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FAIL-SAFE TECHNIQUE AND SYSTEM

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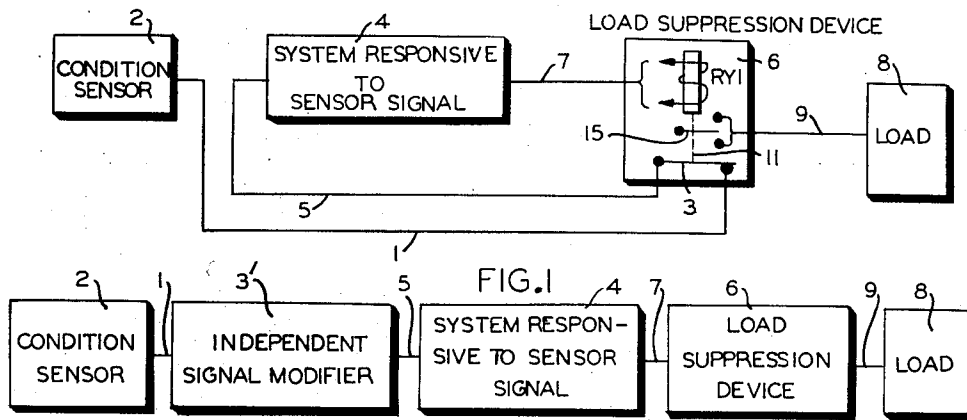


FIG. 2

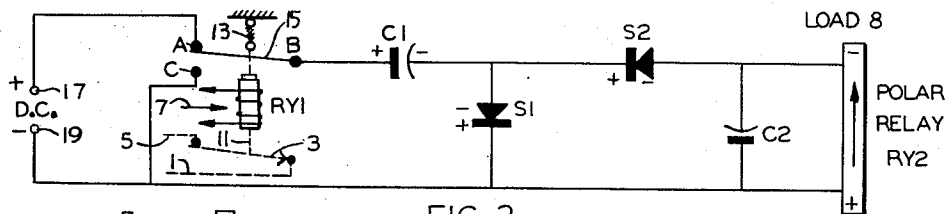


FIG. 3

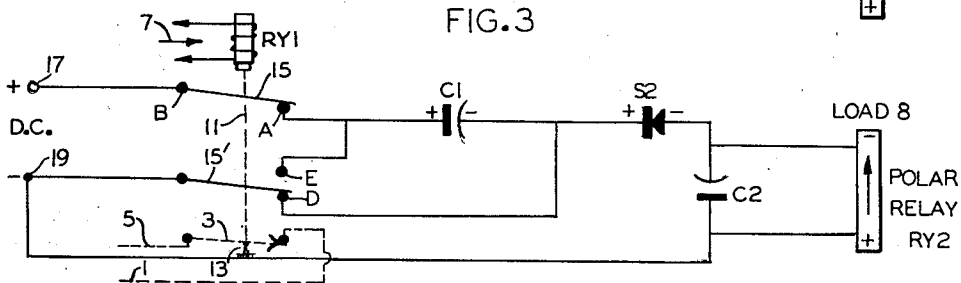


FIG. 4

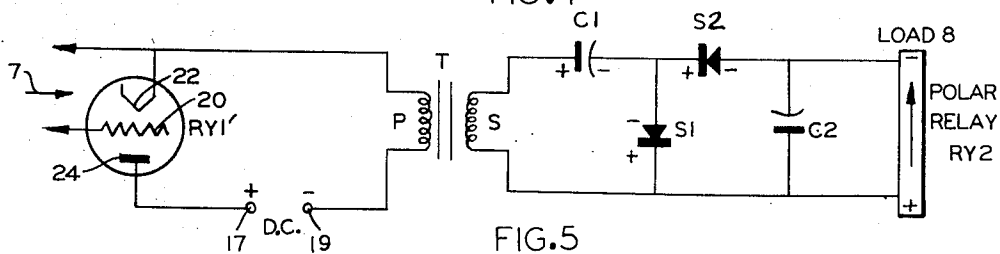


FIG. 5

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FAIL-SAFE TECHNIQUE AND SYSTEM

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26 Claims. (Cl. 340—213)

The present invention relates to electrical systems and methods, and, more particularly, to fail-safe electrical circuits in which a load can not be falsely operated through failure of any of the components of the circuits.

