

Description

This invention relates to a circuit for driving inductive loads and more particularly to a monolithic integrated circuit for supplying in-rush and sustaining current level drive signals to operate an inductive solenoid device.

Description of the prior art

Solenoids operated by generating a magnetic field are generally known in the art. The magnetic field is produced by causing current to flow through an inductive field coil. In most applications utilizing solenoids it is desired to initially place a maximum voltage across the field coil to allow the current to ramp therethrough to a peak magnitude, the value of which is limited only by the time constant of the coil. For example, electronic fuel injection systems have injector valves which are comprised of solenoids with inductive coils for opening and closing the valves in timed relationship to the operation of the automotive engine. Hence, the correct cylinder of the engine can be supplied with the correct fuel mixture at the correct sequence in the engine firing cycle. Because of the magnetic characteristics of the inductive field coils whether used in fuel injection systems for driving the magnetic valves or electronic ignition systems wherein once the magnetic field has been established by the current ramping to the peak magnitude, maintenance of the field requires less current. Thus, in order to open the valves as quickly as possible, rapid current buildup in the coil is needed. However, after the valve is initially opened, a reduced or sustaining level of current can then be applied to maintain the valve in an open state. This sustaining current level allows for fast closing of the valves in the correct time relationship and also helps to prevent overheating of the valves which could otherwise occur with the higher level current being maintained for a period of time.

Most, if not all of the prior art, including fuel injection systems, comprises a driver circuit and a discrete power device. The discrete power device is coupled in series between the injector valve, for instance, and a discrete sense resistor. In operation the driver circuit which may be a monolithic integrated circuit, is driven by an input signal in timed relation to the engine operation to turn on the discrete power device at the correct sequence in the engine cycle to allow maximum in-rush current to open the valves. Once the peak current level is reached, a voltage developed across the sense resistor is usually compared with a referenced voltage set in the driver circuit to reduce the drive to the discrete power device in order to reduce the field current through the inductive coil to a sustaining level.

In both DE—A—2,841,781 and US—A—4,180,026 such installations for the operation of electromagnetic loads, especially solenoid valves, in fuel supply systems in internal combustion engines are disclosed. The integrated

circuit of DE—A—2,841,781 comprises a switch and a sense resistor coupled in series together with the load through which the load current flows, a reference current source that supplies a current independent of the load current, and comparator circuitry coupled to the reference current source and sense resistor, which controls the conduction of the switch in accordance with the magnitude of the voltage level of the voltage developed across the sense resistor to in turn control the magnitude of the load current.

The circuit of US—A—4,180,026 comprises a discrete power stage and a discrete sense resistor coupled in series with the load, a reference current source that supplies a current of either a first or second magnitude at its output to a reference current resistor and circuitry including a comparator having an output coupled both to the reference current source and the power stage and having first and second inputs coupled respectively to the sense resistor and the reference current resistor. The reference current source in response to an applied input signal supplies a current of the first predetermined magnitude to the reference current resistor which establishes a first voltage reference at the second input of the comparator. The comparator switches output states in response to the load current exceeding a first predetermined value which causes the reference current source to supply a current at its output of the second predetermined magnitude to in turn control the magnitude of the load current.

However, both the prior art circuits suffer from a problem in that the maximum voltages that can be applied across the loads are limited by the voltage drops across the sense resistors and since the sense resistors are discrete components and coupled so that the load current flows therethrough the voltage drop is significantly large. This potentially creates a problem since the current ramp time through the coil or load is a function of the voltage established across the coil, and so in order that the load current is ramped up to the required peak value in time to accurately close the solenoid valves of the fuel injection system, the voltage drop across the sense resistor must be as low as possible. Thus, the switching speeds of the prior art systems are limited by the voltage drops across the discrete sense resistors.

In addition, since the sense resistors of both prior art circuits are discrete components, problems due to process and temperature variations can arise which affect the switching characteristics of the system between the peak and lower current levels.

Furthermore, in order to reduce component cost for the inductive driver systems it is desirable to have the driver circuit, the power device and sense resistor on one single monolithic integrated circuit chip.

