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(54) IMPROVEMENTS IN OR RELATING TO ELECTRICAL CIRCUITS

(71) We, ROBERT BOSCH GMBH, a German Company, of Postfach 50, 7 Stuttgart 1, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to electrical circuits comprising integrated circuitry and including an output transistor.

Devices are known which afford protection against voltage polarity reversal and excess voltages in an integrated circuit (IC) to the output of which is connected a load such as a relay. Such known devices for protection against excess voltages which are caused by, for example, the switching-off of an inductive load, comprise a reverse-biased diode which is connected in parallel with the inductive load so as to conduct transients and to the output of the IC, the cathode of the diode being connected so as to face the positive pole. This arrangement has the following disadvantage: the switching part of an output transistor is normally connected in series with this relay. Since the components always form a diode towards the substrate in integrated switching circuits, this output transistor acts, during a voltage reversal, like a diode whose cathode faces the formerly positive pole. Thus, in the event of a voltage reversal, a direct short-circuit is produced across the output transistor, acting as a diode, and the reverse-biased, transient-conducting diode, and necessarily leads to the destruction of the integrated circuit. In order to avoid this, it is known to connect an external, non-integrable protective diode between the negative supply voltage and the output of the integrated circuit leading to the negative supply voltage, the protective diode being reverse-biased like the substrate diode of the switching transistor, thus avoiding a short-circuit.

This known arrangement has the disadvantages that, firstly the protective diode is non-integrable, thus requiring an additional, discrete component for the external wiring of the IC, and that, secondly, the circuit is not proof against excess voltages when the excess voltage is impressed from the supply voltage side and exceeds the breakdown voltage of the switching transistor. Thus, an aim of the invention is to provide a circuit arrangement which ensures protection against excess voltages on an IC, the circuit arrangement being largely integrable.

According to the present invention there is provided an electrical circuit comprising integrated circuitry and including an output stage transistor in series with a load, in which, for the purpose of protecting the integrated circuitry against voltage polarity reversal and excess voltages, a series combination comprising a rectifier element and a voltage-limiting device is provided in parallel with the switching path of the output stage transistor, both the junction between the rectifier element and the voltage-limiting device and other components of the integrated circuitry being connected by way of at least one limiting resistor to that pole of a supply voltage to which the load is connected.

In a further development of the invention, in order to prevent the internal operating voltage of the IC from rising to the level of the limiting voltage of the voltage-limiting device when the relay is switched off, the second terminal of the limiting resistor, connected to the supply voltage, for the current to the IC is connected by way of a second decoupling rectifier element to the junction between the first rectifier element and the voltage-limiting device.

In a further development of the invention, the rectifier elements are in the form of transistors in diode configuration for the purpose of integration, and at least one Zener diode is provided as the voltage-limiting device.

The advantages of the invention reside particularly in the fact that the non-integrable diode connected to earth is omitted and a system is provided which, with the exception of an external resistor, is integrable. This results in simpler and less expensive production and smaller spatial requirements owing to the omission of the discrete component. Protection against voltage reversal and excess voltages is provided. In the case of an inductive load, such as a relay, the load can be suppressed at the same time by means of the internal protection against excess voltages. Transmission of the limiting voltage to the internal operating voltage of the IC is prevented by the decoupling diode provided in a further development of the invention.

The invention will hereinafter be further described by way of example with reference to the accompanying drawings in which:—

Fig. 1 is a circuit diagram of a known protective device,

Fig. 2 is a circuit diagram of a first embodiment of an integrable protective device in accordance with the present invention,

Fig. 3 is a circuit diagram of a second embodiment of an integrable protective device in accordance with the present invention,

Fig. 4 is a circuit diagram of an alternative voltage-limiting device for use in a device in accordance with the present invention, and

Fig. 5 is a circuit diagram of a further alternative voltage-limiting device for use in a device in accordance with the present invention.

The protective device illustrated in Fig. 1, and constituting the prior art, shows an integrated switching circuit comprising an input stage 10 and an output stage 11. The input stage 10 can be any optional input stage and is not further described. The output stage 11 is in the form of an NPN transistor whose base is connected to the input stage 10. The input stage 10 and the emitter of the output stage transistor 11 are connected to earth by way of an externally arranged protective diode 12 of discrete construction. The collector of the output stage transistor 11 is connected to the positive pole 15 of a source of voltage by way of a parallel combination comprising the solenoid 13 of a relay and a reverse-biased diode 14 serving to conduct transients. Moreover, the positive pole 15 is connected to the IC 10 or 11 by way of a current-limiting resistor 16. The limiting resistor 16 is usually not contained in an integrated form in the IC.

In order to elucidate the mode of operation of the arrangement, one must proceed from the fact that all components form a diode towards the substrate in integrated circuits. This is symbolized by the two diodes 110, 111 which bridge the input stage 10 and the output stage 11 respectively. Excess voltages which are induced in the relay 13 upon the switching-off of the output stage 11 are short-circuited by the diode 14. The protective diode 12 is provided to protect the IC against reversal of the polarity of the voltage source which occurs inadvertently or as a result of switching-off operations. If the protective diode 12 were not provided, a direct short-circuit would be produced across the diode 111 and the diode 14 in the event of incorrect polarity. The input stage 10, which also includes a diode 110 towards the substrate, is protected by the limiting resistor 16 in the event of reversal of polarity.

