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White Paper: Medical Power Adapters Design Techniques to Meet the New DoE Level VI Efficiency Standards

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Summary

With less than a year left before the US Department of Energy's Level VI energy efficiency regulation becomes mandatory, system-level engineers and specifiers are now focused on testing and qualifying external power supplies from different vendors that meet the upcoming efficiency and no-load input power requirements. With GlobTek's newly released Level VI compliant product line, these tasks can be simplified and expedited allowing manufacturers shorter time to market. GlobTek will continue to invest in research and development to push the boundaries of power supply efficiency and no-load input power consumption to meet and exceed current and future energy efficiency standards.

As a recognized leader in power systems solutions, GlobTek, Inc recently released a new line of energy-efficient power supplies that will enable system designers and manufacturers to be in compliance with the global energy efficiency regulations, including the upcoming US Department of Energy's (DoE) Energy Conservation Standards for External Power Supplies (EPS), also commonly known as Level VI efficiency standard. Drawing from decades of experience in the design and manufacturing of switch mode power supplies across broad range of applications from Information Technology Equipment, Healthcare, Audio, to Industrial and Consumer Goods, GlobTek understands the intricacies and nuances of both the mandatory and voluntary energy efficiency requirements within the very dynamic global regulatory environment and offer a comprehensive product line of highly efficient and very low no-load input power consumption switchmode power supplies ranging in power levels from 5 watts up to 250 watts.

On February 10, 2014 the US Department of Energy released its final ruling for the new Energy Conservation Standards for External Power Supplies (EPS). This new regulation is a revision to its EISA 2007 EPS efficiency standards.

Mandatory compliance will begin on February 10, 2016 for all covered external power supplies that are manufactured in or imported into the United States. The new standard tightened the prescribed minimum average efficiency of external power supplies during active mode and the maximum input power consumption allowed during no-load mode. It will affect a wide variety of external power supplies used in a wide variety of consumer applications. Compliance with the new regulation is designated by marking roman numeral VI on the product nameplate, packaging or accompanying documentation.

Compared to the current Level V regulation, the new DOE Level VI standard not only has more stringent limits for both power supply average efficiency and no-load input power consumption, it also expanded the range of products it covers to include multiple output voltage power supplies and supplies with power level above 250 watts.

GT-43088

The new regulation also added a classification to the power supplies as direct or indirect operation. Direct operation EPSs are those that can operate the end application devices without the assistance of a battery while indirect operation

EPSs are those that cannot operate the end system without the assistance of a battery. The new Level VI regulation will only cover direct operation external power supplies. Indirect operation power supplies will only have to continue to comply with the current EISA 2007 efficiency limits.

Not all external power supplies are covered by the standard. Devices that require Federal Food and Drug Administration (FDA) listing and approval as a medical device and any AC-DC external power supplies with output voltage less than 3 volts and with output current greater than or equal to 1,000 milliamps that are used to charge the battery of a product that is fully or primarily motor operated are not covered. Also, certain external power supplies used for certain life safety and security equipment do not need to meet the no-load mode requirement.

External power supplies used in medical devices are not covered by the current EISA 2007 standard and it will continue to be excluded in the new Level VI regulation. The original DOE proposal for Level VI standard included EPSs for medical devices because of the significant energy savings and it was also deemed technologically feasible and economically justified to implement. However, based on the comments and suggestions from stakeholders namely, the power supply and medical device manufacturers, DOE reevaluated its proposal to include EPSs for medical devices and decided to keep the current status quo.

This table shows the new average efficiency and

no-load input power

requirements taken directly

from the DoE's 10 CFR

Part 430 standard document.

Single-Voltage External AC-DC Power Supply, Basic Voltage		
Nameplate Output Power (Pout)	**Minimum Average Efficiency in Active Mode (expressed as a decimal)**	**Max. Power in No Load Mode (W)**
Pout ≤ 1W	≥ 0.5 x Pout + 0.16	≤ 0.100
1W < Pout ≤ 49W	≥ 0.071 x ln(Pout)-0.0014 x Pout + 0.67	≤ 0.100
49W < Pout ≤ 250W	≥ 0.880	≤ 0.210
Pout > 250W	≥ 0.875	≤ 0.500
Single-Voltage External AC-DC Power Supply, Low Voltage		
Pout ≤ 1W	≥ 0.517 x Pout + 0.087	≤ 0.100
1W < Pout ≤ 49W	≥ 0.0834 x ln(Pout)-0.0014 x Pout + 0.609	≤ 0.100
49W < Pout ≤ 250W	≥ 0.870	≤ 0.210
Pout > 250W	≥ 0.875	≤ 0.500
Single-Voltage External AC-AC Power Supply, Basic Voltage		
Pout ≤ 1W	≥ 0.5 x Pout + 0.16	≤ 0.210
1W < Pout ≤ 49W	≥ 0.071 x ln(Pout)-0.0014 x Pout + 0.67	≤ 0.210
49W < Pout ≤ 250W	≥ 0.880	≤ 0.210
Pout > 250W	≥ 0.875	≤ 0.210
Single-Voltage External AC-AC Power Supply, Low Voltage		
Pout ≤ 1W	≥ 0.517 x Pout + 0.087	≤ 0.210

