current pulse source, one side of said direct current pulse source connected to said input terminal and the other side connected to ground.

2. A relay flip-flop comprising a polarized latching relay having a first coil, a second coil, a first fixed electrical contact, a second fixed electrical contact, and an armature responsive to said coils with an electrical contact movable therewith for alternate connection with said fixed contacts, an input terminal, an input capacitor connected between said movable contact and said input terminal, and a transfer capacitor having a first terminal and a second terminal, said first terminal being connected to one side of said first coil and said second fixed electrical contact, said second terminal being connected to one side of said second coil and said first fixed electrical contact, and the other sides of said first and second coils being electrically connected to ground, a direct current pulse source, one side of said pulse source connected to said input terminal and the other side connected to ground.

3. A relay flip-flop comprising a polarized latching relay having a first coil, a second coil, a first fixed electrical contact, a second fixed electrical contact, and an armature responsive to said coils with an electrical contact moveable herewith for alternate connection with said fixed contacts, an input terminal, an input capacitor connected between said movable contact and said input terminal, and a transfer capacitor having a first terminal and a second terminal, said first terminal being connected to one side of said first coil and said second fixed electrical contact, said second terminal being connected to one side of said second coil and said first fixed electrical contact, and the other sides of said first and second coils being electrically connected to ground, a direct current pulse source, one side of said pulse source connected to said input terminal and the other side connected to ground wherein the application current pulse to said input terminal results in the simultaneous passage of current through each of said first and second coils and said transfer capacitor provides a higher impedance with respect to one of said first and second coils resulting in a greater current passing through one of said first and second coils thereby causing movement of said movable contact from one of said fixed electrical contacts to the other.

4. The device of claim 3 wherein one end of a resistor is connected to said input terminal and the other end is connected to said electrical contact movable with said armature wherein said resistor provides a discharge current path for said transfer capacitor to ground immediately after the termination of a current pulse from said pulse source.

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