“FA1B00N” 4th-Generation Critical Conduction Mode Power Factor Correction Control IC

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ABSTRACT

As electronic devices become smaller and lighter, switching power supplies are becoming more widely used and are required to help electronic devices, such as LED lighting, to have a long life, low price, and high reliability while reducing power supply costs. To meet these demands, Fuji Electric developed the “FA1B00N” 4th-generation critical conduction mode (CRM) power factor correction (PFC) control IC. In addition to the conventional model’s functions, this IC features a startup overshoot reduction and other protective functions, as well as higher accurate detection for PFC output voltage and overvoltage. These enhancements enable it to improve the reliability of electronic devices and reduce power supply costs.

1. Introduction

Switched-mode power supplies have become widespread as electronic devices become smaller and lighter. The harmonic current produced by switching power supplies can cause equipment and wiring facility operational failures and power factor degradation while also increasing apparent power. Therefore, to suppress the harmonic current to be less than a certain value, electrical and electronic devices are classified into four classes as shown in Table 1 and the regulation values of the power supply harmonic current by class are defined in the international standard IEC 61000-3-2.

To resolve this problem with the power supply harmonic current and the power factor, a power factor correction (PFC) circuit with an active filter method is widely in use.

In order to save power, there is a demand for PFC circuits with reduced standby power and improved efficiency in a wide load range, including light loads[1].

Furthermore, due to recent consumer expectations and demands for longer-service life and price-reduction of electronics such as LED lighting devices, PFC circuits are also expected to achieve high reliability and power cost reduction at the same time.

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	PCs and TVs

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To meet this demand, Fuji Electric has produced the “FA5601N” critical conduction mode PFC control IC that satisfies the class C of harmonic current regulations for LED lighting in quantity. Inheriting the features of this IC and further enhancing its protection functions, Fuji Electric has developed the “FA1B00N” 4th-generation critical conduction mode* PFC control IC to contribute to the reduction of power supply costs.

2. Overview of the “FA1B00N”

Figure 1 shows the external appearance of the FA1B00N that we have developed this time, and Table 2 compares its performance with the previous device, the FA5601N.

Figure 2 shows the block diagram of the FA1B00N. The FA1B00N can replace the FA5601N with the pin arrangement and basic functions being retained, en-

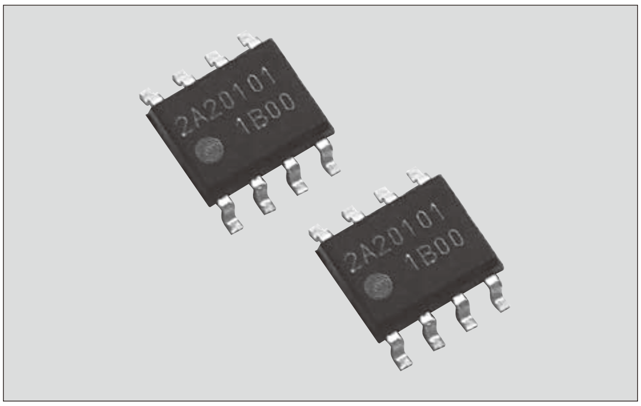

Fig.1 “FA1B00N”

* Critical conduction mode: The operation mode in which the MOSET turns on when a current applied to the inductor reaches 0 A

Table 2 Comparison of performance with conventional product

Item	FA1B00N	FA5601N
Turn-on timing detection	ZCD* winding	ZCD winding
Control method	On-width fixing control	On-width fixing control
Startup overshoot reduction function	Provided	Not provided
PFC output voltage drop suppressing function	Provided	Not provided
V_{CC} overvoltage protection	Provided	Not provided
V_{fb} reference voltage	2.5 V ± 1.0%	2.5 V ± 1.4%
Overcurrent detection voltage	0.65 V ± 2.0%	0.65 V ± 3.1%
Light load switching operation	Maximum oscillation frequency limit	Maximum oscillation frequency limit

* ZCD: Zero current detection

abling the reduction of lead time for power supply design.

In addition to the functions of previous devices, this device has additional functions, including an overshoot reduction at start-up, PFC output voltage reduction suppressing, and V_{CC} overvoltage protection. Furthermore, we have improved the accuracy of the reference voltage V_{fb} for PFC output voltage control and the accuracy of overcurrent detection voltage. These additional functions and the increased accuracy reduces costs and improves the reliability of power supplies.

