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Extron Power Supplies: How We Design to Be the Best

Becoming the best at power supply design is much more than using the right components or applying exhaustive testing schemes. Designing the best power supply requires a commitment to reliability over cost and features. This article provides a look into how Extron designs its power supplies to be the best.

The industry has generally adopted "switchmode" power conversion to reduce size, weight, and waste heat. This type of power supply takes advantage of the fact that an isolation transformer's size and weight are proportional to its operating frequency.

Instead of using the convenient and "free" AC frequency provided by the AC line, 60 Hz in our example, we can use 60 kHz for a reduction in size and weight. In *Figure 1*, this is done by rectifying the line frequency AC to DC, then using active power electronics to create a high frequency AC to pass through the transformer, after which it is rectified to DC again. This results in a great reduction of size and weight.

In this type of circuit, the output voltage is a function of the input voltage and the switch duty cycle. So it is capable of universal input operation if a feedback loop is closed, varying switch duty cycle to maintain constant output voltage. Since the circuit runs directly from rectified 120 VAC or 240 VAC, there is a significant difference in dominant losses for the two cases, usually favoring the low voltage case. There are ways to mitigate these losses and increase efficiency at the expense of increased complexity and design effort. Here is a brief review of some of them.

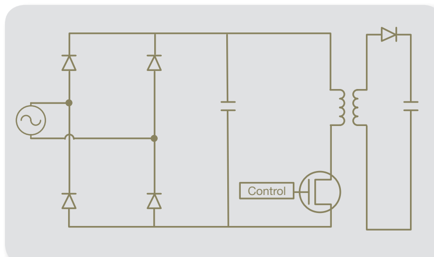


Figure 1: Switchmode Power Supplies

Transistor Loss

Transistor switching losses are very significant for traditional "hard switched" converters. This means there are losses each time a transistor changes state. These losses are from several factors, but the most significant is the discharge of capacitance from the transistor itself. If the transistor's capacitance is allowed to transition "softly", switching can occur nearly without losses as shown in *Figure 2*. In order to keep the switching losses from getting too large, as well as for cost cutting, a traditional design uses as small a transistor as possible since a smaller geometry has smaller capacitance. Unfortunately, this increases the resistance, so conduction losses are increased. In the resonant transitions converter, the transistor can be very large since its capacitance no longer leads to higher switching losses. Then resistance can be made arbitrarily small with a large geometry device, reducing conduction loss as an indirect result of resonant switching.

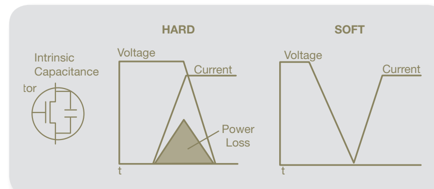


Figure 2: Transistor Capacitance with Hard and Soft Switching Waveforms

Clamp Loss

A traditional converter has some unavoidable energy stored, which can be dissipated with a traditional clamp circuit comprised of a diode and capacitor to clamp stored energy into, and a resistor to dissipate the energy as shown in *Figure 3(a)*. This standard method actually dissipates more than just the stored energy, since it sits across the reflected output voltage all the time. A "resonant clamp" topology is a relatively recent development that recycles the clamp energy in a nearly lossless way. With this approach, an extra transistor is used at a significant increase in cost and complexity, but efficiency is improved as shown in *Figure 3(b)*. Transformers are designed to maximize stored energy instead of minimizing it.

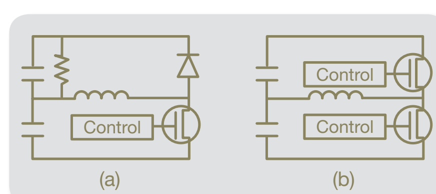


Figure 3: (a) Dissipative Clamp Topology; (b) Resonant Clamp Topology

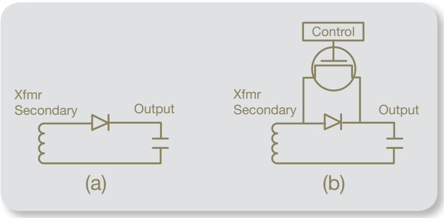


Figure 4: (a) Diode Loss in output
(b) Diode loss reduced with transistor

Diode Loss

The conversion of transformer AC to output DC has traditionally been handled by a simple diode, but at the expense of an additional transistor, we can reduce the conduction losses dramatically as shown in *Figure 4*. The timing of this added transistor must be carefully synchronized to the main transistor, but losses can be cut an order of magnitude.

