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Electromagnetic driving circuit

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FIG. 1

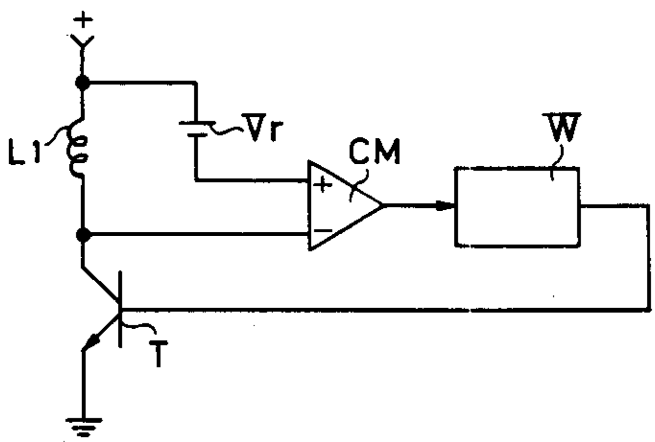

FIG. 2

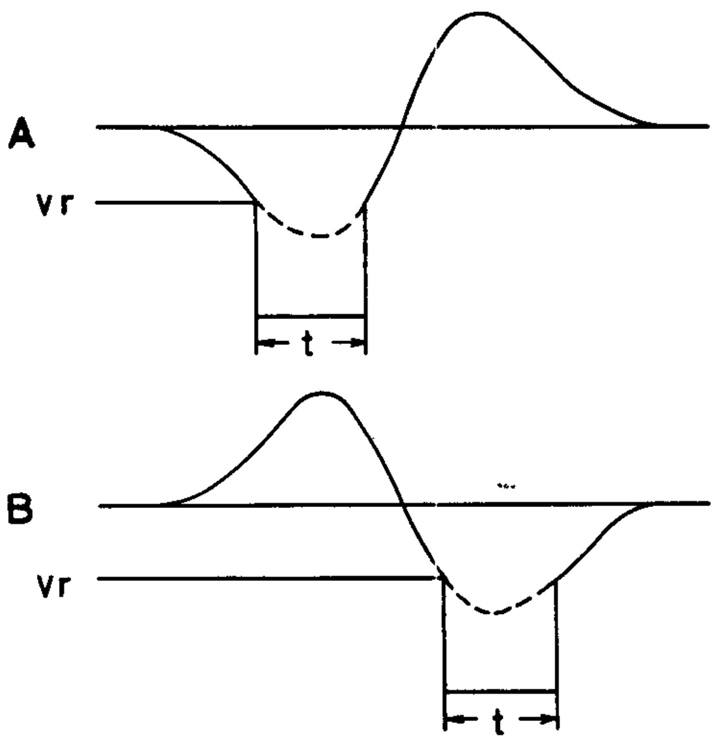

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FIG. 3

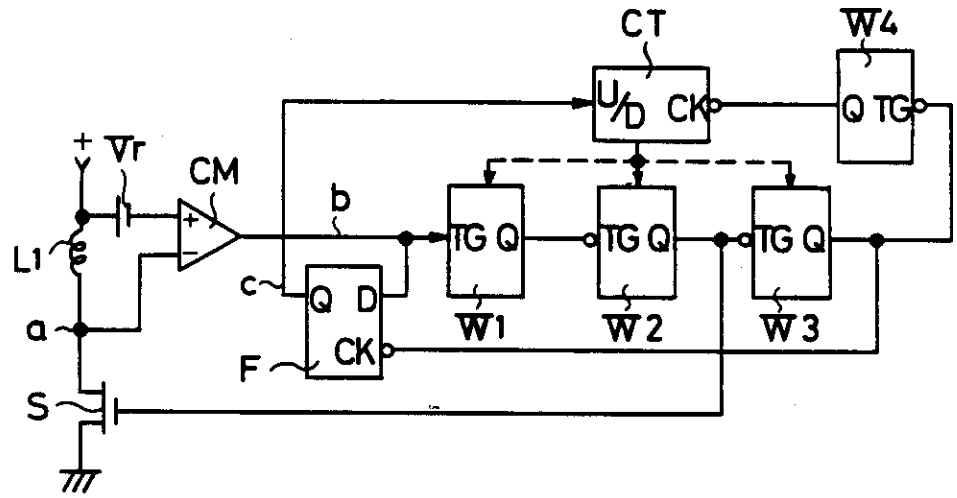

FIG. 4

