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SELECTOR MAGNET DRIVER

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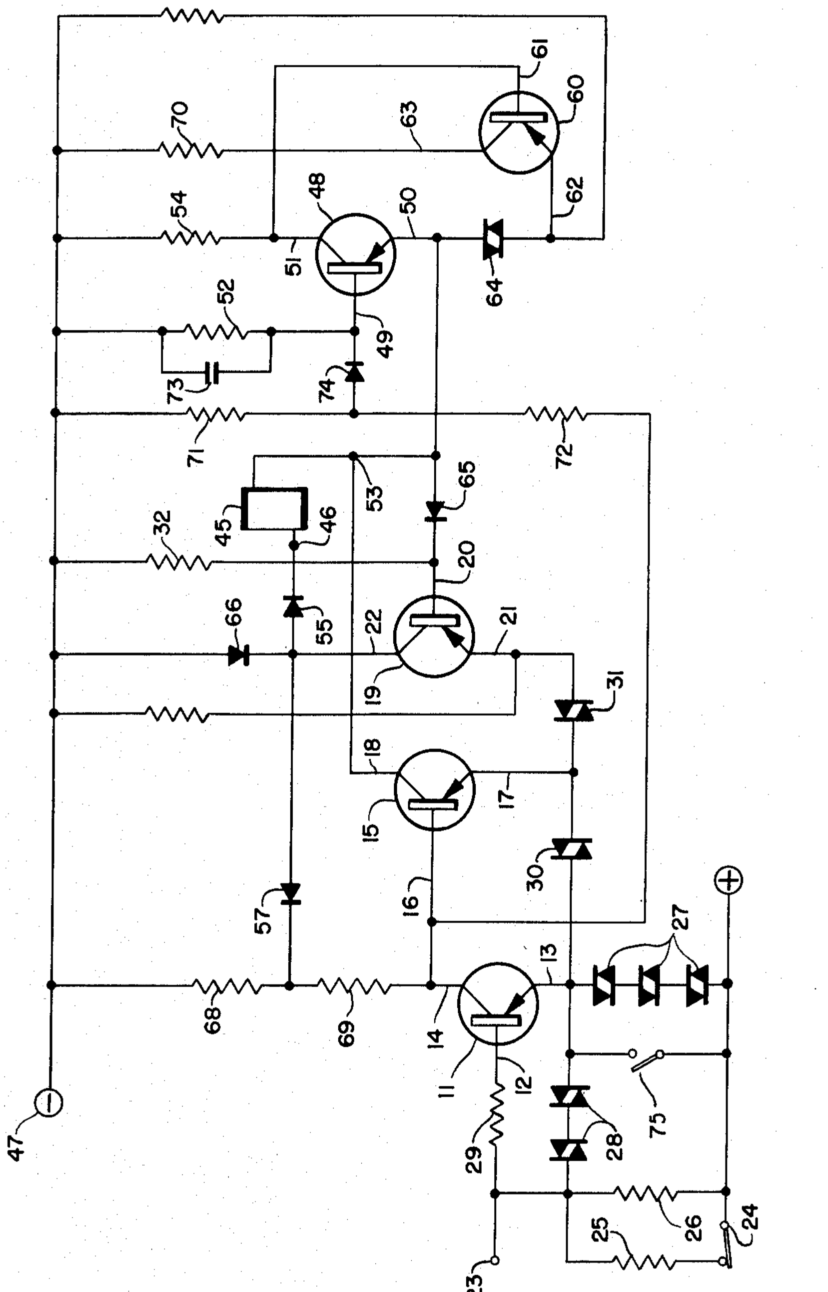

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SELECTOR MAGNET DRIVER

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This invention relates to an amplifier for energizing an inductor and more particularly to a driving circuit for a selector magnet employed in teletypewriter machines which operate in response to signals having substantially rectangular current wave form characteristics.

