

SPECIFICATION

Protecting circuit

- 5 The present invention relates to a protecting circuit, and more specifically to a protecting circuit of the Area of Safety Operation type (Area of Safety Operation hereinafter abbreviated to ASO).
 Output power transistors used, for example, in a transistor power amplifier circuit must be operated within an ASO region so that permanent second breakdown does not occur in the collector/emitter voltage V_{CE} against collector current I_c characteristic. If the point of operation of the transistor moves out of the ASO region, the transistor develops second breakdown and is irreparably damaged.

Fig. 3 of the accompanying drawings shows a protecting circuit of the ASO type for restricting the operation of a transistor within the ASO region to protect the transistor from being damaged, as has been disclosed in Japanese Utility Model Publication No. 101,752/76. The operating condition of an output transistor Q_4 is detected by a detector circuit made up of resistors R_1 , R_2 and R_3 . The output of the detector circuit, from the junction of resistors R_2 and R_3 , is applied to the base electrode of a control transistor Q_1 , which controls the base current of the output transistor Q_4 . If the operation point of the output transistor Q_4 is likely to move outside the ASO region, the control transistor Q_1 is rendered conductive which limits the base current of the output transistor Q_4 . According to the prior art, however, the forward voltage V_{BE} at the base-emitter junction of the control transistor Q_1 is set to be equal to a threshold voltage at which the protecting circuit commences its protecting operation. Therefore, the disadvantages that the level of protecting operation is varied since the junction voltage across the base and emitter electrodes is dependent upon the temperature, or that the level at which the protecting operation commences is varied greatly due to the variation in current amplification factor h_{FE} of the control transistor Q_2 or due to the variation in the base layer resistance r_{bb} occur.

Japanese Patent Publication No. 81247/75 discloses another protecting circuit of the ASO type as shown in Fig. 4, of the accompanying drawings.

As has been disclosed in the above Patent Specification, a collector current I of an output transistor Q_4 of the circuit can be determined from the following equation,

$$I = \frac{kT}{qR_2'} \log_e \left(\frac{I_1 R_1'}{V_{CE} - V_{BEQD}} \right) \quad (1)$$

In this circuit, a voltage V_{BEQD} across a diode QD, formed by short-circuiting the collector and base electrodes of a transistor, is smaller than a voltage V_{CE} across the collector and emitter electrodes of the output transistor Q_4 . Therefore, the voltage V_{BEQD} is negligible. Thus, it is possible to reduce the effects caused by variation in the values of circuit elements, or due to change in temperature (and in particular, it is possible to reduce the effects caused by the temperature dependency of the forward voltage at the base/emitter junction of the transistors).

According to the prior art, however, since the power-limiting equation (1) has a curve of logarithmic function, it is very difficult to design a circuit which corresponds to a curve of allowable power loss of the collector electrode of the output transistor Q_4 or which corresponds to the ASO region.

In a push-pull output amplifier circuit which operates on a power-supply voltage V_{cc} of positive polarity to drive a load resistance R_L via an output coupling capacitor, the two output transistors which are connected in series between the power-supply voltage V_{cc} and earth potential GND are usually D.C. biased so that the voltage across the collector and emitter electrodes of each of the transistors is about $V_{cc}/2$. Therefore, when an output voltage is raised and lowered in response to the input signals, with the D.C. operation level of $V_{cc}/2$ as a centre, and when the input signals do not cause the voltage to rise to the power-supply voltage V_{cc} and do not cause the voltage to lower to earth potential GND, the output of the push-pull amplifier circuit has a non-clipped form. Under the non-clipped output condition, the locus of operation, determined by the collector-emitter voltage V_{CE} against collector current I characteristic of a single output transistor, does not exceed a straight line connecting the two operation points $[0(V), V_{cc}/2R_L (A)]$ and $[V_{cc}(V), 0(A)]$.

However, when excessive input signals are applied, the two output transistors are alternately rendered conductive and non-conductive in response to the input signals. Therefore, the output of the push-pull output amplifier circuit is raised to the power-supply voltage V_{cc} and is lowered to earth potential GND in response to the input signals, thereby to produce pulse waveforms clipped between the upper and lower levels. Under the clipped condition, the two transistors perform switching operations between the two levels, i.e., between the power-supply voltage V_{cc} and the ground potential GND. However, the locus of operation of a single output transistor

under the clipped output condition caused by excessive input signals, does not exceed a straight line connecting the two operation points $[0(V), V_{cc}/R_L (A)]$ and $[V_{cc}(V), 0(A)]$.

