Sept. 9, 1969 R. A. RAGEN 3,466,507

DRIVE CIRCUIT

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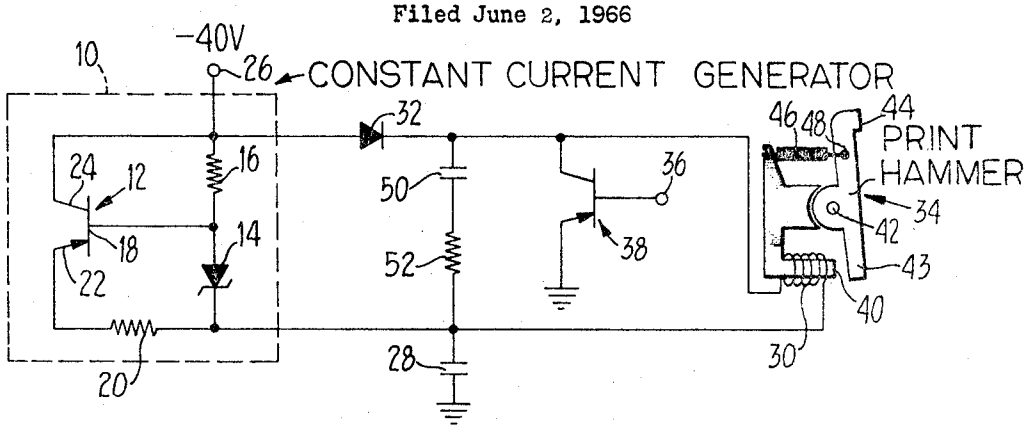