1W < Pout ≤ 49W	≥ 0.0834 x ln(Pout)-0.0014 x Pout + 0.609	≤ 0.210
49W < Pout ≤ 250W	≥ 0.870	≤ 0.210
Pout > 250W	≥ 0.875	≤ 0.500
Multiple-Voltage External Power Supply		
Pout ≤ 1W	≥ 0.497 x Pout + 0.067	≤ 0.300
1W < Pout ≤ 49W	≥ 0.075 x ln(Pout) + 0.561	≤ 0.300
Pout > 49W	≥ 0.860	≤ 0.300
Table I. Energy Conservation Standards for Direct Operation EPSs (Copied from US DoE, 10 CFR Part 430 document)		

Emerging Design Techniques to Meet the New Level VI Requirements

The challenges design engineers face in meeting the new and tougher Level VI efficiency and no-load input power consumption requirements is that traditionally, switch mode power supplies tend to be very efficient only when operating at or near its maximum power rating. The efficiency curve is not flat across the entire load range. Older designed power supplies are far less efficient when running below their rated maximum load. This is partly because of the fix losses in the power supply circuitry that becomes dominant as the output load decreases.

With the very stringent average efficiency and no-load input power consumption requirements, incremental design changes or minor adjustments to an existing design such as using better quality components or using a shorter length and bigger gauge output cable to minimize losses due to the wire voltage drop are no longer sufficient to meet the new requirements. Addressing the new Level VI regulation require significant changes in the design at every level, starting from the selection of power train topology, the operating control techniques to implement, secondary side rectification technique, to the selection of the controller ICs and other critical power components. Also, optimization of the auxiliary circuits that traditionally get minimal design attention when it comes to improving efficiency and no-load power consumption like for example the snubber circuits, controller ICs and feedback circuit operating and standby power consumptions, resistive preload, safety capacitor discharge resistors and start-up circuits are now being looked at closely and optimized for minimum losses.

One of the emerging technique implemented in the industry today to meet and exceed tougher energy efficiency requirements is to effectively combine the best power train topology that inherently offers higher efficiency for a given power level, careful component selection and changes in component materials, best design methodology and multi-mode control strategy.

Very high efficiency and very low no-load input power consumption can be achieved if the power supply control strategy has multiple operating modes that can seamlessly transition back and forth between modes depending on the amount of load drawn by the end system. Each operating mode is optimized for maximum efficiency and low no-load input power consumption for a given load range. This way, the overall efficiency profile of the power supply becomes relatively flat across much of the load range.

GT-43083

For example, for low power applications up to 75W, a flyback topology that operates in quasi-resonant (QR) mode at higher loads and automatically transition into frequency foldback mode (FFM) at a mid power range and then finally operate in burst mode from very light load to no load conditions will significantly improve the average efficiency in a wider load range and the no-load input power consumption. In QR mode, significant improvement in efficiency is achieved due to minimum switching loss. The main transistor switch in the flyback circuit is turned off while the voltage across it is at its lowest level (valley switching) therefore minimizing the losses caused by the parasitic capacitance of the switch. In FFM mode, the reduction in switching frequency will help reduce losses that are proportional to switching frequency like for example the main Mosfet switch and secondary diode turn on and turn off losses and the magnetic core loss of the transformer. Burst or pulse skipping mode will help reduce the no-load input power by turning on the power supply only when it is necessary to replenish the output capacitor voltage to keep it within specification. For much of the time, the power supply is either in off mode or in very low power standby mode.

GT-43086

Operating the power supply in burst mode at no load will significantly lower the no-load input power consumption, but with the very stringent no-load input power consumption limit, operating in burst mode alone may not be sufficient to pass the requirement. Other sources of inefficiencies in the power supply must be looked at and improved. One area is the operating power consumptions of the controller ICs, both the primary side controller and the secondary side synchronous rectifier controller (if used). The quiescent current of these controllers must be very low. New generation controller ICs provide this feature by turning off some parts of its internal circuitry that are not required during no load operation to minimize power consumption. Other areas in the design that can be improved are the power factor correction stage (if used), the bootstrap or start-up circuitry and the discharge resistors for the input safety capacitor. All these circuits can be turned off particularly during no-load condition to minimize the no-load input power consumption. The bias current of the feedback circuitry including the bias current of the optocoupler used to maintain output voltage regulation can also be reduced to further lower the no-load input power consumption of the power supply. Output discharge resistors acting as preload and an LED used as a power-on indicator are not used anymore to conserve power at no-load condition.

