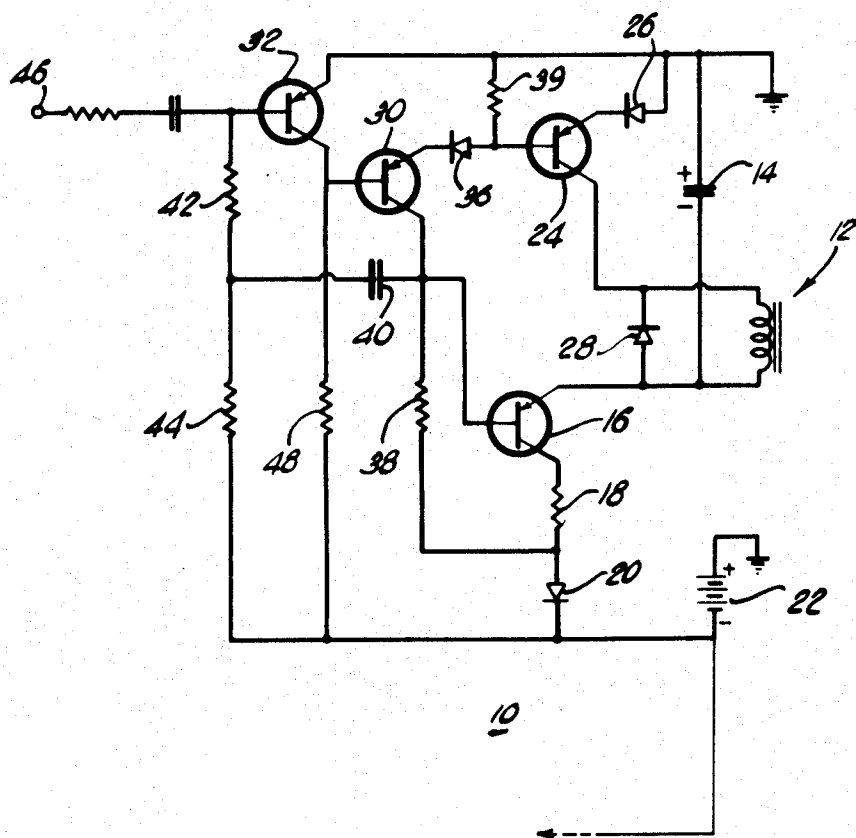


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SOLENOID FIRING CIRCUIT

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TO ONE OR MORE ADDITIONAL SOLENOID FIRING
CIRCUITS IDENTICAL TO THAT ABOVE

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3,140,428 SOLENOID FIRING CIRCUIT

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This invention relates to an improved electric circuit for firing a type-hammer solenoid and the like, in a high speed printer such as described in the inventor's U.S. Patent No. 2,787,210.

An object of this invention is to provide a solenoid firing circuit which operates with as great reliability and efficiency as previously known circuits, but which makes less stringent demands on the power source which energizes it.

A more specific object is to provide such a firing circuit which is virtually immune to transients in power supply voltage and which does not interact with other such circuits connected to the same power supply.

These and other objects will in part be understood from and in part pointed out in the description given hereinafter.

In a high speed printer of the kind described in the above-identified patent, a strip of paper is passed through the machine and printed upon by blows from an array of hammers positioned beneath the paper and fired upward to drive the paper against corresponding ones of a like array of type wheels. These type wheels are mounted side-by-side in the form of a cylindrical drum and carry around their periphery alpha-numeric characters to be printed on the paper. The type wheel assembly is rotated at high speed, for example 1200 r.p.m., and the paper is moved step-by-step at high speed, for example in 10 to 15 milliseconds per shift, so that the printing operation can be carried out at a very rapid rate. Each hammer is in the form of a long, thin rod which is fired or impelled end first upward against the paper to press it against a selected one of the characters around the rim of corresponding type wheel. The time of printing is very short, of the order of fifty microseconds, so that even though the type wheel is continuously rotating its movement is effectively "frozen" during each hammer blow.

In this machine each hammer is propelled against the paper by an electromagnet or solenoid which is energized at the proper instant by a firing circuit electronically controlled to print any desired character. Each hammer, and there may be for example 190 hammers in a machine, is accompanied by an electromagnet to fire it and by a corresponding firing circuit to energize the electromagnet. Thus in a single printer a vast number of electric circuits for firing the hammers is required.

