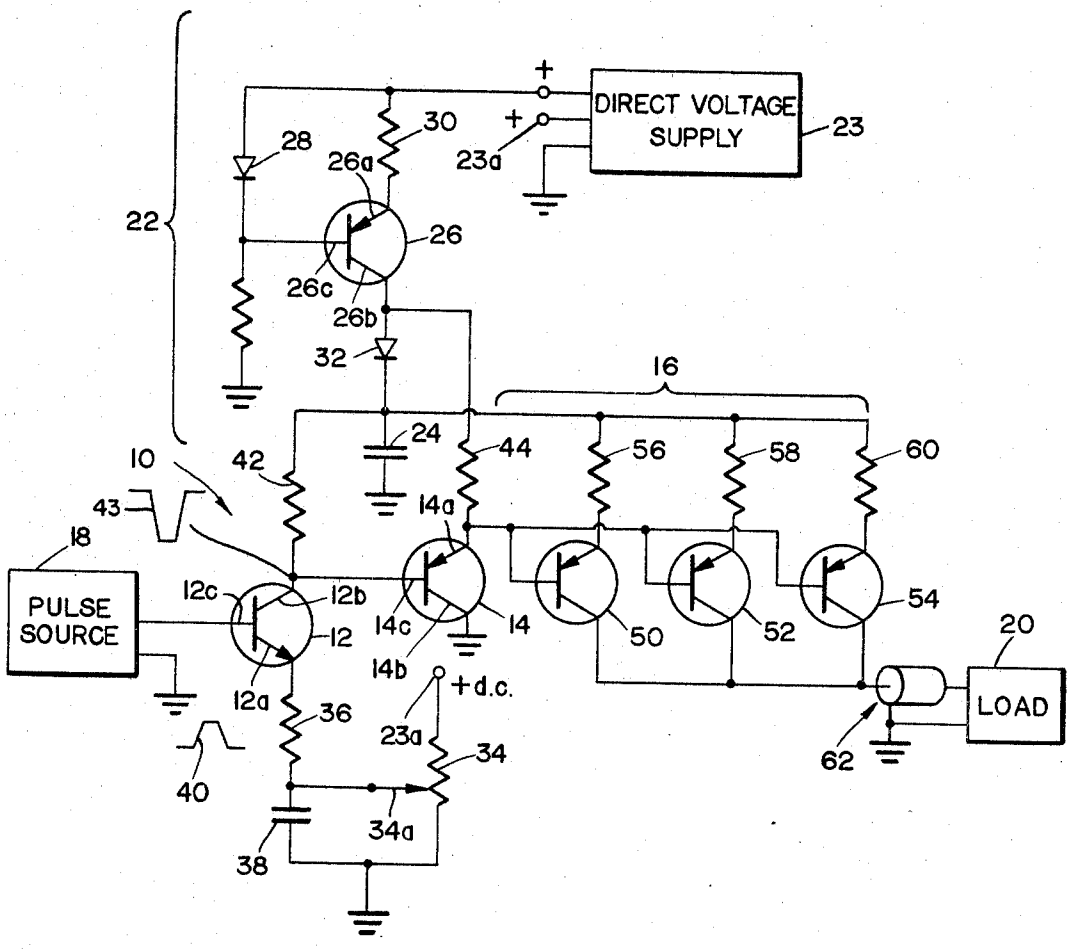
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CURRENT DRIVER WITH OVERLOAD PROTECTION

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CURRENT DRIVER WITH OVERLOAD PROTECTION

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ABSTRACT OF THE DISCLOSURE

A current amplifier having a comparatively high degree of protection against overload damage has an output stage arranged to deliver to a load only the current a storage capacitor accumulates from a constant current source. So long as the storage capacitor is not discharged, the output current level corresponds to an input signal applied to an input control stage that operates the output stage.

BACKGROUND

This invention relates to an electrical current amplifying circuit of relatively high pulse-current capability but of such limited sustained-current capability as to minimize circuit damage due to excessive operation. The invention is particularly useful in a memory-test current driver. This is an electrical supply for impressing on a magnetic core memory a controllable test current, generally in the form of a pulse having short rise and decay times.

Current drivers for memory-test operation, as well as many other current amplifying circuits, generally have to produce current pulses adjustable to relatively large magnitudes. Further, the pulses should faithfully correspond in duration and in rise and fall times to a controlling input pulse. However, current drivers are likely to be subjected to overload conditions that call upon the circuit to produce an excessive average output current. This excessive operation often results in destructive damage to the circuit and/or in like damage to the load. By way of example, memory-test current drivers are subject to overload by accidental application of a low resistance or short circuit across the output terminals by operation with input signals that call for excessively large and/or excessively long output pulses, and by transients developed at the output terminals due to the large reactance of the load impedance. The relatively reactive, principally inductive, input impedance of magnetic core memories causes the latter condition to recur often.