GTM43084

Another area in the power supply design that can be optimized for higher efficiency is the type of rectification implemented on the secondary side. Traditionally, a diode is used to rectify the output voltage of the transformer before it is filtered for a smooth DC voltage. The disadvantage of using a diode for rectification is its high conduction loss due to its forward voltage drop. Substituting the diode with a very low on-resistance Mosfet that operate as a synchronous rectifier will result in a much lower losses and thus improve the overall efficiency of the power supply.

Based on the number of power supply units already deployed worldwide, the benefits of an efficient power supply cannot be denied. The annual energy savings to the consumers and utility providers plus the significant environmental benefits are very compelling reasons that more and more countries started to either adopt the current standard or come up with similar regulations. Although power supplies used in medical devices are not included in the Level VI regulation as mentioned above, a growing number of medical devices and systems design engineers prefer to use power supplies that are compact, reliable, very efficient and has very low no-load input power consumption that can still meet and exceed the stringent safety requirements in designing switch mode power supplies for medical devices such as those listed in IEC 60601-1 which is the primary standard governing the medical electrical equipment device design.

Ahead of the mandatory Level VI efficiency standards' effective date, GlobTek Inc. has already introduced a comprehensive line of compliant power supplies ranging in power level from 5 watts to 250 watts in various form factors.

The design and development strategies employed in all GlobTek's Level VI compliant supplies are based on years of power electronics design and manufacturing experience, are comprehensive, methodical and similar to those power supplies designed for medical applications where the requirements when it comes to safety and reliability are much more stringent than those supplies designed for general use. All products during its design phase were proven by circuit analysis and simulation, external expert consultations, bench testing, multiple stage design verification and validation, third party testing and certification, component derating and qualification.

For 5W and 10W power levels, models GT-83083, GT-83084, and GTM43085 are now available. All three models comes with built-in USB output connector. GT-83083 and GT-83084 are both wall plug-in type with fixed AC input blades. GT-83083 is a 5W series and is available with North American, Australian, China, European and UK AC input blade style while GT-83084 is a 10W series and is available with North American, European and China AC input blade style. The output voltage for both models is 5V, suitable for powering USB type applications.

GTM43085

GTM43085 is a 10W wall plug-in type adapter that comes with a changeable AC input blades. A kit with various AC plug configurations for different countries or region is also available for this model, making it a truly universal power supply. Although medical power supplies are exempted from Level VI compliance, this model, apart from its ITE certification is also approved and certified for medical applications under IEC/EN 60601-1 which is the primary standard governing the medical device design. The output voltage range of this model is from 5V to 6V and load current up to 2A.

GT-43086 is a 6W wall plug-in adapter with a changeable AC input blade. The output is delivered through an output cable with various options in length, diameter, and connector type. The output voltage for this model can be factory set anywhere from 5V to 24V for a maximum of 6W of power. Another series is the GT-43088 which is a more powerful 18W wall plug-in type adapter with changeable AC input blade. The output is also delivered through an output cable with a lot of options including the connector type. The output voltage for this model can be factory set anywhere from 5V to 24V for a maximum of 18W of power.

GT-43090

For medium power range, a desktop model with three AC input connector type options is now available. The GT-43090 is a 20W AC/DC power supply available in three AC input configurations, namely, IEC 60320 C14 and C6 for 3-pin input and C8 for two pin input version. The output voltage range is from 5V to 6V and load current up to 4A.

For high power range, two desktop models are available. The 180W GTM3057 and 250W GTMF3058 series of AC/DC power supply with built-in power factor correction circuit. Output voltage can be factory set anywhere from 12V to 56V and load current capability of up to 18A, depending on the output voltage and total power. Options in the output cable style, length, connector type is also available. Both of these models will soon be approved and certified for ITE under IEC/EN/UL 60950-1 and medical applications under IEC/EN 60601-1.

All models listed above have full features including tightly regulated output voltage, built-in overcurrent, short circuit, overvoltage and over temperature protections. It also has very low earth leakage current which is required for those series with medical approvals, low common mode noise that is a sought-after feature for end applications that has touch screen, and also has low output voltage ripple. All Level VI supplies have multiple agency approvals including IEC/EN/UL 60950-1 for ITE applications. Some of the Level VI series also have agency approvals for medical applications under IEC/EN 60601-1. For a complete list of features, technical specifications, ITE (IEC/EN/UL 60950-1) and Medical (IEC/EN 60601-1) approval reports and certificates, connector options, available configurations and more, click the link below.

en.globtek.com/power-supply-selector/?Efficiency__c=VI

Although most global energy efficiency regulations to date exclude external power supplies used in medical applications, GlobTek's Level VI product line are designed with the same level of quality and attention to details as those power supplies designed and used for medical applications. Some of GlobTek's Level VI power supply lineup also carry medical approvals.

References:

1. US Department of Energy, 10 CFR Part 430, Energy Conservation Program, Energy Conservation Standards for External Power Supplies, Final Rule, April, 11, 2014
2. Various online resources related to power supply energy efficiency topics

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