Nov. 25, 1958 J. L. RUSSELL ET AL 2,862,078

ELECTROMAGNETIC CIRCUIT-CONTROLLING DEVICE AND APPARATUS EMBODYING THE SAME

Filed Feb. 10, 1956 2 Sheets-Sheet 1

Fig. 1

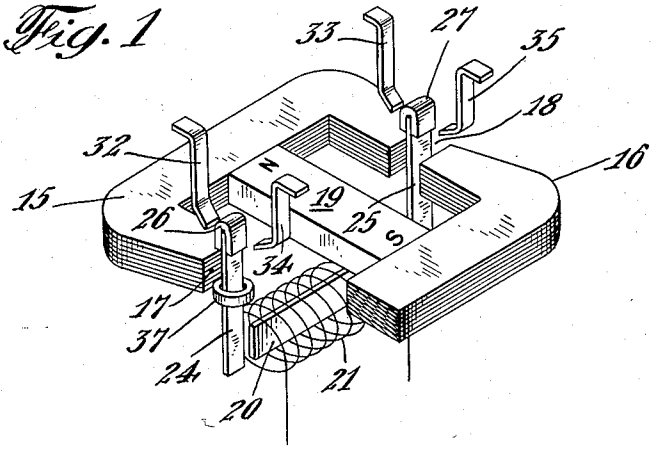


Fig. 2

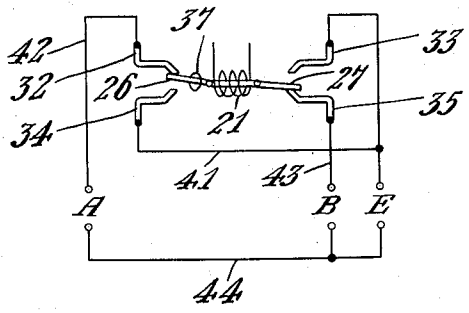


Fig. 3

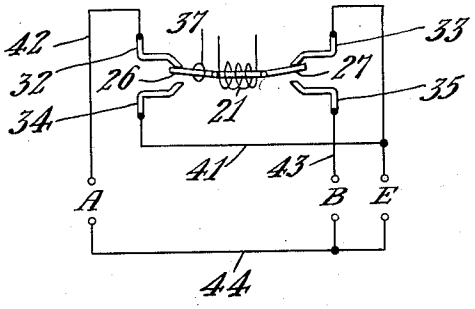


Fig. 4

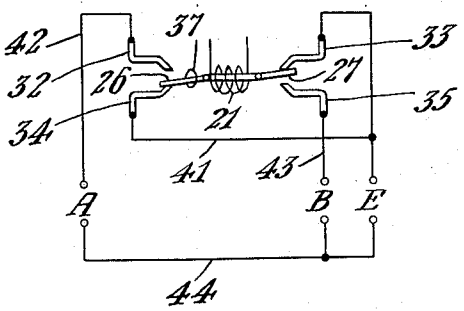
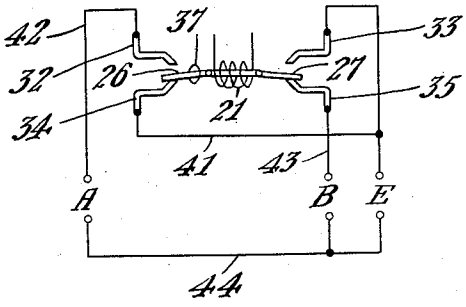


