ISSUE: August 2015

External Power Supplies And the New Level VI Specifications: Evolution Or A Different Species?

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A new generation of external power adapters is entering the market and they are significantly different from their immediate predecessors. The driver behind these changes is the new Level VI specification of the International Energy Efficiency Marking Protocol[1] for External Power Supplies, which was published in 2014 by the U.S. Department of Energy and is scheduled to come into force in the U.S. in February 2016. At the time of adoption, it will be the toughest efficiency specification in force anywhere in the world.

Currently, the EU requires external supplies to meet the protocol's Level V specifications, while other parts of the world including the U.S.A. accept units meeting Level IV. After February 2016, OEMs marketing products with external power adapters in the U.S. must make sure the unit supplied in the end application is compliant with the new Level VI regulations. Historical patterns suggest that important markets such as the EU and Canada will soon adopt the Level VI specification in their own territories. In reality, many OEMs will pre-emptively make the move to ensure that all adapters shipped to all markets worldwide are compliant with Level VI as soon as the new specification comes into force in the U.S.

This article describes the changes to the energy efficiency protocol and explains how one adapter manufacturer has updated the power supply control strategy, secondary rectification circuitry and other aspects of the design to meet the new and tougher standby power and average efficiency targets.

Level VI: More Than Just A Tougher Specification

In accordance with the international marking protocol, external power supplies display a Roman numeral—currently typically IV or V—printed on the label to indicate efficiency, as shown in Fig. 1. Level VI power supplies are beginning to enter the market as manufacturers prepare for adoption of the new, more demanding specification. CUI began introducing Level VI compliant adapters ranging to 5 W to 150 W in late 2014.

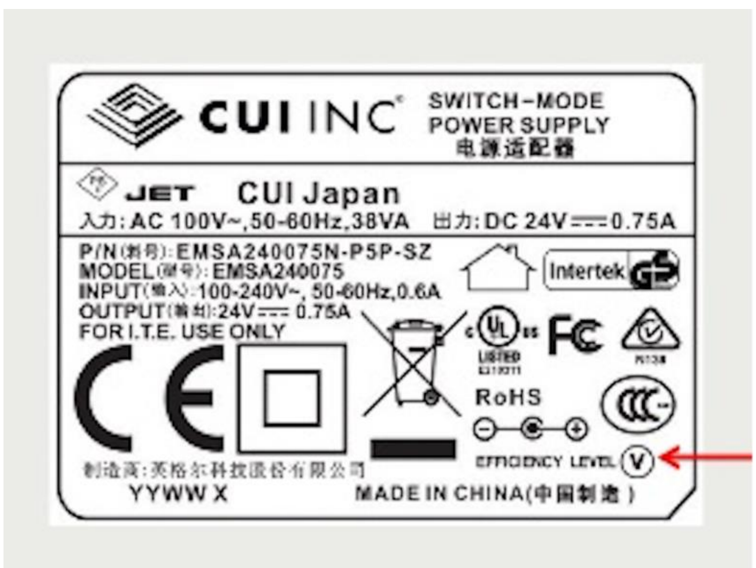

Fig. 1. Level V efficiency marking on power supply label.

[1] The international efficiency marking protocol was first put forward by ENERGY STAR to harmonize power supply eco-design initiatives around the globe.

The efficiency marking protocol aims to minimize the environmental impact of the many millions of external power supplies in use around the world by improving average efficiency and cutting no-load power consumption to the lowest possible levels.

The new Level VI specification represents more than simply a tightening of existing performance targets. It redefines important power supply categories, and for the first time expands the scope of efficiency regulations to include power supplies of more than 250-W rated output power. Separate specifications now cover ac-dc and ac-ac power supplies, and low-voltage and basic-voltage supplies. Low-voltage power supplies are defined as having output voltage less than 6 V and output current greater than 550 mA, while basic voltage refers to power supplies that are not included in the low-voltage group.

Table 1 shows the average efficiency and no-load power consumption targets for Level IV and Level V power supplies. Table 2 details the Level VI specifications, which not only introduce more stringent efficiency and power limits but also are significantly more complex as summarized above.

Satisfying the new, tougher average-efficiency and no-load power targets, without compromising other important performance metrics such as transient response, power quality, size and cost, has called for changes throughout the power supply's primary and secondary circuitry, control ICs and passive components.

Table 1. Maximum no-load power and minimum average efficiency of Level IV and Level V PSUs.