Summary of the invention

In accordance with the present invention there is provided a circuit for providing current to a load comprising:

a power stage and a sense resistor coupled in series with the load;

a reference current source that supplies a current of either a first or second magnitude at its output to a reference current resistor coupled at a first end thereof to the output of the reference current source; and

circuitry including a comparator having an output coupled both to the reference current source and the power stage, and first and second inputs coupled respectively to a first end of the sense resistor and the first end of the reference current resistor, the other ends of these resistors being coupled to a common terminal,

said reference current source being responsive to an applied input signal for supplying a current of said first predetermined magnitude to the reference current resistor which establishes a first voltage reference to said second input of the comparator, said comparator switching output states in response to the load current exceeding a first predetermined value which causes said reference current source to supply a current at its output of said second predetermined magnitude such that the magnitude of the load current is reduced to a second value, characterized in that: the circuit is integrated; and in that

the power stage comprises a power transistor having n emitters, where n is an integer, and a plurality of n ballast resistors (R_b) formed in the integrated circuit, each of said ballast resistors, through which proportional amounts of the load current flow, being coupled in series to a respective emitter of said power transistor, the sense resistor being a particular one of said ballast resistors (R_b) and being co-located with said reference current resistor in said integrated circuit and formed of the same material.

In one embodiment of the invention a programmable circuit is provided which in a first application is adapted to receive an input signal for reducing the load current to the reduced constant level after a predetermined interval if the load current does not reach a value representative of said first reference current. In a second application the input of the programmable circuit is connected to the input of the integrated circuit whereby the integrated circuit functions as a power switch for providing a substantially constant current.

Thus, it will be appreciated that since the sense resistor is formed by a ballast resistor coupled to the emitter of the power transistor in the integrated circuit, only a small current which is proportional to the load current will flow through the resistor and hence the voltage drop across the resistor will be low allowing for a very quick ramp-up time.

Another advantage of the invention over the prior art is that since the sense resistor and reference current resistor are co-located within

the monolithic circuit, the resistors will have equal process variations and temperature characteristics and hence will not suffer from problems which arise from temperature or process variations of the discrete resistor.

Brief description of the drawings

One system in accordance with the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a partial schematic and block diagram for describing the embodiment of the load driver circuit of the present invention;

Figs. 2A—2D are waveforms illustrating waveforms useful for understanding the operation of the present embodiment; and

Fig. 3 is a complete schematic diagram of the embodiment of the present invention.

Detailed description

Turning to Fig. 1 there is shown load driver circuit 10 in block diagram form for explaining the general operation of the preferred embodiment of the invention. As indicated by the dashed outline form, driver circuit 10 which includes an internal power stage is fabricated in monolithic integrated circuit form. Output terminal 12 as shown may be coupled to one terminal of an external inductive coil 14, the other terminal of which is connected to a potential source V_{BAT} . (It is understood that also a resistive load could be driven by driver circuit 10). If, for example, inductive coil 14 is part of a fuel injection system, V_{BAT} would be the battery voltage and inductive coil 14 would be utilized to generate a magnetic field in response to a current conducted therethrough to operate the injector valves of the fuel injector system. Hence, an input signal generated in timed relationship to the operation of the automotive engine is applied to input terminal 16 to open and close the valves in response to the magnetic field produced by inductive coil 14. In response to the input signal, internal power stage 18 of the monolithic circuit is rendered full conductive so that maximum ramp current is generated through inductive coil 14. The current through sense resistor 20 which is coupled in series between power device 18 and ground reference is compared to the current through reference resistor 22 to limit the current through inductive coil 14 to a predetermined peak magnitude. Therefore, in response to an input signal applied to input terminal 16 (Fig. 2b) switching from a low-level state to a high-level state at time t_1 comparator 26 produces an output signal for providing both base drive to the base of transistor 28 as well as placing bistable reference circuit 24 in a first state for supplying a first reference current through resistor 22. Therefore with a source of operating potential V_{CC} being supplied at terminal 32 in response to V_{BAT} via resistor 30, a drive signal to power device 18 is provided through the collector-to-emitter path of transistor 28. Power device 18 is thus driven into a saturated state by the drive

signal to allow the maximum voltage to be placed across inductive coil 14 to allow the current therethrough to ramp to a maximum limit which is substantially equal to the reference current provided by bistable reference circuit 24 through reference resistor 22. This is illustrated in Fig. 2a between times t1 and t2. During the aforementioned time interval, the output from bistable reference circuit 24 is maintained at a first maximum level by comparator 34. When the current through inductive coil 14 reaches the peak magnitude, this condition is sensed across resistor 20 such that comparator 34 is caused to change states to source current away from transistor 28 and at the same time to cause bistable reference circuit 24 to switch states. This causes the current at the output of circuit 24 to be reduced to a lower or sustain level whereby the current conducted through conductive coil 14 is quickly reduced to this sustain level value as shown between time t2 and t3—t4. At time t4 the input signal to circuit 10 goes to a low level state which turns off the driver circuit such that the current through inductive coil 14 is reduced to a zero level. Thus, the current produced through conductive coil 14 is referenced to an internal current provided in the driver circuit.

