3rd-Gen. Critical Mode PFC Control IC "FA1A00 Series"

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ABSTRACT

Switching power supplies, which are widely used for electronic devices, are required to have a power factor correction (PFC) circuit to reduce harmonic current. In order to meet the market demand for less power consumption and lower cost of power supplies, Fuji Electric has developed the third-generation critical mode PFC control IC "FA1A00 Series" intended for PFC circuits. The bottom-skip function has successfully improved the efficiency under low load and the power good signal function has reduced the number of power circuit parts. Safety has also been improved by having an overshoot suppression function and improved reference voltage accuracy.

1. Introduction

Switching power supplies are widely in use to achieve size and weight reduction of electronic devices. Switching power supplies use a capacitor-input rectifier and smoothing circuits and a large harmonic current is generated. An increase in harmonic current causes problems such as device operation failure and an increase of reactive power due to a power factor reduction. In order to restrain the harmonic current to a certain value, international standard IEC 61000-3-2 classifies electrical and electronic equipment into classes A to D as shown in Table 1, and they are respectively assigned regulation values.

To solve these harmonic current and power factor problems, a power factor correction (PFC) circuit is necessary and an active filter PFC circuit, which provides an especially high power factor, is widely used. Meanwhile, Fuji Electric has commercialized many ICs for controlling PFC circuits[1].

In order to curb the deterioration in the global environment, saving the energy consumed by electrical products in general is gaining importance. Standards that limit the energy consumption of electronic equipment, such as the ENERGY STAR program of the U.S. and the Energy-using Products (EuP) Directive of Europe, have been established and the regulations are increasingly becoming stricter year after year.

For example, there are regulations on standby power consumption and the minimum and average efficiency in a wide load range including low load. Accordingly, ICs for controlling PFC circuits are required to reduce standby power consumption and improve the efficiency under low load.

In addition, following the recent demand for lower prices of electronic equipment and growing consumer awareness about safety, power supplies are also strongly required to achieve both reduced cost and improved safety.

To meet these demands, Fuji Electric has developed the 3rd-generation critical control IC "FA1A00 Series" following the 2nd-generation critical control IC "FA5590 Series[1]". The products in the new series is capable of reducing power supply cost and lowering standby power consumption and they have achieved an enhanced protective function as well as improved efficiency under low load.

Table 1 Classification of harmonic current regulation (IEC 61000-3-2)

Classification	Typical equipment
Class A	Major household appliances, audio equipment
Class B	Handheld power tools, arc welders
Class C	Lighting equipment
Class D	TVs, PCs

2. Overview and Features of Product

The appearance of FA1A00 is shown in Fig. 1 and a performance comparison between FA1A00 and FA5590 in Table 2. FA1A00, which meets demands such as improved efficiency under low load, reduced power supply cost and improved stability and safety of PFC circuits, has the following features.

(1) Improvement of efficiency under low load
- ○ Bottom-skip function
  The efficiency has been improved by 14% with 240 V AC and 10% load.

(2) Reduction of power supply cost
- ○ Power good signal function

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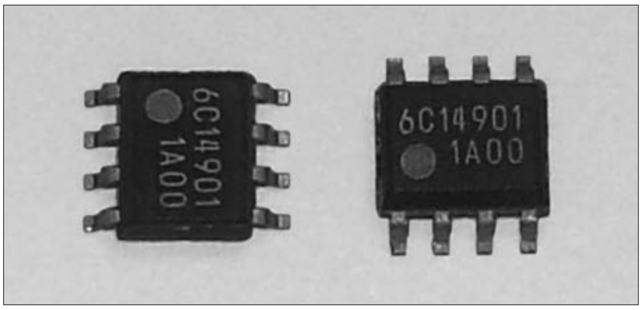

Fig.1 “FA1A00”

Table 2 Critical PFC control IC performance comparison

Item		FA1A00	FA5590
High efficiency	Switching frequency under low load	200 kHz (Efficiency improved by 14 points with 240 V AC and 10% load)	600 kHz
Low cost	Power good signal function	Provided	Not provided
Stability	Stabilization under low-load function	Provided	Not provided
	Zero current detection voltage	−4 mV ±3 mV	−10 mV ±5 mV
Safety	Overshoot suppression function	Provided (Overshoot voltage reduced by 10 V)	Not provided
	Reference voltage	2.5 V ±1.0%	2.5 V ±1.4%
	Overcurrent detection voltage	−0.6 V ± 2.0%	−0.6 V ±3.3%

One n-metal oxide semiconductor field-effect transistor (n-MOSFET) has been added and 1 shunt regulator, 2 resistors and 1 capacitor have been eliminated.

