Pushing the limits of AC/DC power system design to meet the demands of medical applications

By Peter Blyth, Industry Director – Medical, XP Power

While it's clear that reductions in size and improvements in efficiency are constant pressures in the design of AC/DC power supplies, the medical device market has some particular requirements that make the challenge greater still. This article considers these challenges and looks at how recent AC/DC switching power supplies are being designed to meet them.

Medical electronic equipment is no longer just used in hospitals, which means that trained experts do not always operate it, or used in tightly controlled environments. Such equipment is now widely used in doctors' surgeries, in ambulances and even in the home.

The requirement for portability in such equipment means that size and weight are prime considerations in the selection of power supplies. You can always find a smaller power supply, or design one, by including a fan to provide forced air-cooling. You might save one-third to one half of the total volume of a typical unit in this way. The major disadvantage of this approach is fan noise, which disturbs and irritates patients. Other problems include a significant reduction in reliability – the fan will likely be the only moving part in the power supply, and you add a maintenance problem. Due to these issues, system designers are now looking to utilize convection-cooled power supplies to power their equipment.

Minimizing component-count will help in reducing size and cost, but there are limitations here too. Medical equipment must be reliable in a variety of environments – lives may depend upon. This means you can't tolerate compromises with respect to immunity to interference (EMC/EMI/RFI) and production of conducted or radiated emissions. You can't compromise safety either – patients have to be fully protected from potentially lethal voltages.

The size – power - efficiency trade off

The surface area available to provide cooling will be the limiting factor in how much heat you can dissipate from a convection-cooled power supply – one that doesn't need a fan. It follows that the more efficient you make the power supply, the less heat you'll need to remove and the smaller the unit can be. What may appear to be small differences can have great impact here. If you can buy or design a power supply that is 95% efficient, versus one that's 90% efficient, the 5% difference in efficiency means you need to remove less than half of the heat of the less efficient design. Efficiency will also be affected by load – most power supplies operate at maximum efficiency at close to full rated load. It pays to check out the efficiency you can expect in your individual application.

The frequency – size – efficiency trade off

One way to reduce the size of magnetic components and capacitors is to increase the switching frequency of the converter. However, switching losses increase with frequency as do wound component core losses and copper/resistive losses caused, in part, by skin effect. The trade-off for efficiency and switching frequency in a typical 200 Watt power supply produced during the last few years is shown in Figure 1.

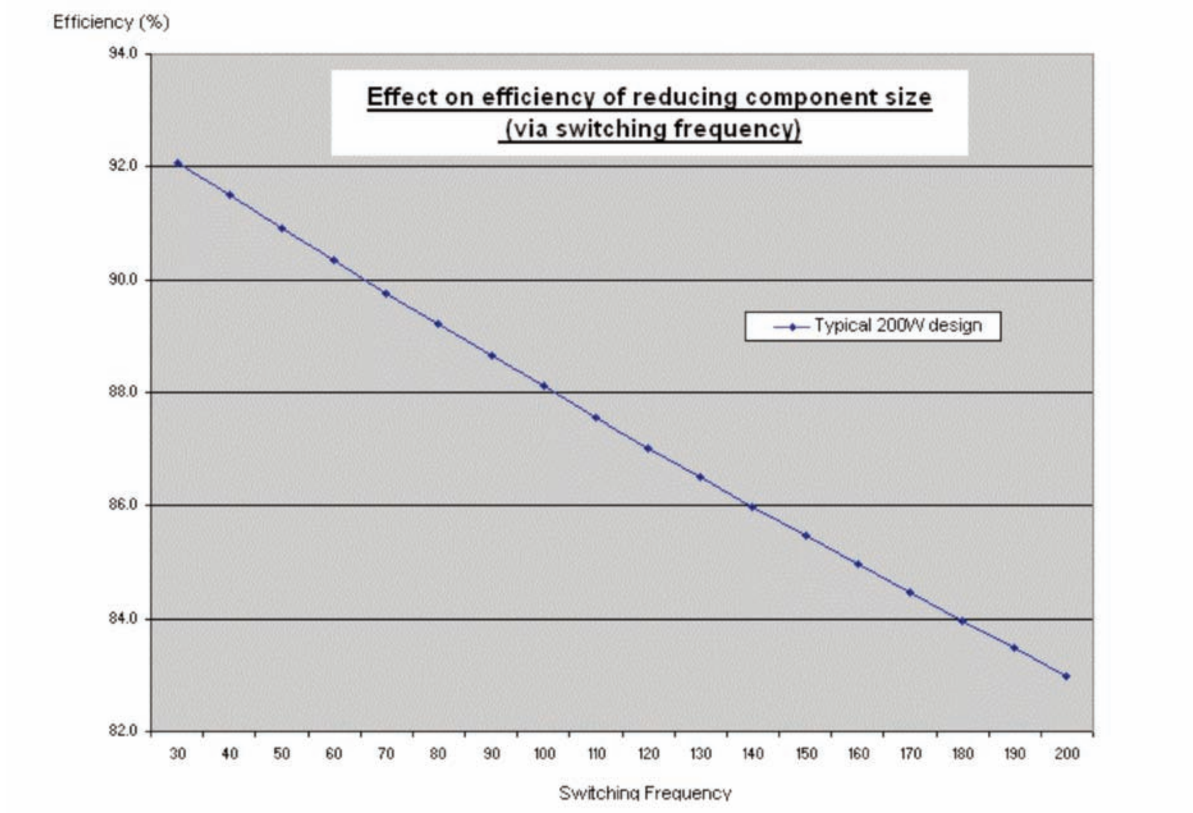

Figure 1: Effect on efficiency of reducing component size by increasing switching frequency

Clearly, a compromise must be reached between size, efficiency, switching frequency, reliability, lifetime, cooling technique and, perhaps most importantly, the cost for a given power rating.

