Oct. 21, 1969 REIJIRO ITO 3,474,314

CONTACTLESS ELECTROMAGNETIC DRIVING DEVICES

Filed Dec. 6, 1967 5 Sheets-Sheet 1

FIG. 1

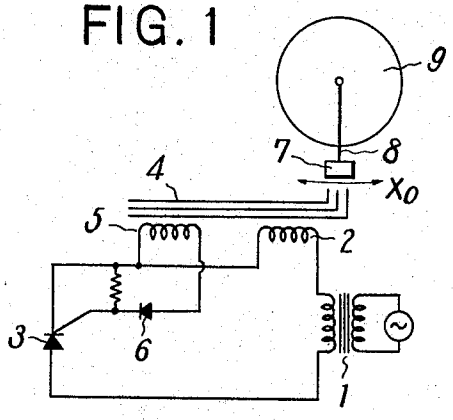


FIG. 3

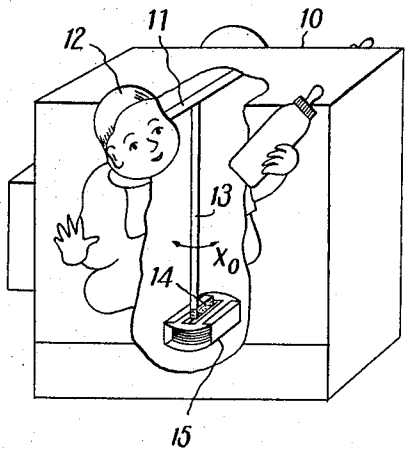
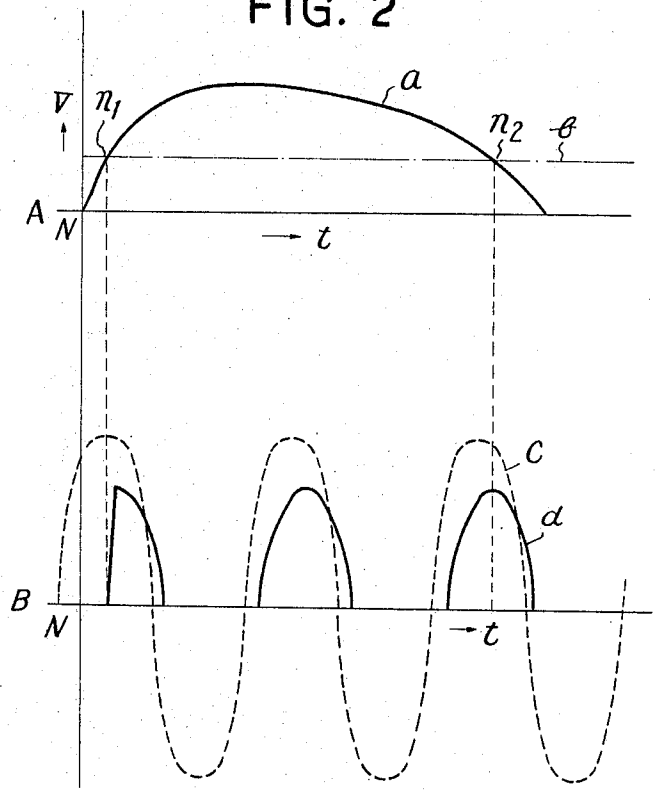