Fig. 5



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Fig. 6

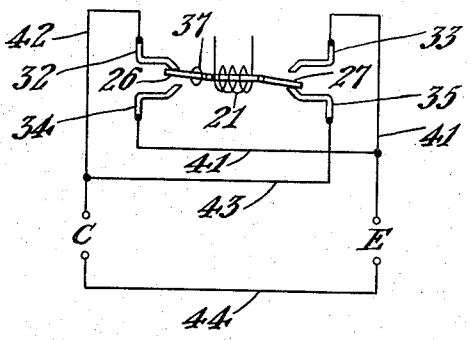


Fig. 7

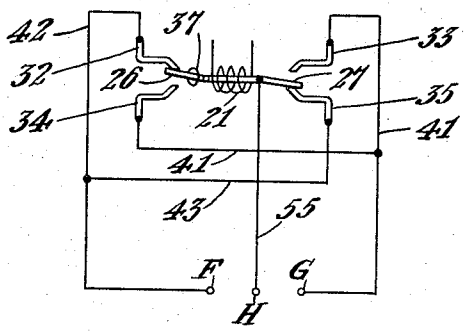


Fig. 9

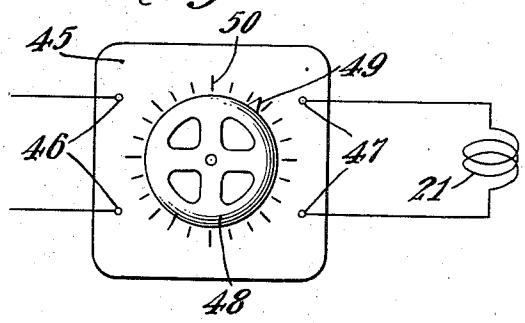


Fig. 8

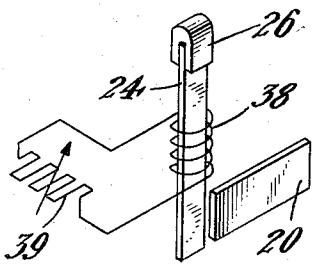


Fig. 10

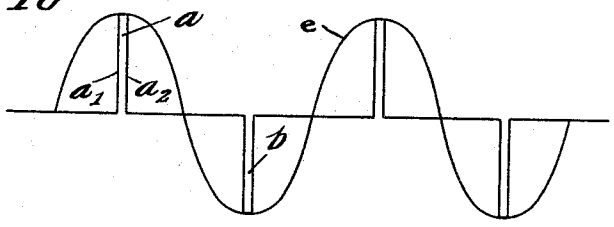
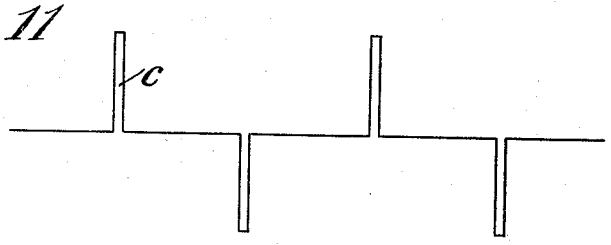


Fig. 11



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2,862,078

ELECTROMAGNETIC CIRCUIT-CONTROLLING DEVICE AND APPARATUS EMBODYING THE SAME

John L. Russell, Naugatuck, and Warren E. Hodges, Northfield, Conn., assignors to The Bristol Company, Waterbury, Conn., a corporation of Connecticut

Application February 10, 1956, Serial No. 564,765

11 Claims. (Cl. 200—103)

This invention relates to synchronous electric contactors, and more especially to a contactor of the type set forth and described in U. S. Letters Patent No. 2,636,094, granted to one of the present applicants, April 21, 1953. The contactor described in said patent is of the double-pole type, comprising a pair of single-pole double-throw switches arranged for operation in synchronism with an alternating-current supply, whereby the combination may be used as a reversing switch or commutator in a two conductor circuit. An outstanding feature of said patented contactor lies in its "zero-switching" characteristic, whereby each movable contact makes a transit from one to the other of its associated stationary contacts at a low value of excitation in the actuating winding, remaining in that position until the excitation again approaches a zero value. By this means switching is rendered abrupt, positive and symmetrical, which characteristics are desirable in synchronous commutating devices, especially when used in conjunction with servo-actuated balancing circuits. A further characteristic possessed by said patented contactor lies in the inherent tendency of the two contacting elements to operate in mutual synchronism, this being assured by the substantial identity in magnitude and in time-phase of the magnetic forces in the ferromagnetic armatures operating the respective contacting elements.

It is a purpose of the present invention to adapt the principle and the structure of said patented device to uses wherein it is desirable that the dwell of the contacts in each cycle of operation shall be controllable with respect to duration and time-phase without otherwise sacrificing the precision of performance and other meritorious features inherent in said device.

By controlling the interval in each cycle during which the device presents a complete electrical circuit, it is possible to apply measurement to selected portions of a wave and reject those portions which at the time are not of interest. By regulating the duration of said intervals it is possible to reduce the selected portion of the wave to values approaching infinitesimal time periods, and by controlling the phase of the same, repeated measurement may be made on the wave at any selected point in its contour.

