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[54] **CIRCUITS FOR REGULATING A CURRENT**

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[58] **Field of Search**................307/297, 300; 330/22; 323/22 T

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[57] **ABSTRACT**

The current flow through a series leg, composed of the collector-emitter path of a transistor, of a load resistor connected to the collector, and of a substantially non-inductive resistor connected to the emitter, is regulated by a reference voltage provided between the free terminal of the latter resistor and the base of the transistor. The voltage can vary linearly with the operating voltage applied to the said free end, in dependence on temperature, or in dependence on some other factor, or can be constant. A diode can be conductively connected between the base and the reference voltage. The resistance of the load resistor is less than that of the substantially non-inductive resistor.

14 Claims, 4 Drawing Figures

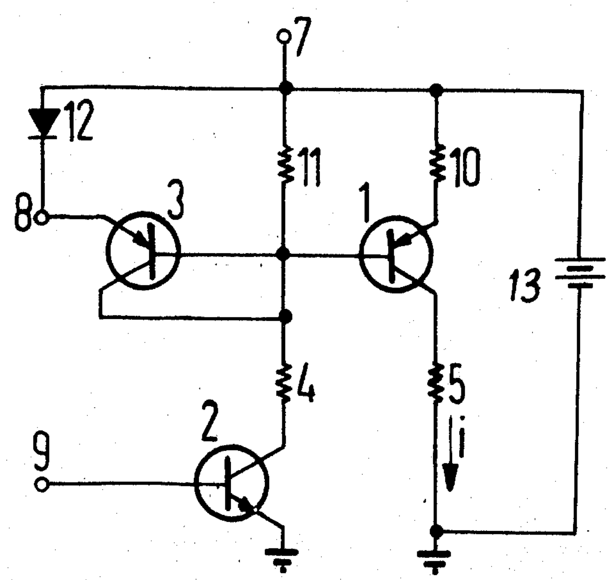

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Fig. 1

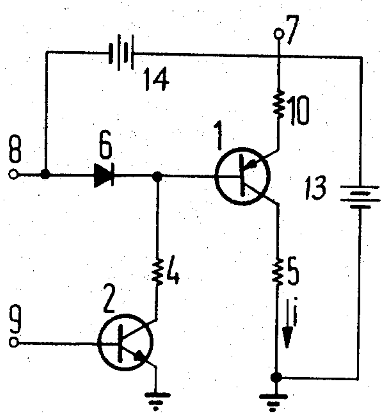


Fig. 2

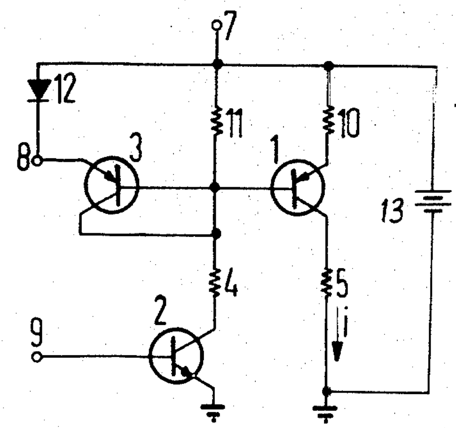


Fig. 3

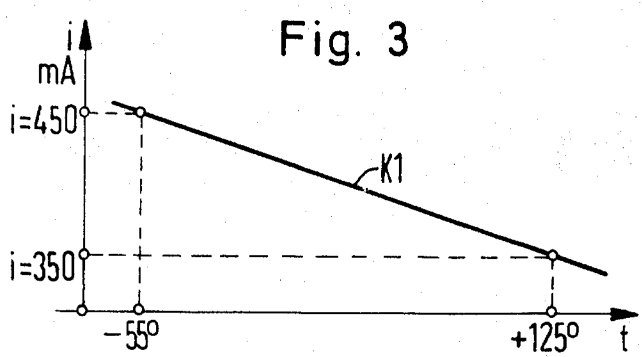
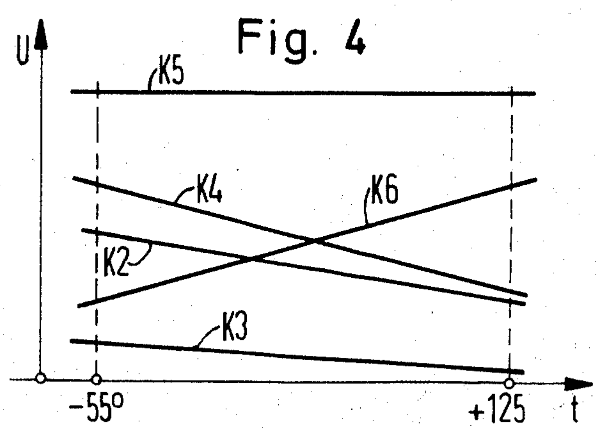


