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(54) ELECTROMAGNET DRIVE DEVICE

ELEKTROMAGNETISCHE ANTRIEBSVORRICHTUNG

DISPOSITIF DE PILOTAGE D'ÉLECTROAIMANT

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Description

BACKGROUND OF THE INVENTION

Field of the invention

[0001] The present invention relates to an electromagnet drive device for driving an electromagnet included in a breaker or the like.

Description of the related art

[0002] An electromagnet drive device for attracting the iron core of an electromagnet included in a breaker or the like performs control such that: at the time of initial attraction, large excitation current is caused to flow in the winding due to a gap of the magnetic circuit; and after the iron core is attracted, the excitation current is reduced and caused to flow in the winding due to the reduced gap of the magnetic circuit to maintain the attracted state.

[0003] In this electromagnet drive device, in order to reduce the excitation current after the iron core is attracted, pulsed voltage is applied to the electromagnet so that, during the period in which no voltage is applied to the electromagnet, excitation current generated by the counter electromotive force of the electromagnet flows in the winding through a flywheel diode, resulting in the excitation current always flowing in the winding. Also, according to one known method for detecting the excitation current after the iron core is attracted, a current detection sensor is provided within a loop formed by the electromagnet and the flywheel diode to detect the excitation current see JP-A-6-311637

[0004] In a method of providing a current detection sensor within a loop formed by the electromagnet and the flywheel diode, such as the technique disclosed in the PTL 1, a resistor is used for the current detection sensor and a voltage drop across the resistor is measured, which poses a problem of the excitation current always flowing in the resistor to increase power loss.

[0005] According to one method for suppressing the power loss, the current detection sensor is provided outside the loop formed by the electromagnet and the flywheel diode and in series with a switching element for applying pulsed voltage to the electromagnet to detect the excitation current by the current detection sensor only when the switching element is in on-state. However, this method poses a problem of needing a high-performance and high-cost microcomputer with a high sampling frequency for detecting excitation current when the pulsed voltage applied to the electromagnet has a narrow pulse width or short pulse period.

[0006] Document US 5,671,115 discloses a circuit arrangement for driving a contactor by selecting a reference voltage proportional to the magnitude of the starting current of the respective contactor. The starting current is kept constant during the starting time of the contactor. For that purpose, a measurement voltage dropping across a measuring resistor is supplied to a first input of a comparator, a reference voltage being applied to a second input of the comparator. The output of the comparator co-operates with a switching element which switches the starting current.

[0007] Document US 5,757,214 discloses a pulse width modulate (PWM) driver circuit for driving an inductive load, having a load-current sensing resistor and a comparator having an input to which a PWM control reference voltage may be applied.

[0008] Document DE 37 07 930 A1 discloses a circuit arrangement for electrical loads having a measurement resistor for monitoring the load current and a protection circuit for cutting off the load in the event of overload conditions, having threshold value switches and a multivibrator stage. A current regulating circuit is connected to the measurement resistor whose regulated signal is applied to a controllable oscillator circuit whose output signal is passed, via a drive circuit, to a pulsed output stage for supplying the load.

SUMMARY OF THE INVENTION

[0009] In order to solve the above problem, it is an object of the present invention to provide an electromagnet drive device that suppresses power loss due to an excitation current detection resistor across which a voltage drop proportional to the amount of excitation current of an electromagnet occurs and that can be controlled by even a microcomputer with a low sampling frequency.

[0010] The electromagnet drive device of the invention includes: a winding power supply circuit that outputs DC power supply voltage to be applied to an electromagnet; a power supply voltage measurement circuit that measures the DC power supply voltage; an excitation current detection resistor connected in series with the electromagnet, across which a voltage drop proportional to the amount of excitation current of the electromagnet occurs; and a control microcomputer that controls the excitation current of the electromagnet through a switching element, wherein the control microcomputer, at the time of iron core initial attraction and the time of iron core re-attraction of the electromagnet, calculates the winding resistance value of the electromagnet from the measurements of a voltage drop across the excitation current detection resistor and the DC power supply voltage, and, in the time other than the time of iron core initial attraction and the time of iron core re-attraction of the electromagnet, performs pulse control in which, through on-duty based on the winding resistance value and a measurement value of the DC power supply voltage (Va), the DC power supply voltage is transformed into pulsed voltage to be applied to the electromagnet by the switching element.

[0011] According to the invention, power loss can be suppressed in the excitation current detection resistor across which the voltage drop proportional to the amount of excitation current of the electromagnet occurs, and, when pulsed voltage is applied to the electromagnet in order to reduce the excitation current after the iron core of the electromagnet is attracted, a low-cost microcomputer with a low sampling frequency can be used to detect an electromagnet excitation current with pulsed voltage applied, which conventionally could not be detected by a microcomputer with a low sampling frequency.

[0012] The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 A circuit diagram showing the configuration of an electromagnet drive device in accordance with a first embodiment of the invention.

Fig. 2 An illustration for describing the voltage applied to the electromagnet drive device in accordance with the first embodiment of the invention.

Fig. 3 An illustration for describing the current flowing in the electromagnet drive device in accordance with the first embodiment of the invention.

Fig. 4 An illustration for describing the relation between the winding resistance value of the electromagnet and the temperature.

Fig. 5 A diagram showing the relation between the correction coefficient and the winding resistance value of the electromagnet drive device in accordance with the first embodiment of the invention.

Fig. 6 A diagram showing the relation between the correction coefficient and the applied voltage of the electromagnet drive device in accordance with the first embodiment of the invention.

Fig. 7 A circuit diagram showing the configuration of an electromagnet drive device in accordance with a second embodiment of the invention.

Fig. 8 An illustration for describing the voltage applied to the electromagnet drive device in accordance with the second embodiment of the invention.

Fig. 9 A timing chart showing the operation of the switching element and the semiconductor switch of the electromagnet drive device in accordance with the second embodiment of the invention.

Fig. 10 A timing chart showing the relation between the voltage across the excitation current detection resistor and the voltage across the capacitor of the electromagnet drive device in accordance with the second embodiment of the invention.

Fig. 11 A circuit diagram showing the configuration of an electromagnet drive device in accordance with a third embodiment of the invention.

Fig. 12 A timing chart showing the relation between the current flowing in the excitation current detection resistor and the current flowing in the input side of the Photo-MOS relay of the electromagnet drive device in accordance with the third embodiment of the invention.

Fig. 13 A timing chart showing the relation between the current flowing in the excitation current detection resistor and the current charging the capacitor of the electromagnet drive device in accordance with the third embodiment of the invention.

Fig. 14 A timing chart showing the relation between the voltage across the excitation current detection resistor and the voltage across the capacitor of the electromagnet drive device in accordance with the third embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] A preferred embodiment of an electromagnet drive device in accordance with the invention is described below with reference to the drawings.

First embodiment

[0015] Fig. 1 is a circuit diagram showing the configuration of an electromagnet drive device in accordance with a first embodiment of the invention.

[0016] In Fig. 1, an electromagnet 1 is connected to a switching element 2. When the switching element 2 is in on-state, DC power supply voltage is applied to the electromagnet 1 by a winding power supply circuit 3. When the switching element 2 is in on-state, excitation current flows in an excitation current detection resistor 4, then a voltage drop proportional to the amount of excitation current occurs across the excitation current detection resistor 4. A flywheel diode 5 is connected in parallel with the electromagnet 1 in order to cause excitation current to flow in the electromagnet 1 using counter electromotive force generated in the electromagnet 1 when the switching element 2 is in off-state. That is, a loop is formed by the electromagnet 1 and the flywheel diode 5.

[0017] An excitation current control section 6a includes: a power supply voltage measurement circuit 10 that measures the DC power supply voltage of the winding power supply circuit 3; an excitation current measurement circuit 11 that measures the voltage drop across the excitation current detection resistor 4 and detects the excitation current of the electromagnet 1 as an excitation current detection means; a pulse drive circuit 12a that pulse-controls the switching element 2; a control microcomputer 13a that calculates the pulse width that can cause excitation current necessary for holding the iron core of the electromagnet 1 to flow based on the values measured by the power supply voltage measurement circuit 10 and the excitation current measurement circuit 11 and controls the pulse width of the pulse drive circuit 12a; and a control power supply circuit 14 that supplies power to the control microcomputer 13a.

[0018] An alarm output circuit 7 outputs an alarm when the winding resistance value is abnormal due to a layer short circuit in the winding of the electromagnet 1 or the like, or when the ambient temperature of the electromagnet 1 increases due to an abnormal heat generation of the current-carrying part of a breaker, causing increase in the winding resistance value, or the like. A time-delay operation capacitor 8 is a power-supply backup capacitor. When the electromagnet drive device is used for an under voltage trip device as an internal accessory device of a breaker or the like, in order to cause time-delay operation for maintaining iron core attraction of the electromagnet 1 for a predetermined time (for example, three seconds or so) after the input power supply is cut off, the time-delay operation capacitor 8 supplies excitation current to the electromagnet 1 during time-delay operation.

[0019] The electromagnet drive device in accordance with the first embodiment is configured as above. Next, its operation is described.

[0020] When the winding power supply circuit 3 and the control power supply circuit 14 are started to supply power to the control microcomputer 13a, which is then started, the control microcomputer 13a uses the power supply voltage measurement circuit 10 to determine whether or not the DC power supply voltage of the winding power supply circuit 3 has increased to a voltage at which the iron core of the electromagnet 1 can be attracted, and is stable at a constant voltage Va. If determined that the DC power supply voltage of the winding power supply circuit 3 is stable at the constant value Va, the control microcomputer 13a operates the pulse drive circuit 12a to perform the iron core attraction.

