Driving AC-DC power supply efficiency even higher

By Peter Blyth, Industry Director, XP Power

Reducing the size and improving the efficiency of AC-DC power supplies are constant pressures. In addition the requirement for portability in some equipment means that not only the size but also the 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. However, in the medical market the main 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 you will be limited here too. 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 – users have to be fully protected from potentially lethal voltages.

Finally, you need to take account of green legislation including RoHS, CEC/EISA, particularly if equipment is going to be sold around the world. The use of RoHS components is obligatory and designing for the highest possible efficiency will not only help in meeting present and future environmental legislation but will also help to ensure best performance from convection- cooled power supplies.

Breakthrough technologies that have a dramatic impact on power supply design are rare. Advances in power semiconductor technology have had most impact, followed by improvements in magnetic materials and capacitors. Reducing power supply size without compromising performance means that you have to work towards incremental improvements in every aspect of the design, both electrical and mechanical.

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. For a 250 Watt power supply, this means 14.6 Watts less heat to be dissipated.

Incidentally, because power supplies for portable equipment might be used in a lot of different environments, you cannot always rely on a 230V or 110V AC power source being available. It's important to look at how well the efficiency is maintained across the range of input voltages defined in the power supply data sheet, particularly at low line (85-90 VAC). Some units are very much worse than others.

Efficiency will also be affected by load – most power supplies operate at maximum efficiency at full rated load. It pays to check out the efficiency you can expect in your individual application. 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 due to wound component core losses and increased 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.

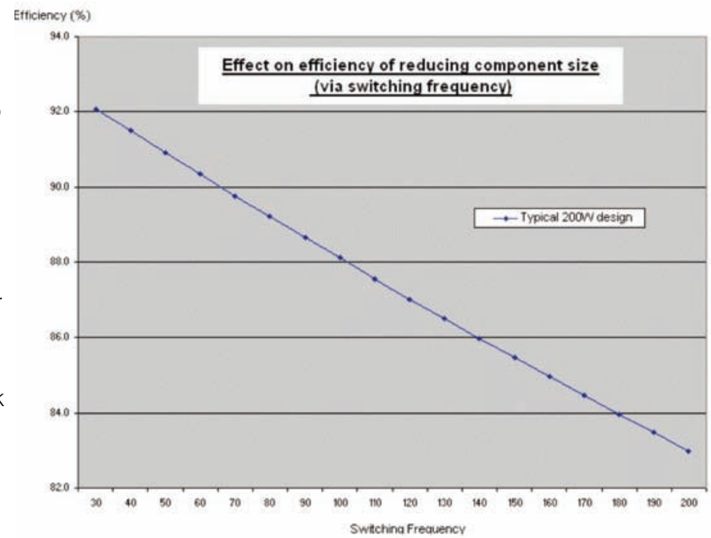

Figure 1: Effect on efficiency of reducing component size by increasing switching frequency

Clearly, you have to reach a compromise 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.

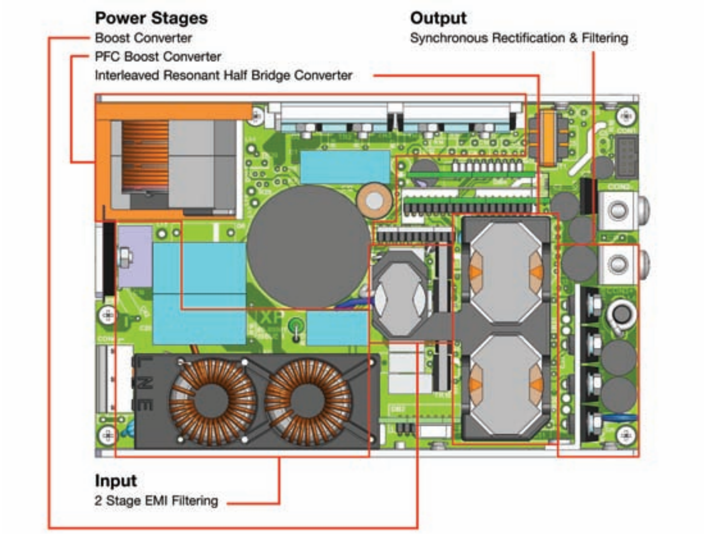

Figure 2: This 250W AC/DC power supply is up to 95% efficient

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. The other components in the filter are X and Y capacitors with the Y capacitor values being chosen so as not to exceed 300uA of earth leakage current, as set out in UL60601-1, the most widely referenced medical standard.

