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[54] APPARATUS FOR EXTENDING CONTACT LIFE OF RELAYS UTILIZED FOR A.C. LOAD SWITCHING

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[58] **Field of Search** 307/138; 317/DIG. 7, 7, 8

[56] **References Cited**

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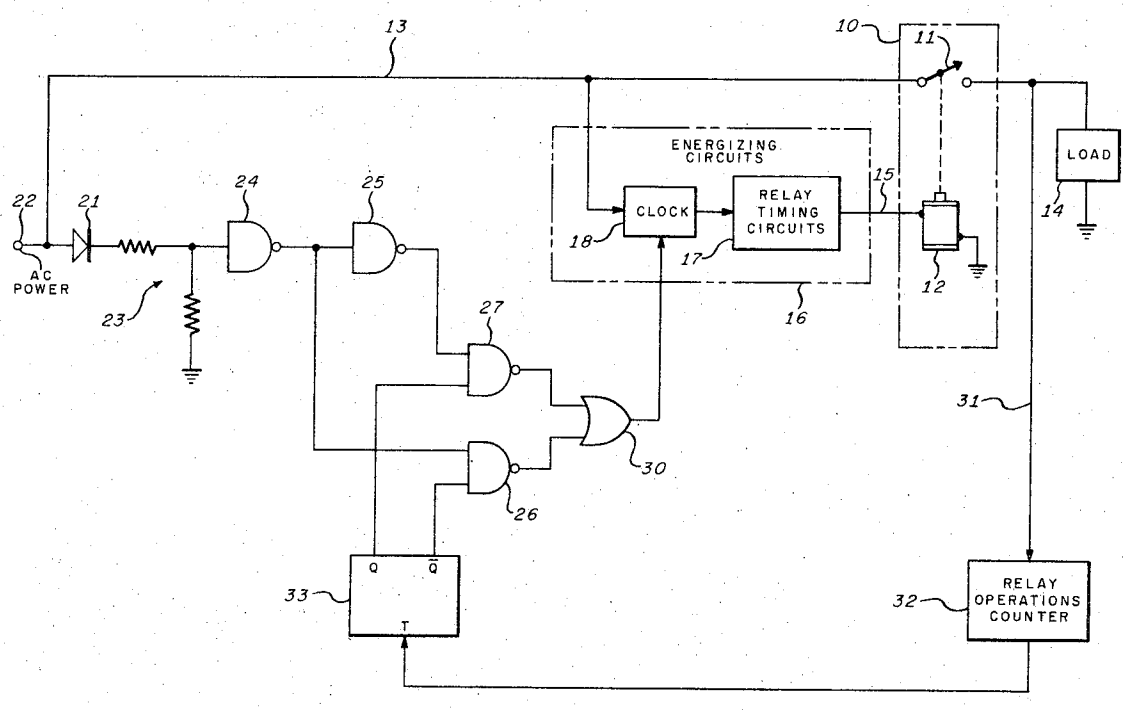
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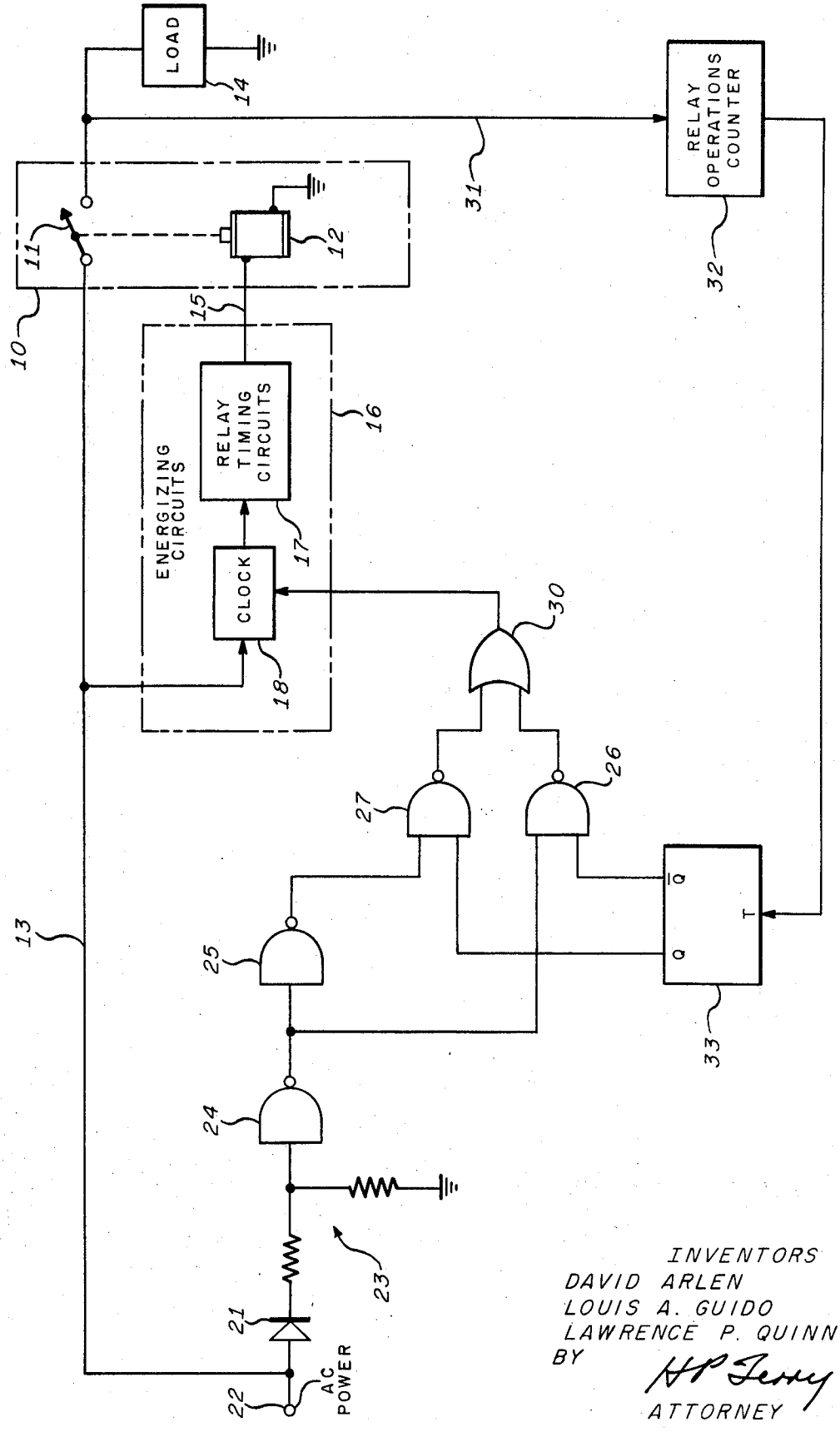
Attorney—S. C. Yeaton

