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BI-STABLE RELAY CIRCUIT

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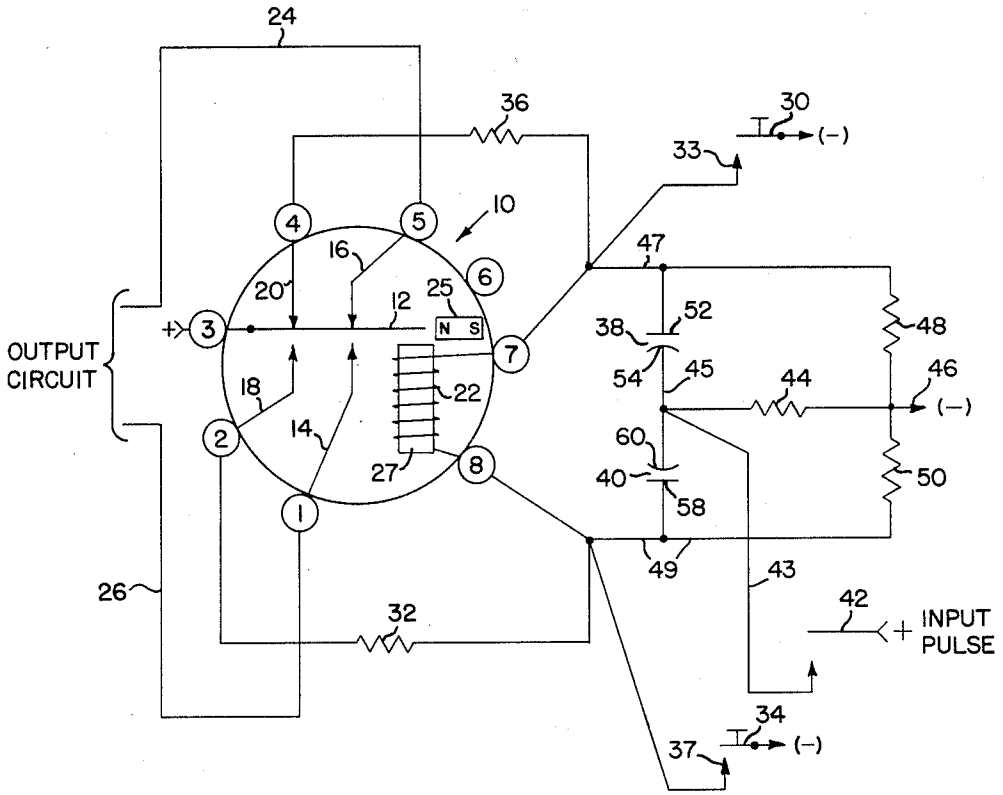

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BI-STABLE RELAY CIRCUIT

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The present inventon relates to an electro-mechanical so-called "flip-flop" circuit, and more particularly to a circuit employing a bi-stable relay, that is a relay whose armature has two positions of stable equilibrium, and is shifted from one position to another by successive input pulses.

This invention may be used in any counting circuit, and is particularly useful in a counting circuit, where the input pulses are divided by two, and the odd and even pulses are differentiated by the operation of a binary counter.

Heretofore, for such counting circuits it has been necessary either to use two relays, or to use a double reversely-wound or two coil relay, where energization of one coil by one input pulse causes the armature of the relay to move to one position, and energization of the other coil by the next input pulse causes the armature of the relay to revert to its original position.

One of the objects of the present invention is to provide a bi-stable relay circuit which can be operated by a single relay and in which that relay has only one coil or winding.

Another object of this invention is to provide a bistable relay circuit wherein the armature of the relay will be shifted alternately from one to the other of its two stable positions by successive input pulses of the same polarity.

Another object of this invention is to provide a bistable relay circuit of the character described wherein input pulses of uni-directional current of the same polarity will cause the armature of a single coil polarized relay to shift alternately to one and then the other of two stable positions.

Another object of this invention is to provide a bistable relay circuit of the character described wherein the relay, which responds to the uni-directional input pulses, is a polarized relay biased by a permanent magnet so that the armature will tend to remain in either of two stable positions when the coil is de-energized.

Another object of the invention is to provide a bistable relay of the character described in which flow of curent through the relay coil itself will lock the relay armature in the position to which it has been shifted until a positive pulse of current causes the core of the coil to be polarized oppositely to its previous direction of polarization.

