

Voltage transformer

5 The invention relates to a voltage transformer for transforming a first d.c. voltage into a higher second d.c. voltage. Such a voltage transformer is needed, for example, in order to operate a colour television receiver with a 12V car battery.

10 A voltage transformer is known (DE-OS 30 17 369) for this purpose, wherein the battery feeds a circuit which is capable of oscillation and a power transistor which is controlled by this and which produces a periodically interrupted current in the primary winding of a transformer. The stepped-up voltage can then be taken
15 off, with the required magnitude, from the secondary winding of the transformer.

Voltage transformers of this type and for the said application, transmit a comparatively high power of the
20 order of magnitude of 100 W. Additional measures are therefore necessary to provide a protection against malfunctioning and prevent the appearance of excessively high voltages, particularly at the power transistor.

25 The present invention seeks to provide a protection arrangement for a voltage transformer of the type described, against malfunctioning and overvoltage which is simple with regard to circuitry.
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According to the present invention there is provided a circuit for transforming a first d.c. voltage (E) into a higher second d.c. voltage (B1) having a transformer, a driver stage and transistor means (T1) controlling the primary winding of the transformer, which are fed by the first d.c. voltage (E) and form a self-oscillating circuit, in which a secondary winding (S) delivers the second d.c. voltage (B1) through a rectifier (D1) operating in the forward conduction direction wherein a feedback path is provided which contains a diode (D4) which is so poled and biased that, in the event of an inadmissible rise in the collector voltage (Vce) of the transistor means (T1) the conduction (H) is prematurely ended and in the event of a greater rise, the diode (D4) is blocked and the self-oscillating circuit remains in the state in which the transistor means (T1) does not conduct.

The rectifier for producing the higher operating voltage or plurality of rectifiers for producing various higher operating voltages work with so-called forward or conducting rectification. This means that these rectifiers are conducting and supply energy to the charging capacitors connected thereto when the power transistors disposed at the primary side is also conducting. Circuits with this mode of operation are

also called flow transformers. In accordance with the invention, in addition to the forward rectification, a reverse rectification is introduced which acts on the same charging capacitor as the forward rectification.

5 This can be achieved by appropriate poling of the rectifier or of the winding feeding the rectifier. The winding which feeds the rectifier for the reverse rectification acts as a so-called demagnetizing winding in an advantageous manner and cause a reduction of the

10 energy stored in the transformer. The rectifier for the reverse rectification also causes a limitation of the amplitude of the pulses at the winding feeding this rectifier during the return, that is to say the cut-off or blocking phase of the power transistor. As a

15 result, the amplitude of the pulses at the other windings of the transformer is also limited and hence also the voltage effective at the power transistor during the return time. The said operation in the reverse or blocking direction is also known as

20 blocking transforming.

Preferably a capacitor is also connected to the collector of the power transistor. This capacitor limits the steepness of the pulse at the collector of

25 the power transistor. At the end of the blocking time, this capacitor, together with the inductances, causes an oscillation in the blocking pulse in such a manner that this blocking pulse automatically assumes the value zero at the end of the blocking time and so no

30 unwanted charging currents appear when the power transistor is changed over into the conducting state at the beginning of the conducting time H.

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The circuit at the primary side is made self-oscillating by a feedback path from the power transistor to the driver circuit. This feedback path is additionally used to provide a protective circuit.

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Preferably a starting circuit is associated with the driver circuit. This has the effect that the circuit can change over automatically out of the non-operative state, that is to say for example in the event of
10 overload or short-circuit, back into the operating state. The starting circuit preferably consists of a self-oscillating circuit which continues to oscillate even when the actual voltage transformer is switched off.

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Circuits according to the invention are particularly advantageous because a particularly reliable protection against damage through malfunctioning is afforded. In addition, a higher efficiency and a longer life of the
20 battery are achieved.

Preferred embodiments of the present invention will now be described, by way of example only with reference to the accompanying drawings, of which:

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Figure 1 shows a simplified circuit diagram of a voltage transformer in accordance with a first embodiment of the present invention;

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Figure 2 shows curves to explain the mode of operation of the circuit shown in Figure 1; and

Figure 3 shows a further embodiment of the present invention which has been tried out in practice.

