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SOLENOID-DRIVING TRANSISTOR CIRCUIT WITH MEANS FOR LIMITING THE CURRENT IN THE SOLENOID TO A PREDETERMINED VALUE

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FIG. I

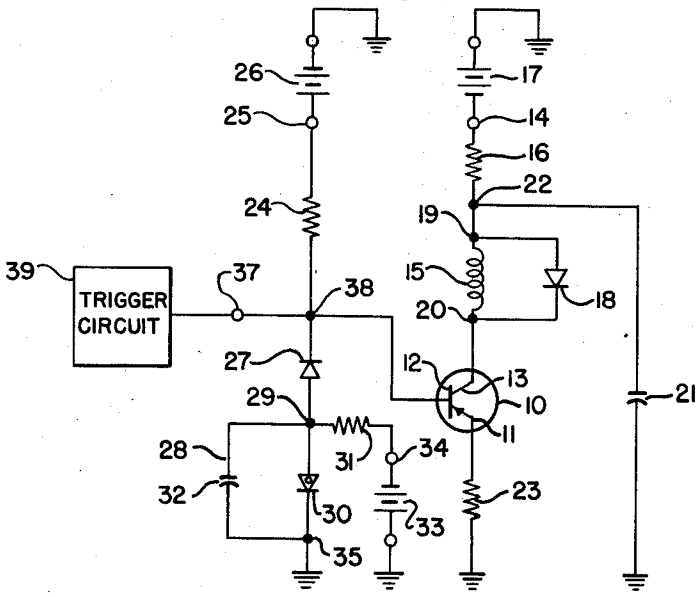
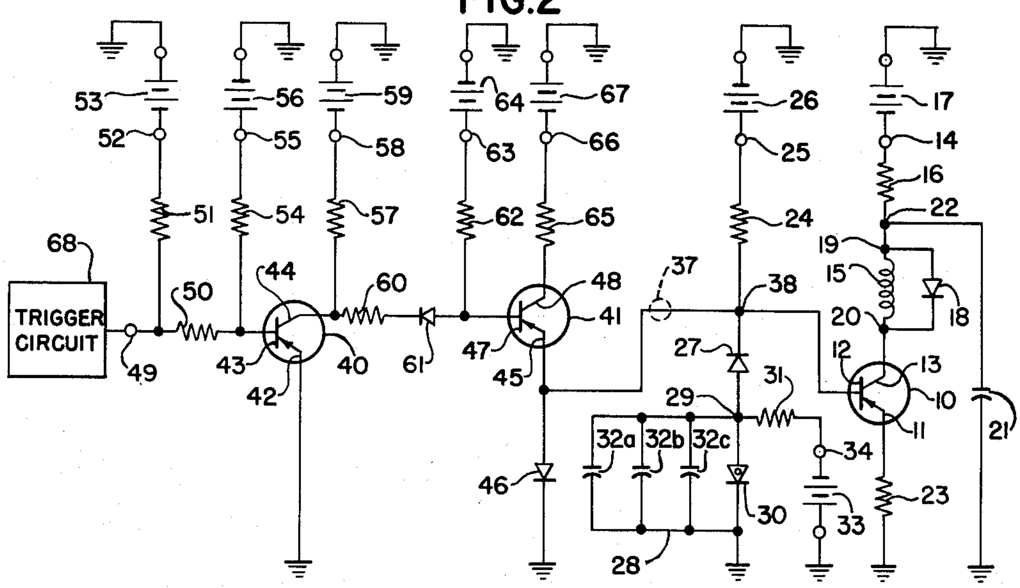


FIG. 2



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SOLENOID-DRIVING TRANSISTOR CIRCUIT WITH MEANS FOR LIMITING THE CURRENT IN THE SOLENOID TO A PREDETERMINED VALUE

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This invention relates to transistor circuits for controlling or driving electrical coils and solenoids, and, in particular, to transistor circuits for driving a solenoid associated with a hammer-actuating arrangement of a high-speed printer.

An object of the present invention is to provide a solenoid-driving transistor circuit which will operate with greater efficiency than previously-known circuits.

Another object is to provide a solenoid-driving transistor circuit utilizing as low a current as possible for energization of its solenoid.

A further object is to provide a high-speed low-current solenoid-driving transistor circuit.

