TECHNICAL ARTICLE

UNDERSTANDING EFFICIENCY: LOOKING FOR THE WORST-CASE SCENARIO

It's standard practice to put the best-case scenario on data sheets, but how does that differ from the efficiency that can actually be achieved in your application? XP's Peter Blyth explains.

Efficiency is one of the key parameters to consider when selecting the correct switch mode power supply. Pressure on equipment designer to deliver more functionality in a small size can result in more power being required which has a direct effect on the form factor of the power supply. The consequence of this is power supplies now have to deliver more output power in a smaller form factor.   This coupled with the need to meet more demanding environmental legislation and to minimise or eliminate fan cooling, is forcing equipment designers to look for more efficient power supplies.

An efficient power supply means less power is wasted as heat, which is the biggest factor in reliability of electronic components. Efficiency therefore has a big effect on the reliability and lifetime of the end equipment. Selecting an efficient power supply may also mean the equipment can be designed for operation without a cooling fan, reducing the audible noise, which is very desirable in many applications.

When deciding on a particular power supply for a piece of equipment, the minimum efficiency required for the equipment to run without a cooling fan, or with a certain lifetime guaranteed, may be calculated. The designer then turns to power supply data sheets to decide whether a particular supply meets their minimum efficiency criteria.

Equipment designers should be aware that the efficiency figure quoted on the manufacturer's website or data sheets is most likely a best-case scenario. The headline efficiency found on marketing material is true only when the power supply is run under favourable, or indeed, optimum, conditions. The actual conditions the power supply will be used in could be very different.

For example, it's common for the same model of industrial and medical equipment to be sold worldwide. Even if a power supply states it has a 'Universal Input', that doesn't guarantee its efficiency matches the headline efficiency for all inputs. The efficiency at the highest input voltage, European mains at 230VAC, will be different to the efficiency the power supply can achieve at the lowest input voltage, Japanese mains at around 100VAC or 115VAC in North America.

The power supply's efficiency, when it's working under the most challenging set of operating conditions, may be thought of as the worst-case efficiency. This worst-case efficiency can be calculated by digging deep into the product's specification, which is essential to ensure the correct product is selected. A product may be selected on headline efficiency alone, perhaps at an attractive cost level, only to find that at the worst-case operating conditions, a cooling fan is needed or a higher power output supply must be used deliver the performance required. Incorrect selection will result in increased cost, which is why it's vital to work with worst-case efficiencies from day one.

Factors affecting efficiency

Efficiency is calculated as the output power divided by the input power, and is usually expressed as a percentage. The difference between the input power and output power is the power wasted in the power supply as heat. The input power is the product of the input voltage, current and power factor. If the input voltage (ie. mains voltage) is lower, to supply the same output power the current will have to increase, resulting in greater losses in the power components. The losses in the inductors and transformers are I2R, where R is the resistance of the component. For the same efficiency, halving the input voltage results in twice the input current. In reality the input current is more than double due to the reduction in efficiency caused by increased power losses, resulting in more than quadrupling the power loss of some of the components within the power supply and more than doubling the losses in others.

The same phenomenon exists for the output power, calculated as the product of the output current and output voltage. The optimum output voltage is the highest the PSU can supply; at lower output voltages, currents increase, and some losses increase proportional to the square of the current.

As an example, a comparison between the efficiency of the XP CCB200 at 264 and 90V, and that of a comparable AC-DC power supply from another manufacturer is shown in figure 1. The different curves show the efficiency at the lowest possible input voltage (Japanese mains minus 10%), and the highest (UK mains plus 10%). With the two different input voltages, the efficiency of the XP CCB200 varies 1-2%, whereas the other power supply's efficiency drops almost 5 percentage points at full load when switching to the lowest input voltages. Putting this in terms of wasted power, the XP product would dissipate 2W to 4W more power at the lower input voltage, whereas the power supply from the other manufacturer would dissipate nearly 10W more power. This device's headline efficiency is 92%, but by switching to Japanese/North American voltages, the maximum efficiency it can achieve is 88.5%, and then only under specific load conditions.