With an audio output amplifier having a small output (10 watts to 20 watts), it is preferable not to operate the protecting circuit even under clipped output conditions caused by excessive input. This is because when the protecting circuit is operated, a negative feedback loop is established to connect the output and the input of the output transistor, giving rise to the occurrence of oscillation phenomena or causing the output to be extremely distorted.

In audio output amplifiers, therefore, it is desired that the ASO characteristics lie between maximum allowable power loss characteristics (hyperbola) of the collector of the output transistor and the operation locus (straight line) under the clipped output condition. Therefore, according to the prior art protection circuit shown in Fig. 4 of the accompanying drawings, the power-limiting equation (1) describes a curve of logarithmic function, causing the design of the circuit to be complicated.

Also, referring to the power-limiting equation (1), even when a resistor R_2' is formed by an equivalent resistance of an aluminum wiring layer in a monolithic semiconductive integrated circuit to have a resistance of about 20 milliohms, the resistance of the resistor R_1' must be set to a considerably great value in order to obtain a limiting current of about 2 amperes. Hence, there is the problem that variation in the resistance of the resistor R_1 greatly affects the limiting current.

According to the present invention there is provided a protecting circuit for protecting a transistor comprising: first means connected across the collector and emitter electrodes of said protected transistor and detecting the voltage across the collector and emitter electrodes of the protected transistor; second means connected in series with the collector-emitter current path of the protected transistor and detecting the collector current or an emitter current of the protected transistor; a first transistor driven by the voltage produced by said first and second means; a constant current circuit for supplying a constant current to said first transistor; and a second transistor, the base electrode of which is driven by the output from collector electrode of the first transistor, the second transistor directly or indirectly controlling the base electrode of the protected transistor; said first means comprising a first and a second resistor connected in series; said second means comprising a third resistor, one end of which is connected to the collector or emitter electrode of the protected transistor; the junction between said first and second resistors being connected to the emitter electrode of said first transistor; a fourth resistor being connected across the collector and base electrodes of said first transistor, the end of said fourth resistor connected to the base electrode of said first transistor also being connected to said constant current circuit, the end of said fourth resistor connected to the collector electrode of said first transistor also being connected to the base of said second transistor.

The circuit may be manufactured in the form of single semiconductor chip.

The present invention will now be described in greater detail, by way of example, with reference to the remaining figures of the accompanying drawings, wherein:—

Figure 1 is a circuit diagram of a protecting circuit according to a first embodiment of the present invention;

Figure 2 is a circuit diagram of a push-pull output amplifier circuit to which is applied the protecting circuit shown in Fig. 1;

Figure 5 shows protecting operation initiating characteristics of the protecting circuit according to the present invention; and

Figure 6 is a circuit diagram of a Balanced-Transformer-Less circuit in which a push-pull output amplifier circuit is constructed in the form of a monolithic semiconductive integrated circuit.

Fig. 1 is a circuit diagram of an ASO-type protecting circuit according to a first embodiment of the present invention and shows an output transistor Q_4 that is to be protected. A transistor Q_3 is placed in a preceding stage with respect to the transistor Q_4 and is Darlington-connected therewith, the transistor Q_3 driving the output transistor Q_4 .

A constant-current circuit CS_2 connected to the base electrode of the transistor Q_3 forms a load for a drive circuit (not shown) which drives the output transistors Q_3 and Q_4 .

A resistor R_3 inserted between the emitter electrode of the output transistor Q_4 and an output terminal 2 operates to detect an emitter current which is nearly equal to a collector current of the output transistor Q_4 . Also resistors R_1 and R_2 connected in series between the collector and the emitter electrodes of the output transistor Q_4 operate to detect a voltage across the collector and the emitter thereof.

The voltage at the junction between the resistor R_1 and the resistor R_2 is applied to the emitter electrodes of a transistor Q_1 . A resistor R_4 is inserted between the base and the collector electrodes of the transistor Q_1 . A constant current I_0 flows through the resistor R_4 from the constant-current circuit CS_1 .

The resistors R_1 , R_2 , R_3 and R_4 and the transistor Q_1 , form a detector circuit for detecting the operating condition of the output transistor Q_4 that is to be protected.

The output of the detector circuit obtained at the collector electrode of the transistor Q_1 is applied to the base electrode of a control transistor Q_2 . Consequently, the collector electrode of the control transistor Q_2 operates to control the base current of the output transistor Q_4 .

In the detector circuit, the level of the voltage applied to the emitter electrode of the detector transistor Q_1 is increased by the emitter-base junction, decreased by the resistor R_4 and constant current I_o , and is applied to the base electrode of the control transistor Q_2 . The forward voltage between the base and emitter electrodes of the transistor Q_2 is as small as 0.6 volt. Therefore, the resistors R_1 to R_3 are selected to satisfy the following relation.

$$R_1 \gg R_2 \gg R_3 \quad (2)$$

To satisfy the relation (2), the resistances of resistors R_1 , R_2 and R_3 may be selected to be 10.7 Kilohms, 100 ohms, and 15 milliohms.

