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This invention relates to an electronic switching power supply for supplying power to an accumulator and an electrical load adapted to be connected in parallel from an AC or DC voltage source of varying voltage levels, with a primary switched-mode blocking oscillator-type converter which includes a transformer having its secondary coil connected in series with the accumulator and a first diode, while its primary coil is connected in series with the collector-emitter circuit of a first transistor having its base connected both to the one end of the secondary coil of the transformer through a feedback resistor and a first capacitor, while the other coil end is connected to the accumulator and, through a first resistor, to the one terminal of the input voltage source and to the collector of a second transistor having its emitter connected to ground potential, with the emitter of the first transistor being connected both to ground potential through a second resistor and the accumulator and, through a first Zener diode, to the base of the second transistor, with a flip-flop circuit being provided having applied to its input the voltage residing at the accumulator, the flip-flop output cutting the first transistor off when the voltage at the accumulator has reached a predetermined value.

An electronic switching power supply of a similar kind is known from EP-A1-30 026 which serves to supply regulated power to a load which is adapted to be operated on different DC and AC voltages as well as different AC frequencies without the need to switch over. The switching power supply includes a blocking oscillator-type converter which is controlled by means of two controllable semiconductor switches in dependence upon the current flowing through the primary coil of a transformer and in dependence upon the input voltage applied, such that the output power delivered is preferably constant. The load is comprised of an accumulator and a DC motor in parallel arrangement, so that the circuit arrangement supplies either the full motor power in mains operation or, with the motor turned off, a charging current for the accumulator (FIG. 1 of EP-A1-30 026).

In a further improvement of this known switching power supply (FIG. 4), the accumulator is boost-charged with a high current when the DC motor is turned off. To avoid damage to the accumulator while being boost-charged, this known switching power supply provides a flip-flop circuit having applied to its input the voltage residing at the accumulator, this circuit comprising a transistor having its collector connected through a resistor to the base of the switching transistor which is connected in series with the transformer, while its base-

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emitter circuit which is serially connected with a further resistor and a Zener diode is connected in parallel with the accumulator to be charged. When the accumulator voltage exceeds during the charging operation the value predetermined by the Zener diode, the transistor will go into conduction, applying a negative potential to the base of the switching transistor which is serially connected with the primary coil of the transformer, causing the switching transistor to be cut off. In this arrangement, the turn-on and turn-off times of the blocking oscillator-type converter depend on the currents flowing through two different resistors, the difference between these currents thus producing a hysteresis behavior. In this manner, the blocking oscillator-type converter does not constantly switch back and forth between a turned-on and a turned-off state, instead it is necessary for the accumulator voltage to have dropped by a certain amount before the charging current is turned on again. As the blocking oscillator-type converter is turned off, a light-emitting diode arranged in the base circuit of the second transistor will be extinguished, thus indicating the end of the charging process.

In the known electronic switching power supply for boost-charging an accumulator, the point of time at which boost charging is turned off is determined by sensing the accumulator voltage during the flow of secondary current.

It is an object of the present invention to provide an electronic switching power supply for supplying power to an electrical load from an AC or DC voltage source of varying voltage levels, in which the accumulator voltage is detected upon termination of the transformer discharge period.

This object is accomplished by the invention in combination with the features initially identified in that the flip-flop circuit is comprised of the second transistor and a third transistor having its emitter connected to the accumulator, its base being connected through a third resistor both to the one end of the secondary coil of the transformer via a second diode and to the base of the first transistor via a third diode, the base being further connected, through a fifth resistor and a fifth diode, to the accumulator, and its collector being connected through a fourth resistor to the base of the second transistor, with the fifth diode having its anode connected to the accumulator.

Considering that sensing of the accumulator voltage occurs following termination of the off period and prior

to turning on the first transistor again, measuring errors caused by charging currents of different magnitudes as well as by different internal resistances of the accumulator cells are eliminated.

An advantageous embodiment is characterized in that the accumulator has connected in parallel therewith the series arrangement comprising the emitter-collector circuit of the third transistor and a light-emitting diode with a series resistor, the diode having its anode connected to the collector of the third transistor.