[57] **ABSTRACT**

Apparatus for use with a relay utilized to switch alternating current loads to extend the contact life thereof. Circuits are included to cause alternate energization of the relay to occur in time coincidence with points on the alternating current waveform that are 180° apart, respectively. Thus, the alternate operations of the relay occur at alternate polarities of the a.c. waveform switched. Hence, contact material transferred from one contact to the other during one relay operation is re-transferred from the other contact to the one on the next following relay operation.

6 Claims, 1 Drawing Figure





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APPARATUS FOR EXTENDING CONTACT LIFE OF RELAYS UTILIZED FOR A.C. LOAD SWITCHING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to electromechanical relays particularly with regard to circuits for extending the contact life thereof.

2. Description of the Prior Art

It is known that the contact life of power switching relays utilized to control d.c. power is usually of short duration. This is because contact material transfers unidirectionally from one contact to the other during the operation of the relay until contact failure occurs.

In apparatus powered by a.c. waveforms such as sampled data systems, clocked systems, or other systems of a digital nature, the frequency of the power source is often used as the basic system timing means for reasons of economy or convenience. In systems of this type, power relay operations usually occur in time coherence with the a.c. power waveform switched by the relay contacts. Therefore, the relays always operate at a predetermined phase angle or cyclic time of the a.c. wave and consequently suffer the short duration contact life associated with the switching of d.c. power.

In prior art power systems, such as servo mechanisms and other continuous signal systems, the relay switching of alternating current power signals often occurs randomly, that is the conditions that determine the switching are not related to the timing of the current that is switched. In such systems a series of relay operations may occur at one polarity of the a.c. waveform followed by a smaller number of operations at the opposite polarity of the waveform switched. Under such conditions a build up of material on one of the contacts may occur, unbalancing the structure of the relay to an extent sufficient to accelerate the rate at which material is transferred; hence again decreasing the contact life duration. Pitted contact surfaces are often observed in relays so operated.

In prior art systems of the type described, the relays may be operated at the zero crossings of the switched a.c. power waveform in an attempt to extend the contact life. Although it is possible to determine the voltage zero crossing points with accuracy, it is difficult to arrange relay closure for these times. This is so because the procedure involves a consideration of the operating times of the relay which change substantially because of use and wear. Although the system may be designed for relay closure at the zero crossings of the power waveform, the closures may actually occur substantially off-zero thus decreasing contact life for the reasons given above with respect to synchronous relay operation.

