

In equipment of the communications engineering industry, such as e.g. a TV receiver or a video recorder, use is predominantly made of switched power supplies (SMPS) for the generation of the operating voltages. A switched power supply contains on the primary side a primary winding, to which the d.c. voltage obtained from the mains is applied via a periodically actuated switch in the form of a switching transistor. The switch is actuated periodically by means of the circuit formed self-oscillating on the primary side or by means of a separate circuit, so that there flows in the primary winding each time during the flow phase or forward sweep time a current increasing in a saw-tooth shape, which is interrupted during the disable phase or flyback time. During the flyback time the energy stored in the transformer is transmitted to the secondary side and supplies there the operating voltages via rectifiers and charging capacitors.

At the end of the forward sweep time, i.e. at the start of the flyback time, the current which has increased in a saw-tooth shape is interrupted. Due to said sudden current interruption and the high di/dt thereby caused, and also to the leakage inductances of the transformer, there is obtained at the start of the flyback time on the primary winding and hence also on the switch a high voltage peak, which exceeds the stationary voltage value by a considerable amount during the flyback time. Due to said high voltage peak of the order of 1 000 V the switching transistor is put at risk. It is therefore necessary to provide measures for reducing said voltage peak.

It is known for an auxiliary winding of the transformer to be loaded with a rectifier and for said auxiliary winding to be coupled with the primary winding with a strength such that the maximum load current of said rectifier lies at or in the vicinity of the voltage peak. There is thereby obtained already at the start of the flyback time a loading of the transformer which reduces the voltage peak. Such solutions are applicable to only a limited extent, because the leakage inductance cannot be varied at will as a function of the layout of the transformer.

It is known for there to be connected parallel with the primary winding of the transformer a series circuit consisting of a capacitor and of the parallel connection of a diode and a resistor (see Bauteile Report, Vol. 13, No. 5, November 1975, pp. 150-151). The capacitor discharged at the start of the flyback time via the respective resistor forms in desirable fashion a loading of the winding, hence slows down the rise in voltage and reduces the voltage peak at the start of the flyback time.

The aim of the invention is to develop a switched power supply with such a series circuit on the primary winding in such a way that an improved reduction in the voltage peak occurs and a higher overall efficiency of the circuit is achieved.

This aim is achieved by the invention described in claim 1. Advantageous developments of the invention are described in the sub-claims.

The invention is based on the following findings and considerations. It is generally accepted per se that a circuit measure has an identical effect on different windings of a transformer, because the windings are coupled magnetically with one another. It has been found, however, that the provision of an additional series circuit parallel to a secondary winding contributes a substantial improvement in terms of a reduction in the voltage peak compared with a circuit with the series circuit only on the primary winding. This may be explained by the fact that the primary winding and secondary winding are not coupled with one another ideally, but rather there operates between said windings a leakage inductance, and that said windings cannot therefore be regarded as equivalent for the present case. It is therefore of advantage if the primary winding and the secondary winding are both loaded independently of one another with the series circuit described. It is advantageous at the same time that a current is also already flowing at the start of the flyback time as a result of the leakage inductance of the secondary winding. The secondary winding is admittedly likewise loaded by a rectifier and a charging capacitor for the generation of an operating voltage, whereby a current also flows during the flyback time. Said current can only flow, however, if the voltage on the secondary winding exceeds the voltage on the charging capacitor. Since the voltage on the charging capacitor falls only slightly however during the forward sweep time, the load current flows through said rectifying circuit too late relative to the voltage peak and is therefore not in a position to cause an attenuation of the voltage peak. The circuit according to the invention on the other hand causes, by means of the capacitor discharged each time at the start of the flyback time, already directly after the start of the flyback time a current which also flows through the leakage inductance of the secondary winding and causes an additional advantageous attenuation of the voltage peak on the transformer.

The series circuit provided on the secondary winding may be constructed in principle as a passive circuit with the above-mentioned components. In so doing there necessarily arises due to the discharging of the capacitor across the resistor lying parallel to the diode a power loss, which reduces the overall efficiency of the circuit. Said power loss is reduced by a development of the invention, which is advantageous in particular for high outputs in the order of 300 to 400 Watt. According to said development the circuit is constructed as an active circuit, in that the resistor serving to discharge the capacitor is constructed as a transistor. In so doing the series circuit of the collector/emitter path of the transistor lies parallel to the diode with an inductance. The discharge current of the capacitor flows through the inductance. Said inductance operates together with a second diode according to the principle of energy recovery so that the energy stored in the capacitor may be recovered and used for the additional generation of an operating voltage. The energy necessarily stored in the capacitor due to its charging is therefore returned positively into the energy balance of the overall circuit. The efficiency is thereby improved and the expenditure on coolants for the components reduced.