In this embodiment, the light-emitting diode will start to blink on termination of boost-charging or in the transition period to the trickle-charging mode, thus providing accurate information on the condition of the accumulator charge.

A further advantageous embodiment is characterized in that the emitter of the first transistor is connected to a tap of the secondary coil of the transformer through the second resistor. A linearization of the secondary current or of the power output is thereby accomplished over the entire operating voltage range.

The idea underlying the invention will be explained in more detail with reference to an embodiment illustrated in the drawings. (1)

In the drawings,

FIG. 1 is a circuit diagram of an electronic switching power supply including electronic control means for boost-charging an accumulator, with automatic transition to a trickle-charge mode;

FIG. 2 is a diagram of a circuit arrangement of FIG. 1, including a blinking indicator for providing a visual indication of when a transition occurs from the boost-charge to the trickle-charge mode; and

FIG. 3 is a diagram of a circuit arrangement of FIG. 1, including a tapping of the secondary coil.

Referring now to FIG. 1, an electronic switching power supply is shown which includes a primary switched-mode blocking oscillator-type converter with a transformer 5 and a first transistor 1 as well as a first diode 31 provided in the load circuit. The blocking oscillator-type converter is energized via a bridge

(1) It is noted that in Patent No. 0 095 072 protection is claimed for further details which may be inferred from the drawings.

rectifier 4 and a resistor 28 from a DC or AC supply the voltage of which may be in the range of between 100 and 250 volts, in the extreme, even 12 volts, and the frequency of which may be nearly arbitrary where an AC supply is used. The rectified output voltage is applied to the input of the blocking oscillator-type converter or the electronic control means through a filtering and smoothing arrangement comprised of a series choke 8 and two smoothing capacitors 91, 92.

Connected in parallel with the DC terminals is the series arrangement comprising the primary coil 51 of the transformer 5 and the collector-emitter circuit of the first transistor 1 and a capacitor 12. A first resistor 21 is connected to the base of the first transistor 1, the other resistor lead being connected to the positive pole of the input voltage terminal through the series choke 8. In addition, the base of the first transistor 1 is connected to ground or reference potential through the collector-emitter circuit of a second transistor 2. The emitter of the first transistor 1 is connected to the cathode of a first Zener diode 41 having its anode connected to the base of the second transistor 2 and also, through a resistor 26, to ground or reference potential. Moreover, the emitter of the first transistor 1 is connected through a second resistor 22 to an end of the secondary coil 52 of the transformer 5. The direction of winding of the primary and secondary coils of the transformer 5 is indicated by the dots shown in the drawings.

A feedback capacitor 11 is connected through a feedback resistor 27 to the base of the first transistor 1 and directly to the one end of the secondary coil 52 of the transformer 5. Connected to the other end of the secondary coil 52 are both the load 6 which includes the parallel circuitry comprised of an accumulator 61 and of a switch 63 and a DC motor 62 in series arrangement, and the anode of a diode 35 to which a resistor 25 connected to the base of a third transistor 3 is serially connected.

A second diode 32 has its anode connected to the junction of the third resistor 23 and the third diode 33, while its cathode is connected to the one end of the secondary coil 52 in the same way as the cathode of the first diode 31 which has its anode connected to the load 6.

In addition, the feedback capacitor 11 is connected to a discharge circuit 7 comprised of a discharge resistor 72 and a discharge diode 71 in series arrangement, its cathode being connected to the feedback capacitor 11.

The discharge resistor 72 is connected to the collector of the third transistor 3 having its emitter connected to the other end of the secondary coil 52 or to the load 6.

To limit the flyback voltage, there is connected in parallel with the primary coil 51 of the transformer 5 a circuitry comprising a Zener diode 42 and a fourth diode 34 in series arrangement, with the diodes having their anodes interconnected.

The base of the third transistor 3 can be optionally connected through an additional resistor 30 to the junction of the DC motor 62 and the switch 63. This connection capability is shown in broken lines in FIG. 1.

The mode of operation of the circuit arrangement of FIG. 1 will be explained in greater detail in the following.