In the prior art, protection against overload conditions has involved considerable additional costs for protective circuitry. In addition, many prior overload-protected current drivers are still subject to damage under certain overload conditions.

Accordingly, it is an object of the present invention to provide a current-supplying circuit having improved overload protection. Further, the circuit should provide overload protection with a high degree of reliability under many different overload conditions.

A more particular object is to provide a transistor circuit of the above character capable of producing relatively large current pulses. The circuit should also be capable of producing such pulses with relatively short rise and fall times.

Another object is to provide a circuit of the above character which protects the load connected thereto from excessive current when the circuit is subjected to overload conditions.

It is also an object of the invention to provide a circuit of the above character of relatively simple and low-cost construction.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts exemplified in the construction hereinafter set forth, and the scope of the invention is indicated in the claims.

SUMMARY OF THE INVENTION

In the present current driver, the output current, both pulse and average, is limited. Further, avalanche breakdown of an output stage transistor is rendered essentially harmless. This multiple overload protection is attained automatically by supplying the output stage with the sum of a limited continuous current and a capacitively stored current. The continuous current is insufficient to damage the output stage components, and the quantity of stored charge in the capacitor is likewise insufficient to damage the circuit components, even during a rapid discharge.

On the other hand, the stored charge enables the output stage to produce current pulses having a magnitude considerably larger than the continuous current.

When the duration and/or frequency of the pulses becomes excessive, the capacitively stored current is consumed and the output current from the driver decreases to a level limited by the continuous supply current. Until the capacitively stored current is largely exhausted, however, the driver maintains the output current at the level prescribed by the input signal it receives.

When an output transistor of the driver avalanches, the transistor in effect consumes the limited capacitively stored current without damage and is then limited to the continuous current, which is also insufficient to damage the transistor.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and object of the invention, references should be had to the following detailed description taken in connection with the accompanying drawing, which is a schematic representation of a current driver employing the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, the current driver has an input control stage indicated generally at **10** comprising transistors **12** and **14**. During normal operation, in response to an input signal from a pulse source **18**, the input stage causes an output stage **16** to apply a current waveform corresponding to the input signal waveform to an electrical load **20**. Where the driver is used for memory-test purposes, the load is a magnetic core memory.

The driver also has a current-supplying stage **22** in which a transistor **26** delivers a constant current in parallel to a storage capacitor **24** in the stage **22** and to the output stage **16**. The control stage transistors **12** and **14** also draw a small part of this constant current.

The maximum current the output stage can deliver to the load, available when the storage capacitor **24** is charged, is the charge on the capacitor plus the larger part of the constant current from the transistor **26**. However, when the storage capacitor is discharged, the output current is limited to the constant current from the supply stage **22**.

The driver is arranged, by appropriate selection of component values, so that the storage capacitor **24** becomes discharged when the average output current approaches an excessive level. The output level can become excessive in many ways, including an avalanche breakdown of an output stage transistor, and an input signal of excessive magnitude calling on the output stage to produce excessive output current. In addition, although the driver can safely produce large output pulses by drawing on the

charge in the capacitor **24**, a rapid succession of such large pulses might damage an output stage transistor by causing excessive heating therein. Accordingly, a succession of pulses that causes an excessive average output current is also an overload condition against which the driver is protected.

More particularly, in the current-supplying stage **22**, the direct voltage from an external supply **23** develops a fixed reference voltage across a diode **28**, which generally comprises plural diodes in series to sum their individual forward voltage drops. This reference voltage causes the transistor **26** to deliver a known constant current at its collector **26***b* from the supply through a resistor **30** connected to its emitter **26***a*. The transistor **26** preferably is a low frequency transistor not subject to avalanche breakdown.

The input stage transistor **14** draws a small part of the constant current from the transistor **26**. The balance passes through a diode **32**, developing a substantially current-independent voltage drop thereacross, and is delivered in parallel to the storage capacitor **24**, the input stage transistor **12**, and the output stage **16**.

With further reference to the drawing, the supply **23** also applies a positive direct voltage across an adjustable voltage divider **34** in the control stage **10**. This voltage develops a relatively small positive voltage at the transistor **12** emitter **12***a* through a resistor **36** connected to the voltage divider tap **34***a*. A high-frequency bypass capacitor **38** is connected to ground from the tap.

In the interval between pulses from the illustrated source **18**, the transistor **12** receives a small positive quiescent voltage at its base **12***c*. The voltage divider **34** is adjusted so that this quiescent voltage at the transistor base biases the transistor **12** to the point where a further increase in its base voltage will cause it to operate on the linear portion of its operating characteristic. In this condition, the transistor **12** draws a small bias current from the transistor **26** through the diode **32** and a resistor **42** connected to the collector **12***b*. The purpose of maintaining the transistor **12** at this quiescent condition is to have it faithfully reproduce positive pulses from the source **18**.