Actual operating load is another parameter to consider and this will be based on the demand from the end equipment. The significant drop in power supply efficiency as the load drops is shown in figure 1. The reason for this is that certain circuits in the power supply (i.e control circuits) require power to drive them under any conditions and the power required does not change proportional to the change in output power. If these are considered as fixed losses then as the output power drops the percentage of these fixed loses relative to the output power becomes higher and ultimately reduces the overall efficiency.
Performance under variable loads is a key factor in determining whether a power supply meets worldwide efficiency legislation, such energy efficiency level V, CEC etc. There may be limits on the average active efficiency; for example, one of the criteria for the 80-Plus standard for server PSUs is that the power supply is more than 80% efficient at 20%, 50% and 100% of its rated load. So, a clear understanding of how a power supply performs under different load conditions is essential.

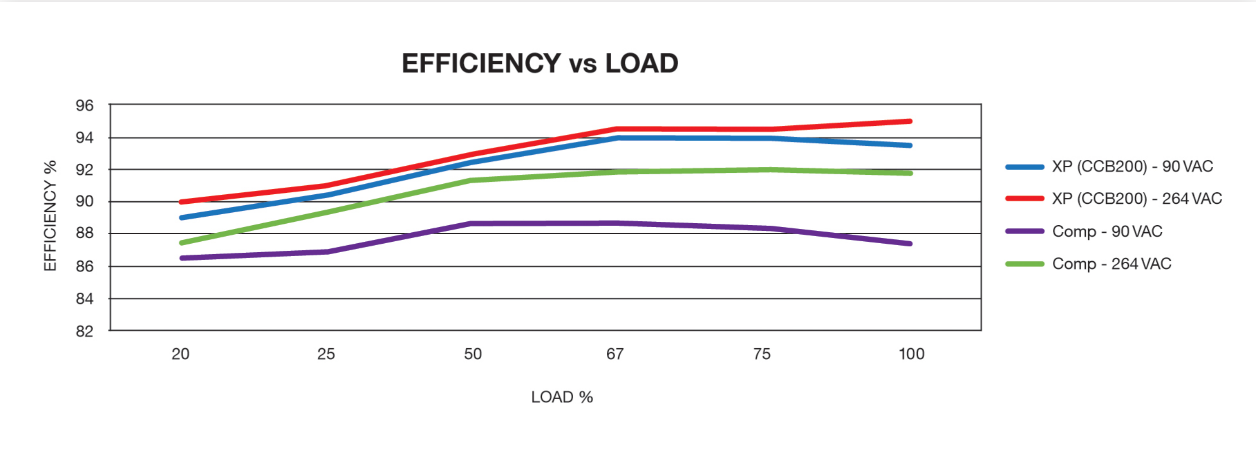

Figure 1 – Power supply efficiency over variable load conditions, with different supply voltages. Curves for the XP CCB200 and a comparable supply from another manufacturer are shown.

Another factor that influences how efficient a power supply can be is its topology (Table 1). The most efficient topologies, are resonant type topologies, which are techniques to minimise switching loses by controlling the switching times of the voltage and current, thus ensuring that they cross at the zero point. Basic designs like flyback converters may be cheaper, but the efficiency may degrade substantially. More expensive products may also employ other techniques to reduce losses, such as synchronous rectification and oversizing their input chokes, for example, to decrease their resistance and therefore decrease any heat wasted.

Topology	Power	Efficiency	Cost
Resonant/LLC	>150W	90% - 95%	$$$
Forward	>250W	85% -90%	$$
Flyback	<150W	87% - 91%	$

Table 1. A power supply's topology will affect the maximum efficiency it can achieve.

Summary

When specifying a power supply, it's vital to understand whether the PSU will perform as required in a reliable and safe manner. Equipment designers should look closely at the data provided, and carry out tests if necessary, in order to calculate what the efficiency would be in a worst-case scenario to determine whether a power supply meets the efficiency criteria or not. This needs to be understood in detail to ensure the correct product is selected.