A still further object of this invention is to provide a bi-stable relay circuit which will be very rapid in operation. To this end it is a further object of the invention to provide a bi-stable relay circuit of the character described which is effective to move the armature from one to the other of its two stable positions in response to input pulses of uni-directional current of a duration of as little as three milliseconds.

Still another object of this invention is to provide a bi-stable relay circuit of the character described which is relatively inexpensive to manufacture, foolproof in operation, and simple in construction.

Other objects of this invention will become apparent hereinafter from the specification, the accompanying drawing, and the appended claims.

In the drawing:

The figure is a schmetic circuit diagram showing the circuit elements and connections used in one embodiment of this invention.

In the illustrated embodiment of the invention, a single

coil polarized relay is employed. This relay is of the type wherein a single coil is energized by current flowing in one direction to move its armature from one position to another and is energized by current flowing in the opposite direction to return the armature to its first position. The relay has two front contacts, and two back contacts; and the free end of the armature swings between these two sets of fixed contacts. The armature is biased by a small permanent magnet element to remain in contact with the front contacts until driven to the opposite contacts by energization of the coil. However, the relay is so wired in the circuit of the present invention that the armature is also held electromagnetically in one or other of its two positions, after it has been moved to that position, until a positive surge of current in the relay coil causes the core of the relay to drive the armature from that position to its other position. One back contact and one front contact of the relay are in the output circuit and are used to provide the energy for operating apparatus such as a relay counting chain, telephone switches, etc.

A feature of the present invention is that with the armature in either position an input pulse from a direct current source of one polarity drives the armature to its other position. In one position of the armature the input pulse travels through the relay coil in one direction; and in the other position of the armature the input pulse travels through the relay coil in the opposite direction. The pulse is of the same polarity, however, in both cases. Two capacitors are connected in a circuit to be charged in either position of the armature; but when the armature is in one position one condenser or capacitor discharges rapidly upon an input pulse, whereas the other capacitor discharges through the relay coil; and it is this discharge which causes a surge of current in the relay coil in the desired direction to drive the armature to its opposite position. The two condensers or capacitors are wired in the circuit so that one is effective when the armature is in one position, and the other is effective when the armature is in its other position.

Referring now to FIG. 1 by numerals of reference, 10 denotes a conventional mercury-wetted-contact relay of the polarized type. This relay has eight terminals numbered 1 through 8, respectively. The armature 12 of the relay is connected to terminal No. 3, which, in turn, is connected to the positive pole of a source of direct current. Front contact 14 and back contact 16 of the armature are connected to terminals Nos. 1 and 5, respectively, of the relay. Front contact 18 and back contact 20 of the armature are connected to the No. 2 and No. 4 terminals, respectively, of the relay. The operating coil 22 of the relay 10 is connected across the No. 7 and No. 8 terminals of the relay.

For the purpose of distinction, when the armature 12 of the relay is in the position shown in FIG. 1, that is, when back contacts 16 and 20 are in contact with the armature 12, the relay is said to be in "non-operated" position. When the armature 12 is in contact with the front contacts 14 and 18, the relay is said to be in "operated" position. The relay is biased by a permanent magnet 25, so that the armature 12 will stand in its "operated" or "non-operated" position when no current is flowing through the relay circuit. Current in one direction is required to move or "flip" the armature to "operated" position, and reverse current is required to move or "flop" it to "non-operated" position. Contacts 18 and 20 are so arranged in connection with terminal No. 3 as to produce, respectively, current through the relay coil 22 in a direction to hold the coil "operated" when the armature is in "operated" position and to hold the relay "non-operated" when the armature is in "non-operated" position. When the armature 12 is in its "operated" position, a positive voltage is connected to output conductor 26

which is connected to terminal No. 1 of the relay; and when armature 12 is in its "non-operated" position a positive voltage is connected to output conductor 24 through terminal No. 5.

A pair of serially-connected capacitors 38 and 40 are connected in the circuit across the coil 22 of the relay. These capacitors may be of the solid dielectric type to be charged with direct current of either polarity. Contact 42 is connected to the positive pole of a source of direct current and is operated by a suitable external means to provide successive input pulses of current for operating the armature 12 alternately to first one and then the other of its stable positions. When the contact 42 is closed, the positive pole of a direct current source is connected by conductor 43 to a conductor 45 which connects the capacitors 38 and 40. One terminal of a resistor 44 is also connected to the wire 45 between the capacitors 38 and 40; and the other terminal of this resistor is connected at terminal 46 to the negative pole of a source of direct current. It is obvious that this resistor 44 prevents a short circuit between the positive and negative poles of the battery, or other source of direct current, which is connected to contacts 42 and 46, when contact 42 is closed.