The selector magnet of teletypewriter machines consists of a coil of wire wound around an iron core, which forms an inductor, and an armature which is thereby operable upon reception of current pulses through the inductor and of sufficient magnitude to attract the armature effecting a conversion from electrical energy, representing character intelligence, to mechanical energy which will be converted to obserable intelligence. The current pulses are normally receivable in groups consisting of five or more character-determination bits and two synchronizing bits normally termed the start and stop pulses. These bits, all seven or more, occur seriatim commencing with the start pulse and terminating with the stop pulse. Each character-determination bit will assume one or the other of two current conditions, the pattern of the current conditions of the character-determination bits establishing the character to be represented upon conversion to mechanical motion, hence observable information. A specific current condition is used to designate the stop pulse, which when applied to the selector magnet coil maintains that coil in the energized condition and this current condition continues until a start pulse is received by the selector magnet coil. The start pulse is represented by the second current condition and causes the selector magnet to become deenergized thus initiating operation of the teletypewriter machine by releasing the armature of the selector magnet so that upon the reception of the first of the five character-determination bits the selector magnet, operable by the current pulses representing the character, will operate the selector mechanism associated with it and thereby allow the teletypewriter machine to print the character represented by the sequence of character-determination pulses. This operation is more fully described in United States Patent No. 2,339,313, granted January 18, 1944 to W. J. Zenner.

As higher and higher printing speeds of teletypewriter machines are demanded, the character-determination pulse rate must likewise increase. As these current pulses are applied to the selector magnet it must positively attract and release its armature at a correspondingly faster pulse rate to prevent the selector magnet from failing to recognize any single character-determination bit applied thereto.

In order to energize a selector magnet coil or any inductor at a rapid rate, correspondingly high electrical power must be available to the coil at the instant of initial energization. This power, the product of voltage and current, is usually limited by a current limiting resistor placed in series with the selector coil or inductor and the voltage source for energizing the coil. The current limiting resistor is used to regulate the amount of current which will flow through the inductor energizing circuit to prevent excessive currents from damaging the inductor once it is energized, but the rate of energization of an inductor is directly proportional to the rate at which current can initially flow through the inductor. Since the object of the present invention is the rapid initial energization of an inductor, an analysis of the equation which determines the voltage drop across an

inductor circuit at the moment of initial energization may prove helpful in determining what components or circuit configurations are necessary to effect the fast energization required. The equation employed for this analysis can be stated as

$$L\frac{di}{dt}+Ri=E$$

where L is the inductance of the coil, R the pure resistance of the circuit comprised of the resistance of the coil and that of the current limiting resistor, E the supply voltage, i the instantaneous current and di/dt the change in current with respect to time. If L, R and E are constant in the above equation, solving expressly for i will result in the determination of what the rate of change of current is dependent upon and thereby indicate what parameters can be varied to gain a faster energization of any given inductor L, in a given amount of time. In order to solve the above-mentioned equation to determine the instantaneous current that will flow through an inductor in any given instant of time, a separation of variables and an integration of the equation is necessary

$$L\frac{di}{(E-Ri)}=dt$$

or

$$L\int\frac{di}{(E-Ri)}=\int dt$$

whence

$$-\frac{L}{R}\log e(E-Ri)=t+c_1$$

or transposing, eliminating the constants of integration, and by applying the definition of a logarithm we may obtain the formula

$$E-Ri=e^{\left(\frac{-Rt}{L}\right)}$$

Solving for i

$$i=\frac{E}{R}-e^{\frac{-Rt}{L}}$$

Evaluating now in terms of the boundary conditions, letting $i=0$, $t=0$ we obtain

$$i=\frac{E}{R}-\frac{E}{R}e^{\frac{-Rt}{L}}$$

or

$$i=\frac{E}{R}\left(1=e^{\frac{-Rt}{L}}\right)$$

From this final equation we may observe that with time as a factor in the current rise, with the voltage source E held constant, the current flow through the coil is directly proportional to the magnitude of the voltage (also varying with time) appearing across the coil to be energized. As

$$e^{\frac{-Rt}{L}}$$

approaches 0, as the time increases, the equation approaches the steady state or quiescent operating current of

