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2,759,130

RELAY CIRCUITS

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FIG. 1

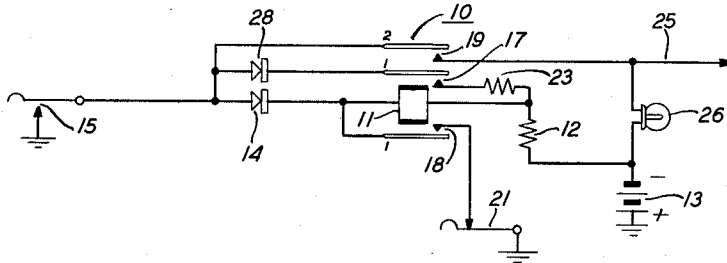


FIG. 2

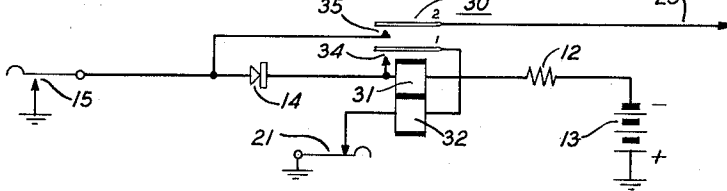


FIG. 3

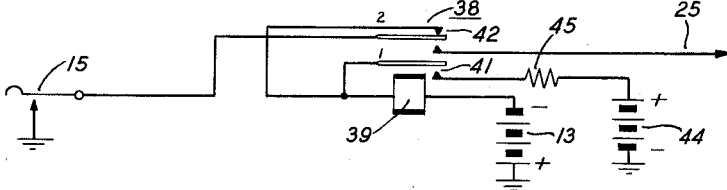


FIG. 4

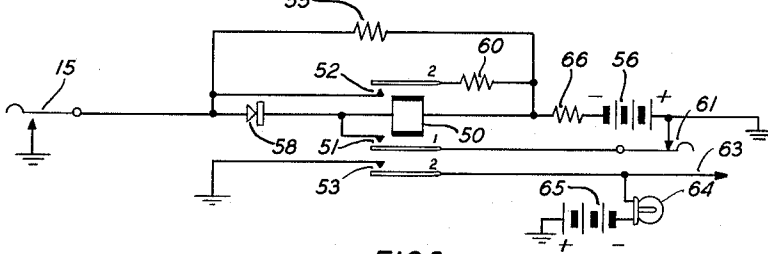
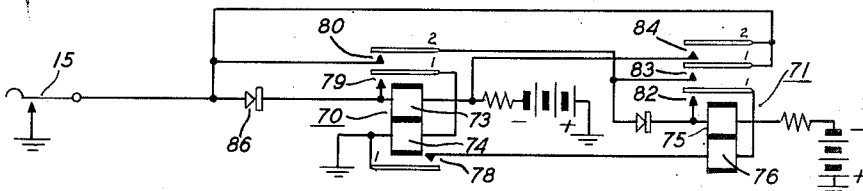


FIG. 5



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2,759,130

RELAY CIRCUITS

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This invention relates to relay circuits and more particularly to such circuits employing relays having multiple memory states.

The function of counting or tracking a single pulse is one which inherently requires three states of memory. These three states correspond to the period before the presence of the pulse, the period during the pulse, and the interval after cessation of the pulse. While a simple two-state memory device might be employed if the duration of the pulse were always constant, the general and usual case requires that there be a distinct memory state in the counting circuit to acknowledge the presence of the pulse. The usual relay is, however, a two-state device, i. e., its contacts are either open or closed, and therefore to recognize three states two relays have been employed in circuits designed for that purpose. Two relays, however, have a total of four memory states so that this results in a waste of one possible memory state.

Similarly in a number of pulse dividing and pulse counting circuits it is desirable to have multiple states of memory capable of cooperating with the associated circuitry to perform the desired function. As large systems employing memory circuits, such as digital computers, toll telephone dialing systems, automatic message accounting networks, etc., grow in complexity, size and speed desired, their memory requirements also are multiplied enormously. It is therefore apparent that very large economies can be realized by the utilization of a fewer number of relays to provide a given number of memory states by utilizing circuits in which the number of memory states possible for each relay is increased.

An object of this invention is to provide relay circuits employing a minimum number of relays to recognize a given number of conditions.

Another object of this invention is to decrease the number of relays required in circuits for counting, tracking, or identifying pulses.