Resistors 20 and 22 are shown within a dashed outline to indicate that these components are collocated within the monolithic circuit. Therefore, with these two components being fabricated of like material, for example, the same semiconductor material utilized in forming the emitter of transistor 28 these two resistors will have equal process variations and temperature characteristics. Hence, the switching characteristics of the system between the peak and sustaining current levels is not an absolute function of the voltages developed across these two resistors. Furthermore, by trimming resistor values, process and temperature variations are eliminated between different integrated circuits. Typically, the ratio between the peak current level and the sustaining current level as shown in Fig. 2a is four to one.

The input levels to circuit 10 are compatible with transistor-to-transistor logic (TTL) such that the circuit can be utilized with TTL logic circuitry.

A thermal shutdown circuit 38 is shown for sensing the power dissipation in power device 18 to shut circuit 10 down if excessive power is dissipated in the power device. Thus damage to the integrated circuit is prevented.

Turning now to Fig. 3, drive circuit 10 of the preferred embodiment is shown in complete detail. As shown, like components to components of Fig. 1 are referenced by the same numerals. Driver circuit 10 of Fig. 3 is shown included within a dashed outline form to indicate that all of the components therein are incorporated into a single monolithic integrated circuit chip. As heretofore described, VCC terminal 32 is coupled to a source of operating potential such as a battery. Zener diode 40 is provided between terminal 32 and a ground reference terminal 42 which is adapted to be connected to ground reference potential.

Zener diode 40 limits the operating potential for driver circuit 10 to a predetermined voltage level and protects the driver circuit from "load dump" transients which could otherwise occur if driver circuit 10 is utilized in the fuel injection system of an automobile, as is generally understood.

In normal operation, with the battery voltage source being substantially equal to 12 volts as shown in Fig. 2c, driver circuit 10 is responsive to an input signal (Fig. 2b) supplied at input terminal 16 to drive conductive coil 14 at output terminal 12 as previously described. Thus, with the input signal at a low level state, transistor 44, which has the base thereof coupled via resistor 46 to input terminal 16, is maintained in a non-conductive state. However, when the input signal goes to a high level state transistor 44 is biased via resistors 46 and 48 to a conducting level state. Hence, with a low input level state transistors 50, 52 and 54, each having their base electrodes coupled via resistors 56, 58 and 60 to the collector of transistor 44, are rendered conductive, being biased from power supply through resistor 62. The collectors of transistors 50, 52 and 54 will therefore be at near ground potential. In this state, the collector of transistor 50 acts to reset latch 64 comprising transistor 66 and 68 along with associated resistors. Transistor 66 will be maintained in a non-conductive state thereby supplying a "logic zero" at the output of the latch taken at node 70. Thus, in the reset mode the output of latch 64, which is coupled to bistable reference source 24, places the reference source in a first state to provide a first current level at the output thereof at node 72 to resistor 22 as will be described hereinafter.

With latch 64 being in a reset state, transistor 74 of bistable reference source 24, which has its base coupled via resistor 76 to the output of the latch, is maintained in a non-conductive state which allows diode 78 to be forward biased. Transistors 80, 82, 84 and 86 which have their emitters respectively coupled to power supply terminal 32 through resistors 88—94, function as constant current sources to supply a current of the magnitude I at the respective collectors thereof. Hence, with diode 78 forward biased, a current equal to a magnitude 4I is supplied at output node 72 to produce a reference current of 4I through resistor 22. This reference current through resistor 22 produces a reference voltage at the base of transistor 96, the non-inverting input of comparator 34. Simultaneously, transistor 52 being in a conductive state, sinks the base current drive away from transistor 28 to maintain transistor 28 in a non-conductive state. Transistor 28, along with transistors 98 and 100 of power stage 18, form a triple transistor Darlington power amplifier to provide maximum current drive at output 12 when transistor 28 is rendered conductive. With transistor 28 being in a non-conductive state no output current is provided at output terminal 12. Thus, as shown in Fig. 2a, at time interval t1, no output current is provided at output terminal 12.

At time t1 when the input signal goes to a high

level state, transistor 44 is rendered conductive to turn off transistors 50, 52 and 54. With transistor 52 being in a non-conductive state transistor 28 is released and base current drive is provided thereto from transistors 102 and 104 which act as a base current source thereto. Thus, transistor 28 is rendered conductive and power stage 18 is driven into a saturated state to supply maximum output current at output terminal 12 as shown between time interval t1—t2 of Fig. 2a. As understood, power stage 18 is realized in integrated circuit form by a multi-emitter transistor having individual ballast resistors R_b connected in series with each multi-emitter. For example, power stage 18 may comprise a power device having 104 emitters with respective ballast resistors R_b . Hence, if 104 ballast resistors are utilized as indicated generally at 106, an equal percentage of total output current supplied at output terminal 12 will be conducted through each resistor. Thus, one of the ballast resistors, i.e., resistor 20 may be utilized to sense the current provided at output terminal 12 to compare this current with the reference current supplied through reference resistor 22 in order to determine when the current at output terminal 12 has reached a predetermined peak magnitude.

