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Electromagnetic drive circuit

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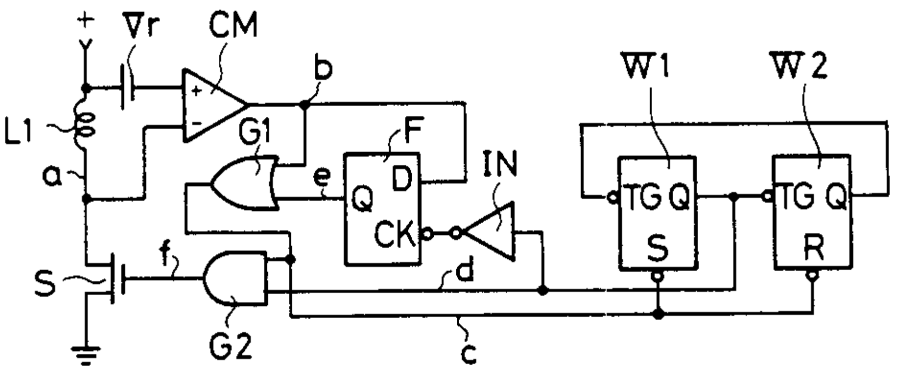
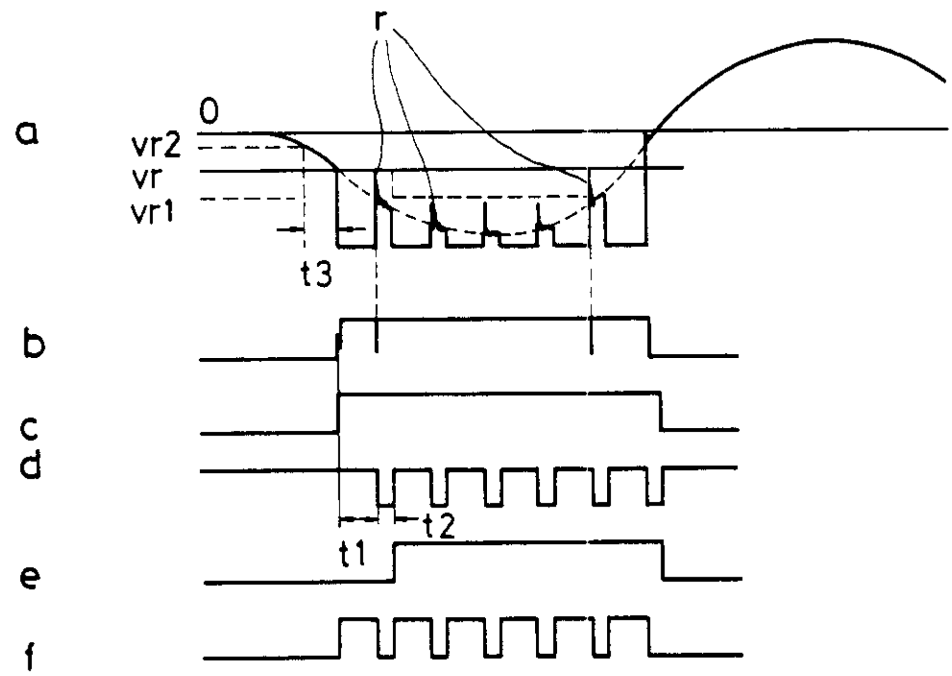
FIG.1