Hence, the voltage V_{BEQ2} appearing across the base and emitter electrodes of the transistor Q_2 can be given approximately by the following equation:

$$V_{BEQ2} = I_{c4} \cdot R_3 = \frac{R_2}{R_1 + R_2} V_{CEQ4} + I_o \cdot R_2 + V_{BEQ1} - I_o \cdot R_4$$

$$\approx I_{c4} \cdot R_3 + \frac{R_2}{R_1} V_{CEQ4} + I_o (R_2 - R_4) + V_{BEQ1} \quad (3)$$

where I_{c4} represents the emitter current of the output transistor Q_4 , V_{CEQ4} the voltage across the collector and emitter electrodes of the output transistor Q_4 , and V_{BEQ1} the forward voltage across the base emitter and electrodes of the transistor Q_1 .

When the voltage-current characteristics at the base-emitter junction of the transistors Q_1 and Q_2 are brought into agreement with each other, the control transistor Q_2 is rendered conductive to reduce the base current of the output transistor Q_4 so that the protecting circuit exhibits the protecting operation only when the forward voltages V_{BEQ1} and V_{BEQ2} across the base and emitter electrodes of transistors Q_1 and Q_2 satisfy the relation $V_{BEQ2} > V_{BEQ1}$. Therefore, the current-limiting equation of the protecting circuit of the embodiment shown in Fig. 1, i.e., the condition by which the protecting circuit commences the protecting operation, can be given by the following relations,

$$R_3 I_{c4} + \frac{R_2}{R_1} V_{CEQ4} + I_o (R_2 - R_4) > 0 \quad (4)$$

$$\therefore I_{c4} > \frac{R_4 - R_2}{R_3} I_o - \frac{R_2}{R_1 \cdot R_3} V_{CEQ4} \quad (5)$$

If the constant current I_o of the constant-current circuit CS_1 is now set to be

$$I_o = \frac{V_{cc}}{R_1},$$

and the resistors R_2 and R_4 are so set as to be $R_4 = 2R_2$ (for instance, $R_2 = 100$ ohms, $R_4 = 200$ ohms), the above relation (5) can be simplified as follows (herein, V_{cc} represents a power-supply voltage applied to a power-supply terminal 1),

$$I_{c4} > \frac{R_2}{R_1 \cdot R_3} (V_{cc} - V_{CEQ4}) \quad (6)$$

In either of the relations (5) or (6), therefore, a straight line Z_4 connecting two operation points P_1 and P_2 on the collector-emitter voltage V_{CEQ4} against collector current I_{c4} characteristic of the output transistor Q_4 , represents a line for commencing the protecting operation as shown in Fig. 5.

For example, in the case of the relation (5), the two operation points P_1 and P_2 are located at

$$[0(V), \frac{R_2 - R_4}{R_3} I_o(A)]$$

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and

$$[\frac{R_1(R_2 - R_4)}{R_2} I_o(V), 0(A)],$$

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respectively. In the case of the relation (6), on the other hand, the two operation points P_1 and P_2 are located at

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$$[0(V), \frac{R_2}{R_1 R_3} V_{cc}(A)] \text{ and } [V_{cc}(V), 0(A)],$$

respectively.

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Also, as shown in Fig. 5, the operation point P_1 is set to be smaller than a maximum allowable collector current I_{cmax} of the output transistor Q_4 but is greater than

$$\frac{V_{cc}}{R_L}$$

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and the operation point P_2 is set to a value V_{cc} which is smaller than a breakdown voltage BV_{CEQ4} across the collector and emitter electrodes of the output transistor Q_4 .

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As mentioned already, the operation locus Z_1 of the output transistor Q_4 of the push-pull output amplifier circuit which operates on the positive power-supply voltage V_{cc} , does not exceed a straight line connecting the points

$$[0(V), \frac{V_{cc}}{R_L}(A)] \text{ and } [V_{cc}(V), 0(A)]$$

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shown in Fig. 5, even during the clipped output condition caused by excessive input signals. The operation locus Z_1 is set to that it will usually lie in an ASO region Z_3 determined by a maximum allowable collector power loss (hyperbola Z_2) of the output transistor Q_4 , maximum allowable collector current I_{cmax} , and a breakdown voltage BV_{CEQ4} across the collector and emitter electrodes.

