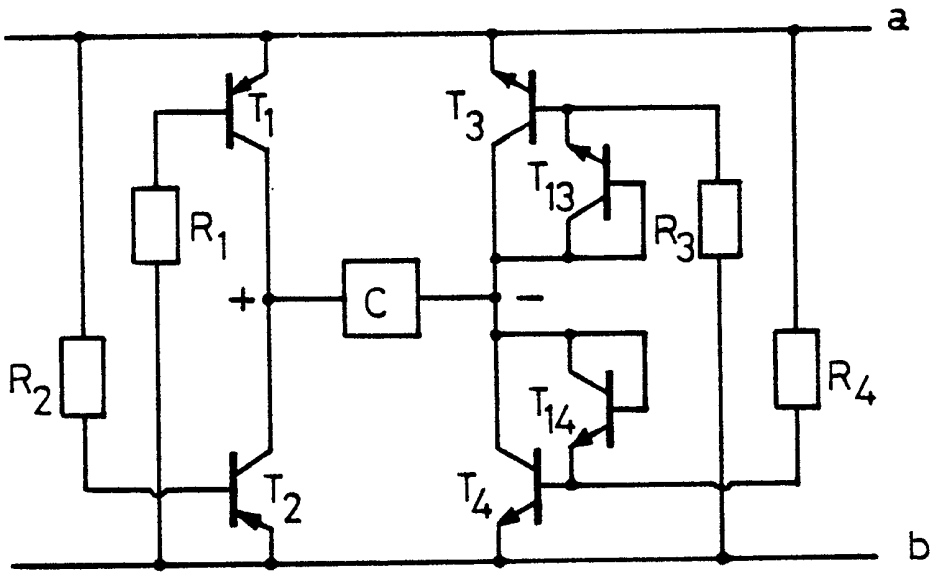
(12) UK Patent Application (19) GB (11) 2 116 788 A

(21) Application No **8302548**
(22) Date of filing
31 Jan 1983
(30) Priority data
(31) **19356**
(32) **29 Jan 1982**
(33) **Italy (IT)**
(43) Application published
28 Sep 1983
(51) **INT CL³ H02H 9/00**
(52) Domestic classification
H2H 25G APC
H2F 9M 9R32B 9R32C 9S1 TAD
U1S 2215 H2F H2H
(56) Documents cited
None
(58) Field of search
H2H
H4T
(71) Applicant
SGS-Ates Componenti Elettronici SpA
(Italy)
20041 Agrate Brianza (Milano)
Via C Olivetti 2
Italy
(72) Inventors
Marco Siligoni
Nazzareno Rossetti
(74) Agent and/or Address for Service
Marks and Clerk
57–60 Lincoln's Inn Fields
London WC2A 3LS

(54) **Improvements in or relating to transistor bridge rectifier circuits for telephones**

(57) A transistor bridge rectifier circuit with surge current protection, which may be monolithically integrated, is provided for connecting to a two-wire telephone line *a, b* the electronic circuits c of a subscriber's telephone set. The circuit comprises transistors T_1, T_2, T_3, T_4 connected in a Graetz bridge circuit arrangement. The bases of two transistors T_3, T_4, which constitute adjacent elements of the bridge connected to the two opposite wires of the telephone line, are connected to the respective collectors by means of semi-conductor elements T_{13}, T_{14} having a reverse biased bipolar junction in normal operating conditions.

