Nov. 18, 1969 J. B. CASEY 3,479,584
SYSTEM FOR ADJUSTING OPERATING AND RELEASE SENSITIVITIES
OF MAGNETICALLY BIASED RELAY ARMATURES
Filed Sept. 20, 1966 4 Sheets-Sheet 1

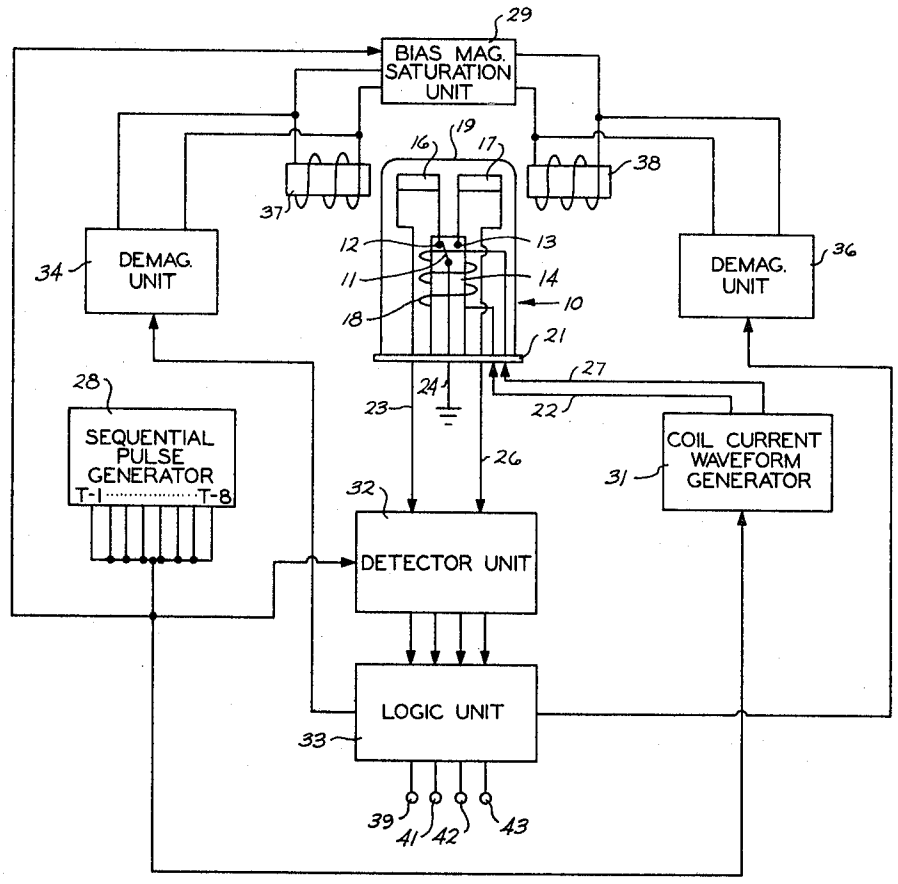


FIG. 1

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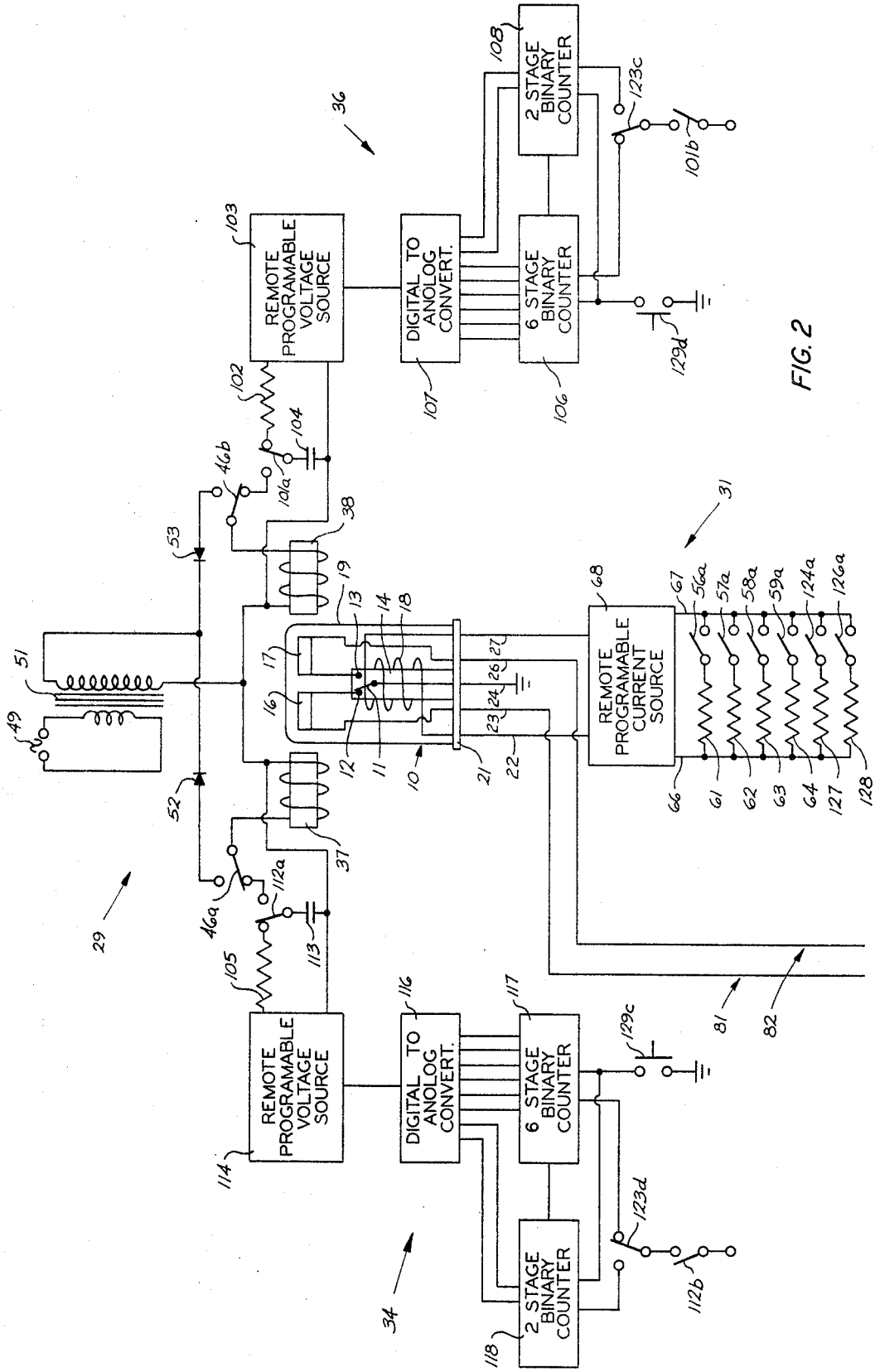
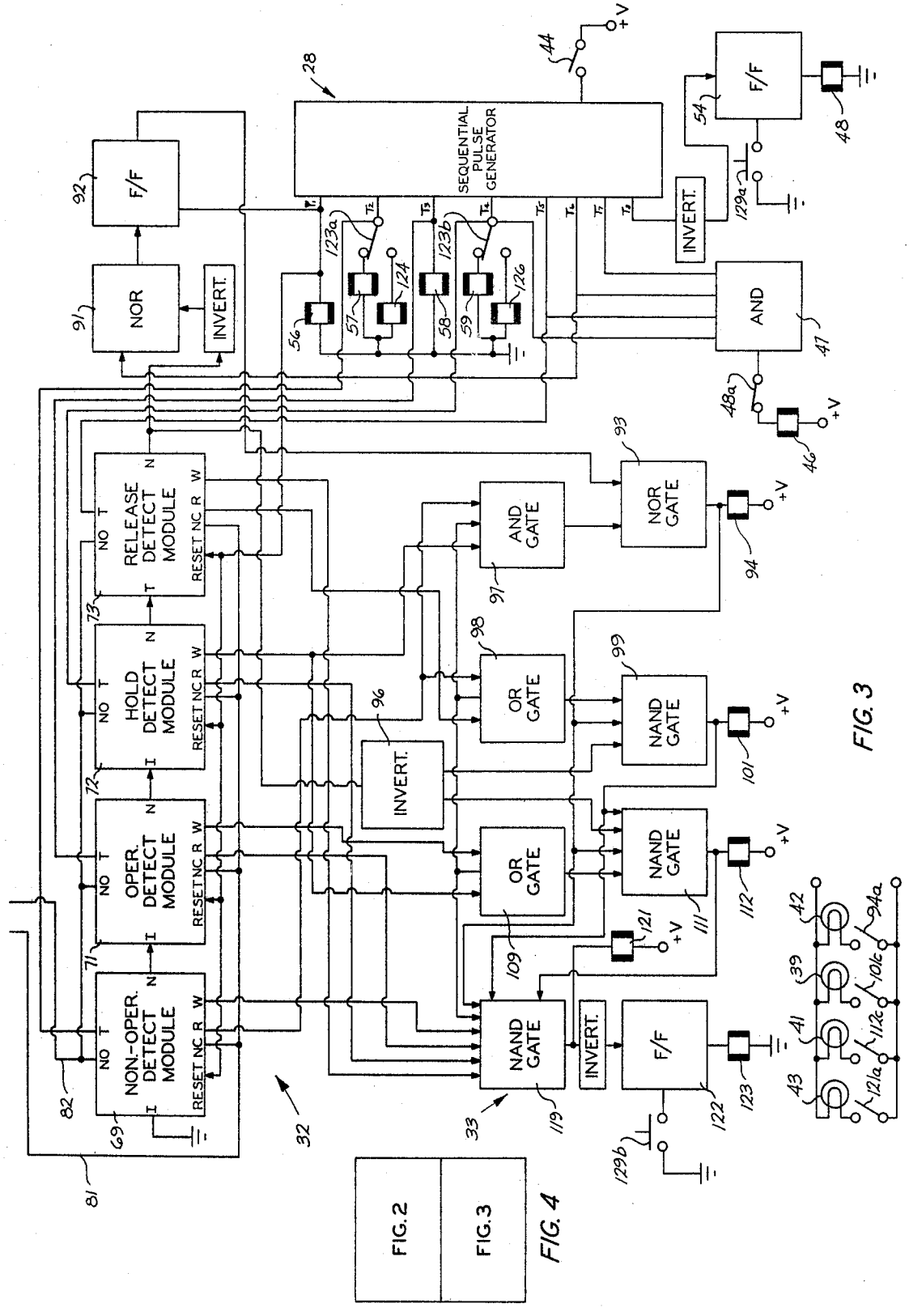

