Switching vs. linear power supplies

Have you heard the latest about switching power supplies? The newest designs offer persuasive advantages compared with linear power supply technology.

By Paul Watkin

Power supplies serve extensive wireless communications applications. Basic distinctions between linear and switching power supplies make a difference, depending on the specific application. Each type has its own advantages and disadvantages.

Transformers

Power supplies contain two main circuits: a primary side and a secondary side. The primary side connects to the power source, and the secondary side connects to the load. The interface between the two main circuits is the heart of the supply: the transformer.

Transformers convert the voltage available on the primary side to the required voltage level on the secondary side. Energy transfers from the primary side to the secondary by the continuous building up and collapsing of a magnetic field. Alternating current passing through the primary winding generates this field. The transfer of energy, from the primary to the secondary, takes place during the build-up and collapse phase of the magnetic field. This electromagnetic energy gets picked up by the secondary winding to generate the required voltage on the secondary side.

The voltage generated on the secondary side is generally proportional to the ratio of number of wire turns between the primary and the secondary windings. A transformer is normally made of a *primary winding* of copper wire, which is isolated from a *secondary winding*, and a *core*, which is made from a ferrous material such as iron or ferrite. Design and construction of a transformer requires consideration of such things as input and output current, voltage, core cross-sectional area and materials, insulation materials and methods, physical size and style, and temperature rise caused by core and wire losses. A transformer that has not been designed correctly may have less efficiency and may be electrically unsafe.

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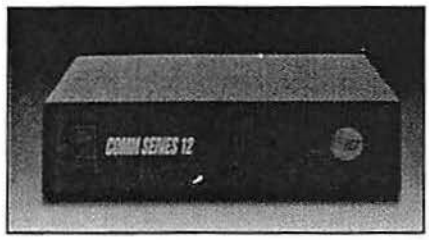

Contemporary switching power supplies offer advantages in light weight and size, coupled with improvements in noise control, and reliability. ***Photo courtesy of ICT.***

The basic technology behind switching transformers is: As the rate of change of the magnetic field increases in the transformer (i.e., increase in switch frequency), the transformer can be made smaller with smaller cores and wires to produce the same output power. Lighter core materials such as ferrite can be used instead of laminated iron. The resulting transformer assembly becomes much smaller and lighter than its linear counterpart.

Linear supplies: basic theory

The incoming ac voltage is stepped down to a lower ac voltage. For example, 120Vac is stepped down to 24Vac. The 24Vac is then rectified through a full-wave bridge rectifier, usually with a high-current, low-voltage bridge. A filter capacitor is used to maintain a constant dc level with minimum ripple.

The output voltage is controlled by a power transistor operating in its linear region. It acts as a variable resistor in series with the load. The power transistor receives its control from a circuit that senses output voltage. The control circuit modifies the transistor bias to maintain a constant voltage output, regardless of changes in the load current.

Switching supplies: basic theory

The incoming ac voltage is rectified and filtered to produce a high-voltage dc. A low-current, high-voltage bridge rectifier (that may not require a heat sink) can be used, as opposed to the linear bridge.

A power transistor—a metal-oxide semiconductor field-effect transistor (MOSFET)—is connected in series with the transformer. The MOSFET serves as an on-off switch and switches at a preset frequency. While the MOSFET is switching, the magnetic field in the transformer is building and collapsing, allowing energy to transfer to the secondary side.

The magnetic energy received by the secondary windings of the transformer is then full-wave-rectified and reconstructed into the proper dc level. A sample of parameters (V_{out}, I_{load}, etc.) can be sent back to the primary side to serve as input to the pulse-width modulator (PWM). The PWM circuit modifies the length of time that the MOSFET is switched "on" in order to maintain output regulation. For example, in a switching power supply producing 12Vdc and powering a 3A load, an increase in the load to 4A causes the output voltage to drop slightly. The feedback circuit detects the voltage drop and passes it to the PWM, which turns the MOSFET on for a longer period (i.e., it increases the duty cycle), causing more magnetic energy to transfer to the secondary side until the output voltage reaches its predetermined value.

Switching frequency

Frequency for a switching power supply usually ranges between 30kHz and 150kHz, but it can be much higher. Frequency for linear power supplies is the same as the line frequency (60Hz in North America). Switching frequency selection

depends on the application for which the power supply is designed. Because high frequency switching occurs at f_o, harmonics are generated at $3f_o$, $5f_o$, $7f_o$.... The selection of the frequency has to be such that none of these harmonics will interfere with the load. With power supplies for two-way radios, for example, the switching frequency should be selected so as not to interfere with VHF, UHF or the intermediate frequencies (IF) used in the radios.

Advantages and disadvantages

▶ *Linear* — One advantage of linear power supplies may be familiarty, because they have been available for many years. They are known to be relatively noise-free and reasonably reliable. They are generally easy to design and fairly inexpensive to manufacture.

Because of the large transformers required, linear power supplies are generally heavy, which may be either an advantage or a disadvantage, depending on the need to balance weight distribution in a given application. As a general rule of thumb, a 16V-output linear power supply weighs about one pound per ampere. A possible disadvantage of linear power supplies relates to the power transistor used to regulate the load. Because the power transistor operates in its linear region, and all the output current must pass through it, it requires large heat sinks to dissipate energy loss. (Recall that the power transistor is in series with the load and acts as a variable resistor.) Except in rare instances where heat is wanted to warm interior space, the inefficiency of linear power supplies—50%—has to be considered a disadvantage.

▶ *Switching power supplies* — Although switching power supplies have been available for a number of years, higher production costs, compared to linear power supplies, have limited their use in some applications. Early switching power supplies used discrete components to control pulse width, and transistors instead of MOSFETs as main switch components. As a result, the disadvantages of switching power supplies once included uneven reliability and radiated EMI (electrical noise). Although they were known to be noisy, unreliable and difficult to mass produce, switching power supplies had the advantage of being lighter and smaller than their linear counterparts. In the last few years, big improvements in PWM and MOSFET design have been made. Today, when all design considerations have been taken into account, switching power supplies are highly reliable and virtually noise-free. Production costs have come down because application-specific components are being designed for use in switching power supplies.

Switching power supplies are about 80%–90% efficient. Higher efficiency usually is an advantage, because heat normally is considered to be wasted energy (at the least) and potentially damaging to nearby electronic components.

Conclusion

Switching power supplies are gaining in popularity mostly because of their smaller size and lighter weight. Reliability and noise characteristics are becoming less-and-less of an issue as customers learn about the latest product developments. When assessing efficiency, size and cost of shipping, one has to consider the alternative to a linear power supply: the switching power supply.