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The schematic diagram shows a differential amplifier circuit. It consists of two input stages, labeled 10 and 12, which are connected to a common differential output stage. Input stage 10 includes an input terminal 17, a resistor 18, and a component 16. Input stage 12 includes an input terminal 32, a resistor 36, and a component 37. The outputs of these stages are connected to a differential output stage, which includes a resistor 21, a resistor 22, a resistor 23, a resistor 24, a resistor 25, a resistor 26, a resistor 27, a resistor 28, a resistor 29, a resistor 30, a resistor 31, a resistor 33, a resistor 34, a resistor 35, a resistor 38, and a resistor 39. The differential output is taken from terminals 13 and 14, which are connected to a load resistor 40.

TIME	1	2	3	4	5	6	7	8
PULSE								
RELAY 19								
RELAY 20								

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PULSE FREQUENCY DIVIDER

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This invention relates to a pulse frequency divider employing only two relays and utilizing only make contacts.

Pulse frequency divider circuits employing two relays are well known in the art and are used in binary counting operations. Such circuits conventionally employ both normally open and normally closed contacts. Normally open, or frontal, contacts are those which rest in the open condition in the absence of current of greater than a predetermined value in the relay operating winding; and normally closed, or back, contacts are those which rest in the closed condition in the absence of current greater than a predetermined value in the operating winding of the relay. The contact springs on relays employing both normally open and normally closed contacts must be carefully adjusted in order to insure proper operation. In addition, such relays frequently do not operate fast enough to meet the requirements for increased speed which are imposed by continuing advances in electric circuit technology. In some instances, electronic switching circuits may be employed as high speed substitutes for relay switching circuits, but such a substitution is not always convenient.

Magnetic reed relays of the type disclosed in Patent No. 2,289,830, which issued July 14, 1942, to W. B. Ellwood, operate considerably faster than many ordinary electromagnetic relays. However, reed relays are generally provided with frontal contacts only; and they have not, therefore, been extensively used in relay frequency dividing circuits.

Pulse frequency divider circuits utilizing only normally open contacts have been designed, but such circuits employ either more than two relays or two level-sensitive relays each having more than one set of contacts responsive to different operating current levels, respectively. Relays which actuate different sets of contacts in response to different current levels in the relay operating windings must be carefully adjusted in order to assure proper operation at their respective current levels.

With the above-mentioned difficulties in mind, it is an object of this invention to perform binary counting operations with only two relays and utilizing only normally open contacts.

Another object is to improve relay pulse frequency divider circuits to meet the demands of advancing technology for increased operating speeds.

A further object is to avoid the use of plural current level responsive relays in pulse frequency divider circuits.

Yet another object is to eliminate the need for critical adjustments in pulse frequency dividers.

These and other objects of the invention are realized in an illustrative embodiment which utilizes only two, double-wound, single-level responsive relays in a pulse frequency divider circuit that depends upon only normally open contacts of the relays. Each relay has an operating winding and a holding winding which are interconnected with the normally open contacts, a source of input pulses, and an operating current source to actuate the two relays in a certain permutation of all possible combinations in response to two successive input pulses. This operation produces an output pulse train at one-half the frequency of an input pulse train.

The following specification provides a detailed description of an embodiment of the invention to enable a

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better understanding of the invention when considered in connection with the attached drawing, in which:

FIG. 1 is a schematic diagram of one embodiment of the invention; and

FIG. 2 is a timing diagram illustrating the operation of the circuit of FIG. 1.

In FIG. 1 a source 10 of input pulses is connected through a lead 11 to drive a pulse frequency divider circuit 12 in accordance with the invention to produce pulses at a pair of output terminals 13. Source 10 is schematically represented to include a relay having an operating winding 16 connected between a pair of input terminals 17 and normally open contacts 18 connected between lead 11 and ground. Each operation of the relay closes and then opens contacts 18 to apply a ground potential pulse to input lead 11.

The pulse frequency divider 12 in accordance with the invention includes two double-wound relays 19 and 20. All contacts of each relay are operated in response to a single flux level for that relay. The operating winding 21 of relay 19 is connected in series with a current limiting resistor 22 and pulse source 10 between the terminals of a battery 23 which supplies operating current to the relays. No contacts of frequency divider 12 are included in the last-mentioned connection. The positive terminal of battery 23 is grounded. The holding winding 26 of relay 19 is connected in series with frontal contacts 27 of relay 19 between ground and a terminal 28 of resistor 22. Windings 21 and 26 tend to produce aiding magnetic fluxes when energized in the connections illustrated.