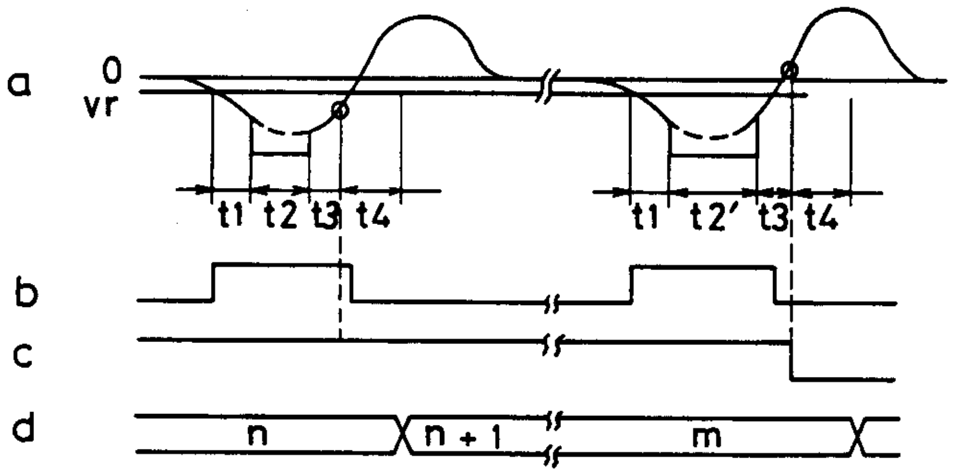

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FIG. 5

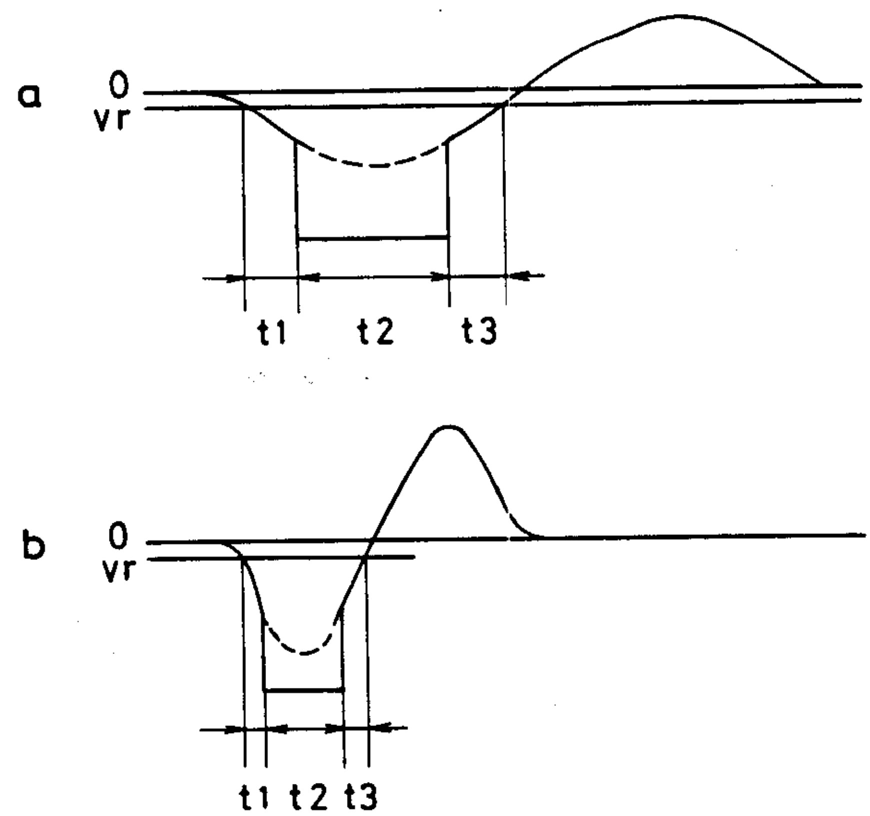
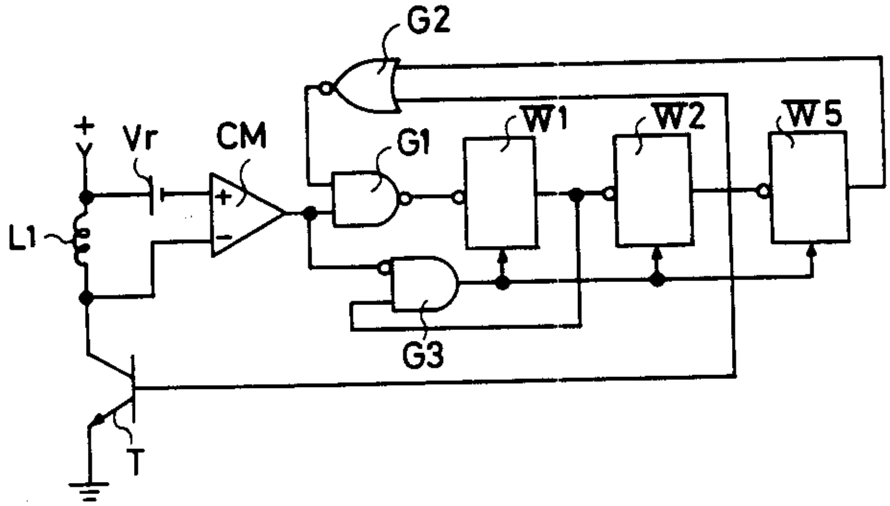


FIG. 6



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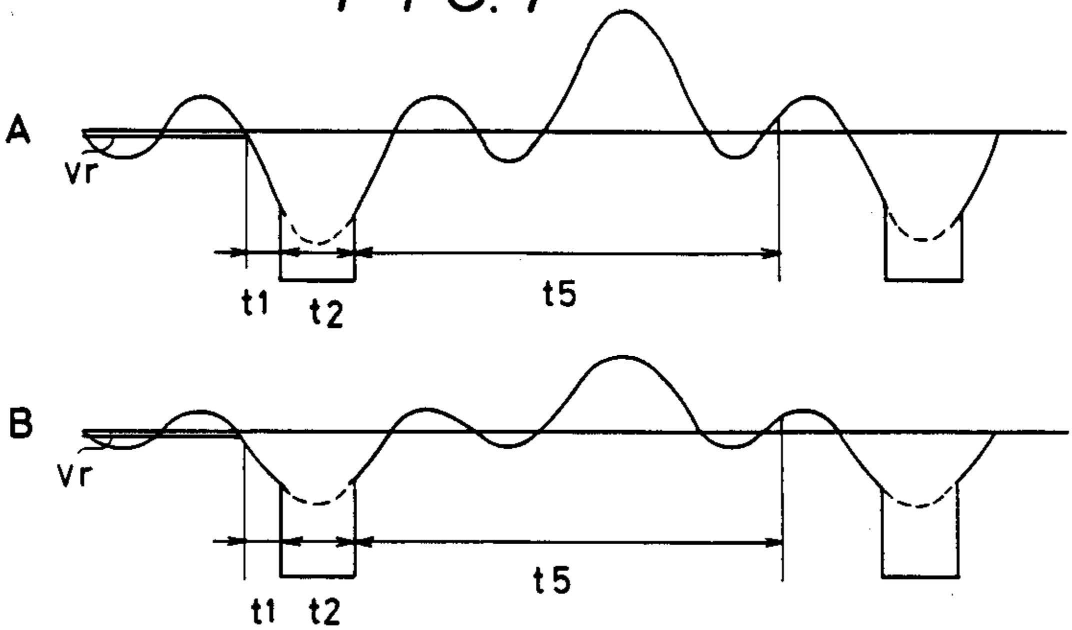
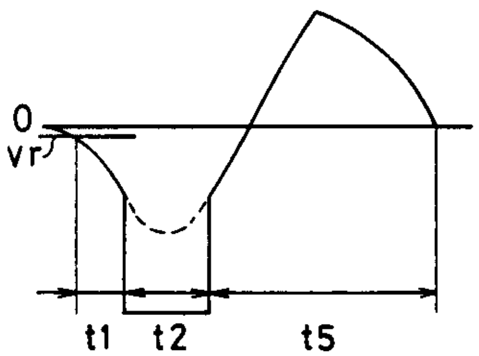
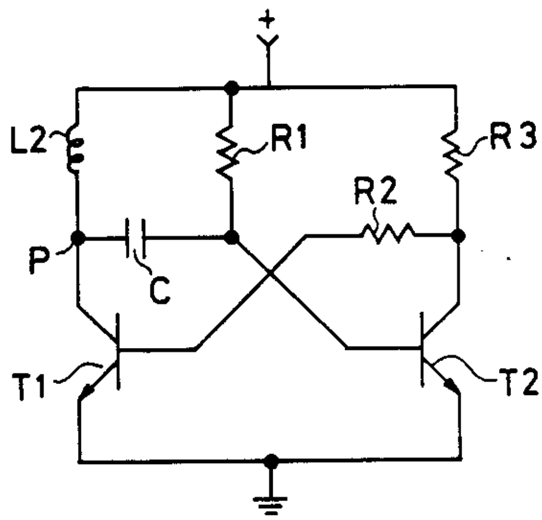
F I G. 7



