Medical power supplies: trends, challenges and design approaches

By Peter Blyth, Industry Director, XP Power

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Medical electronic equipment is getting smaller. Of course, this could be said of all electronic equipment but it is in medical area that the pressure for size and weight reduction is greatest. Not only is the hospital bedside environment very space-constrained but there is a trend for more equipment to be used in the home, in doctors' offices, and even in cars and on planes. This is creating particular pressure on power supply manufacturers to reduce the size of their products.

In the last 10 years a typical convection-cooled, 100W AC/DC power supply has shrunk from a 4 x 7 inch footprint in 1998 to just 2 x 4 inches today, a reduction over 70%. (Note: power supply sizes are still most commonly defined in Imperial measurements.) This size reduction has had to be managed carefully. Smaller packages mean less area for heat dissipation, which in turn requires higher efficiency. This article explains some of the main design issues and briefly introduces some of the most effective techniques that are now employed to achieve power system design goals in medical applications.

Through both empirical measurement and calculation, estimates of the maximum power loss that a chassis mount or open frame power supply can dissipate as heat for a given footprint are shown in Figure 1. The figures are based on using convection cooling and on maintaining compliance with safety agency requirements. They also take account of providing reasonable operating life and acceptable reliability limits. Note that forced air cooling can improve the power rating considerably, but at the expense of decreased system reliability - fans are fundamentally less reliable than the other power system components, and they add to system size and noise. Fan noise is very undesirable in medical applications.

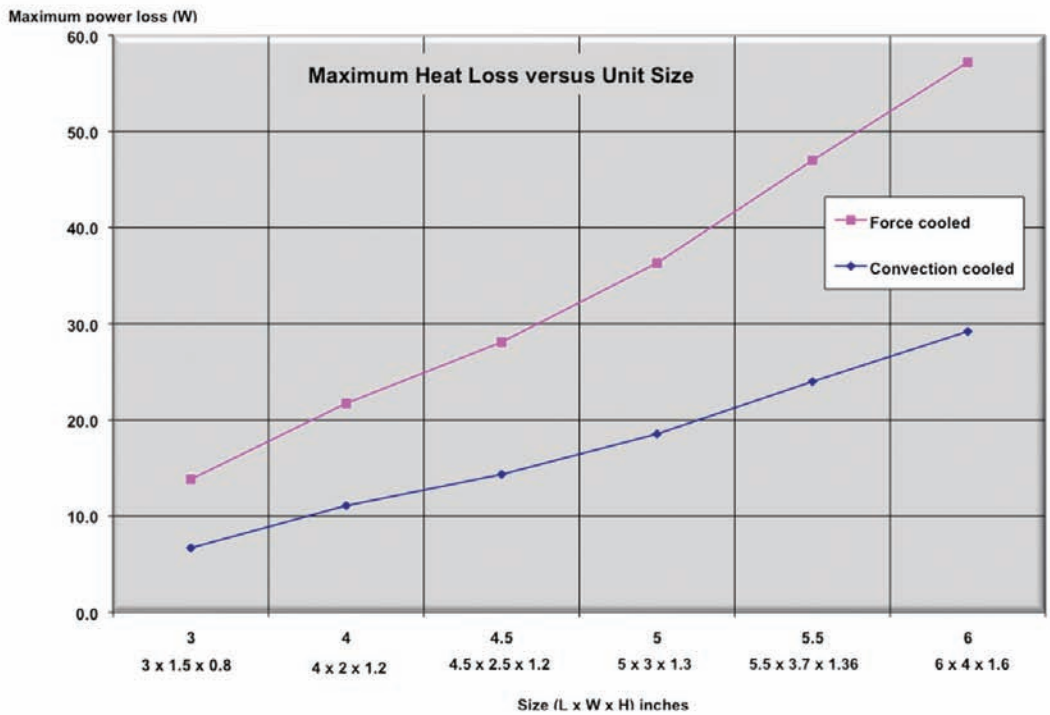


Figure 1: The maximum safe heat dissipation vs. size for power supplies used in medical applications

Figure 2 then shows how power loss translates into required efficiency.