The first embodiment of the invention, illustrated in Fig. 2, is similar to the circuit of Fig. 1 illustrating the prior art. The same components are provided with the same reference numerals. The protective diode 12 and the reverse-biased, transient-conducting diode 14 are omitted. A series combination comprising a diode 17 and a Zener diode 18 is connected in parallel with the collector-emitter path of the output stage transistor 11. The junction between the diode 17 and the Zener diode 18 is connected by way of a decoupling diode 19 to the junction between the current-limiting resistor 16 and the input stage 10. The cathodes of the three diodes 17 to 19 are interconnected.

The mode of operation of the embodiment illustrated in Fig. 2 is such that protection is afforded by the limiting resistor 16 and the resistance of the solenoid 13 in the event of the reversal of the polarity of the voltage source. This is ensured in this arrangement by omitting the diode 14. When the voltage increases as a result of the sitching-off operation on the solenoid 13, this voltage is applied to the Zener diode 18 by way of the diode 17. When this voltage exceeds the breakdown voltage of the Zener diode 18 (typical value approximately 8 volts), the Zener diode 18 breaks down and the voltage is limited by way of the diode 17 by the Zener diode 18.

The decoupling diode 19 prevents the internal operating voltage of the IC from rising to the level of the limiting voltage. Since the diodes 17 to 19 are fully integrable, the integrated circuit is connected externally only to the resistor 16 and the solenoid 13.

The construction and operation of the embodiment illustrated in Fig. 3 correspond to those of the embodiment illustrated in Fig. 2. The diodes 17, 19 are in the form of transistors 170, 190 connected in diode configuration, since diodes in integrated circuits are usually in the form of transistors. For this purpose, the emitter-collector paths of the p-n-p transistors used in the present instance replace the anode-cathode paths of the diodes, the bases and the collectors of the respective transistors being interconnected. The arrangement 20 replaces the Zener diode 18 as a voltage-limiting device. In this arrangement 20, the Zener diode 18 of Fig. 2 is replaced by a series combination comprising the Zener diode 18, a resistor 21 and the collector-emitter path of an NPN transistor 22 which is connected in parallel therewith, the base of the transistor 22 being connected to the junction between the resistor 21 and the Zener diode 18. The transistor 22 is rendered conductive by way of the base when the breakdown voltage of the Zener diode 18 is attained. A second, identical arrangement comprising a Zener diode 23, a resistor 24 and a transistor 25 is connected in series with the first arrangement. The breakdown voltage of the voltage-limiting device 20 is doubled by the second arrangement. The breakdown voltage can be further increased if further three-unit combinations of this type are connected in series. Analogously, a plurality of Zener diodes can also be connected in series in Fig. 2. An additional diode 26 for protection against connection with incorrect polarity is provided in parallel with the switching path of the output stage transistor 11 for the purpose of relieving the substrate diode of the output stage transistor, since substrate diodes are not satisfactory diodes. Advantageously, the diode 26 for protection against connection with incorrect polarity can also be provided in the other embodiments. The same applies to the additional diode 27 for protection against connection with incorrect polarity.

Fig. 4 shows an alternative of a voltage-limiting device 20. A four-layer triode 28 replaces the transistor 25 of the arrangement 20. The resistor 24 is dimensioned such that the four-layer triode 28 is not triggered at normal operating voltage during a switching-off operation of the solenoid. On the other hand, if a correspondingly high excess voltage is impressed externally, the four-layer triode 28 is fired when a specific current flowing through the resistor 24 is attained, and the voltage on the four-layer triode collapses to the latter's forward voltage. The advantage of this arrangement is that, at high external excess voltages, the power loss in the IC is reduced to a considerable extent compared with the arrangement having a transistor.

The embodiment of a voltage-limiting device 20 illustrated in Fig. 5 has the same basic construction of a switching combination 23, 24, 25 in Fig. 3, although the transistor 25 is replaced by the four-layer triode 28. The further Zener diode 18 is connected in series with this arrangement. This circuit has the advantageous property that, when a specific value of the external operating voltage is exceeded, the breakdown voltage of the entire arrangement reverts to the breakdown voltage of the Zener diode 18, since the four-layer triode remains conductive in the first instance when the voltage drops below double the Zener voltage. What has been said with reference to Fig. 4 applies to the design of the resistor 24.

Arrangements in which the inductive load is connected to the negative pole of the supply voltage are also equivalent to the described embodiments. In this case, the protective resistor 16 has to be connected into the negative supply voltage lead of the IC. The switching transistor is in the form of a p-n-p transistor. Furthermore, the excess voltage protective circuit 20 has to be exchanged for the diode 19, and the polarity of the diode 17 has to be reversed. The anodes of the three diodes 17, 18, 19 are now interconnected.