F I G. 8



F I G. 9



F I G. 10

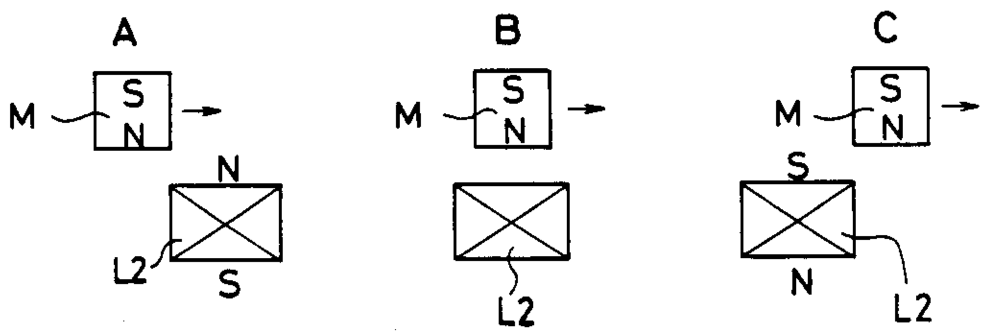
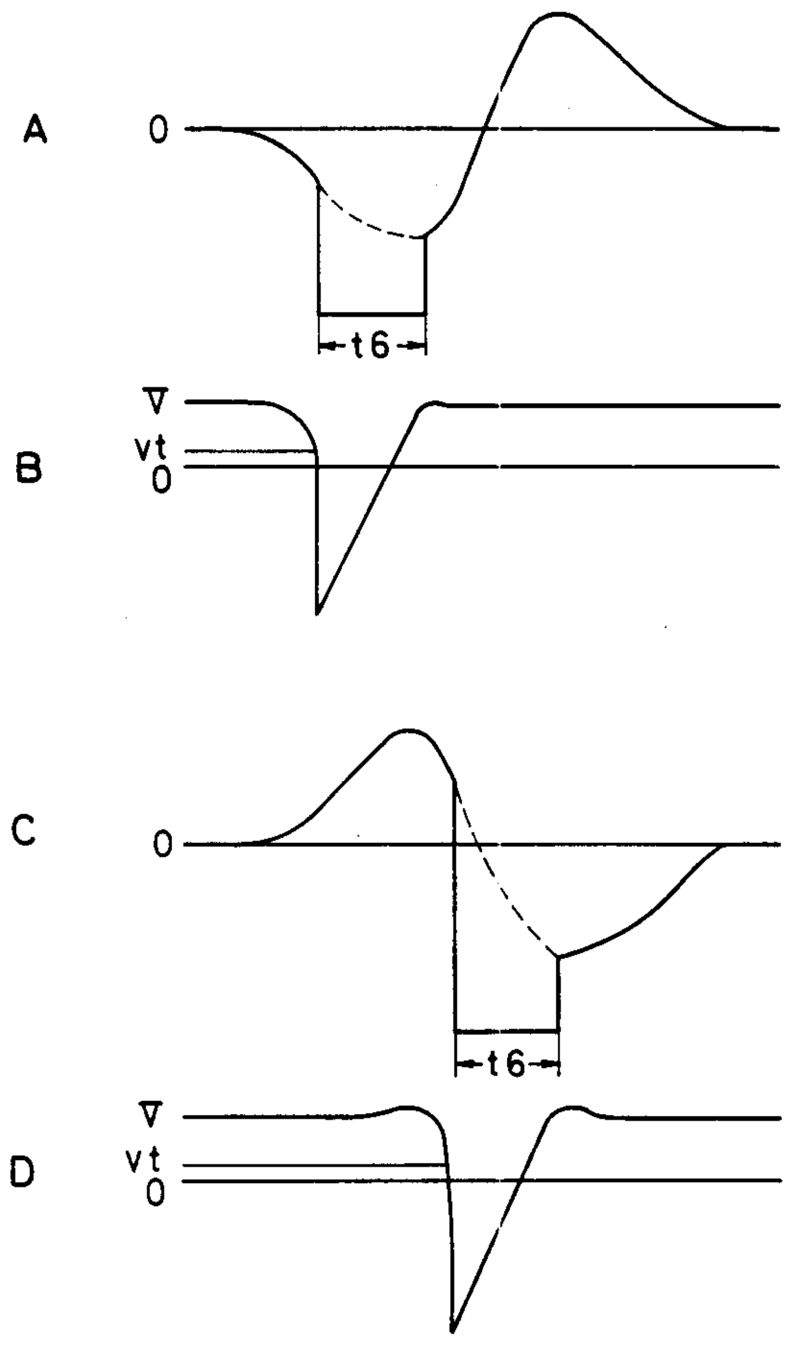