2 STAGE BINARY COUNTER
DIGITAL TO ANOLOG CONVERT.
6 STAGE BINARY COUNTER
REMOTE PROGRAMABLE VOLTAGE SOURCE
REMOTE PROGRAMABLE CURRENT SOURCE
36
31
29
34
10
11
12
13
14
16
17
18
19
21
22
23
24
26
27
37
38
46a
46b
49
51
52
53
61
62
63
64
66
67
68
81
82
102
103
104
105
106
107
108
112a
113
114
116
117
118
123c
123d
126a
127
128
129c
129d
1012b
1018
1126
124a
56a
57a
58a
59a

FIG. 2


SEQUENTIAL PULSE GENERATOR
F/F
NOR
INVERT.
AND
RELEASE DETECT MODULE
HOLD DETECT MODULE
OPER. DETECT MODULE
NON-OPER. DETECT MODULE
AND GATE
NOR GATE
OR GATE
NAND GATE
INVERT.
F/F
+V
FIG. 3
FIG. 2
FIG. 3
FIG. 4

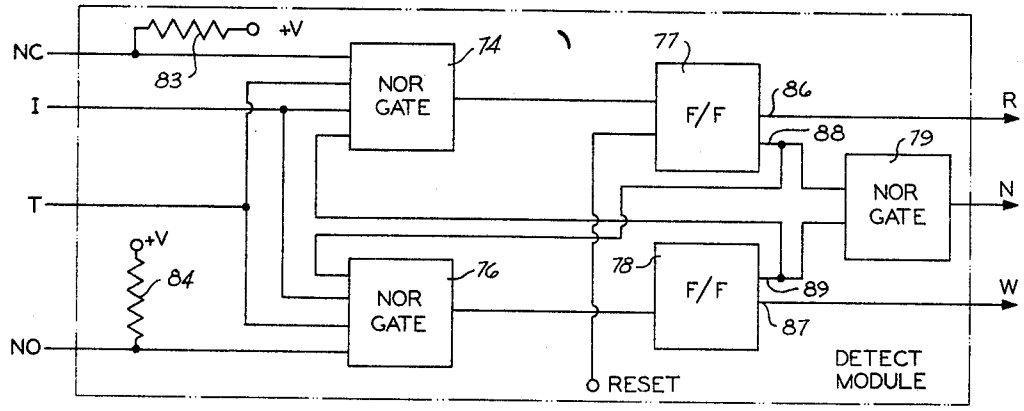


FIG. 5

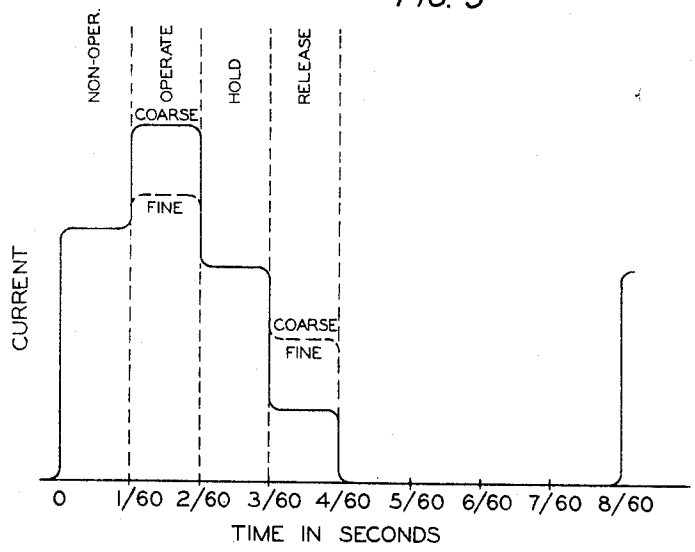


FIG. 6

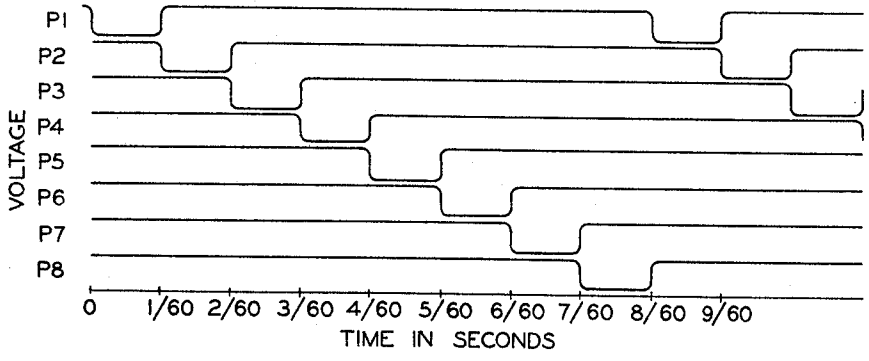


FIG. 7

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3,479,584

SYSTEM FOR ADJUSTING OPERATING AND RELEASE SENSITIVITIES OF MAGNETICALLY BIASED RELAY ARMATURES

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U.S. Cl. 324—28 3 Claims

ABSTRACT OF THE DISCLOSURE

A relay armature biased by first and second bias magnets is adjusted by applying a series of four discrete force levels with a current step waveform generator in conjunction with a coil encircling the relay armature. A detector unit samples the state of the armature by sensing electrical continuity between the armature and a normally opened and normally closed contact. A bias applied to the armature is altered by selectively demagnetizing the bias magnets using exponentially decaying sinusoidal pulses.

This invention relates to a system for adjusting mechanical hysteresis characteristics of adjustably biased armatures and more particularly to a system for adjusting operate and release sensitivities of magnetically biased relay armatures.

In the manufacture of the relays, the force required to shift or operate a relay armature from a first position to a second position and the force required to return or release the relay armature to the first position is normally adjusted by a mechanical bending or a physical moving of the relay structure. This bending or moving requires physical access to the relay structure. A relay, in which a magnetically operable armature is sealed in a container before adjustment, may include a pair of permanent magnets to provide mechanical biasing to the armature for setting the forces required to operate and release the armature. The magnetic field strength of these magnets can be adjusted, thereby adjusting the mechanical bias without requiring physical access to the relay structure. One such relay is described in United States Patent 2,609,464, issued Sept. 2, 1952, to J. T. L. Brown et al. entitled "Relay."

Various systems have been devised to adjust these bias magnets so that the relay armature will shift back and forth between two positions upon application of desired force levels. One system includes saturating both magnets and then alternately demagnetizing the magnets until the armature will operate and release upon application of the desired force levels. It is necessary to make alternate adjustments because the two magnets interact so that the magnetic field strength of each magnet affects both the operate and release forces required. This system will adjust relays susceptible of adjustment, but will not reject other defective relays incapable of proper adjustment. For instance, relays that have nonoperate and/or hold requirements in addition to operate and release requirements.

Another system for adjusting the bias magnets in a relay includes applying a continuously varying increasing force to the relay armature until the armature operates and then applying a continuously varying, decreasing force to the relay armature until the relay armature releases. A line representing the force execution applied to the relay armature is displayed on an oscilloscope provided with markings indicating the desired operate and release forces. An operator manipulates a pair of manual controls provided to adjust the magnetic field strength of each bias magnet until the force execution displayed on the oscilloscope coincides with the desired operate and release forces. The bias magnets may be adjusted in a nonsystematic way so that an operator may not be able to find the proper combination of settings for the manual controls because the interaction of the two magnetic fields of the two bias magnets gives rise to an infinite number of possible combinations of settings of the manual controls of which only one combination is correct. It has been found that a skilled perator using this system will reject relays as unadjustable which could be adjusted by systematic demagnetization.

Therefore, it is an object of this invention to provide a new and improved system for adjusting mechanical hysteresis characteristics of adjustably biased armatures.

It is a further object of this invention to provide a system for adjusting operate and release sensitivities of magnetically biased relay armatures which will adjust relays susceptible of adjustment and reject relays incapable of adjustment.

It is another object of this invention to provide a system for adjusting operate and release sensitivities of magnetically biased relay armatures which adjusts the magnetic bias in a systematic way so that all relays susceptible of adjustment are adjusted thereby.

With these and other objects in view, the present invention contemplates a system for adjusting the force required to shift an armature, having an adjustable bias force applied thereto, from a first position to a second position and the force required to return the armature to the first position wherein a sequential pulse generator sequentially and repetitively generates a series of timing pulses to synchronize the operation of an armature adjusting set through a series of adjusting sequences. An armature force applying device, in response to a signal generated by the sequential pulse generator, impresses a series of discrete force levels to the armature. At the completion of the application of each force level in the series, the sequential pulse generator renders a detector unit effective to sample the state of the armature and store the information thus obtained. Upon completion of the application of the entire series of force levels, a logic unit is rendered effective to provide an output responsive to the sequentially obtained information stored in the detector unit. The output provided by the logic unit will either (1) initiate alteration of the bias applied to the armature, (2) indicate an unadjustable armature, or (3) indicate an adjusted armature.

In one embodiment of the invention, a relay armature biased by first and second bias magnets is adjusted by applying the series of discrete force levels with a current step waveform generator in conjunction with a coil encircling the relay armature. The detector unit samples the state of the armature by sensing electrical continuity between the armature and a normally opened and normally closed contact. The bias applied to the armature is altered by selectively demagnetizing the bias magnets.

Other objects and advantages of the invention will be apparent from the following detailed description when considered in conjunction with the drawings, wherein:

FIG. 1 shows a block diagram of a system embodying the principles of the invention;

FIGS. 2 and 3, taken together, show in detailed block diagram form a relay to be adjusted and a relay adjusting set embodying the principles of this invention;

FIG. 4 shows how FIGS. 2 and 3 are combined;

FIG. 5 is a detailed block diagram of the detector modules used in the relay adjusting seat;

FIG. 6 is a graph showing a relay coil current waveform as a function of time of a relay being adjusted according to the principles of this invention; and

FIG. 7 is a graphic representation of timing pulses which coordinate a system of the invention.