With bistable reference source 24 being in a state wherein a current of magnitude 4I is provided at output 72, a reference voltage is produced across reference resistor 22 and transistor 96 is rendered conductive as current is provided thereto from current source transistor 108. As long as the current through sense resistor 20 is less than the current through resistor 22, transistor 110 will be rendered conductive through current turnaround circuit 112 comprising diode 114 and transistor 116. Transistor 118 will be rendered non-conductive as are transistors 120 and 122. With transistor 120, which is connected as a diode in series between transistor 118 and 122 and which has a collector output connected to the base of transistor 124 being non-conductive, transistor 124 is maintained in a non-conductive state wherein the collector thereof will be in a "logic one" state. Therefore, with transistor 120 being non-conductive, transistor 68 is maintained in a conductive state as previously described.

Driver circuit 10 will remain in the aforescribed state until such time that the current produced at output terminal 12 reaches a peak magnitude, at time t2, i.e., when the peak magnitude of current becomes substantially equal to the current provided at output 72 of reference source 24. At this time, if the output current at output terminal 12 tries to become greater than the value of the current supplied at the output of reference source 24 the gain of comparator amplifier 34 is great enough to rapidly cause transistor 110 as well as transistor 116 to be rendered non-conductive. As transistor 116 becomes non-conductive, transistor 118 is driven from transistor 108 rendering it conductive as well as transistors 120 and 122 connected in series therewith. As transistor 122 becomes conductive, base current

drive is reduced to transistor 28 to reduce power drive to power device 18. Hence, between time intervals t2 and t3 (Fig. 2a), the output current produced at output terminal 12 rapidly decreases to a second predetermined level between time interval t3—t4. The level to which the output current at output terminal 12 is reduced to is established by bistable reference source 24 in the following manner. As transistor 120 becomes conductive current is supplied from the collector thereof through resistor 128. This causes transistor 124 to become conductive putting a "logic zero" at the set terminal of latch 64 to cause transistor 68 to become non-conductive. When transistor 68 becomes non-conductive, transistor 74 is rendered conductive to reverse bias diode 78. Therefore, with diode 74 reverse biased, transistor 86 provides the current output at output node 72 which now has a value of only I. Hence, the voltage across reference resistor 22 is reduced by a factor of four; this causes the current at output terminal 12 to be reduced until such time that the voltage produced across trim network 126 and sense resistor 20 (which is supplied to the base of transistor 110 of comparator 34) becomes equal to the new reference voltage produced across reference resistor 22 by the reduced current drive from the output of bistable reference source 24. The output from output terminal 12 will remain constant until time t4 when the input signal supplied to input terminal 16 of driver circuit 10 goes to a low level state which resets latch 64 to again forward bias diode 78 as previously discussed and to shunt base current drive away from transistor 28 through the collector emitter path of transistor 52.

By co-locating reference resistor 22 with sense resistor 20 within the integrated circuit and by forming these two resistors of like semiconductor material, driver circuit 10 will function independently of temperature variations of the integrated circuit comprising the driver circuit. Also, by utilizing a resistive trim network between the inverting input of comparator 34 and the multiple emitters of the power transistor comprising power device 18, process variations can be eliminated by selective opening by laser or other means of links A. Therefore, the peak magnitude at which the driver circuit 10 is switched is set in production by monitoring the output current at output terminal 12 and trimming to the desired level by opening selective links A. Therefore, process variations between individual integrated circuit chips are eliminated by production trimming.

A startup circuit comprising diode 130 connected in a current mirror configuration with transistor 132 is provided to ensure that driver circuit 10 becomes functional when the power supply potential is supplied thereto. Thus, as driver circuit 10 is turned on, diode 130 which is connected to the power supply rail via resistor 134 is instantly rendered conductive which turns transistor 132 on. With transistor 132 being rendered conductive, the collector-to-emitter path

provides a source for current for transistor 136 to render it conductive. With transistor 136 being rendered conductive, the current source comprising transistors 138, 140 and 142 and associated resistors 144 and 146 are allowed to be biased up to set the current through current source transistors 80—86, 102, 104 and 108 as understood. After driver circuit 10 is biased up into operation as previously described, the turn-on circuit comprising diode 130 and transistor 132 is rendered non-active by the feedback from transistor 108 via lead 148 to the emitter of transistor 132 which shuts this transistor off.