FIG_1

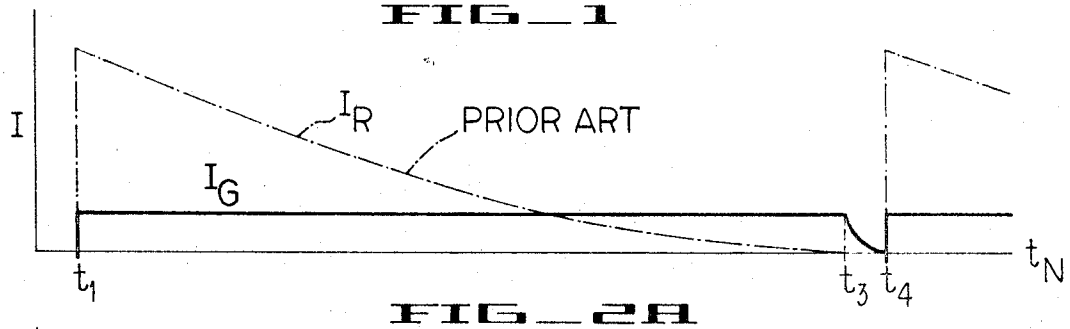


FIG_2A

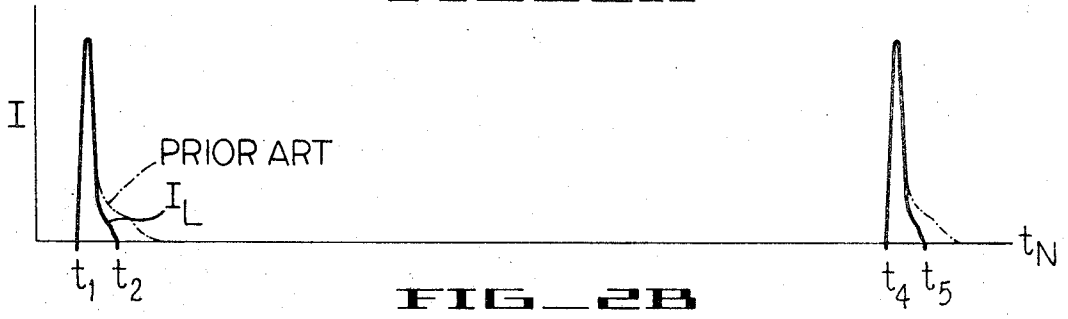


FIG_2B

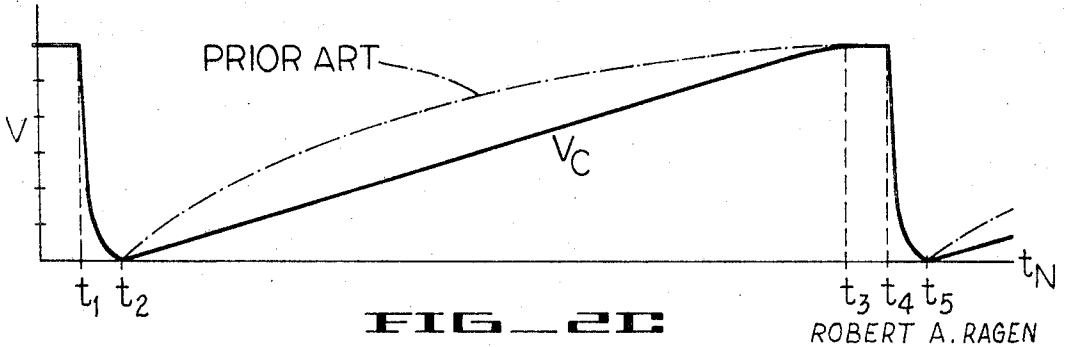


FIG_2C

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DRIVE CIRCUIT

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U.S. Cl. 317—148.5 4 Claims

ABSTRACT OF THE DISCLOSURE

A drive circuit is disclosed having a storage capacitor which is charged by potential source through a constant current regulator and discharged through an inductive load to a reference potential. A unidirectional conducting device is connected between the load and the potential source in order to dissipate the current flowing through the load after the discharge path is interrupted. One such inductive load comprises a coil disposed about a magnetizable core which actuates a pivotable print hammer when the coil is energized. The discharge circuit is adapted to be deactivated in such a manner that the hammer smartly strikes its target in a nonrepetitive fashion.

This invention relates to a drive circuit and, in particular, to a solid state circuit for driving a print hammer utlized in high-speed printer apparatus.

Current technology imposes stringent requirements for high speed in the processing of information or data. This is especially true when providing readout equipment for storage computers. Since computers generally operate at electronic speeds, and printers are basically electromachanical in nature and thus slower in operation, continuous efforts are being made to increase the speed of operation of such printers.

One element of a high-speed printer which is of particular concern is the print hammer. Prior art print hammer drive circuits generally employ electromagnetic actuater, including a coil, to urge the hammer forward to strike a paper target for imprinting. The coil receives energizing current from a discharging capacitor, which is coupled to a power supply through a resistance. Generally, the charging current for the capacitor is a very high peak current, which unduly loads the power supply. Also, in such known circuits, when the drive pulse to the coil is terminated, the change of current in the coil is opposed by the reverse voltage developed by the coil, thus prolonging the fall of the coil current to zero value. Consequently, the hammer may be retarded in its return to home position, or may be activated to move forward again prior to returning to its home position. Thus, the printer apparatus may experience smearing or spurious repetitive striking of the hammer at a single character position, among other things.

An object of this invention is to provide a novel and improved drive circuit for a print hammer assembly.

Another object of this invention is to provide a drive circuit that utilizes substantially less peak power than prior known drive circuits of this type.

Another object is to provide a hammer drive circuit for a high-speed printer apparatus wherein erratic printing is effectively eliminated.

According to this invention, a drive circuit useful with a print hammer of a high-speed printer comprises an electromagnetic actuator, including an inductive coil, which is energized to cause the hammer to move rapidly from a home position to a striking position. The coil receives an energizing current pulse from a discharging capacitor that is coupled to a power supply through a constant current regulator. The current required for operation is held to a value determined by the current

regulator and as a result peak power requirements are greatly reduced. Also, the inventive drive circuit includes a unidirectional conducting device for causing current in the coil to swiftly fall to a negligible value when the drive circuit is opened, thereby affording a rapid, uninterrupted return of the hammer from the target to home position.