Basic construction of the circuit

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In Figure 1, a car battery G feeds the transistor T1, which is constructed in the form of a power transistor, with a voltage of $E=+12V$, through a driver circuit with the transistor T2, the resistor R1, R2, R3, R4 and the capacitor C3. The transistor T1 is connected in series with the primary winding P of the transformer Tr. This circuit is made self-oscillating through the feedback path with the diode D4 and oscillates at a frequency in the order of magnitude of 25 kHz. The secondary winding S1 delivers an operating voltage B1 of +80V for the consuming device Ro to the charging capacitor C18 through the rectifier D1. The windings S3 and S4 deliver operating voltages B2 and B3 of lower value through further rectifiers. This circuit works in the so-called forward rectification mode. This means that the rectifier D1 conducts whenever the transistor T1 is also conducting.

Additionally connected to the charging capacitor C18 is the rectifier D2 which is fed by the secondary winding S2. The polarity of the winding S2 is reversed in relation to that of the winding S1 so that the rectifier D2 effects a so-called reverse or blocking rectification. Thus the rectifier D2 conducts whenever the transistor T1 is cut off. Together with the transistor, the transistor T3 forms a starting circuit.

Demagnetization and voltage limitation

As a result of the action of the rectifier D2, the

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voltage at the upper end of the winding S2 cannot exceed the constant voltage B1. Thus the pulse voltage at the winding S2 is limited in amplitude. As a result, all the other pulse voltages at the transformer Tr, including the voltage at the transistor T1 and the diodes D1 and D2, are also limited in amplitude so that no inadmissibly high voltages can arise. In addition, energy is additionally fed into the charging capacitor C18. The winding S2 acts as a so-called demagnetizing winding to reduce the magnetic energy stored in the transformer Tr. The forward rectification used has the advantage that the energy effective at the consumer device does not flow across the inductance of the transformer.

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Shaping of the blocking pulse

As Figure 2a shows, a flyback pulse appears at the collector of the transistor T1 during the blocking time R caused by the cut-off transistor. Capacitor C1 serves to limit the steepness of the edges of this pulse as shown in Figure 2a. The rising edge has a duration of 1 μ s. At the end of the blocking time R, the capacitor C1 together with the effective inductances, particularly of the primary winding P, causes an oscillation. The tuning is selected so that the pulse shown in Figure 2a approximately reaches the zero value at the end of the blocking time. The falling edge, which roughly corresponds to a quarter of a sine cycle, has a duration of about 3-5 μ s. At the end of the blocking time R, when the transistor T1 is switched on and the voltage across the collector-emitter path has to become zero, the voltage Vce has already substantially reached the zero value at the end of the blocking time, as a result of the oscillation, so that

the voltage V_A and the current through the diode D_2 become zero. If, at the end of the blocking time R , the voltage V_{ce} was not zero but had a greater value, the capacitor C_1 would have to be discharged very quickly across the transistor T_1 as a result of which the transistor T_1 may be endangered. The capacitor C_1 may be connected either in parallel to the collector-emitter path or parallel to the primary winding P . The turn ratio of the windings S_1 and S_2 controls the ratio of the amplitude of the pulse voltage as shown in Figure 2a to the operating voltage E . In this case

$$\frac{V_{ce}-E}{E} = \frac{S_1}{S_2}$$

Self-oscillating driver circuit

The diode D_4 forms a feedback path through which the circuit is made self-oscillating. At the beginning of the conducting time H , the voltage V_{ce} is practically zero, the diode D_4 is conducting and the voltages V_a and V_B are likewise practically zero, the transistor T_2 is cut off and so the transistor T_1 is conducting through the resistor R_1 . During the conducting time H , the capacitor C_3 is charged through the resistor R_2 so that the voltage V_B increases in the positive direction. After a time which is determined by the time constant $R_2.C_3$, the base of the transistor T_2 is so far positive that the transistor T_2 becomes conducting and cuts off the transistor T_1 through the diode D_5 at the end of the conducting time. As a result of the cutting off of the transistor T_1 , the so-called flyback pulse, as shown in Figure 2a with the amplitude defined above, appears during the blocking time R as a result of the inductance of the primary winding P . The duration

