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ACTUATOR DRIVER CIRCUIT

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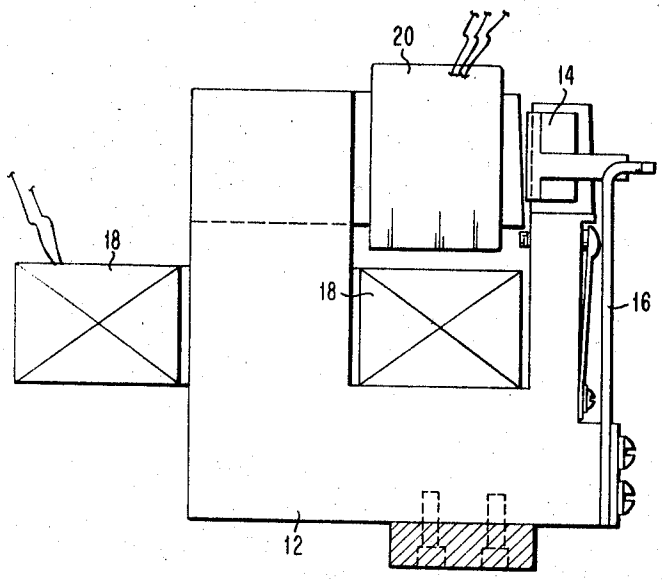


FIG. 1

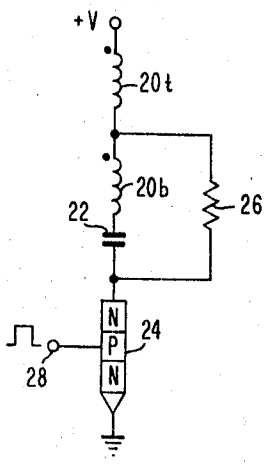


FIG. 2

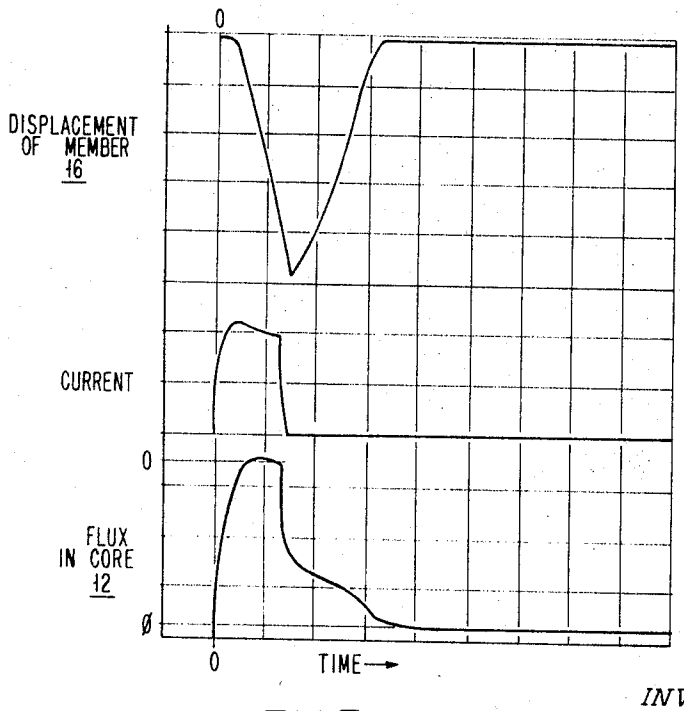


FIG. 3

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ACTUATOR DRIVER CIRCUIT

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ABSTRACT OF THE DISCLOSURE

A driver circuit for an electromagnetic device wherein an actuator coil is coupled in a first circuit path with an energy storage device which permits a high initial current responsive to the energization of a switch means and then progressively shunts current to a second circuit path comprising an impedance element and a part of the actuator coil to produce a second lower level of current. Upon deenergization of the switch means the energy storage device discharges the stored energy through the impedance element and the other part of the actuator coil to rapidly decrease the current in the circuit to substantially zero.

