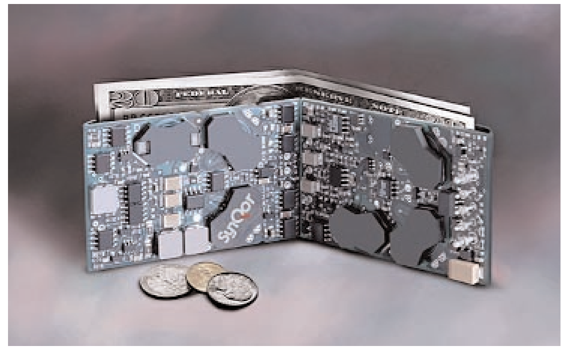
High Efficiency Pays
(and it's Green)

A Technical White Paper by SynQor



When you add up the true cost savings associated with using SynQor's high-efficiency dc/dc converters, they practically pay for themselves.

Introduction

Over the last two years we have seen a new generation of DC/DC converters that use synchronous rectifiers to achieve a very high level of efficiency compared to conventional converters that use Schottky diodes. These new converters sell for approximately the same price as the old ones, even though they are more efficient, smaller, lighter, more powerful, and more reliable. However, by examining all of the system and operating savings that result from the higher efficiency, it is easy to see that the new DC/DC converters are much less expensive. This white paper will discuss these cost savings and provide detailed examples of their dollar amounts. In addition, the SynQor web site (www.synqor.com) provides a downloadable spreadsheet that will allow you to change the various inputs of the savings calculation to match your specific situation.

Efficiency and Dissipated Heat

A converter's rated efficiency measures how much of its input power is converted into useable output power. An ideal converter that is 100% efficient would transfer all of its input power into useable output power delivered to its load. Unfortunately, all converters waste some of their input power due to switching and conduction losses. This power is dissipated as heat throughout the converter and is directly proportional to its measured efficiency (see Figures 1 & 2). Let us now examine some actual numbers that relate the increased efficiency of the new generation of dc/dc converters to a corresponding decrease in input power and heat dissipation.

In our example we will consider a 3.3Vout, 30A half-brick. A conventional, Schottky diode based converter is 80% efficient whereas the best of the new converters, such as the SynQor PQ48033HMA30 is 90% efficient. If we assume these converters are delivering roughly 80W (24.2A) to their loads, which is about 80% of their full rated power, then the conventional converter will draw 100W from its input while the SynQor converter will draw only 89W. The savings in power is 11W under this condition.

Let's compare the required input power and the heat produced by these two converters, relative to the power delivered to the load. The old converter draws an input power equal to 1.25 times the load power, and dissipates an amount of heat (20W) equal to 0.25 times the load power. In comparison, the SynQor converter draws an input power of only 1.11 times the load power, and dissipates heat (8.9W) equal to only 0.11 times the load power.

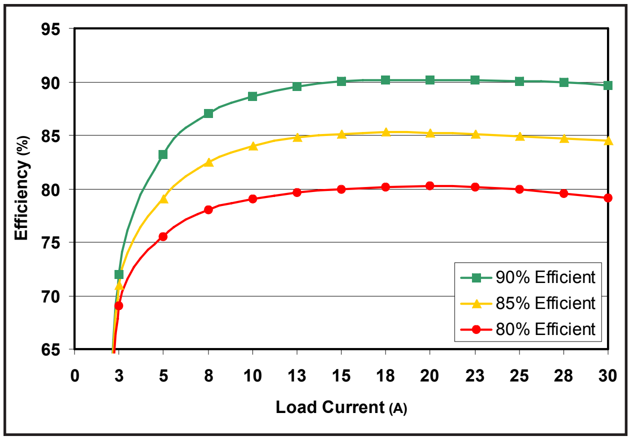


Figure 1: *Efficiency curves of three sparate dc/dc converters. Each converter is an isolated, 48Vin, 3.3Vout, 30A half-brick module.*

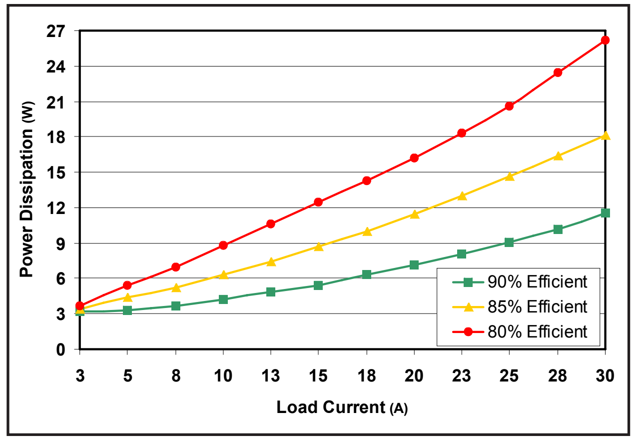


Figure 2: *Power dissipation curves of the same three dc/dc converters, showing how dissipated power is directly proportional to efficiency.*