A still further object is to provide a solenoid-driving transistor circuit using a control or input stage including a transistor connected in the emitter follower configuration for controlling the operation of an output transistor stage including the solenoid.

In a high-speed printer of the kind described in United States Patent No. 2,787,210, which issued to Francis H. Shepard, Jr., on April 2, 1957, 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 peripheries alpha-numeric characters to be printed on the paper. The type wheel assembly is rotated at high speed—for example, 1,200 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 a a very rapid rate. Each hammer is in the form of a long, thin rod which is moved end-first upward against the paper to press the paper 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 in its movement, it is effectively "frozen" during each hammer blow.

In the machine referred to, each hammer is moved against the paper by an electromagnet which is energized or driven at the proper instant by a driving circuit for said electromagnet. The driving circuit is so controlled electronically that any desired character may be printed. Each hammer—and there may be, for example, 120 hammers in a machine—is accompanied by an electromagnet to move it against the paper and by a corresponding driving circuit to energize the electromagnet. Thus, in a single printer, a vast number of electric circuits for actuating the hammers is required. The electromagnet is provided with two coils, for example, wound on a laminated core. When the electromagnet is energized, the armature is moved at high velocity into contact with the printing hammer. Thus, the printing hammer is moved against the paper to effect a printing.

It has been determined that the laminations of the core of the electromagnet will be substantially saturated at a predetermined value of current through the coils of the electromagnet. Accordingly, it was realized that an amount of current through the coils of the electromagnet exceeding the predetermined value would cause a negligible additional force to be imparted to the printing hammer and for the most part would be wasted. The present invention provides a highly efficient circuit for energizing the hammer-actuating electromagnets.

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In accordance with one aspect of the present invention, a solenoid-driving circuit comprising a transistor is provided to effect energization of an associated hammer-actuating solenoid which is operatively connected in the collector circuit of the transistor. A capacitor is discharged through the transistor and the solenoid during a printing time for the desired energization of the hammer-actuating solenoid. The current through the hammer-actuating solenoid is limited effectively by the provision of an impedance in the emitter circuit of the transistor and by the provision of a clamping means coupled to the base electrode of the transistor. Without this current-limiting arrangement, in order to obtain a solenoid current having a rise time sufficient for adequate printing, the peak value of the solenoid current would be higher than that which is required. The capacitor consequently would be discharged to a low voltage and would take a longer time to recharge. In the circuit of the present invention, once the solenoid current is limited, it is maintained at a substantially constant value until the printing time is completed. The rise time of the solenoid current can have the desired characteristic, and, in addition, the solenoid current is limited to a predetermined peak value. Accordingly, the circuit of the present invention provides very fast printing repetition rates, since the capacitor will not be discharged as much, and it will take less time to recharge the capacitor than would be the case were not the solenoid current limited.

In accordance with a further aspect of the present invention, the solenoid-driving circuit in addition includes a control or input stage comprising a transistor whch s connected in the common collector or emitter follower configuration. This additional control circuit is utilized to control the operation of the solenoid-energizing transistor included in the output stage of the solenoid-driving circuit. During a non-print interval, when it is desired that the solenoid in the output stage be not energized, the transistor of the control stage is non-conductive, so as to limit power dissipation. During a print interval, when it is desired that the solenoid in the output stage be energized, the transistor of the control stage is conductive and is operated in saturation (low collector to emitter voltage). Accordingly, during the print interval, this control stage provides current gain, and, since its transistor is operated in saturation, there is low power dissipation.

Other objects and advantages of the invention will become apparent from a consideration of the following specification and claims, taken together with the accompanying drawing.

In the drawing:

FIGURE 1 is a schematic circuit diagram of a solenoid-driving transistor circuit illustrating one embodiment of the present invention; and

FIGURE 2 is a schematic circuit diagram of a three-stage solenoid-driving transistor circuit illustrating a further embodiment of the present invention.

