

High-Efficiency Front End Power Supplies Certified as 80 PLUS

KARUBE Kunihiko † TAWADA Nobuyuki † NAKAHARA Tomoki †

ABSTRACT

Switching power supplies that convert from AC to DC are installed in many electronic devices, and their market is expanding as these devices are becoming more advanced. Fuji Electric has developed and released switching power sources including front-end power supplies for information communication applications, an area that demands compactness, high efficiency, and high quality. We are focused on increasing power supply efficiency as promoted by the 80 PLUS program. We have released five models certified as Gold level, and one model certified as Platinum level. By using the latest semiconductor elements, we are continuing to improve power supply efficiency and increase high power density, and working toward compliance with the newly established Titanium level.

1. Introduction

Switching power supplies that convert from AC to DC are installed in many electronic devices. It is estimated that the world market scale in 2012 is 1.7 trillion yen, and the market is expanding as these electronic devices are becoming more advanced. Fuji Electric has been working on development of power supplies corresponding to changes in various customer needs in information communication field and industrial field for 35 years.⁽¹⁾

2. Front-End Power Supply

Front end power supply is a switching power supply that converts commercial 100 V or 200 V AC input in servers and storage devices to DC, such as 54, 48 or 12 V DC by rectifying and smoothing. For example, in November 2011, it became a popular topic of conversation that the domestic super computer achieved a speed of 10 quadrillion per second in November, 2011. The front-end power supply that is used for this computer system was developed and commercialized by Fuji Electric. Figure 1 shows the external appearance. This power supply converts 200 V AC to 48 V DC and output power is 3,000 W. The development of this power supply had a high degree of difficulty because compactness, high efficiency and high quality were required.

Fuji Electric is concentrating on development and commercialization of switching power supplies including these information communication related front-end power supplies, and is focusing on improving power supply efficiency as promoted by the 80 PLUS program.

This paper describes the high efficient front-end



Fig.1 Front-end power supply of 3,000 W output

power supplies that are certified as this “80 PLUS*1.”

3. Front-End Power Supply Certified as 80 PLUS “Platinum”

There is a need for improvement of efficiency in switching power supplies typically used for servers and hard disk devices. As one index, there is a guideline of industry group, called 80 PLUS. In this guideline, the following two categories are included. One is single output (there is a case for two outputs) and the power supply that enables parallel redundancy operation. The other is multi output (two outputs or more) and

† Fuji Electric Co., Ltd.

*1: 80 PLUS: See “Explanation 1” on page 217

Table 1 80 PLUS efficiency guidelines

80 PLUS rank	Load factor *			
	10%	20%	50%	100%
80 PLUS Titanium	90%	94%	96%	91%
80 PLUS Platinum	—	90%	94%	91%
80 PLUS Gold	—	88%	92%	88%
80 PLUS Silver	—	85%	89%	85%
80 PLUS Bronze	—	81%	85%	81%
80 PLUS Standard	Not applicable			

* : For input power voltage 230 V AC

the power supply with no provisions regarding parallel redundancy operation. The demand for efficiency is higher in the former type and is categorized into 6 ranks (see Table 1)⁽²⁾.

Five models of Fuji Electric power supplies are certified and registered as “Gold” rank, and one model is certified and registered as “Platinum” rank which are shown in Table 1 (as of April 2012). Of the models that are registered as 80 PLUS, 131 models are Gold rank and 88 models are Platinum rank. There are 43 companies with which products are certified in guideline of 230 V AC, including information device manufacturers and electric power supply manufacturers (as of April 2012).

Requirements for front-end power supplies are compactness, high efficiency, parallel redundant function and communication function with external devices. As for external dimensions, 3,000 W power supply presented in Chapter 2 conforms to the standard called, server system infrastructure (SSI). However, as with recent trend of downsizing in customers devices, three to four units of power supply can be basically stored in the rack with dimensions of 1U (44.5 mm) height and 19 inches width.

Although the difference in efficiency between Gold and Platinum is 2%, considering the fact that several thousand units of power supply are used in the large-scale systems such as a data center, this difference is large. For example, if power consumption is 10 MW, the difference in loss of electric power is 2%, which is 200 kW. Furthermore, reduction in cooling device equivalent to 200 kW is also possible, achieving further energy conservation effect.