The invention will be described in greater detail with reference to the drawing in which:

FIG. 1 is a schematic diagram depicting the novel drive circuit, as used with a print hammer; and

FIGS. 2A through 2C are plots of current voltage against time, contrasting the performance of prior art drive circuits with that of the present inventive circuit.

With reference to FIG. 1, the drive circuit comprises a constant current generator which consists of negative voltage source **26** and constant current regulator **10**. Regulator **10** includes a PNP transistor **12**, a Zener diode **14**, a resistor **16** coupled to the base **18** of the transistor **12**, and a resistor **20** connected to the emitter **22** of the transistor **12**. The collector **24** and one end of the resistor **16** are coupled to a source of negative potential **26**; whereas the emitter circuit of the transistor **12** and the cathode of the Zener diode **14** are coupled to a source of reference potential, such as ground, through a capacitance **28**. The transistor base **18** is connected to the junction of resistor **16** and the anode of the Zener diode **14**. The transistor emitter circuit and capacitance **28** are coupled to one end of the coil **30**. The other end of the coil is coupled to the collector of switching transistor **38** and to the cathode of diode **32**. The emitter of transistor **38** is connected to ground; the anode of diode **32** is connected to voltage source **26**.

During the charging period, capacitor **28** charges linearly through constant current regulator **10** to a value determined by the voltage source **26** and the parameters of the regulator. As shown in FIGS. 2A and 2C, the charging current I_G is maintained at constant value until the capacitor is fully charged, at which time the current drops to zero value. Since the charging current is constant, loading of the source **26** remains constant during the charging cycle. This is in contrast to prior art systems utilizing a voltage source charging a capacitor through a resistor, in which the charging current I_R (FIG. 2A) rises quickly to a maximum value and then decreases exponentially, thereby causing heavy loading of the source over a large portion of the cycle and a consequent heavy power consumption. During the charging of the capacitor **28**, switching transistor **38** is turned off and diode **32** is reverse biased so that no current will flow through the coil **30**.

In order to actuate the load which, in this case, is a print hammer **34**, a pulse of negative polarity is applied to the base terminal **36** of a grounded emitter PNP transistor **38**, biasing the transistor **38** into conduction. The negative pulse may be a square wave of short duration, developed by depression of a key in a printer keyboard, by way of example. When the transistor **38** conducts, a current path including the coil **30** is established, resulting in the discharge of capacitor **28** through the coil **30** and transistor **38** to ground. During this interval, the current in the coil at first rises swiftly to a peak value, quickly drops, and then approaches a limiting value, which is the value of the current supplied by the constant current generator. If switching transistor **38** were left on for a relatively long period of time, the current through coil **30** would assume this value.

During the interval of current flow though the coil **30**, a core **40**, encompassed by such coil, is energized, which magnetically attracts one end **43** of the steel print hammer **34**. The hammer rotates about a pivot **42** in response to the attractive pull of the solenoid core **40**. As a result, the other end or head **44** of the print hammer **34** is pro-

pelled with sufficient force so as to traverse a distance sufficient to strike its target, which may be a paper or other record medium disposed adjacent to a character support or other data imprinting device.

Upon termination of the negative pulse to the base of switching transistor **38** (or upon application of a pulse of positive polarity), this transistor is turned off which opens the path between coil **30** and ground. This causes the current through the coil to begin to decrease very rapidly. This rapid decrease is opposed by the coil and a reverse voltage of extremely high magnitude develops across the coil. Since capacitor **28** is at nearly ground potential as shown in FIG. 2C wherein V_C represents the magnitude of the capacitor potential, the end of coil **30** which is connected to the cathode of diode **32** assumes a negative potential much lower than the potential of source **26**. This forward biases diode **32**, thereby providing a conductive path through the diode to source **26** for the aforementioned rapidly decreasing current in the coil. This path remains open so long as the end of coil **30** which is connected to the cathode of diode **32** is at a lower potential than source **26**. This remains true so long as the current in coil **30** is decreasing rapidly. Thus, the opposition to the reduction of current flow in the coil is effectively removed, allowing the current in the coil to fall swiftly to zero, as shown in FIG. 2B, wherein I_L represents the coil current. When the rate of change of coil current becomes zero, the potential across the coil becomes zero which reverse biases diode **32**, thereby opening this current path. When this occurs (at time t_2), the current in the coil also becomes zero and the capacitor **28** begins to charge again.