FIG. 2



GB 2 116 788 A

FIG. 1

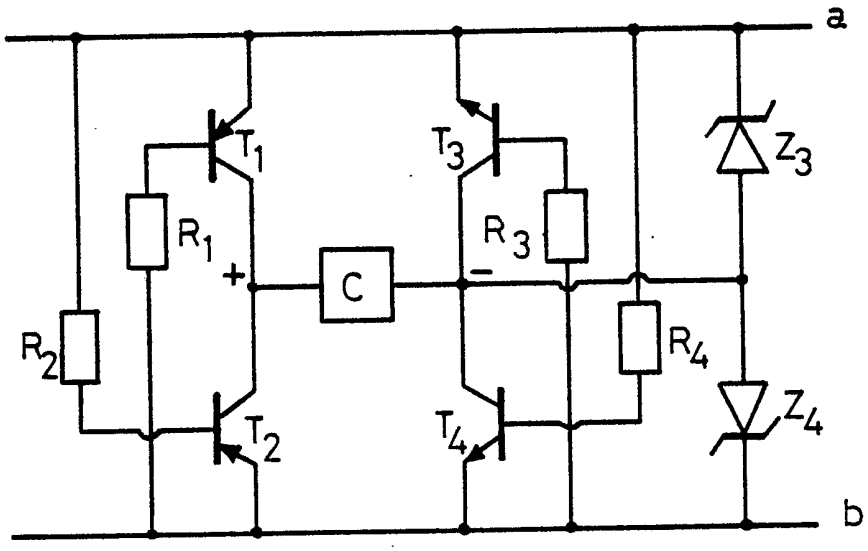
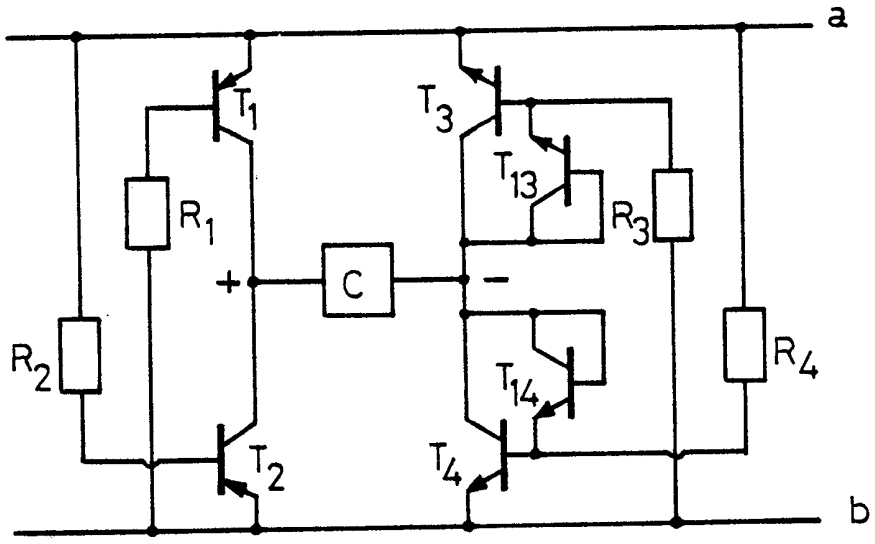
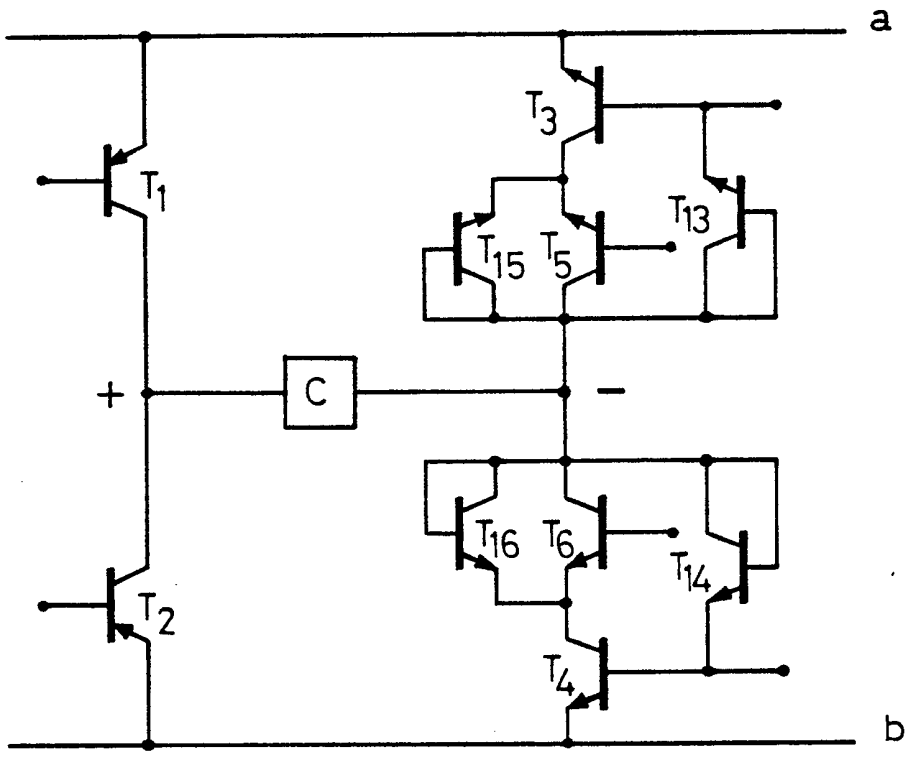