In copending application Serial No. 375,224, entitled Checking Method and System and filed August 19, 1953, now Patent No. 2,798,213, systems and methods for producing the fail-safe operation of electrical, electronic, mechanical and electro-mechanical systems are set forth. Some of these systems and techniques are described, also, in an article entitled "Fail-safe gets new meaning," by William G. Rowell and A. B. Van Rennes, appearing on pages 79 through 81 of Control Engineering, March 1956, and in an article entitled "Fail-safe monitoring," by William G. Rowell, appearing on pages 28 through 31 of Electronic Design, March 1, 1956. In the output of such systems, there is usually provided a switching apparatus that recurrently operates to maintain a slowly responding load, which may assume the form of a slowly acting output or load relay, in either an energized or de-energized state, so long as the switching operation in the output continues. Failure of any of the electrical or other components in the system would produce improper operation of the output switching apparatus and, in turn, would result in de-energizing or energizing the output or load relay, indicating a failure in the system.

An object of the present invention is to provide a new and improved switching apparatus of the above-described character that is particularly adapted for operation in the fail-safe systems above-described.

A further object is to provide a more generally usable electrical switching apparatus that is adapted for recurrent operation and that, through such operation, controls the ultimate response of an electrical load and insures that any failure in the switching apparatus or the associated circuitry will not result in falsely holding the load energized or de-energized, whichever condition it is normally desired to maintain. The term "fail-safe" as used in the specification and claims is intended to connote that integrity failure of any of the components involved in the circuits will not result in false operation of the ultimate output load.

An additional object of the present invention is to provide a new and improved method of fail-safe operation that is adapted for practice with a wide variety of different types of apparatus including electrical, electronic, mechanical and electro-mechanical devices.

Still an additional object is to provide a new and improved system of the character described which embodies presently available conventional inexpensive components, and does not necessitate the utilization of specialized electrical components.

A further object is to provide such a switching apparatus that is particularly adapted for use in installations where the terminal power supply is direct current.

While various proposals have heretofore been made for providing switching systems that recurrently operate

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to store energy and then to deliver energy to an output load, many such systems, with the exception of some of those described in the said copending application and the above-mentioned articles, are subject to the difficulty that the associated electrical switching contacts may become shorted, fused together or otherwise damaged, and other similar circuit failures may take place such that the ultimate load may become falsely operated. Some prior-art devices of this character embody load relays that must be of special construction, such as those of the polar type having special means whereby the relay is slow-acting in the release direction only. Such devices require mechanical dash-pot arrangements and the like in order to obtain the essential slow-action in one direction only, which add to the complexity and cost of the device.

In accordance with the present invention, on the other hand, simple conventional electrical components may be utilized to obtain complete fail-safe operation irrespective of short-circuited or fused-together parts, or other damage or failure in the system. In summary, the technique or method and system underlying the invention provides for switching means that is adapted to occupy alternate positions and that is repetitively operated at a predetermined repetition rate or rates repetitively to alternate between these positions. Means is provided for supplying direct-current potential, as is potential-storing means. An electric circuit operates when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storage means. A slow-response direct-current operated relay is provided that is adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and that is of polarity reverse to that of the supplied direct-current potential. A further electric circuit operates when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position. Preferred constructional details are hereinafter disclosed.

The invention will now be explained in connection with the accompanying drawings, Fig. 1 of which is a block diagram of a system embodying the present invention as a preferred output component thereof;

Fig. 2 is a block diagram of a modification; and

Fig. 3 is a circuit diagram of the invention in preferred form, and Figs. 4 and 5 are similar views of modifications.