FIG. 2



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FIG. 4

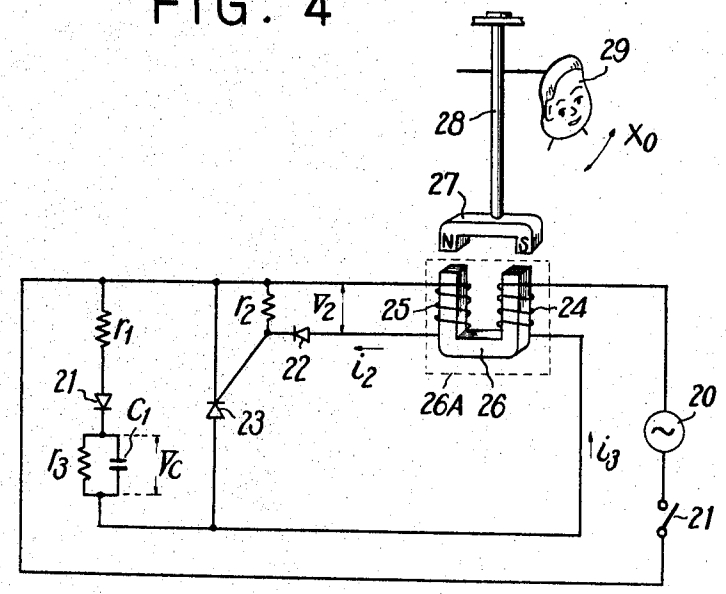


FIG. 5

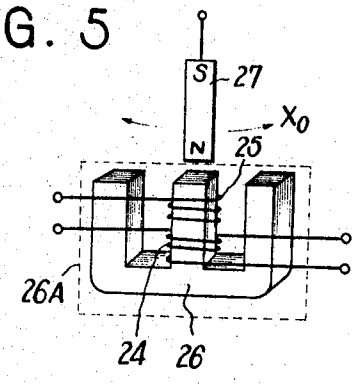


FIG. 6A

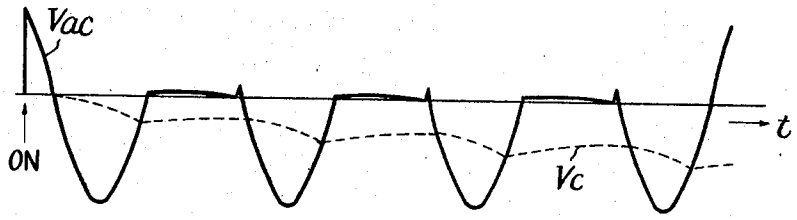


FIG. 6B

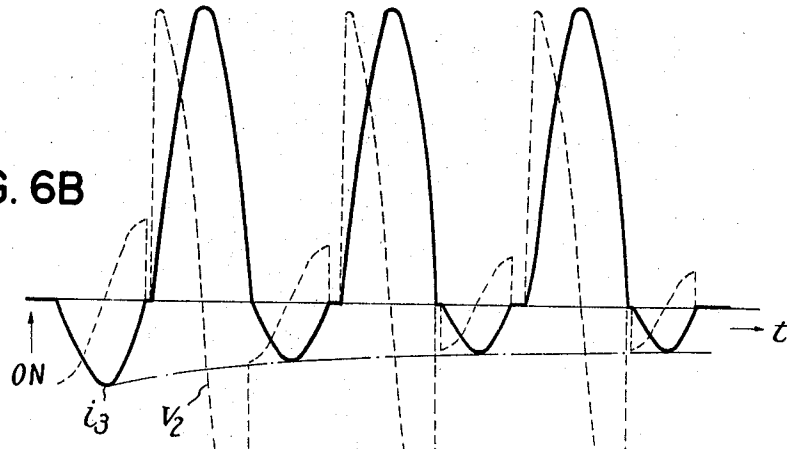


FIG. 6C