FIGURE 1

There is shown in FIGURE 1 a coil or solenoid-driving transistor circuit including a PNP junction transistor **10**, having an emitter electrode **11**, a base electrode **12**, and a collector electrode **13**. The collector electrode **13**. The collector electrode **13** is connected to a terminal **14** through a coil or solenoid **15** and a resistor **16**. A suitable source of negative direct current potential, such as the negative side of a battery **17**, is connected to the terminal **14**, with the positive side of the battery **17** being grounded as shown. In parallel with the coil **15**, there is provided a diode 18, having its anode connected to a point 19 between the resistor 16 and the coil 15, and its cathode connected to a point 20 between the coil 15 and the collector electrode 13. A suitable capacitor 21 is connected between a point 22 and a source of reference potential, such as ground.

The emitter electrode 11 of the transistor 10 is connected to ground through a resistor 23.

The base electrode 12 of the transistor 10 is connected through a resistor 24 to a terminal 25. A suitable source of positive direct current potential, such as the positive side of a battery 26, is connected to the terminal 25, with the negative side of the battery 26 being grounded as shown. A clamping means which comprises a unilateral conducting device, such as the diode 27, is connected between the base electrode 12 and a source of reference potential 28. The base electrode 12 is connected to the cathode of the diode 27. The anode of the diode 27 is connected to a point 29 in the source of reference potential 28. The source of reference potential 28 comprises a threshold or breakdown type diode 30, also known as a Zener diode; a resistor 31; a capacitor 32; and a suitable source of negative direct current potential, such as the negative side of the battery 33. The positive side of the battery 33 is grounded as shown. The negative side of the battery 33 is connected to the terminal 34, which, in turn, is connected to the point 29 through the resistor 31. The anode of the diode 30 is also connected to the point 29, while its cathode is connected to ground. One plate of the capacitor 32 is also connected to the point 29, while its other plate is connected to a point 35 between the cathode of the diode 30 and ground.

An input terminal 37 is provided for the coil-driving transistor circuit and is connected to a point 38. The point 38 is, in turn, connected to the base electrode 12 of the transistor 10, the resistor 24, and the cathode of the diode 27.

The input terminal 37 of the solenoid-driving transistor circuit is connected to a trigger circuit 39, which may take the form of any one of the trigger circuits known in the art. The solenoid-driving transistor circuit is in its non-print condition when the transistor 10 is non-conducting, and it is in its print condition when the transistor 10 is conducting. The trigger circuit 39 causes the point 38 and the base electrode 12 of the transistor 10 to be at a positive potential with respect to the potential appearing on the emitter electrode 11 when it is desired that the transistor 10 be non-conducting and the solenoid 15 be unenergized. When it is desired that the transistor 10 be conductive and the solenoid 15 be energized, the trigger circuit 39 will cause the point 38 and the base electrode of the transistor 10 to be at a negative potential with respect to the potential appearing on the emitter electrode 11 of the transistor 10. Accordingly, a print signal or potential is defined as being applied to the input terminal 37 of the transistor 10 when the trigger circuit 39 causes the transistor 10 to be rendered conductive.

Operation of FIGURE 1

The biasing potential furnished by the battery 26 is such that the transistor 10 is non-conductive in the absence of a print signal being applied to the input terminal 37. During the time that the transistor 10 is non-conductive, the capacitor 21 is charged by the battery 17 through the resistor 16. The source of reference potential 28 provides a constant negative voltage at the point 29 which is applied to the plate of the diode 27. In the absence of a print signal being applied to the input terminal 37, the point 38 will be at a positive potential. Accordingly, the diode 27 will be non-conductive, as it is biased in the reverse, relatively non-conducting direction.

In response to the application of a negative print signal to the input terminal 37, the potential of the input terminal will change from a positive value to a negative value. The print signal causes the potential at the base of the transistor 10 to decrease sufficiently to cause the transistor 10 to be conductive. When the transistor 10 is conductive, current flows through the collector electrode 13, the coil 15, the resistor 16, and the battery 17 to ground. As the current through the emitter electrode 11 increases, the potential of the emitter electrode 11 becomes increasingly negative as a result of the potential drop produced across the resistor 23. The potential of the base electrode 12 also will become increasingly negative. As the potential of the base electrode 12 attempts to go more negative than the output potential of the source of reference potential 28, the diode 27 will be rendered conductive, and the base electrode 12 will be clamped at the voltage of the source 28.