$$i=\frac{E}{R}$$

hence, if E is to remain constant, the only variable which could readily be decreased is the value of the current limiting resistor, from which it follows that the voltage appearing across the inductor will be of greater magnitude, and faster energization will be achieved. Another way of accomplishing a decrease in energization time of an inductor is to provide a substantially greater voltage across the inductor than would be required for quiescent operation. When this latter method is employed there is a large power dissipation in the current limiting resistor that must be placed in series with the inductor to be driven, as the voltage and resulting current might be of too great a magnitude if applied directly to the inductor, and could well damage the inductor. A preferred method, as determined by the analysis of the equation used to determine the instantaneous current value in an inductive circuit, would be to provide a voltage which would effect a rapid energization of the coil with a very low resistance in series with the coil to be energized and upon achieving a predetermined current flow through the coil, to thereupon cause a higher resistance to be placed in series with the coil to limit the current to a steady state or quiescent operating value, thus enabling energization of an inductor coil with a much lower voltage source than would normally be required to energize the inductor at the same rate of speed with but a single current path from the voltage source through the inductor to ground.

To energize inductor coils at rapid rates, associated switching or repeater apparatus such as relays, electron tubes, transistors, etc. must be employed to furnish the current paths from the power source to the inductor in accordance with a received input signal. Hence, as the input signal changes condition, the power furnished to the inductor coil correspondingly changes with the result that fast rising current and voltage pulses are created in the energization path from the switch to the coil. These sharp-rising pulses radiate electrical energy and if the pulses have sufficiently fast rise time they approach the radio frequencies spectra thereby causing radio frequency (R-F) noise on nearby radio receivers and transmitters which is objectionable in many military and commercial installations. By eliminating the large power changes effected by the switches and/or decreasing the rise time or the rate of change of the switched pulse below that which can produce the lowest frequency in the radio frequency spectrum, R-F radiation can be minimized.

Accordingly, it is an object of the invention to generate current wave forms through an inductor having rapid rise and decay characteristics.

Another object of the invention is to generate current wave forms having rapid rise characteristics in an inductor in such a way as to avoid the provision of an excessively high voltage source to produce the rapid rise and a correspondingly high energy dissipation facility to be effective during the steady state condition.

Still another object of the invention is to provide an auxiliary path for current to flow through during the initial energization of an amplifier employed to energize an inductor.

Yet another object of the invention is to make available to an inductor an energizing current substantially exceeding the desired steady state current; and upon occurrence of a current equaling or exceeding the desired steady state current, to limit the current to the desired steady state level.

Yet another object of the invention is to minimize the radio frequency noise radiated from a teletypewriter employing a selector magnet.

The employment of an active element to provide an auxiliary path for a larger amount of current than that normally required for steady state operation of an inductor is one feature of this invention.

Another feature of the invention is the ability of the circuit to provide a normal or steady state current path for an inductor and at the moment of initial energization of the inductor to provide a second current path capable of furnishing current in excess of the steady state requirement until the current in that path at least equals the steady state current, whereupon said second path becomes disabled and said steady state path becomes enabled.

Another feature of the invention is the employment of a bi-stable type input circuit operable to respond positively to one or the other of two signal line conditions and when the condition is that which is to render a teletypewriter selector magnet operable, to simultaneously enable the second or auxiliary current path and disable the steady state or normal current path.

In accordance with the present invention, an output generated by the device is directed to a selector magnet or inductor coil to be energized. During the initial phase of energization of the inductor, before a quiescent or steady state current is observable flowing through the inductor, a high potential is applied across the inductor causing a rapid energization thereof. After the inductor is initially energized, the current created by the high potential is limited to the quiescent operating value for the inductor, which current is of sufficient magnitude to maintain the inductor in an energized state. This initial surge of current is furnished by a collector-emitter current flowing in a transistor connected in a common collector configuration and is controlled by a change in circuit parameters observable when the input signal to the device changes from a spacing (no current) to a marking (current) condition. The current flow during the initial turn-on period is increased until the quiescent operating current value or a value slightly above that, is reached, at which time other associated circuitry disables the transistor furnishing the surge of current.

In order to effect control of the current surge transistor, a bi-stable input circuit is connected to a signal line and is operable to rapidly change states upon the input signal line reaching either of two predetermined current values. This on-off type input circuit contains a first and third transistor which are normally held conductive when the signal is in the marking condition, and a second transistor normally held nonconductive when the signal line is in the marking condition. When a predetermined value of voltage (spacing condition) is applied to the first transistor, the second transistor becomes conductive rendering the third transistor nonconductive which in turn opens the current path through which the selector magnet is energized. A fourth transistor is employed to maintain operating stability of the aforementioned circuitry. To positively maintain the bi-stable effect observable in the input circuit, a positive feed-back loop is employed which prevents any unstable oscillation which may otherwise occur.