It is further possible, by a modified circuit arrangement, to utilize the device as a "make-before-break" double-throw switch, the amount of overlap of the respective contacts being readily adjustable. Such a switching arrangement is especially useful in the commutating of small electromotive forces for amplification, where it is desired that during the interval of reversal there exist a short-circuit condition, to minimize the possibility of "pick-up" and other external parasitic effects.

While the present invention has been found to have maximum utility in its application to synchronous contactors of the "zero-switching," or non-resonant, class, it is also applicable to those of a resonant type wherein mechanical and electrical characteristics are so coordinated that the natural period of vibration of the oscillating part bears a definite and predetermined relationship to the frequency of the alternating current in the exciting winding.

Further objects as well as advantages of this invention will be apparent from the following description and the accompanying drawings in which:

Figure 1 is an isometric representation of a synchronous contactor embodying the principles of the invention;

Figures 2, 3, 4 and 5 are diagrammatic representations of said contactor in characteristic relative operating positions;

Figures 6 and 7 are further diagrammatic representations, illustrating further circuit arrangements;

Figure 8 shows another embodiment of a detail of the structure illustrated in Figure 1;

Figure 9 illustrates a phase-shifting transformer adapted to use with the invention;

Figures 10 and 11 are graphic representations of waveforms characterizing operation of the invention.

Referring to Figure 1, wherein are shown elements corresponding to those of said Patent No. 2,636,094, the numerals **15** and **16** designate two C-shaped ferromagnetic polar members, preferably of laminated construction, disposed with their concave faces directed inwardly, whereby their juxtaposed extremities will form air-gaps **17** and **18** adapted to be traversed by a magnetic flux. A permanent magnet **19**, or equivalent source of unidirectional magnetomotive force, is interposed between the concave faces of the polar members **15** and **16** to provide a magnetic flux therethrough and to maintain in the air-gaps **17** and **18** a field such that the extremities of the polar member **15** will be of one common polarity and those of the polar member **16** of the opposite common polarity.

A ferromagnetic core **20** carries a coil or winding **21** adapted for excitation from an alternating-current source. Juxtaposed to the extremities of the core **20** and having substantial magnetic continuity therewith are deflectable ferromagnetic members **24** and **25** positioned to lie substantially in a common plane central of the air-gaps **17** and **18**, and to be free for limited displacement therein toward and from the respective pole-tips. The members **24** and **25** are formed from saturable ferromagnetic material, having the same properties, and with the same object in view, as the corresponding members fully described in said Patent No. 2,636,094. Mounted at the extremities of the members **24** and **25** and carried thereby are double faced contact pieces **26** and **27** respectively.

Supported by means not shown in the drawing, and juxtaposed to the movable contacts **26** and **27** for electrical engagement thereby are stationary contact members **32** and **33** on the side toward the polar structure **15**, and further stationary contact members **34** and **35** on the side toward the polar structure **16**. Thus, the contacts **32** and **34** are adapted for alternative engagement by the movable contact member **26** according to the sense of its deflection, and the contacts **33** and **35** by the movable contact **27** according to the sense of its deflection.

The structure as thus far described is magnetically and electrically identical to that of said Patent No. 2,636,094, and according to principles therein set forth, upon energization of the winding **21** with an electric current, the members **24** and **25** will be deflected, one toward the polar member **15** and the other toward the polar member **16**, according to the direction of said current. Reversal of the current will reverse the relative position of the movable ferromagnetic members; and, if alternating current be passed through the winding, said ferromagnetic members and the contacts carried thereby will move back and forth in synchronism with said current and with each other. Since, as set forth in said prior patent, the respective contact members **26** and **27** tend to be deflected in

opposite senses at the same time, their joint action with current of one polarity will be to interconnect stationary contacts 32 and 35, and with opposite polarity to interconnect the contacts 33 and 34. The device thus constitutes a double-pole double-throw contactor having its two poles actuated in mutual synchronism and adapted to use as a transfer switch or as a reversing or commutating switch, or to other applications according to circuit arrangements.

In the present invention it is proposed to utilize the device set forth in said Patent No. 2,636,094, and by a structural modification and a change in electrical connections to adapt it to cyclical momentary completion of electric circuits. It is then possible to obtain from an alternating wave successive elements or pulses of voltage of extremely short duration and each occurring at a predetermined instant in the cycle. This procedure is commonly known as "sampling," and has many uses in electrical measurement, the principal utility being probably in the determination of peak voltage, a magnitude, differing materially from the commonly measured "effective" or root-mean-square value, and of special interest in tests on insulating media.