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However, when the load R_L is short-circuited or the power-supply voltage V_{cc} is raised abnormally, the operation locus of the output transistor Q_4 falls outside the ASO region Z_3 so that the output transistor Q_4 may be damaged. Thus, just before the operation point of the output transistor Q_4 moves beyond the line Z_4 connecting the two operation points P_1 and P_2 , at which the protecting circuit starts to operate, the control transistor Q_2 is rendered conductive in accordance with the relations (5) or (6), and hence the base current of the output transistor Q_4 is decreased to protect the output transistor Q_4 .

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As is clear from the current-limiting relations (5) or (6), since the forward voltage V_{BE} across the base and emitter electrode of the transistor, whose characteristic largely depends upon the temperature, is not included in the current-limiting equation, it is possible to construct a protecting circuit having a protecting operation initiating level which has no relation to the changes in junction temperature of the transistor.

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Also in such a protecting circuit, variation in the absolute value of resistance R_3 , variation in the ratio of the resistance of the resistor R_1 to the resistance of the resistor R_2 , and variation in the ratio of the resistance of the resistor R_2 to the resistance of the resistor R_4 , are the only causes of variation in the level of initiating the protecting operation. Consequently, this protecting circuit enables the width of variation to be reduced, when compared with the conventional circuits. In other words, when the resistor R_3 is formed by an equivalent resistance (for example, 10 to 30 milliohms) by means of an aluminium wiring layer in a monolithic semiconductive integrated circuit, the variation in resistance can be reduced. It is also possible to greatly reduce the variation in the ratio of semiconductive resistance of the resistor R_1 to semiconductive resistance of the resistor R_2 formed in the monolithic semiconductive integrated circuit. It is therefore desired to form the protecting circuit shown in Fig. 1 in a monolithic semiconductive integrated circuit, and particularly to form the resistors R_1 and R_2 by way of

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semiconductive resistors, and to form the resistor R_3 in the form of an equivalent resistance of a wiring layer of aluminium.

Also, since the current-limiting relations (5) and (6) of the protecting circuit exhibit linear characteristics, as mentioned earlier, it is simple to set the operation level of the protecting circuit responsive to the operation locus (straight line) required for the output circuit.

Fig. 2 is a circuit diagram in which the protecting circuit of the embodiment shown in Fig. 1 is applied to a push-pull output amplifier circuit and shows output transistors Q_4 and Q_6 . A D.C. bias to the two output transistors Q_4 and Q_6 is set so that the voltage across the collector and emitter electrodes of each of transistors Q_4 and Q_6 will be about $V_{cc}/2$ when no A.C. signal is input. Transistors Q_3 and Q_5 operate to amplify the input fed to a quasi-complementary push-pull output circuit.

The transistors Q_1 , Q_2 and resistors R_1 to R_4 constitute a protecting circuit which was described with reference to Fig. 1, and a transistor Q_7 forms a constant-current circuit CS_1 which supplies the constant current I_0 to the resistor R_4 .

A transistor Q_8 forms a constant-current circuit CS_2 which provides a load for drive transistors Q_{11} and Q_{12} which drive the push-pull output amplifier circuit.

A biasing circuit is formed by diodes D_1 to D_3 which are inserted between base electrodes of the input transistors Q_3 and Q_5 of the output circuit.

Diodes D_4 and D_5 and resistor R_7 form a constant-voltage circuit, and a transistor Q_{10} which receives the forward constant voltage across the diodes D_4 and D_5 and an emitter resistor R_8 generate a constant current. The constant current I_0 is produced by a current mirror circuit in which the constant current is allowed to flow into a transistor Q_9 , and the base and emitter electrodes of the constant-current transistors Q_7 and Q_9 are connected together.

A capacitor C , a resistor R_9 and a speaker SP form a load circuit.

The present invention is not restricted to this embodiment only; for instance, the current detecting resistor R_3 may be located on the collector side of the output transistor Q_4 .

In this case, the level shift transistor Q_1 and a control transistor Q_2 should be of the p-n-p type, and the constant-current circuits CS_1 and CS_2 should absorb constant current.

The protecting circuit of the present invention can be applied not only to the push-pull output circuit shown in Fig. 2, but also to various other types of circuits. In that case, the protecting circuit may be provided for both of the output transistors which perform complementary operation.

The input current to the output transistors Q_3 and Q_5 may be directly interrupted by the transistor Q_2 , or may be indirectly interrupted by means of a Schmidt trigger circuit.

Fig. 6 shows an embodiment in which the protecting circuit of the present invention is applied to a Balanced Transformer-Less circuit (hereinafter referred to as a BTL circuit), having a push-pull output amplifier circuit in the form of a monolithic semiconductive integrated circuit according to the embodiment shown in Fig. 2.