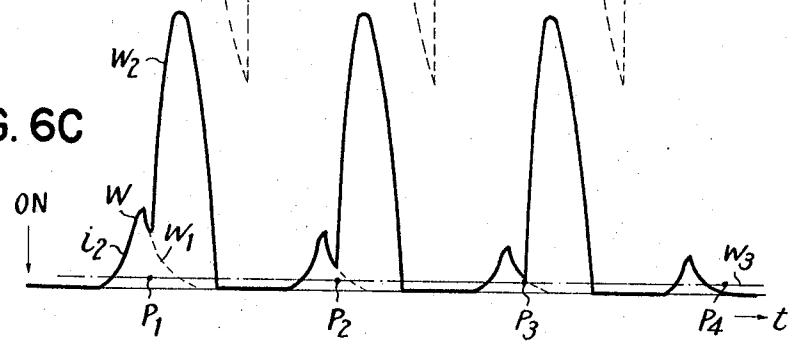


FIG. 7D

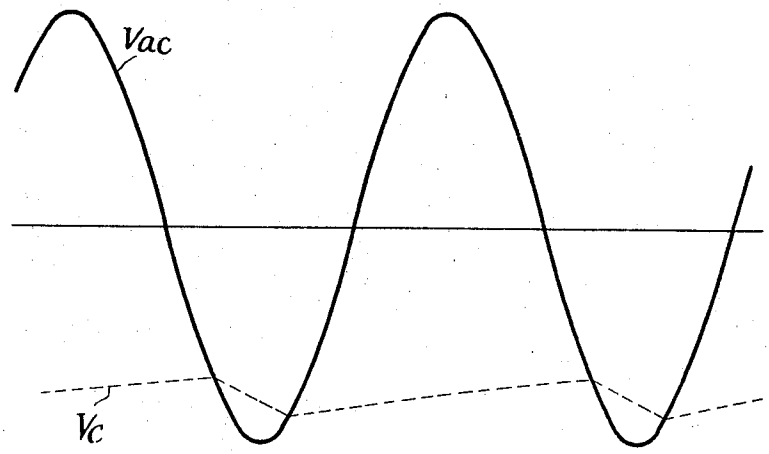


FIG. 7E

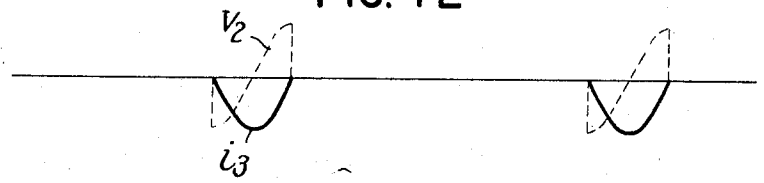


FIG. 7F



FIG. 8G

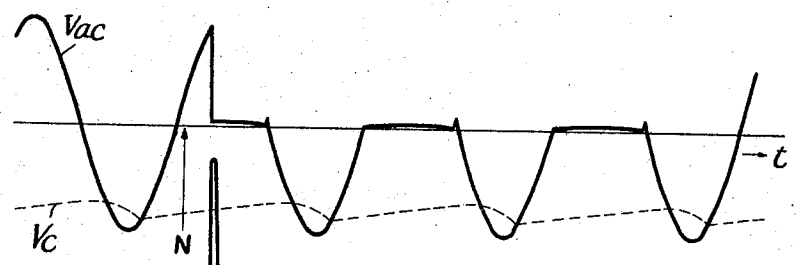


FIG. 8H

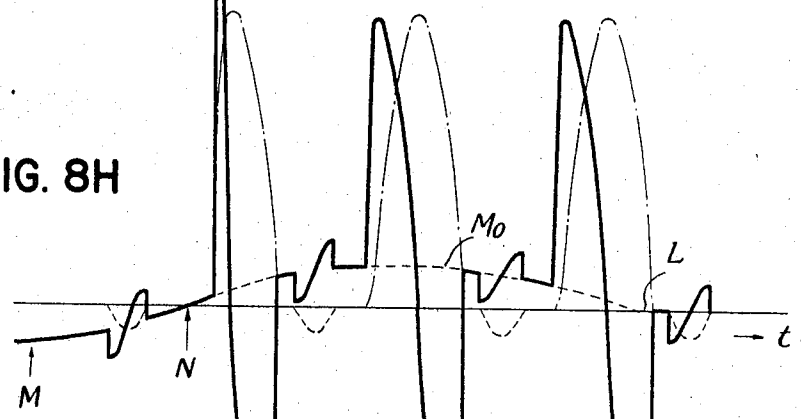
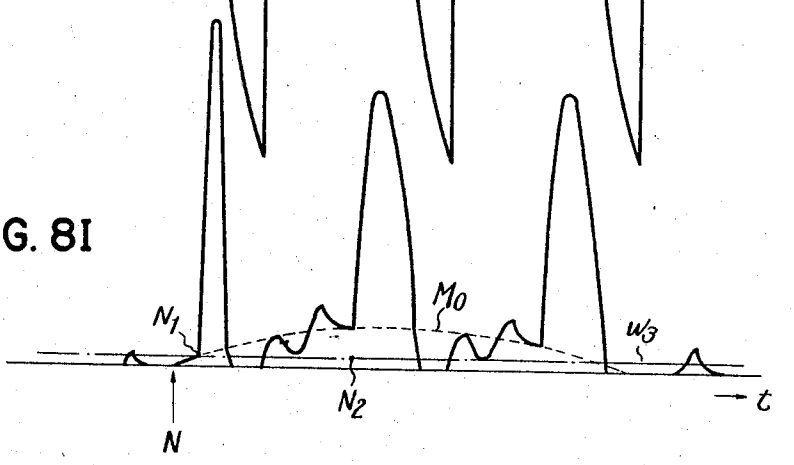


