



## **Inductors**

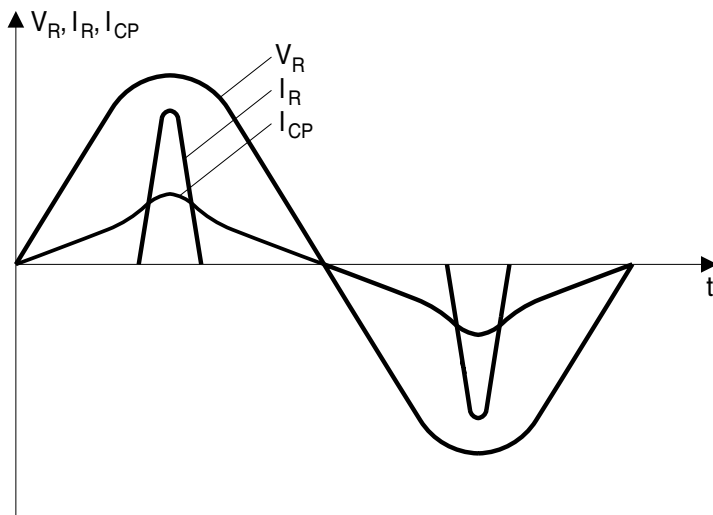
Power line chokes  
Sine-wave chokes

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**General**

In switch-mode power supplies, the line input current is not a sine-wave curve like the line voltage but is pulse-shaped. This current function puts a load on the power supply network and distorts the network's voltage curves. With the aid of a "pump circuit" built up around a "sine-wave choke", it is possible to modify switch-mode power supplies to have a current flow near to a sinusoidal.

*Current and voltage curves*



IND0921-U-E

Figure 1 Graph of the voltage  $V_R$  (sine-shaped) and the mains input current.  $I_R$  shows the pulse-shaped input of a standard switch-mode power supply,  $I_{CP}$  is the current graph of a switch-mode power supply with "current pump", showing the reduced level of upper harmonic components.

In this connection, the international standard IEC EN 61000-3-2 has been worked out. It defines the limits for harmonic current emissions that electrical equipment with input current  $\leq 16$  A per phase must be adhered to. According to this standard, personal computers, monitors and TV receivers are classified as Class D devices.

*Simple add-on circuit*

The ideal solution for obtaining a switch-mode power supply complying to this standard would be a simple add-on circuit which turns a standard switch-mode power supply into a “sine-wave power supply” at moderate costs. A solution of this kind can be implemented with the aid of a “sine-wave pump”, at the heart of which there is a “sine-wave choke”. Here, the sine pump replaces the “cut-off circuit” comprising a diode and an R/C combination, as was previously used in switch-mode power supplies.

In the switch-mode power supply modified by a pump circuit, the drain voltage overshoots are blocked by the fact that, when the diode D is in forward (conducting) state, a resonance circuit is formed by the capacitor C and the primary inductance  $L_1$  of the transformer. In this way, the frequencies and amplitudes of the overshoots are reduced to a level which is not harmful.

An advantage in comparison to the hitherto-used cut-off circuits lies in the fact that no energy is converted into heat, which increases the efficiency of the power supplies.

*Standard switch-mode power supply with cut-off circuit*

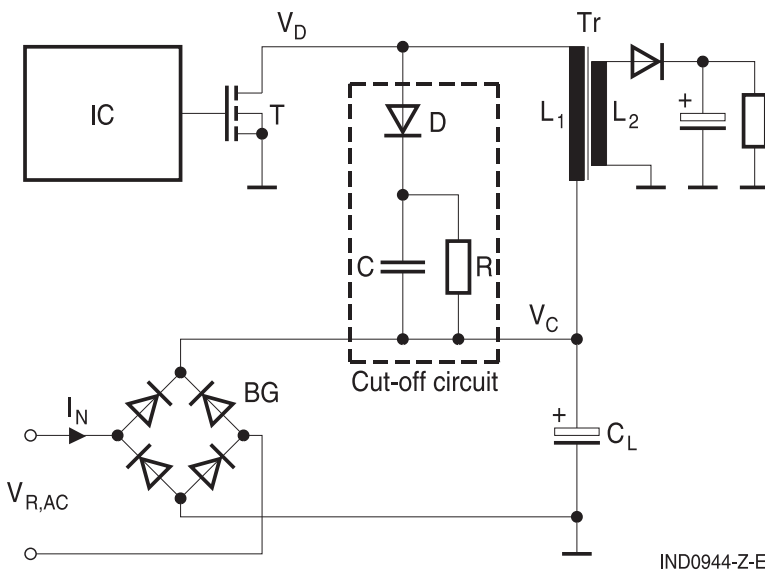


Figure 2 Basic circuit diagram of a standard switch-mode power supply with a cut-off circuit.

A standard switch-mode power supply consists, among other things, of a rectifier bridge BG, load capacitor  $C_L$ , transformer Tr with secondary circuits, switching transistor T and controller IC (e.g. TDA 4646).

