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

An object of this invention is to provide a hammer firing circuit which can be made at lower cost than previously known circuits and which will operate with greater reliability and efficiency.

A more specific object is to provide such a firing circuit which can be made more compactly and have greatly increased service life, together with increased ruggedness and reliability.

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 a hammer in 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 twenty lines a second, 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 first upward against the paper to press it against a selected one of the characters around the rim of the 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 which is energized at the proper instant by a firing circuit electronically controlled to print any desired character. Each hammer, and there may for example be 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 simple printer a vast number of electric circuits for firing the hammers is required. Accordingly, it is very desirable to have these circuits as inexpensive and as compact and reliable as possible. The present invention accomplishes these objectives.

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 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 not be too great nor too small, otherwise the hammer will print with too much or too little energy. A printer may be operated many hours a day for days-on-end, billions of hammer blows will be made during the life of the unit and this demands an extremely high degree of reliability in the electronic circuits which time and fire the hammer.

Previous circuits which have been used throughout the industry to fire hammers in a printer of this general kind employ a relatively large storage capacitor which is charged to a high voltage, for example 600 volts, and then suddenly discharged by means of a thyratron into the coil of its hammer-firing electromagnet. Not only does a circuit of this kind require relatively large standby power and dangerous high voltages but it is relatively inefficient in its operation and poor in reliability. The service life of the thyratron tube in this heavy duty application is limited, and because of the overall inefficiency in the way this circuit operates it is expensive in terms of size of components and in power consumed. The present invention provides a much simpler and far more effective circuit for energizing the hammer-firing electromagnets.

In accordance with the present invention a power transistor is operated as a switch at low voltage and very high current to energize an associated hammer-firing electromagnet. This transistor is operated and controlled by several other transistors to turn on at precisely the desired instant and for a carefully regulated time. It is operated in such a fashion that it is able to handle powers far in excess of its normal rating as an amplifier. By using an all-transistor switching arrangement of this kind, very high speed operation yet extremely precise firing control is obtained and there is need of no storage capacitors which might otherwise tend to cause oscillations in conjunction with the hammer electromagnet. By doing away with these storage capacitors, the delay in discharging them is eliminated and this increases the maximum speed of the printer. The standby power consumption of this transistor circuit is extremely low and this means that a multitude of these circuits can be enclosed in a small cabinet without causing harmful overheating. With this circuit by controlling the "on" time of the power transistor, it is a simple matter to adjust the amount of energy applied to the hammer-firing electromagnet. The power transistor can be triggered on by its associated transistors in response to a very low energy pulse and accordingly the circuit is fully compatible with existing computing equipment normally associated with a high speed printer of this kind. By virtue of the unique way in which the circuit operates, the power or output transistor can be a very inexpensive one rather than one specially designed for high short circuit power dissipation and which at the present time would be very expensive.

A better understanding of the invention together with a fuller appreciation of its many advantages will best be gained from a study of the following description given in connection with the accompanying drawings wherein:

FIGURE 1 shows a type-hammer firing arrangement embodying features of the invention; and

FIGURE 2 shows typical current-voltage curves for a power transistor with certain load lines superimposed on these curves.

The arrangement shown in FIGURE 1 comprises an electric hammer-firing circuit, generally indicated at 10, which is connected by means of a pair of wires 12 to a type-hammer assembly generally indicated at 14. The latter, which is described in more detail in the aforementioned patent, includes an electromagnet 16 having two coils 18 wound on a U-shaped iron core which in turn is part of a stationary frame 20. Positioned within the coils is an armature 22 which is pivoted to the frame at 24 and which when the coils are energized is drawn quickly upward against the core. The normal rest position of armature 22 is determined by a set screw 26, and the armature is urged into this position by a tension spring 28.