Following rectification by means of the bridge rectifier 6 and filtering and smoothing by means of the series choke 8 and, respectively, the parallel capacitors 91, 92, a low base current will drive, through the first resistor 21, the first transistor 1 operating as a switching transistor. Due to the first transistor 1 switching on, a positive feedback effect is produced through the circuit path of the first transistor 1 and the primary coil 51 of the transformer 5, driving the first transistor 1 additionally and placing it in the conductive state. The collector current rises linearly, producing a proportional voltage at the second resistor 22. When the current has reached a predetermined peak value, the second transistor 2 will be driven through the first Zener diode 41, thereby going into conduction and connecting the base of the first transistor 1 to reference potential or ground, whereby base current is withdrawn from the first transistor 1, cutting it off. With the beginning of the off period, the polarity of the voltage induced in the secondary coil 52 of the transformer 5 will change at point P1 of the feedback capacitor 11. In accordance with the principle of a blocking oscillator-type converter, the energy stored in the transformer 5 will thus be delivered to the load 6 through the first diode 31 .

During the reversal process of the transformer 5, the diode 34 as well as the Zener diode 42 which are connected in parallel with the primary coil 51 of the transformer 5 limit the flyback voltage peak during the off period.

The negative voltage occurring at point P1 during the entire transformer discharge phase is passed through the second diode 32 to point P3, that is, to the junction

between the third diode 33 and the third resistor 23 in the base circuit of the third transistor 3. This negative voltage causes the third transistor 3, which is configured as a p-n-p transistor, to conduct.

In the conductive state of the first transistor 1, the feedback capacitor 11 was charged through the feedback resistor 27 to a voltage equal to

$$U_{C11} = U_{sek.} (1-e^{-t/\tau}),$$

with a negative polarity being produced at point P2 of the feedback capacitor 11.

With the third transistor 3 conducting, this negative-polarity charge at point P2 discharges through the discharge circuit 7, that is, through the discharge diode 71, the discharge resistor 72 as well as the light-emitting diode 10 connected in parallel with the discharge resistor 72, and through the conducting collector-emitter circuit of the third transistor 3 to point P4, that is, to the positive terminal of the accumulator 61.

Discharging of the feedback capacitor 11 and subsequent charge reversal will drive the light-emitting diode 10, causing it to give a visual indication that the charging process is taking place. In the process, the parallel-connected discharge resistor 72 also permits charge reversal below the forward voltage of the light-emitting diode 10.

The voltage at the reverse-charged feedback capacitor 11 is as follows:

$$U_{C11} = U_6 (=U_{Batt}) - U_{F31} - U_{CEsatT3} + U_{F71},$$

where U_{C11} is the voltage at the reverse-charged feedback capacitor 11, U_6 is the voltage at the load 6, U_{F71} is the voltage drop across the discharge diode 71, $U_{CEsatT3}$ is the collector-emitter saturation voltage of the third transistor 3, and U_{F31} is the voltage drop across the first diode 31.

The collector-emitter saturation voltage of the third transistor 3 is negligible at the end of the charge-reversal process of the feedback capacitor. The forward voltage drops across the discharge diode 71 and the first diode 31 being nearly equal because the diodes are of approximately identical construction, they cancel one another, so that the voltage at the reverse-charged feedback capacitor 11 corresponds to the load voltage U_6 with positive sign at point P2.

This polarity-reversed voltage at the reverse-charged feedback capacitor 11 and at the load 6 is significant because the positive voltage at point P2 ensures that the first transistor 1 switches on again promptly even at a very low operating voltage of, for example, 12 volts, when, following completion of the transformer discharge period, the voltage comparator formed of the second and third transistor switches to its off state as a result of the output voltage at point P4 having not yet been reached.