Other objects and features of the present invention will become apparent when the description of the invention is read in conjunction with the drawing showing a schematic interpretation of the preferred embodiment.

Reference now is made to the drawing, wherein an inductor driving circuit is shown which includes a first transistor **11** having base **12**, emitter **13** and collector **14** electrodes; a second transistor **15** having base **16**, emitter **17** and collector **18** electrodes; and a third transistor **19** having base **20**, emitter **21** and collector **22** electrodes. For the purpose of illustration the transistors **11**, **15** and **19** are shown as PNP junction type transistors. However, it may be expressly understood that this type of transistor is shown for illustrative purposes only and that these transistors could be replaced by junction transistors of the opposite conductive type, NPN, if the proper voltage and diode polarity changes were made. Coupled to the base **12** and emitter **13** electrodes of transistor **11** is an input circuit which includes signal line terminals **23** and **24**, having connected across them resistors **25** and **26** whose function it is to set the predetermined current level above which transistor **11** will become energized. Also connected across the signal line terminals **23** and **24** are click suppressors **27**, which establish the voltage switching level necessary to render transistor **11** conductive. A click suppressor 27 or 28 consists of a PN semiconductor junction and NP semiconductor junction connected in parallel. These varistors or click suppressors act as current limiting devices for surges of current which might be applied to the signal line and in addition provide a fixed voltage drop for the circuit in which they are placed. Placed in parallel with the base 12, emitter 13 circuit of the first transistor 11 are additional click suppressors 28 which act to shunt excessive currents that might be applied to signal line terminal 23 around transistor 11 to the other side of the signal line, thus preventing the possibility of permanent damage to transistor 11 in case of polarity reversal or excessive currents being applied thereto. These click suppressors 28 begin to conduct and continue to pass an increased amount of current as the voltage increases in direct proportion to the increase of the voltage applied across them.

The first transistor 11 will be normally conductive when a marking current flows through resistors 25 or 26. The marking current required to render transistor 11 conductive may be predetermined by varying the ohmic values of resistors 25 or 26. Base resistor 29 acts to establish a reference voltage which is directly proportional to the base-emitter current of transistor 11. When a predetermined amount of current flows through resistor 29 a voltage is developed across it which serves to render click-suppressor 28 conductive, thus shunting the excess current. To effect this end, the base 12 of transistor 11 is coupled to the voltage reference resistor 29. The emitter 13 is placed in parallel with the voltage reference resistor 29 and click suppressor 28. Resistors 25 and 26 serve to control the amount of current which will be allowed to flow in the base 12, emitter 13 circuit and aid in establishing the voltage switching level necessary to render transistor 11 conductive. When an absence of current or a spacing condition is present upon the signal line terminals 23 and 24, transistor 11 is held nonconductive, as emitter 13 assumes a slightly more negative potential than the base 12.

The base 16 of the second transistor 15 is connected to the collector 14 of the first transistor 11 and is therefore directly controlled by the condition of said first transistor. Obviously, when the first transistor 11 is conductive, a potential approaching the potential of positive battery which may be grounded, will be placed upon the base 16 of the second transistor 15. Due to click suppressor 30 a drop in potential is effected across the base-emitter junction of transistor 15 which effectively renders the second transistor 15 nonconductive when said first transistor 11 is conductive.

A third transistor 19 is conductive when there is a mark condition appearing across the signal line input 23 and 24. This third transistor 19 is held conductive by a potential of more positive magnitude being placed upon the emitter 21 than is placed upon the base 20. The potential placed upon the emitter 21 is furnished from the emitter 13 of the first transistor 11 through click suppressors 30 and 31, while the more negative potential present on the base 20 is drawn from battery 47 through resistor 32. With transistor 19 conductive, a small negative potential is placed upon one terminal 46 of the inductor 45 and corresponds to emitter 21 potential of transistor 19. Since a marking condition is present on the signal line at this time, the inductor 45 should be energized. In order to accomplish this, a path must be furnished to battery from one terminal 46 of the selector magnet. This path is furnished through the winding of magnet 45, the fourth transistor 48 which has a base 49, emitter 50 and collector 51 electrodes.