SUMMARY OF THE INVENTION

The above disadvantages in the prior art operation of relays for switching, for example, alternating power waveforms are obviated in accordance with the present invention by apparatus for extending relay contact life. The apparatus comprises first circuits for applying an energizing signal to the relay at a predetermined phase angle of the alternating current being switched. The apparatus further includes second circuits for applying the energizing signal to the relay at a phase angle that is

180° displaced from the predetermined phase angle. Circuits responsive, for example, to the energizations of the relay are included for alternately actuating the first and second circuits for a predetermined number of energizations of the relay, respectively. By these means, relay contact material is uniformly transferred and re-transferred between the contacts hence extending contact life as discussed above.

BRIEF DESCRIPTION OF THE DRAWING

The sole drawing is a schematic logic diagram partially in block form illustrating a preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the sole FIGURE, a relay **10** is schematically illustrated including, for example, contacts **11** coupled in a conventional manner to a relay actuation coil **12**. The relay **10** is connected to switch an a.c. power waveform on a lead **13** through the contacts **11** to a load **14** and then to ground in response to relay energizing signals applied to a lead **15**. The relay energizing signals on the lead **15** are provided by relay energizing circuits **16**.

In systems of the type described above that derive their basic timing signals from the a.c. power line, the relay energizing signals on the lead **15** are applied to the coil **12** via the relay energizing circuits **16** at a particular phase angle of the a.c. power waveform in accordance with the configuration of the circuits **16**. Accordingly, the circuits **16** are schematically illustrated responsive to the alternating power signal on the lead **13**. For example, the relay **10** may be utilized in digitally-timed control systems of the type utilized at roadway intersections for the actuation of vehicular traffic and pedestrian control signal lights. In such systems the relay energizing circuits may comprise relay timing circuits **17** which are controlled by clock pulses from a clock pulse source **18**. The clock pulse source **18** derives its basic timing from the a.c. power signal on the lead **13**. The relay timing circuits **17** may, for example, comprise complex counter-decoder networks that provide timing energizing signals to the relay actuation coil **12** in response to the clock pulses from the source **18**. Circuits of this type may be found, for example, in U.S. Pat. application Ser. No. 453,072 filed May 4, 1965 in the name of John J. King entitled, "Traffic Intersection and Other Signal Controllers Responsive to a Cyclic Pulse Train" assigned to the assignee of the present invention and now abandoned. The relay timing circuits **17** of the present invention may be instrumented by the interval counter **62** and the sequencer **65** of said Ser. No. 453,072 while the clock pulse source **18** of the present invention may be instrumented by the timer unit **66** of the said Ser. No. 453,072. A specific circuit for providing the clock pulses in response to the a.c. power signal on the lead **13** is described in U.S. Pat. No. 3,379,980 issued Apr. 23, 1968 in the name of J. J. King entitled, "Pulse Generator of Low Frequency Rise Train Synchronous to High Frequency Clock Pulse Source" and assigned to the assignee of the present invention.

It is thus appreciated from the foregoing that in the absence of the present invention the contacts **11** of the

relay **10** are always closed in response to the signal on the lead **15** at the same polarity of the a.c. waveform on the lead **13**. This results in a unidirectional transfer of material between the contacts **11** precipitating early contact failure as discussed above. The present invention embodies the principle of balanced operation on a relay cycle-to-cycle basis to achieve long contact life. The timing of the switching is controlled so that, for example, successive relay operations occur on opposite polarities of the a.c. waveform. The basic timing stability of a digital system of the type described in said Ser. No. 453,072 assures that successive operations of the relay **10** occur at the same amplitude of the a.c. waveform on opposite polarities thereof. The circuits which provide the required controlled reversal of switching times, in accordance with the present invention, will now be described.

The a.c. power waveform is applied to half-wave rectifying diode **21** via a terminal **22**. The positive half-cycles of the a.c. power waveform at the terminal **22** are provided by the diode **21** to a scaling resistive voltage divider **23**. The a.c. line voltage at the terminal **22** scaled by the network **23** to levels suitable for input to conventional logic circuits is applied as the input to an inverter **24**. The inverter **24** provides a binary valued logic signal in response to the half-wave rectified a.c. power signal in a conventional manner. The binary valued logic signal from the inverter **24** is applied as the input to another inverter **25**. The inverter **25** provides a signal that is the logical inverse of the signal provided by the inverter **24**. It is thus appreciated that the inverters **24** and **25** provide binary ONE signals in response to the opposite polarity half-cycles of the a.c. waveform, respectively. For example, the inverter **24** provides a binary ONE when the a.c. power waveform is negative and a binary ZERO when the waveform is positive. Conversely, the inverter **25** provides a binary ONE when the a.c. waveform is positive and a binary ZERO when the a.c. waveform is negative.