4. AC-DC Front-End Power Supply “FH02500UAD” of 2,500 W Output

Figure 2 shows external appearance and Table 2 shows main specification of the power supply. The characteristics of the front-end power supply “FH02500UAD” is introduction of digital control using

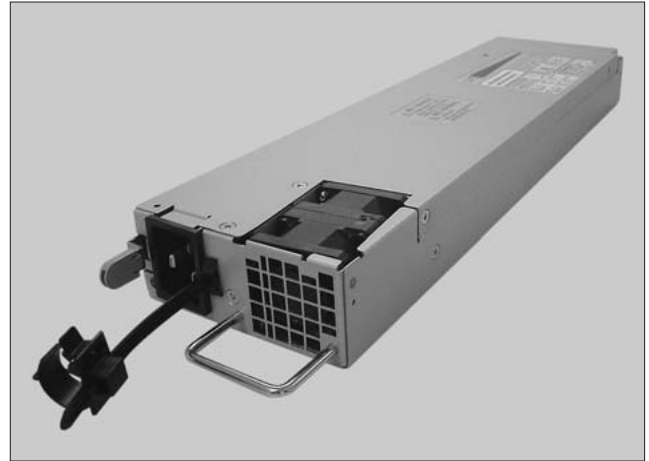


Fig.2 AC-DC front-end power supply “FH02500UAD” of 2,500 W output

Table 2 Main specification of “FH02500UAD”

Item		Specification	
Input characteristic	Input voltage	100/200 V AC	
	Frequency	50/60 Hz	
	Inrush current	20 A or below	
	Efficiency	94% or higher (certified as 80 PLUS Platinum)	
	Power factor Harmonic current regulation	98% (load factor 50 to 100%) JEIDA EN61000-3-2 (compliant)	
Output characteristic		ch. 1	ch. 2
	Output voltage	+54 V	+12 VSB
	Rated current	46 A*1	4 A
	Minimum current	0.4 A	0 A
	Ripple noise	480 mVp-p	120 mVp-p
	Total fluctuation	±5%	±5%
	Overvoltage protection	51 to 55 V	—
Environmental condition	Operational temperature/humidity	0 to +50 °C*2/20 to 95%RH	
	Storage temperature/humidity	-40 to +70 °C/20 to 95%RH	
	Vibration resistance	0.5 G, 3 to 60 Hz, 1cycle/2 minutes×5	
	Heating protection	Yes	
Standard	Safety standard	UL/CSA/TÜV/CCC	
	Noise standard	CISPR/FCC Class A (compliant)	
Others	Dimensions	W102×D355×H41 (mm) (protruded section is not included)	
	Mass	2.5 kg or less	
	Output per unit volume	1.68 W/cc	
	Cooling condition	Forced air cooling	

*1 : 23 A when inputting 100 V system
*2 : With output derating at 35 to 50 °C

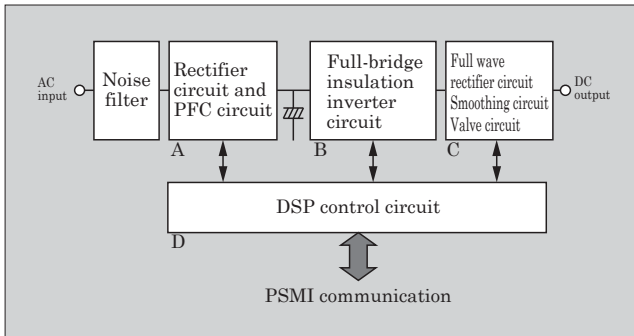


Fig.3 Block diagram of "FH02500UAD"

digital signal processor (DSP) instead of using analog IC for control circuit. Figure 3 shows block diagram of this power supply.

Digital control is introduced for controlling the power factor correction (PFC) circuit, full-bridge insulation inverter circuit and full-wave rectifier circuit.

4.1 Advantage of digital control

There are the following advantages from performing digital control

- (1) It became easy to switch control method corresponding to the load factor, which was difficult with analog control, and efficiency at light-load was improved. Improvement was 2 points or more at load factor 20% compared to the previous control.
- (2) Influence of switching noise can be eliminated by information processing inside the power supply, without setting up a large filter circuit, improving the output accuracy when communicating with outside. Monitor accuracy was improved by 5 points.
- (3) The number of control circuit parts was reduced by 30% compared to before, and downsizing was achieved.
- (4) For reduction of lead time and modification, it became possible to set or change constant value without changing hardware circuit via communication function with personal computer, and 20% reduction of shipping inspection time was achieved compared to before.
- (5) Simulation accuracy is high due to software control, and it became easier to perform desk study for operation of switching power supply.

Fuji Electric uses design support tool for digital control software development. Design support tool generates code automatically by writing the program in block diagram format, enabling development of control software in a short period of time for various customer needs. Figure 4 shows a screen example of the software design support tool.