RELAY TO BE ADJUSTED

Referring now to FIG. 1, there is shown in schematic form a cutaway view of a relay **10** representing one of a class of devices which may be adjusted according to the system of this invention. It is to be understood that any adjustably biased armature including certain relays and pressure differential valves can be adjusted according to the system of the present invention. The relay **10** includes a magnetically operable conductive armature **11** in electrical engagement with a normally closed contact **12** and a normally opened contact **13** spaced from the normally closed contact **12**. A force applied to the armature **11** will move or switch the armature **11** into electrical engagement with the normally opened contact **13**. The armature **11** switches or moves back into electrical engagement with the normally closed contact **12** upon reduction of the force or upon application of a force in an opposite direction. The armature **11** and the contacts **12** and **13** are all sealed in an evacuated glass envelope **14**. For purpose of this specification, the term "to operate" when applied to the relay **10** shall mean switching the armature **11** from the normally closed contact **12** to the normally opened contact **13** and the term "to release" when applied to the relay **10** shall mean switching the armature **11** from the normally opened contact **13** to the normally closed contact **12**. The relay **10** shall be considered to be in an "operated" state when the armature **11** is in contact with the normally opened contact **13** and shall be considered to be in a "released" state when the armature **11** is in contact with the normally closed contact **12**.

A pair of low hysteresis permanent bias magnets **16** and **17** are mounted on opposite sides of the glass envelope **14** for producing magnetic fields which alter the forces required to operate and release the magnetically operable armature **11** therein. The strength of the magnetic field produced by the magnet **16** will predominantly affect the force required to operate the armature **11**, but will also affect the force required to release the armature **11** as will the strength of the magnetic field produced by magnet **17** predominantly affect the force required to release the armature **11** but will also affect the force required to operate the armature **11**.

A coil **18** is provided encircling the glass envelope **14** to magnetically apply operate and release forces to the armature **11**. Alternately an electrostatic force could be used to operate and release the armature **11**. In a pressure differential valve, forces would be applied by fluid pressures acting on opposite faces of an armature therein.

The armature **11**, a normally closed contact **12**, a normally opened contact **13**, the magnets **16** and **17**, and the coil **18** are all enclosed in a casing **19** having an insulating base portion **21** with five electrically conducting pins **22**, **23**, **24**, **26**, and **27** extending therethrough. Opposite ends of the coil **18** are electrically connected to the pins **22** and **27**. Normally closed contact **12** and normally opened contact **13** are electrically connected to pins **23** and **26**, respectively.

BIAS MAGNET SATURATION AND ADJUSTING SEQUENCE

FIG. 1 shows a block diagram of a relay adjusting set embodying the principles of this invention. The relay adjusting set includes the following major components, a sequential pulse generator or time base generator **28**, a bias magnet saturation unit **29**, a coil current waveform generator **31**, an armature position or relay state detector unit **32**, a logic unit **33**, and two bias magnet demagnetization units **34** and **36**.

The sequential pulse generator **28** sequentially and repetitively generates a series of eight timing pulses **P1** through **P8** as seen in FIG. 6, each appearing at a terminal **T1** through **T8**, respectively. A sequential pulse generator may include (1) a pulse source and a ring counter, (2) a stepping switch, or (3) a pulse generator, a binary counter and a decoder. To insure proper operation of the relay adjusting set, the time duration of each pulse **P1** through **P8** should be greater than the switching time of the relay **10**. In this instance, the time duration of each pulse **P1** through **P8** is one sixtieth of a second which is considerably greater than the switching time of the relay so that a standard sixty cycle line voltage may be used to step the sequential pulse generator **28**. The pulses **P1** through **P8** generated by the sequential pulse generator **28** activate associated relays and logic circuits to first saturate the bias magnets **16** and **17** and then to synchronize the operation of the relay adjusting set through a series of adjusting sequences.

In response to a signal generated during the first series of pulses **P1** through **P8** from the sequential pulse generator **28**, the bias magnet saturation unit **29** energizes a pair of electromagnets **37** and **38** to fully magnetize or saturate the bias magnets **16** and **17**. The operation of the bias magnet saturation unit **29** is then disabled so that the degrees of magnetization of the bias magnets **16** and **17** are not altered thereby during or between the adjusting sequences.

After the saturation of the magnets **16** and **17** has been completed and the bias magnet saturation unit has been disabled, the first adjusting sequence begins when the coil current waveform generator **31**, in response to signals generated by the sequential pulse generator **28**, impresses a current step waveform, shown in FIG. 6, through the coil **18**. At the completion of each current step in the current step waveform, the sequential pulse generator **28** renders the detector unit **32** effective to sample the state of the relay **10** and store the information thus obtained. Upon completion of the entire step current waveform, the logic unit **33** is rendered effective by the detector unit **32** to provide an output responsive to the sequentially obtained information stored in the detector unit **32**. The output provided by the logic unit **33** will either: (1) activate one of the demagnetization units **34** or **36** and light an associated light **39** or **41**. Actuation of the demagnetization unit **34** will energize the electromagnet **37** to partially demagnetize the operate bias magnet **16** as will actuation of the demagnetization unit **36** energize the electromagnet **38** to partially demagnetize the release bias magnet **17**; (2) indicate by lighting a lamp **42** an unadjustable relay; or (3) indicate by lighting a lamp **43** an adjusted relay. If an acceptable relay is indicated, the coil current waveform generator **31** and the two bias magnet demagnetization units **34** and **36** are switched by a signal generated in the logic unit **33** from a coarse to a fine adjusting condition.

Upon completion of the first adjusting sequence, the pulse generator **28** recycles to initiate a second adjusting sequence. The pulse **P1** appearing on terminal **T1** of the sequential pulse generator **28** during the second adjusting sequence resets the detector unit **32** and the logic unit **33**. The second adjusting sequence begins when the coil current waveform generator **31**, in response to the signal generated by the sequential pulse generator **28**, impresses the current step waveform through the coil. During each succeeding adjusting sequence, the pulse **P1** resets the detector unit **32** and the logic unit **33**. The bias magnet saturation unit **29** remains disabled until manually reset.

DETAILED DESCRIPTION

Referring to FIGS. 2 and 3, taken together as shown in FIG. 4, there is shown the relay adjusting set including OR gates, AND gates, NOR gates, and NAND gates. The OR gates are characterized as providing a +V output when any of the inputs are brought to +V and a ground level output when all the inputs are grounded. The AND gates are characterized as providing a +V output when all of the inputs are brought to +V and a ground level

output when any of the inputs are grounded. The NOR gates are characterized as providing a +V output when all the inputs are grounded and a ground level output if one of the inputs is at a +V level. The NAND gates are characterized as providing a ground level output when a +V level is provided at all of the inputs and a +V output when any input is grounded. It is to be understood that the use of positive or negative logic is merely a matter of choice.

With the relay **10** connected in the relay adjusting set as shown, the first series of pulses P1 through P8, as seen in FIG. 6 are generated when a switch **44** is closed, applying a voltage V to the sequential pulse generator **28**. Each pulse P1 through P8 is one sixtieth of a second long so that the leading edge of each succeeding pulse occurs one-sixtieth of a second after the leading edge of the preceding pulse. A series of pulses P1 through P8 is generated every eight-sixtieths of a second so that the leading edge of a pulse P1 occurs one-sixtieth of a second after the leading edge of a pulse P8 from the preceding series.