For example, taking an industry standard footprint of 3 x 5 inches, convection cooling can effectively remove about 18 Watts of waste heat. Extrapolating from the 20 Watt power loss curve in Figure 2, a 120 Watt power supply needs to be at least 86% efficient for convection cooling to be sufficient.

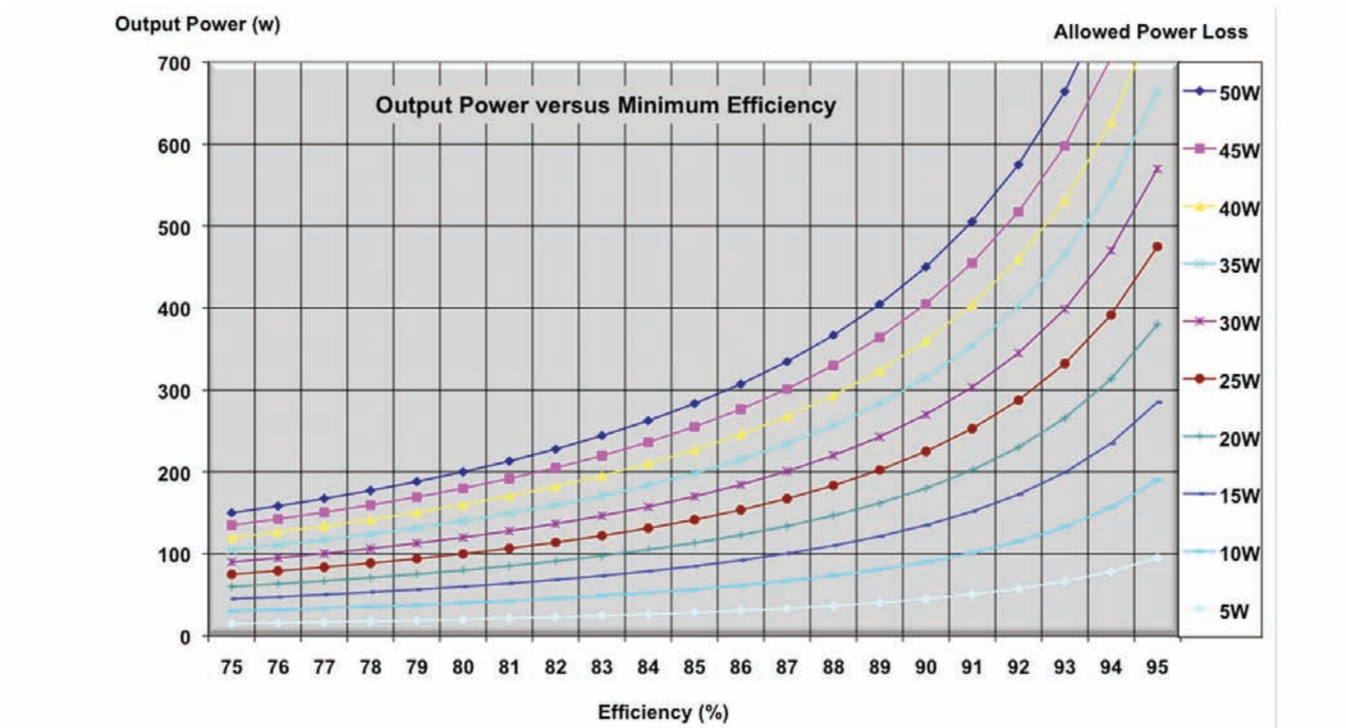


Figure 2: The minimum efficiency required for a given power supply output to ensure compliance with safety standards

Figure 2 also shows the dramatic effect that a relatively small improvement in efficiency can have on the available power from a power supply for a given heat dissipation. Taking the 20 Watt power loss curve, an efficiency gain from 88% to 93% would enable an power supply to deliver over 250 Watts, rather than less than around 150 Watts, within a given footprint.