FIG.11



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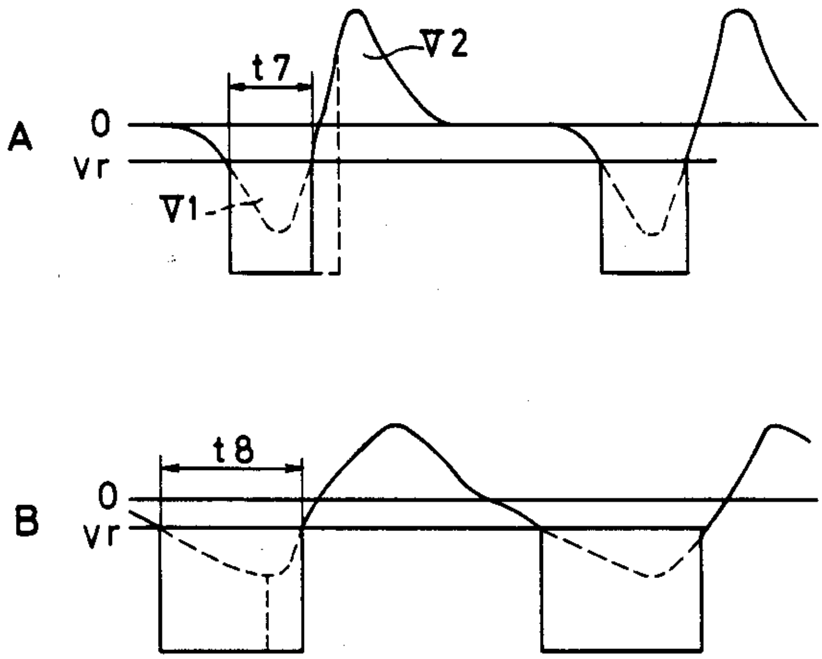
F I G.12



F I G.13

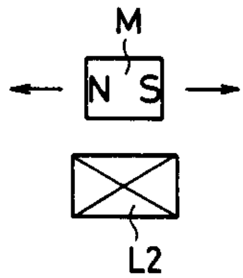


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FIG. 14

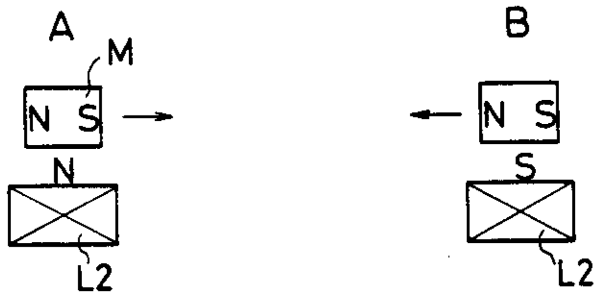
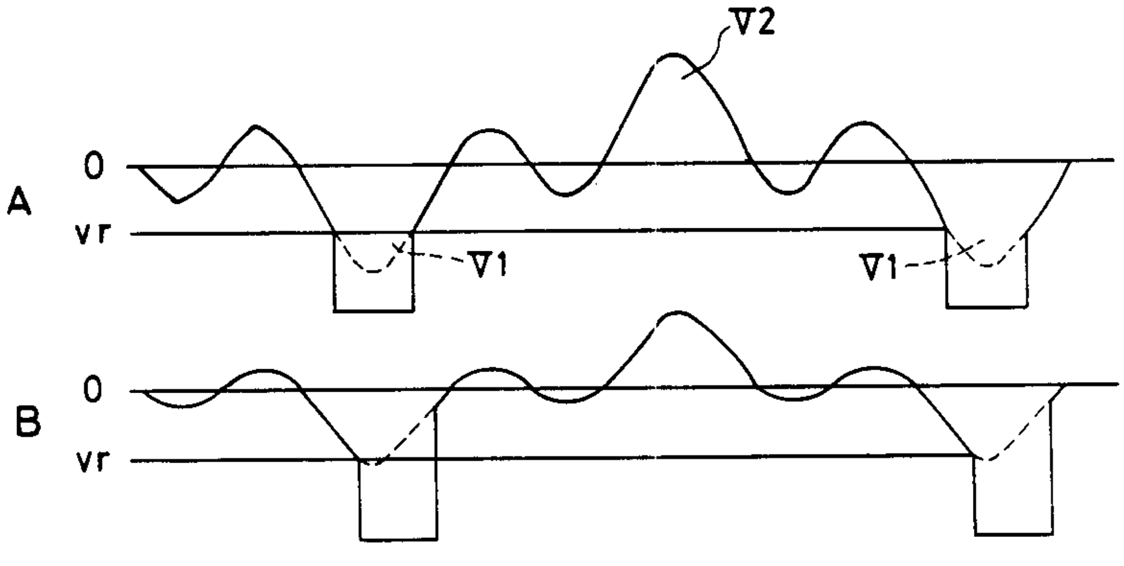


FIG. 15



ELECTROMAGNETIC DRIVING CIRCUIT

This invention relates to electromagnetic driving circuits, for example, for driving pendulums and the like.

Figure 9 illustrates a conventional electromagnetic driving circuit for detecting and driving a pendulum of, for example, a clock, using a coil. When a permanent magnet M, as illustrated in Figure 10A, approaches a coil L2, a voltage is induced in the coil L2 in such a direction as to repell the magnet M. As depicted in Figure 10B, when the magnet M is disposed opposite to the coil L2, the induced voltage is 0. As shown in Figure 10C, when the magnet M moves away from the coil L2, the induced voltage in the coil L2 is in a direction to attract the magnet. The polarity of the induced voltage, as illustrated in Figures 11A or 11C, differs depending on the direction in which the coil L2 is wound. First, operation in the case of the induced voltage shown in Figure 11A will be discussed. A base voltage of a transistor T2 is, as depicted in Figure 11B, clamped by a given voltage V by virtue of the diode properties of its base/emitter. If the base voltage of the transistor T2 decreases below a threshold voltage vt due to the induced voltage shown in Figure 11A which is generated at a terminal P, the transistor T2 is turned OFF and a transistor T1 is turned ON. A driving current flows through the coil L2 for a time t6 determined by the time constant of a capacitor C and a resistor R1, whereby the magnet is attraction-driven. This is the so-called "attraction driving method".

Where the induced voltage is as shown in Figure 11C, the base voltage of the transistor T2 is held substantially at the voltage V because of the diode properties thereof even if the voltage at the terminal P exhibits an increase as illustrated in Figure 11C. When the induced voltage exceeds a peak, the base voltage of the transistor T2 is lowered resulting in a drop in the foregoing voltage. The base voltage then decreases below the threshold voltage vt, at which time the transistor T2 is turned OFF. Subsequently a driving current flows through the coil L2, thereby repelling the magnet M. This is the so-called "repulsion driving method".