2.1 Description of operations (on-width fixing control)

The FA1B00N is a PFC control IC that performs a critical operation using self-oscillation. Figure 3 shows the schematic operation circuit and Fig. 4 shows the waveforms of respective parts in switching operation.

At time t_1 in Fig. 4, when the MOSFET (Q_1) turns on, the current I_{L1} of the inductor (L_1) rises from zero. At the same time, the output V_{ramp} of the RAMP oscillator inside the IC rises at a slope determined by the resistance R_3 of the RT pin.

At time t_2, the PWM comparator (PWM comp.) compares the V_{ramp} and the error amplification voltage V_{comp}, and turns off Q_1 when V_{ramp} is greater than V_{comp}. When the Q_1 turns off, I_{L1} reverses, and while a current is supplied to the output side through a boost-up diode (D_1), I_{L1} decreases, and the voltage V_{sub} of auxiliary winding also reverses, generating positive voltage.

At time t_3, if I_{L1} returns completely to zero, the drain-source voltage V_{ds} of Q_1 resonates with the drain-source parasitic capacitance of Q_1 and rapidly drops. At the same time, V_{sub} also rapidly drops.

At time t_4, the zero current detecting comparator detects the timing when V_{sub} becomes the zero current detection voltage or lower, causing Q_1 to turn on. Repeating these operations, the IC performs a critical operation.

In the operations above, if the PFC circuit load is constant, V_{comp} becomes constant, and thus, the on-width also becomes constant. Here, the peak current