A complete conducting circuit in the form of a closed loop surrounding one of the ferromagnetic members 24, as shown in the drawings, is provided. The closed loop may take the form of a ring 37 of copper or other conducting material, as shown in Figure 1, and constituting a shroud or lagging coil, wherein, according to well known principles, the circulating currents set up by the alternating magnetic flux in the member 24 react upon said flux to produce a component out of phase with the initial magnetomotive force, with a corresponding time lag of said member with respect to the unlagged member 25.

In the form shown in Figure 8, the closed loop surrounding the ferromagnetic member 24 takes the form of a small coil or winding 38 of insulated wire having its circuit completed through a rheostat 39, by whose adjustment it is possible to regulate the conductance of said loop, and thus its lagging effect upon the motion of the member 24 and the contact 26 carried thereby. It will be understood that, while in much experimental work and general testing, adjustability of the lag of contact 26 will be desirable, in production jobs where the timing has been established at one invariable interval, the solid ring or shroud 37 of Figure 1 provides a simpler and less expensive means for effectively obtaining the desired characteristic.

The electrical connections by which the modified form of the contactor is utilized as a "sampling" switch are shown identically in Figures 2, 3, 4 and 5. Movable contact members 26 and 27 are permanently interconnected. Stationary contact members 33 and 34 are interconnected by a conductor 41. A conductor 42 is connected to stationary contact member 32, and a conductor 43 to contact 35. Terminals E between conductor 41 and a further conductor 44 provide a point where may be impressed a voltage to be investigated or otherwise utilized for measurement or control purposes. Terminals A between conductors 42 and 44 and terminals B between conductors 43 and 44, provide points whence may be derived output potentials from the contacting system.

In Figure 9, the numeral 45 designates a phase-shifting transformer having input terminals 46 adapted to be energized from a suitable A.-C. source, and output terminals 47 between which appears an A.-C. potential proportional to the input but having a phase relative to the input which is subject to regulation by a handwheel 48, and which may be determined by the indication of a pointer or index 49 upon a graduated scale 50. Thus, with the winding 21, of the contactor connected to the output terminals 47, the phase of operation of the movable contacts may be adjusted at will; and if the potential to be investigated be of the same frequency as, and of definite phase relation to, the input voltage impressed upon the terminals 46, the phase of operation of the contact system with respect to said potential may be fully controlled.

In order to understand fully the functioning of the device, consideration may first be given to its operation with connections as described, but, as in the form set forth in said Patent No. 2,636,094, lacking the short-circuited loop about the member 24, when the movable contacts will operate in synchronism, alternately assuming positions as indicated in Figures 2 and 4. It will be seen that in the position shown in Figure 2 the movable contacts 26 and 27 are in engagement with stationary contacts 32 and 35 respectively, and the circuit under test is open at the contacts 33 and 34, so that no potential will exist at either point A or B. With the mechanism in the position shown in Figure 4, corresponding to reversed polarity of the exciting current in the coil 21, the stationary contacts 33 and 34 will both be engaged by the associated movable contacts, so that again, there will exist no potential at either point A or B. Thus, so long as the contact members 26 and 27 operate in synchronism and make transition between their respectively associated stationary contacts at the same instant, no potential will at any time make its appearance at point A or B.

Consideration may now be given to operation of the apparatus throughout a cycle when the short-circuited loop 37 or 38 is included in the structure. Starting again with conditions as shown in Figure 2, a complete open circuit exists, so that no potential will appear at either A or B due to a voltage at the point E. With the winding 21 excited from an A.-C. source, as the current passes through its zero value, or shortly thereafter, the un-lagged movable contact member 27 will make an abrupt transition from stationary contact 35 to stationary contact 33; but the contact 26, delayed in its action by the influence of the short-circuited loop 27, will remain in engagement with the stationary contact 32 for a short interval of time after the contact 27 has operated. During that interval, conditions will be as indicated in Figure 3, the movable contacts being in engagement with stationary contacts 32 and 33 respectively, and providing a circuit therethrough, so that for the interval between transits of the respective contact members 27 and 26 there will appear at the point A a potential corresponding to that existing at the point E in the circuit. By adjusting the conductance of the loop surrounding the ferromagnetic member 24 as by setting the rheostat 39 in Figure 8, the interval between said transits may be made as brief as desired, so that the potential appearing at point A becomes but an element of the voltage impressed at E. If, by adjustment of the phase-shifting transformer 45, said voltage element is made to coincide with the peak of the applied voltage, the combination provides means for determining crest or peak voltage as represented in said increment.