Cross-reference to related application

Print Hammer Actuator by Edgar A. Brown, Albert S. Chou and Richard H. Darling, Ser. No. 606,308, filed Dec. 30, 1966.

Background of the invention

This invention relates to a driver circuit for an electromagnet and more particularly to a driver circuit for a high speed electromagnetic actuator.

There are many applications for an electromagnetic device wherein it is desired to rapidly increase flux in the magnetic circuit at the start of an operation and to rapidly decrease flux in the magnetic circuit at the end of an operation. One such application is an electromagnetically actuated printer operating with a data processing system. It is the principal object of this invention to provide a superior driver circuit for the above described class of electromagnetic devices.

It is another object of this invention to provide a driver circuit for an electromagnetic device capable of high speed operation.

It is a further object of this invention to provide a print magnet capable of operation at very high cycle rates.

It is a still further object of this invention to provide a driver circuit to supply a large current of relatively short duration dropping to a lower level for a further time and then dropping to essentially zero at a predetermined time.

Briefly, according to the invention, there is provided a driver circuit for an electromagnetic device comprising an actuator coil coupled in a first circuit path with an energy storage device which permits a high initial current responsive to the energization of a switching means and then progressively shunts current to a second circuit path comprising an impedance element and a part of the actuator coil to produce a second lower level of current and wherein the energy storage device discharges the stored energy responsive to the deenergization of the switching means through the impedance element and the other part of the actuator coil to rapidly decrease the current in the circuit to substantially zero.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment

of the invention as illustrated in the accompanying drawings.

FIGURE 1 is a left side view of a print hammer actuator to which the driver circuit embodying the present invention is particularly suited.

FIGURE 2 is a schematic diagram of a specific embodiment of the driver circuit embodying the invention.

FIGURE 3 shows a plot of displacement of actuator member and waveforms of current and flux on a time scale.

Although the specific embodiment shows the driver circuit related to a print hammer actuator, it will be recognized by those skilled in the art that the application of this circuit is not so limited, but is applicable for driving relays, solenoids and other inductive devices wherein it is important that the flux be increased quickly at the start of an operation, and also that the flux be decreased rapidly at the end of an operation.

Referring to the drawings, a print hammer actuator is shown in FIGURE 1. The actuator assembly comprises a magnetic core structure **12** forming a substantially closed magnetic path. Actuator member **16** is fixed at one end and mounted for movement to the operative position to print a character; and a movable magnetic member **14** is coupled to actuator member **16** and positioned to complete the magnetic circuit formed by core structure **12**. The operation of actuator member **16** is controlled by a first winding **18** which is wound to enclose core structure **12** of all the actuator assemblies and a second control winding **20** is provided for the actuator assembly. Energization of winding **18** by a suitable direct current voltage produces a magnetic flux in the core structure **12** and attracts movable member **14** to store energy in actuator member **16**.

Selective operation of actuator **16** is provided by energizing second winding **20** by a suitable voltage. Winding **20** is energized so that the flux produced by this winding opposes the flux in the magnetic path **12** produced by winding **18**. When the magnetic force from member **14** is reduced below the force produced by member **16**, member **16** is propelled to print a character. The voltage to coil **20** is removed at this time, the actuator member rebounds from the platen member and the flux generated by winding **18** reattracts movable member **14** to a print ready position again so that the actuator member is then in position to start another print cycle.

The print hammer actuator is described in greater detail and claimed in application Ser. No. 606,308, filed concurrently herewith, entitled "Print Hammer Actuator," by Edgar A. Brown, Albert S. Chou, and Richard H. Darling.

To efficiently operate the print hammer actuator, the driver circuit supplies a large current of relatively short duration, dropping off to a lower level of current during the forward flight time (see FIG. 3) of the hammer, and then dropping off to essentially zero during the restore time of the print hammer actuator to thereby produce essentially a square wave of flux in the magnetic circuit. In FIGURE 3 waveforms of the collector current of transistor **24** and the corresponding flux in magnetic core members **12** are shown.