The circuit elements surrounded by a two-dot-dash line are all formed in a single silicon chip by the customary methods of making semiconductive integrated circuits.

An input signal applied to an input terminal 3'' is transmitted to an input terminal 3''' of the integrated circuit. A differential phase separator circuit 100 made up of transistors Q_{11} to Q_{13} and resistors R_{11} to R_{14} operates in response to the input signal and produces two output signals, with an anti-phase relation, to two signal lines Z_{10} and Z_{11} . The value of constant current flowing through the constant-current transistor Q_{13} of the differential phase separator circuit 100 is determined by a biasing current which flows in a biasing circuit 101 made up of a transistor Q_{14} and a resistor R_{15} .

A constant-voltage Zener diode ZD, a resistor R_{16} and a transistor Q_{15} form a constant-voltage regulator 102, which generates an operation voltage of approximately a constant value irrespective of the power-supply voltage V_{cc} fed to the power-supply terminal 1.

The operation voltage is fed to the differential phase separator circuit 100 and to the biasing circuit 101 via a resistor R_{17} .

Reference numerals 103 and 103' represent a pair of power amplifier circuits of the BTL circuit for directly driving the speaker SP without interposing any output coupling capacitors. The pair of power amplifier circuits 103, 103' are constructed to have the same form and therefore only one power amplifier circuit 103 is shown in detail.

The speaker SP is directly connected between a pair of outputs 2 and 2' of the pair of power amplifier circuits 103 and 103'.

To prevent oscillation, a series circuit of a capacitor C_{101} and a resistor R_{101} , is connected in parallel with the speaker SP, a series circuit consisting of a capacitor C_{102} and a resistor R_{102} is connected between the output terminal 2 and an earth terminal 4, and a series circuit consisting of a capacitor C_{102}' and a resistor R_{102}' is connected between the output terminal 2' and the earth terminal 4.

Bootstrap capacitors C_{103} and C_{103}' are connected between output terminals 2 and 2' and bootstrap terminals 5 and 5', respectively.

The two signals sent onto the two signal lines Z_{10} and Z_{11} are applied to the base electrodes of transistors Q_{16} and $Q_{16'}$ in initial-stage amplifier circuits 104 and 104' of the pair of power amplifier circuits 103 and 103'.

The initial-stage amplifier circuit 104 includes a modified differential amplifier circuit consisting of transistors Q_{16} and Q_{17} and a resistor R_{18} , a current mirror circuit consisting of transistors Q_{18} and Q_{19} , and a load consisting of the resistor R_{18} as shown. An approximately constant operation voltage is applied by a constant-voltage regulator 102 to the initial-stage amplifier circuit 104 via a resistor R_{19} . One end of the resistor R_{19} is connected via a terminal 7 to a filter capacitor C_{104} for removing power-supply rippling whereby the differential phase separator circuit 101 is allowed to operate in a stable mode.

An output OUT produced from the output terminal 2 of the power amplifier circuit 103 is transmitted to the base electrode of the transistor Q_{17} of the initial-stage amplifier circuit 104 via a negative feedback circuit 105 consisting of resistors R_{20} to R_{22} , a constant-current transistor Q_{20} , and a capacitor C_{105} connected to a terminal 8, whereby an A.C. voltage gain of the power amplifier circuit 103 is determined, and a D.C. output voltage level at the output terminal 2 of the power amplifier circuit 103 is determined so as to acquire a value of nearly $V_{cc}/2$.

The base electrode of the constant-current transistor Q_{20} is biased by a biasing circuit 106 consisting of a transistor Q_{21} and resistor R_{23} and R_{24} . Since the biasing circuit 106 is connected to the power-supply terminal 1, a constant current which flows into the constant-current transistor Q_{20} is dependent upon the power-supply voltage V_{cc} . Therefore, even when the power-supply voltage V_{cc} is varied, the D.C. output level at the output terminal 2 follows the value $V_{cc}/2$ which varies in response to the changes in the power-supply voltage V_{cc} .

Also, the output signal of the initial-stage amplifier circuit 104 produced across the resistor R_{18} is amplified by a drive amplifier circuit consisting of Darlington connected transistor Q_{111} and Q_{121} , a resistor R_5 , a phase compensating capacitor C_{106} , a diode-connected transistor Q_{22} and a constant-current load transistor Q_8 . The output of the drive amplifier circuit 107 is fed to Darlington connected transistors Q_3 and Q_4 in the push-pull output amplifier circuit 108, and also to complementary-connected transistors Q_5 and Q_6 .

The emitter electrode of the transistor Q_5 is connected to an idling current adjusting circuit 109 made up of diodes D_6 to D_9 , and transistors Q_{23} and Q_{24} , such that the crossover distortion of the push-pull output amplifier circuit 108 can be reduced.