Transistor 48 is normally conductive during both the spacing cycle and marking cycle but is momentarily rendered nonconductive upon the initial change of conditions at the input 23 and 24 from spacing condition to a marking condition and will be hereinafter described. In a static state, however, with a marking potential on the signal line terminals 23 and 24, a path from battery 47 is provided through base bias resistor 52, through the base 49, emitter 50 junction to the other side 46 of the inductor 45. Since the emitter 50 is at a more positive potential than the base 49, transistor 48 becomes conductive thus placing the emitter 50 voltage of transistor 48 upon the collector 51. Resistor 54, a current limiting resistor, provides a current limiting means for the selector magnet 45. The completed path from battery 47 through resistor 54, transistor 48, terminal 53 of the selector magnet, through the selector magnet 45 to the second terminal of the selector 46, through blocking diode 55, transistor 19, click suppressors 30 and 31, through the click suppressors 27 to positive battery completes the current path which maintains the operating current necessary to retain the selector magnet 45 in its energized condition.

A fifth transistor 60 has base 61, emitter 62 and collector 63 electrodes and is normally held in a nonconductive condition during a marking or spacing condition on the signal input 23 and 24. The collector 51 of transistor 48 is held at a sligthly more negative potential than the emitter 50 of that transistor due to the drop across the emitter-collector junction of that transistor 48, and since the base 61 of the fifth transistor 60 is connected to the collector 51 of transistor 48 and the emitter 62 of the fifth transistor 60 is connected through a click suppressor 64 to the emitter 50 of transistor 48, a more positive potential will exist on the base 61 due to the drop across click suppressor 64 causing a greater drop in potential than emitter-collector junction of transistor 48 so that the fifth transistor 60 will be held in a nonconductive state.

Assuming now that the signal or line current applied to signal input terminals 23 and 24, changes to a spacing or no current condition, the first transistor 11 becomes nonconductive as the base 12 is held near positive battery potential through resistor 25 and/or 26 while the emitter 13 is held more negative due to the voltage drop across click suppressors 27. When transistor 11 becomes nonconductive the potential on the collector 14 of that transistor rises sharply toward battery 47 potential which renders the second transistor 15 conductive, as a more negative potential exists on the base 16 than the emitter 17 of that transistor. Transistor 15, rendered conductive, places the nearly positive battery potential of the emitter 17 on the collector 18 of that transistor. This potential is then transferred to the anode of diode 65 appearing at the base 20 of transistor 19, said potential being more positive than the potential on the emitter 21 of that transistor, which is thereby rendered nonconductive, effecting a sharp rise toward battery 47 on the collector 22 of that transistor. With virtually full battery suddenly placed upon the anode side of diode 55, terminal 46 of the inductor 45 is suddenly disconnected from the positive battery path as a more negative potential is placed upon the anode side of diode 55 than the cathode side, thus back biasing diode 55 preventing current flow therethrough. This sharp cut-off of current flow through selector 45 causes a collapse of the the field in the coil of selector 45 causing a back E.M.F. to be generated in the selector magnet 45. This E.M.F. is subsequently dissipated through clamping diode 66 to battery potential 47. In addition to sharply limiting current flow through selector 45, the sudden increase in negative potential on the collector 22 of transistor 19 causes an increase in negative potential on the base 16 of transistor 15 to more effectively render transistor 15 positively conductive. This latter action takes the form of a positive feed-back loop effected by feed-back diode 57 and voltage divider resistors 68 and 69, as a negative current was heretofore flowing through resistors 68 and 69, through transistor 11 to positive battery and through the feed-back diode 57 through transistor 19 to positive battery which paths are now effectively blocked.

During this change from a marking to a spacing condition and, therefore, an energized to a nonenergized condition of the inductor **45**, transistor **48** remains conductive as a current path is retained through resistor **52**, base **49**, emitter **50** of transistor **48**, through transistor **15**, click suppressors **30** and **27** to positive battery. It therefore follows that with transistor **48** in the conductive state, transistor **60** must be nonconductive.