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R of the flyback pulse results essentially from the duration of the conducting time H and the ratio of the number of turns of the windings S1 and S2 in accordance with the equation:

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$$R = H \frac{S_2}{S_1}$$

H being determined by the time constant, C3.R2. Since the flyback pulse originates through the alteration in the current through the transistor T1, this pulse, shaped in the manner described by the capacitor C1, dies away to zero again at the end of the blocking time R. Then the conducting time H begins anew, as described above. In this manner, the whole circuit is made self-oscillating.

Protective function through the feedback path

During the conducting time H, the voltage Vce is proportional to the collector current flowing during this time. In normal operation, the voltage has only low values because the transistor is intended to work as a switch. If the current through the transistor T1 assumes inadmissibly high values as a result of a malfunction, for example a fault or an overload, the voltage Vce also rises inadmissibly during the conducting time H. This is indicated by the line L in Figure 2a. With this operation, the transistor comes out of saturation and no longer works as a pure switch. Too great a power is then produced at the transistor T1 during the conducting time because of the increased voltage present. The transistor T1 may be endangered as a result. This voltage rise is detected by the diode D4 and a result has an effect on the voltage VA which thus likewise rises more rapidly than in normal operation,

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in accordance with the curve L. As a result, the transistor T2 becomes conducting earlier, that is to say during the conducting time H and so the transistor T1 is cut off and protected from too high a power. Thus the conducting time H is shortened and so the frequency of the voltage transformer is increased in desirable manner. The diode D4 continues to remain conducting, as before, during the remaining, shortened part of the conducting time H. Thus the power supply itself continues to work. The voltage Vce, the flyback pulse as shown in Figure 2a and the transmitted power are, however, so limited by the premature ending of the conducting time H that the components cannot be endangered.

On a further increase in the loading, for example a short-circuit, the duration of the conducting time H and the amplitude of the pulse as shown in Figure 2a become even smaller. Ultimately, the voltage Vce changes to such an extent that the diode D4 remains constantly blocked. This means that the feedback path is interrupted, the circuit no longer oscillates and remains in the state in which the transistor T2 is conducting and the transistor T1 is cut off. The circuit is therefore also short-circuit-proof.

One advantage of the circuit consists in that, in order to evaluate the collector current of the transistor, no resistor is necessary at the emitter to take off a voltage proportional to this current. Such a resistor would waste power. The measure of the current flowing in the transistor T1 is merely derived from the voltage Vce during the conducting time.

The said malfunctioning for which the protective circuits described are provided, may arise in the

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following cases, for example:

1. If a heavy load causes desaturation of the transistor T1;
2. If the core of the transformer Tr is damaged;
3. If the transistor T1 has too little current gain;
4. If one of the diodes D1, D2 has broken down, that is to say represents a short-circuit.

Starting circuit

Without additional measures, it may happen that, after a malfunction for example, the circuit remains in the state in which the transistor T2 is conducting and the transistor T1 is cut off and does not start again. Therefore, the starting circuit with the transistor T3, the capacitor C4 and the resistors R5, R6 is additionally provided. Together with the transistor T2, the transistor T3 forms a bistable circuit which oscillates alone at a frequency within the range of about 1 to 3 kHz and preferably about 3 kHz. If the transistor T2 is cut off, the transistor T3 is made conducting through the resistor R4 and the capacitor C4. If the transistor T2 is conducting, the voltage at the collector is nearly zero and as a result the transistor T3 is cut off. So long as the voltage transformer is working satisfactorily at its rated frequency, the bistable circuit with the transistors T2 and T3 necessarily oscillates at the operating frequency of the voltage transformer, for example 25 kHz, the transistor T3 always being conducting when the transistor T2 is cut off. During such operation,

the protective circuit has practically no significance with regard to operation and only oscillates in synchronism. If the circuit stops in the state with the transistor T1 cut off, the bistable circuit with the transistors T2, T3 continues to oscillate at a frequency of 3 kHz which is determined by the resistor R5 and the capacity C4. This means that the transistor T2 is cut off by this frequency and so the transistor T1 is made conducting. In this manner, the voltage transformer would always be started again periodically by the starting circuit with the transistors T2, T3, in order to initiate renewed operation of the transformer.