Fig. 4



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CIRCUITS FOR REGULATING A CURRENT

BACKGROUND OF THE INVENTION

The invention relates to a circuit for regulating the amplitude of current particularly of current pulses, in a series leg, composed of a load resistor, of the emitter-collector path of a transistor, of a substantially non-inductive resistor, and of a source of voltage.

With known circuits of this kind, the current through the load resistor is switched by means of a transistor and of a transformer. Control pulses are conducted to a first winding of the transformer, a second winding of the transformer being connected to the base and to the emitter of a transistor. In this known circuit, the ohmic resistance of the load current circuit is substantially greater than that of the load resistor, so that the current is influenced virtually only by the ohmic resistance and not by the load resistor. Since the tolerance of the ohmic resistance is a relatively small plus or minus 1 percent, the amplitude of the current pulse in the load current circuit can be held largely constant without requiring a special regulatory arrangement. This is particularly the case, when changes in the load current circuit, caused by temperature fluctuations, can be ignored.

This known circuit has the disadvantage, however, that a relatively large amount of power is used in the load current circuit, because the current flow requires a relatively high voltage in view of the large ohmic resistance. Further difficulties arise when temperature fluctuations change the individual circuit parameters.

SUMMARY OF THE INVENTION

An object of the invention is a circuit for regulating the amplitude of the current in a load current circuit, particularly current pulses, which circuit requires relatively little power and is largely stabilized against changes in circuit parameters caused by temperature fluctuations or by changes in the values of the circuit components.

A further object of the invention is a circuit of the preceding object, which circuit is suitable for operation over a temperature range of from **−55°C. to +125°C.**

Briefly, the invention consists of a first transistor, a series current path in which the control pulses are conducted, the series current path including the emitter-collector path of the first transistor and connected in series with the emitter-collector path a load resistor and a substantially non-inductive resistor, the latter resistor being smaller in resistance than the load resistor, a circuit junction, the base of the first transistor being connected to this junction, a source of operating voltage having two terminals, the voltage difference between one terminal of this source and the circuit junction constituting a reference voltage, and controlled electronic switching means connected between the base and a constant potential.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims.

The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram of the first embodiment of the invention, in which the reference voltage is independent of the operating voltage;

FIG. 2 is a circuit diagram of a second embodiment, in which the reference voltage, obtained by means of a diode, is dependent on the operating voltage; and

FIGS. 3 and 4 are graphs in which are plotted the change in current and voltage at different points in the circuit of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, the circuit consists of first transistor **1** and additional transistor **2**, of two substantially non-inductive resistors **4** (56 ohms) and **10** (1.2 ohms), of the load resistor **5** (5.1 ohms), and of the diode **6**. A source **13** of operating voltage (5 volts) is connected between the terminal **7** and the ground terminal. The resistance of the resistor **10** is substantially smaller than that of the load resistor **5**. In many cases, the ratio between the resistors **10** and **5** can be from 1:2 to 1:5 . Resistors **5** and **10**, together with the collector-emitter path of transistor **1**, form a current path for control current or voltage pulses. Fixed potential means, here in form of a simple conductor connects the emitter of transistor **2** to ground.

It will be assumed that the operating voltage is held constant within ± 2 percent. Because of limitations in manufacture, and because of aging, the resistances of the resistors **10** and **5** and the resistance of the emitter-collector path of the first transistor **1** are accurate only within certain tolerances. The tolerance for the resistor **10** is ± 1 percent. The tolerances for the emitter-follower path of transistor **1** and for the load resistor **5** are respectively ± 25 percent and ± 7 percent. The circuit described is intended for operation within a temperature range −55°C. to +125°C. It is also assumed that for changes in temperature over a range from −55°C. to +125°C. the resistor **10** changes plus or minus 1 percent, the resistance of the emitter-collector path of transistor **1** changes ± 10 percent, and the resistance of the load resistance **5** changes ± 5 percent.

