

# Switch Mode Power Supplies and their Magnetics

by Don Braman, Datatronic Distribution, Inc.

In today's day and age the most often used topology for electronic power supplies is that of the Switch Mode Power Supply (SMPS), which is a major user of magnetics. In some applications the "older type" linear supplies are still used, but in the early 70's SMPS came into being spurred by the development of faster switching transistors. This facilitated the use of much smaller magnetic components and greater efficiencies.

## SMPS and their General Magnetic Usages

In general, there are four different types of magnetic components that are needed for the typical SMPS. They include the Output Transformer, usually the most noticeable because of its size compared to the others, the Output Inductors, the Input Inductors and the Current Sense Transformer, each with its own important function.

1. The Output Transformer or "Main" Transformer takes the input voltage that is supplied to its primary winding and then transforms the input voltage to one or more voltages that are the output of the secondary winding or windings.
2. The Output Inductors are used to filter the output voltage so that the load "sees" a filtered DC voltage.
3. The Input Inductors filter out the noise generated by the switching transistors so that this noise isn't emitted back to the source.
4. Current Sense Transformers are used to help regulate the SMPS so that when the load changes the SMPS adjusts the power it is delivering to the load accordingly.

## Output Power Transformers

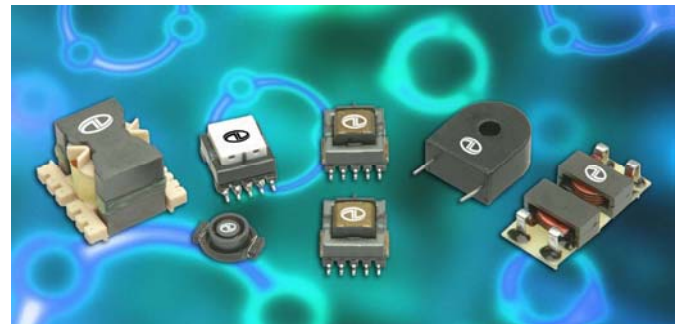
Power transformers for SMPS operate from the input of a chopped waveform at frequencies of 20 kHz and above. These transformers generally operate under loss or saturation limited conditions, which require special power grade ferrites with high saturation levels and low losses. DC to DC converters have the output voltages rectified and filtered to give the required DC output. The output voltage is sensed by a control circuit to vary the ON/OFF time of the switched waveform and compensates for any change at the output.

*Many factors must be considered by designers when choosing the magnetic components required in today's electronic power supplies.*

Numerous circuit designs are used, of which there are four basic converter designs.

- Flyback converters
- Forward converters
- Bridge (half and full wave) converters
- Push-Pull converters

A great deal of overlap exists in topology usages. There are two types of Flyback circuits — continuous mode and discontinuous. The continuous mode is primarily used at power levels up to 250 W and discontinuous up to about 150 W. Forward converters are normally used in the range of 50 to 500 W. The half bridge converters are used in the 100 to 1,000 W range and the full bridge at power levels above 500 W.



The most common magnetics components found in power supply designs include: switcher transformers, gate drive transformers, current sense transformers, inductors and dual planar inductors.

## Core Determination and Shapes for Output Transformers

The frequency of operation should be determined prior to choosing the core to be used. At lower frequencies, the most important limitation is usually core saturation and how hard the transformer is driven toward saturation. In higher frequencies, 50 kHz and above, core loss becomes the limiting factor and saturation levels are not fully considered. It should be noted that saturation is important in

flyback transformers as they are actually multi-winding inductors. All of the core manufacturers have graphs of core losses at various levels of flux density and operating frequencies.

When choosing a core, the window configuration is extremely important at the higher frequencies. A core with the maximum window width, which minimizes the number of layers resulting in lower RAC and leakage inductance, is the best option. Many new core configurations are on the market today, such as the low profile core types of EEM, EER and EFD cores. At the higher frequencies, copper losses become a problem because of skin effect and proximity effect.

For the basic types of converters many core shapes and materials can be used. Flyback transformers use gapped cores; and the best shapes are the gapped “E” core styles and the inherent gapped MPP toroids. “E” cores, RM cores and EFD type cores are typically the best choice for Forward Converter Transformers. The core geometry is often chosen based on the space available for the device. Board space restrictions and height limitations are major factors, from a mechanical standpoint, in the selection of the core.

## Output Inductors

With DC to DC converters, the outputs normally employ inductive filtering using Output Inductors. The majority of these cores are MPP toroids, hi-flux MPP toroids, and Kool Mu (Magnetics Inc. trade name). Ferrites and laminations are also used which are gapped during the assembly process. Gapped planar cores are now more frequently used as they provide a very low profile, and are wound with flex circuits, foil, or ribbon wire where high currents are required.

## Current Sense Transformers

SMPS that use current mode control necessitates the use of a current sensing device for feedback control. Many circuits use resistors for sensing. Other circuits use current sense transformers for sensing. A current sense transformer samples the switching currents from the drain circuit of the FET, thereby introducing no unwanted inductances

or added resistance to the gate drive circuit. The primary winding normally consists of 1 turn of wire through a toroid. The secondary winding normally consists of multiple turns for ratios or factors of 10 or more for current carrying characteristics. The higher the turn ratio, the better the resolution.

## Input EMI Filters — Common Mode and Differential Mode

Typical filters used to suppress EMI include common mode inductors and differential mode inductors. Common mode noises are the high frequency noises that are in phase with each other having circuit paths through ground. The common mode inductor becomes a high impedance to this noise, absorbing it, and then dumping it to ground through low impedance capacitors. Common mode inductors are normally wound on a toroid, each winding of equal turns placed on opposite sides of the toroid in opposite phases to cancel the fluxes developed by each. The common mode inductor is usually wound on a high permeability core to obtain a fairly high inductance on a small core. The differential mode inductor has only a single winding, requiring the core to support the entire line current without saturating. Therefore, the core needs to have a low effective permeability such as a gapped ferrite or distributed gap MPP cores.

In summary, power supply design engineers have many factors to consider in designing the magnetic components required. Many times they rely on the expertise offered to them by design engineers at magnetic component manufacturers/ suppliers like Datatronic. The magnetic component supplier can also help power supply design engineers by providing packaging solutions, safety agency compliance recommendations and prototypes

*Don Braman is Technical Services Manager for Datatronic Distribution, Inc., 28151 Highway 74, Romoland, CA 92585; (909) 928-7700; [www.Datatronic.com](http://www.Datatronic.com)*