+
Vr
CM
b
W1
W2
L1
G1
F
a
e
Q
D
IN
TG Q
TG Q
CK
S
f
d
S
R
G2
c

FIG.2



r
a
0
vr2
vr
vr1
t3
b
c
d
t2
t1
e
f

FIG. 3

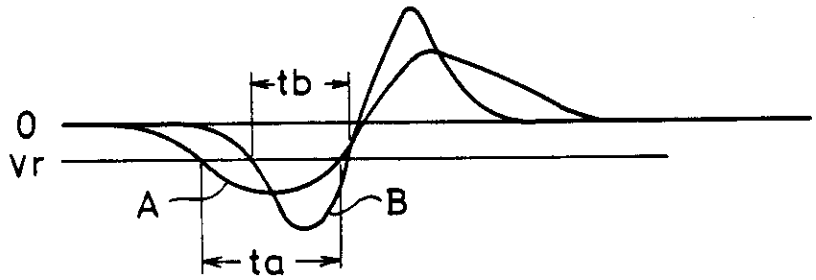


FIG. 4

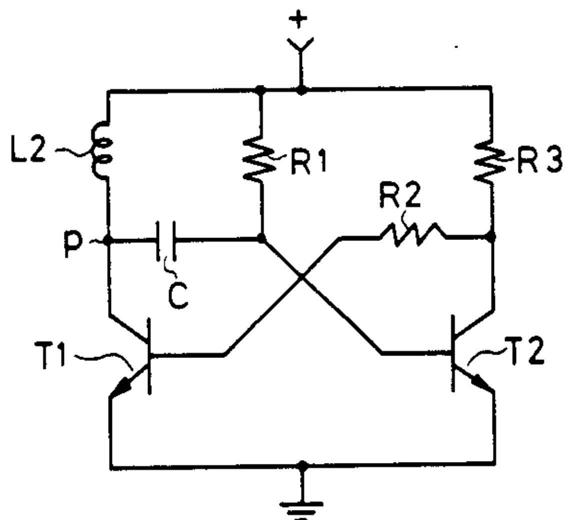


FIG. 5

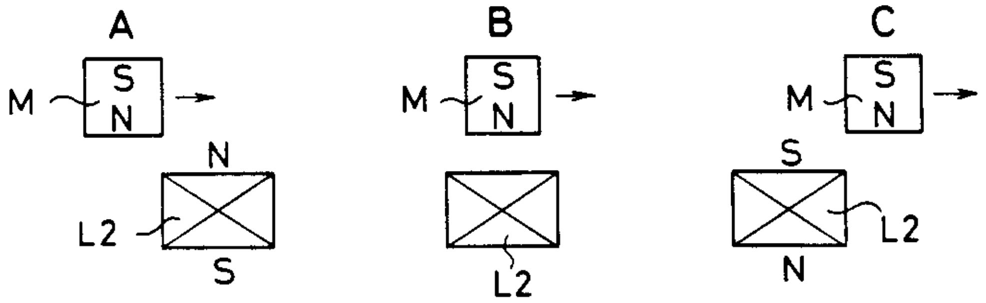
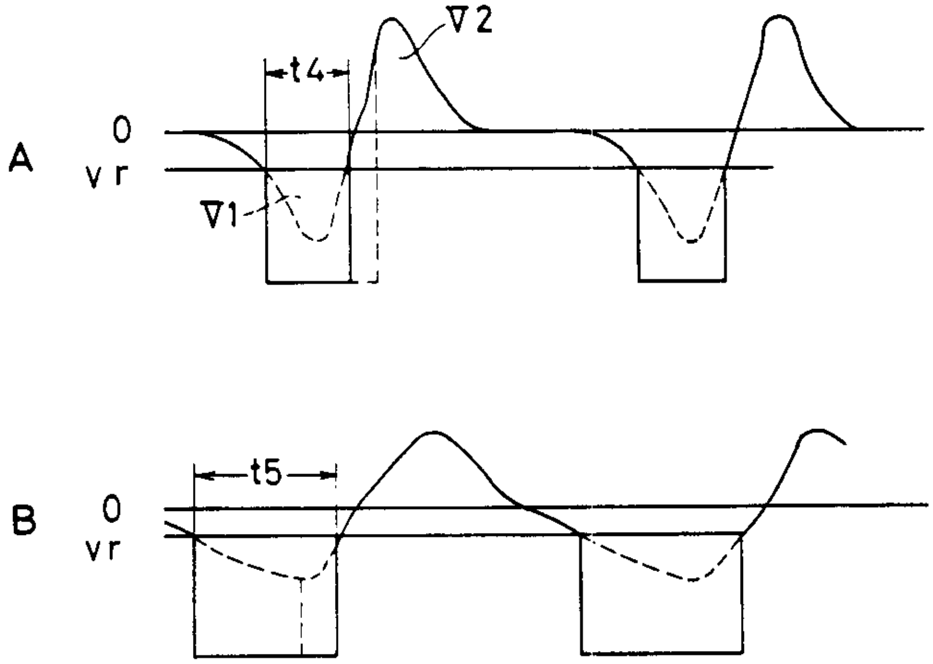