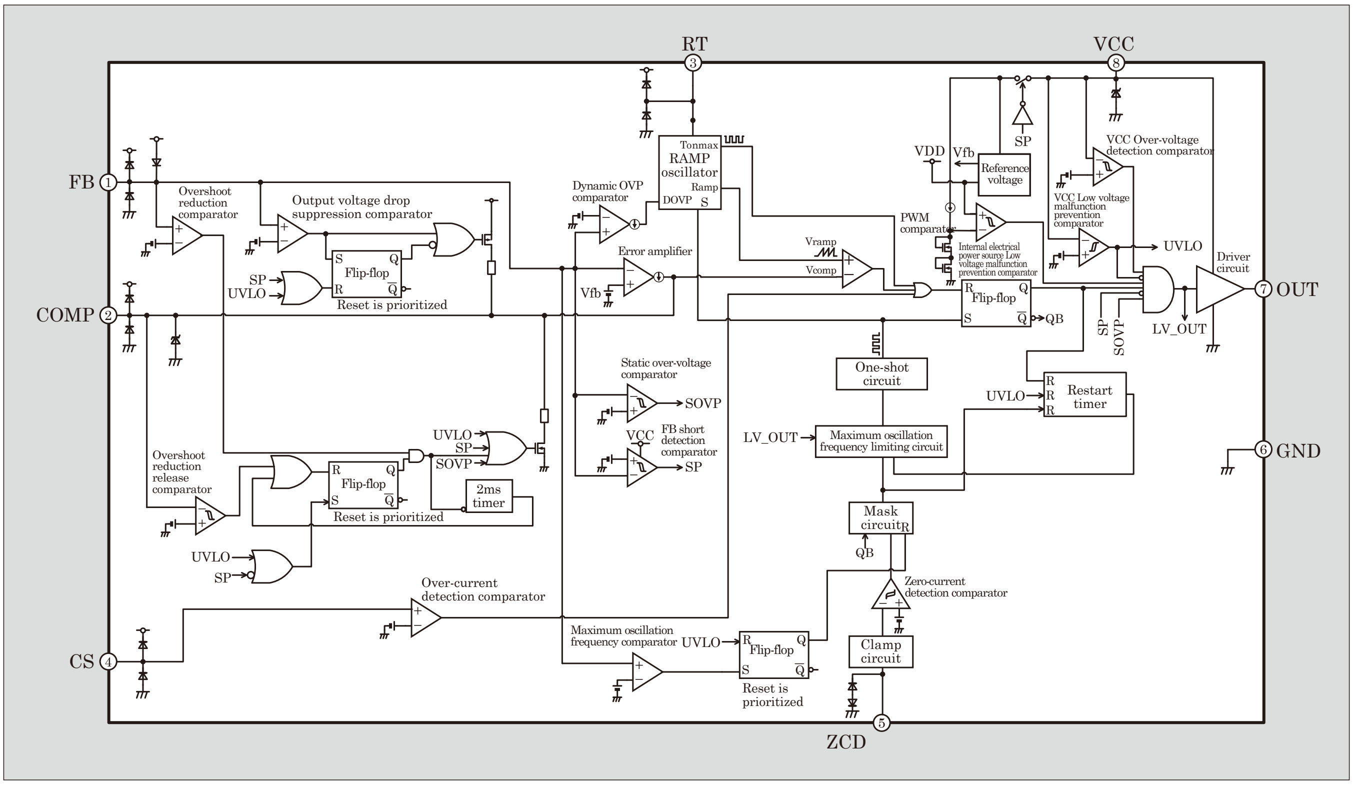

Fig.2 “FA1B00N” block diagram

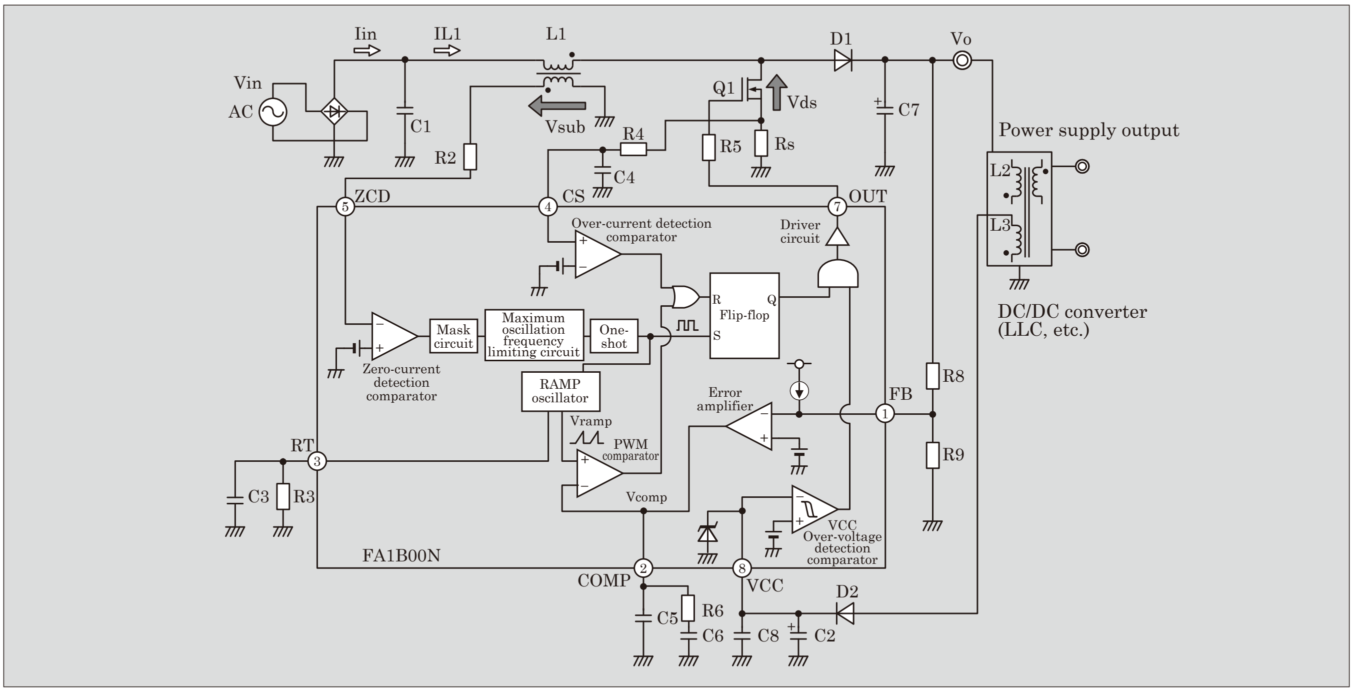

Fig.3 Schematic operation circuit

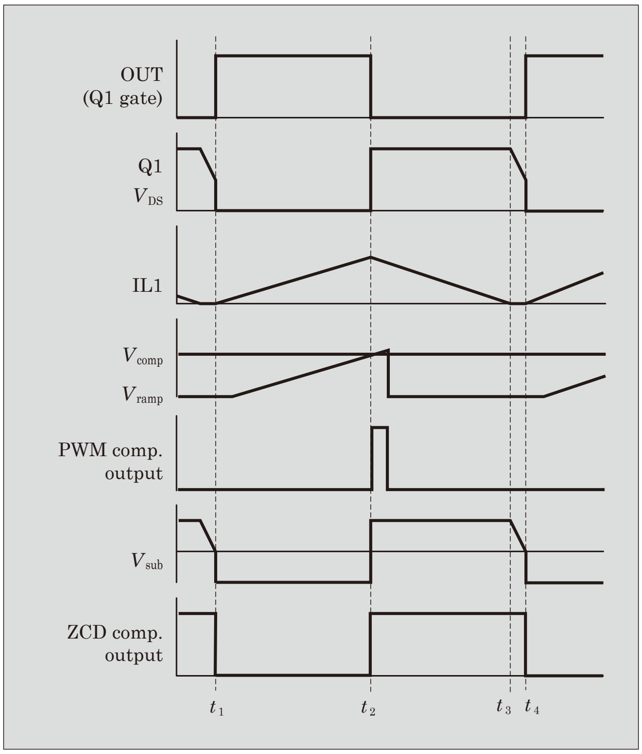

Fig.4 Waveforms of respective parts in switching operation

of the inductor is given by formula (1).

$$I_{max} = \frac{V_{in}}{L} \times T_{on} \quad \cdots\cdots (1)$$

I_{max} : Peak current of L_1
V_{in} : Input voltage
L : Inductance value of L_1
T_{on} : On-width

In formula (1), L and T_{on} are constant, and therefore, the peak current of L_1 is proportionate to V_{in} and the waveform equals the AC waveform of the input voltage. This operation enables power factor correction.

3. Features

3.1 Overshoot reduction function

A PFC circuit generates an output voltage ripple with the frequency components of the AC input voltage. To reduce the impact of this output voltage ripple on PFC control IC operations, it has a large capacity capacitor connected to the COMP pin. However, if the capacitor capacity increases, a delay occurs in the response of V_{comp} at start-up and the output voltage of the PFC circuit increases, causing overshoot.

Moreover, the electrolytic capacitor connected to the output of the PFC circuit often has an insufficient breakdown voltage margin for the output setting voltage of the PFC circuit to reduce the power supply cost. Therefore, the output voltage of the PFC circuit overshoots to near the rated voltage of the electrolytic capacitor at start-up, reducing the life expectancy of the electrolytic capacitor, possibly leading to a breakdown.

