CMOS Power Factor Control IC

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1. Introduction

Most of the electronic systems in widespread use at present require rectifier circuits to convert alternating current into direct current as they utilize a DC power supply to drive their internal electronic circuits. Capacitor input filters are mainly used as the rectifier circuits. However, these have the undesired effect of producing a large amount of harmonic current due to the distorted input current waveform caused by the fact that the electric current flows into the input smoothing capacitor only when the alternating voltage is at a peak value. And at that time, the power factor drops to about 0.6. This type of increase in harmonic current may lead to malfunction of the electronic equipment, which may result in social problems. There is a movement to establish legal regulations for harmonic current problems. Increased loss in electric power transmission and distribution due to lowering of the power factor has also become problematic.

To resolve the problems of harmonic current and of lowered power factor, various measures have been proposed and active filters have come into widespread use as they are small and lightweight and can realize a high power factor.

As active filter control ICs, Fuji Electric had already commercialized power factor control ICs, FA5331P/M and FA5332P/M, which are based on average current mode control. This paper presents Fuji Electric's newly developed power factor control ICs, FA5500P/N and FA5501P/N, which are based on peak current mode control.

2. Overview of Power Factor Improving Circuit

Figure 1 shows a capacitor-input-rectifier circuit and its input voltage and current waveforms. The input current flows only during short intervals when the input voltage is in the vicinity of the peak voltage, and a large amount of harmonic current is generated. Existence of the harmonic current lowers the power factor, and the relation between them can be expressed by the following equations:

$$\mathrm{PF} = 1/\sqrt{1 + \mathrm{THD}^2}$$

$$\mathrm{THD} = \sqrt{(i_2^{\,2} + i_3^{\,2} + \cdots i_n^{\,2})/i_1^{\,2}}$$

Where,

PF: power factor,
THD: total harmonic distortion,
i_1: input current fundamental harmonic,
i_n: n-th order harmonic.

From these equations it is seen that the input harmonic current can be suppressed if the power factor can be improved by a power factor improving circuit.

Power factor is defined as the difference in phases between the waveforms of voltage and current. Accordingly, the power factor can be improved if the current waveform is controlled to be in-phase with that of the voltage. If phases of the voltage and current waveforms coincide completely, the power factor becomes 1.

Figure 2 shows a boost converter circuit used as an active filter circuit to control the current waveform. This is a boost converter circuit connected to a full wave rectifier circuit configured from a diode bridge. Switching element M1 of the circuit in Fig. 2 is switched on and off at a frequency substantially higher than that of the alternating voltage. And by control-

Fig.1 Capacitor-input-rectifier circuit and its input voltage and current waveforms

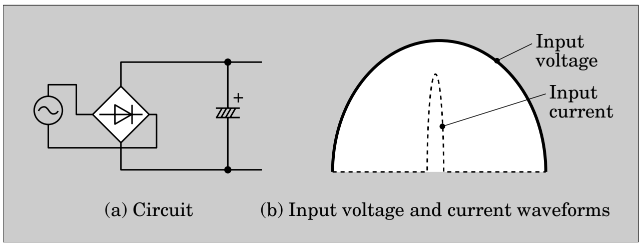


Fig.2 Boost converter circuit

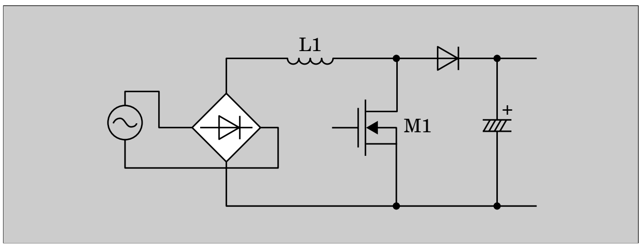


Fig.3 Comparison of waveforms of input voltage and input current between peak current mode control and average current mode control

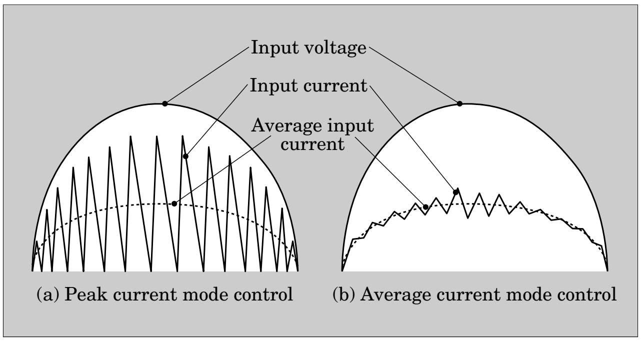


Table 1 Comparison between peak current mode control and average current mode control

Control method	Peak current mode control	Average current mode control
Model	FA5500/FA5501	FA5331/FA5332
Oscillation	Self-oscillation	Externally excited oscillation
Frequency	Variable	Fixed
Output electric power	Small (less than approx. 200 W)	Large (more than approx. 200 W)
Application	Lighting equipment, personal computer etc.	Inverter etc.

ling the on-off ratio, the average of the input current waveform is made into a sinusoidal current in-phase with the waveform of the full-wave rectified input voltage and thus the power factor is improved.