[0021] At the time of iron core initial attraction, large excitation current needs to be caused to flow in the winding due to a gap of the magnetic circuit. So, the control microcomputer 13a operates the pulse drive circuit 12a with a pulse width of 100% for several hundred milliseconds, as indicated by Ta in Fig. 2 in which the horizontal axis indicates time and the vertical axis indicates DC power supply voltage of the winding power supply circuit 3. Then, the switching element 2 is maintained in on-state for several hundred milliseconds, and the DC power supply voltage of the winding power supply circuit 3 is applied to the electromagnet 1. At this time, excitation current flowing in the electromagnet 1 is as shown in Fig. 3 in which the horizontal axis indicates time and the vertical axis indicates the excitation current. That is, the excitation current starts to flow from the voltage application start point indicated by T1. Then, as the gap between the moving iron core and the stationary iron core decreases, the magnetic resistance decreases and the magnetic flux increases, then, when the moving iron core is attracted to abut against the stationary iron core, the magnetic flux rapidly increases to generate counter electromotive force, which temporarily reduce coil current at a point indicated by T2. After the moving iron core abuts against the stationary iron core, the magnetic resistance becomes constant and the magnetic flux no longer changes, then, when the counter electromotive force decreases to zero, the excitation current of the electromagnet 1 becomes a constant value of applied voltage divided by the winding resistance value as in the period indicated by T3.

[0022] At this time, a voltage drop Vb proportional to the excitation current occurs across the excitation current detection resistor 4. The control microcomputer 13a obtains the measurement data of the voltage drop Vb from the excitation current measurement circuit 11 and the measurement data of the DC power supply voltage Va of the winding power supply circuit 3 from the power supply voltage measurement circuit 10. The control microcomputer 13a calculates the winding resistance value Ra of the electromagnet 1 by the expression $Ra = (Va - Vb) / (Vb/Rb)$, where Rb is the resistance value of the excitation current detection resistor 4. Here, the on-resistance of the switching element 2 is several hundred milliohms, which is negligibly small in comparison with the winding resistance value of the electromagnet 1, so, the voltage drop across the switching element 2 is omitted in the calculation.

[0023] After the time of iron core initial attraction Ta of Fig. 2 has passed and the iron core has been attracted, the gap of the magnetic circuit has become small, so, even with the flowing excitation current reduced, the attracted state of the iron core can be maintained. Reduction in the excitation current is performed by the control microcomputer 13a pulse-controlling the switching element 2 through the pulse drive circuit 12a and transforming the DC power supply voltage Va of the winding power supply circuit 3 into pulsed voltage to be applied to the electromagnet 1. However, the winding resistance value Ra of the electromagnet 1 increases in proportion to the ambient temperature as shown in Fig. 4, so, with a constant pulse width, the excitation current decreases as the ambient temperature increases. Also, when the DC power supply voltage Va of the winding power supply circuit 3 decreases due to an instantaneous power failure or the like, the excitation current decreases.

[0024] In order to avoid this, the control microcomputer 13a uses the winding resistance value Ra obtained from the above calculation and the measured value of the DC power supply voltage Va of the winding power supply circuit 3 to determine a correction coefficient K for the on-duty of the pulse control and performs the pulse control with an on-duty of $D1 \times K$, which is the fundamental on-duty D1 multiplied by the correction coefficient K. Note that the fundamental on-duty D1 is an on-duty with which the iron core can be held attracted when the winding power supply circuit 3 stably operates at the ambient temperature of 20°C, which is previously stored in the control microcomputer 13a. On the other hand, the correction coefficient K is calculated by the control microcomputer 13a by the expression $K = K1 \times K2$, where K1 is a correction coefficient considering increase/decrease of the winding resistance value due to the ambient temperature and K2 is a correction coefficient considering reduction in the DC power supply voltage Va of the winding power supply circuit 3. K1 is given by the winding resistance value Ra divided by a reference winding resistance value R1. K2 is given by the DC power supply voltage Va divided by a reference power supply voltage V1. The reference winding resistance value R1 is a resistance value at the ambient temperature of 20°C. The reference power supply voltage V1 is a voltage of the winding power supply circuit 3 in stable operation. As shown in Fig. 5, the correction coefficient K1 performs correction so that the on-duty increases in proportion to the winding resistance value. On the other hand, as shown in Fig. 6, the correction coefficient K2 performs correction so that the on-duty increases as the voltage applied to the winding decreases.

[0025] The resistance value of the winding of the electromagnet 1 increases or decreases depending on the ambient temperature. So, when the pulse control is performed for a long time based on the winding resistance value Ra calculated during the time of iron core initial attraction Ta, the amount of flowing excitation current may fall below the amount necessary for maintaining iron core attraction, or the excess amount of excitation current may flow to cause the electromagnet 1 to generate heat or increase consumption current, or another problem may occur. As such, control is performed to maintain the excitation current constant, in which, as shown in Fig. 2, during the period of several hundred milliseconds indicated by Tb at intervals of several tens of seconds, the pulse drive circuit 12a is operated with a pulse width of 100% and the switching element 2 is caused to be in on-state for several hundred milliseconds, then, when the excitation current becomes constant as in the period indicated by T4 in Fig. 3, the resistance value Ra of the winding of the electromagnet 1 is recalculated to determine an on-duty for next several tens of seconds until iron core re-attraction. Note that in an internal accessory device or the like using the electromagnet of a breaker, an external impact, such as a main body opening/closing impact, hits the electromagnet, then the iron core shifted from an original position by the external impact can also be returned to the original position by the iron core re-attraction at intervals of several tens of seconds.

[0026] When this electromagnet drive device is used as an internal accessory device of a breaker or the like, the winding resistance value of the electromagnet 1 increases due to the influence of heat dissipation of the current-carrying part or increase in the ambient temperature. However, the control microcomputer 13a stores the maximum variation range of the winding resistance value, then, when the resistance value Ra of the winding obtained from the above calculation falls below the lower limit value due to a layer short circuit in the winding or the like, or when the winding resistance value exceeds the upper limit value due to increase in the ambient temperature of the electromagnet 1 caused by an abnormal heat generation of the current-carrying part, the control microcomputer 13a outputs an alarm of an abnormal winding resistance value through the alarm output circuit 7.

[0027] Also, the under voltage trip device as the internal accessory device of the breaker or the like may perform time-delay operation for maintaining iron core attraction of the electromagnet for three seconds or so after the input power supply is cut off, in which, with the time-delay operation capacitor 8 attached, the excitation current is continuously caused to flow in the electromagnet 1 for a time-delay duration after the cut off of the input power supply, using an electrical charge stored before the cutoff. At this time, the voltage Va applied to the electromagnet 1 decreases as the charge of the time-delay operation capacitor 8 is consumed. So, if the switching pulse width of the switching element 2 is constant, the excitation current decreases. As such, the pulse control is performed with an on-duty that is the fundamental on-duty D1 multiplied by the correction coefficient K, so the on-duty increases as the voltage Va applied to the electromagnet 1 decreases, which can maintain the excitation current constant.

[0028] As described above, according to the electromagnet drive device in accordance with the first embodiment, the excitation current detection resistor 4 is provided outside the loop formed by the electromagnet 1 and the flywheel diode 5, so, power consumption occurs in the excitation current detection resistor 4 only when the switching element 2 is in on-state, and does not occur when the switching element 2 is in off-state, which can suppress the power loss.

[0029] Furthermore, the excitation current is measured by the excitation current measurement circuit 11 when the excitation current is relatively large at the time of iron core initial attraction and at the time of iron core re-attraction as indicated by T3 and T4 in Fig. 3, so, assuming that the amount of excitation current at the time of iron core initial attraction and at the time of iron core re-attraction is 5 times as large as that of the held-attraction maintaining current, in order to obtain the same detected voltage, the excitation current detection resistor 4 with a resistance value one fifth as large as that of a resistor used in a method of detecting the held-attraction maintaining current can be used. Using a resistor with a small resistance value can suppress power consumption in the resistor, so a resistor having small normal rated power can be used.

[0030] Furthermore, as shown in Fig. 2, the voltage drop proportional to the excitation current occurring across the excitation current detection resistor 4 occurs only when the switching element 2 is in on-state. If the pulse period of the pulse control at the time of held-attraction maintaining current flowing is set to 15 kHz or higher in order to avoid the audible frequency range, the pulse width would be as narrow as several microseconds to several tens of microseconds. In order to choose a control microcomputer that can sample this pulse several times, a high-performance and high-cost microcomputer must be chosen. For example, in order to sample a 10 μs pulse 10 times, a high-performance control microcomputer with a sampling frequency of 1 MHz or higher is needed. However, with a duration of excitation current detection T3 and T4 in Fig. 3 of 10 ms or longer, in order to sample a 10-ms pulse 10 times, a control microcomputer with a sampling frequency of 1 kHz or higher can be used, so, a low-cost general-purpose microcomputer with a low sampling frequency can be used.

[0031] Furthermore, the control microcomputer 13a stores the maximum variation range of the winding resistance value and, when the winding resistance value is out of the maximum variation range, outputs an alarm of an abnormal winding resistance value through the alarm output circuit 7. So, when an abnormal winding resistance value due to a layer short circuit or the like occurs or when the electromagnet drive device is used as the internal accessory device of a breaker or the like and the winding resistance value increases due to increase in the ambient temperature of the electromagnet 1 caused by an abnormal heat generation of the current-carrying part, the control microcomputer 13a can notify of an abnormality by outputting an alarm.