WHAT WE CLAIM IS: —

1. An electrical circuit comprising integrated circuitry and including an output stage transistor in series with a load, in which, for the purpose of protecting the integrated circuitry against voltage polarity reversal and excess voltages, a series combination comprising a rectifier element and a voltage-limiting device is provided in parallel with the switching path of the output stage transistor, both the junction between the rectifier element and the voltage-limiting device and other components of the integrated circuitry being connected by way of at least one limiting resistor to that pole of a supply voltage to which the load is connected.

2. A circuit as claimed in Claim 1 in which the rectifier element comprises a diode.

3. A circuit as claimed in Claim 1 or 2 in which the voltage limiting device comprises at least one Zener diode.

4. A circuit as claimed in any preceding claim in which the voltage limiting device comprises at least one four-layer triode.

5. A circuit as claimed in Claim 3, in which the voltage limiting device comprises at least one semiconductor switch, the Zener diode being operative to control a control electrode of the semiconductor switch.

6. A circuit as claimed in Claim 5, in which a series combination comprising the Zener diode and a resistor bridges a switching path of the semiconductor switch, the junction between the Zener diode and the resistor being connected to the control electrode of the semiconductor switch.

7. A circuit as claimed in Claim 5 or 6, in which the semiconductor switch is a transistor.

8. A circuit as claimed in any of Claims 5 to 7, in which the semiconductor switch is a four-layer triode.

9. A circuit as claimed in Claim 8, in which at least one further voltage-limiting device is connected in series with the four-layer triode.

10. A circuit as claimed in any preceding Claim, in which the limiting resistor has its second terminal connected by way of a second decoupling rectifier element to the junction between the first rectifier element and the voltage-limiting device.

11. A circuit as claimed in Claim 10, in which the decoupling rectifier element comprises a diode.

12. A circuit as claimed in any preceding Claim, in which, for the purpose of integration, the diodes are in the form of transistors connected in diode configuration.

13. A circuit as claimed in any preceding claim, in which the load is an inductive load.

14. A circuit as claimed in Claim 13, in which the load is a relay.

15. An electrical circuit constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Fig. 2 of the accompanying drawings.

16. An electrical circuit constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Fig. 3 of the accompanying drawings.

17. An electrical circuit constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Fig. 4 of the accompanying drawings.

18. An electrical circuit constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Fig. 5 of the accompanying drawings.

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Sheet 1

Fig.1

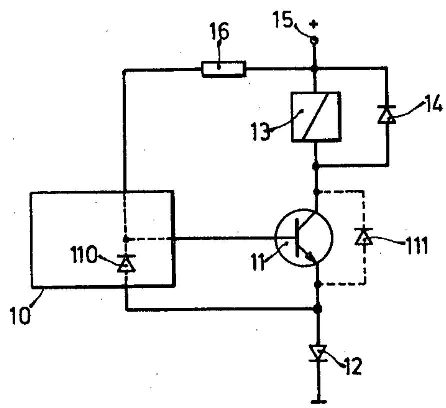
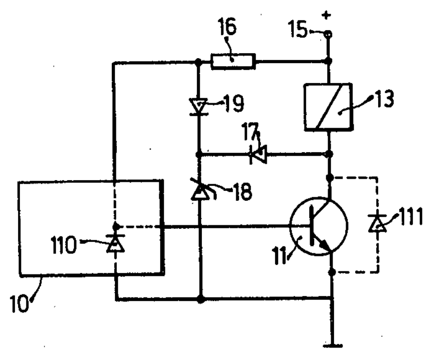


Fig.2



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Sheet 2

Fig. 3

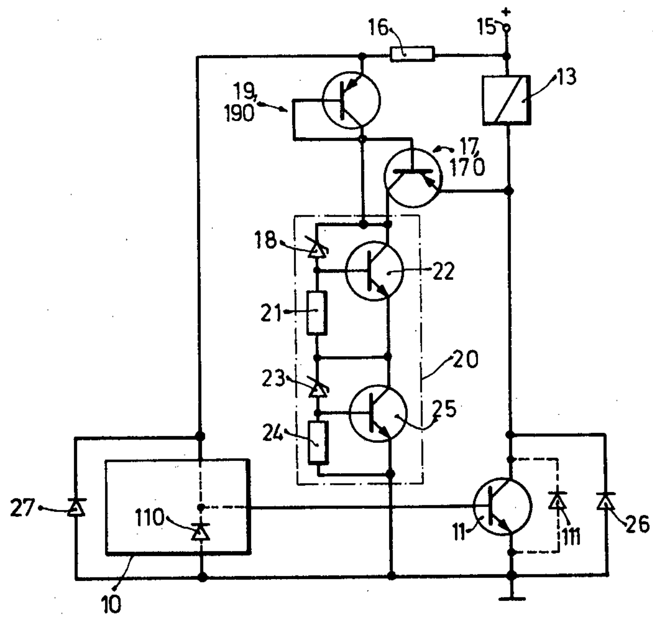

Fig. 4

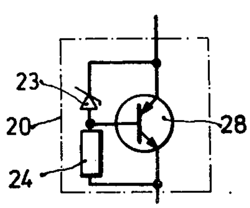

Fig.5