A further object of this invention is to increase the utilization efficiency of relays and thereby to reduce the cost and expense of large switching and other electrical systems wherein a large number of memory states are required.

These and other objects of this invention are attained in accordance with features of this invention by providing a circuit including a relay with two distinct sets of contacts, each set comprising one or more pairs of contacts. In accordance with one feature of this invention, the contacts of the two sets close on different values of flux linkages with the operating winding. The circuit is constructed to allow the magnetic flux in the operating winding to build up to a value sufficient to close the contacts of the first set but insufficient to close the contacts of the second set during the duration of the pulse. The

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circuit, however, allows the operating current flowing through the relay windings after cessation of the pulse to generate sufficient magnetic flux to operate the contacts of the second set.

In one specific embodiment of this invention, a resistance is placed in parallel with the operating winding of the relay to shunt a portion of the pulse current around the winding during the presence of the pulse so that only the contacts of the first set are operated, but a path is provided for the full operating current to flow through the winding alone on cessation of the pulse. In other specific embodiments of this invention, only one winding and one voltage source are utilized during the presence of the pulse to close the contacts of the first set, while either two windings on the relay or two voltage sources are utilized after cessation of the pulse to close the contacts of the second set.

By employing contacts in two different sets operable on different magnetic flux linkages three states of memory are provided, the states corresponding to no contacts being closed, the contacts of the first set alone being closed, and the contacts of the first and second sets being closed. Further memory states can be provided by utilizing contacts with different operating and release magnetic characteristics. Specifically, by providing that the contacts of the first set release on a higher current than the contacts of the second set a fourth memory state can be readily obtained.

These contacts may be provided by employing any of a number of known relay structures wherein current is passed through an operating winding to close contacts against a spring or other restraining force when the magnetic flux due to the operating current has built up to a predetermined value. I have found it advantageous to employ contacts of the reed type which are disclosed in W. B. Ellwood Patent 2,289,830, granted July 14, 1942, as different operating characteristics may readily be obtained for contacts of this type by providing different initial separations between the contacts, different spring tensions, different materials, etc. Further, by properly varying the construction of different contacts of the reed type I have found that contacts may be obtained readily which close on a higher current but release on a lower current than other contacts. Specifically, the release characteristics of particular contacts may be varied by employing different mating surfaces for the contacts. As this change in contact structure primarily affects only the release characteristics, the variations in structure required to alter the close and release flux requirements are substantially independent of each other.

Relay circuits in accordance with this invention may be employed in a wide variety of applications and specific embodiments comprising single pulse counters, a two pulse recycling counter or pulse divider, and a three pulse recycling counter or pulse divider are described herein.

It is a feature of this invention that a relay circuit comprise a relay provided with two sets of pairs of contacts which operate on different values of flux linkages therewith and circuitry to allow the magnetic flux generated by the operating winding of the relay to build up to a value sufficient to operate only the first set of contacts during the presence of the pulse and to build up to a value sufficient to operate the second set of contacts only on cessation of the pulse, whereby at least three memory states are defined by a single relay.

Other features of specific embodiments of this inven-

tion comprise specific circuitry for determining the prescribed build up of magnetic flux in the operating winding of the relay. These features include the employment of a resistor in shunt with the operating winding during the presence of the pulse and a diode or rectifying element for removing the shunt resistor on cessation of the pulse, the employment of two windings on the relay so arranged that current will not flow through the second winding until after the cessation of the pulse, and the employment of two batteries so arranged that the second battery is applied to the operating winding of the relay only on cessation of the pulse.

It is further a feature of this invention that a fourth memory state may be provided in a circuit comprising a single relay by employing contacts of two sets, the contacts of the first set closing on a lower current than those of the second set but releasing on a higher current than those of the second set.

These and various other features of this invention may be readily understood from consideration of the following detailed description and the accompanying drawing, in which:

Figs. 1, 2 and 3 are schematic representations of three relay circuits comprising single pulse counters illustrating three specific embodiments of this invention;

Fig. 4 is a schematic representation of another specific illustrative embodiment of this invention comprising a two pulse recycling counter employing a single relay; and

Fig. 5 is a schematic representation of still another specific illustrative embodiment of this invention comprising a two relay-three pulse recycling counter.