In a high speed printer of this kind, the firing circuit for each type-hammer must be able to energize the coil or solenoid of the hammer-firing electromagnet with a carefully regulated current. This current must suddenly and accurately be applied to the coil in order to fire the hammer at the precise instant and velocity required for it to drive the paper against a particular type character of the continuously rotating type wheel. Moreover, the energy applied to the coil must be uniform each time, and uniform from coil to coil, otherwise the hammers will print too early or too late with too much or too little energy.

Now, one of the problems encountered here is how to supply a large number of hammer firing circuits for example, 190, with electric power. Each circuit when on, must supply to its hammer firing solenoid as much as ten amperes of current and about two or three hundred watts of direct current power, for example. Thus, when all of the circuits are turned on at once, approximately 50 to 60 kilowatts of power is delivered to the solenoids. But it is expensive to provide a power supply with suffi-

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ciently low impedance and good enough regulation so that it can properly energize the hammer firing circuits with pulses of power of this order of magnitude.

The present invention provides a solenoid firing circuit which operates very satisfactorily from even a poorly regulated power supply. This circuit at the moment it is energizing a solenoid effectively disconnects itself from the power supply, the energy applied to its respective solenoid being drawn from a relatively small storage capacitor in the circuit. Thus a large number of these circuits can be connected to a single, relatively low quality direct current supply. The circuits are isolated from each other during their "firing" times so that each will operate uniformly regardless of how many or how few circuits are driving their solenoids at any given instant.

In accordance with the invention in one specific embodiment thereof, a storage capacitor is arranged to be charged from a direct voltage power supply through a first transistor and to be discharged through a second transistor into a hammer-firing solenoid. These two transistors are controlled by a third and a fourth transistor which serve as a self-timing driver to generate a fixed duration high current low impedance pulse in response to a momentary trigger signal. Though the charging and discharging transistors in this circuit have relatively low power-handling capacities in terms of their conventional ratings, they are operated here in a way which permits the solenoid to be energized with uniform amounts of energy at quite high peak power, the peak power being much in excess of the conventional power ratings of these transistors.

When the circuit is initially connected to the power supply, the charging transistor is biased on and charges the storage capacitor through a low ohmage path to the peak supply voltage. Thereafter, the capacitor stays at this voltage, though the supply voltage may fluctuate down and back up, until the discharging transistor is turned on. Then, the capacitor is discharged through a practically zero resistance path into the solenoid coil. Simultaneously, during this interval the charging transistor is turned off so that the power supply now has no influence on the circuit. When the discharging transistor is turned off at the end of the momentary driver pulse, the charging transistor is again turned on. The storage capacitor is thus again recharged in preparation for the next cycle of operation, and so on. Since the "firing" time of the circuit is only a small fraction of the total time of a complete charge-discharge cycle, there is plenty of time available to charge the storage capacitor before the hammer solenoid must again be energized. Since this capacitor effectively is charged to the peak value of supply voltage, the effects of ripple, hum, transients and so forth in the supply voltage are minimized. Also, the interaction of one circuit upon another connected to the same supply is practically eliminated.

A better understanding of the invention together with a fuller appreciation of its many advantages will best be gained from the following description given in connection with the single figure of the accompanying drawing which is a schematic diagram of a circuit embodying features of the invention.

The circuit 10 shown in the drawing is connected at the right to a hammer firing solenoid 12. Connected between the lower side of this solenoid and ground is a storage capacitor 14 which is adapted to be charged in the polarity indicated through a charging transistor 16. The collector electrode of transistor 16 is connected through a low ohmage resistor 18 and a diode 20 to the negative terminal of a direct voltage power supply 22 (shown schematically as a battery), the positive side of which is grounded. The upper side of solenoid 12 is connected through a discharging transistor 24 and a diode

26 to ground. After capacitor 14 has been charged, it can be discharged through solenoid 12 by transistor 24 when it is turned on. To prevent damage to discharge transistor 24 by a reverse kickback voltage across solenoid 12 upon interruption of current through the solenoid, the solenoid is shunted by a diode 28 which clips this negative voltage.

Transistor 24 is controlled by a driver transistor 30 and a transistor 32. The latter two transistors are connected as a self-timing pulse generator. When transistor 30 is turned on, it draws current through a diode 36 from the base of transistor 24 thereby driving it into saturation. This enables capacitor 14 to discharge into solenoid 12. When driver transistor 30 turns on it draws current through resistor 38, and the resultant voltage drop turns off charging transistor 16, thereby disconnecting both it and the power supply from solenoid 12 and capacitor 14. When driver transistor 30 turns off, a small current through a resistor 39 from the base of transistor 24 to ground turns off transistor 24.