The reference current source comprising transistors 138—142 is a well known $\Delta\theta$ current reference source wherein a $\Delta\theta$ voltage (having a positive temperature coefficient) is established across resistor 146. Resistor 146 is fabricated of semiconductor material having a temperature coefficient which is substantially equal to the temperature coefficient of the voltage established thereacross such that the current produced through the collector-emitter of transistor 142 has a substantially zero temperature coefficient. Hence, the current produced at output node 72, from bistable reference current source 24, will also have a zero temperature coefficient. This is an important feature in that, although the resistor values of reference resistor 22 and sense resistor 20 may vary with temperature variations of driver circuit 10, the peak magnitude of output current at which the output current from driver circuit 10 is switched does not vary with temperature variations.

In the preferred embodiment there is provided a novel thermal shutdown circuit 38 for preventing damage of the power stage 18. The novelty associated with thermal shutdown 38 relies in establishing a voltage at the base of transistor 150 which has a positive temperature coefficient that is a ratio of the positive temperature coefficient of the $\Delta\theta$ voltage established across resistor 146. Thus, although the current supplied through the collector of transistor 142 has a zero temperature coefficient and the output collector current of transistor 108 via lead 148 also has a zero temperature coefficient, it is to be remembered that this current was generated from a voltage which had a positive temperature coefficient, i.e., the $\Delta\theta$ voltage across resistor 146. Therefore, the voltage developed across the resistor 152 also has a positive temperature coefficient, the magnitude thereof being a function of the ratio of the values of resistors 152 and 146. This means that the voltage established at the base of transistor 150 will have the pre-determined positive temperature coefficient associated thereto. Hence, as the integrated circuit in which driver circuit 10 is fabricated is caused to heat up by excessive power dissipation in power stage 18 a point will be reached that forward biases the base-to-emitter junction of transistor 150 to cause transistor 150 to become conductive. At this temperature, when transistor 150 becomes conductive, base current drive is shunted via resistor

154 from driver transistor 28 to reduce drive to the power stage which in turn then causes this stage to be turned off. Driver circuit 10 is therefore protected from becoming overheated by excessive power dissipation in power device 18.

Circuit 156 which is controlled by an input signal supplied at control terminal 158 provides several unique functions as will be explained. If, for example, driver circuit 10 is to be utilized in fuel injection systems circuit 156 can be utilized to prevent damage to the injectors when the battery voltage of the automobile is sufficiently low. For instance, if the battery voltage is low (as shown by waveform portion 160 of Fig. 2c) there may not be enough voltage produced across inductive coil 14 to allow the current generated therethrough to ramp to the maximum peak magnitude as shown in Fig. 2a. For instance, if the peak magnitude is set at four amps, the low voltage across coil 14 may only allow the current supplied at output terminal 12 to ramp up to 3.99 amps. Thus, comparator 34 could not be activated to reduce the output current from driver circuit 10 to the low level as previously discussed. Thus, the current through coil 14 would remain at this high level and potentially damage the injectors. Hence, it is desired to be able to sense when the battery voltage is low such that the output of driver circuit 10 will be switched to a lower current level after a predetermined time in order to protect the injectors. Circuit 156 is utilized in conjunction with a derived input signal at terminal 158 to cause the output of driver circuit 10 to be switched to the lower current level after a predetermined time if the peak magnitude of current therefrom has not been reached.

Input terminal 158 may be coupled to an external RC network where the input signal produced thereat is the voltage developed across the capacitor. By utilizing an external RC network the charging of the capacitor is independent of operation of driver circuit and is controlled by the RC time constant. Thus, with a zero level input signal at input terminal 16, transistor 54, as previously discussed, is rendered conductive which, via resistor 160, would cause discharge of the external capacitor to a zero voltage as shown at time t1 (Fig. 2d). With transistor 54 being conductive, transistor 168 is rendered conductive which causes the base of transistor 170 to be at low voltage level rendering this transistor non-conductive. At time t1 when the input signal at input terminal 16 goes to a high level state, transistor 54 is rendered non-conductive which allows the external capacitor to begin ramping upwards as shown by waveform portion 172 of Fig. 2d. Thus, the voltage level at terminal 158 will increase until such time that transistor 168 is rendered non-conductive which allows transistor 162 to become conductive. Transistor 162 is biased through resistors 164 and 166 to a voltage level compatible with TTL circuitry when V_{BAT} is maximum. As transistor 162 becomes conductive, the current from the collector thereof renders transistor 170 conductive via resistor 174. Transistor 170 and