(3) Improvement of operation stability
- ○ Low-load stabilization function

(4) Improvement of safety
- ○ Overshoot suppression function
- ○ The overshoot voltage has been reduced by 10 V.
- ○ Improvement of reference voltage tolerance
- ○ Improvement of overcurrent detection tolerance

2.1 Bottom-skip function

A critical mode PFC circuit, which turns on the MOSFET after the inductor current has dropped to zero, has a problem that the switching frequency increases under low load to increase the switching loss of the MOSFET, and this degrades efficiency.

Fuji Electric has addressed this problem by improving the function to reduce the switching frequency under low load for each new generation of critical mode PFC control IC.

Table 3 lists the frequency reduction functions and switching frequencies of the respective generations under low load. The switching frequency has been reduced from 800 kHz of the 1st generation FA5500 through 600 kHz of the 2nd generation FA5590 to 200 kHz of the 3rd generation FA1A00, thereby improving efficiency.

Figure 2 shows operation waveforms of the bottom-skip function. In critical operation, the MOSFET is turned on when the first bottom of VDS of the MOSFET is detected. With FA1A00, the MOSFET is turned on at the first bottom under high load as with ordinary critical operation, but the turn-on timing is delayed from the first bottom through the second to the third bottom as the load decreases. This operation prolongs the period of MOSFET turn-off, decreasing the switching frequency.

Figure 3 shows the efficiency of FA5590 and FA1A00 under low load with the rated 200 W power supply. The efficiency of FA1A00 has achieved an improvement of 3 points with 20% load and 14 points

Table 3 Frequency reduction functions and switching frequencies under low load

Generation	Model	Frequency reduction function	Switching frequency under low load
1st generation	FA5500	Not provided	800 kHz
2nd generation	FA5590	Maximum switching frequency limiting function	600 kHz
3rd generation	FA1A00	Bottom-skip function	200 kHz

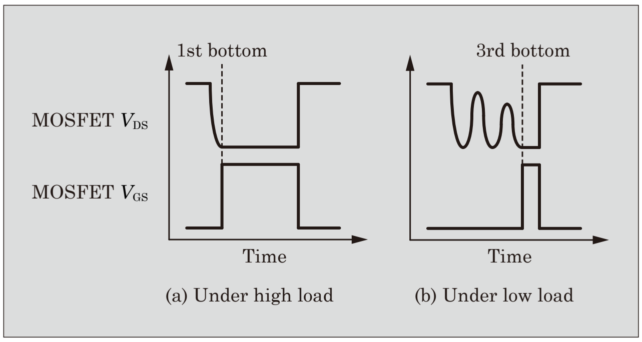

Fig.2 Operation waveforms of bottom-skip function

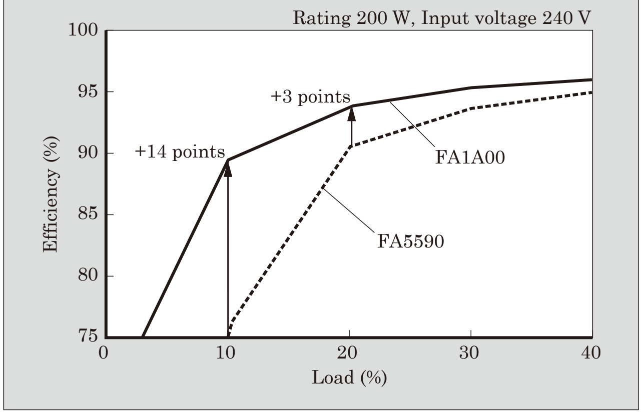

Fig.3 Efficiency under low load

with 10% load from FA5590 due to the bottom-skip function.

Use of FA1A00 provides conformance to standards such as the ENERGY STAR program. In addition, reduction of MOSFET loss decreases heat generation. It allows the heat sink for heat radiation to be made smaller, leading to a reduction in the power supply cost.