Designing for 90% + efficiency

The best of today's 250 Watt, convection-cooled power supplies operate at over 90% efficiency across an input voltage range of 90 to 240 VAC. This level of efficiency is essential in order to keep within an industry-standard 6 x 4 inch footprint whilst still ensuring adequate heat dissipation without a cooling fan or large external heatsinks.

Over 90% efficiency can only be achieved with near lossless switching in the active power factor correction circuit, the main converter(s) and the rectifiers. A diagram for a 250 Watt AC/DC power supply that achieves up to 95% efficiency at 240 VAC input and 92% efficiency at 90 VAC input is shown in Figure 2.

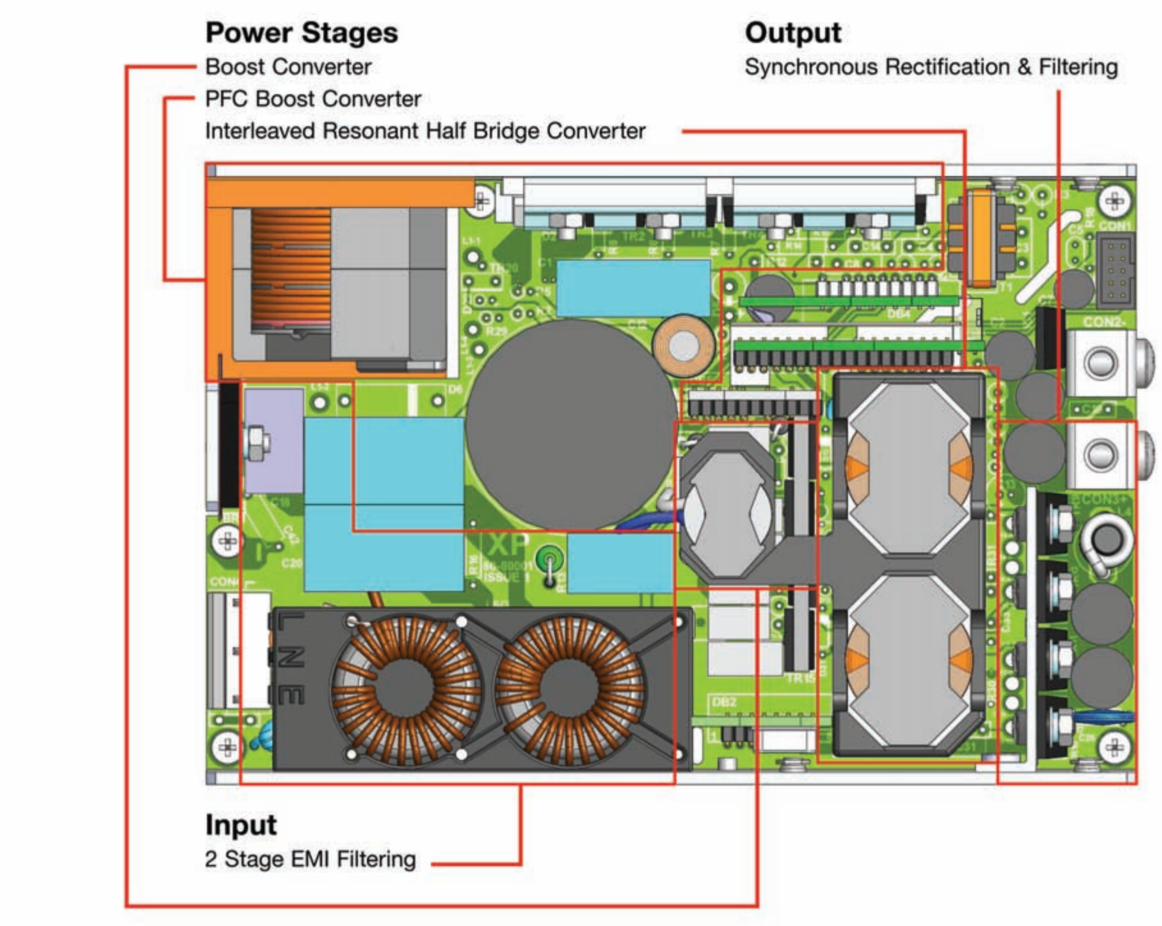

Figure 2: This 250W AC/DC power supply is up to 95% efficient

From the outset achieving high efficiency was the primary design goal for this power supply. Consequently, for each stage the power loss budget was determined and this drove the choice of circuit topology. Power losses were minimized in each stage, striving to save every mW of unnecessary dissipation. For example the input filter for the power supply shown above uses very low resistance winding wire that virtually eliminates I2R losses in the chokes.