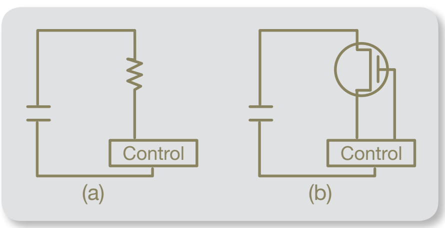


Figure 5: Startup Loss Eliminated by replacing resistor in (a) with transistor (b)

Startup Circuit Loss

Figure 5 shows a startup resistor. This is used to supply start-up power to the 12 V control system from the rectified AC line voltage, 170 VDC to 340 VDC. This is only 4% to 8% efficient, but the worst part is that the resistor stays in circuit, dissipating power for the life of the product. The 240 VAC case dissipates 4 times the 120 VAC case, due to V2/R. High efficiency designs use an actively controlled high voltage current source to start up the control system that dissipates no power during active mode.

Transformer Loss

Power transformer losses can be reduced simply by accommodating the size and cost of a larger part. If the design is not competing on power density or cost minimization, this is a good choice.

Thermal Management Simplification

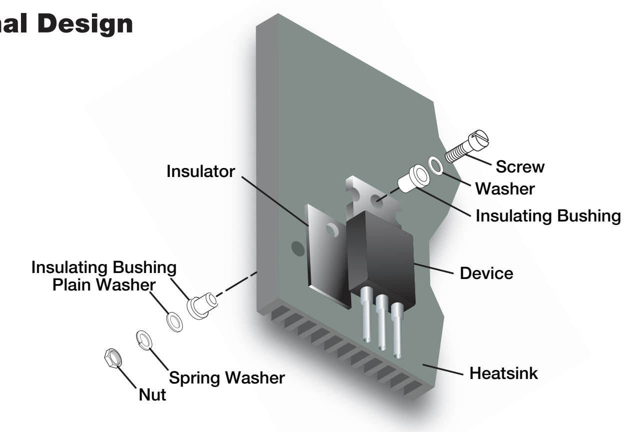
Another benefit of increased efficiency, or reduced dissipation, is that thermal management can be simplified. Traditional designs often require the mounting of a transistor to a dedicated heatsink. This then requires a thermal insulator and a nut and screw combination for mounting. Then some type of locking nut must be used. Due to repeated thermal expansion and contraction, a compression washer must be used to ensure proper force is applied. To maintain electrical isolation, a shoulder washer is used. All this mass is then affixed to the circuit board somehow (as shown in *Figure 6*), but it can be susceptible to shock and vibration, causing broken leads.

A more robust approach involves using surface mount power transistors and diodes, and using the PCB copper area for a heatsink. If the dissipation is low enough, this approach removes all hand labor and human error from the process, leaving just the highly mature and reliable process of a solder interface with a low profile result that is much less susceptible to shock and vibration.

Operating Temperature and Life Expectancy

All the efficiency improvements result in lower power draw, but the benefit of increased efficiency goes much farther than that. Heat accelerates component aging; a cooler product lasts longer and