FIG. 2



2116788

FIG. 3



SPECIFICATION

Improvements in or relating to transistor bridge rectifier circuits for telephones

The present invention relates to bridge rectifiers for use with telephones, and in particular to a transistor bridge rectifier with protection against surge currents, which may be monolithically integrated and used to connect the electronic circuits of a subscriber's telephone set to a two-wire telephone line of low supply voltage.

For correct operation of the electronic circuits of telephone sets, a supply voltage having a predetermined and constant polarity and having a value which always lies within restricted and precise limits must be supplied to the terminals of these circuits.

The polarity of the voltage at the terminals of a two-wire telephone transmission line is not predetermined, since accidental reversals of polarity may occur during maintenance or repair operations. Consequently the electronic circuits of telephone sets must be coupled to the two-wire telephone line by means of a circuit designed to rectify the voltage at the terminals of the line, when its polarity is reversed with respect to the required polarity.

In the case of a surge current on the line, whatever its cause, the resultant drop in voltage in the rectifier circuit may be dangerous for the electronic circuit connected thereto. In order to avoid this drawback, a protection against surge currents may be suitably introduced.

The most commonly used transistor rectifier circuits are those with a Graetz bridge arrangement which, with the addition of a limited number of components, may also protect the electronic circuits connected to these rectifier circuits against the effects of line surge currents.

A known bridge rectifier is constituted, as shown in Fig. 1 of the accompanying drawings, by a bridge configuration, comprising first and second bipolar transistors, shown by T_1 and T_2 of p-n-p type, and third and fourth bipolar transistors, T_3 and T_4, of n-p-n type. The collector of T_1 is connected to the collector of T_2 and the collector of T_3 is connected to the collector of T_4, these connections forming a first terminal, shown by the " + " sign, and a second terminal, shown by the " − " sign, to which the telephone circuit C to be supplied is connected.

The emitter of T_1 and the emitter of T_3 are connected to the wire "a" of a two-wire telephone line. The emitter of T_2 and the emitter of T_4 are connected to the wire "b" of this line.

The base of T_1 and the base of T_3 are connected to the wire *b* of the line *via* a resistor R_1 and a resistor R_3, respectively. The base of T_2 and the base of T_4 are connected to the wire *a* of the line *via* a resistor R_2 and a resistor R_4, respectively. These resistors are designed to suitably bias the transistors of the bridge which, in normal operating conditions, operate at saturation. The second terminal " − " is also connected to the anodes of first and second Zener diodes Z_3 and Z_4, the cathodes of which are connected to the wire *a* and the wire *b*, respectively, of the line. For a predetermined polarity of the line, only the transistor of p-n-p type whose emitter is connected to the terminal of the line at a higher potential and the transistor of n-p-n type whose emitter is connected to terminal having a lower voltage are conductive. The other two transistors are cut off. Consequently, the supply current of the telephone circuit C, irrespective of the actual polarity of the line, always flows through the circuit itself from the terminal constituted by the connection between the collectors of the two transistors of p–n–p type to the terminal constituted by the connection between the collectors of the two transistors of n-p-n type, and the polarity of the voltage between the two terminals is constant.