Suppose the spacing or no current condition present on the signal line terminals **23** and **24** is now changed back to a marking condition. Initially a voltage will be generated across resistors **25** and/or **26** which will cause a current flow through base **12**, emitter **13** of the first transistor **11** as previously described. This current flow renders transistor **11** conductive and once again places a nearly positive battery potential on the collector **14** of that transistor. This nearly positive battery potential effectively back biases transistor **15** thereby rendering it nonconductive. With transistor **15** nonconductive the collector **18** momentarily floats as there is large difference of potential across the terminals **46** and **53** of selector magnet **45**, but current does not flow due to the initial high impedance presented to the fast-rising voltage across the inductor **45**. At this moment, since there is no path for battery through the current limiting resistor **54**, and transistor **48** to positive battery, full battery potential appears on the collector **51** of transistor **48** which potential is correspondingly placed upon the base **61** of transistor **60**. With battery potential placed upon the base **61** of transistor **60**, the emitter **62** floats with approximately the same potential as the base placed thereon. With full battery potential in the emitter **62**, a similar potential is placed upon emitter **50** of transistor **48**. Capacitor **73** maintains the base **49** of transistor **48** at the previously nearly positive battery potential, thereby rendering transistor **48** nonconductive.

As current begins to flow through selector magnet **45** the emitter **62** of transistor **60** correspondingly begins to go positive with respect to the base **61** of transistor **60**, rendering that transistor conductive. Simultaneously capacitor **73** begins to discharge towards battery **47** through resistor **52**. Upon reaching the potential created by voltage divider resistors **71** and **72**, the base **49** of transistor **48** is clamped thereto through diode **74** which is normally back biased during all quiescent operation. If the current building up through selector magnet **45** were allowed to continue to build up to excessively high value, transistors **60** and **19** would be severely damaged. However, when a predetermined current is reached and therefore a specific potential appears on the emitter **50** of transistor **48**, the transistor **48** again becomes conductive due to a correspondingly more negative potential appearing on the base **49** due to the clamping voltage provided. Therefore, when this predetermined current is reached, transistor **60** becomes nonconductive as transistor **48** has become conductive. With transistor **60** nonconductive, full battery potential is no longer available for the selector magnet **45**. There is, however, a holding path for the magnet **45**, furnished through current limiting resistor **54** and transistor **48**, which is now conductive.

In order to assure that the input circuitry remains in the particular electrical state to which it has operated, a positive feed-back loop is employed, hereinbefore described. This positive feed back, when the input signal changes from a spacing to a marking condition, effectively holds transistor **15** in a nonconductive condition as the potential difference between the collector **14** and the cathode of diode **57** approaches zero, thereby effectively holding the base of transistor **15** sufficiently positive to assure stable operation, once transistor **11** becomes conductive. Switch **75** is provided to render the circuit sensitive to polar input signals, where the marking and spacing pulse both assume a positive and negative voltage condition, respectively, rather than only the mark condition assuming a positive voltage.

In summary, upon the line current changing from a spacing condition (no current) to a marking condition (current), the input circuit including transistor **11**, sensing the change in current, is rendered conductive by a predetermined amount of current flowing through the input circuit. Transistor **11**, being conductive, in turn renders transistor **15** nonconductive which momentarily renders transistor **48** nonconductive, thereby allowing transistor **60** to become conductive during the period transistor **48** remains nonconductive. Simultaneously, with the events involving transistor **48** and **60**, mentioned above, transistor **19** becomes conductive, placing nearly positive battery potential on one side, **46**, of the selector magnet **45**. Transistor **60**, now fully conductive, allows virtually full battery potential to be impressed on the other side **53** of the selector magnet **45**. This high potential appearing across the coil **45** permits a fast build up of current through the coil which causes a fast energization of the coil.

As soon as a predetermined amount of current is flowing through the coil **45**, transistor **48** becomes conductive, rendering transistor **60** nonconductive and thus limiting the flow of current, by virtue of a current limiting resistor **54** associated with transistor **48**, through the selector coil. The amount of current which is permitted to flow through the circuit now energizing the coil is of sufficient magnitude to assure complete energization thereof for the duration of the marking condition appearing at the input circuit.