FIG. 6



2203866

ELECTROMAGNETIC DRIVE CIRCUIT

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

A known electromagnetic drive circuit for detecting and driving a pendulum of a clock using a single coil is shown in Figure 4. The operation of this electromagnetic drive circuit is as follows. As a permanent magnet M of a pendulum (not shown) approaches a coil L2, as shown in Figure 5A, a voltage V1 (as shown in Figure 6A is induced) in the coil in a direction to repel the magnet M. When the coil L2 faces the magnet M, as shown in Figure 5B, no voltage is induced. As the coil L2 moves away from the magnet M, as shown in Figure 5, a voltage V2 (as shown in Figure 6A) is induced in the coil in a direction to attract the magnet M.

The voltages thus induced are generated at a terminal P of the electromagnetic drive circuit of Figure 4. If the induced voltage exceeds a reference voltage vr, a transistor T2 is turned off and a transistor T1 is turned on so that a drive current flows in the coil L2. A drive time t4 for which the transistor T1 is ON is determined by the values of a capacitor C and a resistor R1.

In order to drive the magnet M efficiently, it is preferable in the case of a traction drive that the magnet M is driven with the timing illustrated in Figure 5A, i.e., at the maximal point of the induced voltage V1, as shown in Figure 6A. In order to satisfy this condition, therefore, the reference voltage vr and the drive time t4 must be properly set.

In the case where a pendulum is to be driven by the electromagnetic drive circuit, the drive timing and the drive time are normally different and depend upon the length of the pendulum rod or the magnitude of its swing angle.

In the electromagnetic drive circuit described above, however, the drive time is uniquely determined by the time constant which, in turn, is determined by the values of the capacitor C and the resistor R1. This makes it necessary to adjust the time constant in accordance with the length and/or swing angle of each pendulum rod.

In order to change the drive timing, on the other hand, the reference voltage vr has to be properly set.

For example, if the swing angle is reduced using the same pendulum as that of the case of Figure 6A, the induced voltage has a reduced amplitude and a gentle change. In this case, the reference voltage vr has to be regulated to adjust the drive timing. Moreover, the drive current has to be fed to the coil for a drive time t5 which is longer than the drive time t4, at the maximal point of the induced voltage. Because of this, the time constant determined by the values of the capacitor C and the resistor R1 has to be changed.

If, in this case, the drive time is set at a value larger than that of the optimum drive time t4, as indicated by a broken curve in Figure 6A, for example, the swing angle increases more than necessary, and the drive current will flow at the same time as the induced voltage V2 but of opposite polarity so that the drive current is wasted.

If, on the other hand, the drive time is set as in the case illustrated in Figure 6B at a smaller value than the optimum drive time t5, again as indicated by a broken curve, the necessary drive power may fail to be established to stop the pendulum.

Similar adjustments are also required in the case of pendulum rods of different lengths, accompanied by similar defects.

Thus, in this known electromagnetic drive circuit, both the time constant and the reference voltage have to be adjusted in accordance with the magnitude of the swing angle and the length of the pendulum rod. If, moreover, these adjustments are erroneous, the resultant defects result in a waste of current consumption and stopping of the pendulum. The greatest defect, however, of this known electromagnetic drive circuit is that it is incapable of being made as an integrated circuit.

The present invention seeks to provide an electromagnetic driving circuit which, with the exception of a coil, can be integrated and which can accomplish drive efficiently without any waste of current, for example, to stabilise a desired amplitude of swing of a pendulum and optimise the drive automatically even in the case of different swing periods.

