## Linear vs. Switching Power Supplies

# Look at the Facts Before You Leap to Conclusions

**Ask almost any engineer about linear power supplies,** and his or her instinctive reaction likely is, "Sorry, I can't use them — they're too inefficient." Any consideration of using a linear supply usually ends right there; it is as if they are being asked to go back to a vacuum tube AM radio.

Still, a good engineer knows that it's wise to not make decisions based solely on assumptions and clichés, but instead undertake an honest assessment of priorities versus solution alternatives. This applies to the decision of whether to use a switching or linear power supply. Like many engineering decisions, this depends on the specifics of the application, needed features and functions, priorities and acceptable tradeoffs.

## Linear Power Supplies

For AC line-powered supplies, the linear power supply first converts the high-voltage AC into lower-voltage AC using a transformer, and then converts that into an unregulated DC voltage via a rectifier and capacitor filters. An error amplifier with a voltage reference as one input and the output DC as the other controls a series-connected pass element (Figure 1). The error amplifier compares the reference to the output and regulates the output voltage by dropping excess voltage in the pass element, hence the designation "linear" supply.

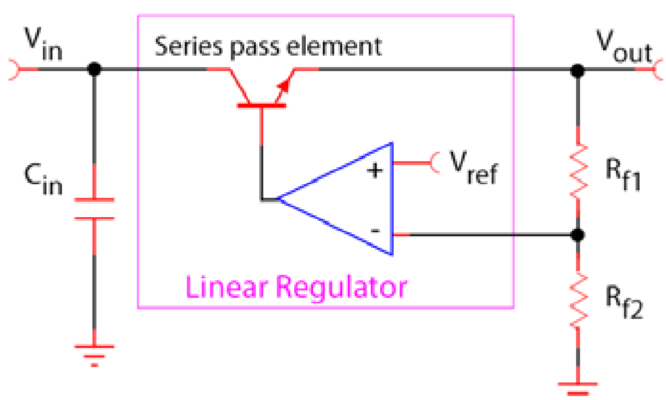


Figure 1. The linear power supply uses an all-analog closed-loop feedback approach to control the pass element, such that the supply output voltage tracks the internal reference voltage. In the block diagram, the voltage divider at the right-hand side allows the user to set the output-voltage versus reference-voltage comparison ratio.

The closed-loop design ensures that the supply output stays at the nominal voltage despite changes in supply line or load values.



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The pass element is in its active region and dissipates power regardless of the power it is also delivering to the load; this is the major source of inefficiency in a linear supply.

## Switching Power Supplies

In a line-powered switching supply, the line AC is usually first converted to unregulated DC (again, via a rectifier and filter) and then the supply regulates that DC voltage down to the desired voltage. There are many topology variations of the switching concept, but the underlying principle is similar for all. Again, an error amplifier compares the regulator output value to an internal reference, but here the pass element is rapidly switched on and off with a PWM or pulse-frequency modulation scheme (Figure 2).

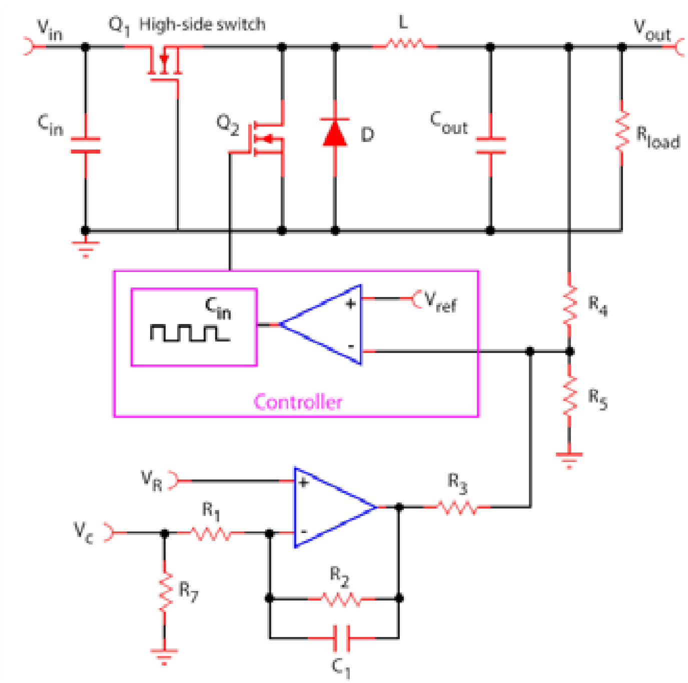


Figure 2. In the SMPS supply, the output voltage is regulated by clocked on/off pulse-width modulation of the pass element, resulting in low losses and high efficiency, but the output has clock noise that must be filtered to establish a clean DC output voltage.