[0032] Furthermore, after the iron core of the electromagnet 1 is attracted, the gap of the magnetic circuit becomes small, so, even the flowing excitation current is reduced, the iron core can be maintained attracted. However, the control microcomputer 13a uses the measured value of the winding resistance value Ra and the DC power supply voltage Va of the winding power supply circuit 3 to determine the on-duty correction coefficient, then perform the pulse control with an on-duty that is the fundamental on-duty multiplied by the correction coefficient, which can maintain the excitation current constant even when the winding resistance value increases or decreases depending on the ambient temperature or when the DC power supply voltage Va of the winding power supply circuit 3 decreases.

[0033] Furthermore, the resistance value of the winding of the electromagnet 1 increases or decreases depending on the ambient temperature, so, when the pulse control is performed for a long time based on the winding resistance value calculated at the time of iron core attraction, the amount of flowing excitation current may fall below the amount necessary for maintaining iron core attraction, or the excess amount of excitation current may flow to cause the electromagnet 1 to generate heat or increase consumption current, or another problem may occur. As such, the excitation current can be maintained constant by recalculating the resistance value of the winding of the electromagnet 1 at intervals of several tens of seconds to calculate the on-duty correction coefficient for next several tens of seconds until iron core re-attraction, thereby determining an on-duty to perform the pulse control.

[0034] Furthermore, when the electromagnet drive device in accordance with the first embodiment is used as the internal accessory device of the breaker or the like, an external impact, such as a main body opening/closing impact, hits the electromagnet 1, however, the iron core shifted from an original position by the external impact can be returned to the original position by the iron core re-attraction at intervals of several tens of seconds.

[0035] Furthermore, when the electromagnet drive device in accordance with the first embodiment is used for time-delay operation for maintaining iron core attraction of the electromagnet 1 for three seconds or so after the input power supply is cut off in the under voltage trip device as the internal accessory device within the breaker or the like, the excitation current is continuously caused to flow in the electromagnet 1 for a time-delay duration after the cut off of the input power supply, using an electrical charge stored in the time-delay operation capacitor 8. At this time, the DC supply voltage Va applied to the electromagnet 1 decreases as the charge of the time-delay operation capacitor 8 is consumed. As such, the pulse control is performed with an on-duty that is the fundamental on-duty multiplied by the correction coefficient, which can maintain the excitation current constant even when the voltage applied to the electromagnet 1 decreases.

[0036] Second embodiment

[0037] Next, an electromagnet drive device in accordance with a second embodiment of the invention is described.

[0038] Fig. 7 is a circuit diagram showing the configuration of an electromagnet drive device in accordance with the second embodiment. The second embodiment is another embodiment of the excitation current control section 6a of the first embodiment and provides various effects similar to those of the first embodiment.

[0039] In Fig. 7, an excitation current control section 6b includes: a control microcomputer 13b that causes excitation current necessary for holding the iron core of an electromagnet 1 to flow by pulse-controlling a switching element 2; a control power supply 14 for the control microcomputer 13b; a power supply voltage measurement circuit 10 that measures DC power supply voltage of a winding power supply circuit 3; a pulse drive circuit 12b that pulse-controls the switching element 2; and a transistor 20, resistor 21 and zener diode 22 that pulse-drive the switching element 2 using a pulse output from the pulse drive circuit 12b.

[0040] The excitation current control section 6b further includes: a capacitor 23 that holds a detected voltage occurring across an excitation current detection resistor 4 in proportion to excitation current when the switching element 2 is in on-state also during the period in which the switching element 2 is in off-state; a resistor 24 that prevents current from flowing from the capacitor 23 toward the excitation current detection resistor 4 during the period in which the switching element 2 is in off-state; a semiconductor switch 25 that connects the capacitor 23 to the excitation current detection resistor 4 only when the switching element 2 is in on-state; and a zener diode 26 and resistor 27 that cause the semiconductor switch 25 to operate only when the switching element 2 is in on-state. Note that the remaining parts are configured in the same way as the first embodiment and are denoted by the same reference numerals with their description omitted.

[0041] The electromagnet drive device in accordance with the second embodiment is configured as above. Next, its operation is described.

[0042] In the first embodiment, the pulse width of the pulse control is determined by calculating the winding resistance value of the electromagnet 1 from a voltage drop occurring across the excitation current detection resistor 4 when the pulse control is performed with a pulse width of 100% at the time of iron core initial attraction and in a period of several hundred milliseconds at intervals of several tens of seconds. However, in the second embodiment, the pulse width of the pulse control is determined from a voltage drop occurring across the excitation current detection resistor 4 in a pulse control period Tc shown in Fig. 8 in which the horizontal axis indicates time and the vertical axis indicates DC power supply voltage of the winding power supply circuit 3. At the time of iron core initial attraction, the control microcomputer 13b calculates the winding resistance value of the electromagnet 1 using the method described in the first embodiment to determine the pulse width and start the pulse control. The winding resistance value of the electromagnet 1 increases or decreases depending on the ambient temperature. So, when the pulse control is performed for a long time based on the winding resistance value calculated at the time of iron core initial attraction, the amount of flowing excitation current may fall below the amount necessary for maintaining iron core attraction, or the excess amount of excitation current may flow to cause the electromagnet 1 to generate heat or increase consumption current, or another problem may occur. As such, the capacitor 23 holds a detected voltage occurring across the excitation current detection resistor 4 in proportion to the excitation current when the switching element 2 is in on-state also during the period in which the switching element 2 is in off-state, so, even a low-cost microcomputer with a low sampling frequency can perform sampling.

[0043] The switching element 2 becomes in on-state when the gate terminal voltage exceeds a threshold. The semiconductor switch 25 becomes in on-state when the control terminal voltage exceeds a threshold. The pulse control is performed by the pulse drive circuit 12b turning the transistor 20 on and off. When the transistor 20 is in on-state, the zener diode 22 is short-circuited and no voltage is applied to the gate terminal of the switching element 2. When the transistor 20 is in off-state, current flows from the resistor 21 to the zener diode 22, then the same voltage as the zener voltage of the zener diode 22 is applied to the gate terminal of the switching element 2.

[0044] The zener diode 26 having a zener voltage characteristics lower than the zener voltage of the zener diode 22 and the resistor 27 are connected in parallel with the zener diode 22 and connected to the control terminal of the semiconductor switch 25. With this configuration, as shown in Fig. 9, until the gate terminal voltage of the switching element 2 reaches the zener voltage of the zener diode 26, no current flows in the zener diode 26 and no voltage occurs across the resistor 27. So, in rising, the control terminal voltage of the semiconductor switch 25 rises later than the gate terminal voltage of the switching element 2, and, in falling, the control terminal voltage of the semiconductor switch 25 falls earlier than the gate terminal voltage of the switching element 2. Accordingly, when the pulse control is performed, the semiconductor switch 25 becomes in on-state after the switching element 2 becomes in on-state, and the semiconductor switch 25 becomes in off-state before the switching element 2 becomes in off-state.

[0045] Accordingly, only when the switching element 2 is in on-state and a detected voltage proportional to the excitation current occurs across the excitation current detection resistor 4, the semiconductor switch 25 becomes in on-state and the capacitor 23 is charged to hold the detected voltage. So, as shown in Fig. 10, a voltage having a value within a range in which the voltage is substantially equal to the detected voltage of the excitation current detection resistor 4 is held across the capacitor 23. As shown in Fig. 10, the voltage held by the capacitor 23 decreases during the period in which the switching element 2 is in off-state due to leak current of the semiconductor switch 25 and self discharge of the capacitor 23 caused by its leak current. However, the excitation current detection is possible by choosing a component having a leak current characteristics enough not to affect the excitation current detection.

[0046] When the switching element 2 and the semiconductor switch 25 become in on- or off-state substantially at the same time and current flows from the capacitor 23 toward the excitation current detection resistor 4, the resistor 24 serves to prevent the voltage held by the capacitor 23 from rapidly decreasing to affect the detection. The control microcomputer 13b reads a voltage signal charged across the capacitor 23 proportional to the excitation current of the electromagnet 1 and pulse-controls the switching element 2 through the pulse drive circuit 12b with a pulse width in which excitation current necessary for holding the iron core of the electromagnet 1 flows.

[0047] As described above, according to the electromagnet drive device in accordance with the second embodiment, the excitation current detection resistor 4 is provided outside the loop formed by the electromagnet 1 and the flywheel diode 5, so, power consumption occurs in the excitation current detection resistor 4 only when the switching element 2 is in on-state, and does not occur when the switching element 2 is in off-state, which can suppress the power loss.

[0048] Furthermore, a detected signal of the excitation current of the electromagnet 1 is held also during the period in which the switching element 2 is in off-state, so, even a low-cost general-purpose microcomputer with a low sampling frequency can detect the excitation current.

[0049] Furthermore, as with the first embodiment, the winding resistance value of the electromagnet 1 is calculated at the time of iron core initial attraction and the time of iron core re-attraction of the electromagnet 1, then, when the winding resistance value is out of the maximum variation range thereof, an alarm of an abnormal winding resistance value is output from the alarm output circuit 7. So, when an abnormal winding resistance value due to a layer short circuit or the like occurs or when the electromagnet drive device is used as the internal accessory device of a breaker or the like and the winding resistance value increases due to increase in the ambient temperature of the electromagnet 1 caused by an abnormal heat generation of the current-carrying part, an abnormality can be notified by outputting an alarm.