To resolve this problem, the FA1B00N contains a built-in function that reduces the output voltage overshoot of the PFC circuit at start-up[(2)]. Figure 5 shows the operation waveform of this function.

The PFC control IC supplies more electric power to the output of the PFC circuit if V_{comp} is higher. At the time of start-up, high electric power is required to raise the output voltage of the PFC circuit to the set voltage, and therefore, V_{comp} rises to the maximum value.

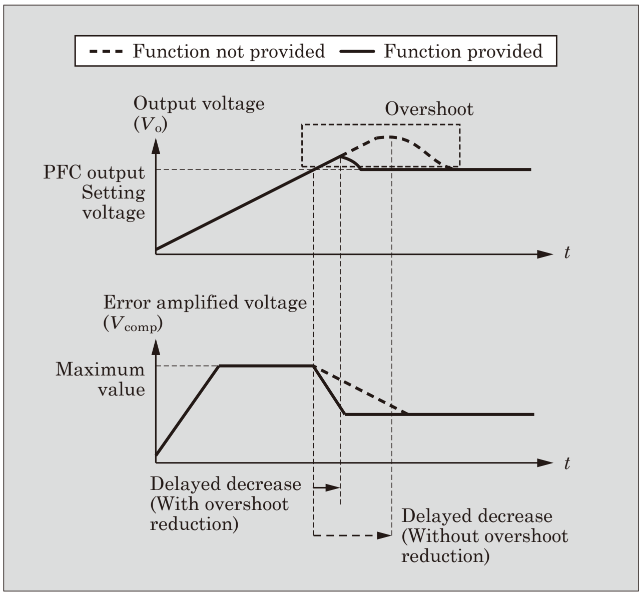

Fig.5 Overshoot reduction function operation waveform

However, even if the output voltage of the PFC circuit reaches the set voltage, a delay in V_{comp} lowering occurs due to the capacitor connected to the COMP pin. Thus, excessive power supply occurs, causing overshoot in the output voltage of the PFC circuit. To cope with this, the FA1B00N temporarily lowers V_{comp} when the PFC output voltage reaches the set voltage value at start-up to release the excessive power supply and reduce the overshoot. This enables the safe use of an electrolytic capacitor with a small breakdown voltage margin and leads to a reduction of the power supply cost.