The circuit for the selective actuation of winding **20** is shown in FIGURE 2. According to the illustrated embodiment of the invention, the driver circuit comprises a first circuit path comprising an energy storage means **22** and actuator coil **20**. Actuator coil **20** is tapped to produce first winding portion **20***b* and second winding portion **20***t*. A switching means **24** is provided to selectively control the actuation of winding **20**. Upon energization of switching means **24** the first circuit path initially permits a high current to flow through energy storage means

22 and both portions of coil 20 to produce a high level of flux in magnetic circuit 12. As energy storage means 22 stores more energy, current is shunted to a second circuit path comprising impedance element 26 and winding portion 20*t*. Thus, a second lower level of current is produced when energy storage device 22 reaches full charge. Upon deenergization of switching means 24, energy storage device 22 starts to discharge through impedance element 26 and winding portion 20*b* so that the flux in the circuit rapidly collapses, thereby producing a substantially square wave of flux.

This driver circuit produces a full cycle of operation from flux level ϕ in the magnetic circuit (see FIG. 3) to substantially zero flux level and then back to ϕ level of flux in the shortest possible time so that the actuator may be operated at a very high recycle rate.

The speed of operation is due to the action of the two portions 20*b* and 20*t* of winding 20 in the circuit. During the intial part of the cycle, the flux produced by current through the first and the second circuit paths is additive to produce a high initial flux to quickly reduce the total flux in core structure 12 below the value required to hold actuator member in the ready position. This circuit action permits actuator member 16 to commence the forward flight of the actuator cycle. Once actuator member 16 has started, it is necessary only to keep the net flux in core member 12 to substantially zero to prevent winding 18 from influencing the forward flight of actuator 16.

Maintaining the flux at a constant value takes less energy and this function is provided by energy storage means 22 which progressively shunts current through the second circuit path as storage means 22 stores energy. Less current is provided due to impedance element 26 and since the current goes through only winding portion 20*t*, the flux level remains substantially constant. This condition is maintained until switching means 24 is turned off. At this time the energy stored in means 22 is discharged through impedance element 26 and winding portion 20*b*. The current produced in winding portion 20*b* produces a field in opposition to that present in winding portion 20*t* so that the mutual coupling of the two portions of winding 20 causes the field to collapse rapidly. This action permits the net flux in core member 12 to return to the flux value produced by winding 18 so that movable member 14 is reattracted to core member 12 and actuator 16 is returned to the print ready position.

In the embodiment of the invention shown, switching means 24 comprises a transistor. Selective operation of the print hammer actuator is accomplished by applying a suitable signal to the base terminal 28 of transistor 24 such as a PRINT CHARACTER signal from the associated data processing system.

Energy storage means 22 comprises a capacitor and impedance element 26 comprises a resistor in the embodiment shown. It will be recognized by those skilled in the art that this circuit will produce many different variations in the relationship of the peak current to the steady state current and the duration of each of the currents by the choice of the values of the circuit components and the ratio of turns in the two section of coil 20. For example, if a particular embodiment resistor 26 is 5 ohms, capacitor 22 is 50 microfarads, coil portion 20*b* has 40 turns, coil portion 20*t* has 60 turns, transistor 24 is a silicon power transistor, and the voltage source is 48 volts. Using this circuit, the resultant collector current of transistor 24, the flux in magnetic core member 12 and the displacement of member 16 are substantially as shown in FIGURE 3.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in the form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A driver circuit comprising:
- a first circuit path including first and second coil portions and an energy storage means;
- a second circuit path including an impedance element and said second coil portion;
- means for initiating current in said first circuit path to produce an initial current of a first magnitude;
- said second circuit path being coupled in shunt with said first circuit path so that storage of energy in said energy storage means is effective to progressively shunt current to said second circuit path to produce a current of a second lower magnitude in said coil; and
- means for interrupting the current in said circuit whereby said energy stored in said energy storage device is effective in rapidly driving the current in said coil to substantially zero.