[0050] Furthermore, when the electromagnet drive device in accordance with the second embodiment is used as the internal accessory device of the breaker or the like, an external impact, such as a main body opening/closing impact, hits the electromagnet 1, however, the iron core shifted from an original position by the external impact can be returned to the original position by the iron core re-attraction at intervals of several tens of seconds.

Third embodiment

[0051] Next, an electromagnet drive device in accordance with a third embodiment of the invention is described.

[0052] Fig. 11 is a circuit diagram showing the configuration of an electromagnet drive device in accordance with the third embodiment. The third embodiment is still another embodiment of the excitation current control section 6a of the first embodiment and provides various effects similar to those of the first embodiment.

[0053] In Fig. 11, an excitation current control section 6c includes: a control microcomputer 13b that causes excitation current necessary for holding the iron core of an electromagnet 1 to flow by pulse-controlling a switching element 2; a control power supply 14 for the control microcomputer 13b; a power supply voltage measurement circuit 10 that measures DC power supply voltage of a winding power supply circuit 3; a pulse drive circuit 12a that pulse-controls the switching element 2; a capacitor 23 that holds a detected voltage occurring across an excitation current detection resistor 4 in proportion to excitation current when the switching element 2 is in on-state also during the period in which the switching element 2 is in off-state; a resistor 24 that prevents current from flowing from the capacitor 23 toward the excitation current detection resistor 4 during the period in which the switching element 2 is in off-state; a Photo-MOS relay 30 that connects the capacitor 23 to the excitation current detection resistor 4 only when the switching element 2 is in on-state; a resistor 31 that causes operating current of the Photo-MOS relay 30 to flow only when the switching element 2 is in on-state; and a resistor 32 for avoiding malfunction of the Photo-MOS relay 30 due to disturbance. Note that the remaining parts are configured in the same way as the first embodiment and are denoted by the same reference numerals with their description omitted.

[0054] The electromagnet drive device in accordance with the third embodiment is configured as above. Next, its operation is described. In the first embodiment, the pulse width of the pulse control is determined by calculating the winding resistance value of the electromagnet 1 from a voltage drop occurring across the excitation current detection resistor 4 when the pulse control is performed with a pulse width of 100% at the time of iron core initial attraction and in a period of several hundred milliseconds at intervals of several tens of seconds. However, in the third embodiment, as with the second embodiment, the pulse width of the pulse control is determined from a voltage drop occurring across the excitation current detection resistor 4 in a pulse control period Tc shown in Fig. 8.

[0055] At the time of iron core initial attraction, the control microcomputer 13b calculates the winding resistance value of the electromagnet 1 using the method described in the first embodiment to determine the pulse width and start the pulse control. The winding resistance value of the electromagnet 1 increases or decreases depending on the ambient temperature. So, when the pulse control is performed for a long time based on the winding resistance value calculated at the time of iron core initial attraction, the amount of flowing excitation current may fall below the amount necessary for maintaining iron core attraction, or the excess amount of excitation current may flow to cause the electromagnet 1 to generate heat or increase consumption current, or another problem may occur. As such, the capacitor 23 holds a detected voltage occurring across the excitation current detection resistor 4 in proportion to the excitation current when the switching element 2 is in on-state also during the period in which the switching element 2 is in off-state, so, even a low-cost microcomputer with a low sampling frequency can perform sampling.

[0056] As shown in Fig. 12, when the switching element 2 is in on-state and current shunted by the excitation current detection resistor 4 and the resistor 31 flows in the input side of the Photo-MOS relay 30, the output side of the Photo-MOS relay 30 becomes in on-state. At this time, the amount of current flowing in the resistor 31 is caused to be one tenth or smaller in comparison with the amount of current flowing in the excitation current detection resistor 4 so as not to affect the excitation current detection of the electromagnet 1.

[0057] Furthermore, in order to prevent the Photo-MOS relay 30 from malfunctioning due to very small current caused by disturbance flowing in the input side of the Photo-MOS relay 30 when the switching element 2 is in off-state, the resistor 32 is provided so that the Photo-MOS relay 30 does not operate until a certain amount of current flows in the input side of the Photo-MOS relay 30. Accordingly, as shown in Fig. 13, only when the switching element 2 is in on-state and a detected voltage proportional to the excitation current occurs across the excitation current detection resistor 4, the output side of the Photo-MOS relay 30 becomes in on-state and charging current flows in the capacitor 23, so, as shown in Fig. 14, a voltage having a value within a range in which the voltage is substantially equal to the detected voltage of the excitation current detection resistor 4 is held across the capacitor 23.

[0058] As shown in Fig. 14, the voltage held by the capacitor 23 decreases during the period in which the switching element 2 is in off-state due to leak current of the Photo-MOS relay 30 and self discharge of the capacitor 23 caused by its leak current. However, the excitation current detection is possible by choosing a component having a leak current characteristics enough not to affect the excitation current detection. Furthermore, when the switching element 2 and the Photo-MOS relay 30 become in on- or off-state substantially at the same time and current flows from the capacitor 23 toward the excitation current detection resistor 4, the resistor 24 serves to prevent the voltage held by the capacitor 23 from rapidly decreasing to affect the detection. The control microcomputer 13b reads a voltage signal charged across the capacitor 23 proportional to the excitation current of the electromagnet 1 and pulse-controls the switching element 2 through the pulse drive circuit with a pulse width in which excitation current necessary for holding the iron core of the electromagnet 1 flows.

[0059] As described above, according to the electromagnet drive device in accordance with the third embodiment, the excitation current detection resistor 4 is provided outside the loop formed by the electromagnet 1 and the flywheel diode 5, so, power consumption occurs in the excitation current detection resistor 4 only when the switching element 2 is in on-state, and does not occur when the switching element 2 is in off-state, which can suppress the power loss.

[0060] Furthermore, a detected signal of the excitation current of the electromagnet 1 is held also during the period in which the switching element 2 is in off-state, so, even a low-cost general-purpose microcomputer with a low sampling frequency can detect the excitation current.

[0061] Furthermore, as with the first embodiment, the winding resistance value of the electromagnet 1 is calculated at the time of iron core initial attraction and the time of iron core re-attraction of the electromagnet 1, then, when the winding resistance value is out of the maximum variation range thereof, an alarm of an abnormal winding resistance value is output from the alarm output circuit 7. So, when an abnormal winding resistance value due to a layer short circuit or the like occurs or when the electromagnet drive device is used as the internal accessory device of a breaker or the like and the winding resistance value increases due to increase in the ambient temperature of the electromagnet 1 caused by an abnormal heat generation of the current-carrying part, an abnormality can be notified by outputting an alarm.

[0062] Furthermore, when the electromagnet drive device in accordance with the third embodiment is used as the internal accessory device of the breaker or the like, an external impact, such as a main body opening/closing impact, hits the electromagnet 1, however, the iron core shifted from an original position by the external impact can be returned to the original position by the iron core re-attraction at intervals of several tens of seconds.

[0063] The first to third embodiments of the invention have been described. However, according to the invention, the embodiments may be freely combined or the embodiments may be appropriately modified or omitted within the scope of the invention.

Claims

1. An electromagnet drive device comprising:

a winding power supply circuit (3) that outputs DC power supply voltage (Va) to be applied to an electromagnet (1);
a power supply voltage measurement circuit (10) that measures the DC power supply voltage (Va);
an excitation current detection resistor (4) connected in series with the electromagnet (1), across which a voltage drop (Vb) proportional to the amount of excitation current of the electromagnet (1) occurs; and
a control microcomputer (13a, 13b) that controls the excitation current of the electromagnet (1) through a switching element (2),
wherein the control microcomputer (13a, 13b), at the time of iron core initial attraction and the time of iron core re-attraction of the electromagnet (1), calculates the winding resistance value of the electromagnet (1) from the measurements of a voltage drop (Vb) across the excitation current detection resistor (4) and the DC power supply voltage (Va), and
characterised in that in the time other than the time of iron core initial attraction and the time of iron core re-attraction of the electromagnet (1), performs pulse control in which, through on-duty based on the winding resistance value and a measurement value of the DC power supply voltage (Va), the DC power supply voltage (Va) is transformed into pulsed voltage to be applied to the electromagnet (1) by the switching element (2).

2. The electromagnet drive device according to claim 1, comprising:
an alarm output circuit (7) that outputs an alarm when the winding resistance value of the electromagnet (1) becomes abnormal.

3. The electromagnet drive device according to claim

1 or 2, comprising:
a time-delay operation capacitor (8) that supplies power for maintaining iron core attraction of the electromagnet (1) after the input power supply to the winding power supply circuit (3) is cut off.

4. The electromagnet drive device according to any one of claims 1 to 3, comprising:

a flywheel diode (5) connected in parallel with the electromagnet (1),
wherein the excitation current detection resistor (4) is provided outside a loop formed by the electromagnet (1) and the flywheel diode (5).

5. The electromagnet drive device according to any one of claims 1 to 4,
wherein the control microcomputer (13a, 13b) determines a correction coefficient for the on-duty of the pulse control, then performs the pulse control with an on-duty that is a fundamental on-duty multiplied by the correction coefficient.