Referring, first, to Fig. 1, a system is therein disclosed in which an element 2, labelled "Condition Sensor," is provided for detecting any signal, event or condition that it is desired to monitor or receive and for passing an electrical signal indication thereof to a system 4, labelled "System Responsive to Sensor Signal." The condition sensor 2 may comprise any kind of detecting device, such as, for example, a light-sensing element, a radiation-sensing element, a sound-sensing element, a heat-sensing element, an electro-mechanical transducer, a force- or pressure-sensing element, a current- or voltage-sensing element, or any other type of monitoring or receiving device, as explained in said application and the said articles. The system 4 may be any kind of receiving, amplifying or transmission system and the like. The connection from the condition sensor or detector 2 to the left-hand side or input of the system 4 is shown provided by means of a conductor 1, a switch 3 and a conductor 5. The signal, event or condition detected by the condition sensor 2 and thus fed to the input of the system 4 may be termed the

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principal signal. There will therefore appear at the right-hand or output side of the system 4, along the conductor 7, an output signal that results from the transmission of the principal signal through the system 4 between its input and output. Connected with the output conductor 7 is a load-suppression device 6 indicated schematically as comprising a relay RY1, the armature of which, indicated by the vertical dotted line 11, controls not only the before-mentioned switch 3, but, also, a further switch generally represented by the numeral 15. The switch 15 is schematically illustrated as adapted either to make or break connection with a further conductor 9 that connects to an ultimate output termination 8, labelled "Load." This schematic representation is intended to indicate that when the relay RY1 is, for example, energized, the switch 15 may connect with conductor 9 and normally energize the load 8. When, however, the relay RY1 is de-energized, the switch 15 may disconnect from the conductor 9. It is to be understood, of course, that the converse condition of normally maintaining the load 8, de-energized and then energizing the same, may, if desired, be employed. Continuing with the assumption of normal energization of the load 8 upon energization of the relay RY1, the advent of the principal signal in the output conductor 7, resulting in the energizing of the coil of the relay RY1, also causes the relay armature 11 to open the switch 3. This opens the connection between the conductors 1 and 5 and thus the connection between the condition sensor 2 and the system 4. Such a break in the input circuit results in modifying, modulating or chopping the principal signal in the input to the system 4 so that the principal signal no longer appears in the output conductor 7. The relay RY1 accordingly becomes thereupon de-energized and its armature again closes the switch 3 thus to restore the feeding of the principal signal to the input of the system 4 from the condition sensor 2 by way of the conductor 1, the closed switch 3 and the conductor 5. This feed-back or reaction from the output to the input of the system 4 is thus caused to occur periodically at a predetermined repetition rate or rates, providing, in effect, a chopping checking signal which accompanies the principal signal flowing through the system 4 between its input and output. So long as this oscillating reactive effect between output and input takes place, the relay RY1 will continue to recover the checking signal at the said repetition rate or rates and continue to modify the principal signal at that rate or rates. The system 4 will thus be maintained in periodic checking operation. Simultaneously therewith, the switch 15 will periodically connect to the conductor 9 and disconnect therefrom, thus, as explained in the said application and articles, and as hereinafter more fully explained, periodically feeding energy to keep the ultimate output load 8 energized. The load 8 is a slowly responsive device that is adapted to respond only in a period of time greater than the said repetition rate or rates of the before-mentioned signal modification, so that only in the event of loss of the checking signal or chopping modification, will the load 8 respond to produce an indication of failure in the system.

It is not necessary, though it is preferred for purposes of simplicity and economy, that the feed-back control of Fig. 1 be utilized. As explained in the previously mentioned application and articles, the checking signal may be introduced by means of an independent signal modifier 3' placed, for example, between the condition sensor 2 and the input of the system 4. Again, however, the recovery of the checking signal in the output load-suppression device 6, will maintain the load 8 energized so long as the checking signal, produced by the independent signal modifier 3', Fig. 2, accompanies the principal signal to the output of the system 4. If desired, moreover, the signal reaching the condition sensor 2 may already be provided with a checking-signal modification.