This is not the only power savings realized from the more efficient SynQor converter. In addition, the lower input power drawn by the SynQor converter means that the upstream power supply equipment does not have to work as hard and will also dissipate less power as a result. For instance, let's assume that the front-end AC/DC power supply that creates the 48V distribution bus is 90% efficient. The power it draws from its AC input therefore equals 1.1 times its own output power. In our example, this equates to 1.39 times the load power of the 80% efficient DC/DC converter, but only 1.23 times for the 90% efficient DC/DC converter. Therefore, the total amount of heat produced by both the DC/DC converter and the front-end power supply is 0.39 times the load power in the first case, and only 0.23 times the load power in the second case. For our example of the 3.3Vout, 30A converters delivering 80W of power, the total power and heat dissipation savings is 12.3W for the high-efficiency converter.

The Direct Savings that Can Result from Higher Efficiency DC/DC Converters

The lower input power requirements and lower power dissipation of the high efficiency converters lead to direct cost savings compared to using the conventional lower-efficiency converters. The following list contains many of these savings and perhaps you can list others that apply to your specific situation.

1. No need for attached heatsinks
2. Less use of electricity by the end user
3. Lower power rating of the front-end power supply
4. Lower energy and power rating of the battery backup system
5. Less fans required to cool the equipment
6. Less air conditioning required to cool the room
7. Less real estate required to deliver a given amount of digital function

Let's explore each of these savings in more detail below. A summary of the cost savings for each item outlined above is presented at the end of this paper.

No Heatsinks

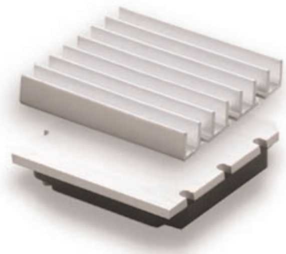


Figure 3: *Conventional dc/dc converter with heatsink*

Figure 4: *SynQor converter with no heatsink or baseplate*

Users of the old, less efficient converters would normally attach a half-inch high heatsink to their converter. A thermal pad or grease would first be applied between the heatsink and the converter's baseplate to aid in the thermal connection between the two. The heatsink would then be screwed into place using the threaded holes available in the four corners of the converter. The typical cost of the materials and labor for doing this task are outlined in Table 1 shown below.

Material[1] & Labor[2]	Cost
Heatsink (2.3" x 2.4" x 0.5")	$4.50
Mounting Hardware	$0.75
Thermal pad or grease	$0.95
Labor	$1.00
TOTAL	**$7.20**

Table 1: *Summary of costs associated with attached heatsinks.*

1. material costs based on 1,000 piece pricing
2. labor based on fully loaded labor rate of $25/hour.

SynQor's converters do not need a heatsink since they dissipate much less heat for the same output power. All the costs shown above in Table 1 can therefore be avoided.

Less Electricity

Continuing our example of the 3.3Vout, 30A converters, the SynQor module required only 89W of input power to deliver 80W to its load, as compared to the 100W of input power for the conventional converter. When we take into account the inefficiency of the front-end converter the total power drawn from the electric utility is 99W when the SynQor converter is used, as compared to 111W when the old converter is used. The total savings in power drawn from the utility is therefore 12.3W in our example.

If we assume that the DC/DC converter operates about 90% of the time over a 5 year end-product life span, then a total of about 485 kWhrs of electricity are saved due to the 12.3W reduction in the AC power requirement.

If we assume that the cost of electricity is $0.12/kWhr, the cost savings afforded to the end customer over the 5 years is about $58, or $11.60 per year. By using a discount rate of 10% per year, the net present value of this savings stream is about $44.

Smaller Front-End Power Supply

In a distributed power supply architechture a front-end AC/DC power supply transforms the ac voltage from the wall outlet into a dc distribution bus (typically 48V) that supplies power to the point of load dc/dc converters. This front-end power supply may be contained within the end product equipment or it may be a separate component that provides power to several cabinets. Either way, this AC/DC converter, with its EMI filter and associated protection features, typically costs about $0.10 per watt of output power. The 11.1W reduction in the power drawn by the new, 90% efficient 3.3Vout converter, as compared to the old, 80% efficient converter, therefore translates into a $1.11 savings on the cost of the front-end power supply.