Turning now to the drawing, the embodiment of Fig. 1 comprises a relay 10 having a winding 11 in series with a resistor 12, a voltage source 13, a diode element 14, which may be a varistor, rectifier or other unidirectional conducting element, and some means for applying a pulse to the coil 11, which is shown in the drawing as switch 15. The relay 10 also comprises contacts 17, 18 and 19 arranged in two sets, identified on the drawing by the small numerals 1 and 2. The contacts 17 and 18 comprise the set 1 contacts and are arranged to close on the coupling thereto of a smaller amount of flux linkage from the winding 11 than the contacts 19 of set 2. These contacts may be of any of a number of types. I have found contacts of the reed type as disclosed in W. B. Ellwood Patent 2,289,830, issued July 14, 1942, to be advantageous in relay circuits in accordance with my invention. In contacts of the reed type disclosed in the Ellwood patent, the magnetic flux requirement for closing the contacts can be varied between the individual contacts of a single relay by providing different initial gap separations or springs of different stiffnesses either with the same gap spacing or different gap spacings. Additional variations in the contact springs that may be employed to provide contacts of different operating characteristics include altering the mechanical dimensions of the springs, employing different materials for the springs and particularly materials of different permeabilities, or mounting the contacts so as to be in more or less intimate relationship with the magnetic circuit of the operating winding.

Before the appearance of any pulse, the relay 10 is fully released and the contacts of both sets are open. A pulse may be applied, in the illustrative embodiment portrayed, by closure of the switch 15 which causes the positive pulse to flow through the diode element 14, the winding 11, and the resistor 12 to the negative side of the battery or voltage source 13. It is to be understood, of course, that the illustration of a switch 15 as the pulsing means is only for purposes of explanation and that a pulse may be derived from any source for application of operating current through the winding 11. This operating current causes the contacts 17 and 18 of set 1 to close. Closure of contacts 18 provides a path from

the battery 13, through the winding 11, the closed contacts 18, and the closed reset switch 21 to ground. However, while the pulse remains this path is ineffectual. Closure of contacts 17 causes a path including contacts 17 and resistor 23 to appear in parallel with the winding 11 between the pulse source 15 and the voltage source 13. Thus before the operating current flowing through the coil 11 comprising the entire pulse current can cause the magnetic flux in the coil 11 to build up to a value sufficient to close the contacts 19 of the second set of contacts on the relay 10, a portion of the pulse current is shunted around the winding 11 through the resistor 23.

As long as the pulse remains the relay will be in a stable condition in which the flux built up by the portion of the pulse current flowing through the winding 11 is sufficient to maintain the contacts of set 1 closed but insufficient to close the contacts of set 2. We have therefore obtained identification of two of the states of the pulse; before the occurrence of the pulse, the contacts of both sets were open, and during the presence of the pulse the contacts of set 1 only were closed. Upon removal of the pulse the full current from the source 13 again flows through the winding 11, but now to ground through the lock up path provided by the closed contacts 18. Contacts 17 will remain closed but on current will flow through this path due to the presence of the diode element 14. Thus in effect removal of the pulse results in a reversal of the voltage across the diode element 14 rendering it non-conducting and thereby removing the shunt path including the shunt resistor 23. As the full operating current is flowing through the winding 11, the flux may now build up to a value sufficient to operate contacts 19 of the second set. Thus the third state of the pulse, the condition or state after completion of the pulse, can be identified by closure of contacts 19. The subsequent appearance of a pulse will occur directly on the output lead 25, which can cause an indicating lamp 26 to be lit. Opening the switch 21 releases the circuit and returns it to its initial unoperated state.

The circuit of Fig. 1 may advantageously be employed as a one pulse counter in that the first pulse applied to it is not passed on through the output lead 25 but all subsequent pulses will be applied directly through closed contacts 19 to the lead 25. Thus the lead 25 may be connected to a subsequent counter stage and to a subsequent counter indicating lamp 26, a number of circuits as illustrated in Fig. 1 being connected in tandem. When thus employed, a second diode element 28 is advantageously employed in the shunt path to assure sufficient operating margins that interference will not occur between successive counter stages. Further if these circuits are connected in tandem, the diode element 14 will function to prevent the relay's locking ground, through contacts 18, from being passed on to succeeding stages as well as preventing conduction through the shunt path upon disappearance of the first pulse.

It may be noted that contacts 17 might be permanently shorted so that there is no initial application of the full pulse to the winding 11 but instead, upon the appearance of the pulse, the shunt path is immediately present. However, I have found that employing contacts 17 in the shunt path increases the operating speed of the relay.