When the output voltage U_6 has reached or exceeds the desired value, the second and third transistor 2, 3 remain conductive, and at point P1 the first capacitor 11 is electrically connected through the secondary coil 52 of the transformer 5 to the positive terminal of the load 6, and at point P2 through the resistor 27 and the conducting second transistor 2 to ground or reference potential. This renders point P2 of the feedback capacitor 11 negative again with respect to point P1. The magnitude of this negative voltage is determined by the discharge diode 71, the light-emitting diode 10 or the discharge resistor 72 and the resistor 27. The conducting voltage comparator, that is, the conducting second and third transistor 2, 3 prevents the first transistor 1 from switching on again until the load voltage U_6 has dropped below the predetermined desired value, thereby causing the comparator, that is, the second and third transistor 2, 3, to be cut off. In the non-conductive state of the second and third transistor 2, 3, the feedback capacitor 11 is again charged through the first resistor 21 as well as the feedback resistor 27 to the sum of the voltage values of the load voltage U_6 and the base-emitter voltage of the first transistor 1. For this process, the third diode 33 decouples the voltage divider formed of the third and fifth resistor 23 and 25, respectively, from the first resistor 21. The diode 35 which is preferably a germanium diode serves to simulate the voltage characteristic of the accumulator as a function of temperature by means of the electronic circuitry.

By connecting the one lead of the resistor 30 shown in broken lines to the junction of the third resistor 23 and the base of the third transistor 3 and its other lead to the junction of the motor switch 63 and the DC motor 62, it is possible, without the need to provide an additional switch, to bring the voltage divider consisting of third and fifth resistors 23 and 25 to a lower output voltage level, for example, from 2.9 to 2.6 volts when the DC motor 62 is turned on. It is thereby achieved that an increased output current will not be produced until the load or the consumption causes the voltage to fall below the lower mean accumulator voltage. In mains

operation, the DC motor 62 then does not run steadily at the high final charging voltage of the accumulator 61. After the DC motor 62 is turned off, the accumulator 61 is thus recharged rapidly.

As becomes apparent from this description of the mode of operation, few components are needed to reduce the high boost charging current of the accumulator 61 to a low trickle charging current upon the voltage comparator formed by the circuitry of the second and third transistors 2, 3 approaching or reaching a predetermined value. In the process, the accumulator voltage is not measured during the high charging current flowing into the accumulator 61 but only when the load is low. This avoids errors occurring due to different internal resistances among the individual cells of the accumulator 61 as well as due to different charging currents. Because the voltage of the reverse-charged first capacitor is approximately equal to the load voltage, normal charging at a trickle charge rated current of the order of 40 to 50 milliamperes can also be performed at a low operating voltage of, for example, 12 volts. Finally, it is ensured that the electronic control means for boost or trickle charging will not draw current from the accumulator 61 with the mains plug pulled because current is then not allowed to flow through the voltage comparator circuit or the blocking oscillator-type converter.

The modification shown in FIG. 2 corresponds largely to the electronic control means for an electronic switching power supply shown in FIG. 1. In this circuit arrangement, like components have been assigned like reference numerals, reference being had to the description of the first embodiment as regards such common components. The circuit arrangement of FIG. 2 differs from the circuit arrangement of FIG. 1 in that the light-emitting diode 10 is not connected in parallel with the discharge resistor 72, but rather is inserted in the collector circuit of the third transistor 3, its anode being connected to the collector of the third transistor 3 and its cathode to ground or reference potential through a resistor 29, and further in that the discharge circuit 7 is not connected to the collector of the third transistor 3, but rather is directly connected to the junction of the secondary coil 52 of the transformer 5 and the load 6.

In this circuit modification, the light-emitting diode 10 begins to blink on completion of the boost-charging process or in the transition period to trickle charging, because the light-emitting diode 10 is connected to the accumulator 61 when the output voltage is reached. Because the light-emitting diode 10 draws a relatively high amount of current, the accumulator

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voltage drops rapidly below the predetermined desired value U_A or the maximum accumulator voltage value, causing the comparator consisting of second and third transistors 2, 3 to be brought back into non-conduction. The blocking oscillator-type converter circuitry subsequently supplies through the switching transistor 1 the energy withdrawn by the light-emitting diode 10 until the desired value of the comparator voltage has again been reached. This process is repeated in cycles of about 2 Hz, thereby indicating that the circuitry is in the transition to the trickle-charge mode.