The circuit shown in FIG. 1 regulates the amplitude of the current pulse *i*. In spite of the aforesaid tolerances and temperature-caused resistance changes, the current pulse should be regulated as precisely as possible, and variation should not exceed ± 1 percent. By way of example, it may be required to regulate the current pulse *i* independent of the temperature. On the other hand, it may be required to regulate the amplitude of the current pulse in dependence on the temperature or in dependence on some other factor.

If a positive pulse is applied to the terminal **9**, the emitter-collector path of the additional transistor **2** becomes conductive, a current thereby flowing through the resistor **4**, the diode **6**, and the base of first transistor **1**. Consequently, the emitter-collector path of transistor **1** becomes conductive, and a current pulse *i* appears in the load current circuit. The amplitude of this current pulse depends on the reference voltage that exists between the terminal **7** and the circuit junction **8** afforded by source of reference voltage **14**. When this reference voltage changes, there changes also the voltage at the base of transistor **1**, the voltage at the emitter of transistor 1, and the voltage drop across the resistor **10**. Because of the change in the voltage drop across the resistor **10**, the amplitude of the current pulse *i* is regulated.

The circuit is characterized by a small power consumption, because the value of the resistor **10** is small in comparison to that of the load resistor **5**, and because a relatively low operating voltage is required in view of the small current demands of the circuit. The power consumed, which is the product of the current and the operating voltage, is therefore also small. Moreover, the circuit has the further advantage that it reduces changes in the current caused by changes in the value of the load resistor **5**. Finally, the circuit is simple and inexpensive, because the transistor **1** plays a double role: it turns on and off the current through the load resistor **5**, and it enables a controllable variation of the voltage across the resistor **10**, thereby enabling regulation of the current.

If it is desired that the amplitude of the current pulse *i* should be independent of the temperature, the reference voltage between the terminal **7** and the junction **8** is held constant.

The changes in the resistances of the load resistor **5** and of the emitter-collector path of transistor **1**, caused by temperature changes and tolerances, are regulated by changing the voltage across the resistor **10**. For example, if the value of the load resistor **5** becomes smaller, the voltage at the collector of transistor **1** is smaller and with a constant emitter voltage, the collector-emitter voltage is larger, so that the amplitude of the current pulse *i* remains constant. The diode **6** regulates changes in the base-emitter voltage of transistor **1**, caused by temperature changes. This diode is connected so that it conducts. The effect of change in temperature on the voltage drop across the diode and across the base-emitter path of transistor **1** is the same. If the voltage drop across the diode **6** increases, the voltage drop across the base-emitter path likewise increases, whereby temperature-caused changes of the emitter voltage of transistor **1** are regulated.

If the amplitude of the current pulses is to be independent of temperature but dependent upon some other factor, there is provided between the terminal **7** and the junction **8** a reference voltage that changes in dependence on this other factor. Temperature changes are of no consequence, because, as previously explained, they are compensated by variations in the voltage drop across the resistor **10**.

If the amplitude of the current pulse *i* is to be made dependent on temperature, the aforesaid reference voltage is also made dependent on the temperature.

With reference to FIG. **2**, there is shown a circuit for regulating the amplitude of the current pulse *i* in dependence on the temperature. The reference voltage must also be temperature-dependent. A temperature-dependent resistance, such as the diode **12**, connected between the terminal **7** and the junction **8**, provides the desired reference voltage. At the same time, this component makes variations of ± 2 percent in the operating voltage ineffective.

The diode **6** is replaced by a second transistor **3**, because the temperature-dependent base-emitter voltage characteristics of the two transistors **1** and **3** can be more accurately matched than can the change in voltage drop of a diode **6** to the change in the base-emitter voltage of transistor **1**. The base electrode of transistor **3** is connected to the base of transistor **1** whereas the emitter electrode of transistor **3** is connected to the circuit junction **8**. The transistors **1** and **3** are advantageously of the same type with the same temperature dependency, exposed to the same temperature conditions, as by mounting them in the same housing. The resistor **11** drains off the current that flows through the base-emitter path of transistor **1** when shutting off. Since the operating voltage at the terminal **7** is more positive (+5 volts) than the ground potential (0 volts), the transistors **1** and **3** are PNP types and the transistor **2** is of NPN types. In accordance with the invention, the terminal **7** can be made negative with respect to ground, in which case the transistors **1** and **3** are NPN types and the transistor **2** is a PNP type.