transistor 124 are connected in an OR configuration such that with either one of these two transistors becoming conductive causes latch 64 to be set which as previously explained causes the output current at output terminal 12 of driver circuit 10 to be reduced to the lower level state. Hence, if the peak magnitude of current (time T2) has been reached previous to transistor 162 becoming conductive, transistor 124 will have already set latch 64 and the output from driver circuit 10 is reduced at time t3 to its lower current level state. However, if the battery voltage source is sufficiently low, as shown by waveform portion 160 of Fig. 2c, the output of driver circuit 10 will never reach the peak magnitude output. This is shown by waveform portion 176 of Fig. 2a. Hence, latch 64 cannot be set by transistor 124 whereby the output current level will remain at a constant level somewhere below the predetermined peak magnitude. Without circuit 156, the output current level of driver circuit 10 will remain constant. However, when the external capacitor is charged to the voltage level to render transistor 168 non-conductive, transistor 170 is rendered conductive to set the latch as shown at time t5 of Fig. 2a to reduce the output current level from driver circuit 10 to the lower current level.

In some applications circuit 156 might be utilized in conjunction with a control voltage being supplied at input terminal 158 as shown by waveform portion 178. In this manner, the current level at output terminal 12 can be switched to its lower current level if the peak magnitude current level has not been reached by a predetermined time interval after the input signal at input terminal 16 has switched to its higher level state.

By connecting input terminal 158 to input terminal 16, circuit 10 functions as a load protected integrated power switch. In this application, whenever the input signal at input 16 goes high the output current provided at output 12 is fully conductive and constant, being set at any desired limit level within the dynamic range of trim network 126. If the load current exceeds the predetermined limit value the output (power stage 18) goes into an active state and thermal shutdown circuit 38 can protect the integrated circuit if excessive heating occurs as was previously described.

The above described driver circuit for driving inductive or resistive loads is suitable to be fabricated entirely as an integrated circuit device including the power stage and functions by comparing a percentage of the load current to an internally generated reference current for switching the load current when a predetermined peak magnitude is reached to a constant, predetermined sustaining level.

Claims

1. A circuit (10) for providing current to a load (14), comprising:
 - a power stage (18) and a sense resistor (20) coupled in series with the load;

a reference current source (24) that supplies a current of either a first or second magnitude at its output to a reference current resistor (22) coupled at a first end thereof to the output of the reference current source; and

circuitry including a comparator (34) having an output coupled both to the reference current source (24) and the power stage (18), and first and second inputs coupled respectively to a first end of the sense resistor (20) and the first end of the reference current resistor (22), the other ends of these resistors being coupled to a common terminal,

said reference current source (24) being responsive to an applied input signal for supplying a current of said first predetermined magnitude to the reference current resistor (22) which establishes a first voltage reference at said second input of the comparator (34), said comparator (34) switching output states in response to the load current exceeding a first predetermined value, which causes said reference current source (24) to supply a current at its output of said second predetermined magnitude such that the magnitude of the load current is reduced to a second value, characterized in that:

the circuit (10) is integrated; and in that

the power stage (18) comprises a power transistor (100) having n emitters, where n is an integer, and a plurality of n ballast resistors (R_b) formed in the integrated circuit, each of said ballast resistors, through which proportional amounts of the load current flow, being coupled in series to a respective emitter of said power transistor (100), the sense resistor (20) being a particular one of said ballast resistors (R_b) and being located with said reference current resistor in said integrated circuit and formed of the same material.

2. The circuit of claim 1 wherein the reference current source is characterized by:

a first current supply (80, 82, 84) for supplying the current of the first magnitude;

a second current supply (86) for supplying the current of the second magnitude, said second current supply being coupled to the output of the reference current source; and

switching circuitry (64, 74, 78) which selectively couples and decouples said first current supply to said output of the reference current source in response to the output state of said comparator.