The solution according to the invention is also applicable in the case of a horizontal scan output for a TV receiver, because a horizontal scan output is similar in its function to a switched power supply. The circuit according to the invention may also be provided parallel to a plurality of primary and secondary windings.

The invention will be explained below by means of several exemplifying embodiments with reference to the drawing, where

- Fig. 1 shows an embodiment in which the circuit according to the invention is constructed as a passive circuit,
- Fig. 2 an embodiment with active circuit and energy recovery,
- Fig. 3 an embodiment with active circuit on the primary side and
- Fig. 4 curves illustrating the mode of operation of the circuit according to the invention.

Fig. 1 shows in simplified form a switched power supply in which a d.c. voltage UP is applied to the series circuit of the primary winding 1 of the transformer $\bar{U}$ with the switching transistor TRP. The switching transistor TRP is controlled and disabled conductively at the terminal 4 by a switching voltage 3 periodically, e.g. with a frequency of 20 - 60 kHz. The secondary winding 2 supplies via the rectifier DG at the charging capacitor CSB and the charging resistor RL a d.c. operating voltage UA. In order to reduce the voltage peak which occurs on disconnection of the switching transistor TRP on the transformer $\bar{U}$ and hence also on the collector of the transistor TRP, there is connected to the primary winding 1 the series circuit consisting of CP, DP, RP. In addition there lies parallel to the secondary winding 2 the series circuit consisting of the capacitor CS and of the parallel connection of the diode DS1 and the resistor RS.

In Fig. 2 the resistor RS according to Fig. 1 is formed by the series connection of the collector/emitter path of the transistor TRS with the coil LS, which forms together with the diode DS2 a circuit for energy recovery.

Since the circuits according to Fig. 1 and Fig. 2 operate similarly in principle, the mode of operation will be described jointly.

At the end of each forward sweep time, i.e. at the moment of disconnection of the transistor TRP, CS is completely discharged. Said discharge takes place in Fig. 1 via the resistor RS and in Fig. 2 via the transistor TRS and the coil LS. In Fig. 1 the energy contained in the capacitor CS is converted into heat. In Fig. 2 said energy passes in the form of a current into the coil LS and is stored there. At the start of the flyback time, i.e. during the build-up of the voltage U2, the capacitor CS is connected directly parallel to the winding 2 via the conductive diode DS1. CS and DS1 thus form a current path which increases in desirable fashion the build-up time of the voltage U2 and hence reduces the undesirable peak in the voltage U2. There is obtained by means of the coupling by the transformer $\bar{U}$ an

additional improvement in the voltage ratios on the primary side of the transformer $\bar{U}$. The network CP, DP and RP provided on the primary side is supported in its action and the negative influence of the leakage inductance is diminished. The leakage inductance reduces per se each time the current which is caused by the winding. At the start of the flyback time the capacitor CS is therefore charged in the circuits according to Figs 1, 2 by the voltage peak to be attenuated of the voltage U_2 . In order that said procedure for the attenuation of the voltage peak may occur afresh each time at the start of the flyback time, the circuit is dimensioned so that the capacitor CS is fully discharged each time during a period, i.e. from the start of one flyback time to the start of the next one, via the resistor RS or the transistor TRS.

The transistor TRS may in addition be controlled at its base by a switching voltage so that it causes the described discharging of the capacitor CS. It has been found that such an additional clocking is not necessary in practice. The required switching operation of the transistor TRS is triggered independently on a sufficient scale by the existing voltages and currents. So long as the capacitor CS is still loaded, there flows through the transistor TRS a current which supplies energy to the coil LS. If the capacitor CS is discharged, it no longer has voltage to earth, in which case the transistor TRS also becomes dead. There then occurs at the collector of TRS a positive voltage peak, since the coil LS releases the energy. The current in LS reverses. The voltage at the collector of TRS becomes more positive until such time as the second diode DS2 becomes live. The current now passes out of the inductance LS through the live diode DS2 onto the charging capacitor CSB and thus contributes in the form of an energy recovery to the output voltage U_A . By means of said circuit the energy stored initially in the capacitor CS is therefore returned into the effective energy cycle and the overall efficiency of the circuit is increased. At the end of the forward sweep time CS is completely discharged and may therefore cause the desired attenuation of the next voltage peak of the voltage U_2 in the manner described. There is preferably used as transistor TRS a quick-action type of switch, in order to keep the losses low.