Referring again to FIGS. 2 and 3, the first series of pulses generated by the sequential pulse generator **28** effectuates saturation of the bias magnets **16** and **17**. Pulses P4 through P7 apply a +V signal across a relay **46**, through an AND gate **47** and a normally closed contact **48***a* of a relay **48**. The energization of the relay **46** switches each of the contacts **46***a* and **46***b* from a normally closed sta'e, as shown in FIG. 2, to a normally opened state. A source of A.C. voltage **49** is applied through a transformer **51** to a pair of diodes **52** and **53**. The A.C. voltage from the source **49** is rectified by the diodes **52** and **53** and the resulting half sinusoids of voltage are applied across the electromagnets **37** and **38** through the now closed paths of contacts **46***a* and **46***b*. The fields thus produced surrounding the electromagnets **37** and **38** saturate the bias magnets **16** and **17** in the relay **10**. Other waveforms, such as a square wave or direct current pulse, are equally suitable for driving the electromagnets **37** and **38** to saturate the bias magnets **16** and **17**. The A.C. voltage source **49**, transformer **51**, the diodes **52** and **53**, and the relay **46** serve as the bias magnet saturation unit **29**.

The pulse P8 in the first series of pulses is applied from terminal T8 to operate a flip-flop **54** and thereby energize relay **48** to open the normally closed contact **48***a*. The opening of normally closed contact **48***a* disconnects the relay **46** from the AND gate **47** so that the pulses P4 through P7, occurring in the succeeding series of pulses, cannot energize the relay **46** to initiate saturation of the bias magnets **16** and **17** until the flip-flop **54** is reset.

The second and each succeeding series of pulses P1 through P8 coordinate the relay adjusting set through a series of adjusting sequences. In the adjusting sequences, pulses P1 through P4 sequentially energize relays **56**, **57**, **58**, and **59**, respectively, each having a normally opened contact **56***a*, **57***a*, **58***a*, and **59***a*, respectively. Each contact **56***a*, **57***a*, **58***a*, and **59***a*, respectively, forms a series circuit with a resistor **61**, **62**, **63**, and **64**, respectively. The series circuits are connected in parallel between a pair of resistance program treminals **66** and **67** of a resistance programmable current source **68**, the output of which is connected to the coil **18** of the relay **10** through pins **22** and **27**. The resistance programmable current source **68** and associated resistors and relays comprise the coil current waveform generator **31**.

A resistance programmable current souce is a well-known device in which the output of the current source is alterted by changing resistors connected between resistance program terminals to alter a resistance value in the current source circuit. The current source circuit is so arranged so that with no resistor externally connected between the resistance program terminals **66** and **67** zero current will flow in the coil **18**. Conventional current or voltage programmable current sources would serve the same function as the resistance programmable current source **68**.

The sequential energization of the relays **56**, **57**, **58**, and **59**, respectively, closes the normally opened contacts **56***a*, **57***a*, **58***a*, and **59***a*, sequentially, to sequentially connect the resistors **61**, **62**, **63**, **64**, respectively, between the resistance program terminals **66** and **67**. The values of resistors **61**, **62**, **63**, and **64** are each chosen so that the current flowing from the current source **68** through the coil **18** corresponds to the coil current waveform shown in solid lines in FIG. 5.

The current levels impressed in the coil **18** in response to connecting resistors **61**, **62**, **63**, and **64** across the terminals **66** and **67** during the pulses P1 through P4, are designated nonoperate, coarse, hold, and coarse release, respectively. If the relay is properly adjusted and initially released, the increase in coil current from zero to the nonoperate level will not operate the relay; further increases in the coil current to the coarse operate level will operate the relay. Reducing the coil current of the now operated relay from the operate level to the hold level will not release the armature, but further reducing the coil current to the coarse release level will release the relay.

The detector unit **32** including four detect modules, designated nonoperate detect module **69**, operate detect module **71**, hold detect module **72**, and release detect module **73**, the details of which are shown in FIG. 5, is provided to sample the state of the relay **10** after each current level is applied to the coil **18**, and store the information thus obtained. Sufficient time is allowed before the state of the relay is sampled for the armature **11** to respond to the current level applied. For purposes of convenience in this embodiment, the sampling of the armature **11** is initiated by the leading edge of the pulse succeeding the pulse initiating the respective current levels. The state of the relay can be sampled at this time even though the next current level is already impressed upon the coil **18** to again alter the state of the relay. The state of the relay can be sampled in several microseconds or less, however, due to mechanical inertia, the armature **11** cannot change or shift the state or even lift off the contact upon which is resting in a microsecond time interval.

Each detect module **69**, **71**, **72**, and **73** (see FIG. 5) comprises a logic circuit including three NOR gates **74**, **76**, and **79**, and two flip-flops **77** and **78**. Each detect module has four input connections designated N.C., I., T., and N.O. and three output connections designated R., N., and W. The N.C. input is directly connected to a first input of the NOR gate **74**, while the N.O. input is connected directly to a first input of the NOR gate **76**. The I. input is connected to a second input of each NOR gate **74** and **76**, and the T. input is connected to a third input of each NOR gate **74** and **76**. The NOR gates **74** and **76** will provide a ground level output unless each of the four respective inputs are grounded to provide an output of +V volts.

Referring now to FIGS. 2, 3, and 4, it is seen that the normally closed contact **12** of the relay **10** is connected through the pin **23** by lead **81** to the N.C. input of each of the detect modules **69**, **71**, **72** and **73**. The normally opened contact **13** of the relay **10** is connected through pin **26** by lead **82** to the N.O. input of each of the detect modules **69**, **71**, **72**, and **73**. The armature **11** of the relay **10** is grounded through pin **24**.

A pair of resistors **83** and **84** are internally connected in each detect module. The resistor **83** is connected between the N.C. input and a voltage +V while the resistor **84** is connected between the N.O. input, and a voltage +V. Therefore, when the armature **11** of the relay **10** is in contact with the normally closed contact **12**, the voltage appearing at the N.C. input of each detect module will be ground; while the input appearing at the N.O. input of each detect module will be +V. In a like

manner, when the armature **11** of the relay **10** is in contact with the normally opened contact **13**, the N.O. input of each detect module will be at ground; while the N.C. input will be at +V.

The I. input of the nonoperate detect module **69** is electrically connected to ground. The I. input of the other detect modules **71**, **72**, and **73** are connected to the N. output of the preceding detect modules **69**, **71**, and **72**, respectively. The T. input of each module **69**, **71**, **72**, and **73** is connected to one of the output terminals T2, T3, T4, T5, respectively, of the sequential pulse generator **28**.