FIG. 8I



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3,474,314

CONTACTLESS ELECTROMAGNETIC DRIVING DEVICES

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Int. Cl. H02p 1/16, 5/06, 7/24
U.S. Cl. 318—128 3 Claims

ABSTRACT OF THE DISCLOSURE

In a contactless electromagnetic driving device for operating a display member, for example, comprising a permanent magnet supported by a pendulum, and an electromagnet cooperating with said permanent magnet and including a driving coil and a detecting coil wound thereon, a thyristor is connected across a source of alternating current in series with the driving coil and a diode is connected across the gate and cathode electrodes of the thyristor in series with the detecting coil for protecting the gate electrode against reverse voltages. In order to make the driving device self-starting a control circuit is connected in parallel with the thyristor including a second diode having a polarity opposite to that of the thyristor and parallel connected condenser and resistor connected in series with the second diode.

This invention relates to a contactless electromagnetic driving device, and more particularly to a contactless electromagnetic driving device utilizing a thyristor, for example, a silicon controlled rectifier element, especially suitable for driving a continuously or intermittently oscillating or rotating body, for example an advertising display member.

In one type of known electromagnetic driving device, a detecting coil is connected to the input of a transistor to amplify the input power induced by the movement of a permanent magnet attached to the free end of a pendulum and a driving coil is energized from a DC source such as a dry cell whereby the pendulum is oscillated by the electromagnetic force produced between the driving coil and the permanent magnet. However, in this type of driving device as the detecting coil and the driving coil are relatively widely spaced apart and the detection and driving are independently performed by two magnetic poles of the permanent magnet attached to the pendulum. The arrangement of respective coils and permanent magnet is complicated, thus increasing the size and cost of the driving device. In the driving device for transistorized clocks, the detecting coil and the driving coil are wound in closed, spaced concentric relation to cooperate with one magnetic pole of a permanent magnet attached to the free end of the pendulum, thus effecting detection and driving by said one magnetic pole. With this type of construction, however, as a result of magnetic coupling between the detecting and driving coils, oscillating current is induced in the driving coil due to a temperature change of the transistor to cause oscillation independent of the movement of the pendulum, thus causing a waste of power. Such a driving mechanism operates satisfactorily in an indoor environment where the temperature change of the atmosphere is small but is not suitable for driving an outdoor signboard and the like which are subjected to direct illumination by sunshine and low temperature in winter.

In the contactless electromagnetic driving device for transistor clocks and the like, electromagnetic percussion movements created by the cooperation of the permanent magnet and the driving coil are utilized to intermittently pass current to the driving coil from a DC source such as a battery to cause the oscillation of the pendulum; however when the same are used as the driving device for a large and heavy object such as an outdoor signboard, such a driving device consumes much electric power. Accordingly, the life of the dry cell is shortened and it is necessary to frequently replace it with a fresh one. In addition, since the power limit of transistors is far lower than silicon controlled rectifier elements, it has been difficult to provide a driving mechanism of large power. Further most of the transistorized contactless electromagnetic driving devices can not be made self-starting so that where the power is supplied from an AC source via a rectifier device, upon interruption of the source, it is necessary to manually restart the driving device. This is very inconvenient where the driving device is installed in an elevated position. Thus it has long been desired to provide a contactless electromagnetic driving device which can supply sufficiently large power and which can operate economically even under adverse weather conditions.

Accordingly, it is an object of this invention to provide an improved contactless electromagnetic driving device utilizing a thyristor.

Another object of this invention is to provide a self-starting contactless electromagnetic driving device which can operate stably with simple and economical construction.

According to one embodiment of this invention, there is provided a contactless electromagnetic driving device comprising a permanent magnet mounted on one end of a pendulum adapted to drive a load, for example a display member, a driving coil and a detecting or pick-up coil are wound on a magnetic core disposed with respect to the permanent magnet with a small air gap therebetween, the driving coil being connected in series with an AC source and a thyristor, the detecting coil being connected across the gate and cathode electrodes of the thyristor through a diode for protecting the gate electrode against reverse voltages whereby the thyristor is controlled with a power generated in the detecting coil by the movement of the permanent magnet.