For more efficient driving of the magnet, the coil L2 is driven with the timing illustrated in Figure 10A in the case of the attraction driving method. Where the repulsion driving method is adopted, it is desirable to drive the coil with the timing shown in Figure 10C.

In the above-described arrangement, however, the drive-timing in some cases deviates depending on the direction in which the coil is wound, with the result that a favourable driving condition with high efficiency cannot be obtained. Namely, since the coil is driven with the timing shown in Figure 10A, there arises no problem in the situation illustrated in Figure 11A. If the winding direction is reversed, however, the repulsion driving method is, as shown in Figure 11C, initiated from a point slightly before the timing shown in Figure 10B and this leads to considerable deterioration of efficiency. For this reason, it is necessary that the circuit is constructed, taking the winding direction of the coil into consideration at the time of manufacture.

Moreover, there is a disadvantage resulting from noise from a power source, and driving pulses of the coil are often produced due to fluctuations in voltage of the power source.

The induced voltage in the electromagnetic driving circuit of Figure 9 is generated at the terminal P. If the induced voltage is greater than a reference voltage vr (Figure 12A), the transistor T2 is turned OFF, while the transistor T1 is turned ON. As a result, the driving current flows through the coil L2. An ON-time t7 of the transistor T1 is determined by the time constants of the capacitor C and the resistor R1.

For the purpose of driving the magnet with high efficiency, it is desirable that the driving operation is effected with the timing shown in Figure 10A, i.e., as illustrated in Figure 12A, at the maximal point of the induced voltage V1 in the case of the attraction driving method. The reference voltage vr and the ON-time t7 are adequately set to satisfy the above-described requirement.

In the great majority of cases, the drive-timing and the ON-time differ according to the length of a swing bar or a magnitude of swing angle when driving a pendulum. In the above-described electromagnetic driving circuit, however, the ON-time is determined by the time constant of the capacitor C and the resistor R1, and the time constants must therefore be adjusted in accordance with the length of the swing bar or the magnitude of the swing angle. In addition, the reference voltage vr has to be properly adjusted in order to vary the ON-timing.

For instance, where the same pendulum as that of Figure 12A is employed and the swing angle is made smaller, the amplitude of the induced voltage is reduced as shown in Figure 12B and moderate variations in amplitude are created. In this case, the drive timing has to be adjusted so that the driving pulses are generated at the maximal point of the induced voltage by adjusting the reference voltage vr. This is necessary to cause the driving current to flow through the coil for an ON-time t8 which is longer than the ON-time t7, and the time constant of the capacitor C and the resistor R1 must be modified.

In the case depicted with a dotted line in Figure 12A, if the ON-time is set to a value longer than the time t7, it follows that the swing angle becomes larger than is required. The driving current flows at a timing when an induced voltage V2 having a reverse polarity is generated, resulting in futile consumption of electric current.

In the situation indicated by a dotted line in Figure 12B, the ON-time is set to a value shorter than the time t8 and so the necessary driving force cannot be obtained and the pendulum ceases to swing in some cases.

Where the swing bar differs in length, the same adjustments as described above in relation to swing angle are needed, and similar defects are created.

As discussed above, some defects inherent in the conventional electromagnetic driving circuit are present: both the time constant and the reference voltage vr must be adjusted each time in accordance with the magnitude of the swing angle and/or the length of the swing bar; and if some deviation is produced in the adjustment the electric current is wastefully consumed or the pendulum stops.

The foregoing conventional electromagnetic driving circuit can be used for the type of pendulum in which the driving operation is performed by orienting two poles of the permanent magnet M as illustrated in Figure 13 towards the coil L2 as well as for the type in which one pole of the permanent magnet M faces the coil L2. Description will herein be centred on the driving operation associated with the type shown in Figure 13. As shown in Figure 14A, the magnet M moves in a direction indicated by an arrow and is positioned opposite to the coil L2. At this time, the coil L2 is excited in such a direction as to stop the magnet M. A maximal induced voltage V1 illustrated in Figure 15A is produced. In contrast with this, the magnet M, as depicted in Figure 14B, moves in the reverse direction and faces the coil L2. The coil L2 is similarly excited in such a direction as to stop the magnet M. Then a maximal induced voltage V2 shown in Figure 15A is generated.

It is most desirable in terms of efficiency that the magnet is energised by causing the driving current to flow through the coil at the maximal point, viz, at the timing shown in Figure 14A or 14B.

A threshold voltage of the transistor T2 depicted in Figure 9 is set to the reference voltage vr shown in Figure 15. As a result of this, if the induced voltage exceeds the voltage vr, the transistor T2 is turned OFF, while the transistor T1 is turned ON. Then, the driving current, as shown in Figure 15A, flows through the coil L2 at the timing of the induced voltage V1 with the result that the magnet M is energised. As in the former case, some deviation is created in the timing at which the coil is driven because of fluctuations in amplitude of the induced voltage, thereby probably decreasing the driving efficiency.

Namely, as shown in Figure 15B, when the amplitude of the induced voltage diminishes, the timing at which the voltage vr is reached is delayed, and it follows that the driving current flows through the coil slower than the optimal timing. While on the other hand, if the amplitude of induced voltage increases, the driving current flows in the coil faster than the optimal timing. In either case, there is a drop in driving efficiency. Such being the case, scatter in a variety of factors which exert influences on the amplitude of induced voltage must be eliminated in order to keep the driving efficiency optimum. Accuracy in manufacture and assembling processes is strictly required.

The greatest defect of the conventional electromagnetic driving circuit described above is that it is incapable of being integrated because of the adjustments needed to match it to the characteristics of the pendulum.

The present invention at least in its preferred form seeks to provide an electromagnetic driving circuit which, with the exception of a coil, can be integrated, which is capable of driving the coil invariably at a highly efficient timing so as not to depend on the winding direction of the coil and without being influenced by the amplitude of the induced voltage in the coil, and which is capable of automatically optimally adjusting a generation timing and/or a pulse width of a driving pulse.

According to the present invention, there is provided an electromagnetic driving circuit comprising: a coil for detecting and driving a permanent magnet; a comparator circuit arranged to compare an induced voltage of said coil with a reference voltage; a one shot pulse generating circuit coupled to the comparator circuit for generating a driving pulse having a predetermined width in response to the output of said comparator circuit; and a driving circuit arranged to receive said driving pulse of said pulse generating circuit and to cause a driving current to flow through said coil during supply of said driving pulse.