When the resistor **42** is equal to the resistor **44** connected to the emitter of transistor **14**, transistor **14** draws essentially the same emitter current as the transistor **12** draws at its collector **12***b*. This is because the series combination of resistor **42** and diode **32** is in parallel with the series combination of resistor **44** and the emitter-base junction of transistor **14**. Further, the forward voltage drop across the diode **32** is substantially equal to the forward voltage drop across the transistor **14** emitter-base junction. Therefore, the voltage across resistor **44** is equal to the voltage across resistor **42** and hence the currents in the two equal resistors are equal.

The transistor **14** is therefore also maintained at a quiescent condition where it draws a small emitter current and will operate on the linear portion of its characteristics with a further increase in the voltage between its base and emitter.

The illustrated pulse source **18** develops positive pulses, typically having the waveform **40**, at the transistor base **12***c*. In response to such a pulse, the transistor **12** draws a collector current determined substantially exclusively by the value of resistor **36** and the difference between the pulse voltage and the voltage at the tap **34***a*. This collector current develops an amplified voltage, across the resistor **42**, with a waveform **43** that is the amplified inverse of the input waveform **40**. The resultant voltage drop at the base of transistor **14** causes it to draw an emitter current through resistor **44** corresponding to the current in resistor **42**.

The transistor **12** thus operates as a common-emitter amplifier and the transistor **14** as an emitter follower.

In the output stage **16**, three transistors **50**, **52** and **54**, each having an emitter resisor **56**, **58** and **60** respectively, are arranged in parallel. The voltage developed across the resistor **44**, less the drop across the diode **32**, is applied across the series combination of the emitter resistor and the emitter-base junction of each output transistor.

The quiescent current in the resistor **44** is insufficient to cause the output transistors to draw more than a small, essentially negligible, current. However, in response to the voltage developed across the resistor **44** by a pulse from the source **18**, each output transistor normally applies to the load **20** a substantial current with a waveform closely corresponding to the input waveform **40**. Accordingly, the load receives a large current pulse equal to the sum of the currents from the three output transistors. The emitter resistors **56**, **58**, **60** determine in part the magnitude of the current each transistor draws and they also equalize the load current between the three transistors **50**, **52** and **54**.

The current the output transistors apply to the load is drawn from the transistor **26** and from the storage capacitor **24**. When the input pulses from the source **18** are of relatively small magnitude or are short relative to the spacing between them, i.e. have a low duty cycle, the output transistors draw a relatively small average current and the capacitor **24** remains essentially charged, i.e. the constant current from transistor **26** essentially fully recharges it in the intervals between successive input pulses.

Further, in this non-excessive operating condition, even though the charge on capacitor **24** fluctuates, and correspondingly, the voltage across it and the voltage applied to the output stage **16** fluctuate, the output current applied to the load **20** remains essentially uniformly related to the magnitude of the input signal. This is because, so long as the capacitor **24** is not substantially entirely discharged, the voltage across the resistor **42**, and therefore the voltage across the resistor **44**, are directly proportional to the magnitude of the input signal. The voltage across each resistor **56**, **58** and **60** then also depends directly on the input signal magnitude.

However, when the overload conditions discussed above cause the output transistors to draw a large average current, the capacitor **24** becomes increasingly discharged. The voltage across the capacitor **24** then drops to the point where the output transistors saturate. In this condition, the total output current from the driver is limited essentially to the constant current provided by the transistor **26**. This current is insufficient to damage the output transistors, even on a continuous basis. Hence, the driver can tolerate prolonged application of an overload condition without damage.

In addition, by drawing on the charge in the storage capacitor **24**, the driver can produce output current pulses at least five times greater than the constant current the transistor **26** develops, so long as the duty cycle does not become excessive.

With further reference to the drawing, it was described above that the diode **32** develops a current-independent forward voltage drop essentially equal to the forward drop across the emitter-base junction of transistor **14**. When both the diode and the transistor are of silicon semiconductor material, as preferred, the two forward voltage drops vary equally with temperature. This is desired, for it enables transistor **14** to have essentially the same quiescent current as transistor **12** over a wide range of operating temperatures. As a result, the waveform of the output current pulse corresponds closely to that of the input pulse. More specifically, with a lesser quiescent current in transistor **14**, its emitter current waveform will not correspond faithfully to the input pulse waveform. And a quiescent current larger than in transistor **12** will retard recharging of capacitor **24**.

It should also be noted that the base of each output transistor is connected, by way of resistor **44**, to a more positive potential than is the emitter. For example, the base of transistor **50** is connected through resistor **44** to the anode of diode **32**, while the transistor base is connected by way of the resistor **56** to the cathode of this

diode. This arrangement facilitates maintaining each output transistor at a quiescent condition where it is substantially just off, ready to conduct without significant delay when the transistor **12** receives an input signal.