2.2 Power good signal function

With general power supplies, the PFC circuit is used to boost the 90 to 264 V AC input voltage to around 400 V, and this is further converted with the DC/DC converter in the later stage for supplying to the load. The DC/DC converter is designed to operate at the voltage boosted by the PFC circuit and may malfunction if the PFC circuit output voltage decreases to a certain voltage level. For that reason, the power supply uses a circuit that monitors the output voltage of the PFC circuit and, if it drops to a certain level, stops the DC/DC converter.

FA1A00 incorporates the function of this circuit. Figure 4 shows operation waveforms of the power good signal function. The power good signal is turned from L to H when the PFC output voltage has increased to a certain voltage or higher and from H to L when it has decreased to a certain voltage or lower. Transmitting this signal to the DC/DC converter in the later stage makes it possible to reduce the output voltage monitoring circuit in a power supply, thus realizing a reduction in power supply cost. A certain hysteresis is provided to the voltage for switching the power good signal, which prevents chattering and allows stable operation.

FA1A00 is provided with a terminal for monitoring the PFC output voltage. In addition, sharing the power good signal output with the existing oscillating frequency setting terminal has achieved the above function without increasing the number of terminals.

2.3 Low-load stabilization function

As described in Section 2.2, a wide-ranging input voltage from 90 to 264 V may be applied on the PFC circuit. Setting a high gain for the pulse width control, so that power can be supplied with a low input voltage

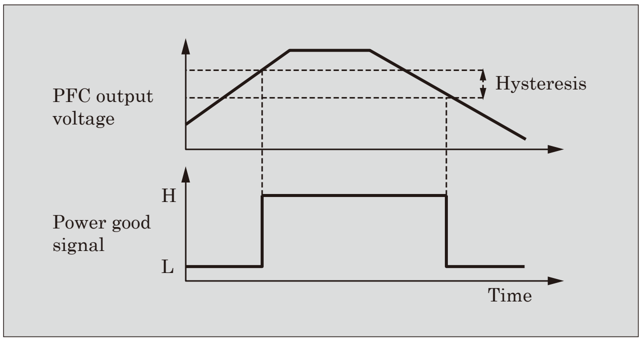

Fig.4 Operation waveforms of power good signal function

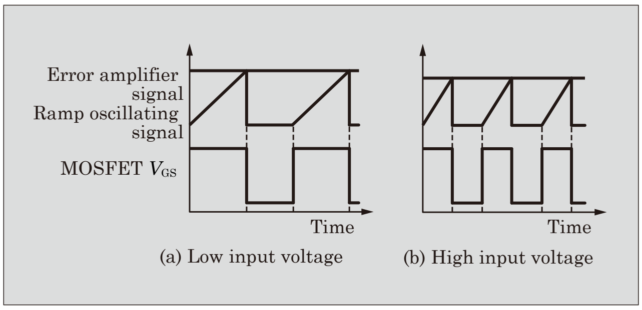

Fig.5 Operation waveforms of low-load stabilization function

and high load, may cause unstable operation with a high input voltage and low load because the gain is too high, and this possibly will increase the output voltage ripples. In this case, problems may occur such as a malfunction of the DC/DC converter connected in the later stage of the PFC circuit and increase of the switching noise.

FA1A00 integrates a function that allows stable supply of power by increasing the gain only when the input voltage is low and load is high and decreasing the gain when the input voltage is high and load is low.

Figure 5 shows operation waveforms of the stabilization under low-load function. The output power of the PFC circuit is controlled by the MOSFET “on” width. The MOSFET “on” width is determined by a turn-on and turn-off of the ramp oscillating signal: its level increases steadily after a turn-on to reach the error amplifier signal level between the output voltage and the reference voltage in the IC, then it turns off. Accordingly, the control gain depends on the gradient of the ramp oscillating signal.

Because a smaller gradient of the ramp oscillating signal provides a higher gain and a larger gradient provides a lower gain, FA1A00 has incorporated a function that increases the gradient of the ramp oscillating signal under high input voltage and low load. With this function, operation can be stabilized by reducing the control gain under high input voltage and low load.