A possible surge current on the line causes an increase in the total voltage drop in the rectifier circuit. However, as soon as the voltage at the terminals of the Zener diode having its cathode connected to the wire of the line with a higher potential equals the breakdown voltage V_Z of the diode junction, the diode starts to conduct in the opposite direction due to the Zener effect. However, the other Zener diode begins to conduct as a normal diode as soon as the voltage at its terminals equals the threshold voltage V_{ONZ} for forward conduction.

Consequently the total voltage drop at the rectifier circuit does not exceed the maximum value

$$V_{R\,MAX} = V_Z + V_{ONZ}$$

when there are surge currents on the line.

The maximum voltage applied to the electronic circuit of the telephone does not exceed the maximum value

$$V_{C\,MAX} = V_Z - V_{CE\,sat}$$

as $V_{CE\,sat}$ is the collector-emitter saturation voltage of a p-n-p transistor of the bridge.

Both the rectifier circuit and the telephone circuit are therefore protected against surge currents.

However, a rectifier circuit of the type described above, with protection against surge currents, is not the best solution from the point of view of economic production.

The addition of power circuit elements, such as the two Zener diodes, in addition to the components of the bridge, significantly increases the cost of the circuit (whether this is constructed using discrete components, or

whether it is monolithically integrated) for reasons, known to persons skilled in the art, involving the use of integration areas and processing technology.

According to the invention, there is provided a transistor bridge voltage rectifier circuit, with protection against surge currents, for coupling to a two-wire telephone line the electronic circuits of a subscriber's telephone set comprising first, second, third and fourth bridge elements each having first and second terminals, the second terminal of the first element being connected to the second terminal of the second element and the second terminal of the third element being connected to the second terminal of the fourth element to provide first and second connection terminals, for connection to the electronic circuit of the telephone set, the first terminals of the first and third elements being connected to a first wire of the telephone line, the first terminals of the second and fourth elements being connected to the second wire of the line, each element of the bridge comprising at least a first bipolar transistor connected with its emitter/collector circuit between the first and the second terminals of the element, the emitter of the first transistor being connected to the first terminal of the element, the transistors of the first and second elements having a type of conductivity opposite to that of the transistors of the third and fourth elements the base of each of the transistors being connected to circuit means for controlling, in response to the polarity of the voltage of the telephone line, the conduction of the transistors of the first and fourth elements of the bridge in phase opposition with respect to the transistors of the second and the third elements of the bridge, the base of the first transistor of each of the third and fourth bridge elements also being connected to the second terminal of the element by means of a first semiconductor element having a bipolar junction which is reverse biased in normal operating conditions.

It is thus possible to provide a transistor bridge rectifier circuit, with protection against surge currents, which may be monolithically integrated and used to couple the electronic circuits of a subscriber's telephone set to a two-wire telephone line of low supply voltage, which circuit is more economic from an industrial point of view than rectifier circuits, with protection against surge currents, of the prior art.

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

Figure 1 is a diagram, already described above, of a known transistor bridge rectifier circuit, with protection against surge currents.

Figure 2 is a diagram of a transistor bridge rectifier circuit with protection against surge current, constituting a preferred embodiment of the invention; and

Figure 3 is a circuit diagram of another embodiment of the invention.

The same reference letters and numbers are used to designate identical components in the all the Figures.

The rectifier circuit with protection against surge currents, constituting a preferred embodiment of the invention, shown in Fig. 2 comprises a transistor bridge circuit arrangement constituted by a pair of bipolar transistors, indicated by T_1 and T_2, of p-n-p type and a pair of bipolar transistors, T_3 and T_4, of n-p-n type.

The collector of T_1 is connected to the collector of T_2 and the collector of T_3 is connected to the collector of T_4, these connections respectively constituting a first terminal, indicated by the " + " sign, and a second terminal, indicated by the " − " sign, to which there is connected the electronic circuit C of the telephone set to be coupled to the line.