As in the arrangement of FIG. 1, the maximum battery voltage in this arrangement is given by:

$$U_{Battmax} = U_6 = \left(\frac{R23 + R25}{R25}\right) \cdot (U_{BET3} - U_{F35}) + U_{F33} + U_{CEsatT2},$$

where R23 and R25 are the resistances of the third and fifth resistor 23, 25, respectively.

The modification shown in FIG. 3, while corresponding to the circuit arrangement of FIG. 1 in its details, includes unlike the arrangement of FIG. 1 a connection of the second resistor 22 to a tap of the secondary coil 52 of the transformer 5. In the turn-on period of the first transistor 1, this produces at the tap of the secondary coil 52 a positive voltage electrically connected in series with the voltage of the accumulator 61. The counter voltage varying in proportion to the operating voltage at this tap effects a variation of the peak current of the first transistor 1 and thus a linearization of the secondary current or the power over the entire operating voltage range. This occurs independently of the type of cut-off of the first transistor 1.

In the arrangement shown in FIG. 3, the first transistor 1 is cut off when the linearly rising current at the second resistor 22 produces the voltage

$$U = U_{z41} + U_{BET2}.$$

When this condition is satisfied, the second transistor 2 is driven, withdrawing the base current from the first transistor 1 whereupon it is cut off.

A further modification of the arrangement shown in FIG. 3 is possible by connecting the first Zener diode 41 to the base of the first transistor 1 instead of to the emitter. The base of the first transistor 1 is thereby maintained at a predetermined potential. When the

voltage at the emitter of the first transistor 1 reaches the value of the base minus the base-emitter threshold voltage due to the linearly rising current, positive base current is prevented from flowing and the first transistor 1 is placed in its non-conductive state.

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Patent Claims

1. An electronic switching power supply for supplying power to an accumulator (61) and an electrical load (62) adapted to be connected in parallel from an AC or DC voltage source of varying voltage levels, with a primary switched-mode blocking oscillator-type converter which includes a transformer (5) having its secondary coil (52) connected in series with the accumulator (61) and a first diode (31) while its primary coil (51) is connected in series with the collector-emitter circuit of a first transistor (1) having its base connected both to the one end of the secondary coil (52) of the transformer (5) through a feedback resistor (27) and a first capacitor (11), while the other coil end is connected to the accumulator (61), and, through a first resistor (21), to the one terminal of the input voltage source and to the collector of a second transistor (2) having its emitter connected to ground potential, with the emitter of the first transistor (1) being connected both to ground potential through a second resistor (22) and the accumulator (61) and, through a first Zener diode (41), to the base of the second transistor (2), with a flip-flop circuit being provided having applied to its input the voltage (U_6) residing at the accumulator (61), the flip-flop output cutting the first transistor (1) off when the voltage at the accumulator (61) has reached a predetermined value, wherein the flip-flop circuit is comprised of the second transistor (2) and a third transistor (3) having its emitter connected to the accumulator (61), its base being connected through a third resistor (23) both to the one end of the secondary coil (52) of the transformer (5) via a second diode (32) and to the base of the first transistor (1) via a third diode (33), the base being further connected, through a fifth resistor (25) and a fifth diode (35), to the accumulator (61), and its collector being connected through a fourth resistor (24) to the base of the second transistor (2), with the fifth diode (35) having its anode connected to the accumulator (61).

2. An electronic switching power supply as claimed in claim 1,
characterized in that the accumulator (61) has connected in parallel therewith the series arrangement comprising the emitter-collector circuit of the third transistor (3) and a light-emitting diode (10) with a series resistor (29), said diode having its anode connected to the collector of the third transistor (3).

3. An electronic switching power supply as claimed in claim 1 or claim 2, characterized in that the electrical load is comprised of a DC motor (62) adapted to be connected to the accumulator (61) through a switch (63), and that a seventh resistor (30) has its one lead connected to the junction of the DC motor (62) and the switch (63) and its other lead to the base of the third transistor (3).

4. An electronic switching power supply as claimed in any one of the preceding claims, characterized in that the emitter of the first transistor (1) is connected to a tap of the secondary coil (52) of the transformer (5) through the second resistor (22).

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