The electromagnetic driving circuit, in one embodiment, includes a judgement circuit for judging a level of said induced voltage at a predetermined timing after halting generation of said driving pulse, and a control circuit for controlling timing and/or pulse width of said next driving pulse on receipt of an output of said judgement circuit.

The pulse generating circuit may be arranged to generate the driving pulse with a predetermined time delay from generation of the output of said comparison circuit.

Preferably the electromagnetic driving circuit includes a prohibit circuit for prohibiting supply of said output from said comparator circuit to said pulse generating circuit during a preset period from a predetermined timing after generation of said output from said comparator circuit.

The electromagnetic driving circuit may include an inhibit circuit for inhibiting the generation of said driving pulse from said pulse generating circuit when said output of said comparator circuit discontinues within said predetermined time delay.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:-

Figure 1 is a circuit diagram of one embodiment of an electromagnetic driving circuit according to the present invention;

Figure 2 is a voltage waveform diagram illustrating the operation of the electromagnetic driving circuit of Figure 1;

Figure 3 is a circuit diagram illustrating another embodiment of an electromagnetic driving circuit according to the present invention;

Figures 4 and 5 are voltage waveform diagrams, illustrating in combination, the operation of the electromagnetic driving circuit of Figure 3;

Figure 6 is a circuit diagram of another embodiment of an electromagnetic driving circuit according to the present invention;

Figures 7 and 8 are voltage waveform diagrams illustrating, in combination, the operation of the electromagnetic driving circuit of Figure 8;

Figure 9 is a circuit diagram illustrating a conventional electromagnetic driving circuit;

Figure 10 is an explanatory diagram depicting one example of the relation between a permanent magnet of a pendulum and a coil of the conventional electromagnetic driving circuit of Figure 9;

Figures 11 and 12 are voltage waveform diagrams illustrating the operation of the conventional electromagnetic driving circuit of Figure 9;

Figure 13 is an explanatory diagram depicting another example of the relation between a permanent magnet of a pendulum and a coil of the conventional electromagnetic driving circuit of Figure 9;

Figure 14 is an explanatory diagram showing an excited polarity of the coil in connection with the example of Figure 13; and

Figure 15 is a voltage waveform diagram showing the operation of the conventional electromagnetic driving circuit of Figure 9 in the relation shown in Figure 13.

Throughout the drawings like parts have been designated by the same reference numerals.

In Figure 1 there is shown one embodiment of an electromagnetic driving circuit according to the present invention. The coil L1 detects and drives a permanent magnet (not shown). The electromagnetic driving circuit has a reference voltage source Vr, a comparator CM for comparing an induced voltage of the coil L1 with a reference voltage, a one-shot pulse generating circuit W, and a transistor T which constitutes a driving circuit. The circuit components except for the coil L1 can be integrated.

The induced voltage is compared with a reference voltage vr by means of the comparator CM. If the induced voltage exceeds the reference voltage vr, outputs are generated from the comparator CM, and pulses having a time t are produced from the one-shot pulse generating circuit W. These pulses cause the transistor T to turn ON, and a driving current flows through the coil L1, thereby driving the permanent magnet.

That is, the induced voltage is, as illustrated in Figure 2A or 2B, generated in the coil L1 according to the direction in which the coil is wound. In either case, the driving current continues to flow during the time t when the induced voltage is greater than the reference voltage vr. Hence, there is always a flow of driving current at the peak of the induced voltage regardless of the winding direction of the coil. This leads to a highly efficient driving condition.

Figure 3 shows another embodiment of an electromagnetic driving circuit according to the present invention comprising one-shot pulse generating circuits W1 to W4. Pulse widths of the one-shot pulse generating circuits W1, W3 and W4 are set to t1, t3 and t4, respectively. The one-shot pulse generating circuit W2 involves the use of a programmable one-shot circuit the pulse width of which is variable. The electromagnetic driving circuit has a flip-flop circuit F and an up-down counter CT. The one-shot pulse generating circuit W3 and a flip-flop circuit F are combined to constitute a judgement circuit, while the one-shot pulse generating circuit W4 and the counter CT cooperate to constitute a control circuit. A transistor S forms a driving circuit.

Next, the operation of the electromagnetic driving circuit of Figure 3 will be described with reference to Figure 4. Assuming that a content in the counter CT is now n, the pulse width of the one-shot pulse generating circuit W2 is set to t2 by the output thereof.

If the induced voltage of the coil L1, as shown in Figure 4a, exceeds the reference voltage vr, the output shown in Figure 4b is produced by the comparator CM. The pulse having a width t1 is accordingly produced from the one-shot pulse generating circuit W1. A driving pulse having a width t2 is generated from the one-shot pulse generating circuit W2 at the falling edge of the aforementioned pulse, thereby turning ON the transistor S. Then the driving current flows in the coil L1. A pulse having a width t3 is produced from the one-shot pulse generating circuit W3 at the falling edge of the driving pulse and both the flip-flop circuit F and the one-shot pulse generating circuit W4 are triggered by the falling edge thereof. An input D of the flip-flop circuit F is supplied with the output of the comparator CM, and this output condition is read to the flip-flop circuit F. Specifically, this step is to judge whether a level of induced voltage at the falling edge of the pulse from the one-shot pulse generating circuit W3 is greater than the reference voltage vr or not. If it exceeds the reference voltage, the output of the flip-flop circuit F comes to "1", and the counter CT is brought into an up-count mode. Namely, in this case, it is judged that the width of the driving pulse is small and the pulse is not generated in a highly efficient manner in the vicinity of the maximal point of the induced voltage.

A pulse having a width t4 is produced by the one-shot pulse generating circuit W4 at the falling edge of the pulse from the one-shot pulse generating circuit W3. The pulse associated with the one-shot pulse generating circuit W4 becomes a clock pulse input of the counter CT, whereby the content of the counter CT is increased by one. Then the count, as illustrated in Figure 4d, becomes (n + 1). Therefore, the width of the next pulse from the one-shot pulse generating circuit W3 is increased.

After this operation has been repeated, the counter content becomes m, and the driving pulse width, as illustrated in Figure 4a, is t'2. At this time, if the level of induced voltage at the falling edge of the pulses of the one-shot pulse generating circuit W3 is lower than the reference voltage, the output of the flip-flop circuit F is, as shown in Figure 4c, inverted to "0", and the counter CT is put into a down-count mode. Hence, the content of the counter CT is decreased to (m - 1), and the width of the next driving pulse is reduced by one step.