2.4 Overshoot suppression function

In the PFC circuit, response of the output voltage control is set to be slow in order to decrease the output voltage ripples generated at the input power supply frequency. With slow response, however, an overshoot occurs in the output voltage at start-up. In addition, there are more cases recently to connect an electrolyte capacitor with a withstand voltage that does not have a sufficient margin from the actual use condition, to the output of a PFC circuit to reduce the power supply cost. It causes temporary overvoltage due to an overshoot at start-up, which reduces the lifespan of the electrolyte capacitor.

With FA1A00, if the output voltage reaches the setting voltage at start-up, the response is temporarily quickened to reduce the overshoot of the output voltage. Figure 6 shows operation waveforms of the overshoot suppression function.

PFC control IC supplies larger power to the output with a higher error amplifier signal. At start-up, large power is required to raise the output voltage to the setting voltage and the error amplifier signal level is raised to the maximum value. As described above, the output voltage control response is set to be slow, which causes a delay in the decrease of the error amplifier signal level when the output voltage reaches the setting, and excessive power is supplied, resulting in overshoot of the output voltage.

FA1A00 reduces the response delay by forcing to lower the error amplifier signal level when the output voltage reaches the setting, thereby reducing the overshoot at start-up. This makes it possible to safely use electrolyte capacitors with a low withstand voltage.

In addition to the protective function described above, FA1A00 has improved the safety of power supply by improving the reference voltage tolerance of the output voltage control and tolerance of the overload