In one specific illustrative embodiment in which a single three-state relay employing reed contacts, in accordance with this invention, was employed in a single pulse counting circuit as illustrated in Fig. 1, the contacts of set 1 operated on the magnetic flux due to a steady state current of approximately half that required to operate the contacts of set 2.

In Fig. 2 there is illustrated another embodiment of this invention as a single pulse counter comprising a relay 30 having a first winding 31 and a second winding 32

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and contacts 34 comprising the set 1 contacts of the relay and contacts 35 comprising the set 2 contacts of the relay. In this embodiment application of the pulse, as by closure of the switch 15, causes the full operating current to flow from battery 13 through the winding 31 and diode element 14 thereby closing the contacts 34, i. e., the set 1 contacts. The magnetic flux generated by this current flowing through the winding 31 is sufficient to close the contacts 34 but insufficient to close the contacts 35, i. e., the set 2 contacts. While the pulse is present no current can flow through the closed contacts 34 and the winding 32 to ground as the presence of the pulse causes ground to be applied to both sides of the winding 32. Upon cessation of the pulse, however, the battery 13 is also applied to the winding 32 which is arranged so that its flux aids the flux generated by the current flowing through winding 31. The current flowing through the two windings 31 and 32 in series generates a magnetic flux sufficient to cause the contacts 35 to close so that the next pulse applied to the circuit is applied directly to the output lead 25. Diode element 14 prevents the battery voltage 13 causing current to flow in lead 25.

In Fig. 3 is illustrated another embodiment of this invention as a single pulse counter comprising a relay 38 having a single winding 39 and a pair of contacts 41 comprising the first set of contacts and front and back contacts 42 comprising the second set of contacts. In this circuit application of a pulse causes the pulse current to flow through the normally closed back contacts 42 and the winding 39 to the voltage source 13. Voltage source 13 is so chosen that the current through winding 39 and the number of turns of the winding are such as to generate a flux sufficient to close the contacts of set 1, i. e., contacts 41, but not to operate the contacts of set 2, i. e., transfer the contacts 42. Closure of contacts 41 causes current to flow from a second voltage source or battery 44 through a resistor 45 to the ground at switch 15. As switch 15 is closed while the pulse is applied battery 44 has no effect on the winding 39.

Removal of the pulse, however, means an opening of the switch 15 which applies the pulse in the simplified illustrative circuit depicted, and battery 44 now aids battery 13 thereby causing an increased current to flow through winding 39 with a resultant increase in the ampere-turns of the winding. This increased current thus causes the winding 39 to generate sufficient flux to operate the contacts of set 2 by transferring the contact 42 so that the next pulse is applied directly to the output lead 25. As the batteries 13 and 45 are not connected to the output lead 25 when the back contacts 42 are open, no diode element need be included in the circuit to assure against the sending of false information to subsequent circuits.

The principles of my invention are of course not limited to single pulse counter circuits or to any particular types of circuits but may be utilized in a large number of different relay circuits where it is desired to employ relays with several states of memory in accordance with this invention in place of a larger number of relays with but two states of memory. Thus the counting of two pulses on a recycling basis is a task which fundamentally requires four memory states. These are the two states corresponding to the two intervals when pulses are present and the two states corresponding to the intervals between pulses. With prior two-state relays, therefore, a minimum of two relays has been required. However, in circuits in accordance with my invention a single relay with four memory states can be employed. As pointed out above the magnetic fluxes required to operate the different contacts of a single relay may be varied by altering slightly the constructions of the contacts, as by providing different spring tensionings, different contact separation gaps, etc. Similarly the release characteristics of the contacts, i. e., the minimum magnetic flux required in the magnetic circuit to keep the contacts closed, may

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be varied. This may most advantageously be varied between similar contacts of the reed contact type by providing different mating surfaces on the contacts or different mating surfaces on the armatures of other relay types. The mating surfaces may differ from each other in their shape, in the material employed for the mating surface, in their magnetic properties, etc. The mating surfaces of the contacts have a direct and primary effect on the release characteristics of the contacts, but only a slight secondary effect on their operating characteristics. Therefore the operating and release characteristics can be varied substantially independently of each other. Variations in the retractile force of the contact spring will also effect the release characteristics of the contacts but this variation is not independent of the operating characteristics of the contacts but this variation is not independent of the operating characteristics. While various types of relays and contacts may be employed in circuits in accordance with this invention, I have found that distinct operating and release variations may readily be introduced into reed type relays as disclosed in the above-mentioned Ellwood patent.