This method of damping the coil current after turning off the switching transistor **38**, wherein an alternate path including the diode is provided for current to flow, substantially dissipates all the energy in the coil **30**, whereby the hammer **34** is no longer attracted to the core **40**. The damping technique disclosed herein takes place in a much shorter time than that achieved by previously known methods, as can be seen from FIG. 2B. This damping occurs before the lower end **43** of the hammer reaches the core **40**. Thus the solenoid is de-energized and the force of attraction is terminated while the hammer is still pivoting (clockwise as shown) with the hammerhead **44** moving forward in the direction of the target. The head **44** of the hammer nevertheless maintains its forward motion toward the target by virtue of its momentum. The current in the coil **30** is substantially at zero before the hammer strikes the paper, so that the hammer does not dwell on the paper. This eliminates smearing and a multiple impression of the imprinted character.

Immediately after the head **44** contacts the target, a resilient means or spring **46** acts to retract the head of the hammer freely to reset position, from which the hammer may be actuated again for the next strike at a succeeding print position. The spring **46** is linked to an aperture **48** in the hammer assembly **34**, the aperture being disposed adjacent to the hammerhead **44** and at the other side of the pivot point than the hammer end **43** which is located in juxtaposition to the solenoid **30**. After the hammer has rebounded to rest or normal position, the capacitor **28** continues to charge, and the hammer is ready for the next actuating signal to print.

The drive circuit also includes a capacitor **50** and resistor **52** that serve as an R.F. suppressor, which minimizes noise and transient effects.

The drive circuit of this invention allows a substantial reduction in peak power, in the order of 5:1, for example. In a successful embodiment of this invention, power requirements for charging a capacitor used in a hammer drive circuit of a high-speed printer were reduced from 1 ampere to 200 milliamperes approximately.

The drive circuit of this invention provides energy for urging a print hammer forward to impinge on the paper target, and also to rebound from the paper upon impact. Since substantially no current flows in the coil **30** at the instant of the impact, the hammer may return freely to its home position. In addition, the print hammer can be retracted rapidly so that its action is compatible with the the high-speed operation of the printer apparatus.

In a successful embodiment of the novel circuit, typical values of circuit elements were as follows:

Transistor **12**		2N669
Transistor **38**		2N1358
Resistor **16**	ohms	330
Resistor **20**	do	22
Resistor **52**	do	22
Capacitor **28**	μfarads	120
Capacitor **50**	do	0.1
Coil **30**	millihenries	5.6
Zener diode		1N709

It is understood that the invention is not limited to the particular values or parameters set forth above, and that modifications may be made within the scope of this invention.

What is claimed is:

1. A print hammer drive circuit for intermittently driving an inductive load to cause a print hammer to strike a target in nonrepetitive fashion comprising:

a storage capacitor;

a constant current generator means for charging said capacitor at a constant rate comprising a source of electrical potential and a constant current regulator coupled between said source and said capacitor;

an inductive load comprising a coil disposed about a magnetizable core;

a pivotable print hammer responsive to energization of said coil, said print hammer having a head end and a core end;

means coupled to said capacitor for discharging said capacitor through said load at desired intervals, said discharging means including a switching transistor coupled between said inductive load and a reference potential and adapted to be deactivated before said head end strikes its target; and

means coupled to said load for dissipating the current in said load before said head end strikes its target upon deactivation of said discharging means, said dissipating means comprising a unidirectional conducting device coupled between said load and said source for enabling current to flow from said load to said source when said discharging means is deactivated.

2. The circuit of claim **1** wherein the collector of said switching transistor is coupled to one end of said load and the emitter of said switching transistor is coupled to said reference potential.

3. The circuit of claim **1** further including means for biasing said head end of said print hammer away from said target.

4. The circuit of claim **3** wherein said biasing means comprises a spring coupled to said print hammer.

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U.S. Cl. X.R.

317—151; 320—1