The capacitor 21 is discharged when the transistor 10 is rendered conductive. When the transistor 10 is rendered conductive, a flow of current is started through the collector electrode 13 and flows into the capacitor 21 as a source of energy, from ground, through the resistor 23, the transistor 10, and the solenoid 15. A small portion of current flowing through the transistor 10 flows through the resistor 16 and the battery 17 to ground. The capacitor 21 is thereby discharged. The current flow through the collector electrode 13 of the transistor 10 energizes the solenoid 15.

Upon the termination of the print signal at the input terminal 37, the potential at the point 38 will become positive with respect to the potential at the emitter electrode 11. Accordingly, the transistor 10 will be rendered non-conductive. In rendering the transistor 10 non-conductive, and thereby cutting off the current through the solenoid 15, a back E.M.F. which is developed by reason of the inductance of the solenoid 15 is established. This back E.M.F. may be sufficient to exceed the potential difference tolerance between the emitter electrode 11 and the collector electrode 13 of the transistor 10. The diode 18 serves to short-circuit this back E.M.F. and therefore prevents the potential across the transistor 10 from becoming greater than the voltage of the source 17.

The Zener type diode 30 is of the type that presents a low forward resistance and, in the reverse direction, presents a high resistance throughout a preassigned voltage range, known as the Zener voltage, and then a very low variational resistance for reverse voltages beyond this range. For example, with a reverse biasing voltage equal to the threshold or Zener voltage, across the diode 30, the current flowing therethrough will place the diode at a point on its characteristic curve which is the approximate breakdown point of the device. Any further increase in current flow through the diode 30 results in a negligible increase in voltage across the device. The battery 33 and the resistor 31 are so chosen that the diode 30 is reverse-biased beyond its threshold value and will be operated in its breakdown region. Accordingly, the voltage at the point 29 will remain substantially constant regardless of current variations through the diode 30. The capacitor 32 will be charged when current is drawn from the source of reference potential 28 upon the conduction of the diode 27, and it will be discharged when no current is drawn therefrom. Accordingly, the capacitor 32 acts to stabilize the potential at the point 29 as current is drawn through the diode 27.

The values of the source of reference potential 28 and the resistor 23 are so chosen for each circuit that the energizing current through the solenoid 15 does not exceed a certain predetermined value.

FIGURE 2

The solenoid-driving transistor circuit shown in this figure comprises the circuit of FIGURE 1 and, further, includes two transistor amplifier stages. Certain of the circuit elements in FIGURE 2 are the equivalents of their counterparts in FIGURE 1 and have been given the same reference numerals.

The circuit of FIGURE 2 includes, in addition to the circuit of FIGURE 1, two PNP junction transistors **40** and **41**. The transistor **40** has an emitter electrode **42**, which is connected directly to ground; a base electrode **43**; and a collector electrode **44**. The transistor **41** has an emitter electrode **45**, which is connected to the point **38** and to the anode of a diode **46**; a base electrode **47**; and a collector electrode **48**. The cathode of the diode **46** is connected to ground.

An input terminal **49** is provided for the circuit of FIGURE 2 and is connected through a resistor **50** to the base electrode **43** of the transistor **40**. The input terminal **49** is also connected through a resistor **51** to the terminal **52**. A suitable source of direct current potential, such as the negative side of the battery **53**, is connected to the terminal **52**, with the positive side of the battery **53** being grounded as shown. The base electrode **43** of the transistor **40** is connected through a resistor **54** to the terminal **55**. A suitable source of direct current potential, such as the positive side of the battery **56**, is connected to the terminal **55**, with the negative side of the battery **56** being grounded as shown.

The collector electrode **44** of the transistor **40** is connected through a resistor **57** to a terminal **58**. A suitable source of direct current potential, such as the negative side of the battery **59**, is connected to the terminal **58**, with the positive side of the battery **59** being grounded as shown. The collector electrode **44** is also connected through a resistor **60** to the cathode of a diode **61**. The anode of the diode **61** is connected to the base electrode **47** of the transistor **41** and, through a resistor **62**, to a terminal **63**. A suitable source of direct current potential, such as the positive side of the battery **64**, is connected to the terminal **63**, with the negative side of the battery **64** being grounded as shown.

The collector electrode **48** of the transistor **41** is connected through a resistor **65** to a terminal **66**. A suitable source of direct current potential, such as the negative side of the battery **67**, is connected to the terminal **66**, with the positive side of the battery **67** being grounded as shown.