The output of the NOR gate **74** is connected to a set input of the flip-flop **77**. The output of the NOR gate **76** is connected to a set input of the flip-flop **78**. The flip-flops **77** and **78** each have first outputs **86** and **87**, respectively, normally at +V volts connected to the outputs R. and W., respectively, and second outputs **88** and **89**, respectively, both connected to a pair of inputs of the NOR gate **79** and each connected to a fourth input of the NOR gates **76** and **74**, respectively. An output of the NOR gate **79** is connected to the output terminal N.

Looking now at the nonoperate detect module **69**, it is seen that the I. input is at ground, the T. input will be at ground only during the occurrence of the pulse P2 of the sequential pulse generator **28**, and that only one of the inputs N.O. and N.C. can be at ground at any one time since the armature **11** can only be in contact with one of the contacts **12** or **13** unless the contacts **12** and **13** are shorted together. However, it is possible for the N.C. and N.O. input to both be at +V if the armature **11** "sticks" in a position between the two contacts. This situation is referred to in the relay art as "hanging up." The fourth input of each NOR gate **74** and **76** will remain at ground until one of the flip-flops **77** or **78** is set.

Assume that the nonoperate current level generated in response to pulse P1 is insufficient to operate the relay **10**. Upon occurrence of the pulse P2, the input T. will be brought to ground, the N.C. input of the detect module **69** will be grounded through the relay armature **11**, and the N.O. input will remain at +V. Therefore, it is seen that all the inputs of NOR gate **74** will be at ground providing an output to set the flip-flop **77**. Setting of the flip-flop **77** will switch the output **88** to +V, thereby disabling NOR gate **76** from operating even if during the time interval of pulse P2 the relay armature **11** operates to close the normally opened contact **13** and open the normally closed contact **12**. Therefore, it is seen that the flip-flop **77** acts as both a storage device to store information indications of the state which the relay occupied in response to the first current level and also serve to lock out any additional information from being put into the detect module until the flip-flop **77** is reset by the first pulse P1 of the next adjusting sequence.

The output **86** of the flip-flop **77** provides a ground signal on the output terminal R., while the output **87** of the flip-flop **78** maintains a +V on the output terminal W. The +V level on the output **88** provides a signal to the NOR gate **79** to put a ground signal on the output terminal N., in this way enabling the succeeding detect module, such as modules **71** or **72** or **73**, to be sampled by the succeeding pulse. It is readily apparent that if the armature **11** has operated in response to the applied current level, the flip-flop **78** would have been set so as to provide the ground level signal on the output terminal W. leaving a +V signal on the output terminal R. and disabling the NOR gate **74** from providing a set signal to the flip-flop **77**. If the contacts **12** and **13** are shorted together, there is a possibility that both the flip-flops **77** and **78** will be set simultaneously, thereby providing +V levels on both the R. and W. outputs.

In a like manner, pulses P3, P4, and P5 render effective the operate detect module, hold detect module, and release detect module, respectively, to sample the state of the relay **10** in response to the operate, hold, and release current levels generated, The I. input of the operate, hold, and release detect modules are each connected to the N. output of the immediately preceding detect module; thus, if the relay armature **11** of the relay **10** under test does not contact one or the other of the contacts **12** and **13** during any one of the pulse periods P2, P3, P4, and P5, the succeeding detect modules are disabled from operation and the N. output of the release detect module **73** will remain at +V volts indicating a "hung up" relay. If the relay does not "hang up" during the current applying and relay state sampling interval, a ground output appears at the N. output of the release detect module **73**, enabling the logic unit **33** to evaluate the information now stored in the detect modules **69**, **71**, **72**, and **73**.

The N. output of the release detect module **73** is inverted and the inverter output is gated through NOR gate **91** by the pulse P6 to a flip-flop **92**. If the output of the release detect module **73** is at +V volts indicating a hung up relay, the flip-flop **92** changes state to provide +V output to an input of a reject NOR gate **93** providing a ground level at an output of the NOR gate **93** energizing a reject relay **94** having a normally opened contact **94***a* in series with the light **42**. Energization of the relay **94** closes normally opened contact **94***a* connecting the light **42** between a voltage +V and ground, thereby lighting the light **42** indicating that relay **10** under test is not susceptible of adjustment.

The output N. of the release detect module **73** is provided as an input to an inhibit inverter **96**, the output of which is connected to inhibit operation of other circuits in the logic unit **33** until the completion of the current applying and relay state sampling interval.

The R. output of the nonoperate detect module **69**, the W. output of the hold detect module **72**, and the output of the inhibit inverter **96** are applied to three inputs of an AND gate **97** to provide a +V signal to a second input of the reject NOR gate **93** when the relay **10** operates in response to the nonoperate current level and releases in response to the hold current level. The +V signal applied to the second input of the NOR gate **93** provides a ground level to the output of the NOR gate **93**, energizing the relay **94** to light the light **42** and inhibiting further outputs from the logic unit **33**.

When a relay **10** under test operates at a current level which is at a nonoperate level and releases at a current level which is at a hold level, subsequent demagnetization of the bias magnets **16** and **17** will not be able to bring the relay **10** into proper adjustment because demagnetization of either of the bias magnets **16** or **17** will tend to adjust the actual nonoperate and hold current levels toward each other. To adjust such a relay, the actual nonoperate current level and the actual hold current level must be adjusted away from each other, that is the difference in current level needed (1) to operate and (2) the current level to hold must be increased.

When the relay **10** operates in response to the nonoperate current level or fails to release in response to the release current level the R. output of the nonoperate detect module **69** or the R. output of the release detect module **73** applies a +V signal to an input of an OR gate **98** to provide a +V signal to a first input of a NAND gate **99**. The output of the inhibit inverter **96** is connected to a second input of the NAND gate **99** so that upon completion of operation of the last detect module **73** a +V signal is applied to the NAND gate **99** from the inverter **96**. The output of the reject NOR gate **93** is connected to a third input of NAND gate **99** so that a +V level is applied to NAND gate **99** if a reject is not indicated. The three +V inputs to NAND gate **99** provide a ground level output to NAND gate **99**, thereby energizing a relay **101** having three sets of contacts **101***a*, **101***b*, and **101***c*.

The energization of relay **101** switches contact **101***a* from a normally closed contact connected through a resistor **102** to a remote programable voltage source or facility **103** to a normally opened contact. The switching

of contact **101***a* connects a storage capacitor **104** initially charged by the voltage source **103** across the electromagnet **38** through the normally closed path of the relay **46**, discharging the capacitor **104** so that an exponentially decaying sinusoid of current flows through the winding of the electromagnet **38**. The period of the sinusoid is determined by the value of the capacitor **104** and the inductance of the electromagnet **38** while the exponential time constant of the decaying waveform is determined by the value of the capacitor **104**, the inductance of the electromagnet **38**, and the coil resistance of the electromagnet **38**. A magnetic field results from the current flowing in the electromagnet **38** which demagnetizes the bias magnet **17** an amount proportional to the initial charge on the capacitor **104**, thereby increasing (1) the current required to operate a released armature **11** and (2) the current at which an operated armature **11** will release.