3.2 Output voltage drop suppressing function for PFC circuits

To reduce the power supply cost, it is desirable to reduce the capacity of the electrolytic capacitor connected to the output of the PFC circuit. However, if the capacity of the electrolytic capacitor is small, the output voltage of the PFC circuit will drop significantly when the load increases rapidly at the DC/DC converter connected to the rear stage of the PFC circuit. Figure 6(a) shows the conventional operation waveform. If the output voltage of the PFC circuit drops, V_{comp} rises to make the output voltage rise to the set voltage value. However, if the capacity of the capacitor connected to the COMP pin is large, the V_{comp} response is delayed, and thus, the output voltage drops. If this output voltage drops below the minimum input voltage of the DC/DC converter, the DC/DC converter may stop and no longer be able to supply power to the load.

To cope with this, the FA1B00N contains a built-in function that suppresses the PFC circuit output voltage drop. Figure 6(b) shows the operation waveform of this function.

The FA1B00N forcibly raises V_{comp} when the output voltage of the PFC circuit falls below the PFC output voltage threshold to widen the on-width of the OUT pin and suppress the output voltage of the PFC circuit from dropping. As a result, it becomes possible to supply a stable output voltage to the DC/DC converter at the rear stage. Moreover, this enables the use of a small-capacity electrolytic capacitor and leads to a reduction of the power supply cost.

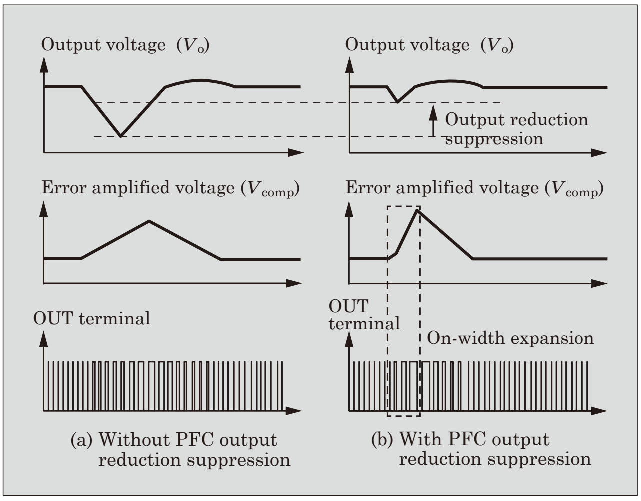

Fig.6 PFC output reduction suppressing function operation waveform

3.3 Overvoltage protective function for V_{CC} voltage

Voltage supply to the VCC pin of the PFC control IC is achieved generally through the method of lowering the AC input voltage with the transformer auxiliary winding (L_3), rectifying the voltage generated on the auxiliary winding with a diode, and smoothening it with a capacitor. This method may cause a breakdown of the circuit inside the IC and the MOSFET connected to the VCC pin if the output voltage of the power supply becomes large due to certain factors such as overload. Therefore, a protective Zener diode may be connected.

The FA1B00N contains a built-in function that protects the MOSFET against breakdown due to overvoltage by stopping OUT pin switching if the VCC pin

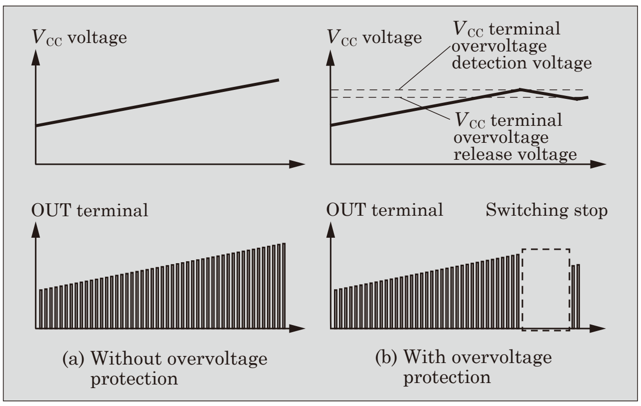

Fig.7 Operation waveform of the overvoltage protective function for V_{CC} voltage

voltage reaches the V_{CC} overvoltage detection voltage as shown in Fig. 7. This function eliminates the need for the circuit inside the IC connected to the VCC pin and the Zener diode to protect the MOSFET gate and leads to a reduction of the power supply cost.