Patentansprüche

1. Schaltung (10) zur Lieferung eines Stromes an eine Last (14),

mit einer Leistungsstufe (18) und einem Abtastwiderstand (20), welche mit der Last in Reihe liegen,

mit einer Bezugsstromquelle (24), die über ihren Ausgang einen Strom einer ersten oder zweiten Stärke einem Bezugsstromwiderstand (22) zuleitet, der an seinem ersten Ende mit dem Ausgang der Bezugsstromquelle verbunden ist, mit einer Schaltung, die einen Komparator (34)

transistor 124 are connected in an OR configuration such that with either one of these two transistors becoming conductive causes latch 64 to be set which as previously explained causes the output current at output terminal 12 of driver circuit 10 to be reduced to the lower level state. Hence, if the peak magnitude of current (time T2) has been reached previous to transistor 162 becoming conductive, transistor 124 will have already set latch 64 and the output from driver circuit 10 is reduced at time t3 to its lower current level state. However, if the battery voltage source is sufficiently low, as shown by waveform portion 160 of Fig. 2c, the output of driver circuit 10 will never reach the peak magnitude output. This is shown by waveform portion 176 of Fig. 2a. Hence, latch 64 cannot be set by transistor 124 whereby the output current level will remain at a constant level somewhere below the predetermined peak magnitude. Without circuit 156, the output current level of driver circuit 10 will remain constant. However, when the external capacitor is charged to the voltage level to render transistor 168 non-conductive, transistor 170 is rendered conductive to set the latch as shown at time t5 of Fig. 2a to reduce the output current level from driver circuit 10 to the lower current level.

In some applications circuit 156 might be utilized in conjunction with a control voltage being supplied at input terminal 158 as shown by waveform portion 178. In this manner, the current level at output terminal 12 can be switched to its lower current level if the peak magnitude current level has not been reached by a predetermined time interval after the input signal at input terminal 16 has switched to its higher level state.

By connecting input terminal 158 to input terminal 16, circuit 10 functions as a load protected integrated power switch. In this application, whenever the input signal at input 16 goes high the output current provided at output 12 is fully conductive and constant, being set at any desired limit level within the dynamic range of trim network 126. If the load current exceeds the predetermined limit value the output (power stage 18) goes into an active state and thermal shutdown circuit 38 can protect the integrated circuit if excessive heating occurs as was previously described.

The above described driver circuit for driving inductive or resistive loads is suitable to be fabricated entirely as an integrated circuit device including the power stage and functions by comparing a percentage of the load current to an internally generated reference current for switching the load current when a predetermined peak magnitude is reached to a constant, predetermined sustaining level.

Claims

1. A circuit (10) for providing current to a load (14), comprising:

a power stage (18) and a sense resistor (20) coupled in series with the load;

a reference current source (24) that supplies a current of either a first or second magnitude at its output to a reference current resistor (22) coupled at a first end thereof to the output of the reference current source; and

circuitry including a comparator (34) having an output coupled both to the reference current source (24) and the power stage (18), and first and second inputs coupled respectively to a first end of the sense resistor (20) and the first end of the reference current resistor (22), the other ends of these resistors being coupled to a common terminal,

said reference current source (24) being responsive to an applied input signal for supplying a current of said first predetermined magnitude to the reference current resistor (22) which establishes a first voltage reference at said second input of the comparator (34), said comparator (34) switching output states in response to the load current exceeding a first predetermined value, which causes said reference current source (24) to supply a current at its output of said second predetermined magnitude such that the magnitude of the load current is reduced to a second value, characterized in that:

the circuit (10) is integrated; and in that

the power stage (18) comprises a power transistor (100) having n emitters, where n is an integer, and a plurality of n ballast resistors (R_b) formed in the integrated circuit, each of said ballast resistors, through which proportional amounts of the load current flow, being coupled in series to a respective emitter of said power transistor (100), the sense resistor (20) being a particular one of said ballast resistors (R_b) and being located with said reference current resistor in said integrated circuit and formed of the same material.

2. The circuit of claim 1 wherein the reference current source is characterized by:

a first current supply (80, 82, 84) for supplying the current of the first magnitude;

a second current supply (86) for supplying the current of the second magnitude, said second current supply being coupled to the output of the reference current source; and

switching circuitry (64, 74, 78) which selectively couples and decouples said first current supply to said output of the reference current source in response to the output state of said comparator.

Patentansprüche

1. Schaltung (10) zur Lieferung eines Stromes an eine Last (14),

mit einer Leistungsstufe (18) und einem Abtastwiderstand (20), welche mit der Last in Reihe liegen,

mit einer Bezugsstromquelle (24), die über ihren Ausgang einen Strom einer ersten oder zweiten Stärke einem Bezugsstromwiderstand (22) zuleitet, der an seinem ersten Ende mit dem Ausgang der Bezugsstromquelle verbunden ist,

mit einer Schaltung, die einen Komparator (34)



aufweist, dessen Ausgang sowohl mit der Bezugsstromquelle (24) als auch mit der Leistungsstufe (18) in Verbindung steht, während sein erster und zweiter Eingang mit einem ersten Ende des Abtastwiderstandes (20) bzw. mit dem ersten Ende des Bezugsstromwiderstandes (22) verbunden ist und die anderen Enden dieser Widerstände an eine gemeinsamen Klemme angeschlossen sind,