According to a modified embodiment of this invention, there is provided a self-starting type contactless electromagnetic driving device comprising a permanent magnet mounted on one end of a pendulum adapted to drive a load, an electromagnet including a magnetic core opposing the permanent magnet and a driving coil and a detecting coil wound on the magnetic core, a thyristor connected to an AC source through the driving coil, a control circuit connected in parallel with the thyristor, said control circuit including a parallel connected condenser and resistor and a first diode connected in series therewith having a polarity opposite to that of the thyristor and an ignition circuit including said detecting coil and a second diode connected across the gate and cathode electrodes of the thyristor, thus effecting automatic starting of the pendulum.

The features of the invention which are believed novel are set forth with particularity in the appended claims. The invention, itself, however, as to its organization together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIGURE 1 shows a connection diagram of one embodiment of this invention;

FIGURE 2 shows voltage and current curves at various portions of the circuit shown in FIGURE 1;

FIGURE 3 is a perspective view, partly broken away, of the novel contactless electromagnetic driving device as applied to an outdoor signboard;

FIGURE 4 shows a connection diagram of a modified embodiment of this invention;

FIGURE 5 is a perspective view of a modified electromagnet of the electromagnetic driving mechanism shown in FIGURE 1;

FIG. 6 shows voltage and current curves in transient conditions at various portions in the circuit shown in FIG. 5;

FIG. 7 shows voltage and current curves shown in FIG. 6 under a steady state driving condition and magnified by a factor of two; and

FIG. 8 shows voltage and current curves at the driving state with the same scale as in FIG. 6.

Referring now to the accompanying drawings, in the embodiment shown in FIG. 1, an AC source device **1** including a transformer and source of alternating current energizes a driving coil **2** wound upon a magnetic core **4** of an electromagnet; and a thyristor, for example, a silicon controlled rectifier element **3** is connected in series with the driving coil. Across the gate and cathode electrodes of the thyristor are connected a detecting coil **5** and a reverse voltage protective diode **6** which are connected in series. Driving coil **2** and detecting coil **5** may be wound concentrically upon the magnetic core **4** or may be wound in any other suitable manner dependent upon the configuration of the core. A permanent magnet **7** is disposed to oppose the magnetic core **4** with a small air gap therebetween. The permanent magnet is secured to the free end of a pendulum **8** supporting a display member **9** such as a signboard or the like.

The operation of the electromagnetic driving device shown in FIG. 1 will be described hereunder by referring to FIG. 2. When oscillation of the pendulum **8** is manually started, a voltage shown by a curve in FIG. 2 will be induced in the detecting coil **5** as the permanent magnet **7** passes by the magnetic core **4** associated with the detecting coil **5**. Up until the time N shown in FIG. 2 is reached at which the magnetic pole of the permanent magnet **7** is just facing the pole of the magnetic core **4**, a reverse voltage would be applied to the gate electrode of the thyristor **3** but this reverse voltage is blocked by the protective diode **6**, thus preventing gate current from flowing. As the permanent magnet **7** further advances beyond point N or across the magnetic pole of the magnetic core, a forward voltage will be applied to the gate electrode of the thyristor to pass gate current. Thus, the thyristor would become conductive, if at this time an AC voltage as shown by curve *c* in FIG. 2B were applied across the thyristor **3** via the driving coil **2**. Thus, the thyristor **3** is in the on state during the interval from n_1 to n_2 in which the gate voltage of the thyristor **3** induced by the oscillating movement of the permanent magnet exceeds the gating voltage level shown by a straight line *b* in FIG. 2A required for igniting the thyristor. As a result, as shown by solid lines *d* in FIG. 2B, in each forward half cycle of the voltage applied to the thyristor **3**, current flows through the driving coil **2**. This current excites the magnetic core **4** to create a magnetic flux which repels the permanent magnet, thus accelerating the motion of the pendulum **8**.