Turning now to Fig. 4 a one relay pulse divider which can count two pulses on a recycling basis is depicted employing a single relay 50 having a pair of contacts 51, comprising the set 1 contacts and designated on the drawing by the small numeral 1, and contacts 52 and 53 comprises the set 2 contacts and designated on the drawing by the small numeral 2. Where in the prior embodiments of Figs. 1, 2 and 3 it was only necessary that the contacts of the first set operate on a lower value of flux linkage than the contacts of the second set, in the embodiment depicted in Fig. 4, the contacts of set 1 must also have a higher release current than the contacts of set 2. This may readily be obtained as described above, so that four memory states are provided by a single relay. These four memory states of relay 50 are identified by the following conditions:

1. Neither set of contacts operated;
2. The contacts of set 1 operated on a low current;
3. The contacts of sets 1 and 2 operated on a high current;
4. The contacts of set 1 released but the contacts of set 2 still operated on a low current.

The utilization of these four states of memory of a single relay in a circuit can be exemplified by a consideration of the operation of the circuit of Fig. 4. Prior to the application of the first pulse to the circuit, the relay 50 is fully released. Upon the appearance of the first pulse, which is depicted in the drawing by a closing of the switch 15, the contacts of set 1, i. e., contacts 51 are operated. The contacts of set 2, i. e., contacts 52 and 53, are not operated due to the shunting of a portion of the pulse current through the shunt resistor 55, as described above with reference to Fig. 1, the resistor 55 being permanently across the winding 50 as shown in the drawing. Upon removal of the first pulse the full current from the battery 56 can flow through the winding 50 and through the closed contacts 51 back to the other side of the battery, the shunt path through resistor 55 being blocked by the diode element 58. The current through the winding 50 thereby is increased allowing the set 2 contacts to operate, thereby closing contacts 52 and 53.

When the second pulse appears the current through the winding 50 is again decreased due to the shunt path through the resistor 55 and also due to the shunt path through the now closed contacts 52 and resistor 60. This causes the current to drop to a low enough value to release the set 1 contacts, i. e., contacts 51, but leaving enough current through winding 50 to keep the set 2 contacts operated. Disappearance of the second pulse then releases the set 2 contacts restoring the circuit to normal. Since the circuit is a recycle counter no reset switch is needed, but such a switch 61 is depicted in the

circuit in case it is desired to restore the circuit to normal before the end of a cycle.

An output pulse is applied to the output lead 63 only on the release of the first pulse, when contacts 53 are closed, and the circuit will thus operate as a pulse divider which transmits only every other pulse applied to it. An indicating lamp 64 may also be connected between the output lead 63 and a battery 65 to indicate the occurrence of every other pulse applied to the circuit.

In one specific embodiment of this circuit resistor 55 was 1200 ohms, resistor 60, 200 ohms, the resistor 66 in series with battery 56, 1000 ohms, the resistance of the winding 50, 3200 ohms, the battery 56, 45 volts, the diode 58 a germanium diode, and the contacts of the type shown in the above-mentioned Ellwood patent.

Turning now to Fig. 5 there is depicted another specific embodiment in which the principles of this invention are applied to a two relay-three pulse recycling circuit. In this embodiment of the invention the operating characteristics of the contacts of the two sets only need be predetermined and not also their release characteristics. The circuit employs two relays 70 and 71 each comprising two windings so arranged that the magnetic fluxes due to current passing through the windings during the operation of the relays are additive. The relay 70 has two windings 73 and 74 and the relay 71 the two windings 75 and 76. Relay 70 has contacts 78 and 79 comprising the set 1 contacts and contacts 80 the set 2 contacts while relay 71 has contacts 82 and 83 comprising the set 1 contacts and contacts 84 the set 2 contacts. The operation of relay 70 on the appearance of the first pulse is the same as the operation of the circuit depicted in Fig. 2, the appearance of the pulse causing the set 1 contacts to close and the cessation of the pulse then closing the set 2 contacts due to the presence of the diode element 86 and the double winding on the relay. When the second pulse appears it is directly transmitted to relay 71 over the closed contacts 80 of relay 70 and causes the relay 71 to operate to its intermediate state in which the set 1 contacts are closed but the set 2 contacts open. On cessation of the second pulse the operating current also flows through the second winding 76 in series with winding 77, as described above with reference to Fig. 2, and the set 2 contacts, i. e., contacts 84, are closed.