6. The electromagnet drive device according to any one of claims 1 to 5, comprising:

a semiconductor switch (25) that becomes in on-state only when the switching element (2) is in on-state and a detected voltage proportional to the excitation current occurs across the excitation current detection resistor (4); and
a capacitor (23) connected to the control microcomputer (13b),
wherein the capacitor (23) is charged with a voltage equal to the detected voltage of the excitation current detection resistor (4) and holds the charged voltage.

7. The electromagnet drive device according to any one of claims 1 to 5, comprising:

a Photo-MOS relay (30) that becomes in on-state only when the switching element (2) is in on-state and a detected voltage proportional to the excitation current occurs across the excitation current detection resistor (4); and
a capacitor (23) connected to the control microcomputer (13b),
wherein the capacitor (23) is charged with a voltage equal to the detected voltage of the excitation current detection resistor (4) and holds the charged voltage.

Patentansprüche

1. Elektromagnet-Ansteuerungsvorrichtung, die aufweist:

eine Wicklungsspannungsversorgungsschaltung (3), die eine an den Elektromagneten (1) anzulegende Versorgungsgleichspannung (Va) ausgibt,
eine Spannungsversorgungsspannungsmessschaltung (10), die die Versorgungsgleichspannung (Va) misst,
einen mit dem Elektromagneten (1) in Reihe geschalteten Erregerstromerfassungswiderstand (4), an dem ein zum Wert des Erregerstroms des Elektromagneten (1) proportionaler Spannungsabfall (Vb) auftritt, und
eine Mikrocomputersteuerung (13a, 13b), die den Erregerstrom des Elektromagneten (1) mit Hilfe eines Schaltelements (2) steuert,
wobei die Mikrocomputersteuerung (13a, 13b) bei einer initialen Anziehung des Eisenkerns des Elektromagneten (1) und bei einer wiederholten Anziehung des Eisenkerns des Elektromagneten (1) den Wert des Wicklungswiderstands des Elektromagneten (1) aus den Messungen eines Spannungsabfalls (Vb) am Erregerstromerfassungswiderstand (4) und der Versorgungsgleichspannung (Va) berechnet, und
dadurch gekennzeichnet ist, dass
sie während einer Zeit, die von einer Zeit einer initialen Anziehung des Eisenkerns des Elektromagneten (1) und einer Zeit einer wiederholten Anziehung des Eisenkerns des Elektromagneten (1) verschieden ist, eine Impulssteuerung ausführt, bei der die Versorgungsgleichspannung (Va) durch das Schaltelement (2) mit einem Tastgrad, der auf dem Wert des Wicklungswiderstands und einem Messwert der Versorgungsgleichspannung (Va) basiert, in eine an den Elektromagneten (1) anzulegende gepulste Spannung transformiert wird.

2. Elektromagnet-Ansteuerungsvorrichtung nach Anspruch 1, die aufweist:
eine Alarmausgabeschaltung (7), die einen Alarm ausgibt, wenn der Wert des Wicklungswiderstands des Elektromagneten (1) anormal wird.

3. Elektromagnet-Ansteuerungsvorrichtung nach Anspruch 1 oder 2, die aufweist:
einen Zeitverzögerungsfunktionskondensator (8), der nach einer Trennung der Eingangsspannungsversorgung von der Wicklungsspannungsversorgungsschaltung (3) eine Spannung zum Aufrechterhalten einer Anziehung des Eisenkerns des Elektromagneten (1) bereitstellt.

4. Elektromagnet-Ansteuerungsvorrichtung nach einem der Ansprüche 1 bis 3, die aufweist:

eine Freilaufdiode (5), die parallel zum Elektromagneten (1) geschaltet ist, wobei der Erregerstromerfassungswiderstand (4) außerhalb einer von dem Elektromagneten (1) und der Freilaufdiode (5) gebildeten Masche angeordnet ist.

5. Elektromagnet-Ansteuerungsvorrichtung nach einem der Ansprüche 1 bis 4, wobei die Mikrocomputersteuerung (13a, 13b) einen Korrekturkoeffizienten für den Tastgrad der Impulssteuerung bestimmt und die Impulssteuerung anschließend mit einem Tastgrad ausführt, der einem mit dem Korrekturkoeffizienten multiplizierten Basistastgrad entspricht.

6. Elektromagnet-Ansteuerungsvorrichtung nach einem der Ansprüche 1 bis 5, die aufweist:

einen Halbleiterschalter (25), der nur dann in den leitenden Zustand übergeht, wenn sich das Schaltelement (2) im leitenden Zustand befindet und an dem Erregerstromerfassungswiderstand (4) eine zum Erregerstrom proportionale Spannung erfasst wird, und
einen Kondensator (23), der mit der Mikrocomputersteuerung (13b) verbunden ist,
wobei der Kondensator (23) mit einer Spannung geladen wird, die der am Erregerstromerfassungswiderstand (4) erfassten Spannung entspricht, und die Ladespannung hält.

7. Elektromagnet-Ansteuerungsvorrichtung nach einem der Ansprüche 1 bis 5, die aufweist:

ein Photo-MOS-Relais (30), das nur dann in den leitenden Zustand übergeht, wenn sich das Schaltelement (2) im leitenden Zustand befindet und an dem Erregerstromerfassungswiderstand (4) eine zum Erregerstrom proportionale Spannung erfasst wird, und
einen Kondensator (23), der mit der Mikrocomputersteuerung (13b) verbunden ist,
wobei der Kondensator (23) mit einer Spannung geladen wird, die der am Erregerstromerfassungswiderstand (4) erfassten Spannung entspricht, und die Ladespannung hält.

Revendications

1. Dispositif de pilotage d'électroaimant comprenant:

un circuit d'alimentation en courant d'enroulement (3) qui délivre en sortie une tension d'alimentation en courant continu (Va) à appliquer à un électroaimant (1);
un circuit de mesure de tension d'alimentation en courant (10) qui mesure la tension d'alimentation en courant continu (Va);
une résistance de détection de courant d'excitation (4) raccordée en série avec l'électroaimant (1), à travers laquelle une chute de tension (Vb) proportionnelle à la quantité de courant d'excitation de l'électroaimant (1) se produit; et
un microcalculateur de commande (13a, 13b) qui commande le courant d'excitation de l'électroaimant (1) par l'intermédiaire d'un élément de commutation (2),
dans lequel le microcalculateur de commande (13a, 13b),
au moment d'une attraction initiale de noyau de fer et au moment d'une ré-attraction de noyau de fer de l'électroaimant (1), calcule la valeur de résistance à l'enroulement de l'électroaimant (1) à partir des mesures d'une chute de tension (Vb) à travers la résistance de détection de courant d'excitation (4) et de la tension d'alimentation en courant continu (Va), et
caractérisé en ce que
à un moment autre que le moment d'attraction initiale du noyau de fer et le moment de ré-attraction de noyau de fer de l'électroaimant (1), réalise une commande d'impulsion dans laquelle, par un rapport cyclique basé sur la valeur de résistance à l'enroulement et une valeur de mesure de la tension d'alimentation en courant continu (Va), la tension d'alimentation en courant continu (Va) est transformée en tension impulsionnelle à appliquer à l'électroaimant (1) par l'élément de commutation (2).

2. Dispositif de pilotage d'électroaimant selon la revendication 1, comprenant:
un circuit de sortie d'alarme (7) qui délivre en sortie une alarme lorsque la valeur de résistance à l'enroulement de l'électroaimant (1) devient anormale.

3. Dispositif de pilotage d'électroaimant selon la revendication 1 ou 2, comprenant:
un condensateur à fonctionnement temporisé (8) qui fournit du courant pour maintenir une attraction de noyau de fer de l'électroaimant (1) après que l'alimentation en courant d'entrée du circuit d'alimentation en courant d'enroulement (3) est arrêtée.

4. Dispositif de pilotage d'électroaimant selon l'une quelconque des revendications 1 à 3, comprenant:
une diode à effet de volant (5) raccordée en parallèle avec l'électroaimant (1), dans lequel la résistance de détection de courant d'excitation (4) est prévue à l'extérieur d'une boucle formée par l'électroaimant (1) et la diode à effet de volant (5).

5. Dispositif de pilotage d'électroaimant selon l'une quelconque des revendications 1 à 4,
dans lequel le microcalculateur de commande (13a, 13b) détermine un coefficient de correction pour le

rapport cyclique de la commande d'impulsion, puis réalise la commande d'impulsion avec un rapport cyclique qui est un rapport cyclique fondamental multiplié par le coefficient de correction.

6. Dispositif de pilotage d'électroaimant selon l'une quelconque des revendications 1 à 5, comprenant:

un commutateur à semi-conducteur (25) qui passe dans l'état passant uniquement lorsque l'élément de commutation (2) est dans l'état passant et qu'une tension détectée proportionnelle au courant d'excitation apparaît à travers la résistance de détection de courant d'excitation (4); et
un condensateur (23) relié au microcalculateur de commande (13b),
dans lequel le condensateur (23) est chargé avec une tension égale à la tension détectée de la résistance de détection de courant d'excitation (4) et maintient la tension à l'état chargé.

7. Dispositif de pilotage d'électroaimant selon l'une quelconque des revendications 1 à 5, comprenant:

un relais PhotoMOS (30) qui passe dans l'état passant uniquement lorsque l'élément de commutation (2) est dans l'état passant et qu'une tension détectée proportionnelle au courant d'excitation apparaît à travers la résistance de détection de courant d'excitation (4); et
un condensateur (23) relié au microcalculateur de commande (13b),
dans lequel le condensateur (23) est chargé avec une tension égale à la tension détectée de la résistance de détection de courant d'excitation (4) et maintient la tension à l'état chargé .