In addition to such protective functions, we have improved the accuracy of the reference voltage for PFC circuit output voltage control. Thus, the upper limit output voltage of the PFC circuit is now lower, and the breakdown voltage margin of the electrolytic capacitor connected to the PFC circuit is larger than the conventional one, enabling the prevention of a breakdown of the electrolytic capacitor.

We also have improved the accuracy of detecting an overcurrent applied to the MOSFET. As a result, the overcurrent can be limited by immediately turning off the MOSFET when an overcurrent occurs, thus preventing the destruction of power supply components such as MOSFETs and improving the reliability of the power supply.

3.4 Efficiency improvement during light load conditions (maximum oscillating frequency limiting)

In critical operation, the switching frequency increases during light load conditions, which causes a problem in which the switching loss of the MOSFET increases and the efficiency decreases.

To improve the efficiency during light load conditions, the FA1B00N has the same maximum oscillating frequency limiting function as the previous device, the FA5601N. If the switching frequency exceeds the maximum oscillating frequency F_{max} determined by the RT pin resistance during light load conditions, it turns on at a cycle slower than $1/F_{max}$ even if the timing when the inductor current becomes zero is detected. This maximum oscillating frequency limiting function suppresses the increase in the switching frequency, which reduces switching loss and improves the efficiency during light load conditions. Furthermore, it reduces heat generation in the MOSFET, and the heat sink for emitting heat is smaller, leading to a reduction of the power supply cost.

4. Sample Application Circuit

Figure 8 shows an application circuit example of the PFC circuit assuming LED lighting (input 90 to 264 V, output 390 V, 150 W).

As shown in Fig. 9, at standard input voltage (110 V, 220 V) and rated load (150 W), a power factor was 0.95 or higher, which is required for general electronic devices.

As shown in Fig. 10, harmonic current characteristics have satisfied class C in the international standard IEC 61000-3-2 required for lighting devices.

As shown in Fig. 11, the average efficiency (average of efficiency values under 25%, 50%, 75%, and 100% loads) at standard input voltages (110 V, 220 V) was ensured to be 89% or more, which is required for general electronic devices.