Energization of relay **101** also closes contact **101***b* to apply a voltage input to a six stage binary counter **106** to advance the counter **106** one count. The output of the binary counter **106** is fed into a digital-to-analog converter **107** which converts the count stored in the counter to an analog voltage having an amplitude proportional to the stored count. This voltage is applied to the remote programable voltage source **103** to alter the output voltage of the voltage source **103** by a proportional amount. It should be understood that a resistance, conductance, or current programable voltage source could be substituted for the voltage programable voltage source **103**, in which case, the digital-to-analog converted **107** would provide a resistance, conductance, or current output. The six stage counter **106** is set to an initial count so that an initial charging voltage appears at the output of the voltage source **103**.

The voltage source **103** applies the initial low voltage to the capacitor **104** through the resistor **102**. The time constant of the resistor **102**-capacitor **104** network is such that the capacitor **104** will charge to the output voltage of the voltage source **103** in approximately forty milliseconds, but will not appreciably change the voltage across the capacitor **104** should contact **101***b* close a few microseconds before contact **101***a* switches. The stepping of the counter **106** therefore increases the voltage output of the voltage source **103** when the contact **101***b* closes, but does not increase the voltage across the capacitor **104** until the next adjusting sequence. If it were desired to charge the capacitor **104** in the same adjusting sequence as the capacitor **104** is discharged through the electromagnet **38**, not only would more involved switching be necessary, but a voltage source having a higher current capability than the voltage source **103** would be required to charge the capacitor **104** in a shorter period of time. By setting the voltage source **103** to an initial voltage, the bias magnet **17** can be demagnetized a fixed increment during the first adjusting sequence, thus decreasing the total adjusting time.

Further, the energization of relay **101** closes normally opened contact **101***c* to connect a light **39** between +V and ground, thereby illuminating the light **39** to give a visual indication of partial demagnetization of the bias magnet **17**. It may be appreciated that the capacitor **104**, the remote programable voltage source **103**, the digital-to-analog converter **107**, the six stage binary counter **106**, the relay **101**, and a two stage binary counter **108** all cooperate to function as the bias magnet demagnetization unit **36**, shown in FIG. 1.

When the relay **10** does not operate in response to the operate current level or releases in response to the hold current level, the W. output of the operate detect module **71** or the W. output of the hold detect module **72** applies +V signal to one of the two inputs of an OR gate **109** to provide a +V signal to a first input of a NAND gate **111**. Upon completion of operation of the last detect module **73**, the output of the inverter OR gate **96** applies a +V signal to a second input of the NAND gate **111**. If no reject is indicated, NOR gate **93** provides a +V signal to a third input of NAND gate **111**. If demagnetization of bias magnet **17** is not required, NAND gate **99** provides +V signal to a fourth input so that a ground level signal is provided at the output of the NAND gate **111**, thereby energizing a relay **112** having three sets of contacts **112***a*, **112***b*, and **112***c*.

The second bias magnet demagnetization unit **34**, the relay **112**, a capacitor **113**, a resistor **105**, a remote programable voltage source **114**, a digital-to-analog converter **116**, a six stage binary counter **117**, and a two stage binary counter **118** comprise the contacts of the relay **112** connected in the bias magnet demagnetization unit **34** and operate in the same manner as the relay **101** operates in the bias magnet demagnetization unit **36**.

The energization of relay **112** switches contact **112***a* from a normally closed contact connected through a resistor **105** to a remote programable voltage source **114** to a normally opened contact. The switching of contact **112***a* connects a storage capacitor **113** initially charged by the voltage source **114** across the electromagnet **37** through the normally closed path of the relay **46**, discharging the capacitor **113** so that an exponentially decaying sinusoid of current flows through the winding of the electromagnet **37**. The period of the sinusoid is determined by the value of the capacitor **113** and the inductance of the electromagnet **37**, while the exponential time constant of the decaying waveform is determined by the value of the capacitor **113**, the inductance of the electromagnet **38**, and the coil resistance of the electromagnet **37**. A magnetic field results from the current flowing in the electromagnet **37** which demagnetizes the bias magnet **16** an amount proportional to the initial charge on the capacitor **113**, thereby increasing (1) the current required to operate a released armature **11** and (2) the current at which an operated armature **11** will release.

Energization of relay **112** also closes contact **112***b* to apply a voltage input to a six stage binary counter **117** to advance the counter **117** one count. The output of the binary counter **118** is fed into a digital-to-analog converter **116** which converts the count stored in the counter to an analog voltage having an amplitude proportional to the stored count.

Operation of the bias magnet demagnetization unit **34** decreases (1) the current required to operate a released armature **11** and (2) the current at which an operated armature **11** will release.

After the completion of operation of the last detect module **73** if a reject is not indicated and if demagnetization is not indicated and the relay **10** (1) does not operate in response to the nonoperate current level, (2) operates in response to the operate current level, (3) holds in response to the hold current level and (4) releases in response to the release current level, the W. output of the nonoperate detect module **69**, the R. output of the operate detect module **71**, the R. output of the hold detect module **72**, and the W. output of the release detect module **73** each apply a +V signal to one of four inputs of a NAND gate **119** to provide a ground level output signal. The ground level is inverted to set a flip-flop **122** and energize a relay **121** having a normally opened contact **121***a*. The energization of the relay **121** closes normally opened contact **121***a* to connect the light **43** between +V and ground to indicate a properly adjusted relay.

If the contacts **12** and **13** are shorted together to provide +V outputs on both the R. and W. outputs of the detect modules **69**, **71**, **72**, and **73**, it is desirable that a properly adjusted relay is not indicated. Therefore, inhibit signals are applied from NOR gate **93** to (1) the NAND gates **99** and **111** and (2) the NAND gate **119** to prevent a properly adjusted relay from being indicated when, in fact, the relay under test is defective.

Setting of the flip-flop **122** provides a +V output signal which energizes a relay **123** having four sets of con-

tacts **123***a*, **123***b*, **123***c*, and **123***d*. Energization of the relay **123** switches contacts **123***a* and **123***b*, associated with sequential pulse generator **28**, from a normally opened state to a normally closed state, disconnecting relays **57** and **69** from the terminals T2 and T4 of the sequential pulse generator **28** and connecting relays **124** and **126** to the terminals T2 and T4, respectively, and switches the contacts **123***c* and **123***d* from a normally opened to a normally closed state, disconnecting contacts **101***b* and **112***b* from the input of the six stage binary counters **106** and **117**, respectively, and connecting the contacts **101***b* and **112***b* to the input of the two stage binary counters **108** and **118**, respectively. A most significant or last digit output of the two stage counters **108** and **118** is provided to drive the six stage counters **106** and **117**.