There are two methods to control the on-off ratio. One is the peak current mode control method to control the peak value of the current flowing through the switching element M1 and the other is the average current mode control method to control the continuous current flowing through the reactor L1.

Figure 3 shows a comparison of the waveforms of input voltage and input current for the cases of peak current mode control and average current mode control. When either of these methods is applied to actual products, a high frequency filter is inserted between the active filter circuit and the alternating input voltage. The action of this filter causes the waveform of the input current to become similar to that of the average input current as shown by the broken lines in Fig. 3.

Table 1 shows a comparison between peak current mode control and average current mode control. As shown in this table, the types of products to which these control methods are applied are generally determined according to their required output power capacity. The FA5331P/M and FA5332P/M, with average current mode control, are suited for relatively large output (more than approx. 200 W) and are used for inverters etc. In contrast, the newly developed FA5500P/N and FA5501P/N, with peak current mode

Fig.4 Appearance of FA5500 and FA5501

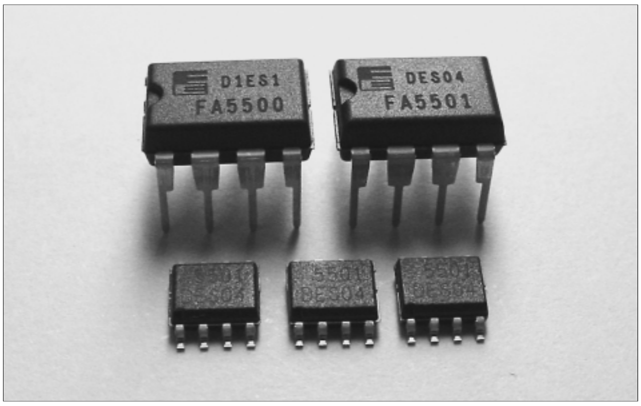
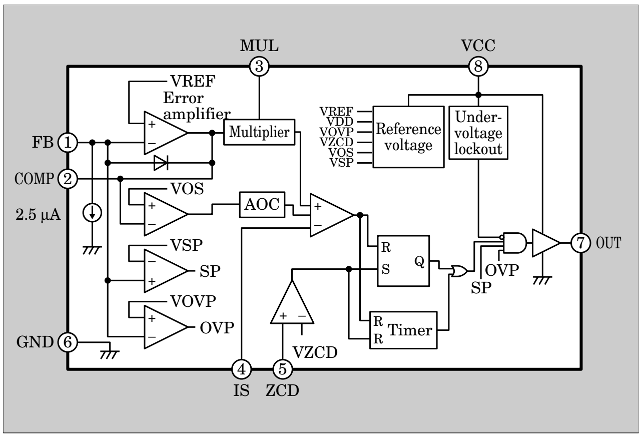


Fig.5 Block diagram



control, are suited for relatively small output (less than 200 W) and are intended for use in lighting equipment, personal computers, etc.

3. Overview of Products

The recently developed FA5500 and FA5501 ICs contain various built-in functions and are housed in 8-pin DIPs (dual in-line packages) or SOPs (small outline packages). Their appearance and block diagram are shown in Figs. 4 and 5, respectively.

3.1 Characteristics

The features of this IC element are as follows:

(1) Low power dissipation is realized due to adoption of a 30 V high voltage CMOS (complementary metal oxide semiconductor) process.
Start-up power dissipation: 20 µA
Operating power dissipation: 2 mA

(2) A correction circuit for light loads enables constant voltage control throughout the range from the rated load to no-load.

(3) If the output voltage detector malfunctions, circuit action is stopped by means of an FB short detecting circuit.

(4) Overvoltage protection is built-in.