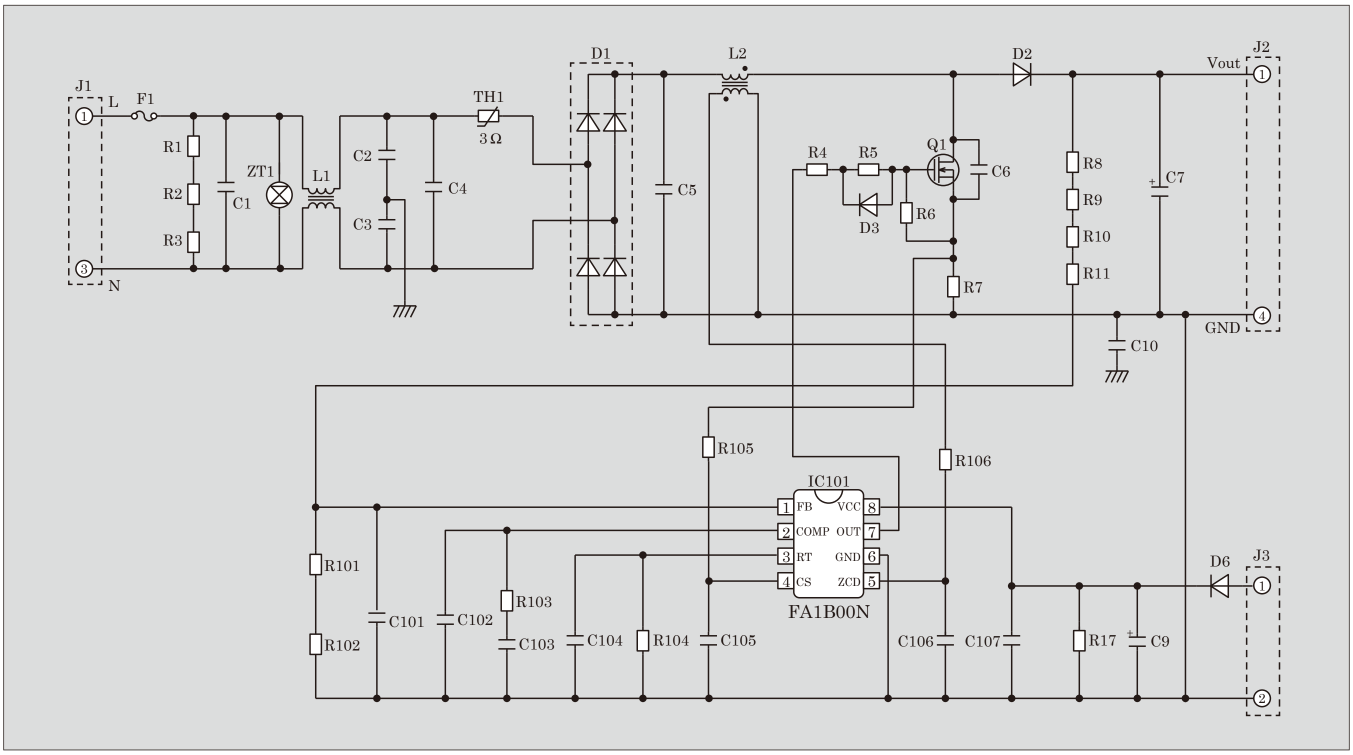

Fig.8 Application circuit example

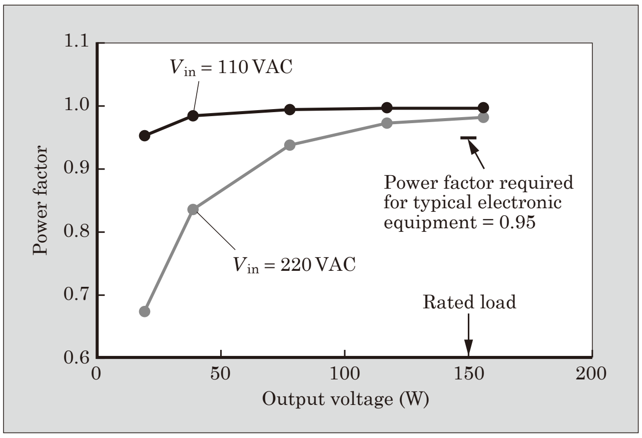

Fig.9 Power factor characteristics

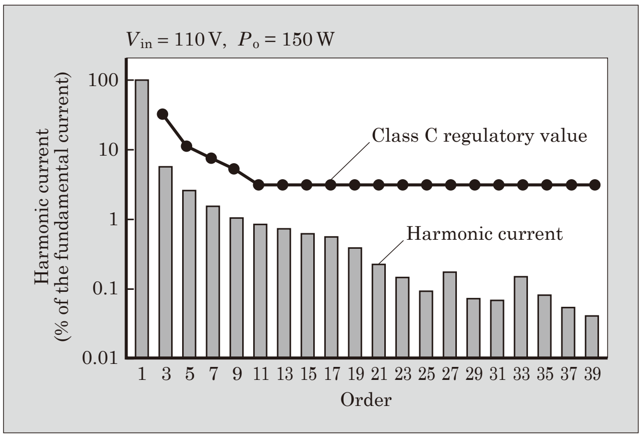

Fig.10 Harmonic current characteristics

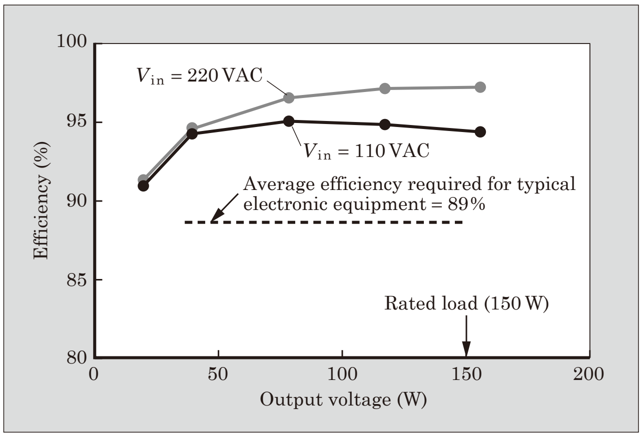

Fig.11 Efficiency characteristics

5. Postscript

This document described the 4th-generation critical conduction mode PFC control IC "FA1B00N." This IC achieves standby power reduction, efficiency improvement in a wide load range including light loads, reliability improvement, and power cost reduction.

In the future, we will work to further reduce standby power, improve efficiency, and provide products that enable the reduction of power supply parts.

References

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