Marking protocol		PSUs ≤ 1 W	1 to 50 W	50 to 250 W
Level IV	No-load power	≤ 0.5 W		
	Average efficiency	Power x 0.50	[0.09 x ln(power)] + 0.50	≥85%
Level V Standard-voltage ac-dc (output > 6 V)	No-load power	≤0.3 W		≤0.5 W
	Average efficiency	0.48 x power + 0.140	[0.0626 x ln(power)] + 0.0262	≥87%
Level V Low-voltage ac-dc (output < 6 V)	No-load power	≤0.3 W		≤0.5 W
	Average efficiency	1 W: 0.497 x power + 0.067	[0.0750 x Ln(power)] + 0.561	86%

Table 2. The Level VI no-load and dynamic efficiency specifications have become more complex.

Power supply type		≤ 1 W	1 W to 49 W	49 W to 250 W	≥ 250 W
Single-voltage ac-dc	No load max.	0.1 W	0.1 W	0.21 W	0.5 W
	Dynamic efficiency (min.)	0.5 x Pout + 0.16	0.071 x ln(Pout) – 0.0014 x Pout + 0.67	0.880	0.875
Single-voltage ac-ac	No load max.	0.21 W	0.21 W	0.21 W	0.5 W
	Dynamic efficiency (min.)	0.5 x Pout + 0.16	0.071 x ln(Pout) – 0.0014 x Pout + 0.67	0.880	0.875
Low-voltage ac-dc	No load max.	0.1 W	0.1 W	0.21 W	0.5 W
	Dynamic efficiency (min.)	0.517 x Pout + 0.087	0.0834 x ln(Pout) – 0.0014 x Pout + 0.609	0.870	0.875
Low-voltage ac-ac	No load max.	0.21 W	0.21 W	0.21 W	0.5 W
	Dynamic efficiency (min.)	0.517 x Pout + 0.087	0.0834 x ln(Pout) – 0.0014 x Pout + 0.609	0.870	0.875
Multiple-voltage	No load max.	0.3 W	0.3 W	0.3 W	-
	Dynamic efficiency (min.)	0.497 x Pout + 0.067	0.075 x ln(Pout) + 0.561	0.860	-

Inside The New Level VI Power Supplies

The new targets have not demanded a fundamental change in power supply topology. For Level VI power supplies rated in power below 120 W, CUI is using its established flyback design, while adapters over 120 W continue using LLC resonant topology. However, for low-voltage/high-current models, the design of the secondary-side circuitry has been changed from simple diode rectification to synchronous rectification in order to meet the average efficiency and no-load targets. Synchronous rectification, of course, has required the addition of an extra controller in the secondary side to manage the turn-on/turn-off of the sync and control FETs.

As far as the main control IC is concerned, several changes have been required in order to meet the higher Level VI specifications. Key among these is a change in switching frequency to improve efficiency at lower load levels, which helps meet the higher Level VI average efficiency target. This is because the standardized IEC-approved AS/NZS 4665 test method for assessing average efficiency involves measuring the input and output power at 25%, 50%, 75% and 100% of rated load. Data for all four points are reported separately, and the arithmetic average is calculated. Since the 25% measurement gives the worst-case efficiency, improving performance at the lighter loading helps increase the average efficiency.

In CUI's latest Level VI power supplies (see the reference), the control IC uses the same 65-kHz switching frequency in normal operation as used in the Level V-generation products. At light and no load, however, the frequency is reduced to 22 kHz to reduce power loss and improve efficiency. Fig. 2 compares the efficiency of equivalent Level V and Level VI power supplies, measured at 25%, 50%, 75% and 100% of full load (7.5 V, 4 A) in accordance with AS/NZS 4665. The graph shows significant improvements at all levels, and particularly at lower loads. It is true that ripple and noise can be more significant at lower switching frequencies. This has been addressed by re-optimizing the capacitor and resistor values in the secondary feedback circuit.