wobei die Bezugsstromquelle (24) auf ein ihr zugeführtes Eingangssignal anspricht, um einen Strom der ersten vorgegebenen Stärke an den Bezugsstromwiderstand (22) heranzubringen, der an der zweiten Eingangsklemme des Komparators (34) eine erste Bezugsspannung aufbaut, und

wobei der Komparator (34) den Ausgangszustand entsprechend dem einen ersten vorherbestimmten Wert übersteigenden Laststrom schaltet, der die Bezugsstromquelle (24) zur Lieferung eines Stromes der zweiten vorgegebenen Stärke an ihrem Ausgang veranlaßt, so daß die Stärke des Laststromes auf einen zweiten Wert vermindert wird, dadurch gekennzeichnet,

daß die Schaltung (10) eine integrierte Schaltung ist, und

daß die Leistungsstufe (18) einen Leistungs-transistor (100) mit n Emit-mittern (n =eine ganze Zahl) und mehrere von n in der integrierten Schaltung ausgebildeten Ballastwiderständen (R_b) enthält, durch die proportionale Beträge des Laststromflusses in Reihe zu einem jeweiligen Emitter des Leistungstransistors (100) hindurchgehen, wobei der Abtastwiderstand (20) als spezieller Ballastwiderstand (R_b) mit dem Bezugsstromwiderstand in der integrierten Schaltung angeordnet und aus demselben Material gebildet ist.

2. Schaltung des Anspruches 1, bei der die Bezugsstromquelle gekennzeichnet ist:

durch eine erste Stromquelle (80, 82, 84) zur Lieferung des Stromes der ersten Stärke,

durch eine zweite Stromquelle (86) zur Lieferung des Stromes der zweiten Stärke, die mit dem Ausgang der Bezugsstromquelle verbunden ist, und

durch eine Schaltung (64, 74, 78), die in Abhängigkeit vom Ausgangszustand des Komparators wahlweise die erste Stromquelle an dem Ausgang der Bezugsstromquelle anschließt bzw. von ihm abtrennt.

Revendications

1. Circuit (10) pour fournir du courant à une charge comprenant:

—un étage de puissance (18) et une résistance de détection (20) couplés ou connectés en série avec la charge;

—une source (20) de courant de référence qui

fournit un courant ou bien d'une première amplitude ou bien d'une seconde amplitude à sa sortie sur une résistance de courant de référence (22) connectée à une première extrémité de la sortie de la source de courant de référence et

un circuit comprenant un comparateur (34) ayant une sortie connectée à la fois à la source (24) de courant de référence et à l'étage de puissance (18) et des première et seconde entrées connectées respectivement à une première extrémité de la résistance de détection (20) et à la première extrémité de la résistance de courant de référence (22), leurs autres extrémités étant connectées à une borne commune,

ladite source de courant de référence (24) étant activée par un signal d'entrée appliqué pour fournir un courant de ladite première amplitude prédéterminée à la résistance de courant de référence (22) qui établit une première tension de référence pour ladite seconde entrée du comparateur (34), ledit comparateur (34) commutant les états de sortie en réponse au courant de charge excédant une première valeur prédéterminée qui provoque la fourniture à la sortie de la source de courant de référence (24) d'un courant d'une seconde amplitude prédéterminée de telle sorte que l'amplitude du courant de charge soit réduite à une seconde valeur, caractérisé en ce que:

—le circuit (10) est intégré; et en ce que

—l'étage de puissance (18) comporte un transistor de puissance (100) ayant n émetteurs où n est un entier et une pluralité de n résistances ballast (R_b) formées sur le circuit intégré, chacune desdites résistances ballasts à travers lesquelles circulent des quantités proportionnelles du courant de charge, étant connectée en série à un émetteur respectif dudit transistor de puissance (100), la résistance de détection (20) étant une résistance particulière parmi lesdites résistances de ballast (R_b) et étant disposée au même endroit que ladite résistance de référence de courant dans ledit circuit intégré et est formée avec le même matériau.

2. Circuit selon la revendication 1, dans lequel la source de courant de référence est caractérisée par:

—une première alimentation de courant (80, 82, 84) pour fournir le courant de la première amplitude;

—une seconde alimentation en courant (86) pour alimenter le courant de la seconde amplitude, ladite alimentation seconde de courant étant connectée à la sortie de la source de courant de référence; et

—un circuit de commutation (64, 74, 78) qui couple sélectivement et découple ladite première alimentation en courant à ladite sortie de la source de courant de référence en réponse à l'état de sortie dudit comparateur.