Despite the sharp turn-on or turn-off of current flow that occurs as each transistor becomes conductive and/or non-conductive the radio-frequency radiation remains non-objectionable as the total power switched at any given instant of time is insufficient to effectively initiate radiation for more than a nominal distance. The fifth transistor **60** is the only element that controls power of sufficient magnitude to become objectionable if radiated as R–F noise; however, since the rise time of the current through this transistor is restricted to a frequency characteristic below the minimum radio frequency, the entire circuit, for all practical purposes, is devoid of radio frequency radiation.

While there has been described and illustrated herein one of the known embodiments of this invention, it will be apparent to those skilled in the art that changes may be made in this embodiment so that in certain cases features of the invention may be adopted to advantage without a corresponding use of the entire embodiment, and without departing from the spirit of the invention.

What is claimed is:

1. In a driving circuit for supplying an inductor with current having a rapid rise, an electronic voltage responsive input means having two stable states and driven to one of its stable states by an input signal of one magnitude and to the other of its stable states by an input of a different magnitude inductor energizing switching means controlled by said input means for furnishing a substantially steady energizing potential to said inductor when the input means assumes one of its two stable states; and means controlled by a current at a first predetermined magnitude flowing through said inductor for establishing a current flow through said inductor at a second predetermined magnitude.

2. Apparatus as defined in claim **1** wherein said means controlled by a current at a first predetermined magnitude through said inductor maintains said current flow through said inductor at said first predetermined magnitude.

3. In a driving circuit for an inductor having two terminals, a source of energizing current and potential, a voltage responsive input means capable of assuming one or the other of two stable states in accordance with the magnitude of a control pulse applied thereto, inductor energizing means comprising a first switching means controlled by the input means and connected between the potential source and one terminal of said inductor for providing substantially the potential of the potential source to the one terminal of said inductor upon reception by the input means of a control pulse of one magnitude, a second switching means controlled by the first switching means for providing a low impedance return path from the other terminal of said inductor to the potential source, a third switching means for disabling said second switching means and for maintaining an optimum energizing current flow from said other terminal of said inductor in place of said second switching means upon sensing a predetermined level of current flow through said inductor, and a deenergizing switching means connected to said other terminal of said inductor and to said first switching means for disabling said first switching means and for connecting said other terminal of said inductor to the potential source in place of said one terminal upon the changing of said control pulse to a different magnitude for reversing the energizing path of said inductor to cause said inductor to deenergize against said source of energizing current and potential.

4. In a driving circuit for supplying current from a voltage source having two terminals to an inductor having two terminals, a signal-responsive input means capable of assuming one or the other of two stable states in accordance with the magnitude of an input signal, inductor energizing means controlled by the signal-responsive input means comprising a first transistor connected between one terminal of the voltage source and one terminal of the inductor and operable for a predetermined time interval to furnish a low impedance current flow path between one terminal of said voltage source and one terminal of said inductor upon assumption by said signal-responsive input means of one of its two stable states, a second transistor connected between the other terminal of said voltage source and the other terminal of said inductor to operate concurrently with said transistor to furnish a low-impedance return path between the other terminal of said inductor and the other terminal of said voltage source, a third transistor connected in parallel with said first transistor to operate upon sensing a predetermined level of current flow through said inductor to disable said first transistor but not said second transistor simultaneously to establish a current path between said one terminal of said voltage source and said one terminal of said inductor to provide a circuit through said inductor for conducting a predetermined amount of current of a lesser magnitude than that capable of being furnished by the current flow path of said first transistor, and a fourth transistor connected from said other terminal of said voltage source to said second and third transistors and said one terminal of said inductor to operate upon assumption by the signal responsive means of the second of the two stable states to render said second and third transistors nonconductive and simultaneously to provide a low impedance path from said one terminal of said inductor to said other terminal of said voltage source to deenergize said inductor against the voltage of said voltage source.