The emitter of T_1 and the emitter of T_3 are connected to a first wire *a* of the two-wire telephone line. The emitter of T_2 and the emitter of T_4 are connected to the second wire *b* of the line.

The base of T_1 and the base of T_3 are connected to the wire *b* of the line *via* a resistor R_1 and a resistor R_3, respectively. The base of T_2 and the base of T_4 are connected to the wire *a* of the line *via* a resistor R_2 and a resistor R_4, respectively. The base of T_3 is also connected to the emitter of a bipolar transistor T_{13} of n-p-n type, whose base and collector are connected to the collector of T_3.

The base T_4 is also connected to the emitter of a bipolar transistor T_{14} of n-p-n type, whose base and collector are connected to the collector of T_4.

Fig. 3 shows the circuit diagram of a different embodiment of the invention comprising a pair of bipolar transistors T_1 and T_2 of p-n-p type and two pairs of bipolar transistors T_3, T_5 and T_4, T_6 of n-p-n type.

The collector of T_1 is connected to the collector T_2 and the collector of T_5 is connected to the collector of T_6, these connections respectively constituting a first terminal, indicated by the " + " sign, and a second terminal, indicated by the " − " sign, to which there is connected the electronic circuit C of the telephone apparatus to be coupled to the line.

The emitters of T_5 and T_6 are connected to the collector of T_3 and the collector of T_4, respectively.

The emitters of T_1 and T_3 are connected to a first wire *a* of the two-wire telephone line. The emitters of T_2 and T_4 are connected to the second wire *b* of the line.

The Figs. do not show the circuit means for biasing, of a type known to persons skilled in the art, to which are connected the bases of

the transistors T_1, T_2, T_3, T_4, T_5 and T_6.

The circuit of Fig. 3 also comprises two pairs of bipolar transistors T_{13}, T_{15} and T_{14}, T_{16} of n-p-n type.

The emitters of T_{13} and T_{15} are connected to the base and the collector, respectively, of T_3. The emitters of T_{14} and T_{16} are connected to the base and the collector, respectively, of T_4. The bases and the collectors of T_{13} and T_{15} are connected to the collector of T_5. The bases and the collectors of T_{14} and T_{16} are connected to the collector of T_6.

The operation of the circuit illustrated in Fig. 2 is as follows.

In normal operating conditions, T_1 and T_4 or T_2 and T_3 conduct in accordance with the polarity of the line, and the conducting transistors operate at saturation. T_{13} and T_{14} which are reverse biased are cut off.

A possible surge current on the line causes a decrease in the total voltage drop in the rectifier circuit. If it is supposed that the polarity of the voltage at the line terminals is such that, in normal conditions, T_1 and T_4 are saturated and T_2 and T_3 are cut off, as soon as the value of the emitter-collector voltage of T_3 equals, as a result of the surge current, the breakdown voltage from the emitter to the collector, with an open base, $BV_{ECO\,T_3}$, T_3 conducts in a reverse direction. T_{13}, which is reverse biased by the base-collector voltage of T_3, is cut off.

Following breakdown, T_3 may conduct currents which may be very high without increases in its collector-emitter voltage, so that the voltage at the terminals of the electronic telephone circuit connected to the bridge do not exceed the maximum value

$$V_{C\,MAX} = BV_{ECO\,T_3} - V_{CE\,sat\,T_1}$$

wherein $V_{CE\,sat\,T_1}$ is the collector-emitter saturation voltage of T_1.

The entire current from T_1 and T_3 passes throught the collector of T_4 which, as its own base biasing conditions remain unchanged, is no longer saturated and begins to operate in the active zone of its own area of operation.

In the active zone the collector-emitter voltage of T_4 increases with the increase in the collector current. When its value equals the sum of the base-emitter voltage of T_4, $V_{BE\,T_4}$, and the threshold conduction voltage $V_{BE\,T_{14}}$ of the base-emitter junction of T_{14}, the transistor T_{14} connected as a diode begins to conduct, supplying current to the base of T_4 which may step up its own conduction without further increases in the collector-emitter voltage.