According to the present invention, there is provided an electro-magnetic drive circuit comprising: a coil for detecting and driving a permanent magnet; a comparator for generating a signal when an induced voltage of said coil exceeds a reference value; a pulse generator coupled to an output of the comparator so as to generate a drive pulse train in response to generation of the signal; drive means responsive to said drive pulse train for feeding a drive current to said coil; and a controller arranged to receive the signal and responsive to interruption of the signal for interrupting generation of the drive pulse train from said pulse generator.

The electromagnetic drive circuit may include change-over means for changing over the reference voltage of said comparator after the generation of said drive pulse train has started.

In one embodiment said controller includes two gates and a flip-flop.

Said pulse generator may include two one-shot pulse generators.

Preferably said drive means includes a transistor.

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

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

Figures 2 and 3 are voltage waveform charts for explaining the operation of the electromagnetic drive circuit of Figure 1;

Figure 4 is a circuit diagram of a known electromagnetic drive circuit;

Figure 5 is a diagram for explaining the position or relationships between a permanent magnet and a coil; and

Figure 6 is a voltage waveform chart for explaining the operation of the electromagnetic drive circuit of Figure 4.

In Figure 1, which shows an electromagnetic drive circuit according to the present invention, Vr designates a reference voltage source which produces a reference voltage vr shown in Figure 2a. The electromagnetic drive circuit has a comparator CM for generating an output when the irduced voltage of a coil L1 exceeds the reference voltage vr, gates G1,G2 and a flip-flop F which, together with the gates G1,G2 constitutes a controller. One-shot pulse generators W1,W2 together constitute a pulse generator. These one-shot pulse generators W1,W2 are set to have output pulse widths t1,t2 respectively. The electromagnetic drive circuit has an inverter IN, and a transistor S constituting a driver.

The operation of the electromagnetic drive circuit of Figure 1 will be described with re erence to Figure 2. While no output is being generated by the comparator CM, the one-shot pulse generators W1,W2 are set and reset, respectively, by the output of the gate G1.

When, in this state, the voltage induced in the coil L1 exceeds the reference voltage vr, as shown in Figure 2a, the comparator CM generates its output, as shown in Figure 2b, to release the one-shot pulse generators W1,W2 from their respective set and reset states through the gate G1. As a result, the output of the one-shot pulse generator W1 is inverted to "0" after a lapse of time t1, as shown in Figure 2d, so that the one-shot pulse generator W2 is triggered to generate a pulse train having a pulse width t2 at its output. Thus, a drive pulse train shown in Figure 2d is generated from the output of the one-shot pulse generator W1. The flip-flop F is triggered by the rise of the first pulse of this drive pulse train and the output Q of the flip-flop is held at "1", as shown in Figure 2e. As a result, the output of the gate G1 is held at "1" on and after the generation of an output from the comparator CM, as shown in Figure 2c, and the drive pulse train is generated through the gate G2, as shown in Figure 2f. The transistor S is turned on by this drive pulse train so that a drive current flows in the coil L1. That drive pulse train is fed to the clock input CK of the flip-flop F so that the output state of the comparator CM is judged in terms of the rise of the drive pulse train. As a result, this drive pulse train is being generated while the comparator CM is generating its output to drive the coil L1.

When, on the other hand, the aforementioned induced voltage drops below the reference voltage vr so that the output of the comparator CM is interrupted, the output of the flip-flop F is inverted to "0" by the first rise of the drive pulses that will occur after interruption of the output of the comparator CM. Then, the drive pulse train and accordingly the drive of the coil L1 are interrupted.

As has been described above, the drive current will be flowing in the coil while the induced voltage exceeds the reference voltage vr. As a result, the drive can be efficiently accomplished at the maximal point of the induced voltage at all times and be stabilised at a constant swing angle. More specifically, the curve of the induced voltage is gentle for a small swing angle so that a drive time ta is elongated, as indicated at A in Figure 3, but becomes steep for a larger swing angle, as shown at B in Figure 3, so that a drive time tb is shortened. In this way, an automatic control is achieved to stabilise the swing angle at a constant value.

For a pendulum having a different swing period (or a pendulum rod of different length), moreover, an optimum drive can be automatically accomplished.