Figure 5 shows a waveform of output voltage and the output current when load is fluctuating between 100% and 75%. Fluctuation range is $\pm 1.5\%$, and good result can be obtained, which is no way inferior to ana-

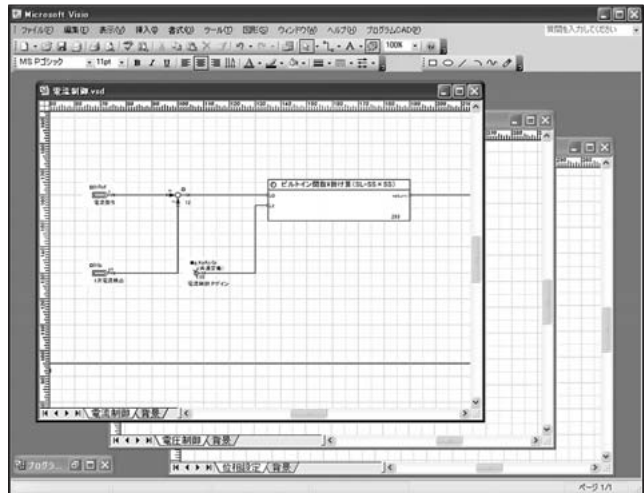


Fig.4 Screen example of software design support tool

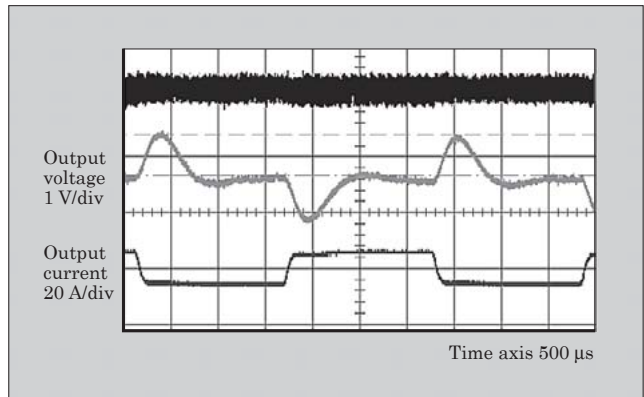


Fig.5 Load fluctuation waveform of "FH02500UAD"

log control.

4.2 Method of high efficiency

Engineering method which achieved high efficiency of Platinum rank is described below⁽³⁾.

- (1) One tier structure of rectifier circuit and PFC circuit

With the previous method, control was performed by straight two-tier structure of rectifier circuit and PFC circuit so that input current makes a sine waveform, and a stable direct-current middle voltage (input voltage of full-bridge insulation inverter circuit) was obtained. Meanwhile, in FH02500UAD, a method that put all these functions together was developed and the conversion tier was reduced to one tier (see Fig. 3: Section A).

- (2) Application of SiC diode and SJ-MOSFET

By applying silicon carbide (SiC) diode and super junction metal-oxide-semiconductor field-effect transistor (SJ-MOSFET) to the switching semiconductor of PFC circuit and full-bridge insulation inverter circuit, the switching loss and conduction loss were improved (see Fig. 3: Section A and B).

Figure 6 shows efficiency characteristic corresponding load factor. For load factor that 80 PLUS specifies,

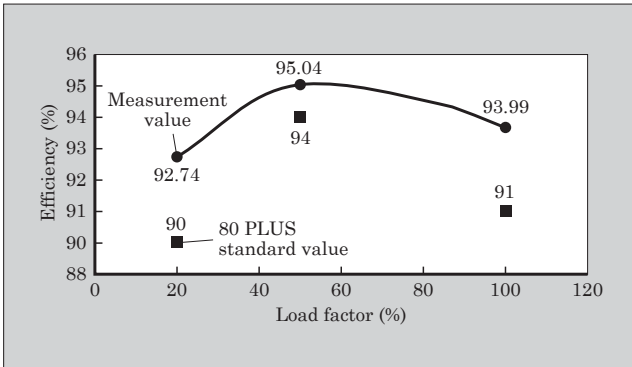


Fig.6 Efficiency characteristic corresponding load factor

it is possible to obtain 1 to 3 points higher efficiency.

(3) Improvement of conduction loss of full wave rectifier circuit

Previously, diodes were used in full-wave rectifier circuit for power supply of 48 to 60 V class. As a result of recent progress in switching semiconductor, diodes were replaced with MOSFET for power supply of 48 to 60 V class, and conduction loss of semiconductor device was improved (see Fig. 3: Section C).

(4) Change of switching method corresponding to load factor

Previously, switching losses of element was reduced and efficiency was improved by phase shift method operated by soft switching, which enables Zero Volt Switching (ZVS) operation of full-bridge insulation inverter circuit. However, phase shift method has a disadvantage that the soft switching operation becomes disabled at light-load and efficiency is lowered. By applying the aforementioned digital control, the disadvantage was improved as a result of changing to a hard switching method, which is more efficient than the phase shift method at light-load, and reduction of loss in all regions was achieved (see Fig. 3: Section D).

The front-end power supply, which utilizes these technologies were adopted by customers who focus on compactness and high-efficiency in the industrial field such as semiconductor manufacturing equipment, besides the information communication field.