FIG.1

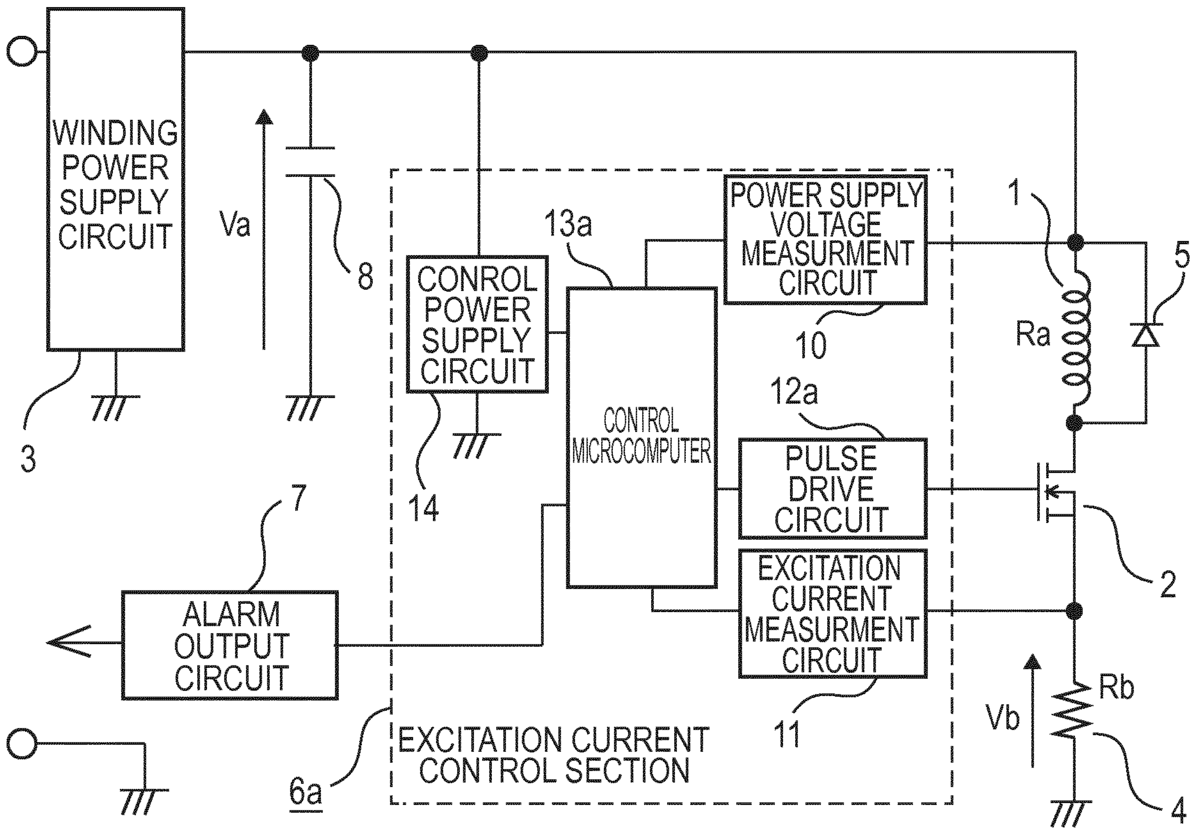

WINDING POWER SUPPLY CIRCUIT
Va
8
3
CONROL POWER SUPPLY CIRCUIT
14
13a
CONTROL MICROCOMPUTER
POWER SUPPLY VOLTAGE MEASURMENT CIRCUIT
10
12a
PULSE DRIVE CIRCUIT
EXCITATION CURRENT MEASURMENT CIRCUIT
11
1
Ra
5
2
Rb
Vb
4
7
ALARM OUTPUT CIRCUIT
EXCITATION CURRENT CONTROL SECTION
6a

FIG.2

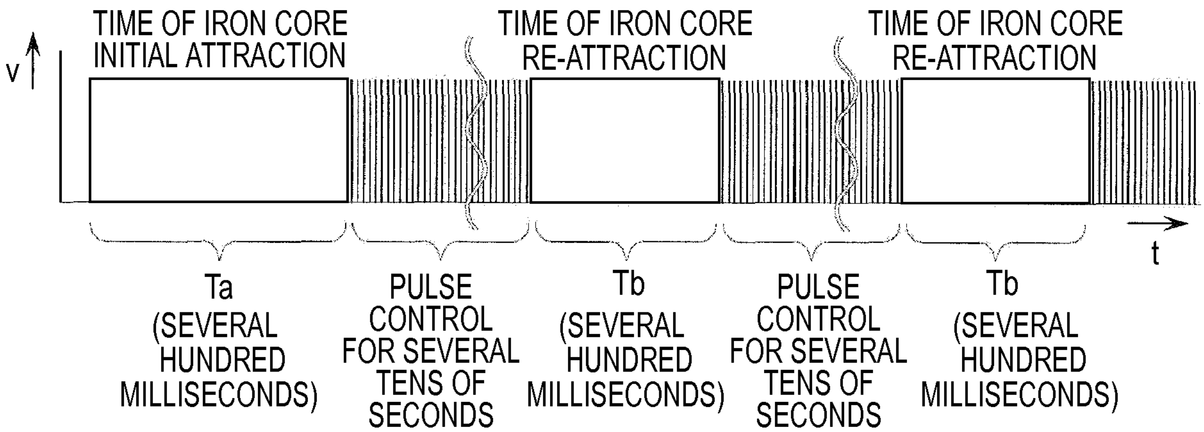

TIME OF IRON CORE INITIAL ATTRACTION
TIME OF IRON CORE RE-ATTRACTION
TIME OF IRON CORE RE-ATTRACTION
v
t
Ta (SEVERAL HUNDRED MILLISECONDS)
PULSE CONTROL FOR SEVERAL TENS OF SECONDS
Tb (SEVERAL HUNDRED MILLISECONDS)
PULSE CONTROL FOR SEVERAL TENS OF SECONDS
Tb (SEVERAL HUNDRED MILLISECONDS)

FIG.3

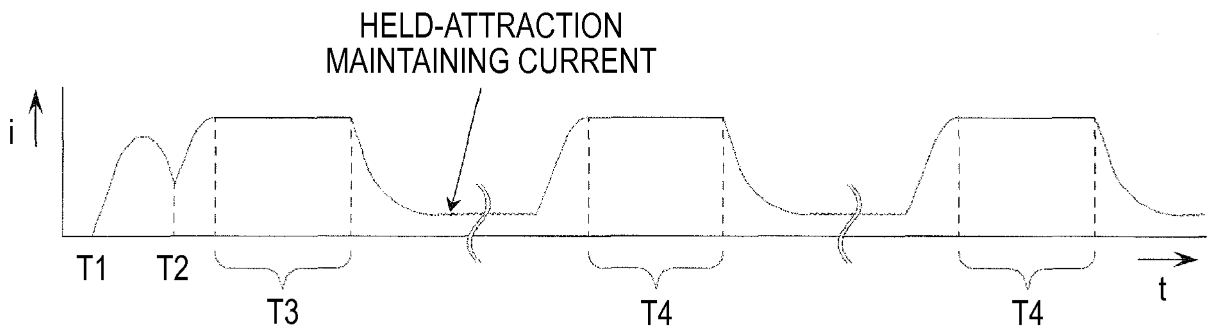


FIG.4

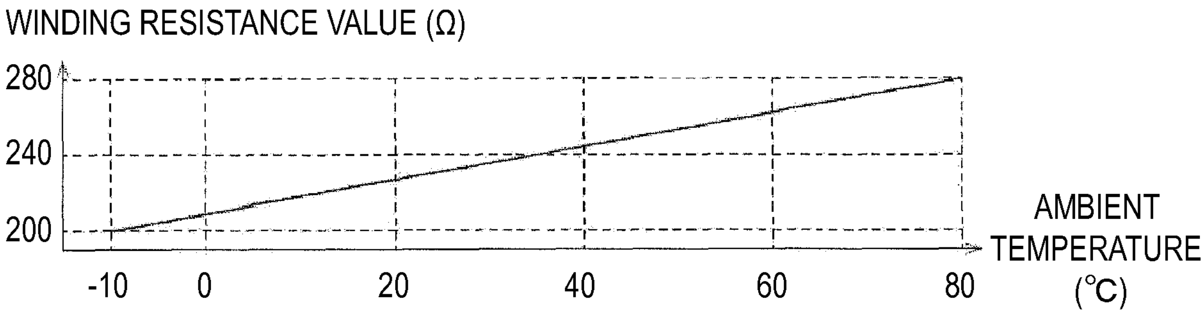

WINDING RESISTANCE VALUE (Ω)
280
240
200
-10
0
20
40
60
80
AMBIENT TEMPERATURE (°C)