The output pulses are filtered to low-ripple DC and the resulting waveform becomes DC voltage output. Since the pass element is either completely on or off, it is always in a mode where its dissipation is minimal, with the main losses being from series on-resistance when it is conducting and switching losses as it transitions between on and off state.

# Key Characteristics of Linear vs. Switching Supplies

There is no doubt that the linear supply's typical efficiency of about 20% to 40% is less than that of the switching supply at 60% to 80% (reaching 90% in some cases).

Size and weight are also major differences. The switching supply is much smaller and lighter, largely due to the smaller transformer, discrete semiconductors and passive components. For example, a 250 W linear power supply would require 600 in3 (a little under 9000 cm3) of mounting space and weighs 26 lb, (about 12 kg) (Figure 3, on left is an Acopian Gold Box supply). A comparable AC/DC switching power supply would require one-tenth that volume of mounting space and weighs just 2 lb (0.9 kg) (Figure 3, on right is an Acopian Low Profile unit).

Figure 3. The linear supply (left) is far larger and heavier than a comparable switching supply (right) by a factor of ten, but the linear unit has some beneficial attributes which the switcher supply cannot match. Source: Acopian Power Supplies

The size of the switching supply is also a function of its switching frequency, ranging between a few hundred kilohertz for larger supplies to as high as a few megahertz for lower power ones. Operation at high frequencies allow for small passives and overall footprint, although overall efficiency will decrease due to the high switching losses.

Why would an engineer even consider a linear supply with its lower efficiency, larger size and higher weight? Here, noise on the DC output and transient response come into play.


## Noise

The linear supply is a continuous function unit with no discrete time clocking or switching action. As a result, the output is virtually noise and ripple free, and any noise seen at the load is due to pickup outside the supply itself in the power wiring between supply and load. Using chokes and other filter components as well as careful routing of the output cabling can attenuate this noise. The linear supply itself does not generate any EMI or RFI.

In contrast, the switching supply is inherently a source of noise, with a fundamental at its clock frequency as well as numerous harmonics. Typical noise levels are on the order of hundreds of microvolts to tens of millivolts. This is unacceptable for many applications where the output voltage is at single-digit levels, or the load is sensitive to supply rail noise.

This switching-based noise can be filtered to some extent but is very difficult to eliminate entirely. In addition to noise on the output cables, there is also noise radiated by the supply, which can induce unexpected and frustrating problems elsewhere in the system. Further, while filtering can attenuate the output noise to an acceptable level, the problem of radiated noise is much more difficult to manage.

Further, the frequency of the switching-induced noise may interfere with other clocked signals, resulting in beat frequencies and other interfering signals. In some cases, the switching supply's clock frequency must by synchronized with the system clock.

Further aggravating the situation, there are increasingly stringent regulatory limits on how much noise a power supply can generate in different frequency bands, both as a function of power supply wattage and global zone. Some switching supplies meet the regulatory mandates by using spread spectrum clocking, which spreads the noise energy across a wide band. By doing so, the noise does not exceed allowed limits at the clock frequency or its harmonics. While this technique works in the "legal" sense to meet mandatory standards, the supply noise can still affect internal system circuitry.






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# Transient Response

There is also the issue of transient response to sudden changes in load. The all-analog linear supply can be tuned to have optimal response to step changes in load. The goal is to have fast response without overshot or ringing, and a properly designed supply can provide this. In contrast, the closed-loop dynamics of the switching power supply are much more difficult to control, may be slower or have excessive overshoot and ringing before it stabilizes, depending on design specifics and clock frequency.

There is no doubt that the switching supply offers major benefits with respect to efficiency, weight and size. Before assuming it is the right or only choice, engineers should consider the application as well as the impact of more noise and ripple. There are installations where these attributes are not the priorities; instead, low ripple and output noise are the top priorities along with superior transient performance. These include extremely low-noise amplifiers, advanced signal processing and data acquisition systems (including sensors, multiplexers, A/D converters and sample and hold circuits) and precision automatic test equipment (ATE) and laboratory test equipment.

Considering vendors who offer both power supply topologies is a wise decision, so solution bias will not be a factor. Look to Acopian Power Supplies for advice on linear versus switching power supplies.