2. An actuator driver circuit comprising:
- an actuator coil operatively associated with the magnetic circuit of said actuator,
- a first circuit path including first and second actuator coil portions and an energy storage means;
- a second circuit path including an impedance element and said second coil portion;
- means for initiating current in said first circuit path to produce an initial current of a first magnitude;
- said second circuit path being coupled in shunt with said first circuit path so that storage of energy in said energy storage means is effective to progressively shunt current to said second circuit path to produce a current of a second lower magnitude to said actuator coil; and
- means for interrupting the current in said driver circuit whereby said energy stored in said energy storage device is effective in rapidly driving the current in said actuator coil to substantially zero.

3. The driver circuit according to claim 1 wherein said energy storage means comprises a capacitor.

4. The driver circuit according to claim 1 wherein said means for initiating current in said first circuit path and said means for interrupting the current comprises a transistor.

5. The actuator driver circuit according to claim 2 wherein said energy storage means comprises a capacitor.

6. The actuator driver circuit according to claim 2 wherein said means for initiating current in said first circuit path and said means for interrupting the current comprises a transistor.

7. A driver circuit comprising a tapped control winding, a voltage source, a capacitor, a switching means and an impedance element;
- means for coupling one end of said control winding to said voltage source;
- means for coupling the other end of said control winding to one terminal of capacitor;
- means for coupling the other terminal of said capacitor to one terminal of said switching means;
- means for coupling the other terminal of said switching means to a reference potential;
- means for coupling an impedance element from said tap on said control winding to said other terminal of said capacitor; and
- means for selectively energizing said switching means for a predetermined time to produce an initial high current in a first time which drops to a lower current at a second time and drops to substantially zero at the end of said predetermined time.

8. A print hammer actuator comprising:
- a control winding operatively associated with a magnetic circuit, said control winding being divided into two portions;
- circuit means to selectively energize said control winding to produce a flux in said magnetic circuit to produce one cycle of operation of said actuator;

said circuit means comprising a first circuit path including said first and second control winding portions and an energy storage means;

a second circuit path including an impedance element and said second winding portion;

means for initiating current in said first circuit path to produce an initial current of a first magnitude;

said second circuit path being coupled in shunt with said first circuit path so that storage of energy in said energy storage means is effective to progressively shunt current to said second circuit path to produce a current of a second lower magnitude to said control coil; and

means for interrupting the current in said circuit means whereby said energy stored in said energy storage device is effective to rapidly drive the current in said control coil to substantially zero to produce a substantially square wave of flux.

9. A print hammer actuator comprising:

a control winding operatively associated with a magnetic circuit, said control winding being divided into two portions;

means to produce a predetermined level of flux in said magnetic circuit;

circuit means to selectively energize said control winding to produce a flux to buck said predetermined flux in said magnetic circuit to produce one cycle of operation of said actuator;

said circuit means comprising a first circuit path including said first and second control winding portions and an energy storage means;

a second circuit path including an impedance element and said second winding portion;

means for initiating current in said first circuit path to produce an initial current of a first magnitude;

said second circuit path being coupled in shunt with said first circuit path so that storage of energy in said energy storage means is effective to progressively shunt current to said second circuit path to produce a current of a second lower magnitude to said control coil; and

means for interrupting the current in said circuit means whereby said energy stored in said energy storage device is effective to rapidly drive the current in said control coil to substantially zero to produce a substantially square wave of flux.

10. An inductive circuit driver comprising a coil, a capacitor, a resistor, a switching means and a voltage source;

means for connecting said coil in series with said capacitor, said switching means, and said voltage source;

means for connecting said resistor in parallel with said capacitor and a portion of said coil; and

means for selectively energizing said switching means for a predetermined time to produce an initial high current in a first time which drops to a lower current at a second time and drops to substantially zero at the end of said predetermined time.

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U.S. Cl. X.R.

317—148.5, 151, 155, 155.5