FIG.5

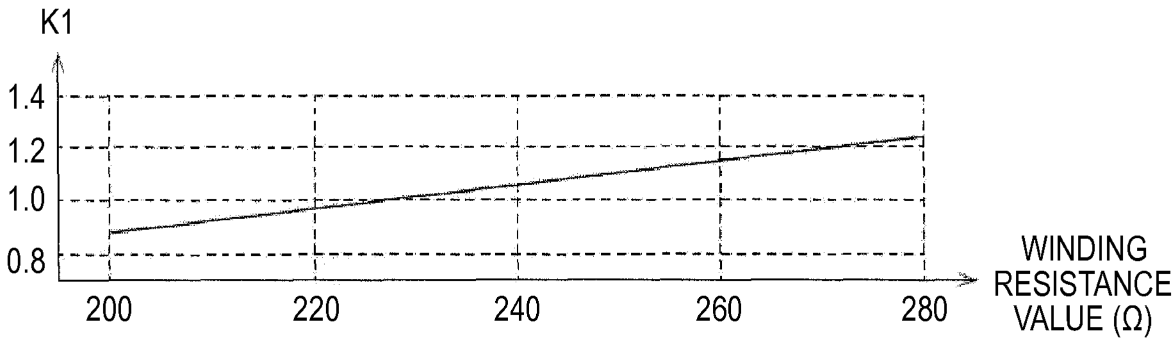


FIG.6

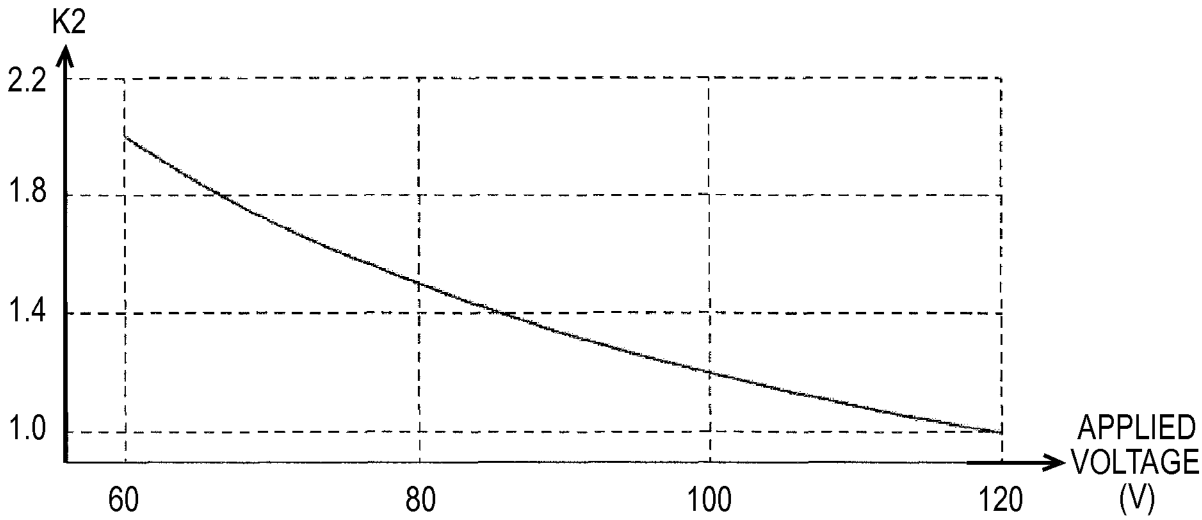


FIG.7

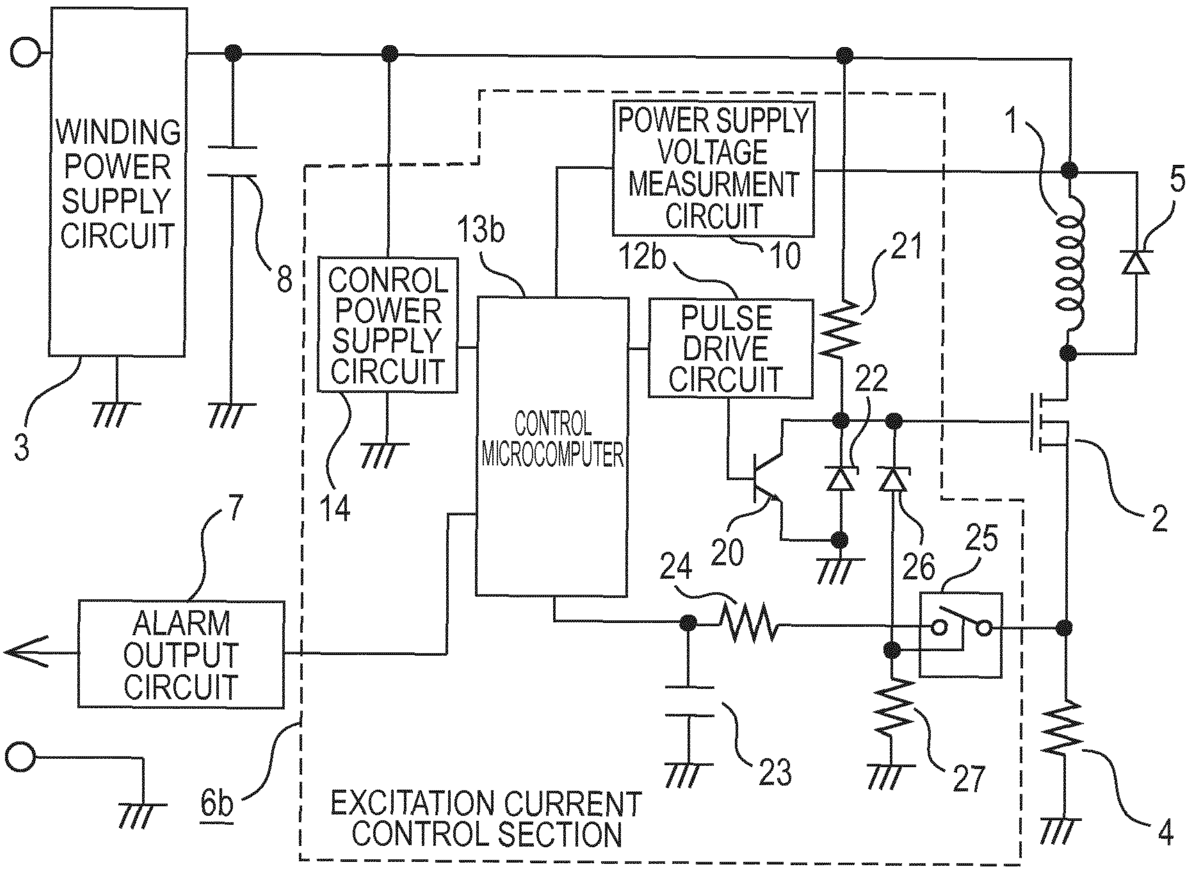

WINDING POWER SUPPLY CIRCUIT
3
8
CONROL POWER SUPPLY CIRCUIT
14
13b
CONTROL MICROCOMPUTER
POWER SUPPLY VOLTAGE MEASURMENT CIRCUIT
10
12b
PULSE DRIVE CIRCUIT
1
5
21
22
20
26
25
24
2
ALARM OUTPUT CIRCUIT
7
6b
23
27
4
EXCITATION CURRENT CONTROL SECTION