In Fig. 3, a preferred type of load-suppression device 6 is illustrated, comprising the electromagnetic relay RY1

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for receiving the periodically modified principal signal by means of the conductor 7. The switch 15 of Fig. 3 is operated between switch contacts A and C, about the pivot contact B, in response to movement of the armature 11. A restoring spring 13 normally holds the switch 15 in the illustrated position in engagement with the contact A. When the armature 11 moves downward in response to energization of the relay RY1, it pivots the switch 15 downward about the pivot contact point B to a lower position of operation. When switch 15 makes electrical contact between the pivot point B and the switch contact A, this serves to connect into electrical circuit a terminal 17, the switch 15, a storing capacitor C1, a one-way switch apparatus illustrated as a semi-conductor rectifier S1 having the indicated polarity, and a further terminal 19. Direct-current voltage D. C. is supplied to the terminals 17 and 19 in the +, - polarity illustrated so that the capacitor C1 may charge in the low-impedance or forward direction of the element S1, thereby to store or charge direct-current potential in the capacitor C1. At the same time, the switch 3 connects together the conductors 1 and 5. The relay RY1 thus becomes energized, drawing the armature 11 downward so that the switch 15 engages the contact C. The capacitor C1 may then feed-out or deliver its stored direct-current potential to the load 8, which is illustrated as a conventional polarized slow-release direct-current-operated relay RY2, which is designed to provide a high impedance to alternating-current energy, as is customary with conventional direct-current relays. In accordance with the present invention, the ultimate load relay RY2 is polarized in reverse polarity to the polarity at the terminals 17 and 19 so that the relay RY2 can only be energized by current flow in the direction of the arrow drawn thereupon. The load relay RY2, moreover, is shown shunted by the conventional holding capacitor C2. It will be observed that the capacitor C1 may, with the switch 15 in the down position, deliver its stored direct-current potential energy to the load 8 in the circuit traceable from the left-hand terminal of the capacitor C1 through the switch 15 to contact C and then to the lower terminal of the load relay RY2; thence, upward in the direction of the arrow to the upper terminal thereof and through a further uni-directional element S2 back to the right-hand terminal of the capacitor C1.

Since, as before stated, the relay RY1 is being periodically energized and de-energized at the repetition rate or rates of the checking signal before-referred to, the switch 15 is alternately operated at the said rate or rates, thus alternately to store energy in the condenser C1 through the uni-directional element S1 from the direct-current supplying means 17, 19, and thence to deliver the stored energy to the slow-response load relay RY2. The response of the direct-current relay RY2 is adjusted to permit, for example, a release response after the lapse of a period of time greater than the period or periods of the before-mentioned repetition rate or rates. So long as the switch 15 is recurrently operated at the stated rate or rates, the load relay RY2 will remain effectively energized. The frequency, of course, may be determined by the values of C1, C2, and the resistance of the load-relay coil RY2 with the applied voltage. It has been found, in actual practice, however, that the charged holding capacitor C2 has a tendency falsely to discharge through the supply-voltage terminals 19 and 17 when the switch 15 returns to the illustrated upward position in which there is engagement between the contacts A and B, thus effecting the immediate release of the relay RY2 instead of holding the relay energized. This undesirable effect, which, indeed, destroys the time-delay slow release of the relay, is overcome through the use of the element S2 which prevents such false discharge of the capacitor C2. The element S2 also serves to prevent spurious reverse-direction energization of the load relay RY2 which could otherwise be produced as a result of the voltage drop built up

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across the element S1 during the charging of the capacitor C1.

It will be evident that the system of Fig. 3 is completely fail-safe, in that the load 8, no matter what form it may assume, provided it has the characteristics before mentioned, will not be falsely energized if the integrity of any of the components of the circuit is lost. Inasmuch as the negative terminal 19 of the power supply is connected to the lower positive terminal + of the relay RY2, no component in the system can possibly fail in such a way that the positive terminal + of the power supply can be connected solely to the positive terminal + of the relay RY2. This provides inherent fail-safe characteristics.