The total voltage drop at the rectifier bridge does not therefore exceed the maximum value

$$V_{R\,MAX} = BV_{ECO\,T_3} + B_{BE\,T_4} + V_{BE\,T_{14}}$$

Therefore both the rectifier circuit and the telephone circuit are protected against surge current on the line using the same transistors of the bridge as power elements for protection.

The circuit operates in an identical and symmetrical manner when the line voltage is of the opposite polarity. The value of the voltage BV_{ECO} of the transistors T_3 and T_4 is suitably regulated using known technological means for base doping.

However, when the normal line voltage is already very high and it is therefore necessary for the voltage BV_{ECO} of the n-p-n transistors of the bridge to be high, so that in normal operating conditions the disconnected n-p-n transistor does not conduct by reverse breakdown, it is possible to use two pairs of n-p-n transistors in cascade, as shown in Fig. 3.

A variation of the circuit diagram for protection against surge currents is also shown in this case. The circuit means for biasing the transistors of the bridge, not shown, but easy to embody by a person skilled in the art, are necessarily more complicated than those of Figs. 1 and 2.

In normal operating conditions of the circuit of Fig. 3, only T_1, T_4 and T_6 or T_2, T_3 and T_5 are conductive in accordance with the polarity of the line.

The conductive transistors operate in saturation, given the biasing conditions.

If it is supposed that the wire *a* of the telephone line has a higher potential than the wire *b*, in this case T_1, T_4 and T_6 are conductive at saturation. The transistors T_{14} and T_{16}, connected as diodes, do not conduct, as their collector-emitter voltage is too low as a result of the saturation conditions of T_4 and T_6.

A possible surge current on the line causes an increase in the total voltage drop at the rectifier circuit. As soon as the emitter-collector voltage of T_3 and T_5 equals the breakdown voltage from the emitter to the collector, with an open base, of these transistors ($BV_{ECO\,T_3}$ and $BV_{ECO\,T_5}$), T_3 and T_5 begin to conduct in a reverse direction.

Even in the case of very high currents the voltage at the terminals of the electronic telephone circuit does not exceed the maximum value.

$$V_{C\,MAX} = BV_{ECO\,T_3} = BV_{ECO\,T_5} - V_{CE\,sat\,T_1}$$

wherein $V_{CE\,sat\,T_1}$ is the collector-emitter saturation voltage of T_1.

The entire current from T_1, T_3 and T_5 flows through the collector of T_6 which, as its base biasing conditions remain unchanged, passes from the saturation zone to the active zone of its own area of operation.

In the active zone the collector-emitter voltage of T_6, increases, with the increase of the collector current, until the conduction of T_{16} is enabled.

The emitter currents of T_6 and T_{16}, flow through the collector of T_4 which, similarly to

T_6, begins to operate in the active zone, increasing its own collector-base voltage with the collector current, until the conduction of T_{14} is enabled. The transistor T_4 may, independently of T_6, increase its own conduction, receiving the required base current from T_{14} in order to absorb the entire current from T_{16} and T_6, without further increases in its own collector-emitter voltage.

The total voltage drop at the rectifier bridge does not exceed the maximum value

$$V_{R\,MAX} = BV_{ECO\,T_3} + BV_{ECO\,T_5} + V_{BE\,T4} + V_{BE\,T_{14}}$$

wherein $V_{BE\,T_4}$ is the base-emitter voltage, when conducting, of T_4 and $V_{BE\,T_{14}}$ is that of T_{14}.

When the line voltage has the opposite polarity the circuit operates in an identical and symmetrical manner.

The embodiment of the invention shown in Fig. 3 also enables both the rectifier circuit and the telephone circuit connected thereto to be protected against surge currents on the line, using the same elements of the bridge as power elements for protection.