The transistors **10** and **40** are connected in the common emitter configuration, wherein their emitter electrodes **11** and **42**, respectively, are common to the input and output circuits of these transistors. The transistor **41** is connected in the common collector or emitter-follower configuration, wherein the collector electrode **48** is common to the input and output circuits of this transistor.

The input terminal **49** of the solenoid-driving transistor circuit is connected to a trigger circuit **68**, which may take the form of any one of the trigger circuits known in the art. The solenoid-driving transistor circuit is in its non-print condition when the transistors **10** and **41** are non-conductive and the transistor **40** is conductive, and it is in its print condition when the conductive states of these transistors are reversed. The trigger circuit **68** causes the input terminal **49** and the base electrode **43** of the transistor **40** to be at a negative potential with respect to the potential appearing on the emitter electrode **42** when it is desired that the transistor **40** be conductive and the solenoid **15** be unenergized. When it is desired that the transistor **40** be non-conductive and the solenoid **15** be energized, the trigger circuit **68** will cause the input terminal **49** to be at a slightly negative potential and the potential appearing on the base electrode **43** to be at a positive potential with respect to the potential appearing at the emitter electrode **42** of the transistor **40**. Accordingly, a print signal or potential is defined as being applied to the input terminal **49** of the transistor **40** when the trigger circuit **68** causes the transistor **40** to be rendered non-conductive.

Operation of FIGURE 2

The biasing potential furnished by the battery **53** is such that the transistor **40** is conducting to saturation in the absence of a print signal being supplied to the input terminal **49**. The transistor **40** is driven to saturation by the current flowing from the base electrode **43** through the resistors **50** and **51** to the terminal **52**. The potential at the collector electrode **44** of the transistor **40** will be negative at this time. The diode **61** will be biased in the forward direction and will therefore be conducting. The diode **61** for this circuit is so chosen that its value of forward resistance, together with the value of the resistor **60**, is such that the magnitude of the potential drop across these two circuit elements is sufficient to cause the base electrode **47** of the transistor **41** to be biased positively with respect to the emitter electrode **45** when the transistor **40** is saturated. Therefore, the divider network comprising the resistor **60**, the diode **61**, and the resistor **62** will cause a positive potential to appear on the base electrode **47** of the transistor **41**. The base electrode **47** being positive with respect to the emitter electrode **45**, the transistor **41** will be non-conductive, or cut off. When the transistor **41** is non-conductive, current flow from the terminal **25** through the resistor **24** and the diode **46** causes a positive potential to appear at the point **38** and at the base electrode **12** of the transistor **10**. The base electrode **12** being positive with respect to the emitter electrode **11**, the transistor **10** will be cut off. The capacitor **21** will be charged when the circuit is in the foregoing condition.

When a print signal is received at the input terminal **49**, the solenoid **15** will be energized in the following manner. The voltage divider network comprising the resistors **50** and **54** will cause a positive potential to be applied to the base electrode **43** of the transistor **40**, thereby rendering it non-conductive. When the transistor **40** is rendered non-conductive, the negative potential appearing on its collector electrode **44** is increased, which causes the potential appearing on the base electrode **47** of the transistor **41** to become negative. The current flow from the base electrode **47** of the transistor **41** through the diode **61**, the resistor **60**, and the resistor **57** is sufficient to cause the transistor **41** to become saturated. The transistor **41** is connected in the common collector configuration and provides current gain for the following transistor stage.

When the transistor **41** is rendered conductive to saturation, the potential of its emitter electrode **45** decreases, causing the diode **46** to become non-conductive. The potential at the point **38** becomes negative. With the potential at the base electrode **12** of the transistor **10** negative with respect to the potential appearing at the emitter **11**, the transistor **10** is caused to be conductive. As the current through the emitter electrode **11** increases, the potential appearing thereat becomes increasingly negative because of the voltage drop across the resistor **23**. The potential appearing at the base electrode **12** and the point **38** tends to go more negative than the potential at the point **29** in the source of reference potential **28**. When the potential appearing at the base electrode **12** becomes more negative than the potential of the source of reference potential **28**, the diode **27** will conduct, and the base electrode **12** is clamped at the value of the source of reference potential **28**. Accordingly, the current through the solenoid **15** is limited by the clamping means **27** and the resistor **23**. The current from the collector electrode **13** energizes the solenoid **15** and causes the discharge of the capacitor **21**. The resistor **24** is effective in the circuit to cause the transistor **41** to saturate and also limits the power dissipation.