It is not necessary, however, that the one-way or uni-directional rectifier type of switch S1 be used in the charging circuit of capacitor C1. An actual mechanical switch member 15' is shown in Fig. 4, therefore, that provides a low-impedance connection from the negative terminal 19 of the power supply to the contact D and hence to the right-hand terminal of the capacitor C1 during the charging cycle. The charging circuit is completed from the left-hand terminal of the capacitor C1 through contact A and the switch member 15 to the positive power-supply terminal 17. The switch members 15, 15' and 3 are synchronously operated by the armature 11 which moves upward when the relay RY1 is energized to disconnect the switch member 15 from contact A, to connect the switch member 15' to contact E, and to open the switch 3 to break contact between the conductors 1 and 5. The capacitor C1 is then connected from its left-hand terminal by way of the contact E and the switch 15' to the lower or + terminal of the polar relay RY2, of reverse polarity to that obtaining at the power-supply terminals 17, 19, and thence from the upper terminal of the relay RY2 through the element S2 to the right-hand terminal of the capacitor C1. The load relay RY2 and its holding capacitor C2 are thus energized as before described. The element S2 serves the same purposes as in Fig. 3, namely, preventing reverse current in the relay RY2 and preventing the false discharge of the capacitor C2 during the charging of the capacitor C1.

While the recurrently operated relay RY1 has been heretofore illustrated as of the electromagnetic type, it may be of the electric-current electron-tube, gaseous-discharge-tube, transistor, or other type, as well. Thus, in Fig. 4, an electron-tube relay is shown at RY1' recurrently operated between open and closed positions or conditions by, for example, feeding successive positive voltage impulses from conductors 7 between the control electrode 20 and the cathode 22 of the relay tube RY1', thereby to render the relay alternately conductive and non-conductive between its cathode 22 and plate or anode 24. The relay tube RY1' is connected in circuit with the direct-current power supply terminals 17, 19, which serve as a source of plate voltage for the relay tube, and the primary winding P of a transformer T, preferably of the step-up variety. The upper terminal of the secondary winding S of the transformer T becomes positive during the periods of conduction of the relay RY1', thus charging the capacitor C1 through the element S1 in the shown polarity. When the relay RY1' ceases conducting, the capacitor C1 discharges through the secondary winding S into the reversely polarized relay RY2. Other types of coupling means than the transformer T may also be employed. Again, the system is fail-safe since no component failure can result in connecting the power supply to the polar relay RY2 in the correct polarity to cause its false operation.

It is to be understood that the ultimate load 8 may assume other forms than the relay RY2, as explained in the said application and the said articles. It may, for example, comprise an indicating or a controlling apparatus, or it may comprise a meter or any other suitable type of direct-current load. The load relay RY2, moreover, may

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itself have contacts not shown, as discussed in the said articles and in the said application, which, in turn, can operate to control further apparatus.

In the case where the circuits of Figs. 3 and 4 are utilized in the system of Fig. 2, moreover, the switches 3, shown dotted in Figs. 3 and 4 to illustrate operation in the system of Fig. 1, need not be employed. The circuit of Fig. 5, moreover, may be employed in the system of Fig. 1 by causing the switching tube RY1' to modulate the input to the system 4. While the invention has been described in connection with its important application to the fail-safe systems of Figs. 1 and 2, furthermore, the invention is of broader utility in any applications where periodic or switched feeding of a load is desired. The conductor 7 feeding the relay RY1 may therefore comprise any kind of recurrent signal source, for periodically energizing the relay RY1 or RY1'. In addition, the invention is by no means restricted to operation with electromagnetic or electric-current relays. The switches 15 and 15' may, for example, be entirely mechanically operated through a mechanical timer device and the like. The techniques underlying the present invention, accordingly, are completely adaptable for use with purely mechanical vibrating systems, as well as the electrical systems before referred to. Similarly, other types of electro-mechanical switching mechanisms may be employed to attain the fail-safe results achieved in accordance with the present invention.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In an electrical system in which a principal signal modified by a repetitive checking signal having a predetermined rate or rates of repetition is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the recovery of the checking signal from the principal signal in the output and adapted repetitively to occupy alternate positions at the said repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

2. In an electrical system in which a principal signal modified by a repetitive checking signal having a predetermined rate or rates of repetition is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the recovery of the checking signal from the principal signal in the output and adapted repetitively to occupy alternate positions at the said repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a uni-directional device that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and

a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

3. In an electrical system in which a principal signal modified by a repetitive checking signal having a predetermined rate or rates of repetition is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the recovery of the checking signal from the principal signal in the output and adapted repetitively to occupy alternate positions at the said repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus operated synchronously with the said switching means that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