FIG.8

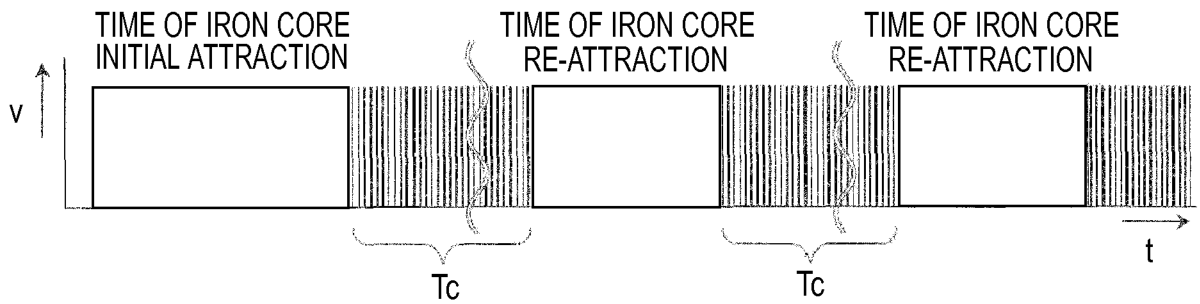

TIME OF IRON CORE INITIAL ATTRACTION
TIME OF IRON CORE RE-ATTRACTION
TIME OF IRON CORE RE-ATTRACTION
V
Tc
Tc
t

FIG.9

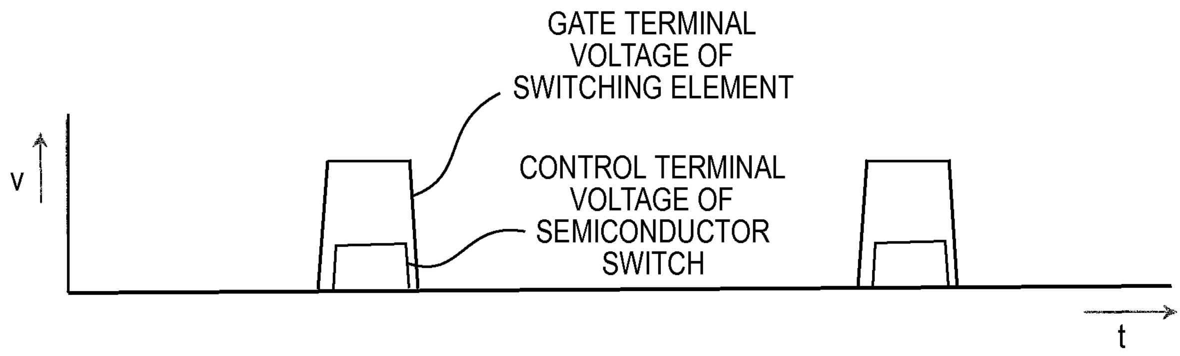

GATE TERMINAL
VOLTAGE OF
SWITCHING ELEMENT
CONTROL TERMINAL
VOLTAGE OF
SEMICONDUCTOR
SWITCH
V
t

FIG.10

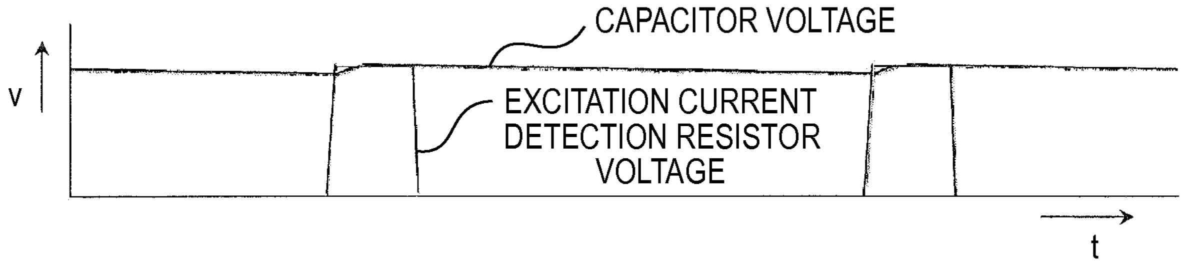

CAPACITOR VOLTAGE
v
EXCITATION CURRENT
DETECTION RESISTOR
VOLTAGE
t

FIG.11

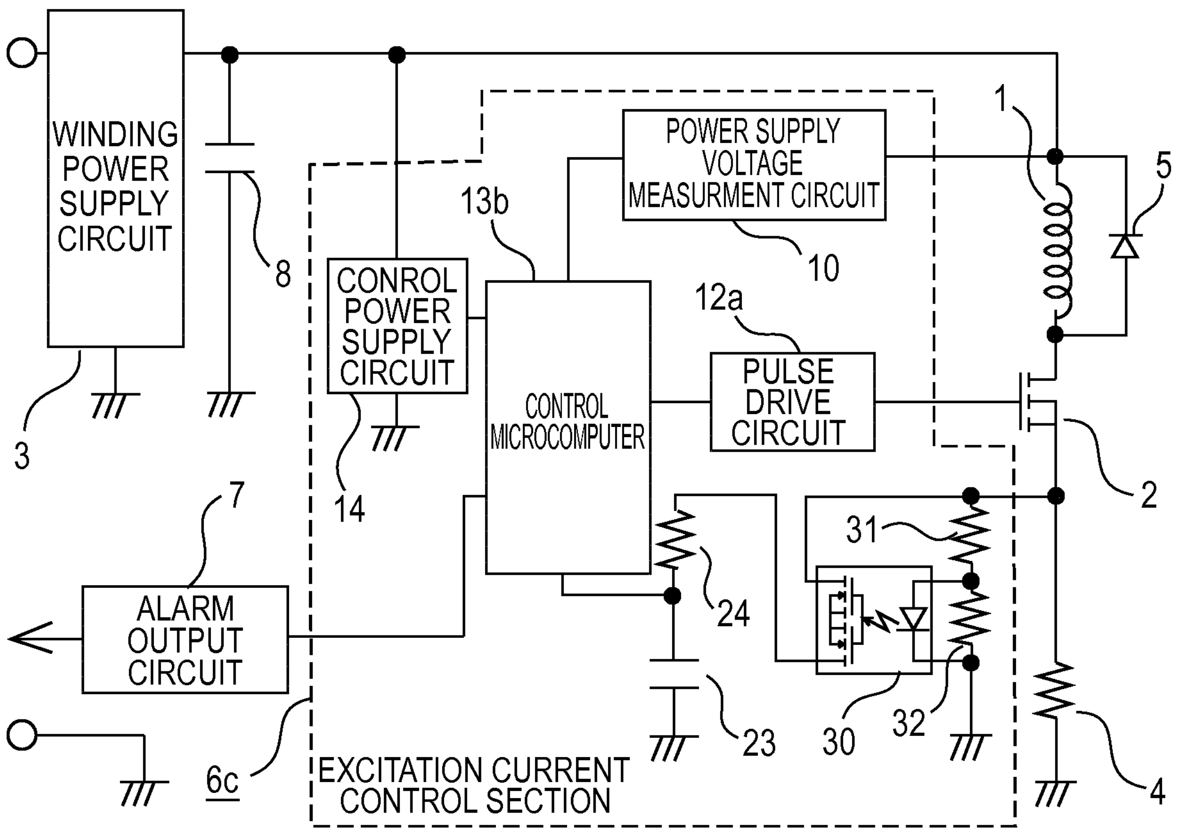

WINDING POWER SUPPLY CIRCUIT
3
8
CONROL POWER SUPPLY CIRCUIT
14
13b
CONTROL MICROCOMPUTER
POWER SUPPLY VOLTAGE MEASURMENT CIRCUIT
10
12a
PULSE DRIVE CIRCUIT
1
5
2
31
24
30
32
23
4
7
ALARM OUTPUT CIRCUIT
6c
EXCITATION CURRENT CONTROL SECTION

FIG.12

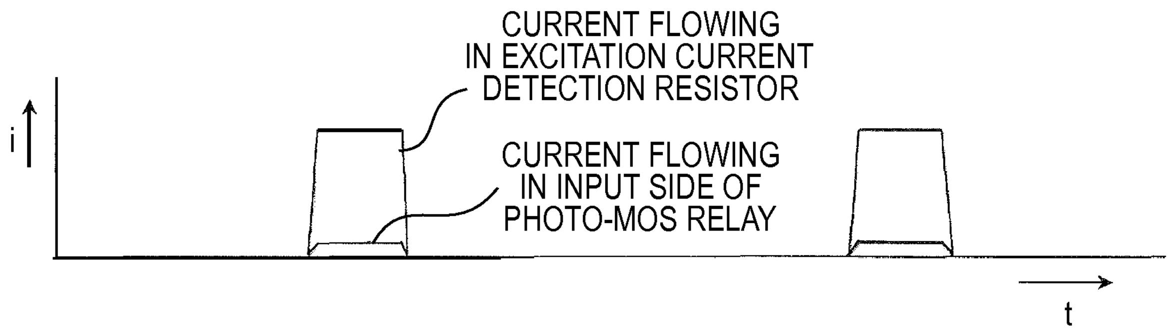

CURRENT FLOWING
IN EXCITATION CURRENT
DETECTION RESISTOR
CURRENT FLOWING
IN INPUT SIDE OF
PHOTO-MOS RELAY
i
t

FIG.13

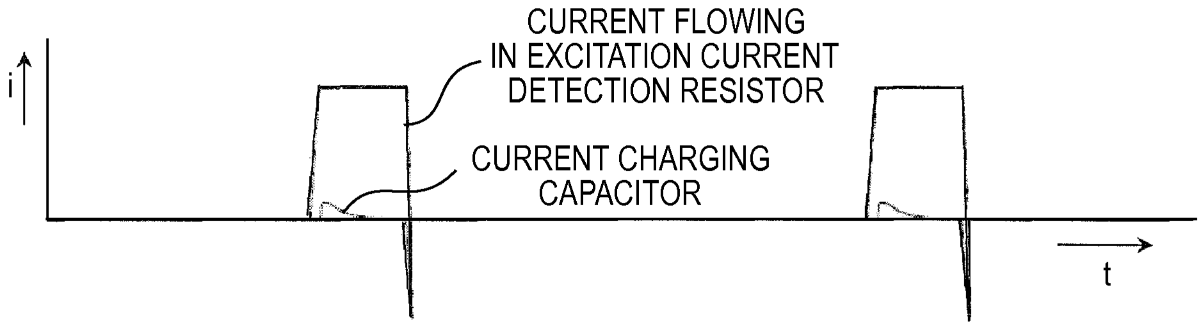
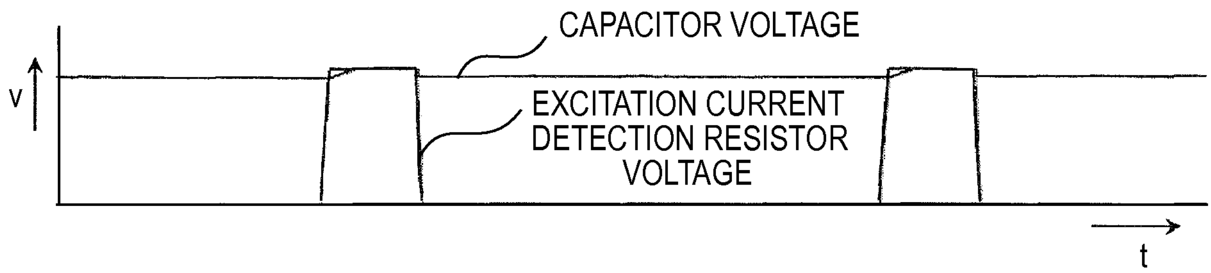

i
CURRENT FLOWING
IN EXCITATION CURRENT
DETECTION RESISTOR
CURRENT CHARGING
CAPACITOR
t

FIG.14


CAPACITOR VOLTAGE
v
EXCITATION CURRENT DETECTION RESISTOR VOLTAGE
t

REFERENCES CITED IN THE DESCRIPTION

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- US 5671115 A **[0006]**
- US 5757214 A **[0007]**
- DE 3707930 A1 **[0008]**