The base electrode of the constant-current load transistor Q_8 of the drive amplifier circuit 107 and the base electrode of the transistor Q_{24} of the idling current adjusting circuit 109 are connected to the base electrode of the transistor Q_9 of the biasing circuit 110. The biasing circuit 110 is composed of transistors Q_{10} and Q_{25} , and resistors R_6 , R_{25} and R_{26} , and is operated by an approximately constant operation voltage from a constant-voltage regulator 102. Therefore, the D.C. biasing current flowing into the drive amplifier circuit 107 and a D.C. biasing current flowing into a push-pull output amplifier circuit 108 are maintained at approximately constant values despite the changes in power-supply voltage V_{cc} .

The resistors R_1 to R_4 and the transistor Q_1 form a detector circuit 111 which operates with the same operation principle as the circuits shown in Fig. 1 and Fig. 2. The detector circuit 111, is different from the embodiment shown in Fig. 1 and Fig. 2, however, in that the transistors Q_1 and Q_2 are of p-n-p type, the diode-connected transistors Q_{26} and Q_{27} are connected in series with the resistor R_1 , the current detecting resistor R_3 formed in the form of an equivalent resistance in the aluminium wiring layer is connected to the collector electrode of the transistor Q_4 , and the constant-current circuit CS_1 for producing the constant current I_0 has been constructed in the form of a constant-current absorbing circuit.

Another difference is that the collector electrode of the control transistor Q_2 which is driven by the output of the detector circuit 111 is not constructed to the base electrode of the transistor Q_3 but is connected to the base electrode of the transistor Q_{29} of the biasing circuit 112. Also, the collector electrode of the control transistor Q_2 has been connected to the base electrode of another transistor Q_{28} .

The biasing circuit 112 also includes transistors Q_{30} and Q_{31} , and a resistor R_{29} , and is operated by the operation voltage V_{cc} of the power supply.

The collector electrode of the transistor Q_{28} in the power amplifier circuit 103 and the collector electrode of the transistor $Q_{28'}$ in the power amplifier circuit 103' are connected to a capacitor C_{107} via a terminal 9. Since the transistors Q_{28} and $Q_{28'}$ are usually rendered non-conductive, the capacitor C_{107} is electrically charged to the operation voltage of the constant-voltage regulator 102 via a resistor R_{30} .

The terminal 9 is also connected to an input of a Schmidt trigger circuit 113 via a resistor R_{31} . The Schmidt trigger circuit 113 is constructed, as shown, by means of transistors Q_{32} and Q_{33} and resistors R_{32} to R_{35} . The output of the Schmidt trigger circuit is obtained at the junction between the resistor R_{34} and the resistor R_{35} . The resistance R_{32} is set to be, for example, 10 Kilohms which is greater than the resistance (for example, 2 Kilohms of the resistor R_{33} , such that the output of the trigger circuit acquires a low level when the capacitor C_{107} has been

electrically charged.

The detector circuit 111, however has been so designed that a line Z_4 for initiating the operation of the protecting circuit lies between the operation locus Z_1 of the output transistor Q_4 and the line Z_4 of the ASO region, similar to the characteristics shown in Fig. 5.

- 5 Thus, the constant current I_0 which flows into the transistor Q_7 of the constant-current circuit CS_1 is given by the relation;

$$10 \quad I_0 = \frac{V_{CC} - (V_{BEQ30} + V_{BEQ31})}{R_{29}} \quad (7)$$

where V_{CC} represents the power-supply voltage V_{CC} , V_{BEQ30} and V_{BEQ31} represent forward voltages across the base and emitter electrodes of the transistors Q_{30} and Q_{31} , and R_{29} the resistance of the resistor R_{29} .

- 15 When the resistors R_1 to R_3 satisfy the requirement $R_1 \gg R_2 \gg R_3$, the voltage V_{BEQ2} appearing across the base and emitter electrodes of the control transistor Q_2 is given by the following relation, which is similar to the equation (3) described previously:

$$20 \quad V_{BEQ2} \approx I_{C4} \cdot R_3 + \frac{R_2}{R_1} (V_{CEQ4} - V_{BEQ26} - V_{BEQ27}) + I_0(R_2 - R_4) + V_{BEQ1} \quad (8)$$

- 25 where V_{BEQ26} and V_{BEQ27} represent forward voltages across the base and emitter. From relations (7) and (8),

$$30 \quad V_{BEQ2} \approx I_{C4} \cdot R_3 + \frac{R_2}{R_1} (V_{CEQ4} - V_{BEQ26} - V_{BEQ27}) + \frac{(R_2 - R_4)}{R_{29}} \{V_{CC} - (V_{BEQ30} + V_{BEQ31})\} + V_{BEQ1} \quad (9)$$