The “cut-off circuit”, consisting of a diode D, a capacitor C and a resistor R is connected between the drain of the switching transistor and the positive terminal of the load capacitor.

The purpose of this circuit is to short the overshoots drain voltage and dissipate their energy in the form of heat in resistor R.

## Power line chokes

### Sine-wave chokes

#### “Sine-wave” power supply with pumping circuit

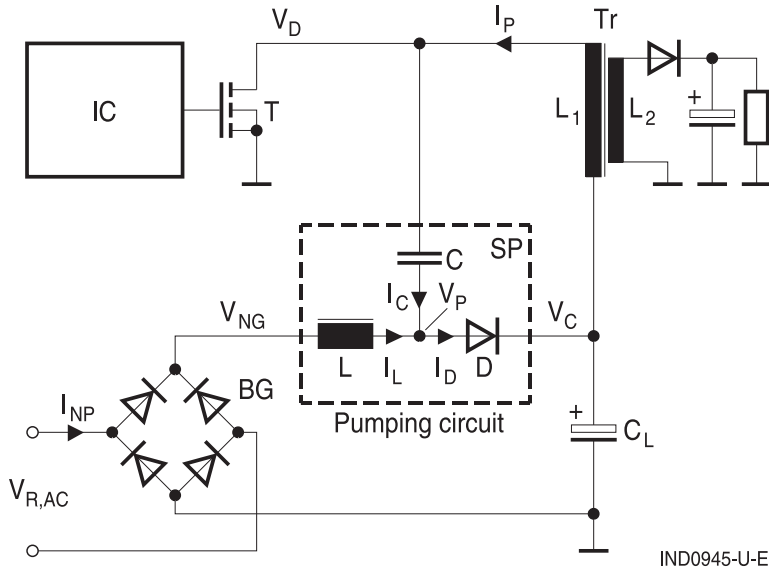


Figure 3 Basic circuit diagram of a switch-mode power supply converted to “sinusoidal input current”.

Instead of using the cut-off circuit, the above power supply operates with a current pump circuit. Between the output of the rectifier bridge BG and the positive terminal of the load capacitor  $C_L$ , a series circuit comprising a choke L and a diode D is connected, whereby the cathode of the diode D is connected to the load capacitor. A coupling capacitor C is inserted between the connection of L and D and the drain of switching transistor T. This “pump circuit” substitutes for the function of the hitherto-used cut-off circuit, but also ensures that the current drawn from the power line has a low magnitude of harmonics.

#### *Sine-wave choke reduces harmonics*

In coordination with the developers of the pump circuit, EPCOS has developed a favorably priced inductive component to match this application and which offers the required features to suit the power of the respective switch-mode power supply. The harmonics which normally occur on the power input side of switch-mode power supplies are reduced by the choke L, also known as the sine-wave choke.

An additional problem occurs on the secondary side of switch-mode power supplies. Here, interference voltages at frequency ranges of several MHz occur. Up to now, complex and frequently expensive active circuits were used to reduce the harmonics here. As opposed to the active solution, EPCOS now offers a considerably less bulky passive solution with greater reliability, since often only a single component, the sine-wave choke, is necessary.

In order to reduce interference voltages and generation of harmonics, a choke is required which has the lowest possible losses while ensuring a high saturation limit even at high currents. Low losses can be achieved by using a high-permeability ferrite material, which would, however, become saturated at high currents. To prevent this, the cores have an air gap (see figure 4).

*Hysteresis curve of the choke*

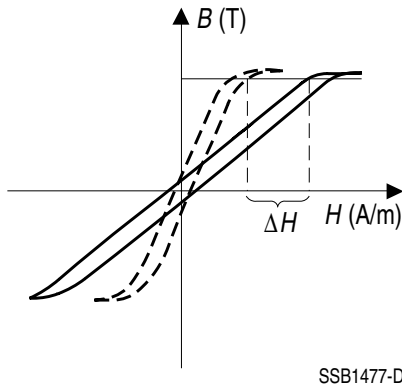


Figure 4 Due to a gap in the core, the hysteresis curve is sheared apart, so that the core becomes saturated at a higher current. The lower inherent heating of the choke as opposed to conventional circuits is a further advantage.

*Low saturation effects and whirring noise*

Apart from achieving a reduction of the harmonics, the use of a sine-wave choke leads to lower interference voltages in the MHz range. To reduce such interference voltages, it is necessary to employ chokes featuring cores with low saturation effects, i. e. which retain their attenuation characteristics even under those conditions.

Up to now, energy-storage chokes with pot cores were used here. One of the disadvantages of these designs is that they may emit acoustic noise when in operation, due to the many individual parts they consists of. In addition, such chokes as have been used up to now are larger and more expensive than the sine-wave choke solution.

*Sine-wave choke*

New production techniques have made it possible to develop the sine-wave chokes under consideration of ecological aspects, they can be completely recycled. Currently, EPCOS offers sine-wave chokes for switch-mode power supplies with up to 300 W. However, it is possible to produce chokes for higher-powered applications.