For the power supply designer, size and efficiency are usually the most important trade-offs. Increasing the switching frequency means that smaller components can be used – notably capacitors and inductors. However, switching losses rise and a power supply that may be 92% efficient at 30kHz will be only 83% efficient at 200kHz. Reliability is always of paramount importance in medical applications, so keeping the power system running well within its maximum ratings is always desirable. Finally, cost is the ever-present final determinant of a power supply's suitability for a given application.

Techniques for managing the design trade-offs

Despite the substantial reductions in power system size over the last decade, no single design leap has made this possible. Rather, a combination of small improvements in both design techniques and components technologies have come together to create the end result. Taking power supply from input to output, these are some of the design approaches that are now adopted.

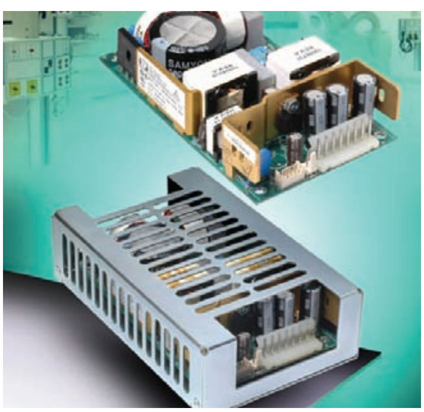
Two stage input filters use high permeability cores to minimise size while providing high common mode and differential noise reduction. Smaller footprints can be realised by stacking components vertically. This can also improve cooling through better airflow.

In many power supplies, it has become economical to use silicon carbide diodes in power factor correction circuits. These need no snubber circuits, reducing component count and saving space while giving a typical 1% boost to efficiency.

The main converter topology is critical to efficiency. For power supplies in the 100 Watt to 200 Watt range, a resonant topology is often chosen. This can virtually eliminate switching losses, enabling smaller heatsinks to be used – so contributing to the dual goals of smaller size and higher efficiency. In some cases, ceramic heatsinks can replace metal ones. This results in lower noise because the heat sinks are not subject to capacitive coupling with the drain connections of the switching MOSFETS. Simplified filtering can then be used. An additional advantage of ceramic heatsinks is that smaller creepage distances can be used, compared with those needed for conductive metal heatsinks, so further board space savings are achieved.

The falling price of power MOSFETS has meant that they are now becoming more common than diodes in the main rectifier of switching power supplies. Efficiency improvements of more than 40% in this part of the circuit are possible. For example, a 20 Amp diode with 0.5V forward voltage dissipates 10W, whereas a MOSFET with an ‘ON’ resistance of, say, 14 mΩ at 100 degrees C dissipates just 5.6W. Once again, ceramic heatsinks can be used to advantage.

Lastly, control circuits have been greatly simplified in recent years, largely through higher integration of semiconductor functions. Application specific chips are now available that can provide the main converter voltage and a host of automatic protection features. Comprehensive monitoring and control signals are also more easily implemented thanks to more highly integrated power management devices.



How small can they get?

Figure 3 shows XP Power’s ECM140 - an example of a compact, efficient power supply that’s available today. It has a 3 x 5 inch footprint and is rated at 120 Watts with convection cooling or 148 W with forced-air cooling. A 12V fan supply is included in the design, which has a typical efficiency of 88%. Later this year, AC/DC switching power supplies with medical approvals will take efficiency to levels well in excess of 90%. This will enable 250 Watt convection cooled units to be compressed into a 6 x 4 inch footprint.

Figure 3 (left): XP Power’s ECM140 adopts some of the techniques described to deliver 120W from a 5 x 2 inch footprint, with 88% typical efficiency enabling convection cooling at this power level

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