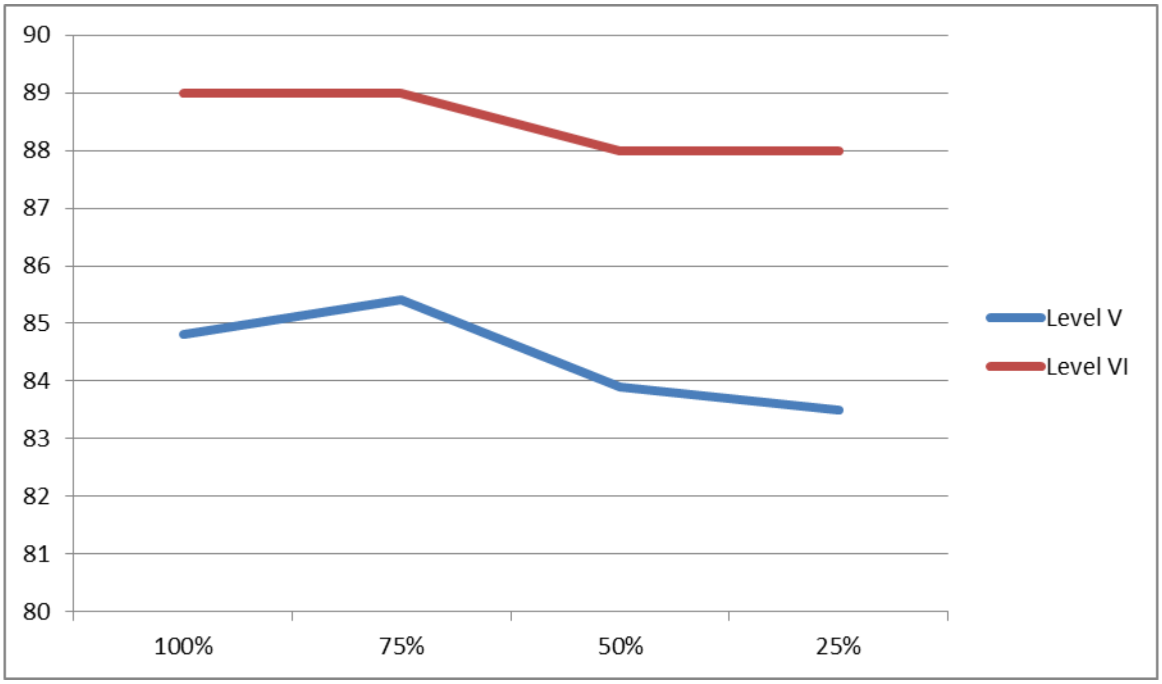

Fig. 2. Reducing switching frequency at light/no load has helped meet the Level VI average efficiency specifications.

In addition the control IC takes advantage of new technologies to reduce quiescent power, which contributes further toward meeting the tougher maximum limits on no-load power consumption.

For power supplies rated at 90 W or over, power-factor correction (PFC) is mandatory. The control IC chosen for these models is able to disable the PFC circuitry at light load. This reduces power consumption, and so helps to increase average measured efficiency and satisfy the maximum standby power limit. One tradeoff in turning off the PFC circuitry is the potential for ripple noise to be slightly higher during light load. For most applications, this has not shown to be a problem.

In addition to the improvements in the IC, additional components have been upgraded to help meet the performance targets. The component upgrades have included increased wire gauges, as well as newer MOSFETs with lower on-state resistance, which have contributed to higher efficiency at heavier loads.

While numerous changes have been implemented throughout the new power supplies, mostly associated with the control IC and switching components, the main power circuitry is arranged in much the same way as in existing Level V units. This has allowed the original case sizes and external appearance to be retained in most instances. It is also worth noting that the increased average efficiency of the Level VI power supplies has enabled a reduction in typical working temperature, which helps to boost reliability compared to equivalent Level V products.

Conclusion

The new Level VI efficiency marking specifications represent a significant upgrade in performance, and have required significant changes within the power supply design. Not all power supply makers will have solutions in place when Level VI becomes mandatory in the U.S. in February 2016. OEMs, however, need to start adapting their supply chains now, to be ready in time for the new regulations. Level VI power supplies already in the market enable forward-thinking OEMs to begin tackling the challenges straight away.

For more information about the U.S. Department of Energy's Level VI regulation, visit http://www.cui.com/efficiencystandards.

Reference

CUI's Level VI External AC-DC Power Supplies

About The Author

Jeff Schnabel joined CUI in 2001 as a market research analyst, later transitioning into a product manager role and then a division manager role for CUI's V-Infinity Power Group. During his time managing V-Infinity, Jeff quickly expanded the product portfolio and customer base, helping to establish V-Infinity as the fastest growing business unit for CUI over the past decade.

Since 2009, Jeff has served as vice president of marketing. In that time, Jeff successfully established a centralized product marketing department within the company. He has also implemented a number of programs and processes that have greatly increased awareness and visibility of CUI within the industry, strengthened brand equity, and positioned the company for the rapid global growth that is expected in the coming five years. Jeff holds a bachelors of science degree in business administration with a focus in marketing from the University of Oregon and an MBA from Portland State University.

For further reading on energy efficiency, see the How2Power Design Guide, select the Advanced Search option, go to Search by Design Guide Category and select "Efficiency" in the Design Area category.