The length of time that transistor 30 remains on is determined by a feedback capacitor 40 and a voltage dividing network consisting of a resistor 42 and a resistor 44. A positive trigger pulse applied to the base electrode of transistor 32 from an input terminal 46 causes transistor 32 to turn off. This allows the potential on the base of transistor 30, this base being connected to the negative side of battery 22 by a resistor 48, to go negative. This turns on driver transistor 30, one result of which is to apply a positive potential to capacitor 40 which in turn holds transistor 32 off for a pre-determined time. When capacitor 40 has discharged to a certain point, transistor 32 automatically turns on and stays on until triggered off again.

Diode 20, which is a silicon type and has a forward voltage drop of about 0.6 volt across it when conducting, serves as a non-linear resistance in the charging circuit to capacitor 14. When the capacitor is initially charging, this diode offers very low resistance, but when the capacitor is almost charged, the diode offers a very high resistance thereby providing effective de-coupling from the power supply. This diode also prevents voltage transients in the power supply from triggering off transistor 32.

Diodes 26 and 36, which are also silicon types, insure that when transistors 24 and 30 are off, they are fully off. Resistor 18 in addition to providing an impedance in the charging path to capacitor 14, permits transistor 16 when on to be saturated.

In a circuit substantially identical to circuit 10 which has been built and successfully operated, the following elements and values were found satisfactory: transistor 16, and 30, type 2N586; transistor 24, type 2N1146; transistor 32, type 2N426; capacitor 14, 150 microfarads, resistor 18, 5 ohms; resistor 39, 39 ohms; resistor 38, 47 ohms; capacitor 40, 0.33 microfarad; resistor 42, 2.2K ohms; resistor 44, 6.8K ohms; resistor 48, 1K ohms; diodes 20, 26, 28, and 36 type 1N2069; the supply voltage was 27 volts, and solenoid 12 had a resistance of about 3 ohms. One hundred and ninety circuits 10 were energized from the same power supply 22.

The above description is given in illustration and not in limitation of the invention. Various changes or modifications in the embodiment described may occur to those skilled in the art and these can be made without departing from the spirit or scope of the invention as set forth.

I claim:

1. A solenoid firing circuit of the character described comprising a solenoid coil, a storage capacitor, a charging

transistor, low ohmage means connecting said capacitor and charging transistor in series with voltage supply terminals adapted to be energized by a direct voltage, a discharging transistor connecting said capacitor across said coil, a driver transistor connected to turn said discharging transistor fully on and to turn said charging transistor off and vice versa, and means to turn said driver transistor on and off, whereby said circuit operates efficiently without interference from other such circuits connected to a common power supply.

2. The circuit in claim 1 wherein said low ohmage means includes a resistor to limit the charging current to said capacitor.

3. The circuit in claim 1 wherein said capacitor and charging transistor are connected in series, one side of said coil being connected to the junction of said capacitor and transistor, said coil and said discharging transistor being connected in series with said capacitor.

4. The circuit in claim 3 wherein said driver transistor has two low ohmage resistors connected in series with it and said voltage supply terminals, the voltage drops across said resistors controlling said charging and discharging transistors.

5. The circuit in claim 1 wherein each of said transistors has in series with it a respective one of three current blocking diodes.

6. The circuit in claim 4 wherein said coil is shunted by a clipping diode.

7. In a multi-load arrangement of the character described, a direct voltage power supply, and a plurality of load energizing circuits connected thereto, each of said circuits including a load adapted to be energized with a pulse of current, a storage capacitor, a charging transistor connected to supply current from said supply to said capacitor, a discharging transistor connecting said capacitor across said load, and driver means to turn on said discharging transistor and simultaneously turn off said charging transistor and vice versa, whereby each of said circuits is isolated from the others and said supply when energizing its respective load.

8. A multi-load, single power source arrangement in which each load is to be energized, independently and with minimum interference from the others, said arrangement comprising a relatively low quality power source, a first load which may be energized at independent times, a discharging transistor, a charging capacitor, a charging transistor, said load, charging capacitor, and discharging transistor being connected in series, low ohmage means connecting said charging capacitor in series with said power supply, externally controllable switch means to turn said discharging transistor on and simultaneously turn said charging transistor off and vice versa, and at least one additional load and corresponding discharging transistor, charging capacitor, charging transistor, low ohmage means and switch means connected together and to said power supply in the same way as said first load and its associated elements.

9. The arrangement in claim 8 wherein said low ohmage means includes a de-coupling diode connected between said charging transistor and said power supply.

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