The output width t2 of the one-shot pulse generator W2 is set as follows. Since the coil L1 is driven by the drive pulse train, ringing r will usually occur for 1ms, as shown in Figure 2a, when the drive pulse train is interrupted. Since the induced voltage in the coil L1 is unstable during that ringing, a malfunction may occur if a subsequent drive pulse is generated during that ringing so that the output of the comparator CM is judged by the flip-flop F. Therefore, in order that the subsequent drive pulse may not be generated before the induced voltage is stabilised, the output pulse width t2 of the one-shot pulse generator W2 is set at several milliseconds.

Incidentally, in the case where the coil is to be driven, energisation of a permanent magnet is not adversely affected but can be ignored even in the presence of a drive stop time of several milliseconds.

In the embodiment thus far described, the reference voltage for determining the drive starting time and the drive interrupting time are set at a common value vr. However, the two timings may made be different to adjust the drive ending time. For example, the trailing drive pulses can be generated by using a reference voltage source of voltage-variable type and by changing over the reference voltage to a value vr1, as shown in Figure 2a, with the output of the flip-flop F. Thus a finer adjustment of the drive time can be achieved.

Generally speaking, the amplitude of the induced voltage is influenced by fluctuations of the supply voltage. Any fluctuations of the amplitude of the induced voltage will result in that the timing, at which the reference voltage is exceeded, is shifted to cause fluctuations of the drive timing and time period. In order to reduce the influence of the fluctuations of the power supply, therefore, the reference voltage vr may be set at such a relatively low value as to receive little influence from the fluctuations of the power supply so that the output of the comparator CM may be delayed a constant time by a delay circuit to start the drive from the delayed instant. As shown in Figure 2a, for example, the reference voltage is set at a lower value vr2 so that the output, which is generated by the comparator CM when the induced voltage exceeds the voltage vr2, may be delayed by a delay circuit (not shown) and fed with a delay time t3 to the flip-flop F and the gate G1. Thus, it is possible to reduce the influences due to fluctuations of the voltage of the power supply and to drive the coil at the optimum timing and for the optimum drive time.

According to the present invention, the permanent magnet is detected and driven by the single coil so that the output may be generated by the comparator when the induced voltage of the coil exceeds the reference voltage, and the drive pulse train is generated during generation of that output to feed the drive current to the coil. As a result, the constitution, except for the coil, can be integrated. The coil can always be efficiently driven at the maximal point of the induced voltage, and the permanent magnet can be driven with stable amplitude. In other words, the driving force is increased for a smaller swing angle whereas the drive time is shortened for a larger swing angle so that the automatic control acts to stabilise the swing angle to a constant value. Moreover, the amplitude can be easily adjusted merely by changing over the reference voltage.

Furthermore, a pendulum having a different intrinsic period can be automatically driven at optimum timing and for optimum drive time. By changing over the reference voltage after generation of the output of the comparator, the timing of the drive interruption can be adjusted to refine the control of the drive time.

C L A I M S

1. An electro-magnetic drive circuit comprising: a coil for detecting and driving a permanent magnet; a comparator for generating a signal when an induced voltage of said coil exceeds a reference value; a pulse generator coupled to an output of the comparator so as to generate a drive pulse train in response to generation of the signal; drive means responsive to said drive pulse train for feeding a drive current to said coil; and a controller arranged to receive the signal and responsive to interruption of the signal for interrupting generation of the drive pulse train from said pulse generator.

2. An electromagnetic drive circuit as claimed in claim 1 including change-over means for changing over the reference value of said comparator after the generation of said drive pulse train has started.

3. An electromagnetic drive circuit as claimed in claim 1 or 2 in which said controller includes two gates and a flip-flop.

4. An electromagnetic drive circuit as claimed in any preceding claim in which said pulse generator includes two one-shot pulse generators.

5. An electromagnetic drive circuit as claimed in any preceding claim in which said drive means includes a transistor.

6. An electromagnetic drive circuit substantially as herein described with reference to and as shown in Figures 1 to 3 of the accompanying drawings.

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RENEWAL DETAILS

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