In a conventional contactless transistor oscillator driving device for a pendulum, when the base current is supplied from the detecting coil, the collector current flows through the driving coil and since the detecting coil is wound concentrically with the driving coil, the base current supplied by the detecting coil would be varied by the induction caused by the variation in the current flowing through the driving current which in turn causes variation in the collector current. Thus, oscillations are created by the dense coupling between the detecting and driving coils which are wound concentrically. On the other hand, according to the present invention even when the two coils are wound concentrically to induce a voltage in the detecting coil **5** by the current flowing through the driving coil **2**, the gate current caused by said induced voltage is not a sufficient current for ignition. In addition, by the characteristics of the thyristor, for instance, a silicon controlled rectifier element, the curent is interrupted at the end of each half cycle during which voltage is applied in the forward direction across the anode and cathode electrodes so that no current flows through the driving coil **2** during the negative half cycles. Thus, during these negative half cycles, said induced voltage does not effect the operation of the thyristor. In other words, the only factor which ignites the thyristor **3** is the movement of the permanent magnet **7** so that even when the driving and detecting coils are magnetically coupled, no regeneration circuit is formed and hence no oscillation is created.

Thus, in accordance with this invention, since use is made of a thyristor, a silicon controlled rectifier element for example, when compared with the conventional transistor type, greater power can be provided sufficient to oscillate or rotate a large sized display member, such as a signboard, against wind pressure. Further, since a commercial AC source is employed, the device can operate over a long period of time without the trouble involved in changing dry cells.

Further, even when the driving and detecting coils are wound concentrically on the same magnetic core, the occurrence of undesirable oscillations can be positively prevented, thus providing stable operation. Concentric arrangement of the two coils on the magnetic core improves the space factor and reduces the physical size as well as the manufacturing cost of the device. Further, it becomes possible to arrange the electromagnet to oppose only one pole of the permanent magnet secured to the pendulum, thus simplifying the assembly and eliminating complicated adjustable components.

While in the embodiment shown in FIG. 1 the permanent magnet is in the form of a bar magnet, it may take a form of a rotor comprising a plurality of alternate N and S salient poles, like a rotor utilized in dynamoelectric machines.

FIG. 3 shows one application of the invention, in which a shaft **11** is provided to extend through a box shaped outdoor signboard **10** to support a display member, for example, a board **12** printed with the figure of a face of a baby. At an intermediate point on the shaft **11**, there is connected the upper end of a pendulum, the lower end thereof is supporting a permanent magnet **14** in opposing relation to an electromagnet **15** with a small air gap. Thus, according to this invention it is possible to readily and stably oscillate in the direction Xo shown in FIG. 3 a relatively heavy and large display member installed out of doors.

FIG. 4 shows a self-starting type contactless electromagnetic driving device embodying this invention. As shown, a display member **29** is mounted on a driving member or a pendulum **28** carrying a permanent magnet **27** on its lower end. An electromagnet generally shown by **26A** comprises a U-shaped magnetic core **26** facing the permanent magnet **27**, a driving coil **24** and a detecting coil **25** wound upon the core. The driving coil **24** and a thyristor **23**, for example a silicon controlled rectifier element, poled as shown, are connected in series across a source of alternating current **20**. In parallel with the thyristor **23** is a series circuit including an over current protective resistor r_1, a first diode having a polarity opposite to that of the thyristor and a parallel combination consisting of a resistor r_3 and a condenser C_1. Hereinafter this short circuit is termed a control circuit.

The ignition circuit for the silicon controlled rectifier element **23** comprises a resistor r_2 connected across the gate and cathode electrodes thereof, and a series circuit connected in parallel with the resistor r_2 including the detecting circuit **25** and a second forward diode **22** for protecting against reverse voltage. A suitable switch **21** is connected in series with the AC source **20**.

A modified electromagnetic device **26A** is illustrated in FIG. 5 in which an E shaped magnetic core **26** is em-

ployed and both driving coil **24** and detecting coil **25** are wound on the center leg of the core.

The operation of the embodiment shown in FIG. 4 is as follows.

FIG. 6 shows a set of curves illustrating the transient phenomena occurring within a short period after energizing the circuit by the closure of switch **21**. A solid line curve *Vac* shown in FIG. 6A shows the voltage impressed across the anode and cathode eletcrodes of the silicon controlled rectifier element just after the closing of the switch while the dotted line curve shows the terminal voltage *Vc* across condenser C_1. The solid line curve i_3 shown in FIG. 6B shows the current flowing through the driving coil **24** at the moment of closing the switch while the dotted line curve V_2 shows the voltage induced in the detecting coil **25** wound upon the same magnetic core **26** as the driving coil by the egect of the current flowing through the driving coil **24**. It is to be understood that curve V_2 shows the induced voltage when no current is passed through the detecting coil **25**, or one terminal thereof is opened. A solid line curve i_2 shown in FIG. 6C shows the gate current of the silicon controlled rectifier element after closing the switch while dotted line curve W shows the gate current when considering only the effect of current which has passed through the driving coil as the condenser charging current and ignoring the effect of the current that has passed through the driving coil as the forward current through the silicon controlled rectifier element. P_1, P_2, P_3 and P_4 show ignition points.