5. A driving circuit for an inductor having two terminals, comprising a source of energizing current and potential, a oltage sensitive input circuit, a first switching means responsive to reception of a predetermined voltage by the voltage sensitive input circuit to connect one of said inductor terminals to said source, a second switching means responsive to operation of said first switching means to connect the other terminal of said inductor to said source to furnish a low impedance path to said inductor which is capable of furnishing a current significantly exceeding an optimum steady state current, a third switching means connected to the same terminal of the inductor as said second switching means responsive to occurrence of a predetermined level of current flow through said second switching means to disable said second switching means and to furnish an optimum impedance path between said inductor and said source for delivering a steady state current to said inductor, and a fourth switching means connected to the same terminal of said inductor as said second and third switching means and operable in conjunction with said first switching means upon reception of a different predetermined voltage by said voltage sensitive input circuit to effectively reverse the energizing path of said inductor to cause said inductor to deenergize against said source of energizing current and potential.

6. Apparatus as defined in claim 5 wherein the voltage responsive input means is comprised of a transistor having a base, collector and emitter, a resistor having two sides with one side connected to the base of said transistor, a signal line having an input terminal and a return terminal, said input terminal being connected to the other side of said resistor, at least one varistor connected between said input terminal and said emitter of the transistor to maintain bias for the transistor and to afford current overload protection, at least one varistor connected from the emitter of the transistor to the return terminal of said signal line to maintain bias, variable resistive means connected from the input of said signal line to the return terminal of said signal line to present varying input impedances to said signal line and to enable signal line currents of different magnitudes to develop the same voltage drop across the signal line terminals to cause said voltage sensitive input circuit to be similarly responsive to a plurality of different current levels.

7. In a driving circuit for an inductor having a voltage-responsive input means for assuming one or the other of two stable states in response to the magnitude of an input signal, inductor-energizing means activated by the voltage-responsive input means in assuming one of its two stable states for providing to the inductor a current higher than a predetermined steady-state current, means responsive to the occurrence of a first predetermined magnitude of current flowing through said inductor to establish a current flow through said inductor at a second predetermined magnitude, and means responsive to the other of the two stable states of the input means to reverse the energizing potential across said inductor to effectively deenergize said inductor.

8. An apparatus as defined in claim 1 wherein said inductor is deenergized by a deenergizing switching means for reversing the energizing path of said inductor to cause said inductor to deenergize against a source of energizing current and potential provided for the operation of said driving circuit.

9. A driving circuit for an inductor comprising:

a voltage responsive input means driven to one or the other of two states in accordance with the magnitude of an input signal;

a plurality of energizing circuit paths each connected in series with said inductor, one of said paths being of relatively low impedance in comparison with another;

means responsive to a change of state of said voltage responsive means for enabling said energizing circuit paths when said voltage responsive input means assumes one of its two states; and

means effective in time coincidence with the rising of current in said low impedance path and inductor to a predetermined level for disabling said low impedance path.

10. A driving circuit for an inductor according to claim 9, wherein said other energizing circuit path supplies energizing current for said inductor following disablement of said low impedance path.

11. A driving circuit for an inductor comprising:

a voltage-responsive input means capable of assuming one or the other of two states in accordance with the magnitude of an input signal;

a source of current and voltage;

means for providing a low impedance path between the source and the inductor temporarily during the build up of current in the inductor when the voltage-responsive input means assumes one of its states;

means for providing a high impedance path between the source and the inductor following the temporary provision of said low impedance path and while the voltage-responsive means remains in the same one of its states; and

means for maintaining across the inductor substantially the same voltage as the voltage source but of opposite polarity upon assumption by the voltage-responsive input means of the other of the two states and until current through the inductor ceases.

12. A driving circuit for selectively energizing an inductor comprising:

a voltage-responsive input means capable of assuming one or the other of two states in accordance with the magnitude of an input signal;

a source of current and voltage;

a first switch connected between the inductor and the source which operates temporarily during the build up of current in the inductor to furnish a low impedance current path between the source and the inductor upon assumption by the voltage-responsive input means of one of its two states;

a second switch connected in parallel with the first switch which furnishes a high impedance current path between the source and the inductor when the voltage-responsive input means is in said one of its two states;

means for maintaining across the inductor substantially the same voltage as the voltage source but of opposite polarity upon assumption by the voltage-responsive input means of the other of its two states; and

means for disabling the maintaining means upon cessation of current flow through the inductor.

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3,097,307	7/63	Bonn	307—88.5
3,101,441	8/63	Curry	323—22
3,116,441	12/63	Gieffers	317—148.5
3,123,746	3/64	Wachowiak	317—148.5

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