When the electromagnet is energized the right end of the armature is moved at high velocity upward and into contact with the rear end of a type hammer 30. This imparts an upward velocity to the hammer which then flies as a free projectile out of contact with the armature...
When driver transistor 48 is turned on, a positive voltage is generated across load resistor 56 and this is fed back over a lead 78 wheel 08. This hammer blow (which may be of the order of 50 microseconds in duration) prints a letter on the paper and then the hammer quickly returns to the position shown and the paper advances to the next line prior to printing another letter. The paper may be printed at speeds of up to twenty lines per second. In a single machine there may, for example, be 190 hammers arranged side-by-side in a row perpendicular to the plane of FIGURE 1, each hammer being controlled by a separate circuit 10.

As will be appreciated, the instant of firing of hammer 39 may be precisely controlled in time in order for it to strike a desired one of the characters around wheel 38 as it rotates. At the precise instant, determined by a timing or trigger pulse applied to circuit 10, electromagnet 16 is suddenly connected via leads 12 by means of a power transistor 40 across a battery 42 (or other suitable low resistance source) whose positive side is grounded. The current build-up thereafter in coils 18 is very rapid (being determined by their inductance). The time delay between the triggering of circuit 10 and the printing of a character is small, but whatever delay is incurred, however, is uniform from cycle to cycle so that once the triggering pulse has been adjusted for proper printing it can be left alone. The same triggering pulse can be used to actuate only one hammer or all of the hammers in the machine at the same time. Some control of the instant of printing of any given hammer without adjustment of the triggering pulse can therefore be effected simply by controlling the length of time during which voltage from battery 42 is applied to coils 18.

In order to turn transistor 40 on and fire the hammer, the base 44 of the transistor is suddenly made negative and a heavy current drawn from it. To this end base 44 is connected to the emitter 46 of a driver transistor 48, emitter 46 being connected in series with a resistor 50 to the positive side of a bias battery 52 whose negative side is connected to the emitter of transistor 40 and the positive terminal of battery 42. The collector 54 of transistor 48 is connected through a current-controlling resistor 56 to common lead 55. This lead is connected through a de-coupling resistor 60 to the negative side of battery 42 and is bypassed to ground by a large filter capacitor 61. Current drawn from base 44 of transistor 40 is returned to the emitter through transistor 48, resistors 56 and 60, and battery 42. When current flows in the circuit, it draws a heavy current from the base of transistor 40 so that the emitter-to-collector resistance of this transistor is extremely small. Thus, for load currents through the transistor far in excess of normal rated value, the voltage drop across and power dissipated in it are still well within permissible ratings. The maximum current which flows through this transistor when on is determined primarily by the voltage of battery 42 and the resistance of coils 18. To prevent transistor 40 from being damaged by inductive surge from coils 18 when the transistor is turned off, the collector of the transistor is bypassed to the negative side of battery 42 by a rectifier 58 which prevents the collector from going too negative.

The base 62 of transistor 40 is connected to the collector 63 of a transistor 64, this collector being also connected to lead 59 through a low-value load resistor 66. The emitter 60 of transistor 64 is connected to the positive side of battery 52 so that the transistor is normally biased on. The base 70 of transistor 64 is biased through a diode 72 and a diode 74 connected in series to the positive terminal of battery 42. The junction of diodes 72 and 74 is connected through a high value bias resistor 75 to lead 59. Normally transistor 64 is turned on but when a positive pulse is applied to base 70 through capacitor 76 from a timing or trigger source (not shown) the transistor is turned off. This turns transistors 48 and 40 on to fire hammer 30.