The coil current waveform generator **31** is switched to fine when relays **124** and **126** have normally opened contacts **124***a* and **126***a* forming series circuits with resistors **127** and **128**, respectively. The series circuits are connected in parallel across the resistance program terminals **66** and **67**. The values of the resistors **127** and **128** are chosen so that upon the occurrence of succeeding adjusting sequences, the operate current level of the coil current waveform is reduced and the release current level of the coil current waveform is increased, as shown in FIG. 4 by the dashed lines. Now with the two stage binary counters **108** and **118** in series with the six stage binary counters **106** and **117**, respectively, each time an input is applied by actuation of the contacts **101***b* and **112***b* the voltage of the remote programable voltage sources **103** and **114** are changed by smaller increments than if the contacts **101***b* and **112***b* directly actuated the six stage binary counters **106** and **117**.

During the next adjusting sequence, the relay adjusting set operates as previously described except that (1) the values of the operate current level of the coil current waveform is reduced and the release current level of the coil current waveform is increased, thereby requiring the relay **10** to be adjusted to a more stringent tolerance, and (2) the increments of the demagnetization of the bias magnets **16** and **17** are reduced to enable the relay **10** to be adjusted to the more stringent tolerance.

In summary, referring again to FIG. 2, it may be appreciated that a relay to be adjusted by the system described is first subjected to the pair of saturating magnetic fields to fully saturate the bias magnets **16** and **17**. Next, the coil current waveform is applied to the coil **18**, the response thereto sampled and stored in the detect module **32**. The information stored in the detect module **32** is evaluated in the logic unit **33**. If the information indicates as unadjustable relay, the relay **94** (see FIG. 3) is closed, lighting the reject light **42**. It is apparent that the relay **94** could have any number of contacts with which any number of indicators could be actuated, one contact could be used to terminate operation of the sequential pulse generator **28**. In this particular embodiment, however, the sequential pulse generator **28** continuously cycles so that even if a reject is indicated, a second coil current waveform is applied to the coil **18** and another adjusting sequence proceeds.

If evaluation indicates that either of the bias magnets **16** or **17** requires demagnetization, such action is initiated. If an acceptable relay is indicated, the relay adjusting set is switched from coarse to fine adjusting and again another adjusting sequence is commenced. It is possible that one can satisfactorily adjust a relay set without the coarse and fine control. However, using both the coarse and fine controls there is an increase in both the speed and accuracy with which relays may be adjusted. It should also be apparent that the signal from the logic unit **33** indicating an acceptable relay also could be used to terminate operation of the sequential pulse generator **28** or eject the relay from the adjusting set. However, in this particular embodiment, a properly adjusted relay or a rejected relay is indicated when the lights **42** and **43** continuously light on a series of succeeding adjusting sequences. When a relay is removed from the adjusting set and a new relay is placed therein for adjustment, a switch **129** having four contacts **129***a*, **129***b*, **129***c*, and **129***d* is depressed to reset the flip-flops **54** and **122** and the binary counters **117**, **118**, **106**, and **108** so that the first series of pulses from the sequential pulse generator **28** saturates the bias magnets **16** and **17** of the new relay and the first adjusting sequence will begin thereafter with the relay adjusting set in the coarse adjusting condition.

What is claimed is:

1. In a system for adjusting an operating characteristic of a relay having a coil and an armature biased by a first and second permanent magnet;

an inductive coil for applying a demagnetizing force to said first permanent magnet;

a repetitively operated sequential pulse generator for generating successive control pulses;

means operated by a predetermined plurality of said control pulses for applying a current waveform comprised of four predetermined steps to said relay coil to operate said armature in accordance with a desired characteristic;

a normally nonoperated counting circuit responsive to an operating signal for providing digital outputs;

a digital-to-analog converter connected to and operated by said counting circuit for producing analog voltage outputs of successively larger magnitudes;

means responsive to said operating signal for energizing said inductive coil to demagnetize said first permanent magnet an increment proportional to said analog voltage;

a gating circuit for providing said operating signal;

first detection means responsive to each failure of said armature to function in accordance with the desired characteristic and in response to two of said steps applied to said relay coil for conditioning said gating circuit to operate;

a second means for applying a demagnetizing force to said second permanent magnet;

a second normally nonoperated counting circuit responsive to a second operating signal for energizing said second demagnetizing means to incrementally demagnetize said second permanent magnet;

a second gating circuit for providing said second operating signal;

second detection means responsive to each failure of said armature to function in accordance with the desired characteristic and in response to two of said steps applied to said relay coil for conditioning said second gating circuit to operate; and

means for applying one of said succeeding control pulses after said predetermined plurality of control pulses to operate at least one of said conditioned gating circuits.

2. In a system for demagnetizing a saturated bias magnet positioned to control an armature of a relay:

means for applying a demagnetizing field to said bias magnet;

a power supply facility having a control means for varying an output voltage from said facility;

a digital-to-analog converter for applying a signal to said control means to accordingly vary the output of said power supply facility;

a first multistage counter circuit for applying digital signals to said converter upon operation of each stage;

means for periodically applying first operate signals of a first predetermined magnitude to said relay to operate said armature;

first switching means responsive to the failure of said armature to operate in response to said first operate signal for pulsing said first counter circuit to operate said converter and said control means in said power supply facility;

means also responsive to the failure of said armature to operate in response to said first operate signal for applying the output of said power supply facility to said demagnetizing means;

a second multistage counter circuit for applying digital signals to said converter upon operation of each stage;

means for applying the output of the last stage of said second counting circuit to drive said first counting circuit;

a second normally unoperated switching means responsive to the operation of the armature in response to said first operate signal for connecting said first switching means to said second counter circuit and for disconnecting said first first counter circuit from said first switching means;

means also responsive to the operation of the armature in response to a first operate signal for applying second operate signals of a second predetermined magnitude to said relay to operate said armature; and

means responsive to the failure of said relay to operate said armature in response to a second operate signal for operating said first and second switching means to successively apply the output of said first and second counting circuits to said converter whereupon the output from said power supply facility is varied in applying a demagnetizing field to said bias magnet.

3. In a system for controlling the demagnetization of a bias magnet associated with an armature of a relay:

a coil for applying a demagnetizing field to said bias magnet;

a power supply means;

a capacitor;

a movable contactor for selectively connecting the capacitor to said power supply means and then said coil;

a first multistage counting means for controlling the output of said power supply means in accordance with the stage of operation of said counting means to control the charging of said capacitor;

a second multistage counting means for controlling the output of said power supply means in accordance with the stage of operation of said second counting means to control the charging of the capacitor;

means operated by the operation of the last stage of said second counting means for successively driving said first counting means;

means for generating a series of first operate pulses of a first predetermined magnitude and then a series of second operate pulses of a second predetermined magnitude;

means for applying sequentially said operate pulses to said relay to operate said armature;

means responsive to the failure of said armature to operate upon application of said first operate pulses for operating said first counting means and for moving said contactor to connect said capacitor to said coil to demagnetize said bias magnet; and

means responsive to the failure of said armature to operate upon application of said second operate pulses for operating said second counting means and for moving said contactor to connect said capacitor to said coil to demagnetize said bias magnet.

References Cited

UNITED STATES PATENTS

2,806,186	9/1957	Brown	324—28 XR
3,235,776	2/1966	Ireland	317—157.5

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