Figure 5: *Typical AC/DC front-end power supply.*

Smaller Battery Backup

In many systems a backup power system is required to guarantee operation during utility outages. In its simplest form, this backup system takes the form of a battery (with its associated charging circuit) attached to the 48V DC bus. In a more complicated form, the backup system may be required to create an AC output from its DC battery source, while diesel engine driven generators may be included to handle longer outages. Costs can vary substantially depending on the details of the backup system, however, we will assume here that the cost of a typical backup system is $0.30 per watt. This translates into a $3.70 savings for the more efficient 3.3Vout converter since the total reduction of power drawn from the utility is 12.3W.

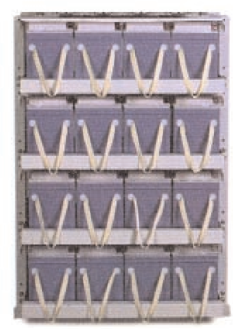


Figure 6: *Typical battery backup power system.*

Less Fans

Most electronic equipment use fans to remove the heat produced by both the digital circuits and the DC/DC converters. The total heat that must be removed is simply equal to the power drawn from the 48V bus by the DC/DC converters (we'll assume that the front-end power supply has its own fan). As we have seen, this amount is substantially lower with the new generation of high efficiency DC/DC converters. For the case of the 3.3Vout converter, the reduction in total heat production is 11.1W, or 11% of the heat produced when the old converter is used. If we assume that the cost of the fans, with

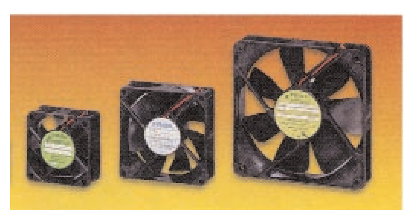


Figure 7: *Typical cooling fans used to remove excess heat.*

their associated drive circuits, is $0.15 per watt, then the cost savings associated with using the more efficient converters is $1.67.

Less Air Conditioning

Once the fans expel the heat produced by the electronic equipment (and the front-end power supply) out into the room, the heat must be removed from the room by an air conditioning system. The air conditioner costs approximately $2.00 per watt of installed heat removal capability, and it requires approximately 0.25 watts of electricity for every watt of heat removal it provides.

Figure 8: *Typical building air conditioning unit.*

For the case of the higher efficiency 3.3Vout converter, the total savings in heat generation, combining the improvements in both the converter and the front-end supply, is 12.3W. This translates into a $24.69 savings on the cost of the installed air conditioner. Assuming that the cost of electricity is $0.12/kWhr, the reduced electricity consumption of the air conditioner saves the end customer about $14.50 over a five year period, or $2.90 per year. If we use a discount rate of 10% per year, the net present value of this savings stream is about $11. The total net present value of the air conditioning savings that result from improved converter efficiency is therefore $35.

Less Real Estate

The cost of real estate is not negligible, particularly in an urban environment. Let's assume that the space that houses the electronic equipment costs $30 per square foot per year. A typical cabinet that consumes 1000W of power, and its required surrounding space, might take up 10 square feet, and therefore cost $300 per year in rent.

Let us further assume that the amount of digital function that can be put into a given piece of equipment is limited by the power that can be delivered to, and removed from, the cabinet. This is a reasonable assumption since the absence of a heatsink on the more efficient converters allows individual printed circuit boards to be placed much closer together. For the same amount of input power, a 90% efficient converter can deliver 11% more output power than an 80% efficient converter. Therefore, we can fairly assume that a system designer could put 11% more digital function into a given piece of equipment.

Figure 9: *Typical telecom cabinet housing electronics equipment.*

Continuing our example, if our 10 $ft.^2$ piece of equipment consumes 1000W of input power, then it can have 10 logic boards powered by the less efficient 3.3Vout converters or 11 logic boards powered by the more efficient 3.3Vout converters. The cost of the real estate needed to house this equipment drops from $30.00 per year per logic board to only $27.30 per year per logic board. The savings of $2.70 per year, over 5 years, is $13.50. The net present value of this savings stream, using a 10% discount factor, is $10.50.

Summary of the Direct Savings

Table 2 below lists all of the system and operating cost savings that we have discussed above. The total savings, in net present value, for the end user of the equipment is about $104 for each SynQor converter they use to replace an old, 80% efficient converter. In this example, the savings can actually be greater than the cost of the converter.