The self-starting operation of the novel device commencing at the moment of closure of the source switch **21** will now be described by referring to the graphs shown in FIGS. 6A, 6B and 6C. In the stationary condition wherein there is no relative motion between the permanent magnet **27** and the core **26** of the electromagnet which causes the flow of gate current during a half cycle in which a forward voltage is applied across the silicon controlled rectifier element, at the moment ON the silicon controlled rectifier element is in its forward blocked state so that no current will flow through the driving coil connected in series therewith until the forward half cycle ends. Upon commencement of the next cycle, since the voltage is applied in the reverse direction across the silicon controlled rectifier element, no current flows therethrough from the source, but as a result of the control circuit connected in parallel with the silicon controlled rectifier element and including condenser C_1 and oppositely poled diode **21**, a sinusoidal half wave current i_3 as shown by solid lines in FIG. 6 flows through the diode **21** as well as the driving coil **24** to charge condenser C_1. This will induce a voltage V_2 shown by dotted lines in FIG. 6B in the detecting coil **25** wound on the same magnetic core **26** but actually due to the self-induction of the detecting coil and rectifying action of the reverse voltage protective diode **22** a current having a wave form shown by the first solid line spike W and following dotted line W_1 shown in FIG. 6C will flow through the gate electrode of the silicon controlled rectifier element. At the instant when the next half cycle of the forward voltage is applied across the silicon controlled rectifier element the rectifier element will become conductive because the gate current is still maintained by the self-indution action of the detecting coil to pass current represented by the upper half cycles of the solid line i_3 in FIG. 6B whereby the magnetic core of the electromagnetic is energized to impart an electric percussive force to the permanent magnet **27** which has been stationary in the opposing position to the core. Then a very steep AC voltage as shown by dotted lines in FIG. 6B is induced in the detecting coil by said exciting current, but actually a highly peaked gate current W_2 shown by solid lines i_2 of FIG. 6C will flow. However, at this time, as the silicon controlled rectifier element has already been rendered conductive there is no fear of producing regenerated oscillation as in the case of transistorized contactless clocks.

As mentioned hereinabove, during each half cycle in which a reverse voltage is applied across the silicon controlled rectifier element as the charging current of the condenser C_1 flows through the driving coil the gate current of the silicon controlled rectifier element induced in the detecting coil by the action of mutual induction exceeds the ignition level represented by dot dash line W_3 in FIG. 6C which is necessary to ignite the silicon controlled rectifier element at the beginning of successive half cycles of the forward voltage across the silicon controlled rectifier element, the phase of this driving current being delayed by the action of self-induction of the detecting coil. Consequently, the silicon controlled rectifier element becomes conductive to pass current through the driving coil to energize the core of the electromagnet thus accelerating the permanent magnet **27**.

However, as shown by dotted line *Vc*, since the charging current of the condenser C_1 supplied through diode **21** is larger than the discharge current thereof flowing through the discharge resistance r_3 the terminal voltage of the condenser will increase gradually so that the charging current will be gradually decreased in proportion to the difference between the anode-cathode voltage *Vac* shown in downward direction in FIG. 6A and the condenser voltage *Vc* with the result that the charging time in each cycle will be gradually limited to the peaked portion of each half wave. Consequently, finally the value of the gate current can not reach the value necessary to ignite the silicon controlled rectifier element at the beginning of each half cycle of the forward voltage, thus making it impossible to ignite the silicon controlled rectifier element.

Accordingly, the magnetic core of the electromagnet would not be energized and thus the permanent magnet would not be accelerated. However, the permanent magnet which has been previously accelerated tends to restore its original position by the action of the pendulum. When the permanent magnet passes the core of the electromagnet its movement is sensed by the detecting coil whereby a current is supplied to the gate electrode of the silicon controlled rectifier element, thus turning it on. In this manner, the permanent magnet is accelerated each time it passes the electromagnet and the pendulum is oscillated thus enabling self-starting.