- 35 The resistances are set so that the resistors R_1 to R_3 satisfy the requirement $R_1 \gg R_2 \gg R_3$, the resistors R_2 and R_4 satisfy the requirement $R_4 \geq 2R_2$, and the resistors R_1 , R_2 , R_4 and R_{29} satisfy the requirement

$$40 \quad \frac{R_2}{R_1} \approx \frac{(R_2 - R_4)}{R_{29}}$$

$R_1 = 10$ Kilohms (semiconductive resistor),

$R_2 = 100$ ohms (semiconductive resistor),

$R_3 = 15$ milliohms (equivalent resistance in the layer of aluminium wiring),

45 $R_4 = 200$ ohms (semiconductive resistor),

$R_{29} = 10$ Kilohms (semiconductive resistor).

Hence, if the base/emitter junction characteristics of the transistors Q_{26} and Q_{27} are equal to the base/emitter junction characteristics of the transistors Q_{30} and Q_{31} , the current-limiting equation obtained from equation (9) can be written as follows:

$$50 \quad I_{C4} > \frac{R_2}{R_1 \cdot R_3} (V_{CC} - V_{CEQ4}) \quad (10)$$

- 55 As is clear from the current-limiting equation (10), the dispersion in base/emitter junction characteristics of the transistors Q_{30} and Q_{31} in the biasing circuit 112, and the temperature dependency, are cancelled by those of the transistors Q_{26} and Q_{27} in the detector circuit 111, and hence it is possible to obtain a line for initiating the operation of the protecting circuit which does not depend on the base/emitter junction characteristics of the transistors.

- 60 Similarly to the case of Fig. 5, just before the output of the output transistor of the power amplifier circuit 103 exceeds the line Z_4 connecting the two operation points P_1 and P_2 for initiating the protecting operation, the transistor Q_{28} is rendered conductive according to the equation (10), and hence the electric charge stored in the capacitor C_{107} at the terminal 9 is discharged through the transistor Q_{28} . Hence, the output of the Schmidt trigger circuit 113 at 65 the connection point between the resistor R_{34} and the resistor R_{35} acquires a high level to render

the transistor Q_{34} conductive.

The transistor Q_{34} rendered conductive causes the transistors Q_{25} , Q_{10} and Q_9 in the biasing circuit 110 to be non-conductive. Therefore, since the transistor Q_8 forming the constant-current load CS_2 of the drive amplifier circuit 107 is rendered non-conductive, the transistors Q_3 and Q_4 of the push-pull output amplifier circuit 108 are rendered non-conductive.

Since the transistor Q_9 of the biasing circuit 110 has also been rendered non-conductive, the transistor Q_{24} of the idling current adjusting circuit 109 is rendered non-conductive, and the transistors Q_5 and Q_6 of the push-pull output amplifier circuit 108 are also rendered non-conductive.

Thus, the base currents of the output transistors Q_4 and Q_6 of the push-pull output amplifier circuit 108 are interrupted, preventing them from being damaged.

CLAIMS

1. A protecting circuit for protecting a transistor comprising; first means connected across the collector and emitter electrodes of said protected transistor and detecting the voltage across the collector and emitter electrodes of the protected transistor; second means connected in series with the collector-emitter current path of the protected transistor and detecting the collector current or an emitter current of the protected transistor; a first transistor driven by the voltage produced by said first and second means; a constant current circuit for supplying a constant current to said first transistor; and a second transistor, the base electrode of which is driven by the output from collector electrode of the first transistor, the second transistor directly or indirectly controlling the base electrode of the protected transistor; said first means comprising a first and a second resistor connected in series; said second means comprising a third resistor, one end of which is connected to the collector or emitter electrode of the protected transistor; the junction between said first and second resistors being connected to the emitter electrode of said first transistor; a fourth resistor being connected across the collector and base electrodes of said first transistor, the end of said fourth resistor connected to the base electrode of said first transistor also being connected to said constant current circuit, the end of said fourth resistor connected to the collector electrode of said first transistor also being connected to the base of said second transistor.

2. A protecting circuit according to claim 1, wherein the resistance of the first resistor is greater than that of the second resistor, and the resistance of said second resistor is greater than that of the third resistor.

3. A protecting circuit according to claim 1 or claim 2, wherein the resistance of the third resistor is set by the equivalent resistance of a wiring layer in a semi-conductive integrated circuit.

4. A protecting circuit according to claim 3, wherein the resistances of the first, second, third and fourth resistors, and a value of constant current of said constant-current circuit are selected so that a straight line for initiating the protecting operation lies between the locus of operation of said protected transistor and an Area of Safety Operation region determined by the collector/emitter voltage against collector current characteristics of said protected transistor.