4. In an electrical system in which a principal signal modified by a repetitive checking signal having a predetermined rate or rates of repetition is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the recovery of the checking signal from the principal signal in the output and adapted repetitively to occupy alternate positions at the said repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with a uni-directional device for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

5. In an electrical system in which a principal signal modified by a repetitive checking signal having a predetermined rate or rates of repetition is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the recovery of the checking signal from the principal signal in the output and adapted repetitively to occupy alternate positions at the said repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means,

a direct-current-operated capacitor-shunted load relay adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the capacitor-shunted load relay to energize the same, the further electric circuit being provided with means for preventing false de-energization of the capacitor shunting the load relay during the time that the repetitively alternating switching means occupies its said one position.

6. An electrical system as claimed in claim 1 and in which the switching means comprises an electromagnetic relay-controlled switching device.

7. An electrical system as claimed in claim 1 and in which the switching means comprises an electric-current device adapted to conduct in varying degrees, thereby to occupy alternate positions of conduction to produce a switching action.

8. An electrical system as claimed in claim 7 and in which the first-named electric circuit comprises a transformer.

9. In an electrical system in which a principal signal is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the reception of the principal signal in the output for alternately first reacting upon the principal signal in the input to modify the same and then responding to the resulting modification in the output to restore the principal signal at the input, thereby to produce a repetitive checking-signal modification of the principal signal at a predetermined rate or rates of repetition, the switching means occupying alternate positions during such operation, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

10. In an electrical system in which a principal signal is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the reception of the principal signal in the output for alternately first reacting upon the principal signal in the input to modify the same and then responding to the resulting modification in the output to restore the principal signal at the input, thereby to produce a repetitive checking-signal modification of the principal signal at a predetermined rate or rates of repetition, the switching means occupying alternate positions during such operation, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a uni-directional device that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position

to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

11. In an electrical system in which a principal signal is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the reception of the principal signal in the output for alternately first reacting upon the principal signal in the input to modify the same and then responding to the resulting modification in the output to restore the principal signal at the input, thereby to produce a repetitive checking-signal modification of the principal signal at a predetermined rate or rates of repetition, the switching means occupying alternate positions during such operation, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus operated synchronously with the said switching means that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

12. In an electrical system in which a principal signal is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the reception of the principal signal in the output for alternately first reacting upon the principal signal in the input to modify the same and then responding to the resulting modification in the output to restore the principal signal at the input, thereby to produce a repetitive checking-signal modification of the principal signal at a predetermined rate or rates of repetition, the switching means occupying alternate positions during such operation, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with a uni-directional device for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

13. In an electrical system in which a principal signal is transmitted from the input to the output of the system, an output circuit comprising switching means responsive to the reception of the principal signal in the output for alternately first reacting upon the principal signal in the input to modify the same and then responding to the resulting modification in the output to restore the principal signal at the input, thereby to produce a repetitive checking-signal modification of the principal signal at a predetermined rate or rates of repetition, the switching

means occupying alternate positions during such operation, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a direct-current-operated capacitor-shunted load relay adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the capacitor-shunted load relay to energize the same, the further electric circuit being provided with means for preventing false de-energization of the capacitor shunting the load relay during the time that the repetitively alternating switching means occupies its said one position.

14. An electrical system as claimed in claim 13 and in which the switching means comprises an electromagnetic relay-controlled switching device.

15. An electric system having, in combination, switching means adapted repetitively to occupy alternate positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

16. An electric system having, in combination, switching means adapted repetitively to occupy alternate positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a uni-directional device that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

17. An electric system having, in combination, switching means adapted repetitively to occupy alternate positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus operated synchronously with the said switching means that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current operated

load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

18. An electric system having, in combination, switching means adapted repetitively to occupy alternate positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with a uni-directional device for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

19. An electric system having, in combination, switching means adapted repetitively to occupy alternate positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a direct-current-operated capacitor-shunted load relay adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the capacitor-shunted load relay to energize the same, the further electric circuit being provided with means for preventing false de-energization of the capacitor shunting the load relay during the time that the repetitively alternating switching means occupies its said one position.

20. An electric system having, in combination, electromagnetic relay-controlled switching means adapted repetitively to occupy alternate positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false deenergization of the load during the time that the repetitively alternating switching means occupies its said one position.