The described performance may be better understood by reference to Figure 10 of the drawings, wherein appears a graphic representation of voltage conditions associated with successive positions of the respective contact members. The sinusoidal wave e represents the alternating voltage impressed upon the terminals E. So long as the contacts maintain the position indicated in Figure 2, and as hereinbefore explained, no potential will appear at the terminals A. As the respective contacts assume the positions indicated in Figure 3, a circuit is completed so that the instantaneous potential at the terminals E appears as a at the terminals A, corresponding to a_1 in Figure 10. As, a short interval after attainment of conditions in Figure 3, the contact member 26 assumes the position shown in Figure 4, said circuit is interrupted, and the potential a between terminals A again drops to zero as indicated at a_2 in Figure 10. Thus, there will appear at terminals A a series of potential pulses, one for each cycle of the applied A.-C. voltage, all of the same polarity, of duration depending upon the conductance of the loop 40, and phase depending upon that selected, and estab-

lished by the setting of the phase-shifting transformer **45**. Similarly, at terminals B will appear a series of impulses *b* of polarity opposite to those at A, but (assuming a symmetrical input voltage) otherwise identical in all respects to the impulses appearing at A.

In the arrangement shown in Figure 6 the electrical connections are modified to the extent of interconnecting the conductors **42** and **43**, and providing between the point of interconnection and the conductor **44** terminals C. The potential appearing at C will be a combination of those at terminals A and B in the previous diagrams, and, as shown graphically as *c* in Figure 11 of the drawings, will comprise a series of pulses of alternating polarity representing brief elements of the applied voltage, selected as to durations and phase as hereinbefore set forth.

In the form of the invention shown in Figure 7, electrical connections are made such that the device operates as a single-pole double-throw make-before-break switch. In this arrangement, contacts **32** and **35** are connected to terminal F and conductor **41** interconnecting contacts **33** and **34** is connected to terminal G. Movable contacts **26** and **27**, as in the previously disclosed embodiments, are interconnected, and by means of a common conductor **55** are connected to a terminal H. With movable contacts **26** and **27** engaging stationary contacts **32** and **35** respectively, there are provided parallel paths between terminals F and H, while terminal G is isolated. Upon reversal of the positions of the movable contacts, a circuit is similarly provided between terminals G and H, and terminal F is isolated. Utilizing the time-lag which may controllably be applied to the motion of contact **26**, said contact may be caused to remain in engagement with either of its associated stationary contacts until contact **27** has completed its transition from one to the other of its associated stationary contacts, thus providing the desired make-before-break characteristic.

The terms and expressions which we have employed are used as terms of description and not of limitation, and we have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but recognize that various modifications are possible within the scope of the invention claimed.

We claim:

1. An electromagnetic circuit-controlling device, comprising two double-throw contactors, electromagnetic means for translating said contactors through their respective ranges of operation, said means comprising movable ferromagnetic armatures adapted individually to actuate said contactors, a winding adapted to energization from an alternating-current source to excite both said armatures for motion through a limited range, and means for shifting the time response of one of said armatures to said excitation relative to that of the other of said armatures to said excitation whereby to introduce a predetermined time differential between the motion of said respective armatures.

2. An electromagnetic circuit-controlling device, comprising two movable contact members, independent ferromagnetic armatures for individually and cyclically actuating the same, a winding adapted to energization from a source of alternating electric potential to simultaneously excite both said armatures for motion, and means for delaying the response of one of said armatures to said excitation relative to that of the other of said armatures to said excitation whereby to introduce a predetermined time differential between the motion of said movable contact members.

3. An electromagnetic circuit-controlling device, comprising two movable contact members, independent ferromagnetic armatures for individually and cyclically actuating the same, a winding adapted to energization from a source of alternating electric potential to simultaneously excite both said armatures for motion, means for delaying the response of one of said armatures to said excitation whereby to introduce a predetermined time differential between the motion of said movable contact members, and further means for adjusting identically the phase relation between the cyclical response of said armatures and the alternating potential of said source.