Traditional Design



Simplified Design

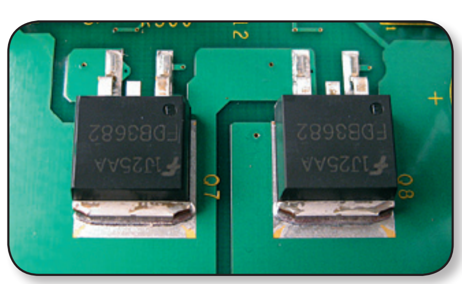


Figure 6: Thermal management simplification

	TRADITIONAL DESIGN 120VAC	240 VAC	HIGH EFFICIENCY DESIGN 120VAC-240VAC	
Transistor Switching Loss	High ↑	Very High ↑	None ↓	Resonant Soft Switching
Transistor Conduction Loss	Very High ↑	High ↑	Low ↓	Larger Die
Clamp Loss	High ↑	Very High ↑	None ↓	Resonant Active Clamp
Diode Loss	High ↑	High ↑	Low ↓	Active Synchronous Rectifiers
Startup Resistor Loss	High ↑	Very High ↑	None ↓	Intelligent Active Circuitry
Transformer Switching Loss	High ↑	Very High ↑	None ↓	Larger Transformer
Transformer Conduction Loss	High ↑	High ↑	Low ↓	Larger Transformer
Operating Temperature	High ↑	Very High ↑	Low ↓	
Failure Rate	High ↑	Higher ↑	Low ↓	

Figure 7: Loss Summary

is more reliable. The general relationship is a doubling of lifetime for every 10˚C temperature reduction. The benefits of high efficiency are seen as reduced failure rate and increased life expectancy.

New Standard of Efficiency: Level V

The US Environmental Protection Agency's ENERGY STAR program has long been the standard of efficiency for power supplies. In 2010 the program was phased out with the advent of other federal minimum efficiency standards mandated for external power supplies that meet or exceed current ENERGY STAR standards. A new standard for indicating a power supply's efficiency level has been adopted by the EPA and by the EU. The latest efficiency standard is Level V, which requires testing of no-load power consumption as well as the average efficiency. Average efficiency is the unweighted average of the efficiencies measured at 25%, 50%, 75% and 100% load. This rating system is now part of the international energy efficiency marking protocol being implemented worldwide.

Electromagnetic Interference (EMI)

EMI is a concern in switchmode power converters to a far greater degree than it is in linear supplies. A switchmode circuit operating with 60 kHz square waves produces harmonics easily up to the 60 MHz region in the form of electrical noise, electric fields, and magnetic fields, which can interfere with operation of the very circuits that the power supply is supposed to be serving. These harmonics can also exit the product via cabling acting as unintentional antennae, or openings in the chassis. Once in the outside world, they can interfere with all types of equipment. The last 20 years have seen an industry-wide focus on compliance as regulating bodies worldwide have been created or strengthened to deal with the problems of electromagnetic interference. Early designs were notoriously noisy from an EMI perspective, but again, companies were able to rise to the challenge and produce switchmode designs effectively as quiet as the old linear ones while retaining all the benefits.

Conclusion

Reliability is a primary concern of professionals, whether they are customers, system designers, or product manufacturers. At Extron, we have adopted the philosophy regarding power supplies for our products that reliability is our primary objective, not cost, not power density, not specsmanship. To achieve this, we start with a highly efficient topology made from the highest quality components available and manufacture them with the same process used for our high-end video products, using the same care and attention to detail in every step of the process. From Purchasing to Manufacturing, from Test Engineering to Quality Assurance, Extron switchmode power supplies ensure more high quality Extron products.

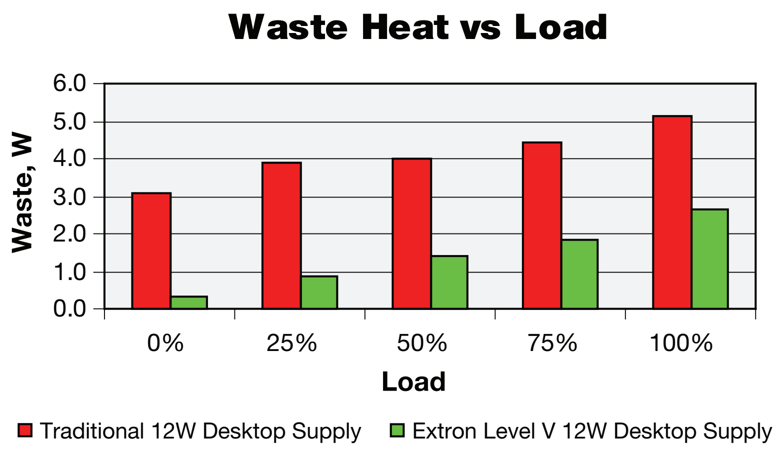


Figure 8: Comparison of Traditional versus Level V Power Supplies