A conductor 47 connects terminal No. 7 of the relay to the negative terminal 46 through a resistor 48. A conductor 49 connects terminal No. 8 of the relay to the negative terminal 46 through another resistor 50.

When the armature 12 of the relay is in its "non-operated" position shown in FIG. 1, a circuit is completed which extends from (+) through terminal No. 3, armature 12, contact 20, terminal No. 4, resistor 36, terminal No. 7, coil 22, terminal No. 8, conductor 49, resistor 50, and terminal 46 to (—). This circuit causes a slight current flow through the coil 22 of the relay. The current flow produces a polarity in core 27 which causes the core to repel armature 12 with the result that core 27 holds the armature 12 locked in its "non-operated" position.

The capacitors 38 and 40 are charged when the armature is in either its "non-operated" or its "operated" position. When the armature is in its "non-operated" position capacitor 38 is charged so that its plate or side 52 is positive with respect to its plate or side 54 by a circuit which extends from (+) through terminal No. 3, armature 12, contact 20, terminal No. 4, resistor 36, conductor 47, capacitor 38, conductor 45, resistor 44, and terminal 46 to (—). Capacitor 40 is charged so that its side or plate 58 is positive with respect to its side or plate 60 by a circuit extending from (+) through terminal No. 3, armature 12, contact 20, terminal No. 4, resistor 36, terminal No. 7, coil 22, terminal No. 8, conductor 49, capacitor 40, conductor 45, resistor 44, and terminal 46 to (—).

Since the circuit for charging capacitor 40 includes coil 22, whereas the circuit for charging capacitor 38 does not, it will be obvious that capacitor 40 will take longer to charge than capacitor 38. However, at this stage of the operation this is not of any critical importance.

Now, when the input contact 42 is momentarily closed and the armature 12 is in its "non-operated" position, a circuit is made from (+) through contact 42, conductor 43, capacitor 40, conductor 49, terminal No. 8, coil 22, terminal No. 7, resistor 36, terminal No. 4, contact 20, and terminal No. 3 to (+). Capacitor 40 therefore discharges causing a surge of current to pass through coil 22 from terminal No. 8 to terminal No. 7. While the current pulse is flowing, as described, to capacitor 40, it is also flowing to the side 54 of the capacitor 38, but side 52 of the capacitor 38 is at this time connected in a circuit which includes line 47 and resistor 36; and does not include the coil 22 of the relay. Therefore capacitor 38 does not discharge through the coil 22. It is because contact 18 is open that capacitor 40 discharges through coil 22 from terminal No. 8 to terminal No. 7.

The direction of flow of the current from capacitor 40 through coil 22 is the reverse of that which has previously been flowing in the coil 22 and is such as to magnetize the core 27 to attract armature 12, causing the armature

to break contact at 16 and 20 and to make contact at 14 and 18.

When the armature 12 has shifted to its "operated" position into contact with contact 18 a circuit is completed from (+) through terminal No. 3, contact 18, terminal No. 2, resistor 32, terminal No. 8, coil 22, terminal No. 7, conductor 47, resistor 48, and terminal 46 to (—). The direction of this current flow, however, is such as to cause core 27 to maintain armature 12 locked in its "operated" position.

In the "operated" position of the armature, capacitors 38 and 40 are again charged also. The circuit for charging capacitor 40 is now from (+) through terminal No. 3, contact 18, terminal No. 2, resistor 32, conductor 49, capacitor 40, conductor 45, resistor 44 and terminal 46 to (—). The circuit for charging capacitor 38 is from (+) through terminal No. 3, armature 12, contact 18, terminal No. 2, resistor 32, terminal No. 8, coil 22, terminal No. 7, conductor 47, capacitor 38, conductor 45, resistor 44, and terminal 46 to (—). In this instance, however, the time for charging capacitor 38 will be greater than the time for charging capacitor 40 because of the slight additional resistance of coil 22.

It is apparent that when the relay 10 is in either of its stable states or positions current flows in the circuits for charging the capacitors 38 and 40 only long enough to charge the capacitors.