The circuit shown in FIG. **2** is suitable as a current driver for operating a matrix store. A circuit of this kind can send, for example, inhibit current pulses through the inhibit leads of matrix memories. If a current driver of this kind is to be used in the temperature range of from −55°C. to approximately 125°C., the circuit is advantageously so designed that the current pulse *i* through the load resistor **5** (the inhibit lead of the memory) flows in accordance with the curve K1, shown in FIG. **3**. The temperature is plotted along the abscissa, and the current *i* is plotted along the ordinate. At −55°C., the current *i* through the load resistor **5** should be 450 milliamperes, and at +125 C., the current should be 350 milliamperes, corresponding to a change in current of 1 milliampere /°C.

The circuit enables the successive connection of a series of load resistors, the values of which are not exactly equal.

With reference to FIG. **4**, the temperature *t* is plotted along the abscissa, and the voltage U is plotted along the ordinate. Assuming that the current *i* is to follow the curve K1, shown in FIG. **2**, the voltage across the load resistor **5** must follow the curve K2. The curve K3 shows the variation in voltage across the emitter-collector path of transistor **1**. The curve K4 shows the variation in the voltage between the emitter of transistor **1** and ground, if the current through the load resistor **5** is to follow the curve K1. The worst case is taken into account in the curves K1 through K4. The curve K5 shows the voltage at the terminal **7** with respect to ground.

The curve K6 is the difference between the curve K5 and K4. Curve **K6** thus shows the voltage across the resistor **10** required to obtain the desired current *i*. The voltage corresponding to the curve K6 is obtained by the diode **12**, which produces the reference voltage at the junction **8**. This reference voltage causes the desired current *i* throughout the entire temperature range.

In accordance with the invention, the reference voltage can be linearly dependent on the operating voltage.

In will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of circuits differing from the types described above.

While the invention has been illustrated and described as embodied in circuits for regulating the current, it is not intended to be limited to the details shown, since various modifications and circuit changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is:

1. A circuit for regulating the amplitude of control pulses, comprising in combination current path means for control pulses including a load, resistance means, a first transistor having a base and a collector-emitter path connected in series with said load and said resistance means, said first transistor having predetermined temperature-dependent base-emitter voltage characteristics, and terminal means for connection with a source of operating voltage; controlled switch means connected with said base of said first transistor and with a point of reference potential; a circuit junction; a second transistor comprising base and emitter electrodes defining a junction having temperature-dependent voltage characteristics at least approximating said predetermined characteristics, one of said electrodes being connected with the base of said first transistor, the other of said electrodes being connected with said circuit junction; and reference voltage means connected between said terminal means and said circuit junction.

2. A circuit as defined in claim 1, wherein said controlled switch means comprise an additional transistor having a collector-emitter path connected with said base of said first transistor and providing a path for the base current of said first transistor.

3. A circuit as defined in claim 1, wherein said first and second transistors are of the same conductivity type.

4. A circuit as defined in claim 1, wherein said one of said electrodes is said base electrode and wherein the other of said electrodes is said emitter electrode.

5. A circuit as defined in claim 1, wherein said second transistor comprises a collector electrode short-circuited to said base electrode.

6. A circuit as defined in claim 1; and further including a resistor connected between said terminal means and said base of said first transistor.

7. A circuit a defined in claim 1, wherein said load has a predetermined resistance and said resistance means has a resistance less than said predetermined resistance.

8. The circuit as defined in claim 1, said reference voltage means including temperature dependent resistance means connecting said terminal means to said circuit junction.

9. The circuit as defined in claim 8, wherein said temperature dependent resistance means is a diode.

10. A circuit as defined in claim 1; and further comprising a source of operating voltage connected with said terminal means.

11. The circuit as defined in claim 10, wherein said reference voltage means is linearly dependent on said operating voltage.

12. The circuit as defined in claim 10, wherein said reference voltage means is temperature dependent.

13. A circuit as defined in claim 1; and further said reference voltage means comprising fixed-potential means for providing a fixed potential, and wherein said controlled switch means is connected between said base of said first transistor and said fixed-potential means.

14. The circuit as defined in claim 13, wherein said fixed potential is ground.

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