A quasi-resonant, lossless power factor correction circuit operates in a discontinuous mode. Its operating frequency changes between 30kHz and 500kHz to achieve zero current switching (ZCS) throughout the specified range of loads and input voltages. This is important because it ensures that the voltage switches when the current is truly at zero, thereby eliminating switching losses.

The main converters are of fixed frequency, resonant, half-bridge design – again with lossless ZCS. Two transformers are employed; the combination has lower I2R switching loss than if one larger transformer had been utilized. The two converters operate at 51.2 kHz and one of them has its output phase-shifted by 90-degrees. Combining the outputs reduces ripple and doubles the ripple frequency, as illustrated in Figure 3. In turn, this halves the value, and size, of the output filter capacitors.

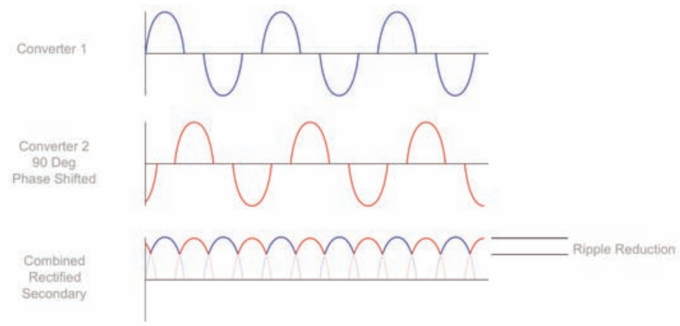

Figure 3: Combining the outputs of two converters that are 90-degrees out of phase reduces ripple level and doubles ripple frequency

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 380Vdc to 420Vdc. This enables the design of the main converters to be optimized around tightly defined voltage parameters, another factor that helps to achieve high efficiency. 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.

This power supply architecture results in high efficiency across a wide range of loads and input voltages, as Figure 4 demonstrates.

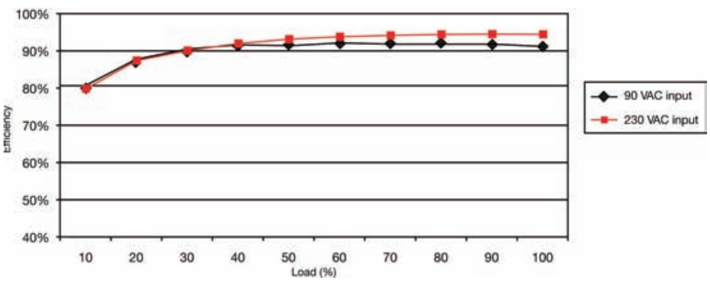

Figure 4: ZCS switching and the use of resonant converters delivers high efficiency over a wide range of loads and input voltages, not just at full load

A further benefit of ZCS is the relatively low levels of both conducted and radiated emissions as well as the output ripple and noise. The power supply referred to above exhibits less than 90mV peak-to-peak ripple and noise at 20MHz bandwidth and is below the level B limit line for EN55011 for conducted and radiated emissions. 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. 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. Further incremental improvements are going to be harder to achieve, but the decades of experience that many engineers now have in power supply design, coupled with advances in semiconductor technology, will make them possible.

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

European HQ

XP Power
Horseshoe Park, Pangbourne, Berkshire, RG8 7JW
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

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

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 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

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
Hungary	+36 1 705 2345	JAMSoft
India	+91 80 4095 9330/31/32	Digiprotech
Israel	+972 9 7498777	Appletec
Israel	+972 (0)73 7001212	Cidev
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
Romania	+4 0348 730 920	Multichron T.L.
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

Global Catalog Distributors

Americas	Newark	newark.com
Europe	Farnell	farnell.com
Asia	element14	element14.com

THE XPERTS IN POWER

09-Feb-11