Cost Item	Savings	Net Present Value
Heatsink	$7.20	$7.20
Electricity	$58.16	$44.09
Front-end Power Supply	$1.11	$1.11
Battery Backup	$3.70	$3.70
Cooling Fans	$1.67	$1.67
Air Conditioning	$39.23	$35.71
Real Estate	$13.50	$10.50
TOTAL Savings	**$124.57**	**$103.98**

Table 2: *Summary of total system and operating cost savings that result from using SynQor's 90% efficient 3.3Vout ,30A dc/dc converter versus the conventional 80% efficient converter. Both units run at 80W load over a 5 year system lifetime.*

The following tables show the results of a similar analysis done for dc/dc converters having different output voltages. Table 3 compares typical efficiencies for the Schottky diode based converters versus the new, high efficiency SynQor converters. The table also lists the power savings that result from using the higher efficiency converter. Table 4 uses this information to show the various cost savings that result from using the high efficiency converters. This summary shows that in terms of dollars per converter, the savings increase as the output voltage decreases.

As mentioned earlier, the SynQor web site has a spreadsheet calculator that will let you adjust the cost and performance parameters used in this analysis to more closely match a situation you may wish to examine.

Output Voltage	Full Load Output Current (80% load in parenthesis)	Efficiency of Conventional Schottky Diode Converter	Efficiency of SynQor's 30A Synchronous Rectifier Converter	Reduction in Dissipated Power Offered by SynQor's Converter
15V	10A (8)	88%	91%	4.5 W
12V	12.5A (10)	86%	91%	7.7 W
5V	30A (24)	83%	90%	11.2 W
3.3V	30A (24)	80%	90%	11.0 W
2.5V	30A (24)	74%	88%	12.9 W
2.0V	30A (24)	68%	87%	15.4 W
1.8V	30A (24)	65%	86%	16.2 W
1.5V	30A (24)	62%	85%	15.7 W

Table 3: *Full load efficiency comparison for conventional converters versus SynQor's high-efficiency converters. The resulting reduction in power dissipation at 80% load is shown in the last column.*

Cost Item	3.3 V	2.5 V	1.5 V
Heatsink	$7.20	$7.20	$7.20
Electricity	$44.09	$51.19	$62.35
Front-end Power Supply	$1.11	$1.29	$1.57
Battery Backup	$3.70	$4.30	$5.24
Cooling Fans	$1.67	$1.93	$2.36
Air Conditioning	$35.71	$41.46	$50.50
Real Estate	$10.50	$16.45	$27.97
TOTAL Savings	**$103.98**	**$123.82**	**$157.19**

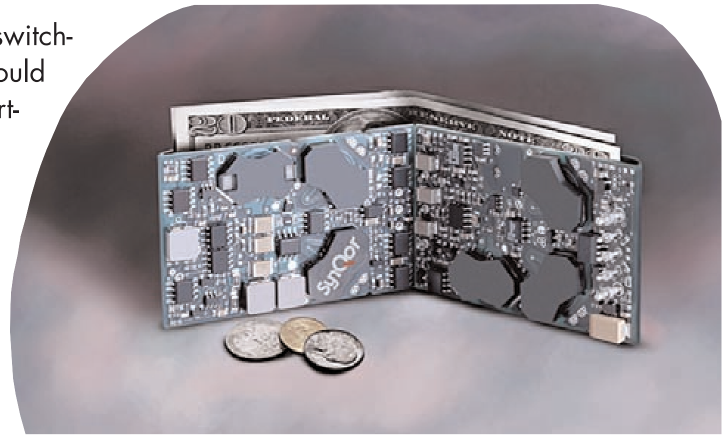
Table 4: *Summary of total net present value of cost savings based on using high efficiency converters with various output voltages.*

The Intangible Value of Higher Efficiency

In these days when the total power consumed by digital equipment is growing quickly, the total capacity of the electric utility is growing slowly, and everyone is concerned about preserving the environment, a more efficient piece of digital equipment has a value greater than the direct cost savings outlined above. Acheiving higher efficiency shows a commitment from the OEM to responsible product design and an understanding of the issues faced by the end-users. Such a demonstration will help win and keep customers in a way that cannot be easily quantified here, but which nevertheless can be far more valuable than the cost savings calculated above. This is particularly true as the world watches California deal with its energy crisis.

Conclusion

With all the cost savings outlined above, switching to high efficiency DC/DC converters would seem to make sense even if the new converters were more expensive than the old converters. Interestingly, the new converters are not more expensive, and so all of the benefits mentioned above, along with other benefits such as lower height, lower weight, more usable power, and higher reliability come without a premium price. There's no reason not to take advantage of the many benefits and cost reductions that this new technology provides.



Using a SynQor high efficiency dc/dc converter is like putting money in your wallet. The direct savings can more than pay for the price of the converter, in addition to helping the environment.

SynQor

Advancing The Power Curve

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