21. An electric system having, in combination, electric-current switching means adapted to contact and to cut-off, thereby to occupy alternate open and closed positions at a predetermined repetition rate or rates, means for supplying direct-current potential of a predetermined polarity, potential storing means, an electric circuit operative when the switching means occupies one of its positions to connect the supplying means to the storing means through a further switching apparatus that at such time permits the storage of direct-current potential in the storing means, a slow-response direct-current-operated load adapted to respond after the elapse of a period greater than the period or periods of the said repetition rate or rates and of polarity reverse to the said predetermined polarity, and a further electric circuit operative when the switching means occupies its alternate position to cause the storing means to deliver stored direct-current potential to the load to energize the same, the further electric circuit being provided with means for preventing false de-energization of the load during the time that the repetitively alternating switching means occupies its said one position.

22. An electric system as claimed in claim 21 and in which the first-named electric circuit comprises a transformer the secondary winding of which is included in the further electric circuit.

23. An electric system as claimed in claim 21 and in which means is provided for feeding electric impulses to the electric-current switching means to render the same repetitively conductive and non-conductive at the same repetition rate of rates.

24. A fail-safe system for preventing false effective energization of an electrical load through integrity failure of any component in the system, having, in combination, voltage terminals adapted to be energized with direct-current potential, electromechanical switching means having at least two positions, a first capacitor arranged to be energized from the said terminals when the switching means is in one of its positions, a first semi-conductor associated with the said capacitor so arranged to provide a low-impedance path for the energizing of the capacitor from the said terminals; an electrical load consisting of a magnetic relay which is effectively energized only when energy flows through it in a predetermined direction, a second capacitor connected in parallel with the said relay for delaying the de-energization of the relay, the said switching means being arranged to connect the energized first capacitor to the said relay when in another of its positions, thereby effectively to energize the relay and the second capacitor, a second semi-conductor disposed in the path for energizing the relay and the second capacitor from the energized first capacitor for preventing energy from flowing through the relay in a direction opposite to the said predetermined direction and to prevent the false de-energization of the second capacitor when the switching means is in the said one position, and means for recurrently operating the said switching means from one to another of its said positions at a predetermined frequency to maintain the load effectively energized.

25. A fail-safe system for preventing false effective energization of an electrical load through integrity failure of any component in the system, having, in combination, voltage terminals adapted to be energized with direct-current potential, switching means having at least two positions, a first capacitor arranged to be energized from the terminals when the switching means is in one of its positions, an electrical load arranged to be energized from the first capacitor when the switching means is in another of its positions, the said load consisting of a magnetic relay which can only be effectively energized when energy flows through it in a predetermined direction, a second capacitor connected to be simultaneously energized with the said load and arranged to delay the de-energization of the load, means for preventing false de-energization of the second capacitor when the switch-

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ing means is in its said one position, and means for recurrently operating the said switching means from one to another of its said positions, thereby to maintain the load effectively energized.

26. A fail-safe system for preventing false effective energization of an electrical load through integrity failure of any component in the system, having, in combination, voltage terminals adapted to be energized with direct-current potential, a transformer having a primary and secondary winding, electronic switching means adapted to be energized from the said terminals and arranged to supply energy having a predetermined fixed polarity to the primary winding of the transformer, a first capacitor arranged to be energized during periods when energy of the said predetermined polarity exists in the transformer secondary winding, a semi-conductor associated with the said first capacitor so arranged to provide a low-impedance path for the energizing of the capacitor from the said terminals, an electrical load consisting of a magnetic relay which is effectively energized only when energy flows

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through it in a predetermined direction, a second capacitor arranged in parallel with the said relay for delaying the de-energization of the relay, the said load being so arranged that it is effectively energized from the said first capacitor during the periods that the switching means does not effect the energizing of the primary winding of the transformer, further semi-conductor means arranged to prevent false de-energization of the second capacitor during the periods that the first capacitor is being energized, and means adapted for recurrently operating the said electronic switching means to supply energy pulses to the transformer at a predetermined frequency, thereby to maintain effective energization of the said load.

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