When the armature 12 is in its "operated" position, and input contact 42 is momentarily closed to provide the next pulse of current of positive polarity, capacitor 38 discharges through the coil 22 to provide a surge of current wherein terminal No. 7 of the relay is more positive than terminal No. 8 of the relay to move the armature to its "non-operated" position.

Pre-setting, normally-open buttons 30 and 34 are provided to be operated, manually or otherwise, for initially energizing the relay coil 22 to insure that its armature 12 is in the proper starting position depending upon the position in which the armature stopped at the end of the previous period of operation of the relay. The pre-setting button 30 which is connected to the negative pole of a source of direct current is operated to pre-set the armature in "operated" position. If the armature is standing in its "non-operated" position, when the button 30 is actuated, the relay coil 22 is energized by a surge of current of the proper polarity to move the armature to "operated" position. This surge of current is caused by discharging the capacitor 40 through coil 22, a circuit being completed which extends from (—) and nicludes button 30, contact 33, terminal No. 7 of the relay, coil 22, terminal No. 8 of the relay, wire 49, and side 58 of the capacitor 40, which is positively charged. The presetting button 34 is operated to move the armature to its "non-operated" position. If the armature is in "operated" position when button 34 is actuated, capacitor 38 is discharged through the coil 22 by a circuit which extends from (—) and includes button 34, contact 37, terminal No. 8, coil 22, terminal No. 7, wire 47, and positively charged plate 52 of the capacitor 38. If the button 30 is operated when the armature is in its operated position, or the button 34 is operated when the armature 12 is in its non-operated position, the current which flows through the coil 22 as a consequence thereof, is of the same polarity as that which causes the armature to stay in its "operated" or "non-operated" position, respectively. Resistors 32 and 36 prevent a short circuit between the positive pole of direct current connected at terminal No. 3 of the relay and the negative pole which is connected to the pre-setting buttons 30 and 34.

The operation of the circuit will be readily understood from the preceding description, but may be briefly summed up here.

When the armature 12 is in its "non-operated" position, shown in FIG. 1, it will take longer to charge capacitor 40 than capacitor 38 because the circuit for charging capacitor 40 is then through coil 22. Resistor 50 provides

a slight flow of current in the coil from terminal No. 7 to terminal No. 8; and this serves to polarize core 27 sufficiently to repel armature 12 and lock the armature in its "non-operated" position. The path for this current is from (+) through terminal No. 3, contact 20, terminal No. 4, resistor 36, terminal No. 7, coil 22, terminal No. 8, conductor 49 and resistor 50 to (−). When the input contact 42 is closed momentarily, however, capacitor 40 discharges and a pulse of reverse current flows through coil 22 from terminal No. 8 to terminal No. 7. This is powerful enough to polarize core 27 in the reverse direction to cause it to attract armature 12, and shift the armature to its "operated" position. Capacitor 38 now takes slightly longer to charge than capacitor 40; and a slight current now flows through resistor 48, coil 22, and resistor 32 in a direction to lock the armature in its "operated" position until another pulse of current is created in the circuit through momentary closure again of input contact 42. This shifts the armature 12 back again to its "non-operated" position.

When the relay armature is in its "non-operated" position, the positive pole of the direct current source is connected from terminal No. 3 through armature 12 to the conductor 24 of the output circuit; while when the relay is in its "operated" position the positive pole of the direct current source is connected to the conductor 26 of the output circuit.

In one practical application of this invention, the direct current source was capable of delivering forty-eight volts of energy, coil 22 had a resistance value of four thousand ohms, resistors 32 and 36 each had a value of two hundred and fifty ohms, resistor 44 had a value of twelve hundred ohms, and resistors 48 and 50 each had a value of twenty-two thousand ohms.

While the invention has been described in connection with a specific embodiment thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. A bi-stable relay circuit comprising a relay having a single coil, a single movable contact arm and at least two front and at least two back contacts, first circuit means including a source of electrical energy, the contact arm, one front contact, a resistor, and the coil to cause current to flow through the coil in a direction to hold the contact arm in contact with said front contacts when the contact arm is in contact with said front contacts, second circuit means inluding the source of energy, the contact arm, one back contact, a resistor, and the coil, when the contact arm is in contact with said back contacts, to cause current to flow in the opposite direction through said coil to hold the contact arm in contact with said back contacts, polarizing means tending to hold said contact arm in engagement with the contact with which it is engaged, and a third circuit means connectable to said first and second circuit means to cause a surge of current to flow in a direction opposite to the current then flowing through said coil upon the momentary connection to said third circuit means to one pole of a direct current source to drive the contact from the contacts, with which it is then engaged, to the opposed contacts.