Relay 20 is provided with an operating winding 29 and a holding winding 30 as well as a plurality of normally open contacts. Windings 29 and 30 also tend to produce aiding fluxes when energized in the connections shown. A terminal 31 of operating winding 29 may be connected to ground through the normally open contacts 32 of relay 19. A second terminal 33 of operating winding 29 may be connected to input lead 11 through a third set of normally open contacts 36 of relay 19. The connections from ground and from lead 11 through normally open contacts 32 and 36 to winding 29 cause the operation of relay 20 to be inhibited if relay 19 is operated when a pulse is applied to input lead 11 since both terminals 31 and 33 of winding 29 are at ground potential under these conditions.

Terminal 33 of winding 29 is also connected through a second current limiting resistor 37 to the negative terminal of battery 23. Holding winding 30 is connected in series with normally open contacts 38 between the negative terminal of battery 23 and input lead 11 to be energized upon the occurrence of a pulse on input lead 11 after relay 20 has been actuated. Contacts 39 of relay 20 are connected between lead 11 and terminal 28 to short circuit windings 21 and 26 and thereby disable relay 19 upon the occurrence of an input pulse after relay 20 has been operated. An additional set of normally open contacts 40 is provided to connect output terminals 13-13 together and thereby provide for the operation of utilization means that may be connected to those terminals.

In the absence of an input pulse on lead 11, relays 19 and 20 are inoperative and all normally open contacts associated with them are open. The closing of contacts 18 in pulse source 10 extends ground to input lead 11 thereby completing the operating circuit for winding 21 and actuating relay 19. Contacts 27 are closed to energize holding winding 26 in the circuit including resistor 22 and battery 23. Contacts 32 and 36 are also closed to prepare the operating circuit for relay 20 but the operation of relay 20 is inhibited as previously described. Upon the termination of the first input pulse, ground is removed from lead 11. Winding 29 on relay 20 is now

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energized in the circuit which includes contacts 32, winding 29, resistor 37, and battery 23. Relay 20 is actuated and closes contacts 40 to initiate an output pulse at terminals 13. Contacts 39 are closed to short-circuit winding 21, but this has no immediate effect on relay 19 because lead 11 is no longer grounded and holding winding 26 is energized. Contacts 38 in the circuit of holding winding 30 are also closed but likewise have no effect on the operation of the relays because lead 11, to which they are connected, is not grounded.

Upon the second closure of contacts 13, lead 11 is grounded once more. Winding 26 of relay 19 is now also short-circuited by contacts 39, lead 11, contacts 18 and ground. Relay 19 is thus de-energized and all of its contacts are opened. The opening of contacts 32 de-energizes operating winding 29, but relay 20 is held operated by its holding winding 30 which is now energized through contacts 38, lead 11, contacts 18, ground, and battery 23. This circuit of winding 30 includes essentially zero impedance aside from the impedance of winding 30 and battery 23. Since resistor 37 is included in the circuit of operating winding 29, the complete decay of current in winding 29 takes place over a longer time interval than is required for the build-up of current in the lower resistance circuit of winding 30. This arrangement assures that relay 20 remains operated upon the occurrence of the second pulse.

Upon the termination of the second input pulse, contacts 13 open and the ground is removed from lead 11. This removal of ground from the circuit of holding winding 30 releases relay 20 and terminates the output pulse. Frequency divider circuit 12 is now in its initial condition again with both relays de-energized and all contacts open.

The timing diagram of FIG. 2 illustrates the above-described operation of the circuit of FIG. 1 for two full cycles of operation. Horizontal lines to the right of the designation "Relay 19" and "Relay 20," respectively, indicate time intervals during which the particular relays are actuated. Inherent time delays in the operation of the relays are indicated on the diagram of FIG. 2. This operation is outwardly identical to the operation of well known two-relay pulse frequency dividers of the type shown in the O. Cesario Patent 1,751,263, which issued March 18, 1930, and which utilizes both make and break contacts. However, the pulse frequency divider circuit 12 accomplishes such operation by means of particular circuit connections to two relays which employ frontal contacts only.

What is claimed is:

1. A pulse frequency divider comprising two electromagnetic relay devices having coil means and having only normally open contacts, a source of pulses, a source of operating potential, non-contact means connecting coil means of a first one of said relays between said sources for closing the contacts of said first relay in response to a first pulse, means connecting a part of said contacts of said first relay to said potential source to establish a holding circuit for said first relay, additional contacts of said first relay connecting terminals of said second relay coil means to said pulse source and to said potential source, respectively, for inhibiting the operation of said second relay during said first pulse, means connecting contacts of said second relay between said pulse source and said first relay coil means to de-energize such coil means in response to a second pulse from said pulse source, and means connecting contacts of said second relay to said pulse source to establish a hold circuit for said second relay via said pulse source.

2. A pulse frequency divider comprising two relays, each of said relays having at least two make contacts, a source of input pulses, non-contact means applying a first pulse from said pulse source to actuate said first relay, means connecting two of said make contacts of said first relay in a circuit with a winding of said second relay for

inhibiting the operation of said second relay during said first pulse, means connected to said winding for actuating said second relay upon the termination of said first pulse, means including one of said contacts of said second relay applying a second pulse to said frequency divider for de-actuating said first relay, and means including another one of said contacts of said second relay and responsive to the termination of said second pulse for de-actuating said second relay.