As indicated above, when a transient condition causes the load **20** to impress a voltage between the driver output terminals **62** which causes at least one transistor to avalanche, that transistor will tend to draw such an excessive current that it will burn out. However, in the present driver, just as the output transistors are prevented from drawing excessive average current due to excessive input signals, the avalanched output transistor will discharge the capacitor **24** without being damaged and is then constrained to the safe level of constant current that the transistor **26** produces. Thus, the driver is not damaged by avalanche in its output transistors. Likewise, the load does not receive a sustained excessive current and is not damaged.

The value of the storage capacitor **24** is accordingly selected so that its charge is insufficient to destroy an output transistor even during a rapid discharge of the capacitor. On the other hand, the capacitor is large enough to produce the longest output pulse desired at the required maximum output current level.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained. It is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A current amplifying circuit that normally produces an output signal with a waveform corresponding to the waveform of an input signal applied thereto, said circuit comprising

(A) a source (**22**) of limited current,

(B) a capacitor (**24**) connected to be charged with the current from said source,

(C) circuit means (**10, 16**) for summing said limited current and the charge on said capacitor, said sum having a waveform substantially corresponding to the waveform of said input signal, and

(D) terminals (**62**) connected to receive the output of said circuit means.

2. A circuit according to claim **1** in which said circuit means comprises a transistor (**50**) having its emitter-collector path in series with said output terminals, and having the series combination of said emitter-collector path and said output terminals in parallel with said capacitor.

3. A circuit according to claim **1**

(A) further comprising a semiconductor junction (**32**) in series between said source and said capacitor and connected to conduct said current with a substantially current-independent voltage drop thereacross, and

(B) in which said circuit means comprises

(1) a resistor (**44**),

(2) a first transistor (**14**)

(a) having its emitter-collector path in series with said resistor, and

(b) having the combination of its emitter-collector path and said resistor in parallel with the series combination of said junction and said capacitor, and

(3) a further transistor (**50**)

(a) having its emitter-collector path in series with said output terminals and with the combination of its emitter-collector path and said output terminals in parallel with said capacitor, and

(b) having its base in circuit with the emitter of said first transistor to receive a potential corresponding to the potential at the emitter of said first transistor.

4. A circuit according to claim **3** in which said voltage drop of said semiconductor junction and the voltage drop of the base-emitter junction of said first transistor vary substantially equally due to changes in the temperatures of said junction.

5. A current amplifying circuit according to claim **1** in which said source of limited current comprises a transistor arranged as a source of substantially constant current.

6. A current amplifying circuit according to claim **5** in which

(A) said capacitor is connected in the path of the collector current of said transistor, and

(B) said circuit means is connected to the inter-connection of said capacitor and said source, thereby to deliver to said output terminals the sum of current from said source available at said interconnection and current drawn from said capacitor.

7. A current driver comprising

(A) a first transistor (**26**),

(B) a first resistor (**30**) connected to the emitter of said first transistor,

(C) a first diode device (**28**)

(1) connected in parallel with the series combination of said first resistor and the emitter-base junction of said first transistor, and

(2) conducting current with a substantially current-independent voltage drop of such a polarity as to forward bias the emitter-base junction of said first transistor,

(D) a second diode device (**32**) connected with the collector of said first transistor and developing a current-independent voltage drop thereacross in response to collector current from said first transistor,

(E) a common return conductor,

(F) a capacitor (**24**) connected between said second diode device and said common return conductor,

(G) a second resistor (**44**),

(H) a second transistor (**14**)

(1) having said second resistor connected between the emitter thereof and the collector of said first transistor,

(2) having the collector thereof in circuit with said common return conductor,

(I) a third resistor (**56**)

(J) an output terminal (**62**)

(K) a third transistor (**50**)

(1) arranged with said third resistor connected between the emitter thereof and the inter-connection of said capacitor and said second diode device, and

(2) having the collector thereof connected with said output terminal.

8. A current driver according to claim **7** further comprising

(A) a fourth resistor (**42**),

(B) a fourth transistor (**12**)

(1) arranged with said fourth resistor connected between the collector thereof and the interconnection of said capacitor and second diode device,

(2) having the collector thereof in circuit with the base of said second transistor to apply to said second transistor base a potential corresponding to the potential at the collector thereof.

9. A current driver according to claim **8** further comprising

(A) a fifth resistor (**36**) connected to the emitter of said fourth transistor, and

(B) direct voltage supply means arranged to apply a biasing voltage between said return conductor and the end of said fifth resistor remote from said fourth transistor.

10. A current driver according to claim **8**

(A) in which each of said second and fourth transistors are arranged to draw substantially the same quiescent current.

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