4. An electromagnetic circuit-controlling device, comprising means for producing a magnetic field, electromagnetic means adapted to energization from a source of varying current for producing a corresponding magnetomotive force independent of said field, a pair of independently movable armatures each subject substantially simultaneously to the joint influence of said field and said magnetomotive force to partake of motion through a limited range between two extreme positions, contact means carried by each of said armatures, a pair of stationary contact members for each of said first mentioned contact means and adapted to be engaged thereby upon displacement of said armatures to their respective extreme positions, and means responsive to said magnetomotive force for shifting the time response of one of said armatures to said force relative to that of the other of said armatures whereby to introduce a predetermined time differential between the motion of said respective armatures.

5. An electromagnetic circuit-controlling device, comprising means for producing a substantially constant magnetic field, electromagnetic means adapted to energization from a source of varying current for producing a corresponding magnetomotive force to partake of motion through a limited range between two extreme positions, contact means carried by each of said armatures, a pair of stationary contact members for each of said first mentioned contact means and adapted to be engaged thereby upon displacement of said armatures to their respective extreme positions, and means comprising a closed loop positioned to link magnetically with the flux in one of said armatures and responsive to said magnetomotive force for shifting the time response of said one armature to said force relative to that of the other armature whereby to introduce a predetermined time differential between the motion of said respective armatures.

6. An electromagnetic circuit-controlling device as set forth in claim 5, wherein said closed loop includes a variable resistance.

7. An electromagnetic circuit-controlling device as set forth in claim 5, wherein said loop comprises a winding surrounding said one armature, and a variable resistance completing the circuit of said loop.

8. An electromagnetic circuit-controlling device, comprising means for producing a substantially constant magnetic field, electromagnetic means adapted to energization from a source of varying current for producing a corresponding magnetomotive force independent of said field, a pair of independently movable armatures each subject substantially simultaneously to the joint influence of said field and said magnetomotive force to partake of motion through a limited range between two extreme positions, contact means carried by each of said armatures, a pair of stationary contact members for each of said first mentioned contact means and adapted to be engaged thereby upon displacement of said armatures to their respective extreme positions, and means comprising a conductive member surrounding one of said armatures and responsive to said magnetomotive force for shifting the time response of said one armature to said force relative to that of the other armature whereby to introduce a predetermined time differential between the motion of said respective armatures.

9. An electromagnetic circuit-controlling device comprising a double-pole double-throw contactor, each pole having two stationary contacts and a movable contact adapted alternatively to engage the same, means for cyclically translating said movable contacts through their respective excursions and comprising ferromagnetic armatures adapted individually to actuate said contactors, elec-

tromagnetic means adapted to energization from an alternating-current source to excite said armatures substantially simultaneously, means to delay the response of one of said armatures to said excitation whereby to retard the cyclic action of one of said poles and introduce a phase differential between said poles, and external circuit means interconnecting pairs of said stationary contacts, each interconnected pair including a contact of the retarded pole and a contact of the unretarded pole.

10. An electromagnetic circuit-controlling device, comprising means for producing a substantially constant magnetic field, electromagnetic means adapted to energization from a source of varying current for producing a corresponding magnetomotive force independent of said field, a pair of independently movable armatures each subject substantially simultaneously to the joint influence of said field and said magnetomotive force to partake of motion through a limited range between two extreme positions, contact means carried by each of said armatures, a pair of stationary contact members for each of said first mentioned contact means and adapted to be engaged thereby upon displacement of said armatures to their respective extreme positions, means for delaying the response of one of said armatures to said magnetomotive force whereby to retard the action of one of said armatures relative to the other armature and thereby introduce a predetermined time differential between the motion of said armatures,

and circuit means interconnecting said stationary contacts so that each contact associated with said retarded armature is connected respectively with a contact associated with the other armature.

11. An electromagnetic circuit-controlling device comprising two double-throw contactors, electromagnetic means for translating said contactors through their respective excursions of operation, said means comprising movable ferromagnetic armatures adapted individually to actuate said contactors, a winding adapted to energization by electrical pulses to excite both armatures simultaneously, and means to delay the response of one of said armatures to said excitation relative to the response of the other of said armatures to said excitation.

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