(5) Serialization of undervoltage lockout circuit ac-

Fig.6 An example of typical application circuit

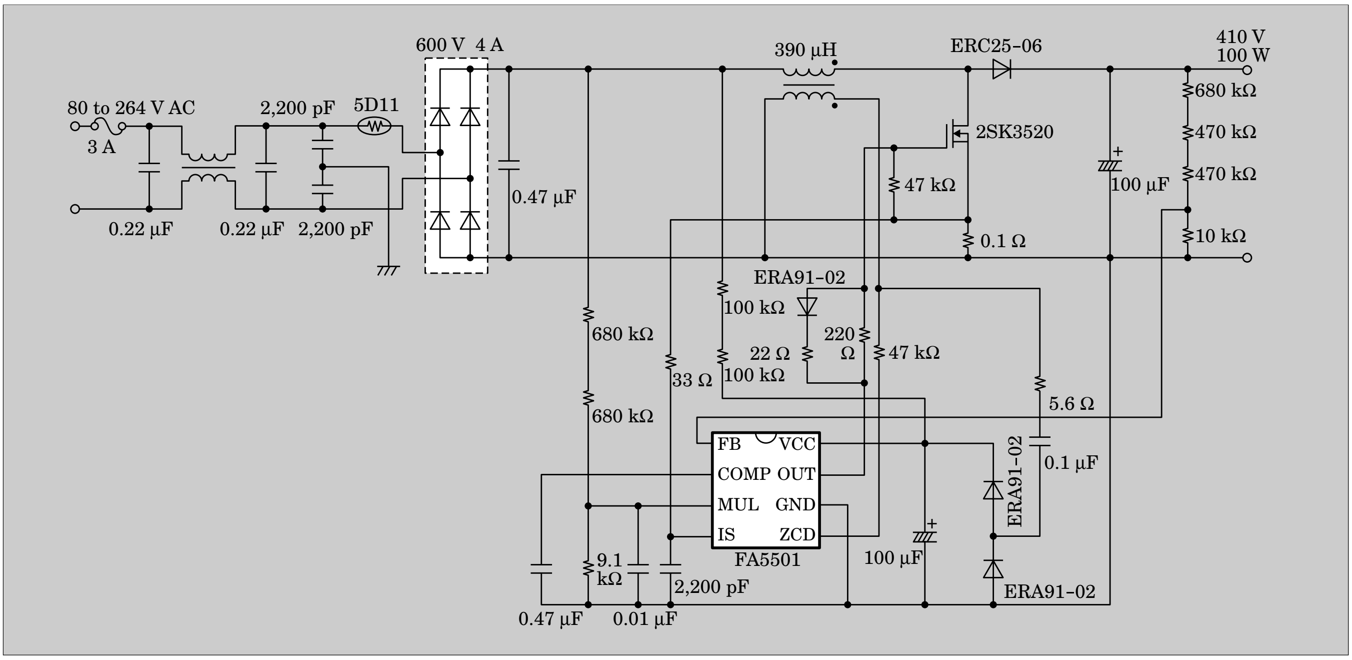
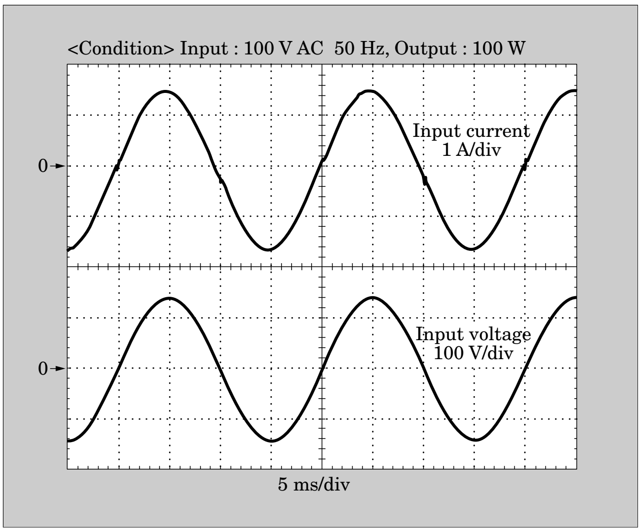


Fig.7 Waveforms of input voltage and current



cording to the on-voltage.
FA5500P/N: 11.5 V on / 9 V off
FA5501P/N: 13 V on / 9 V off

(6) Restart timer is built-in.

(7) Direct driving of power MOSFET (metal oxide semiconductor field effect transistor) is possible.
Output peak current: 500 mA source current and 1 A sink current

3.2 Correction circuit for light load

The power factor control circuit currently in use has a problem whereby the output voltage rises during light loads due to the influence of the internal circuit offset voltage of the power factor control IC.

As a countermeasure, the newly developed IC is equipped with an auto-offset control (AOC) circuit in its internal current comparator to correct the offset voltage inside the IC. Thus, constant voltage control throughout the range from rated load to no-load has become possible by correcting the offset voltage in the internal circuit during light loads.

3.3 FB short detecting circuit

The IC is equipped with an FB short detecting circuit to stop the output from the IC in case the FB input becomes short-circuited to ground or becomes open-circuited. Accordingly, the external protection circuit that was required before can be omitted.

4. Typical Application

Figure 6 shows an active filter circuit with 100 W output as one of the typical applications of this IC. Figure 7 shows the waveforms of input voltage and current. The current waveform is sinusoidal and in-phase with the voltage waveform. It can be seen that the power factor is controlled to a value near 1 and that the current waveform has become sinusoidal by being averaged with the filter in the input stage.

5. Conclusion

An overview of the power factor control ICs that utilize peak current mode control has been presented. Demand for power factor improving circuits is expected to increase even more in the future. Fuji Electric intends to keep abreast of market needs by developing ICs with integrated power factor control circuitry and PWM (pulse width modulation) control circuitry to control DC output.