FIGURE 2 shows curves of emitter-to-collector voltage (Vce) versus current (Iec) for various emitter-to-base bias currents (Ieb) and illustrates the mode of operation of transistor 49. When off, the current through this transistor is substantially zero and the voltage across it is equal the voltage of battery 42 as indicated at point A. When the emitter-to-base current of the transistor is suddenly increased to saturation value, as indicated by point B, the internal resistance of the transistor drops from a value of many thousands of ohms to nearly zero. At saturation, i.e. any value of base current where the current from emitter to collector is primarily determined by the load resistance and supply voltage, the voltage drop from emitter to collector for a germanium transistor is only a tenth of a volt or so. When the current flowing into coils 18 through the transistor begins to build up, the coils are inductive and the load line follows along the curve L in FIGURE 2 instead of the straight line R which illustrates a resistive load. Accordingly, at no time in going from points A to B along curve L is the power dissipation of the transistor, indicated by curve P, exceeded. When the base of the transistor 49 is again turned off to turn transistor 48 off and collector suddenly jumps to point C and thereafter rectifier 58 immediately reduces the current to its value at point A. The time required for the current and voltage to change along line BCA is only a few microseconds; however, and hence though the normal power rating of the transistor may be momentarily exceeded, it is not damaged.

In an actual circuit arrangement which has been built and successfully operated, the following elements and circuit values were used: battery 42, 27 volts; battery 52, 2 volts; coils 10, 5 ohms total; transistor 40, BCA type 2N301 germanium and rated at 40 volts and 7 watts maximum; transistors 48, 46, and 44, RCA type 2N217; resistor 56, 47 ohms; resistor 50, 150 ohms; resistor 66, 1000 ohms; resistor 75, 100,000 ohms; resistor 82, 33,000 ohms, resistor 83, 1000 ohms, capacitor 80, 0.1 microfarad; resistor 69, 50 ohms; capacitor 61, 100 microfarads. The time transistor 40 remained on to each trigger pulse was of the order of 1 to 3 milliseconds. The maximum current (Iec at point B) was about 6 amperes and reached this value near the end of each on cycle. The voltage drop across transistor 40 at point B was about 0.2 volt.

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

I claim:

1. An improved hammer-firing arrangement for a high speed printer comprising: a hammer-firing solenoid, a low resistance source of voltage adapted to supply a relatively large pulse of current to said solenoid, a power transistor having its emitter and collector connected in series with said solenoid and said source, a rectifier connected across said solenoid and pulsed to prevent the voltage thereacross from reversing, a driver transistor having an input and an output, said output being connected to the base of said power transistor so that when said driver transistor is off said power transistor is off and when said driver transistor is on the base of said power transistor is biased to saturation and said power transistor conducts a large current with a small voltage drop across itself, a trigger transistor having an input and an output and which is normally turned on, said output being coupled to the input of said driver transistor, and time-constant positive feedback means for applying to the input of said trigger transistor a voltage pulse derived from the turning-on of said power transistor to keep said power transistor on for a controlled time.

2. The arrangement as in claim 1 wherein said trigger and driver transistors are interconnected so that when said trigger transistor is pulsed off by a momentary pulse, said driver transistor is turned on and holds said power transistor on and said trigger transistor off for a precise time determined by said feedback means.

3. The arrangement as in claim 2 wherein said power transistor is a Type 2N301 or its equivalent, said battery has a voltage of about 27 volts, and said solenoid has a resistance of about 5 ohms.

4. The arrangement as in claim 1 in further combination with inhibit means connected to said trigger transistor to prevent it from turning off.

5. A high speed controllable switching circuit comprising a relatively low resistance load, a very low resistance direct voltage source, a power transistor having an input and an output said output being connected in series with said load, and a plurality of transistors connected as a multivibrator arrangement and having an input and an output, said output being connected to the input of said power transistor and adapted to drive it to saturation so that its internal resistance is very low, said input of said multivibrator arrangement being adapted to be connected to an external signal source, said arrangement constituting a variable element whereby the power supplied to said load can be variably controlled.

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2,864,978 Frank ----------------- Dec. 16, 1958
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,997,632
August 22, 1961
Francis H. Shepard, Jr.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the drawings, Fig. 1, the upper resistor 75 which is connected to the positive side of battery 52 should be deleted.

Signed and sealed this 27th day of March 1962.

(SEAL)
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