3. A pulse frequency divider comprising two relays, each of said relays having an operating winding and a holding winding, said relays having only normally open contacts associated therewith, an input lead for receiving grounding pulses, a source of potential having one terminal thereof grounded, means including said source and said lead energizing the operating winding of a first one of said relays for operating said first relay to close the contacts thereof, means connecting a first set of said contacts of said first relay and the holding winding of said first relay to said source for energizing such holding winding, a connection including second and third contacts of said first relay connecting the operating winding terminals of said second relay to ground and said lead, respectively, for inhibiting the operation of said second relay during a first ground pulse on said lead, means including said second contacts connecting the operating winding of said second relay across said source, means including said lead connecting a first set of contacts of said second relay in a circuit with said source for energizing the holding winding of said second relay, and means including said lead and a second set of contacts of said second relay short-circuiting the windings of said first relay to de-energize said first relay.

4. A pulse frequency divider circuit comprising a first relay having an operating winding and a holding winding, a source of operating current, a first current limiting resistor, a control switch, non-contact means including said resistor and said control switch connecting said operating winding in a series circuit between the terminals of said source for operating said first relay in response to the closing of said switch, first contacts of said first relay connecting said holding winding in series with said first resistor between the terminals of said source, a second relay having an operating winding and a holding winding, a second current limiting resistor, second contacts of said first relay connecting said second relay operating winding in series with said second resistor between the terminals of said source, third contacts of said first relay connected between one terminal of said second relay operating winding and said control switch, means including first contacts of said second relay and having essentially zero resistance connecting the holding winding of said second relay in series with said switch between the terminals of said source, and second contacts of said second relay connected between the terminals of said first relay operating winding.

5. A pulse frequency divider comprising a first relay having a first and a second winding and having first, second, and third sets of make type switching contacts, a second relay having a third and a fourth winding and having fourth and fifth sets of make type switching type contacts, a source of pulses, a source of operating potential, a first resistor connected in series with said first winding and said pulse source between terminals of said potential source, means also connecting said first resistor in series with said second winding and said first set of make contacts between the terminals of said potential source, means further connecting said first resistor and said fourth set of make contacts in series with said pulse source between the terminals of said potential source, a second resistor connected in series with said second set of contacts and said pulse source between the terminals of said potential source, means also connecting said second resistor and said third winding in series with said third set of contacts between the terminals of said potential source, and means connecting said fourth winding in series with

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said fifth set of make contacts and said pulse source between the terminals of said potential source.

6. A pulse frequency divider circuit comprising two relays each having only frontal contacts, a source of pulses, a source of operating potential, means connecting a first one of said relays to said sources for operating said first relay in response to the beginning of each of said pulses, said means comprising non-contact means connecting a winding of said first relay to said sources for actuating said first relay in response to the beginning of a first pulse, and means including a frontal contact of said second relay short-circuiting the windings of said first relay in response to the beginning of a second pulse, and means connecting a second one of said relays to said sources for operating said second relay in response to the termination of each of said pulses, the last-mentioned means comprising frontal contacts of said first relay connected to the terminals of a winding of said second relay for inhibiting the operation of said second relay in response to said first pulse, additional means connected to a terminal of said second relay winding for actuating said second relay in response to the termination of said first pulse, and means including a frontal contact of said second relay de-activating said second relay in response to the termination of said second pulse.

7. A pulse frequency divider comprising two relays, each having an operating winding, a holding winding, and only normally open contacts, each winding of each of said relays being adapted when energized to pick up all contacts of that relay, a switch, a potential source, means including said switch connecting the operating winding of said first relay to said source for actuating said first relay in response to a first closure of said switch, means including said switch and contacts of said first relay connecting the operating winding of said second relay to said source for actuating said second relay in response to a

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first opening of said switch, means including said switch and first contacts of said second relay transferring control of said first relay from its operating winding to its holding winding in response to the first opening of said switch and for disabling said first relay in response to a second closure of said switch, and means including second contacts of said second relay transferring control of said second relay from its operating winding to its holding winding in response to the second closure of said switch and for disabling said second relay in response to the second opening of said switch.

8. A pulse frequency divider comprising two double-wound relays, each having only normally open contacts, all of the contacts of each of said relays being operable in response to a single flux level generated by current in any one of the relay windings, a switch, a potential source, a current limiting resistor connected in separate series circuits with each of the windings of one of said relays, an additional current limiting resistor connected in series with only one winding of the other relay, means including said switch and contacts of said second relay for enabling and disabling said one relay in response to first and second closures of said switch, and means including said switch and contacts of said one relay for enabling and disabling said other relay in response to first and second openings of said switch following said closures, respectively.

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