Rectifier circuits of this type are particularly suitable for integration in a monolithic semiconductor chip using known integration techniques.

The transistors T_{13}, T_{14}, T_{15} and T_{16} are normal n-p-n transistors of the low cost type. An integrated circuit is therefore advantageous both from the point of view of processing difficulties and from a point of view of the size of integration areas. The economic advantage is obvious even in the case of an embodiment using discrete components.

Although two single embodiments of the invention have been described and illustrated, various modifications may be made within the scope of the invention.

For example, it would be possible to use, with a similar structure, the p-n-p transistors of the bridge instead of the n-p-n transistors as protection elements.

CLAIMS

1. A transistor bridge bridge voltage rectifier circuit, with protection against surge currents, for coupling to a two-wire telephone line the electronic circuits of a subscriber's telephone set comprising first, second third and fourth bridge elements each having first and second terminals, the second terminal of the first element being connected to the second terminal of the second element and the second terminal of the third element being connected to the second terminal of the fourth element to provide first and second connection terminals, for connection to the electronic circuit of the telephone set, the first terminals of the first and third elements being connected to a first wire of the telephone line, the first terminals of the second and fourth elements being connected to the second wire of the line, each element of the bridge comprising at least a first bipolar transistor connected with its emitter/collector circuit between the first and the second terminals of the element, the emitter of the first transistor being connected to the first terminal of the element, the transistors of the first and second elements having a type of conductivity opposite to that of the transistors of the third and foruth elements the base of each of the transistors being connected to circuit means for controlling, in response to the polarity of the voltage of the telephone line, the conduction of the transistors of the fist and fourth elements of the bridge in phase opposition with respect to the transistors of the second and the third elements of the bridge, the base of the first transistor of each of the third and fourth bridge elements also being connected to the second terminal of the element by means of a first semi-conductor elements having a bipolar junction which is reverse biased in normal operating conditions.

2. A rectifier circuit as claimed in claim 1, in which the semi-conductor element having a reverse biased bipolar junction is a diode.

3. A rectifier circuit as claimed in claim 1, in which the semi-conductor element having a reverse biased bipolar junction is a bipolar transistor having its base short-circuited to its collector.

4. A circuit as claimed in any one of the preceding claims, in which each bridge element is a bipolar transistor, the emitter and the collector of which respectively constitute the first and second terminals of the element.

5. A rectifier circuit as claimed in any one of claims 1 to 3, in which each of the third and fourth bridge elements comprises a second bipolar transistor connected with its emitter collector circuit between the two terminals of the element the emitter being connected to the collector of the first transistor, the collector of the first transistor also being connected to the second terminal of the element by means of a second semi-conductor element having a reverse biased bipolar junction in normal operating conditions.

6. A rectifier circuit as claimed in claim 5, in which the second semi-conductor element having a reverse biased bipolar junction is a diode.

7. A rectifier circuit as claimed in claim 5, in which the second semi-conductor element having a reverse biased bipolar junction is a bipolar transistor having its base short-circuited to its collector.

8. A rectifier circuit as claimed in any one of the preceding claims, in which each of the first and second bridge elements is a bipolar transistor, the emitter and the collector of which constitute the first and the second terminals, respectively, of the element each of the third and fourth bridge elements compris-

ing a pair of bipolar transistors in cascade, the emitter of the first transistor and the collector of the second transistor of each pair consitituting the first and second terminals, respectively, of the element.

9. A rectifier circuit as claimed in any one of the preceding claims, in which each bipolar transistor of the first and second elements of the bridge is of the p-n-p type and each bipolar transistor of the third and fourth bridge elements is of the n-p-n type.

10. A rectifier circuit as claimed in any one of the preceding claims, in which the entire circuit is integrated in a monolithic semi-conductor chip.

11. A transistor bridge voltage rectifier circuit substantially as hereinbefore described with reference to and as illustrated in Fig. 2 or 3 of the accompanying drawings.

12. A subscriber's telephone set including a rectifier circuit as claimed in any one of the preceding claims

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1983.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.