The EMI filter employed in this design is a 2-stage filter with a high permeability magnetic core. This was carefully selected to attenuate switching noise and to minimize power loss.

A quasi-resonant, lossless switching power factor correction circuit operates in a discontinuous mode. Its operating frequency changes between 30 kHz and 500 kHz to achieve zero current switching (ZCS) throughout the specified range of loads and input voltages.

A feedback loop monitors the power supply output and varies the boost converter voltage, which in turn varies the voltage at the input to the main converters. The primary purpose of the boost converter is to boost the PFC voltage of approximately 380 VDC to 420 VDC.

The final stage uses synchronous rectification instead of normal diodes as this greatly reduces power loss.

Timing for the boost converter, main converters and synchronous rectifiers needs to be precisely controlled to achieve accurate ZCS. A crystal-controlled clock is used as the timing reference and a divider network is employed to get the desired switching frequency. Using this approach is crucial for the efficient operation of synchronous rectifiers, especially for higher output voltages.

Creative mechanical design minimizes size and improves thermal performance

You can greatly improve the thermal performance of a power supply through creative mechanical design. Avoiding hot spots and ensuring the best possible air-flow around components that are going to get hot are both important. In the power supply described above, XP Power's CCM250 (Figure 3), has input chokes stacked above other components to save board space. Normally this might create hotspots but the low-loss design of the chokes prevents them.

Figure 3: XP Power's CCM250 power supply uses creative mechanical design to pack a 250 W (300 W peak) convection-cooled power supply into a 6 x 4 x 1.5 inch format

Medical applications are now amongst the most demanding with respect to the size, efficiency, performance and cost of AC/DC power supplies. Combining the best of proven design technologies with creative mechanical design has led recently to the introduction of units that can reach up to 95% efficiency, a figure thought impossible only a few years ago.

North American HQ

XP Power
990 Benecia Avenue, Sunnyvale, CA 94085
Phone : +1 (408) 732-7777
Fax : +1 (408) 732-2002
Email : nasales@xppower.com

North American Sales Offices

Toll Free........................+1 (800) 253-0490
Central Region..............+1 (972) 578-1530
Eastern Region ....+1 (973) 658-8001
Western Region............+1 (408) 732-7777

European HQ

XP Power
Horseshoe Park, Pangbourne,
Berkshire, RG8 7JW, UK
Phone : +44 (0)118 984 5515
Fax : +44 (0)118 984 3423
Email : eusales@xppower.com

German HQ

XP Power
Auf der Höhe 2, D-28357
Bremen, Germany
Phone : +49 (0)421 63 93 3 0
Fax : +49 (0)421 63 93 3 10
Email : desales@xppower.com

European Sales Offices

Austria ....+41 (0)56 448 90 80
Belgium ....+33 (0)1 45 12 31 15
Denmark ....+45 43 42 38 33
Finland.......................+46 (0)8 555 367 01
France ....+33 (0)1 45 12 31 15
Germany...................+49 (0)421 63 93 3 0
Italy ....+39 039 2876027
Netherlands ....+49 (0)421 63 93 3 0
Norway............................+47 63 94 60 18
Sweden .... +46 (0)8 555 367 00
Switzerland .... +41 (0)56 448 90 80
United Kingdom........+44 (0)118 984 5515

Global Catalog Distributors

Americas ....Newark newark.com
Europe & Asia..................................Farnell farnell.com
China ....Premier Electronics premierelectronics.com.cn

Asian HQ

XP Power
401 Commonwealth Drive, Haw Par Technocentre, Lobby B,
#02-02, Singapore 149598
Phone : +65 6411 6900
Fax : +65 6741 8730
Email : apsales@xppower.com
Web : www.xppowerchina.com / www.xppower.com

Asian Sales Offices

Shanghai .... +86 21 51388389
Singapore......................... +65 6411 6902

Distributors

Australia ....+61 2 9809 5022 Amtex
Balkans ....+386 1 583 7930 Elbacomp
Czech Rep. ....+420 235 366 129 Vums Powerprag
Czech Rep. ....+420 539 050 630 Koala Elektronik
Estonia ....+372 6228866 Elgerta
Greece ....+30 210 240 1961 ADEM Electronics
Israel ....+972 9 7498777 Appletec
Japan ....+81 48 864 7733 Bellnix
Korea ....+82 31 422 8882 Hanpower
Latvia ....+371 67501005 Caro
Lithuania..........................+370 5 2652683 Elgerta
Poland............................+48 22 8627500 Gamma
Portugal.........................+34 93 263 33 54 Venco
Russia ....+7 (495)234 0636 Prosoft
Russia ....+7 (812)325 5115 Gamma
South Africa....................+27 11 453 1910 Vepac
Spain.............................+34 93 263 33 54 Venco
Taiwan ....+886 3 3559642 Fullerton Power
Turkey ....+90 212 465 7199 EMPA

THE XPERTS IN POWER

Jan-10