The driving pulse width is changed over alternately to t2 and the width smaller than t2 by one step, thus achieving a stable state.

In this way, the driving pulse width automatically achieves a predetermined value at the optimal timing, thereby stabilising the specified swing angle.

In the above-described example, only the driving pulse width is adjusted. The arrangement is not, however, confined to this. A programmable one-shot circuit serves as the one-shot pulse generating circuits W1 and W3, and the pulse width thereof may properly be adjusted in accordance with the content of the counter CT. For instance, where the swing angle of the pendulum is set to a small value, it is necessary to stabilise the times t1 to t3 to assume, as illustrated in Figure 5a, a slightly lengthy configuration. It is because the amplitude of the induced voltage is, as shown in Figure 5a, smaller than the stable state that the variation is moderate. If the swing angle of the pendulum is set to a large value, the amplitude of the induced voltage is, as depicted in Figure 5b, large in a stable state and the variation thereof is, in consequence, sharp. Hence, the driving pulse width may be small. It is therefore necessary for the times t1 to t3 to be stabilised within a relatively shorter time than that of Figure 5a. A ratio of the time t2 to the times t1 and t3 in Figure 5a is different from that in Figure 5b. The stability of the swing angle is set by adjusting this ratio. For example, when obtaining stability in the state shown in Figure 5b, the pulse widths of the one-shot pulse generating circuits W1 to W3 are so set that the respective times have the ratio shown in Figure 5b. Consequently, the setting is so performed that the individual pulse widths may be varied keeping that ratio in accordance with the content of the counter CT.

The times t1 to t3 are automatically adjusted in the following manner, thereby stabilising a desired swing angle. Provided that the pulse widths of the one-shot pulse generating circuits W1 to W3 are set to the value of Figure 5b on the basis of the content of the counter CT in the initial state, the power source is then inputted to start swinging the pendulum. Initially, the swing angle is small, and hence the induced voltage approximate to that of Figure 5a is produced. For this reason the induced voltage is in excess of the reference voltage at the falling edge of the pulses from the one-shot pulse generating circuit W3. The driving pulse width is judged to be small, and the content of the counter CT is thereby increased by one. The times t1 to t3 are each set to become longer by one step. The times t1 to t3 are incremented step wise by repeating this operation. Thus, the driving pulse widths gradually increase. Following this increment, the swing angle of the pendulum gradually augments a little bit behind that timing. The amplitude of the induced voltage increases with this augmentation.

There comes a stage when there is a surplus in the driving pulse width. Then the counter CT is changed over to the down-count mode. The times t1 to t3 diminish. Followed by the diminution, the swing angle of the pendulum decreases slightly behind that timing.

The aforementioned operations are repeated, thus approaching the state depicted in Figure 5b, and finally this state is brought into stability. That is, automatic adjustment is effected so that the driving operation is efficiently carried out with the optimal driving pulse width at the maximal point of the induced voltage.

On the other hand, the pulse width t3 of the one-shot pulse generating circuit W3 is so set that the level of induced voltage is decided at such a timing as to obtain the easiest judgement of the induced voltage. However, the setting of the pulse width requires consideration of the following conditions.

From the coil L1 is produced ringing generally for approximately 1 ms when the driving pulses terminate. Inasmuch as the induced voltage of the coil L1 loses its stability during the occurrence of this ringing, there exists the probability of a malfunction occuring if the judgement about the induced voltage is made during this period. To cope with this, the output width t3 of the one-shot pulse generating circuit W3 is set to exceed the time for which the ringing takes place in order that the level of induced voltage can be judged under stable conditions.

In the above-described embodiment, the automatic control is effected by making the pulse width of the one-shot pulse generating circuit W2 variable. The reference voltage may, however, be adjusted by the outputs of the counter CT, which adjustment involves the use of a variable-voltage source serving as the reference voltage source Vr. This adjustment of the reference voltage permits adjustment of the timing at which the driving pulses are generated as well as that of the pulse width of the one-shot pulse generating circuit W1. In this case, both the width of the driving pulse and the timing of generation are adjusted simultaneously by adjusting the pulse width of the one-shot pulse generating circuit W2.

In the aforementioned embodiment, set to the same voltage vr are the reference voltage for determining the timing at which the driving operation is initiated and another reference voltage for judging the level of the induced voltage after termination of the driving operation. The latter reference voltage may be modified on the basis of the content of the counter CT. For instance, the variable-voltage source is employed as the reference voltage source, and the voltage thereof is changed over to a voltage corresponding to the content of the counter CT only during a period for which output pulses are generated from the one-shot pulse generating circuits W2 to W4. This arrangement has a significance equivalent to that of adjusting the pulse width of the one-shot pulse generating circuit W3.

In general, the amplitude of induced voltage is influenced by fluctuations in voltage of the power source. If the amplitude of the induced voltage fluctuates, the timing when increasing over the reference voltage deviates, resulting in fluctuations both in the drive-timing and in the driving time. In this embodiment of the present invention, the reference voltage vr is set to a low value having less influence on the fluctuations in voltage in order to minimise the influence derived from fluctuations in voltage of the power source. Subsequently, there is created a delay equivalent to the time t1 after the occurrence of the output of the comparator CM by means of the one-shot pulse generating circuit W1. From this moment the drive is started. If fluctuations in voltage of the power source are not taken into consideration, the one-shot pulse generating circuit W1 is unnecessary and the output of the comparator CM may be supplied directly to the one-shot pulse generating circuit W2.

In the above-described embod ment, a clock pulse is supplied to the counter CT every driving pulse. For example, however, the content of the counter CT for the first time may be increased by one, if the up-down count mode of the counter CT remains invariable during a sequence of three driving pulses. In this case, a ternary counter is provided between the one-shot pulse generating circuit W4 and the counter CT. The arrangement may be such that this ternary counter is reset for every inversion of the output level of the flip-flop circuit F. This makes it possible to prevent malfunction caused by noise or the like.