The logic signal outputs from the inverters **24** and **25** are applied as inputs to NAND gates **26** and **27** respectively. The outputs of the NAND gates **26** and **27** are combined in an OR gate **30** to provide a signal to the clock pulse source **18** for reasons to be discussed.

A lead **31** is coupled with the relay load **14** to provide pulse signals representative of the individual relay actuations. The signals on the lead **31** are applied to a relay operations counter **32** which in turn provides signals, in a conventional counter **32** which in turn provides signals, in a conventional manner, representative of a predetermined number of energizations of the relay **10**. The relay operations counter **32** may be set by conventional means (now shown) to provide signals representative of any selected number of relay actuations. It is appreciated that if the selected number is one, the signals on the lead **31** may be utilized directly and the relay operations counter **32** eliminated.

The output of the counter **32** is applied to the toggle input of a flip-flop **33**. The Q output of the flip-flop **33** is connected as a control input to the NAND gate **27** and the $\bar{Q}$ output of the flip-flop **33** is connected as a control input to the NAND gate **26**. Thus when the flip-flop **33** is in the Q state, the logic signal from the inverter **25** is transmitted through the NAND gate **27** and the OR gate **30** to the clock pulse source **18**. Conversely, when the flip-flop **33** is in the $\bar{Q}$ state the logic signal from the inverter **24** is transmitted through the NAND gate **26** and the OR gate **30** and again to the clock pulse source **18**. It is therefore appreciated that when the flip-flop **33** is in the Q state, a binary ONE logic signal is applied to the clock pulse source **18** during the positive half-cycles of the a.c. waveform at the terminal **22**, and when the flip-flop **33** is in the $\bar{Q}$ state a binary ONE logic signal is applied to the clock pulse source **18** during the negative half-cycles of the a.c. waveform. The flip-flop **33** toggles between the Q and $\bar{Q}$ states in response to successive signals from the relay operations counter **32**. It is therefore understood that for a predetermined number of energizations of the relay **10**, binary ONE signals are applied to the clock pulse source **18** during the positive half-cycles of the a.c. waveform and during the next following predetermined number of relay energizations, binary ONE signals are applied to the clock pulse source **18** during the negative half-cycles of the a.c. waveform. As previously mentioned, the predetermined number is set by the relay operations counter **32**. These binary ONE signals alternately applied to the clock pulse source **18** with respect to the positive and negative half-cycles of the a.c. waveform in accordance with alternately occurring predetermined numbers of relay actuations operate to extend the contact life of the relay **10** in a manner now to be explained.

In operation, the energizing circuits **16** provide the relay energizing signals on the lead **15** during the positive half-cycles of the a.c. waveform when the flip-flop **33** is in the Q state and during the negative half-cycles when the flip-flop **33** is in the $\bar{Q}$ state. The energizing signals are applied during the respective half-cycles so that the relay contacts **11** are caused to close at respective phase angles of the a.c. waveform that are approximately 180° displaced from one another. The binary ONE levels, selected by the state of the flip-flop **33** and transmitted through the OR gate **30**, cause the source **18** to provide clock pulses selectively at approximately zero degrees or at approximately 180° in accordance with the flip-flop **33** being in the Q state or the $\bar{Q}$ state respectively. Generally, this may readily be achieved in accordance with the circuits utilized to instrument the clock pulse source **18** in any conventional manner. Specifically for the clock pulse source disclosed in said U.S. Pat. No. 3,379,980, the transformer **10** of the said patent is removed and the signals from the OR gate **30** of the present invention are applied to set the flip-flop **11** of the patent. The signals from the OR gate **30** are applied through an inverter (not shown) to reset the flip-flop **11** of the patent. It is therefore appreciated that the clock pulses from the clock pulse source **18** are caused to occur at approximately 0° or approximately 180° in accordance with the Q or the $\bar{Q}$ state of the flip-flop **33**, respectively. Thus, the relay timing circuits **17** of the type hereinabove described provide the relay energizing signals on the lead **15** selectively at either approximately 0° or 180° in accordance with the state of the flip-flop **33**. Because of the inherent delay in relay actuations, the relay contacts **11** will be caused to close at a particular phase angle in the positive half-cycles of the a.c. waveform when the flip-flop **33** is in the Q state and will be caused to close at a phase angle displaced approximately 180° from the particular phase