The series circuits shown preferably have roughly the same time constants on the primary side and on the secondary side. Two active circuits may also lie on the primary and secondary side as per Fig. 2. The attenuation energy is then supplied on the primary side beneficially to the voltage U_P and on the secondary side to the voltage U_A in the form of an energy recovery.

In Fig. 3 the active circuit with energy recovery as per 2 is provided on the primary side of the transformer $\bar{U}$. The components CP, DP, TRSP in Fig. 3 correspond to the elements CS, DS1 and TRS in Fig. 2, and the components LSP and DP1 to the components LS and DS2. The mode of operation is the same. The energy recovery takes place onto the primary d.c. voltage U_P .

Fig. 4 shows the voltages and currents occurring in the circuits according to Figs 1 to 3. The disturbing voltage peak S in the voltage U2 at the secondary winding 2 exceeds only slightly the generated d.c. voltage UA. There is labelled as Td the time during which the attenuation by means of the series circuits described takes place. UCS is the voltage on the capacitor CS. Said voltage rises during the time Td due to the load current flowing in desirable fashion for the winding and is subsequently reduced during the forward sweep time by discharging via the resistor RS or the transistor TRS. UDS1 is the voltage at the diode DS1 and hence in Fig. 2 at the emitter of the transistor TRS. UCTRS is the voltage at the collector of the transistor TRS. iLSP is the current in the coil LS in Fig. 2. Moreover there is labelled as Sp the time of the energy storage in the coil LS and as E1 the time of the energy discharge out of the coil LS. iDS2 is the current through the diode DS2. Said current causes the transmission of energy from LS into the charging capacitor CSB in the circuit according to Fig. 2. The curve shown under iDS2 therefore indicates simultaneously the gain in power due to the energy recovery as per Fig. 2.

CP: 6.8 nF
 CS: 0.97 μ F in Fig. 1, 470 μ F in Fig. 2
 CSB: 4x470 μ F
 DG: diode of the type BYT 13 P 200
 DS1: diode of the type BYW 98 (Thomson)
 DS2: diode of the type BYW 98 (Thomson)
 LS: 70 μ H
 RB: 100 ohm
 RL: 1 ohm
 RP: 330 ohm
 RS: 10 ohm
 TRP: transistor of the type BUD 48 I
 TRS: transistor of the type 2 SC 2562 (Toshiba)
 corresponding to BUV 45 of Thomson
 UP: + 320 V
 UA: + 18 V
 Winding 1: 38 turns
 Winding 2: 3 turns

Claims

1. Switched power supply with a transistor (TRP) working as a switch and with a transformer (Ü) to whose primary winding (1) a series circuit consisting of a capacitor (CP) and of the parallel connection of a diode (DP) and a resistor (RP) is connected, characterised in that a second such series circuit (CS, DS1, RS) is connected parallel to a secondary winding (2) of the transformer (Ü).
2. Power supply according to claim 1, characterised in that the series circuit lies directly parallel to a secondary winding (2) generating an operating d.c. voltage (UA).
3. Power supply according to claim 2, characterised in that the series circuit is provided parallel to a plurality of secondary windings.
4. Power supply according to claim 1, characterised in that the series circuit lies parallel to that winding of the transformer (Ü) which exhibits the strongest coupling with the primary winding (1).
5. Power supply according to claim 1, characterised in that the resistor (RS) of the series circuit is formed by a transistor (TRS) (Fig. 2).
6. Power supply according to claim 5, characterised in that the discharge current of the capacitor (CS) flowing through the transistor (TRS) is utilized by an energy recovery circuit (LS, DS2) to generate or complement an operating voltage (UA, UP) (Figs 2, 3).
7. Power supply according to claim 6, characterised in that there lies parallel to the diode (DS1) the series circuit consisting of the collector/emitter zone of the transistor (TRS) and an inductor (LS) (Figs 2, 3).
8. Power supply according to claim 7, characterised in that the inductor (LS) is connected via a second diode (DS2, DP1) to a charging capacitor (CSB; CPS) conducting an operating voltage (Figs 2, 3).
9. Power supply according to claim 7, characterised in that the transistor (TRS) is controlled conductively at the base by an additional control voltage for the discharge of the capacitor (CS).



10. Power supply according to claim 1, characterised in that the two series circuits have approximately equal time constants on the primary winding (1) and on the secondary winding (2)