Next, another embodiment of an electromagnetic driving circuit according to the present invention will be discussed with reference to Figure 6. A reference voltage generating source Vr produces a reference voltage which, as illustrated in Figure 7, is of a lower level than in the previously described embodiments. The electromagnetic driving circuit of Figure 6 has gate circuits G1,G2, a gate circuit G3 which constitutes an inhibit circuit, and a one-shot pulse generating circuit W5 for generating pulses each having a width t5. In this electromagnetic driving circuit, the permanent magnet is as depicted in Figure 13. The induced voltage of the coil L1 is compared with the reference voltage vr by means of the comparator CM. If the induced voltage is, as illustrated in Figure 7a, in excess of the reference voltage vr, the comparator CM produces an output whereby the one-shot pulse generating circuit W1 is triggered to the gate circuit G1, and a pulse having a width t1 is generated at the output thereof. At the maximal point of the induced voltage, the width t1 is preset to a period extending from the time when the induced voltage exceeds the reference voltage to the time when a driving pulse is generated at the optimal timing. To be specific, the one-shot pulse generating circuit W2 is triggered by the falling edge of the foregoing pulse and a pulse having a width t2 is produced by the output thereof. This driving pulse causes the transistor T to be turned ON and the driving current then flows in the coil L1.

The one-shot pulse generating circuit W5 is triggered by the falling edge of this driving pulse and a pulse having a width t5 is generated by the output thereof. This pulse and the previous driving pulse are supplied to the gate circuit G2, while the gate circuit G1 remains closed during the occurrence of each individual pulse. Namely, even if the output is produced from the comparator CM, the one-shot pulse generating circuit W1 is never triggered for the times t2 and t5 shown in Figure 7, thereby preventing malfunctioning. The reason for this is that because the reference voltage vr is set to low level, the induced voltage in some cases exceeds the reference voltage, excluding the maximal point and in such a situation a generation of driving pulses is prevented.

It is to be noted that the output of the one-shot pulse generating circuit W1 is fed to the gate circuit G2 and the gate circuit G1 may continue to be closed for the time t1.

The output of the one-shot pulse generating circuit W1 is (though not stated in the description given above) fed to the gate circuit G3, and the gate circuit G3 remains open during the generation of its pulse. Hence, if the comparator CM ceases to output during that period, the one-shot pulse generating circuits W1, W2 and W5 are reset, and the occurrence of the driving pulse is thereby inhibited. This action is intended to prevent malfunction attributable to noise or induced voltage except at the maximal point. Only when continuously exceeding the reference voltage over the time t1, is it deemed to be a maximal induced voltage. In this case alone, the driving pulse may be generated.

In the above-described construction, even if the amplitude of the induced voltage, as depicted in Figure

7B, diminishes, since the reference voltage vr is set to a low level, amplitude-fluctuations in the vicinity thereof are extremely small. Furthermore, the timing at which the output of the comparator CM is much the same as that shown in Figure 7A. Hence the generation timing of the driving pulse does not substantially deviate, and the driving pulse can be produced surely at the maximal point of induced voltage. The situation is the same in the case where the induced voltage increases in amplitude.

In the above-described example, the explanation is focussed on the bipolar magnet arrangement depicted in Figure 13, but the application may include the use of such a magnet arrangement as shown in Figure 10. In this case, an illustration of the induced voltage waveform is given in Figure 8. As in the former case, the driving current flows through the coil at the maximal point of the induced voltage.

The present invention provides the following effects. It is practicable to integrate all the components except for the coil. Miniaturisation in size and a decrease in cost can be achieved.

The coil can be driven constantly with high efficiency regardless of the direction in which the coil is wound. It is therefore feasible to assemble the parts without considering the winding direction of the coil at the time of manufacture, and this brings about a reduction in time required for assembly.

Futhermore, the present invention provides a construction which is substantially unaffected by noise of a power source and is suited to integration because there is no provision of a capacitor.

The drive-timing and/or the driving pulse width is adjusted by judging the level of the induced voltage at a predetermined time after termination of the driving pulse, and hence automatic control is effected so that the driving operation is performed in a highly efficient manner invariably at the maximal point of the induced voltage. The permanent magnet can efficiency be driven with a stable amplitude.

In addition, it is possible to drive pendulums each having a different inherent cycle at the optimal timing during the optimal driving time.

The driving current is arranged to flow in the coil with a delay of specified time when the induced voltage of the coil is in excess of the reference voltage, whereby the reference voltage can be set at a relatively low level. By virtue of this arrangement, the timing at which the driving pulses are generated undergoes almost no influence caused by fluctuations in amplitude of the induced voltage. This permits the driving current to run through the coil constantly at the most efficient timing. Hence, the manufacturing and assembling processes do not require so high accuracy as does the conventional electromagnetic driving circuit described above. This results in simplification of these processes.

After the output has been generated once from the comparator, malfunction due to noise and induced voltage except at the maximal point can be prevented by prohibiting regeneration of the output of the comparator during the setting process and by generating the driving pulses only when the induced voltage is continuously greater than the reference voltage over a predetermined period.

CLAIMS

1. An electromagnetic driving circuit comprising: a coil for detecting and driving a permanent magnet; a comparator circuit arranged to compare an induced voltage of said coil with a reference voltage; a one shot pulse generating circuit coupled to the comparator circuit for generating a driving pulse having a predetermined width in response to the output of said comparator circuit; and a driving circuit arranged to receive said driving pulse of said pulse generating circuit and to cause a driving current to flow through said coil during supply of said driving pulse.

2. An electromagnetic driving circuit as claimed in claim 1 including a judgement circuit for judging a level of said induced voltage at a predetermined timing after halting generation of said driving pulse, and a control circuit for controlling timing and/or pulse width of said next driving pulse on receipt of an output of said judgement circuit.

3. An electromagnetic driving circuit as claimed in claim 1 or 2 in which the pulse generating circuit is arranged to generate the driving pulse with a predetermined time delay from generation of the output of said comparator circuit.

4. An electromagnetic driving circuit as claimed in any preceding claim including a prohibit circuit for prohibiting supply of said output from said comparator circuit to said pulse generating circuit during a preset period from a predetermined timing after generation of said output from said comparator circuit.

5. An electromagnetic driving circuit as claimed in claim 4 when dependent upon claim 3 including an inhibit circuit for inhibiting the generation of said driving pulse from said pulse generating circuit when said output of said comparator circuit discontinues within said predetermined time delay.

6. An electromagnetic driving circuit substantially as herein described with reference to and as shown in Figures 1 to 8 of the accompanying drawings.

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