angle when the flip-flop 33 is in the $\bar{Q}$ state. Thus it is appreciated that because the flip-flop 33 alternates between the Q and $\bar{Q}$ states in response to alternately occurring predetermined numbers of relay operations, the relay contacts 11 will be caused to close at alternately occurring positive and negative voltages of equal magnitude. Thus contact material transferred from one contact to the other when the flip-flop is in the Q state will be re-transferred from the other contact to the one when the flip-flop 33 is in the $\bar{Q}$ state. Hence, it is appreciated, as previously described, that by the use of the present invention the operating life of the contacts 11 will be significantly extended with respect to the prior art method of relay switching described above. Typically, the flip-flip 33 may be toggled in response to alternate operations of the relay 10. Thus contact material will be transferred back and forth between the contacts as the relay 10 undergoes its successive operations.

From the foregoing it will be appreciated that the rectifier 21, the inverter 24, the gates 26 and 30 and the relay energizing circuits 16 comprise first means for applying the energizing signal on the lead 15 to the relay 10 at a predetermined phase angle of the alternating current signal applied to the terminal 22. Furthermore from the foregoing, it will be appreciated that the rectifier 21, the inverters 24 and 25, the gates 27 and 30 and the relay energizing circuits 16 comprise second means for applying the energizing signal on the lead 15 to the relay 10 at a phase angle of the alternating current signal approximately 180° phase displaced from the predetermined phase angle. It will also be appreciated from the foregoing that the relay operations counter 32 and the flip flop 33 comprise controlling means for alternately actuating the first and second means as described above for a predetermined number of energizations of the relay 10.

In practice, an even finish is developed on relay contact surfaces operated in accordance with the present invention which contributes to long relay contact life far in excess of that normally achieved by relays operated in accordance with prior art methods.

Although the present invention has been explained in terms of a timing control system, it is appreciated that an external relay energization command signal may be applied through appropriate circuits to energize the relay. The timing of the external command signal may be controlled by the output of the OR gate 30 in a manner similar to that described above. It is furthermore appreciated that although the flip-flop 33 is caused to toggle in response to the operations of the relay 10, an external control signal related to the functioning of the system in which the relay 10 is included, may be utilized to toggle the flip-flop 33 to the same beneficial effect described above.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than limitation and that changes may be made within the purview of the appended claims without departing from the true scope and spirit of the invention in its broader aspects.

We claim:

1. Apparatus for extending the life of the contacts of a relay adapted to be responsive to an energizing signal for switching an alternating current signal comprising

first means (21, 24, 26, 30, 16) for applying said energizing signal to said relay at a predetermined phase angle of said alternating current signal,

second means (21, 24, 25, 27, 30, 16) for applying said energizing signal to said relay at a phase angle of said alternating current signal approximately 180° phase displaced from said predetermined phase angle, and

controlling means (32, 33) for alternately actuating said first and second means for a predetermined number of energizations of said relay respectively.

2. The apparatus of claim 1 in which said controlling means comprises bistable means (33) responsive to said energizations of said relay for alternately providing first and second control signals in response to said predetermined number of said energizations, respectively.

3. The apparatus of claim 2 in which said first means includes

rectifying means (21) responsive to said alternating current signal for providing the half-cycles thereof of one polarity,

means (24) responsive to said half-cycles for providing a first logic signal in accordance therewith,

first gating means (26, 30) coupled to receive said first logic signal and said first control signal for transmitting said first logic signal in response to said first control signal, and

relay energizing means (16) for applying said energizing signal to said relay at said predetermined phase angle in response to said transmitted first logic signal.

4. The apparatus of claim 3 in which said second means includes

inverter means (25) responsive to said first logic signal for providing a second logic signal in accordance with the half-cycles of said alternating current signal of the polarity opposite said one polarity, and

second gating means (27, 30) coupled to receive said second logic signal and said second control signal for transmitting said second logic signal to said relay energizing means in response to said second control signal thereby applying said energizing signal to said relay at said phase angle approximately 180° phase displaced from said predetermined phase angle.

5. The apparatus of claim 1 in which said controlling means comprises

counting means (32) responsive to said energizations of said relay for providing signals representative of said predetermined numbers thereof, and

bistable means (33) responsive to said counting means signals for alternately providing first and second control signals in response thereto, respectively.

6. The apparatus of claim 1 in which said controlling means comprises bistable means (33) responsive to said energizations of said relay for alternately providing first and second control signals in response to alternate energizations of said relay, respectively.

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