2. A bi-stable relay circuit, comprising a relay having a single coil, a single movable contact arm, and a front and a back contact, polarizing means tending to hold said contact arm in engagement with the contact with which it is engaged, a pair of serially-connected capacitors connected across said coil, at least two resistors, a first circuit means including a source of energy, the contact arm, the front contact, the coil, a resistor, and one capacitor to charge one capacitor and to cause current to flow in a direction through the coil to hold the contact arm in contact with said one contact, a second circuit means including the source of energy, the contact arm, the back contact, the coil, a resistor, and the other of said capacitors when the contact arm is in contact with the back contacts to charge said other capacitor and to cause current to flow in the opposite direction through the coil to hold the contact arm in contact with the back contacts, and means for momentarily connecting one pole of a direct current source between said capacitors to discharge one of said capacitors to cause a surge of current to flow in a direction opposite to the current then flowing through said coil to drive the contact arm from the contact with which it is then engaged to the opposed contact.

3. A bi-stable relay circuit as claimed in claim 1, wherein said movable contact arm is connected to one terminal of said source of direct current.

4. A bi-stable relay circuit, comprising a relay having a single coil, a single contact arm connected to one pole of a source of energy, a front and a back contact, polarizing means tending to hold said contact arm in engagement with the contact with which it is engaged, first circuit means including, in series, said one pole, said contact arm, one of said contacts, said coil, a resistor, and means connecting said resistor to the opposite pole of said source of energy to cause current to flow through said coil to hold said contact arm in engagement with said one contact, a second circuit means including the source of energy, the contact arm, the other contact, said coil, and a second resistor to hold said contact arm in engagement with the other contact when said contact arm has been moved into engagement with said other contact, a pair of capacitors connected serially across said coil and across said first and second circuit means, means including a third resistor connected between said capacitors and connecting said capacitors to said opposite pole, and means for intermittently connecting one pole of a direct current source between said capacitors to discharge said capacitors alternately to cause surges of current to flow alternately in opposite directions through said coil to drive said contact arm alternately in opposite directions from engagement with the contact with which it has been engaged into engagement with the other contact.

5. A bi-stable relay circuit as claimed in claim 4, wherein there is a second front contact and a second back contact, said contact arm is in engagement with both said front contacts in one position and with both said back contacts in its other position, and said second contacts are connected to an output circuit so that current flows always in the same direction in said output circuit.

6. A bi-stable relay circuit, comprising a relay having a single operating coil, a pair of front contacts, and a pair of back contacts, a single contact arm movable between engagement with said front contacts and engagement with said back contacts, means connecting said contact arm to one pole of a source of direct current, first circuit means including a first resistor and a second resistor for connecting one of said back contacts, and said coil in series with the opposite pole of said source of direct current, when said contact arm is in engagement with said one back contact, second circuit means including a third resistor and a fourth resistor for connecting one of said front contacts and said coil in series with said opposite pole of said source of direct current, when said contact arm is in engagement with said one front contact, means connecting the other front contact and the other back contact to an output circuit, a pair of capacitors connected serially across said coil and across said second and fourth resistors of said first and second circuit means, means including a fifth resistor connected between said capacitors and connecting both capacitors to said opposite pole, polarizing means tending to hold said contact arm in engagement with the contacts with which it is engaged, and means for intermittently connect-

ing between said capacitors a pole of a direct current source which is of the same polarity as the first-named pole, said first circuit means being operative to charge one of said capacitors and to cause current to flow through said coil of one polarity to aid in holding said contact arm in contact with said back contacts when said contact arm is in contact with said back contacts, and said first circuit means being operative to charge the other of said capacitors and to cause current to flow through said coil of the opposite polarity to aid in holding said contact arm in contact with said front contacts when said contact arm is in contact with said front contacts, said capacitors being operative alternately, upon successive momentary

connections to the last-named pole, to discharge to cause a surge of current to flow through said coil of the proper polarity and of sufficient magnitude to drive said contact arm alternately away from contact with the contacts with which it has been engaged and into engagement with the other contacts.

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