5. A protecting circuit according to any one of the preceding claims, wherein the constant current of said constant-current circuit is determined by a biasing circuit including a fifth resistor and a third transistor which are connected in series between the power supply voltage and a reference potential, and the base/emitter junction characteristics of said third transistor are cancelled by the base/emitter junction characteristics of a fourth transistor connected in series with said first resistor.

6. A protecting circuit according to claim 5, wherein the resistance of said fifth resistor is selected to be equal to the resistance of the first resistor, and the resistance of said fourth resistor is selected to have a resistance which is approximately twice the resistance of said second resistor.

7. A protecting circuit substantially as herein described with reference to, and as illustrated in Fig. 1 of the accompanying drawings.

8. A push-pull output amplifier circuit incorporating a protecting circuit according to any one of the preceding claims.

9. In combination a protecting circuit and a push-pull output amplifier circuit constructed substantially as herein described with reference to and illustrated in Fig. 2 or Fig. 6 of the accompanying drawings.



the transistor Q_{34} conductive.

The transistor Q_{34} rendered conductive causes the transistors Q_{25} , Q_{10} and Q_9 in the biasing circuit 110 to be non-conductive. Therefore, since the transistor Q_8 forming the constant-current load CS_2 of the drive amplifier circuit 107 is rendered non-conductive, the transistors Q_3 and Q_4 of the push-pull output amplifier circuit 108 are rendered non-conductive.

Since the transistor Q_9 of the biasing circuit 110 has also been rendered non-conductive, the transistor Q_{24} of the idling current adjusting circuit 109 is rendered non-conductive, and the transistors Q_5 and Q_6 of the push-pull output amplifier circuit 108 are also rendered non-conductive.

Thus, the base currents of the output transistors Q_4 and Q_6 of the push-pull output amplifier circuit 108 are interrupted, preventing them from being damaged.

CLAIMS

1. A protecting circuit for protecting a transistor comprising; first means connected across the collector and emitter electrodes of said protected transistor and detecting the voltage across the collector and emitter electrodes of the protected transistor; second means connected in series with the collector-emitter current path of the protected transistor and detecting the collector current or an emitter current of the protected transistor; a first transistor driven by the voltage produced by said first and second means; a constant current circuit for supplying a constant current to said first transistor; and a second transistor, the base electrode of which is driven by the output from collector electrode of the first transistor, the second transistor directly or indirectly controlling the base electrode of the protected transistor; said first means comprising a first and a second resistor connected in series; said second means comprising a third resistor, one end of which is connected to the collector or emitter electrode of the protected transistor; the junction between said first and second resistors being connected to the emitter electrode of said first transistor; a fourth resistor being connected across the collector and base electrodes of said first transistor, the end of said fourth resistor connected to the base electrode of said first transistor also being connected to said constant current circuit, the end of said fourth resistor connected to the collector electrode of said first transistor also being connected to the base of said second transistor.
2. A protecting circuit according to claim 1, wherein the resistance of the first resistor is greater than that of the second resistor, and the resistance of said second resistor is greater than that of the third resistor.
3. A protecting circuit according to claim 1 or claim 2, wherein the resistance of the third resistor is set by the equivalent resistance of a wiring layer in a semi-conductive integrated circuit.
4. A protecting circuit according to claim 3, wherein the resistances of the first, second, third and fourth resistors, and a value of constant current of said constant-current circuit are selected so that a straight line for initiating the protecting operation lies between the locus of operation of said protected transistor and an Area of Safety Operation region determined by the collector/emitter voltage against collector current characteristics of said protected transistor.
5. A protecting circuit according to any one of the preceding claims, wherein the constant current of said constant-current circuit is determined by a biasing circuit including a fifth resistor and a third transistor which are connected in series between the power supply voltage and a reference potential, and the base/emitter junction characteristics of said third transistor are cancelled by the base/emitter junction characteristics of a fourth transistor connected in series with said first resistor.
6. A protecting circuit according to claim 5, wherein the resistance of said fifth resistor is selected to be equal to the resistance of the first resistor, and the resistance of said fourth resistor is selected to have a resistance which is approximately twice the resistance of said second resistor.
7. A protecting circuit substantially as herein described with reference to, and as illustrated in Fig. 1 of the accompanying drawings.
8. A push-pull output amplifier circuit incorporating a protecting circuit according to any one of the preceding claims.
9. In combination a protecting circuit and a push-pull output amplifier circuit constructed substantially as herein described with reference to and illustrated in Fig. 2 or Fig. 6 of the accompanying drawings.