The capacitors **32***a*, **32***b*, and **32***c* operate to stabilize the potential at the point **29** as current is drawn through the diode **27**.

Upon the termination of the print signal at the input terminal **49**, the transistor **40** is rendered conductive, and the transistors **10** and **41** are rendered non-conductive. The diode **18** squelches the inductive kick from the inductance of the solenoid **15** when the transistor **10** is rendered non-conductive, and the capacitor 21 is then recharged through the resistor 16.

The following values are given to aid in understanding and practicing the invention, it being understood that they should not be construed as limitations, since it is well known in the art that a wide range of component values is possible and that the selection of potentials and parameters of transistors is purely arbitrary. For example, it will be apparent to one skilled in the art that the interchange of PNP and NPN transistors may be readily accomplished.

Transistor 10	Germanium PNP power transistor, type 2N1073.
Transistor 40	Germanium PNP, type 2N404.
Transistor 41	Germanium PNP, type 2N597.
Diode 18	I.R.C. type SD91, silicon.
Diode 27	Radio Receptor type DR453, germanium.
Diode 30	I.R.C. type 1N1600A, breakdown voltage of −4.7 volts.
Diode 46	Germanium type 1N949.
Diode 61	Transitron type SG22, silicon.
Resistor 16	60 ohms.
Resistor 23	1 ohm.
Resistor 24	700 ohms.
Resistor 31	Two 75-ohm resistors, connected in parallel.
Resistor 50	2,200 ohms.
Resistor 54	24,000 ohms.
Resistor 57	700 ohms.
Resistor 60	470 ohms.
Resistor 62	10,000 ohms.
Resistor 65	80 ohms.
Capacitor 21	110 microfarads.
Capacitors 32*a*, 32*b*, and 32*c*	33,000 microfarads.
Battery 17	60 volts.
Battery 26	20 volts.
Battery 33	20 volts.
Battery 53	20 volts.
Battery 56	20 volts.
Battery 59	20 volts.
Battery 64	20 volts.
Battery 67	20 volts.
Solenoid 15	Two coils, connected in parallel. Each coil has 330 turns and has a direct current resistance of from 5.03 to 5.1 ohms.
Input signal (print), at input terminal 49 (FIGURE 2)	6.55 milliamps at 0 to −0.3 volt. Time duration of 850 ±5% microseconds.
Energizing current for solenoid 15	3.5 amperes minimum value having a duration of 870 ±5% microseconds, with a rise time of 400 microseconds.

The above values are approximate due to variations in individual components but should give an example of order of magnitude.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the circuit illustrated and its operation may be made by those skilled in the art without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the following claims.

What is claimed is:

1. A solenoid-driving transistor circuit comprising a transistor having an emitter electrode, a base electrode, and a collector electrode; means providing a source of direct current energizing potential for said transistor; a solenoid connected between said energizing potential providing means and said collector electrode; an impedance connected between said emitter electrode and a source of first reference potential; a capacitor connected between said energizing potential providing means and said source of first reference potential; means for applying an input signal potential to said base electrode to render said transistor conductive; and clamping means connected between said input signal potential applying means and a source of second reference potential; said emitter electrode impedance and said clamping means being effective in combination to limit the current through said solenoid to a predetermined value.

2. The solenoid-driving transistor circuit as defined in claim 1 wherein said clamping means comprises a unilaterally conducting device so oriented that it can conduct when the base electrode potential exceeds the value of said source of second reference potential.

3. The solenoid-driving transistor circuit as defined in claim 1 wherein said clamping means comprises a unilaterally conducting device, and said source of second reference potential comprises a source of direct current potential and a Zener diode connected in series therewith.

4. The solenoid-driving transistor circuit as defined in claim 1 wherein said clamping means comprises a diode having a cathode and a plate, and wherein said source of second reference potential comprises a source of direct current potential and a Zener diode connected in series therewith, and wherein the cathode of said diode is connected to said input signal potential applying means, and the plate of said diode is connected to a point between said source of direct current potential and said Zener diode.