On the appearance of the third pulse relay 70 is shorted through the closed contacts 84 of relay 71 as the pulse, which in this case is ground, is applied to both sides of relay 70. Relay 70 therefore releases. Relay 71, however, is held during the presence of the pulse through its contacts 83. On cessation of this pulse, however, relay 71 also releases thereby returning the circuit to normal and completing the recycling operation.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A circuit comprising relay means comprising operating coil means and at least two sets of contacts operable thereby, the first set of contacts being closed by said coil means on occurrence of a smaller amount of flux linkages with said coil means than required to close the second set of contacts, means for applying a pulse to said coil means, means for shunting a portion of said pulse from said coil means during occurrence of said pulse, the portion of said pulse shunted being such that the remaining pulse current in said coil means is insufficient to close said second contacts, and means for passing current through said coil only on cessation of said pulse sufficient to close said second contacts.

2. A circuit in accordance with claim 1 wherein said last-mentioned means comprises a voltage source and diode means preventing the passage of current from said voltage source through said shunting means.

3. A circuit comprising relay means comprising operating coil means and at least two sets of contacts operable thereby, the first set of contacts being closed by said coil means on occurrence of a smaller amount of flux linkages than required to close said second set of contacts, means for applying a pulse to said coil means, said last-mentioned means including a diode poled for passage of said pulse to said coil means, means for shunting a portion of said pulse from said coil means when said first contacts are closed, the portion of said pulse shunted being such that the remaining pulse current in said coil means is insufficient to close said second set of contacts, and means for passing a current through said coil only on cessation of said pulse sufficient to close said second contacts, said last-mentioned means including a pair of contacts of said first set and a source of voltage of such polarity that said diode prevents current from said voltage source passing through said shunting means.

4. A circuit comprising relay means comprising an operating winding and at least two sets of contacts operable thereby, potential means connected to said operating winding for producing magnetic flux linkages therein, the first set of contacts being closed on the occurrence of a smaller amount of magnetic flux linkages therewith than required to close the second set of contacts but being released on the occurrence of a larger amount of flux linkages therewith than required to release said second set of contacts, means applying a first pulse to said coil means to close said first set of contacts, means for applying current to said coil means only on cessation of said pulse to build up sufficient flux to close said second set of contacts, means for reducing the current through said coil means on application of a second pulse thereto to cause said first set of contacts to open, and means for releasing said second set of contacts only on cessation of said second pulse.

5. A circuit comprising relay means comprising operating coil means and two sets of contacts operable thereby, the first set of contacts releasing on the occurrence of a larger amount of magnetic flux linkages with said coil means than required to release the second set of contacts, means for applying current to said coil means to close both of said sets of contacts, means for reducing the current through said coil means on application of a pulse thereto to a value such that only said first set of contacts release, and means for removing said current through said coil means only on cessation of said pulse.

6. A two pulse counting recycling circuit comprising relay means comprising an operating winding and at least two sets of contacts operable thereby, potential means connected to said operating winding for producing magnetic flux linkages therein, the contacts of said first set being closed on the occurrence of a smaller amount of magnetic flux linkages therewith than required to close the second set of contacts but being released on the occurrence of a larger amount of flux linkages therewith than required to release said second set of contacts, means applying a first pulse to said coil means to close said first set of contacts, said last-mentioned means including means for shunting a portion of said pulse current around said coil means, means for applying current to said coil means only on cessation of said first pulse to build up sufficient flux to close said second set of contacts, said last-mentioned means comprising a source of voltage and diode means for preventing current from said voltage source from passing through said shunting means, means for reducing the current through said coil means on application of a second pulse thereto to cause said first set of contacts to open, said last-mentioned means comprising a shunt path including a pair of contacts of said second set across said coil means, and means for releasing said second set of contacts only on cessation of said second pulse.

7. A circuit comprising relay means comprising a single operating winding and two sets of contacts operable thereby, the first set of contacts being operable on the

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occurrence of a smaller amount of magnetic flux link-
ages with said single winding than required to operate
the second set of contacts, means for applying a current
pulse to said single winding of a first value to operate
only said first set of contacts, and means for applying
current of a second value to said single winding only on
cessation of said current pulse to build up sufficient flux
to operate said second set of contacts.

8. A circuit in accordance with claim 7 wherein said
means for applying a current pulse to said winding to
operate said first set of contacts includes a first voltage

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source, and said means for applying current to said wind-
ing only on cessation of said pulse to operate said second
set of contacts includes a second voltage source.

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