In addition, currently, Platinum rank product having output voltage of 12 V with identical output power is being developed.

5. Front-End Power Supply “FH02100JAD” of 2,100 W Output

The external appearance of front-end power supply, “FH02100JAD” is shown in Fig. 7, and the main specification is described in Table 3.

Because output voltage is as low as 12 V, output current becomes 3.8 times of FH02500UAD that was explained in Chapter 4. Therefore, for secondary side of full-wave rectifier circuit in full-bridge insulation inverter circuit, MOSFET of surface mounting type that enables soldering directly on the printed board is used

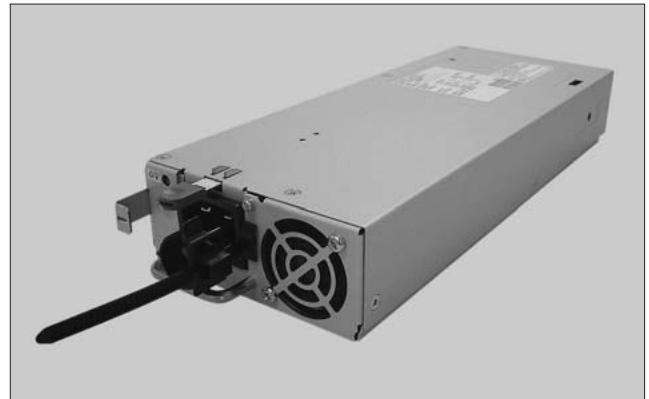


Fig.7 Front-end power supply “FH02100JAD” of 2,100 W output

Table 3 Main specification of “FH02100JAD”

Item		Specification	
Input characteristic	Input voltage	100/200 V AC	
	Frequency	50/60 Hz	
	Inrush current	15 A or below	
	Efficiency	94% or higher (certified as 80 PLUS Platinum)	
	Power factor Harmonic current regulation	95% (load factor 50 to 100%) EN61000-3-2(compliant)	
Output characteristic		ch. 1	ch. 2
	Output voltage	+12 V	+5 VSB
	Rated current	175 A*	5 A
	Minimum current	0 A	0 A
	Ripple noise	120 mVp-p	50 mVp-p
	Total fluctuation	±3%	±5%
	Overvoltage protection	13.2 to 14 V	5.5 to 6 V
	Overcurrent protection	105 to 117%	110 to 120%
Environmental condition	Operational temperature/humidity	0 to +40°C/5 to 90%RH	
	Storage temperature/humidity	-20 to +65°C/5 to 95%RH	
	Vibration resistance	0.25 G, 5 to 55 Hz 1cycle/5 minutes×6	
	Heating protection	Yes	
Standard	Safety standard	UL/CSA/TÜV	
	Noise standard	CISPR/FCC Class A (compliant)	
Others	Dimensions	W112×D279×H47 (mm) (protruded section is not included)	
	Mass	2.0 kg or less	
	Output per unit volume	1.43 W/cc	
	Cooling condition	Forced air cooling	

* : 80 A for 100 V input

to reduce conduction loss of semiconductor device and switching loss as much as possible. In addition, in or-

der to reduce conducting loss of printed board, bus bar is used at the same time. Furthermore, for smoothing circuit coil, straight angle plates are used for windings to achieve efficient utilization of the space.

6. Postscript

In this paper, high efficient front-end power supplies certified as 80 PLUS were presented. Along with the rapid advancement of ICT in the society, information communication devices are becoming more high-density and power-saving style. Improvement of efficiency is also demanded for power supply of device along with this trend. In 2011, the rank called "Titanium" was set up for 80 PLUS. Compared to Platinum, which used to be the highest level so far, the maximum 4 points of efficiency improvement is required, and a new load factor, 10% was specified. Therefore, the hurdle for power supply manufacturers got higher.

While receiving support from customers, Fuji Electric is developing application technology on the latest semiconductor devices, such as SiC-MOSFET and GaN (gallium nitride)-MOSFET toward being certified as Titanium. In addition, magnetic components such as transformer and coil, and improving characteristic of printed wiring board that allows large current to be applied, are focused. Fuji Electric intends to promote further improvement in efficiency and increase in high power density.

Reference

- (1) ANDOU, K. et al. Power Supply Technology for Energy and Environmental Solutions. FUJI ELECTRIC REVIEW. 2009, vol.55, no.4, p.148-153.
- (2) 80PLUS Program, <http://www.80plus.org>. (accessed 2012-04-10).
- (3) MINO, K. et al. "A Front-End Converter with High Reliability and High Efficiency." ECCE, 2010, p.3216-3223.





* All brand names and product names in this journal might be trademarks or registered trademarks of their respective companies.