5. The solenoid-driving transistor circuit as defined in claim 1 wherein said clamping means comprises a unilaterally conducting device, and said source of second reference potential comprises a source of direct current potential, an impedance, a Zener diode, and at least one capacitor, said source of direct current potential, said impedance, and said Zener diode being connected in series, and said one capacitor being connected in parallel with said Zener diode.

6. A solenoid-driving transistor circuit comprising a transistor having an emitter electrode, a base electrode, and a collector electrode; means providing a source of direct current energizing potential for said transistor; a solenoid connected between said energizing potential providing means and said collector electrode; an impedance connected between said emitter electrode and a source of first reference potential; means for biasing said transistor to be non-conductive in the absence of an input signal potential; a capacitor connected between said energizing potential providing means and said source of first reference potential to store energy received from said energizing potential providing means when said transistor is non-conductive; clamping means connected between said base electrode and a source of second reference potential; and means for applying an input signal potential to said base electrode to render said transistor conductive whereby said capacitor is discharged through said transistor and said solenoid; said clamping means being operable when the base electrode potential exceeds the value of said second reference potential to limit the variation of potential of said base electrode; said impedance and said clamping means being effective in combination to limit the current through said solenoid to a predetermined value.

7. A solenoid-driving transistor circuit as defined in claim 6 wherein said clamping means comprises a unilaterally conducting device, and said source of second reference potential comprises a source of direct current potential and a Zener diode.

8. A solenoid-driving transistor circuit comprising a first and a second transistor each having an emitter electrode, a base electrode, and a collector electrode; first means providing a source of direct current energizing potential for said first transistor; a solenoid connected between said first energizing potential providing means and said collector electrode of said first transistor; an impedance connected between said emitter electrode of said first transistor and a source of first reference potential; second means providing a source of direct current energizing potential for said second transistor; direct current conductive means connecting said emitter electrode of said second transistor with said base electrode of said first transistor; a capacitor connected between said first energizing potential providing means and said source of first reference potential; means for applying an input signal potential to said base electrode of said second transistor to cause said second transistor to be saturated,

said second transistor when saturated causing said first transistor to be rendered conductive; and clamping means connected between said direct current conductive means and a source of second reference potential; said emitter electrode impedance of said first transistor and said clamping means being effective in combination to limit the current through said solenoid to a predetermined value.

9. A solenoid-driving transistor circuit as defined in claim 8 wherein said clamping means comprises a unilaterally conducting device so oriented that it can conduct when the base electrode of said first transistor exceeds the value of said source of second reference potential.

10. A solenoid-driving transistor circuit as defined in claim 8 further comprising an impedance connected between said collector electrode of said second transistor and said second energizing potential providing means, and a unilaterally conducting device connected between said emitter electrode of said second transistor and said source of first reference potential.

11. A solenoid-driving transistor circuit comprising a first and a second transistor each having an emitter electrode, a base electrode, and a collector electrode; first means providing a source of direct current energizing potential for said first transistor; a solenoid connected between said first energizing potential providing means and said collector electrode of said first transistor; an impedance connected between said emitter electrode of said first transistor and a source of first reference potential; second means providing a source of direct current energizing potential for said second transistor; direct current conductive means connecting said emitter electrode of said second transistor with said base electrode of said first transistor; means for biasing said second transistor to be non-conductive in the absence of an input signal potential; means for biasing said first transistor to be non-conductive when said second transistor is non-conductive; a capacitor connected between said first energizing potential providing means and said source of first reference potential to store energy received from said first energizing potential providing means when said first transistor is non-conductive; clamping means connected between said base electrode of said first transistor and a source of second reference potential; and means for applying an input signal potential to said base electrode of said second transistor to cause said second transistor to be saturated, said second transistor when saturated causing said first transistor to be rendered conductive, whereby said capacitor is discharged through said first transistor and said solenoid; said emitter electrode impedance and said clamping means being effective in combination to limit the current through said solenoid to a predetermined value.

12. The solenoid-driving transistor circuit as defined in claim 11 wherein said clamping means comprises a unilaterally conducting device, and said source of second reference potential comprises a source of direct current potential and a Zener diode connected in series therewith.

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