In Figure 3, the components which correspond to those in Figure 1 are provided with the same reference numerals. Because of the relatively high collector current needed for the transistor T1, T1 is replaced by a secondary circuit which acts as a power transistor for this power stage. In this secondary circuit the emitter of a transistor T1b is connected to the base of a transistor T1a and the collector of T1a is connected to the collector of T1b through a resistor R27 and a winding. The transistor T2 is formed by a Darlington circuit with the transistors T2a and T2b.

Provided in series with the on/off switch S there is also a battery protection circuit. This responds if the battery voltage drops below the value of 8V. The circuit consists of a Schmidt trigger with the components T4, D6, DZ, R7, R8, R9, R10, R11. The circuit works in the normal operating state when the voltage VE is greater than 9V and switches off if the voltage VE is less than 8V. In order to reduce the saturation voltage of the transistor T1a, the base current flowing through the transistor T1b is taken off from the tap a and limited by the resistor R27.

In order to achieve a sufficiently short switching-off

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time of the transistor T1a, the transistor T2a must deliver a base current which is brief, but the polarity of which is reversed very quickly. This current flows through the diode D27, the capacitor C27, diode D5 and the transistor T2a. The Darlington circuit with the transistors T2a and T2b is used for this reason. The diode D29 is necessary for the switched-off state and prevents a flow of current parallel to the switch S. The diode D5 serves for decoupling between the collector of the transistor T2a and the base of the transistor T1b so that the voltages appearing there can assume the desired course.



Claims

1. A circuit for transforming a first d.c.voltage (E) into a higher second d.c.voltage (B1) having a transformer, a driver stage and transistor means (T1) controlling the primary winding of the transformer, which are fed by the first d.c.voltage (E) and form a self-oscillating circuit, in which a secondary winding (S) delivers the second d.c.voltage (B1) through a rectifier (D1) operating in the forward conduction direction wherein a feedback path is provided which contains a diode (D4) which is so poled and biased that, in the event of an inadmissible rise in the collector voltage (Vce) of the transistor means (T1) the conduction (H) is prematurely ended and in the event of a greater rise, the diode (D4) is blocked and the self-oscillating circuit remains in the state in which the transistor means (T1) does not conduct.
2. A circuit as claimed in Claim 1, wherein the transistor means (T1) comprises two transistors of like type with the emitter of one being connected to the base of the other.
3. A circuit as claimed in Claim 1 or 2, wherein a capacitor (C1) is connected between the collector of the transistor means (T1) and a reference point (earth).
4. A circuit as claimed in Claim 3, wherein the capacitor (C1) is connected in parallel to the collector-emitter path of the transistor means (T1).
5. A circuit as claimed in Claim 3, wherein the capacitor (C1) is connected in parallel with the primary winding.



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6. A circuit as claimed in any of claims 3 to 5, wherein the capacitance of the capacitor (C1) is such that the course of the oscillation of the voltage (Vce) at the collector, caused by the capacitor (C1) and the effective inductances, has a passage through
5 substantially zero at the end of the blocking period.

7. A circuit as claimed in any preceding Claim, wherein a self-oscillating starting circuit is
10 associated with the driver stage.

8. A circuit as claimed in Claim 7, wherein the driver stage forms a circuit capable of oscillation which, during normal operation, oscillates in
15 synchronism with the operating frequency of the voltage transformer circuit and, when the diode (D4) remains blocked, continues to oscillate at a lower frequency and serves as a starting circuit.

9. A circuit as claimed in Claim 8, wherein the driver stage comprises a driver transistor (T2) which is associated with a further transistor (T3), and the two transistors (T2, T3) form a bistable circuit.
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10. A circuit for transforming a first d.c.voltage into a second d.c.voltage substantially as herein described with reference to Figs 1 and 2 or Figs 2 and 3 of the accompanying drawings.
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