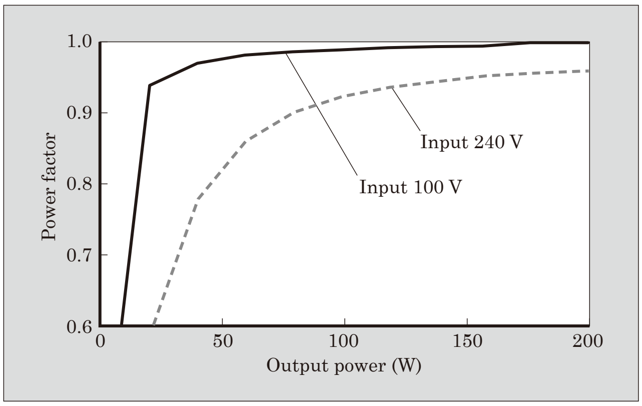

Fig.8 Power factor characteristics

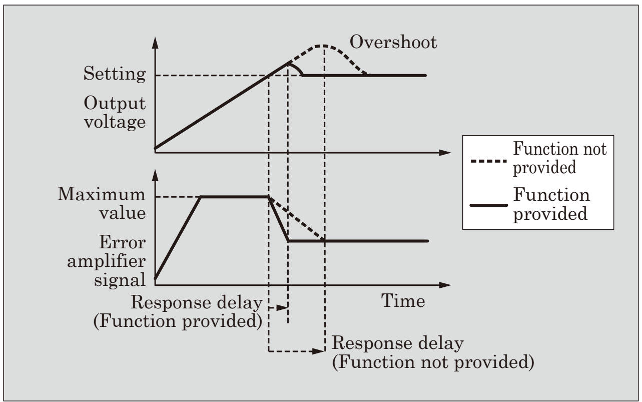

Fig.6 Operation waveforms of overshoot suppression function

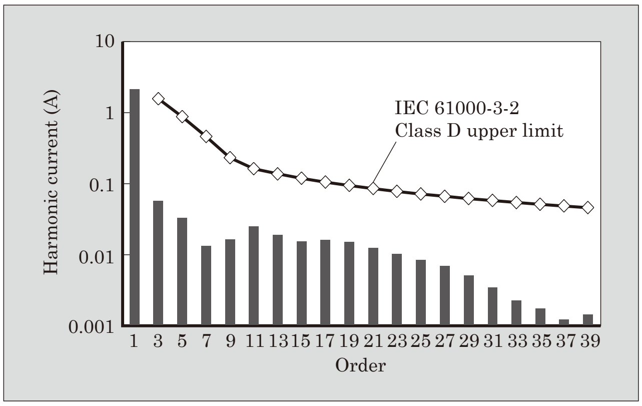

Fig.9 Harmonic current characteristics

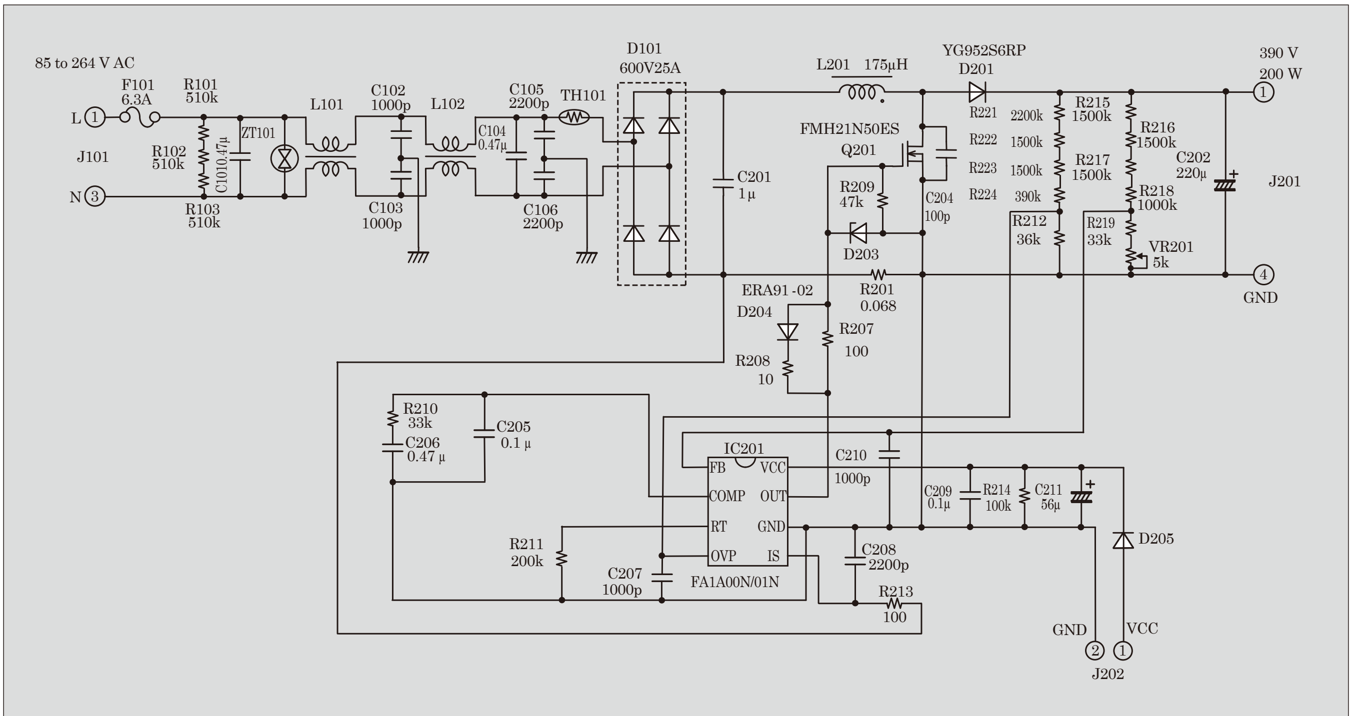

Fig.7 Sample application circuit

protection detection voltage.

3. Sample Application Circuit

Figure 7 shows a sample application circuit (input 90 to 264 V, output 390 V and 200 W) and Fig. 8 and Fig. 9 respectively show the power factor and harmonic current characteristics measured with the circuit.

Regarding the power factor characteristic, a minimum power factor of 0.95, which is required of general electronic equipment, is ensured with the standard input voltage (100 V and 240 V) and rated load. The harmonic current characteristic satisfies the requirement of IEC 61000-3-2 Class D, which is necessary for TVs, PCs and other electronic equipment.

4. Postscript

This paper has described the 3rd-generation critical mode PFC control IC "FA1A00 Series" capable of realizing reduced standby power consumption, improved efficiency under low load, cost reduction and improved safety of switching power supplies. In the future, we intend to continue to incorporate functions that meet the demands of the market. We will strive to establish a product line and work on development to comply with the standards and regulations that are becoming increasingly stricter year after year.

References

(1) Kashima, M.; Shiroyama, H. CMOS Power Factor Control IC. FUJI ELECTRIC REVIEW. 2002, vol.48, no.1, p.6-8.

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