FIG. 7 is a graph to illustrate the steady state driving state wherein the quantity of charging current balances with the quantity of discharge current. This graph indicates the manner in which the charging current i_3 to the condenser through the driving coil flows only through the peaked portion of each half wave in proportion to the difference between the reverse voltage *Vac* across the silicon controlled rectifier element and the terminal voltage *Vc* of the condenser as well as the phase relationship thereof. FIG. 7 shows that at the moment at which the forward voltage is impressed across the silicon controlled rectifier element no gate current flows so that the rectifier element can not be ignited by the charging current of the condenser. FIG. 7 shows the detail of the characteristic curves shown in FIG. 6 multiplied by a factor of two. FIGS. 7D, 7E and 7F correspond to FIGS. 6A, 6B and 6C respectively and represent voltage and current waves under a steady state condition.

FIG. 8 shows the relationship between the intermittent electromagnetic percussive force and the movement of the permanent magnet.

As the permanent magnet which has once started passes by the electromagnet, the magnetic pole of the permanent magnet will just oppose the magnetic pole of the core of the electromagnet at the instant N. Prior to this instant, as shown by a curve M–N of FIG. 8H, a downwardly directed voltage or a voltage acting as a reverse gate voltage of the silicon controlled rectifier element will be induced in the detecting coil by the action of the permanent magnet, whereas immediately after point N, a voltage will be induced in the detecting coil which supplied a forward voltage to the gate electrode.

When the gate current exceeds the required ignition current W_3 at point N_1 shown in FIG. 8I, a forward current will flow through the silicon controlled rectifier element to induce a rapidly increasing voltage in the detecting coil by the effect of the current flowing through the driving coil to turn on the silicon controlled rectifier element and the rectifier element continues to conduct until the end of the particular half cycle. At the next ignition moment N_2, at which the next forward voltage is impressed across the silicon controlled rectifier element, the value of current shown by curve Mo and induced in the detecting coil by the action of the permanent magnet exceeds the required ignition value W_3 so that the silicon controlled rectifier element will be turned on again. Thus at each forward half cycle, the silicon controlled rectifier element becomes conductive to sequentially energize the magnetic core of the electromagnet to impart percussive force to the permanent magnet thereby accelerating it.

At a point L, the voltage induced in the detecting coil disappears and hence the gate current decreases below the value W_3 so that the silicon controlled rectifier element does not become conductive. However, the permanent magnet will continue its motion by reason of its inertia to return back to the core of the electromagnet, and a new cycle of operation is initiated.

FIGS. 8G, 8H and 8I show voltage and current waves under the driving condition corresponding to those shown in FIGS. 6A, 6B and 6C respectively.

According to this modified embodiment, by mere application of AC voltage the permanent magnet automatically starts to oscillate to vibrate the display member **29** in the direction indicated by arrow Xo (in the direction perpendicular to the sheet of the drawing).

While the invention has been explained by describing particular embodiments thereof, it will be apparent that improvements and modifications may be made without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A contactless electromagnetic driving device comprising a pendulum, a permanent magnet secured to the free end of said pendulum, a magnetic core of an electromagnet with a pole closely spaced from said permanent magnet, a driving coil and a detecting coil wound upon said magnetic core, a source of alternating current, thyristor connected across said source in series with said driving coil and a diode connected across the gate and cathode electrodes of said thyristor in series with said gate electrode for protecting said gate electrode against reverse voltages whereby to control said thyristor in accordance with the electric power induced in said detecting coil by the movement of said permanent magnet.

2. The contactless electromagnetic driving device as claimed in claim **1** wherein said device further includes a control circuit including a second diode of a polarity opposite to that of said thyristor and parallel connected condenser and resistor connected in series with said second diode, said control circuit being connected in parallel with said thyristor whereby said driving device can be made self-starting.

3. The contactless electromagnetic driving device as claimed in claim **1** wherein a display member is connected to said pendulum to be oscillated thereby.

References Cited

UNITED STATES PATENTS

2,945,168	7/1960	Steinke	318—128
3,122,690	2/1964	Dion et al.	318—132 X
3,215,916	11/1965	Hermann	318—129 X
3,332,229	7/1967	Klinck et al.	310—39 X
3,359,473	12/1967	Negri	318—128
3,400,316	9/1968	Kuschel	318—132 X

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U.S. Cl. X.R.

40—138; 310—36; 318—132; 323—16